Koncept

Read Me!!

Hi! This is the contents of Koncepten but badly translated into english by me (SA0CVJ) If you notice something very wrong or off then please drop me a message so I can fix it :) I only have 1 pair of eyes and I sort of speedran translating this lmao. Anyway, Enjoy!!
I have also highlighted the parts that were most important for me when studying for the swedish version of the harec license,,, if you're doing other licenses then this might not be everything since they are a bit varied but if you read the contents of this and the really amazing irish book,,,

Highlight Key:
Important Parts, Swedish Words/Info,

Memorize me:

V=IR P=IV W=pt
R= ohms/mm2 x length / area

Series
R =R1+R2
L=L1+L2
1/C = 1/C1+1/C2

F hz=1/t Wavelength = 300 (speed of light)/f (Mhz)
V Peak voltage = √2 *V rms (root mean square) V rms = 0.707 v Peak V average = 0.636 v Peak
XL =2πfl (inductive reactance) Xc =1/2πfc (capacitive reactance) X=Xl-Xc
At Resonance XL = XC, so 2πfl = 1/2πfc, thus F = 1/ 2π√lc

I e = I c+I b(Transistors) Amplification Factor = Ic : Ib

V/V = N/N = I/I (Transformers) Z/Z = (N/N)^2

Am modulation index = max modulator amplitude/carrier
FM index = peak deviation / max modulating frequency

Reflector coefficient = (vswr - 1)/(vswr+1)
P reflected = (reflector coefficient)^2
FM bandwidth =2 (peak deviation +max modulating frequency)
F(local oscillator) = F(intermediate frequency) + f(recieved frequency)
Image frequency = 2* Flo - Frf
Superheterodyne Image frequency = Frequency of incoming signal + (2 x IF)

Troposphere influences vhf +uhf
Ionosphere = d layer (absorbs lf in day) + f layer (skywave / bends)
(Vswr+1/vswr-1) = Fraction

Low Frequency (LF): 30 kHz to 300 kHz
Medium Frequency (MF): 300 kHz to 3 MHz
High Frequency (HF): 3 MHz to 30 MHz

Very High Frequency (VHF): 30 MHz to 300 MHz
Ultra High Frequency (UHF): 300 MHz to 3 GHz

Useful links:
https://examen.ssa.se ssa website has practice tests
http://hackgreensdr.org:8901/ fun listening!
https://falstad.com/circuit/ great little circuit emulator

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Introduction

Amateur radio

Amateur radio is a technical hobby with a focus on communication and experiments with radio equipment and the propagation of radio waves. It is a hobby that's practiced worldwide by licensed radio amateurs (sändaramatörer).

The purpose of amateur radio is to promote personal development and international understanding as well as technical skill and exchange of experience in the field. Amateur radio can also be an asset when society's normal resources for radio communication needs to be supported.

A hobby with demands

To use a radio transmitter, and in some cases possess one, a person requires permission (a radio license) from their respective communications bureau (teleadministration). For an amateur radio permit, it's prescribed in the radio regulations [21] about usage-related and technical qualifications required by each person who wishes to use an amateur radio station. The national telephonic administrations fulfill this requirement by applying a test of competence.

To be able to broadcast with amateur radio transmittersΩou must have an amateur radio certificate.

CEPT is a cooperation body between European Countries telecommunications administrations (authorities). One of them is the Swedish Post and Telecommunications Authority (PTS) (Post- och telestyrelse). These administrations have adopted recommendations on mutually harmonized requirements for radio operators' competence.

Sweden has adopted the CEPT recommendation Harmonized Amateur Radio Examination Certificate, Vilnius 2004, version 5 February 2016, T/R 61-02 [15].

When conducting the competency test, they must in it the requirements specified in the recommendation are particularly taken into account. Those who pass the exam are issued a Harmonized Amateur Radio Certificate (HAREC).

The Swedish certificate is based on CEPT HAREC requirements [15], with adaptation to Swedish frequency plan in Appendix G.

Training

You can either apply to one of the clubs who have a course orΩou can obtain the SSA's training package and study onΩour own.

The Swedish Post and Telecommunications Board has practice tests online thatΩou can testΩour knowledge, highly recommended for all students regardless of form of study.
https://examen.ssa.se/

The amateur radio clubs conduct the majority of the training with an amateur radio certificate as the goal. Some schools, military associations, FRO associations and several have amateur radio on the program. See the SSA's website <www.ssa.se> for current course opportunities.

WhenΩou are ready to take the certificate exam you can write to one of the adjudicators to begin the process for taking the test..

The clubs that have training usually plan tests with the group of students they have. After taking and passing the test,Ωou can then apply for call sign and certificate, which the SSA manages according to delegation from the Swedish Post and Telecommunications Authority.

The permit is linked to an internationally unique call sign.Ωou may request a call signal, but ifΩou don't a free call signal is taken out of the series and given toΩou.

The Swedish Association Broadcasting amateurs – SSA is a non-profit association for people with an interest in amateur radio. The SSA is secular and apolitical. One of the SSA's aims is to increase technical knowledge and good radio traffic culture amongst swedish radio amateurs. SSA represents Sweden as the national association of International Amateur Radio Union (IARU), Region 1.

International cooperation

The national associations within IARU cooperate across national borders. An example is when DARC (Deutscher Amateur-Radio-Club e.V.) set up their Ausbildungsunterlagen a numberΩears ago [16] wrote the book that was used as the source material for the predecessor to this book.

This book

This book covers the entire theory of CEPT HAREC and PTS requirements. It is included in the training package which can be purchased from SSA.

So far, this book covers topics such as basic adding electricity, electronics, components, circuits, radio technology, electrical safety, rules, regulations, band-plans and traffic methods. There is also learning material for morse signaling for those who want to learn telegraphy.

The appendices include basic themes and frequency plans for amateur radio traffic.

Recruitment of supervisors for semester-long courses is a key issue for the course organiser, as well as targeted, adapted learning materials.

The idea of this book is to deliver a material which can be the basis for this training as well also for some deepening and understanding of the concepts which is commonly encountered in the hobby.

Preface to the second edition
The book is based to a very large extent on the work that to the first edition was performed by Lennart Wiberg, with signal SM7KHF, and more. Over time, a need to expand and adapt the existing educational material to a more modern way of educating, not at least to be able to use a modern web-based education system.

An important aspect has been that the material should cover the entire CEPT HAREC, which has been updated over theΩears, and be traceable to these requirements. For this second edition, all previous material has reviewed and updated. New chapters have been added to, among other things, about electromagnetic fields, digital mode of transport and digital signal processing. The sections about electrical safety and emergency traffic have been revised and all references to laws and regulations are in writing moment current.

The current second edition is available as a digital format. This not only facilitates the reader to search for specific information, but constitutes also a basis for future web-based education.

THANKS!

A big thankΩou to all those who contributed in different ways to realize the book, sourced all the parts from the previous edition, updated it, rewrote the material, redid the layout, typed and worked with the content in different forms.

Sixth printing

The sixth printing of KonCEPT has been processed for to get a better interaction between the placement of images in relation to the text in order to make the text simpler and easier to read. A number of small errors in formulas have adjusted and some misspelled words corrected. A few new comments and explanations of concepts have added.

There are most likely still errors and we want to continue the work of ensuring that the text is accurate and includes relevant information. We would likeΩou to send in suggestions for improvements, ifΩou think something is unclear or information about wrong to us. Send an email to hq@ssa.se. We warmly thankΩou for the emails we have received so far!

- The authors

RECAP of Introduction: WHAT, HOW, WHERE?

WHAT does a radio amateur need to know?
CEPT is a cooperation body between European counties telecommunications administrations (authorities). One of them is the Swedish Post and Telecommunications Authority (PTS).

These administrations have adopted recommenda- tions on mutually harmonized requirements for radio operators' competence.

Sweden has adopted the CEPT recommendation T/R 61-02 [15]. When conducting competency tests must specify the requirements specified in the recommendation considered.

Those who pass the exam are issued a Harmonized Amateur Radio Certificate (HAREC).
The recommendation indicates the HAREC competence level. The Swedish certificate is based on CEPT HAREC requirements [15], with adaptation to Swedish band plan i Appendix G.

HOW do you become a radio amateur?

In order to broadcast with amateur radio stations,Ωou must have an amateur radio certificate.Ωou can either apply to one of the clubs that have a course, or get SSA's training package and study onΩour own hand. SSA has practice tests online thatΩou can test their knowledge on WhenΩou are ripe for take a certificate exam,Ωou write for one of the examiners who exist. The clubs that have education usually plans exams with that group of students they have.

After taking and passing the test,Ωou can then apply for signal and certificate, something that SSA takes care of according to a delegation from the Swedish Post and Telecommunications Agency. The permit is linked to an internationally unique call sign.Ωou have the opportunity to propose a calling signal, but in the absence of suggestions, a free call sign is taken out of the series.

WHERE are certificate courses held?

Some amateur radio clubs, military units, FRO- federations and other associations hold certification courses. It is also possible to study onΩour own.

WHICH teaching aids do you need?

This book covers the entire theory of CEPT HAREC and PTS requirements. It is included in the training package which can be purchased from SSA

1 Electricity Learning

1.1 Basic electrical concepts

HAREC a.1.1

Electric charge, voltage and current are related with how matter is structured. The ability
For a material to conduct charge; current, is called conductivity.

1.1.1 Basics

There are many forms of matter. Many materials are composed of different elements. Matter can be broken down into different forms chemically.. All matter is made up of atoms. The simplest materials the elements, contain only one kind of atoms. There are over 100 different known element.

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Each of the elements has a unique atomic structure and thus a unique material structure, different from every other element. Three quarters of all elements are metals (electrical conductors) while most others are non-metals (insulators). There is also a small inter-group called semiconductors.

1.1.2 Structure of atoms

For a long time, atoms were considered to be the smallest constituent parts of matter. But around the turn of the last century, we discovered that atoms consist of even smaller constituents, called elementary particles.

These are protons, neutrons, electrons and more. The common name for all these particles are Nucleons. An atom consists of a nucleus which is made up of protons and neutrons, and electrons, which revolves around the nucleus.

• The protons are positively (+) charged.
• Neutrons are neutral, not charged.
• The electrons are negatively (–) charged.

The electrons revolve in orbits around the atomic nucleus, like our planet revolves around the sun, shown in figure 1.1.

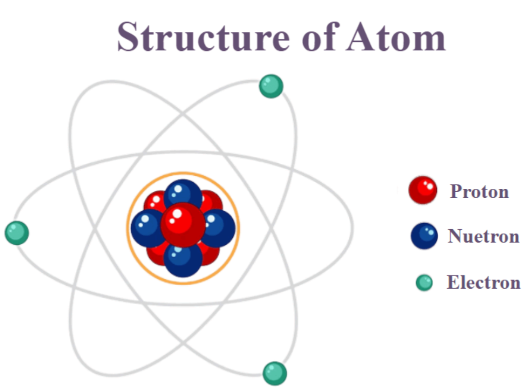

Figure 1.1: Structure of atoms

Orbits with the same distance to the atomic nucleus have the same energy level and are said to form a shell. There can be several electron shells. The more electrons found in an electron shell, the stronger the electrons in the shell bind to the atom. The outermost shell however, can never contain more than 8 electrons.

The electrons in the outermost shell are called valence electrons, which are used by adjacent atoms in a chemical bond to make new structures, molecules and substances.

A certain number of valence electrons is needed for the bond.The valence electrons not needed for the binding can move freely through the material. They are called free electrons and are what we call electrical current. The valence electrons are therefore not only of importance to the materials chemical structure but also to its electrical properties.

The mass and volume of the atoms is extremely small. Take, for example, a cube of copper with a volume of 1 cm3 and the weight 8.9 grams. It consists of approx. 8.5·1022 copper atoms, i.e. 85,000,000,000,000,000,000,000 atoms in total!

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The phenomenon of metal bonding means that the number of free electrons is approximately equal to the number of atoms in it. Each elementary particle has a mass and an atom's total mass is the sum of the elementary particles. The simplest atom is the hydrogen atom with a proton and an electron. The total mass of the hydrogen atom has been able to be calculated to 1.66 · 10−24 grams. Almost all of the mass in an atom is gathered into the nucleus's protons and neutrons. Every single neutron and proton has a mass roughly 2000 times greater than the mass of an electron.

1.1.3 Electric charge and force

According to legend, Thales of Milteus already discovered 2500Ωears ago, that a piece of amber attracted small blades of grass, after being rubbed against a piece of wool.

The Greek word for amber is ELEKTRON and the forces that arose came to be called "electric". The electric tension between bodies with different charges, forces act between them and their environment. The forces are called electric fields and is what makes electrically charged bodies able to move.Ωou can see this every timeΩou combΩour hair with a comb made from insulating material (wood, plastic).Ωour hair gets pulled towards the comb because the hair and the comb have received different electrical charges.Simultaneously, each individual hair has the same charge and thus they repel each other – so the hair rises fromΩour head.. Like charges repel each other - unlike charges attract each other.

Subject	Resistivity at 20 ◦C [Ω · mm2/m]
Aluminum 0.028	0.028
Lead	0.22
Gold	0.024
Iron	0.105
Copper	0.018
Mercury	0.958
Nickel	0.078
Platinum	0.108
Silver	0.016
Tin	0.115
Tungsten	0.056
Zinc	0.058

Table 1.1: Resistivity of metals

1.1.4 Conductivity – conductors, semiconductors and insulator HAREC a.1.1.1

An electric current is said to flow when the free charge carriers in a material – a current conductor – are made to move simultaneously in the same direction. How many are moving depends on the characteristics of the current conductor and the voltage between the ends of the conductor.
All materials have some degree of electrical conductivity that depends on the atomic structure of the material, dimensions and temperature. Some materials (e.g. metals, carbon, semiconductors) conduct electric current better than others (eg glass, rubber, plastic). The amount of free charge carriers in the material limit how big the current can be.

1.1.4.1 Manager

Metals have good electrical conductivity and are called conductors (Ledare). The best conductors are the metals whose atoms have the least number of valence electrons in the outermost electron shell. The copper, silver and gold atoms have a single valence electron and thus very good conductivity. Iron, zinc and magnesium have two valence electrons and thus have somewhat poorer conductivity. Table 1.1 gives examples of the metals resistivities. Even worse conductors are the semiconductors with 3 to 5 valence electrons.

1.1.4.2 Insulators

Glass, plastic, porcelain and some minerals have poor conductivity and are called insulators (Isolatorer). Insulators are bad conductors because they have many valence electrons in their outermost shell. Maximum capacity 8 valence electrons. In non-conducting materials, the electrons are tightly bound to their valence shell and therefore difficult to move. In solid materials positive charges are also difficult to move, because they are bound in atomic nuclei.. The atoms are in turn bound in a lattice which characterize each material.

1.1.4.3 Semiconductors

Some elements have an electrical properties which sit between electrical conductors or insulators. These subjects belong to the group semiconductor and has an electrical conductivity which varies with the substance's structure, purity and temperature. A pure crystal of the mineral germanium [Ge] or of silicon [Si] forms a crystal lattice in which the atoms are bound to each other by covalent bonds. It shares its four valence electrons with four other atoms to form a full octet of eight
electrons in the valence shell. As the valence shell contains eight electrons, it is full. There are no free electrons and the substance does not conduct electric current. Both of these minerals in this form are seen as insulators. (intrinsic semiconductor)

If some atoms of a foreign material. eg, arsenic, antimony, indium or gallium were mixed into the crystal structure,they could change the electrical properties and increase the electrical conductivity a thousandfold.

1.1.4.4 N line

One speaks of N-conducting material and N-conduction; "electron conduction". Germanium, silicon, etc. semiconductors have four electrons with “fixed places” in the valence shell – provided that the material is purely germanium. There are no free electrons for charge transport.

To create free electrons, the pure material can be contaminated – doped – with atoms of, for example, arsenic [As] or antimony [Sb]. Both of these materials are 5-rated. They have 5 electrons in the valence shell; 4 electrons are tightly bound while the 5th is loosely bound to the atom. The 5th electron can be detached from the atom by an external force, for example heat or electric voltage, and then a free electron is created.

When a voltage is applied to the material, the free electron will migrate towards the positive pole.
The material is N-conductive.

1.1.4.5 P line – "hole line"

When germanium or silicon is doped with indium [In] or gallium [Ga], they become P-conductive. Indium and gallium is 3-valent – their valence shell contains 3 electrons. But for a solid bond with germanium or silicon, one electron is missing and a "hole" - a "missing electron" - then arises. The hole can be filled by an electron from another atom. In the atom that the electron leaves, a hole is formed in turn, etc.

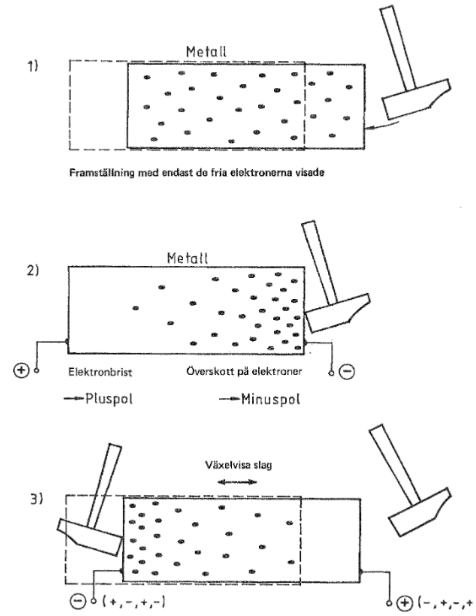


Image 1.2: Thought experiment with balls in a tube

When a voltage is applied, the "hole" will migrate towards the negative pole. The material is then P-conductive.

1.1.5 Electric voltage – the unit volt HAREC a.1.1.2, a.1.1.3

Picture 1.2 illustrates a thought experiment with a pipe with balls in. The material in the tube is thought to correspond to the atomic structure of a current conductor and the balls the free electrons. IfΩou imagine a hit to one end of the pipe, it moves due to the energy that is supplied. Due to inertia the balls end up at one end of the pipe.

The idea that balls gather at one end of the tube is thought to correspond to an electron surplus at one end of a conductor and a corresponding deficit at the other end.

The end with an excess of electrons is called the negative pole and the end with an electron deficit is called the positive pole. Different electric charges at the poles mean that they have different potentials between them. The potential difference is called the voltage.
Direct current DC means an excess of electrons and always at the same connection pole.

Alternating current AC implies an excess of electrons, alternating at one connection pole and the other.

The unit of measurement for voltage is the volt [V]. In formulasis denoted voltage by
• U for the effective value
• u for the instantaneous value (instantaneous)
• ˆu for the peak value (amplitude-).
(In swedish, U is used for voltage but in other countriesΩou may find V for voltage!, substitute asΩou see fit!)

Figure 1.16 in section 1.6 illustrates the relationship between the values of a sine curve.

The voltage across the endpoints of a current conductor is 1 volt [V], when a direct current of 1 ampere [A] during the power development 1 watt [W].

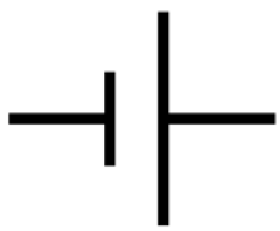


Figure 1.3: Schematic symbol for battery

1.1.6 Symbols

When drawing electrical circuit diagrams, symbols are used. The symbol in Figure 1.3 shows an electric battery with a single cell. Clarifying comments and the characters next to the symbol appear. Often these refer to a component list. See also chapter 2

1.1.7 Electric current – The unit ampere HAREC a.1.1.2, a.1.1.3

When a closed current circuit contains a voltage source, a charge equalization can occur through the circuit. This means that free electrons move through the circuit in the direction from the minus pole of the voltage source to its plus pole. At the plus pole there is a lack of negative charges and nature always seeks an equalization.

During the equalization process, the voltage source is also a current source. In gases and electrolytes (electrically conductive liquids and gels) and in semiconductors, the current consists of ions (positive or negative charges), in metals, on the other hand, of electrons (negative charges).

By tradition, the current direction is considered to be positive in the direction of the ion current – the so-called technical current direction – while the direction of the electron current is the opposite – the so-called physical current direction. The unit of measurement for current is the ampere A [19].

In formulas, current is denoted by: I for the effective value i for the instantaneous value (instantaneous) ˆi for the peak value (amplitude) The current is 1 A when 6.25 · 1018 electrons per second flow through a given conductor cross-section, which corresponds to the charge 1 coulomb.

1.1.8 Current circuit

Figure 1.4 shows potential and voltage in a current circuit. An electrical circuit consists of one or more energy sources and energy consumers. Sources can be batteries, power supplies, etc. Consumers can be lamps, wires, etc.

Each energy consumer has a resistance and the electrical charges "queue" the consumer before it, just after the consumer there is no queue. A difference in amount of charge (a potential difference) occurs between each point in a circuit when current flows. We talk about voltage drops.

1.1.9 Current flow

The direct current and alternating current flows can be composed of a main flow and subordinate flows. Direct current can have constant strength or it can vary according to some course, but never changes direction. Alternating current can vary according to a certain course, for example sine wave, square wave, and constantly changes direction.

1.1.10 Resistance – The unit ohm HAREC a.1.1.2, a.1.1.3

When free electrons are forced through the atomic structure of a conductor, for example the filament of a lamp, energy is released in the form of heat. This phenomenon is called resistance (from the Latin resistere meaning to resist). The resistance and thus the losses in a current circuit are distributed in relation to the constituent materials and their dimensioning. Resistance is expressed in the unit ohm [19] and denoted by the Greek letter omega (Ω). In formulas, the resistance of an electrical circuit or part of it is denoted by R. The resistance of a resistor is 1 Ω, when a voltage of 1 V drives a current of 1 A through that resistor.

1.1.11 Ohm's law HAREC a.1.1.4

Ohm's law describes the relationship between the basic concept of current I [ampere], voltage U [volt] and resistance R [ohm]. The relationship applies both to direct voltage and to the rms value of alternating voltage and alternating current. In a conductor with resistance R, the current I through the resistance is proportional to the applied voltage U .

$$U = I \cdot R \qquad I = \frac{U}{R} \qquad R = \frac{U}{I}$$

U = I · R I = U R R = U I

1.1.12 Kirchhoff's laws HAREC a.1.1.5

$$I_1 + I_2 + I_3 + \cdots + I_n = 0$$

The German physicist G R Kirchhoff (1824–1887) formulated his well-known laws first in 1845 and then in 1847. Kirchhoff's current law: The algebraic sum of all currents flowing to or from any point in an electrical circuit are equal to zero.

I1 + I2 + I3 + · · · + In = 0

Kirchhoff's voltage law: In any closed current circuit, the algebraic sum of all voltage sources is equal to the total voltage drop across all resistors. Stated another way, the algebraic sum of the voltages in a circuit equals zero.

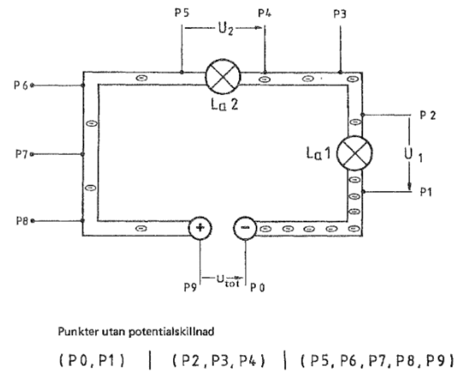


Figure 1.4: Potential and voltage in a current circuit

1.1.13 Electric power – the unit watt HAREC a.1.1.6, a.1.1.7

When a current flows through a resistance, heat is developed. Heat is a form of power, which is higher the stronger the current and the higher the voltage. The unit of measurement volt-ampere [VA] for electrical power is derived from the product of volt [V] and ampere [A].

P = UI

For power generated by direct current, the unit watt [W] [19] is used instead of volt-ampere [VA]. In addition to the basic unit 1 W, parts and multiples of this are used. 1 volt [U] · 1 ampere [I] = 1 watt [P] The power formula P = U · I applies primarily to direct current but also to alternating current if the load is resistive and current and voltage are not out of phase.

To facilitate calculations, the formula can be rewritten in several ways. We start by solving I from Ohm's law U = R · I: I = U R

We then insert the expression for I into the power formula
P = U · I ⇒ P = U · U R ⇒ P = U 2 R

Correspondingly, we can replace U with R · I:
P = U · I ⇒ P = R · I · I ⇒ P = R · I2

With the help of these formulas the power can be calculated from the resistance and current values respectively from the resistance and voltage values. For other formulas see the formula

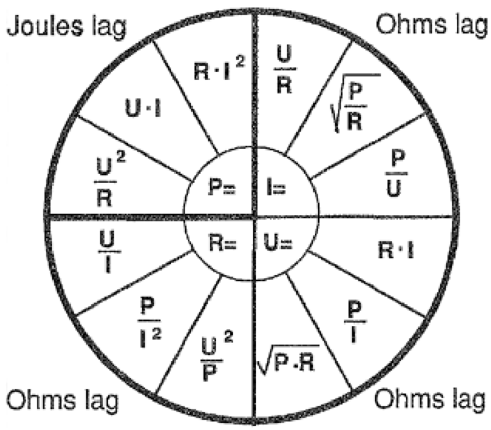


Figure 1.5: "Spin" for Ohm's and Joule's law

1.5. 1.1.14 Electrical work – the unit joule

Energy exists in various forms, always and everywhere. Energy can neither be created nor destroyed, only transformed from one form to another. The form can be mechanical, chemical, electrical, etc. Work is the conversion process from one form of energy to another.

The amount of work in all forms of energy can be measured with the same unit joule [J] [19] and is indicated by the symbol W for Work. 1 joule corresponds to the work that develops when an object is moved 1 meter with a force of 1 newton [N], i.e. 1 newton meter [Nm]. W = I · F [J] = [Nm] The work W [J] is more the longer time t [s] a certain power P [W] develops. W = t · P [J] = [sW]

1.1.15 Joule's law HAREC a.1.1.8

Since the power is expressed as P = U · I, the electrical work can be expressed as W = U · I · t, which is also Joules law.

Work = Power · time [W] = [P] · [s]

If the basic units of volt [U], ampere [I] and second [s] are inserted into the formula, a unit of measurement is obtained, expressed 9 Figure 1.5: "Spin" for Ohms and Joules laws as volt-ampere-seconds [VAs] or watt-seconds [Ws] or joules [J].

The unit of electrical work is 1 joule, which is commonly called 1 watt second 1 [Ws]. In addition to the basic unit, multiples of this are used.

1 kilowatt second = 1 kWs = 1000 Ws = 1.0 · 10^3Ws
1 watt hour = 1 Wh = 3600 Ws = 3.6 · 10^3 Ws
1 kilowatt hour = 1 kWh= 1000 Wh= 3.6 · 10^6 Ws

1.1.16 The formula dial

So hereΩou can find the correct formula in the formula wheel (picture 1.5): Select a segment with the desired magnitude I, U , R or P as the first term in the formula. Within the selected segment there are three options for the second term in the formula.

Choose the option that contains two known quantities.

1.1.16.1 Ohm's law

R is sought, U and I are known;
If U = 230 V and I = 2 A,
then R = U I = 230 2 = 115 Ω

1.1.16.2 Joule's law

P is sought, U and I are known.
If U = 230 V and I = 2 A,
then P = U · I = 230 · 2 = 460 W

1.1.17 Ampere-hours (Ah) and battery capacity HAREC a.1.1.9

There are several ways to store energy. One way is to do it in chemical form in special cells, whereΩou can extract the energy in electrical form. There are cells that can be charged and discharged repeatedly. Such cells are usually called accumulator, secondary battery or secondary cell.

There are also cells that can only be used once and cannot normally be recharged. Such cells are usually called primary cell or primary battery.

Energy in the form of an electrical charge can also be stored in a capacitor. The energy can then be stored and taken out without conversion. The capacity in an electric cell is expressed as the product of the current A that the cell emits and the time [s, h] this can take place. Expressed with the time unit hours, the capacity then becomes Ah.

The capacity stated in a cell's product data is the nominal. This capacity only applies under certain standardized conditions such as cell temperature, amperage and discharge time. The practical capacity of a cell is limited by its use. An electric cell thus regularly emits a smaller amount of energy, the higher the discharge current. The capacity in an electric cell differs in that respect from that in, for example, an oil tank, whereΩou can take out as much energy asΩou pour in and regardless of how fastΩou do it.

Electric cells can be assembled into batteries, whereby the cells are usually connected in series. The battery's pole voltage is then the sum of the cells' pole voltages. How much work a battery emits depends both on the pole voltage of the entire battery and on the capacity of the individual cells. Example: A battery with a pole voltage of 12 V and a cell capacity of 100 Ah can nominally emit $P = U \cdot I = 12 \cdot 100 = 1200$ VAh = 1.2 kWh.

How long the battery "lasts" per charge depends, among other things, on the amperageΩou use. IfΩou take 1 A out of the 100 Ah cell above, the discharge time is nominally $t = 100$ Ah/1 A = 100 h.

1.2 Electrical power sources HAREC a.1.2 1.2.1 Electromotive force – EMF HAREC a.1.2.1

What drives current through an electric current circuit is the circuit's electromotive force (EMF). The unit of measurement for EMF is volts [V]. EMF is the sum of the potential increases that occur in the circuit. The most common types of EMF are:

- electromagnetic EMF which arises in current conductors in magnetic fields that vary (e.g. the windings of a rotating generator)
- electrochemical EMF which arises in the contact surface between a metallic conductor and a electrolyte (e.g. battery cell) 10
- electrostatic EMF, for example in capacitors
- contact EMF in the contact surface between metals with different thermoelectric potential or between metal and oxygen in the air (e.g. corrosion between metals)
- thermal EMF which arises in a current circuit where two soldered metals with different temperatures are included (e.g. thermocouples for current measurement).

1.2.2 Pole voltage

The voltage that can be measured between the connection poles of the circuit when the circuit is open.

1.2.3 Internal resistance

In the same way that the components in a current circuit have a certain resistance, a current source also has an internal resistance. The internal resistance of a current source is included in the total resistance of the circuit.

1.2.4 Short-circuit current

IfΩou connect the connection poles of the current source in the shortest possible way, the total resistance of the circuit is equal to the internal resistance of the source. The short-circuit current that then occurs is limited only by the pole voltage and internal resistance of the current source. Since the internal resistance is usually very small, the short-circuit current is correspondingly high.

1.2.5 Series and parallel connected power sources HAREC a.1.2.2

1.2.5.1 Series-connected power sources

In order to achieve a higher total voltage (EMF), several power sources (partial voltages) can be connected in a loop one after the other. This is called series connection. Series-connected partial voltages act with or against each other, depending on their mutual polarities. The total voltage across the connection is the sum of the constituent partial voltages, taking into account their polarities.

1.2.5.2 Power sources connected in parallel

In order to obtain a higher current, several weaker power sources can be connected in parallel. However, when connected in parallel, a higher voltage is not obtained. When connecting power sources in parallel, their polarity must be the same. For minimum equalization current between parallel-connected power sources, their pole voltage and internal resistance should also be as equal as possible. " Parallel connection of power sources is often directly unsuitable because in practice it is difficult to achieve a balance, whereby only one source supplies. There are power units designed to be connected in parallel.

1.3 Electric field HAREC a.1.3

1.3.1 Potential

The potential difference – the voltage – between different charged bodies creates forces between them and between them and their surroundings. This phenomenon is called an electric force field and is the reason why electrically charged bodies can move

1.3.2 Electric charge

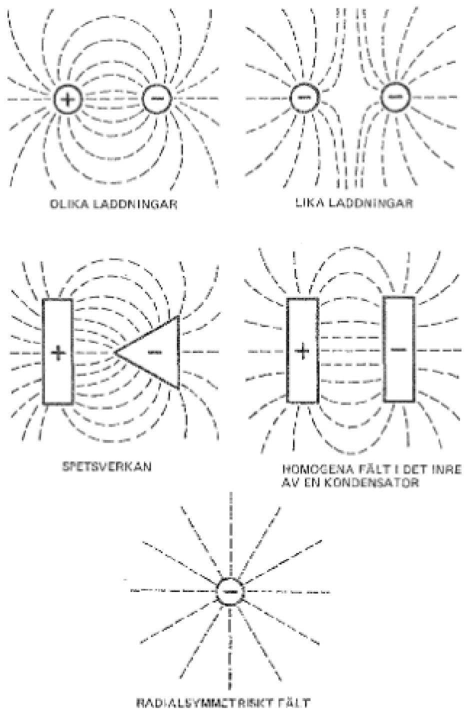
Electric charges are the basis for the study of electricity. Each proton in the atomic nucleus carries a positive charge. The neutrons in the atomic nucleus are electrically neutral. The number of protons in the nucleus therefore determines the nucleus's total positive charge, called the nuclear charge number.

The electrons orbiting the atomic nucleus are carriers of their own negative charge. The elementary charge [e] is the charge found in an electron and has long been considered the smallest possible charge. Modern electron physics finds even smaller units, but we won't go into that here.

The number of protons and electrons in an atom is equal, and the negative charge of the electrons then becomes as great as the positive charge of the protons. When charges with different polarities are equal, they balance each other out and become electrically neutral to their surroundings.

The unit of measurement for electric charge is the coulomb [C]. The amount of charge 1 coulomb corresponds to 6.25 trillion (6.25 · 1018) elementary charges. The relationship between charge and current is: $Q = I \cdot t$

Charge [Q] is current [I] during time [t]: 1 C = 1 A · 1 s = 1 ampere-second [1 As] 1 coulomb = 1 ampere · 1 second



11 Image 1.6: Electric force fields

1.3.3 Force fields around electric charges

Forces are formed between electric charges (image 1.6).

- Each charge is surrounded by an electric force field.
- Forces are formed between positive (+) electrical charges and (–) negative charges.
- The strength and direction of the field forces are symbolized as lines between positive and negative charges, where the strength is the same along each line.

Bodies with different types of charges are attracted to each other. Bodies with the same type of charges repel each other. Uncharged bodies are not affected and do not produce a force effect.

1.3.4 Electric field strength HAREC a.1.3.1, a.1.3.2

In a wire-shaped conductor, through which direct current flows, the current is distributed equally over the cross section. If the conductor is instead a thin plane, the current distribution will be different.

Figure 1.7 shows a plane with two electrodes connected to a voltage source. Along the distance between the electrodes, the current is distributed over the plane like the current lines in the picture. The distribution depends on the design of the electrodes and the current density is not equal over the entire plane, because the plane can be seen as many parallel-connected resistors whose resistances increase with increasing current line length. The current density in the plane is greater where the resistance between the electrodes is small.

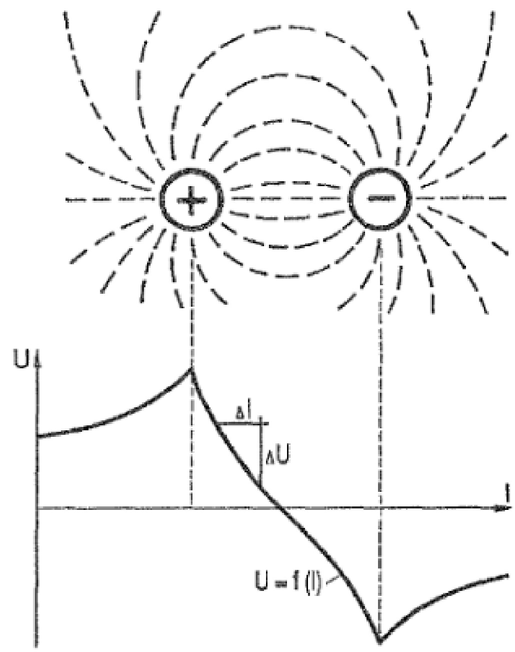


Figure 1.7: Electric field strength polarity.

Closest to the electrodes, where all current lines come together, the current density is extremely high. Where the current density is greatest, there is the greatest potential difference (voltage) per unit length of power line.

You can measure the potentials in the plane. The voltage between two points along an imaginary streamline is then proportional to the length of the line between the points. Half the tension is found in the middle between the points. Electric fields are stored energy. The field strength can become so high that there is a discharge between the poles. Corona discharge from the ends of an antenna is another sign of high field strength. To make discharge more difficult, the electrode surface can be increased, for example by making it spherical.

Conversely, one can contribute to discharge by reducing the electrode surface. An example is the tip of the lightning rod. In picture 1.7 U = f (l) the voltages are shown along the "center current line" through the plus and minus poles. The curved appearance is also typical for surrounding lines, regardless of length.

The picture presents a conductor as an ideal plane, while in practice it is a volume. To mimic a volume, we imagine the image rotating around the center streamline, with the field lines unchanged. Even if the resistance in the rotating body that occurs is so high that no current flows, the voltage picture is still the same.

The voltage pattern also applies to insulating solid materials, gases and vacuum. There is therefore tension between different points even in the "fresh air". This tension field strength can be measured with special instruments, so-called field strength meters.

12 The steepness of the voltage curve in the picture shows what the partial voltage is per partial length of a voltage line. The ratio of partial voltage and the distance between the measurement points is called electric field strength. In formulas, electric field strength is denoted by the letter E. Electric field strength is measured in volts per meter.

E = ∆U /∆l

[volt] [meter]

$$E = \frac{\Delta U}{\Delta l} \qquad \frac{[volt]}{[meter]}$$

1.3.5 Shielding of electric fields HAREC a.1.3.3

Basically there are two types of fields, the electric and the magnetic. In addition, there are also electromagnetic fields, which are composed of both of these. Fields can be static or dynamic, where dynamic is used here. A dynamic electric field generates a magnetic field. Conversely, a dynamic magnetic field generates a dynamic electric field. This interaction means that the fields can be kept running by each other with the addition of external energy. Fields in motion generate electromagnetic radiation, which affects the environment.When the impact is not desired, the field must be screened off. One way to shield an electric field is a metallic enclosure connected to the device's ground reference. The screen does not need to be tight, but designed so that all magnetically induced current in it is broken. (Cf. 1.4.9)

1.4 Magnetic field HAREC a.1.4

1.4.1 Magnetism

According to the Roman writer Pliny, at the time approximately 160Ωears BC. the shepherd Magnes one day felt how the iron pins in the sandals stuck to a certain kind of stone. It could have been black iron ore, which the Greeks in ancient times called Lithos herakleia after the city of Herakleia in Lydia, where such ore occurs.

The city was later named Magnesia and one can imagine that the stone came to be called Magnetes. A whole mineral group with similar properties, such as iron, nickel etc. called magnetic.

Magnetism arises from electric charges in motion. The movements of the electrons in an atom create magnetic fields. This means that the atoms individually act as a magnetic dipole - a magnet. In most materials, the atoms are oriented so that their magnetic forces cancel each other out.

The material as a whole is then non-magnetic and exerts no external forces. But when affected by an external magnetic field, the dipoles (atoms) in a material can be oriented in the same direction and their magnetic fields will then interact. The entire material then becomes magnetic. When the external magnetic field is removed, the orientation remains only partially – magnetic remanence.

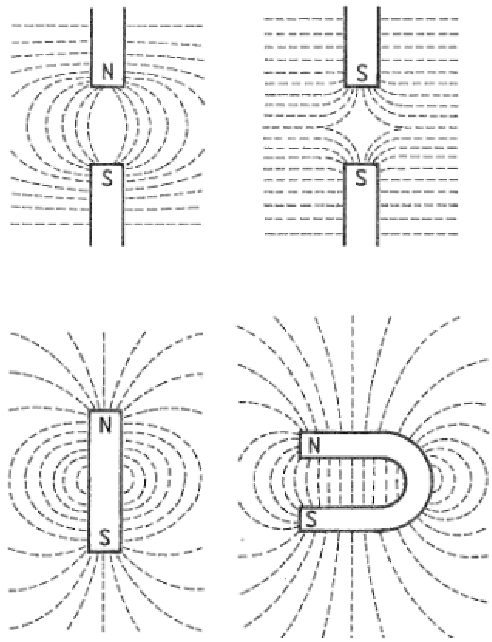


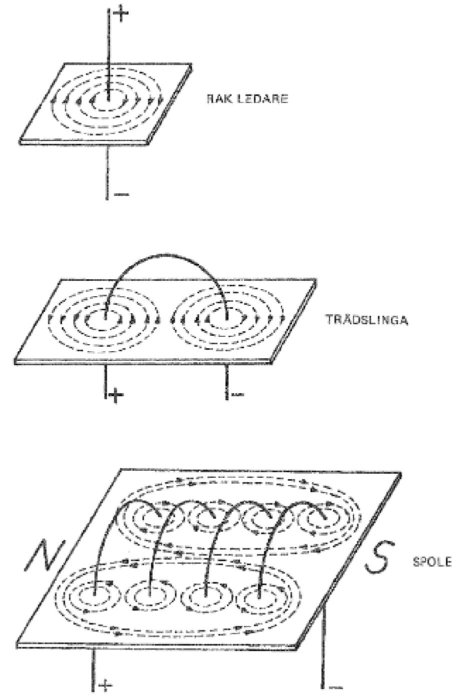
Figure 1.8: Force field around magnets

In ferromagnetic alloys, a greater part of the orientation remains, even if the influence of the external magnetic field has ceased. The material is then permanently magnetic.

1.4.2 Force fields in and around magnets

Figure 1.8 shows force fields around magnets. Each magnet is surrounded by a magnetic force field. The magnetic field's distribution, strength and directions are described as lines of force with closed circuits. Outside the magnet the lines of force run from north to south pole and inside the magnet the opposite direction. The direction of force at each point of the field is the direction the north end of a compass needle would point. IfΩou hang a magnet by a wire, it will take the same direction as the Earth's magnetic field.

• Poles of the same polarity repel each other (repel). • Poles of different polarity are drawn to each other (attract).



13 Figure 1.9: Magnetic fields around current conductors

1.4.3 Magnetic fields around current paths HAREC a.1.4.1

Figure 1.9 shows magnetic fields around current conductors. Around each conductor through which an electric current flows, a magnetic force field is generated. The magnetic lines of force are distributed concentrically around a straight conductor and perpendicular to it.

Between the ends of a conductor with an arcuate extension, lines of force are formed which act with each other. A current-flowing cylindrical coil – inductor – exhibits the same magnetic field pattern as a rod-shaped permanent magnet.

1.4.4 Determining the magnetic field direction

The direction of the magnetic field around a conductor can be determined using the right-hand rule. When a conductor is grasped with the right hand and with the thumb in the direction of the current, the fingers will point in the direction of the field (B). In picture 1.9 (upper), the current goes from the plus pole (+) to the minus pole (–), whereby the current will go downwards in the picture on the top side, that is, exactly as the thumb points ifΩou grasp the conductor with the thumb downwards, and the magnetic field will spin like the arrows just like the other fingers on the right hand.

When a conductor is shaped like a coil and an electric current flows through it, the magnetic field will have an appearance similar to that around a permanent magnet. Such a coil is called an electromagnet. The direction of the magnetic field in a coil can also be determined using the right-hand rule. When a coil is grasped with the right hand and with the fingers in the direction of the current, the outstretched thumb will point towards the north pole of the coil.

In picture 1.9 (bottom), the current goes from the plus pole (+) to the minus pole (–), whereby the current will go inward in the picture on the top side, i.e. just like the fingers point whenΩou putΩour hand on the coil, and the magnetic field will point north (N) just like the thumb of the right hand. The fields around all kinds of magnets, both permanent magnetic and electromagnetic, react on each other.

Even simple electrical conductors are electromagnets.

1.4.5 Examples of electromagnets

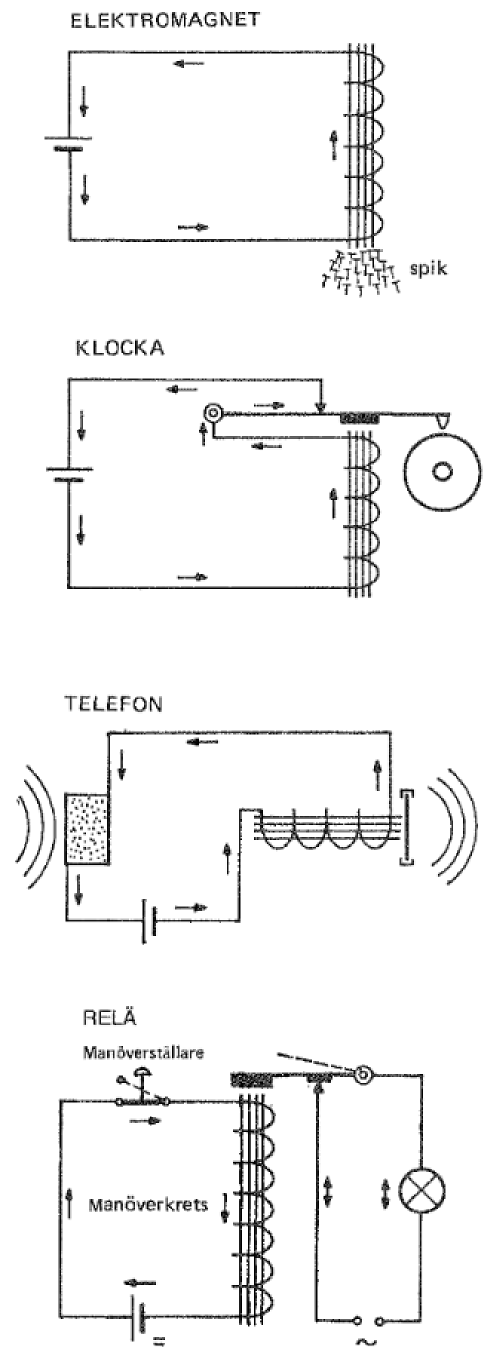


Figure 1.10 shows examples of electromagnets.

1.4.5.1 Electromagnets

A magnetic field is formed through a coil as long as current flows through it. An iron core in the coil concentrates the field due to the greater magnetic conductivity. Electromagnets are used to set magnetic materials in motion or hold them.

1.4.5.2 Electric bell

The device consists of an electromagnet and an iron plate on a spring. On the plate is a self-breaking contact and a clapper that can turn on a clock. The contact causes an alternating breaking and closing of the current through the electromagnet. The armature with the valve then swings and turns on the clock.

1.4.5.3 Telephone

A simple telephone includes, among other things, a microphone, a battery and an earpiece. Especially in older phones, the microphone consists of a carbon grain chamber with a membrane. Pressure variations (sound) cause the membrane to vibrate, whereby the resistance through the carbon grains varies to a corresponding degree. Thus, the speech stream through the microphone varies. The handset consists of an electromagnet and a membrane made of soft iron. Variations in the speech current through the microphone also pass through the earphone and cause its magnetic field to vary. The earphone's membrane then produces pressure variations, that is, sound.

1.4.5.4 Electromagnetic relay

The relay consists of an electromagnet, an iron plate (armature) on a spring and an electrical contact. With a weak current / low voltage through the coil in the control circuit,Ωou can use the relay's working contact to control a stronger current / higher voltage in the main circuit.

Figure 1.10: Examples of electromagnets

1.4.6 Magnetic field strength

Magnetic field strength is understood as the flow per meter field line, that is:

$$H = \frac{\Theta}{l} = \frac{I \cdot N}{l}$$

$$H = \frac{\Theta}{l} = \frac{I \cdot N}{l}$$

$$\begin{array}{ll} H & [\mathrm{A/m}] \\ I & [\mathrm{A}] \\ N & \text{varvtal} \\ l & \text{fältlinjelängd} \end{array}$$

H = Θ /l = I · N/ I
H = Θ/ I = I · N /l

H [A/m]
I [A]
N speed
l field line length

Magnetic field strength is thus expressed as amperes per meter of flow path.

1.4.7 Magnetic flux density

The magnetic flux density B is measured in the unit tesla [T]

(before gauss):

$$B = \mu \cdot H \quad B\,[\mathrm{Vs/m^2}] \quad H\,[\mathrm{A/m}]$$

B = μ · H B [Vs/m2] H [A/m]

μ is the permeability number for the material.
μ0 is the permeability number (field constant) for the magnetic conductivity of vacuum.

For iron or other magnetically conductive material, the permeability number μr is added. It indicates how many times better than air, etc., the material conducts a magnetic flux. The permeability number can then be written μ = μr μ0: B = μ0 · μr · H

1.4.8 Magnetic flux

The magnetic flux is the product of the flux density B and the cross-sectional area A of the flux path:

$$\Phi = B \cdot A$$

$$\Phi\,[\text{weber eller Vs}] \quad B\,[\text{T eller tesla}] \quad A\,[\text{m}^2]$$

Φ = B · A Φ [weber or Vs] B [T or tesla] A [m2]

1.4.9 Shielding of magnetic fields HAREC a.1.4.2

Basically there are two types of fields, the electric and the magnetic. There are also electromagnetic fields that are composed of both of these. Fields can be permanent or movable, of which here is meant the movable ones. A moving magnetic field generates an electric field. Conversely, a moving electric field generates a moving magnetic field. This interaction allows the fields to be kept going with the supply of external energy. Fields in motion generate electromagnetic radiation, which affects functions in the environment. When the impact is not desired, the field must be screened off. One way to shield magnetic fields is a metallic enclosure. The enclosure must be tight and form a closed magnetic circuit. The enclosure must be made of a material that is a good conductor of magnetic flux. (Compare 1.3.5)
15

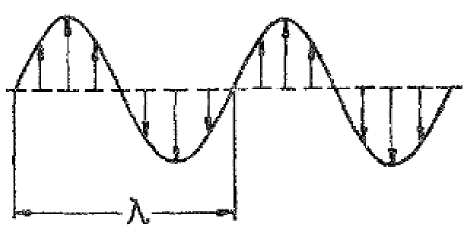


Figure 1.11: Waves along a line

1.5 Electromagnetic waves HAREC a.1.5 1.5.1 Wave propagation HAREC a.1.5.1

A change of state in a medium means that energy is added or removed. If this happens alternately, processes such as oscillation, oscillation, wave formation etc. occur. Since nature seeks equilibrium, the process spreads through the medium according to a model. Energy can take different states. In a pendulum, the energy alternates between positional energy and kinetic energy. Waves on a liquid surface as well as suspension in solid materials are examples of this. It can also mean pressure fluctuations in gases and so on. This section deals with electromagnetic fields. Such arise from oscillations in electric and magnetic fields. To explain commuting and propagation, models are used here.

1.5.2 Propagation models

1.5.2.1 Wave propagation along a line

Figure 1.11 shows waves along a line. When the end of a wire is set to oscillate with a frequency f, the whole wire eventually oscillates with that frequency.

The oscillation, which was first created, travels along the wire with the propagation speed v. The wavelength is λ (lambda), which is the distance between two adjacent points with the same oscillation position and direction of oscillation.

1.5.2.2 Wave propagation on a surface

Figure 1.12 shows wave propagation on a surface. When an object is dropped through a liquid surface, waves are formed that spread out as circles within each other (concentric). The points on the wave, which for the moment have the same oscillation mode, and are the same distance from the energy source, are called wave fronts. The relationship between propagation velocity v, wavelength λ and frequency f is:

$$v = \lambda \cdot f \quad v\,[\text{m/s}] \quad \lambda\,[\text{m}] \quad f\,[\text{Hz}]$$

v = λ · f v [m/s] λ [m] f [Hz]

Example: When the wavelength λ = 2 [m] and the number of oscillations per second f = 10 [Hz], then the wave propagates with the speed v = 20 [m/s].

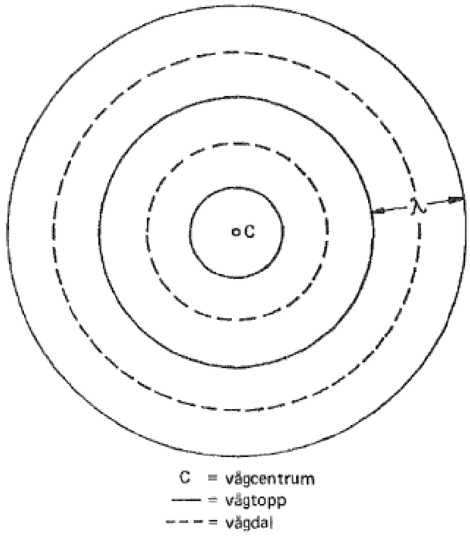


Figure 1.12: Wave propagation on a surface

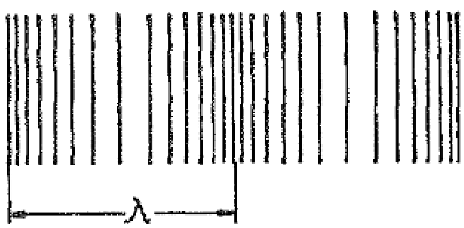


Figure 1.13: Wave propagation in the room

1.5.2.3 Wave propagation in the room

Figure 1.13 shows wave propagation in the room. Sound is energy in the form of pressure waves in the air. When a mechanical body is set into oscillation (tuning fork, drinking glass, etc.), the oscillations are transferred to the surrounding air mass, which begins to oscillate with it. In the air mass, alternating high and low pressure zones are formed, which spread out in all directions. The mechanical oscillations in the sound source are thus converted into pressure waves. The human ear perceives pressure waves in the frequency range approx. 15–18,000 Hz as sound. These waves are called sound waves. The propagation speed of sound waves is v = approx. 340 m/s at 15 ◦C and normal air pressure.

1.5.3 Electromagnetic fields HAREC a.1.5.2

Table 1.2 shows the electromagnetic spectrum. In this section, mainly only a comparison is made between light waves and radio waves, both of which are electromagnetic radiation. How an electromagnetic field is released from a conductor is shown in chapter 8.

Electromagnetic fields are energy, which is composed of very rapidly fluctuating electric and magnetic fields. When electric current through a conductor changes in strength, a magnetic field is formed around the conductor. This magnetic field produces an electromotive force

Frequency	Wavelength	Properties
300 Hz 1 kHz	100 mil 300 km	ULF
3 kHz 10 kHz	100 km 30 km	VLF
30 kHz 100 kHz	10 km 3 km	LF
300 kHz 1 MHz	1 km 300 m	MF
3 MHz 10 MHz	100 m 30 m	HF
30 MHz 100 MHz	10m 3 m	VHF
300 MHz 1 GHz	1 m 300 mm	UHF
3 GHz 10 GHz	100 mm 30 mm	SHF
30 GHz 100 GHz	10 mm 3 mm	EHF
300 GHz 1 THz 3 THz 10 THz 30 THz 100 THz	1 mm 300μm 100 μm 30 μm 10 μm 3 μm	Infrared
300 THz	1 μm	Visible Light
1 PHz	300 nm	Ultraviolet

3 PHz	100 nm	
10 PHz	30 nm	
30 PHz	10 nm	Xray
100 PHz	3 nm	
300 PHz	1 nm	
1 EHz	300 pm	
3 EHz	100 pm	Gamma
10 EHz	30 pm	
30 EHz	10 pm	
100 EHz	3 pm	
300 EHz	1 pm	

1.5.3.1 Light waves

The eye only perceives electromagnetic radiation within a certain frequency range as light. The propagation speed of light depends on the material it passes through. In a vacuum, the speed is greatest, c = 299,792,458 [m/s] (= approx. 3 · 108 [m/s]) [19].

In denser substances the speed is lower, for example in glass approx. 200,000,000 m/s. The light visible to humans has wavelengths between 7.7 · 10−7 and 3.9 · 10−7 [m], corresponding to 7.7 to 3.9 ten-thousandths of a mm. The relationship between the propagation speed of light c in a vacuum, the frequency f and the wavelength λ is c = λ · f c [m/s] λ [m] f [Hz]

1.5.3.2 Radio waves

Radio waves are also electromagnetic radiation, but within a lower frequency range than that of light . But the propagation speed of radio waves through different materials still follows the same laws as those for, for example, the propagation of light.

Radio waves are considered to cover a frequency range from about 10 kHz (λ = 30 [km]) to 300 GHz (λ = 1 [mm]). Broadcasting is assigned frequencies in the range of 100 kHz to 1000 MHz. Amateur radio is assigned a number of frequency ranges in the range 136 kHz to 250 GHz.

To notice is that electromagnetic fields, as said above, occur as far down in frequency as a few kHz.

This should of course not be confused with sound pressure at the same frequency.

1.5.3.3 Properties of electromagnetic waves

Electromagnetic waves with a higher frequency than radio waves are perceived as heat radiation, waves with an even higher frequency as light, etc., but the main properties are still the same. Examples include polarized waves. In addition, one can find the equivalent of such properties as interference and superimposition also in other wave types, for example in sound. 17 Figure 1.14: Polarization of electromagnetic waves

1.5.4 Wave polarization HAREC a.1.5.3

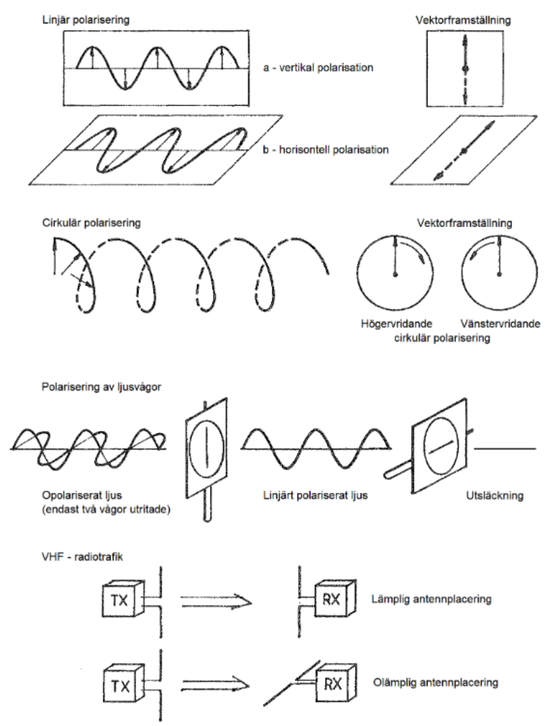


Figure 1.14 shows polarization of electromagnetic waves.

1.5.4.1 Waves along a line (wire etc.)

A wave motion in a plane is called linearly polarized. If the end of a horizontal wire is moved up-down, a linearly polarized wave movement occurs on the wire in the vertical plane - vertical polarization.

If the wire is set in right-left motion, its oscillation will be horizontally polarized.

If the wire is set to oscillate in a plane and this plane is constantly twisting, the wave movement along the wire will also twist. A wave movement whose polarization twists rotates - is called circularly polarized.

Counter-clockwise and clockwise rotation are called left- and right-handed polarization, respectively.

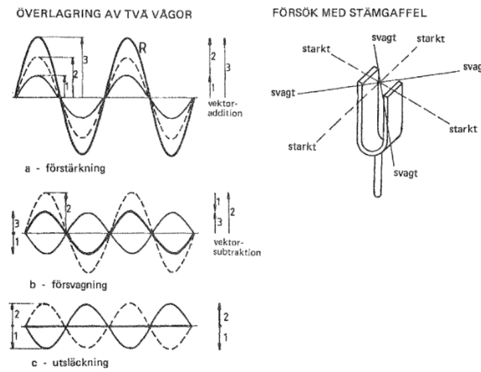
1.5.4.2 Electromagnetic waves

The magnetic and electric fields around a conductor are oriented at right angles to each other. The electromagnetic field they form together forms a wavefront oriented perpendicular to them.

The polarization direction of an electromagnetic wave is defined as the direction its electric field has:
• vertical electric field – vertical polarization
• horizontal electric field – horizontal polarization.

1.5.4.3 Light waves

Light is electromagnetic waves. When daylight, which is otherwise unpolarized, illuminates a polarization filter, only those wave components that have the same polarization as the filter pass through the filter. When the polarized light is then sent towards a subsequent filter, the light passes through the filter only when it has the same polarization as the light. When the two filters are rotated 90◦ relative to each other, no light passes through at all.



18 Figure 1.15: Wave interference

1.5.4.4 Radio waves

Radio waves are electromagnetic waves within the frequency range suitable for radio communication. Depending on the design of the transmitting antenna, it emits waves with a polarization. Similarly, a receiving antenna is most receptive to waves with a certain polarization. Transmission losses are lowest between antennas with the same polarization. In the higher frequency range of radio (VHF, UHF, SHF), polarization distortion during transmission is less common.

By designing the antennas with horizontal, vertical or circular (right- or left-turned) polarization, transmission characteristics are obtained for different purposes. Circularly polarized antennas produce the lowest transmission losses when the direction of polarization is the same in the transmitter and receiver antenna. In the lower frequency range for radio (HF and lower), space wave propagation is most often used. Since the emitted waves are then reflected against the ionosphere layer, polarization distortions occur that cannot be predicted. Then it is an advantage to be able to switch between antennas with different polarization.

1.5.5 Wave interference

Figure 1.15 shows wave interference. When waves from different energy sources are mixed with each other (superimposed), they will either cooperate or oppose each other. Depending on the temporal position between the waves and their amplitudes, the result is an amplification or an attenuation. If they have the same frequency and equally large, oppositely directed amplitudes, an extinction occurs, which is called fading. This wave mechanism is similar in gases (air), liquids, electromagnetic fields, etc.

An experiment can be done with a tuning fork thatΩou strike and hold close toΩour ear. AsΩou rotate the tuning fork around its longitudinal axis, the distance between each of the fork legs and the ear will vary. Then there is an alternating cooperation and counteraction between the tones from the fork legs and thus varying tonality. This phenomenon is used, among other things, in antennas for directional transmission and reception of radio waves. 19

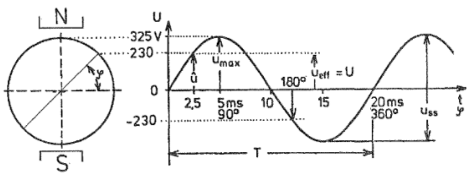


Figure 1.16: Generation of a sinusoidal signal

1.6 Sinusoidal signals HAREC a.1.6, a.1.6.1

Figure 1.16 shows the generation of a sinusoidal signal. In this section, some basic concepts in alternating current theory are dealt with. The processes are presented with vector and line diagrams. For a more detailed description, terms such as instantaneous value, peak value, peak-to-peak value, effective value, phase position, phase shift and arc speed are used

1.6.1 Instantaneous value HAREC a.1.6.2a

The instantaneous value is the magnitude of a voltage u, a current i etc. at a certain time t. (Quantities that change as a function of time are often characterized by lowercase letters.)
Figure 1.16 shows a sinusoidal alternating voltage with a frequency of 50 Hz.

The voltage u is +230 V at the time 2.5 milliseconds after a positive zero crossing. After a total of 5 ms, the peak value umax is reached, i.e. +325V. After a total of 10 ms, a negative zero crossing occurs. After a total of 12.5 ms, the voltage is −u, i.e. −230 V etc.

1.6.2 Peak value or amplitude HAREC a.1.6.2b

$$U = \frac{\hat{u}}{\sqrt{2}} \qquad I = \frac{\hat{i}}{\sqrt{2}} \qquad (\sqrt{2} = 1{,}414)$$

Peak value umax is the highest value above or below zero. In Figure 1.16, the highest values are +325 V and −325 V.

1.6.3 Peak-to-peak value

$$\omega = 2\pi f \qquad [\mathrm{rad/s}]$$

Peak-to-peak value is the sum of the peak values above and below zero. In figure 1.16, this value is 650 V.

1.6.4 Effective value HAREC a.1.6.2c, a.1.6.2d

The effective value of an alternating voltage u is the value that results in the same power development as a direct voltage U . For a sinusoidal course, the following relationship applies between the peak value and the effective value (the so-called square mean value), which corresponds to the amplitude at the angles 45, 135, 225 and 270◦. U = ˆu √2 I = ˆi √2 (√2 = 1.414)

1.6.5 Phase position

The phase position φ is when, within a period, a given instantaneous value occurs. The time of each instantaneous value corresponds to a fraction of 360◦ electrical degrees. For example, the value zero volts is reached at 0◦, 180◦ and 360◦ (= 0◦).

1.6.6 Arc measurement

In calculations of alternating current circuits, angle measurement for the phase position (number of degrees) is often not used, but instead the concept of arc measurement. In a so-called unit circle with radius r = 1, the angle 360◦ corresponds to an arc of length 2 · π · r = 2 · π · 1 = 2π = the circumference. At f periods per second, the arc length = 2πf . This quantity is called arc velocity or more often angular velocity and is denoted by ω (pronounced omega): ω = 2πf [rad/s]

1.6.7 Period HAREC a.1.6.3a

A period has passed, when a quantity (voltage, current, etc.) the same state or value after making a complete change, such as a full pendulum motion or a full revolution in rotation. 20

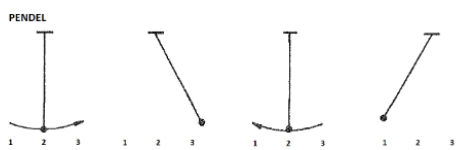


Figure 1.17: Pendulum as an illustration of frequency

1.6.8 Period time T HAREC a.1.6.3b

Period time T is the time required for the current or voltage to run through a period. The period is the inverse value of the frequency. The unit of measurement for period time is second [s]. Period time (T) = 1 / f

$$\text{Periodtid} \qquad (T) = \frac{1}{f}$$

Example:
T1 = 1 10 s = 0.100 s = 100 ms (10 Hz)
T2 = 1 50 s = 0.020 s = 20 ms (50 Hz)
T3 = 1 1000 s = 0.001 s = 1 ms (1 kHz)
T4 = 1 1000000 s = 0.000 001 s = 1 μs (1 MHz)

1.6.9 Frequency HAREC a.1.6.4

Frequency is the number of periods per time unit. The following concepts are demonstrated using the pendulum: Period = a complete back and forth swing in a system, for example the path of the pendulum between the points 2-3-2-1-2-3- etc.

$$f = \frac{1}{T}$$

Figure 1.17 shows pendulum motion as an illustration of frequency. Period time T = the time required for a complete oscillation. Amplitude A = the largest deviation from rest. Frequency f = number of oscillations/time unit. The relationship between the frequency f and the period time T is: f = 1 T for example: 5[Hz] = 1 5 [seconds]

1.6.10 The unit hertz HAREC a.1.6.5

The unit of measurement for frequency is hertz [Hz].
In formulas, the frequency is denoted by f.
1 Hz = 1 period per second (p/s)
10 Hz = 10 periods per second
50 Hz = 50 periods per second
1000 Hz = 103 Hz = 1 kHz (kilohertz)

1000 kHz = 106 Hz = 1 MHz (megahertz)
1000 MHz = 109 Hz = 1 GHz (gigahertz)

The grid frequency for electric power in Europe is 50 Hz. Other mains frequencies exist, for example 60 Hz in the USA and Japan. The frequency range for the transmission of qualitative speech and music, low frequency LF, is between approx. 16 Hz and 16 kHz. The frequency range for speech transmission, for example over telephone lines or communication radio, is approximately 300 to 3000 Hz. The frequency range for radio transmission, high frequency HF, is essentially between 50 kHz, so-called long wave, and 100s of GHz, so-called microwave.

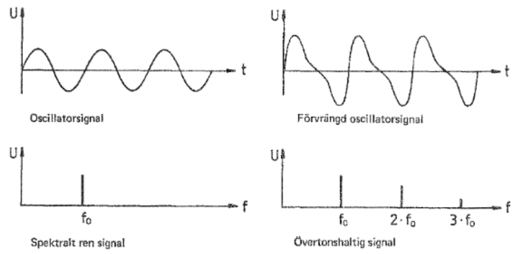


Figure 1.18: Pure sine wave and harmonic wave

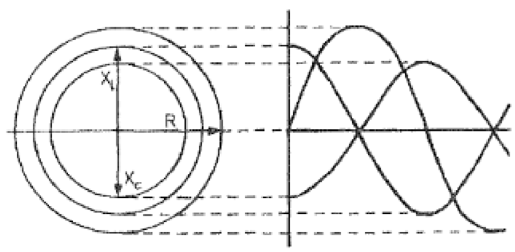


Figure 1.19: Vectors and phase shift

1.6.11 Phase shift HAREC a.1.6.6

Figure 1.19 shows vectors and phase shift. By phase shift is meant the time difference between processes, for example voltages and/or currents. The phase shift between the vectors is also called the phase angle and is expressed as a number of degrees between 0 and 360◦.

1.6.12 Vectors

A voltage, current, force, etc. can be described as a vector with a magnitude and direction. In figure 1.19, the vectors XL, R and XC have a mutual phase shift of 90◦. They correspond to the voltage drops in a circuit with an inductor, a resistor and a capacitor connected in series, where the common current is a sine wave. Assume that the vectors rotate in an unchanged relative position and with an angular velocity of $\omega = 2\pi f$. The system then rotates 360◦ = 2π radians = 1 revolution/period. At each point in time, the vector system has reached a certain angle of rotation. The instantaneous value of the voltages of the vectors is placed to the right of the image. The distance between a vector tip and the zero line is the current value of the vector, which can be positive or negative.

1.7 Non-sinusoidal signals HAREC a.1.7

1.7.1 Fundamental, harmonics and edge waves HAREC a.1.7.2, a.1.7.3, a.1.7.4b

Figure 1.18 shows a pure sine wave and wave containing harmonics. A sinusoidal waveform with a single frequency – a single note – is said to be spectrally pure. Such an oscillation is called a fundamental tone. Any signal that is not sinusoidal is composed of several sinusoidal oscillations.

It is the fundamental tone of the signal and its harmonic overtones, which can have 2, 3, etc. times higher frequency than the fundamental tone. The relative strength of the fundamental and overtones determines the shape of the signal. If the signal is within the audible range, one can notice how it changes character depending on the harmonic content.Ωou can say that the overtones modulate the fundamental.

Figure 1.20 shows the division of a signal into fundamental and overtones. The oscillator signal in the example in the picture has 1 volt amplitude on the fundamental f0 (1st harmonic), 0.7 volt amplitude on the 1st harmonics (2nd harmonic) and 0.2 volt amplitude on the 2nd harmonic (3 :th harmonic). However, the total amplitude will not be the sum of 1, 0.7 and 0.2 volts because the peak values of the different partial voltages do not occur simultaneously.

Instead, the partial voltages must be added at each time separately. Figure 1.21 shows the division of a square wave into fundamental and overtones. This analysis of waves was invented by Jean-Baptiste Joseph Fourier (1768–1830) in the analysis of heat propagation and vibration presented in 1822. This method is powerful and has had a great influence on science and development both as a mathematical tool and as a practical analysis with spectrum analyzers and with modern modulation and demodulation. They talk about Fourier analysis (eng. Fourier analysis) and Fourier transform (FT) for conversion from time to frequency and inverse Fourier transform for conversion from frequency to time.
For the discrete-time (sampled) form, the terms discrete fourier transform (DFT) and
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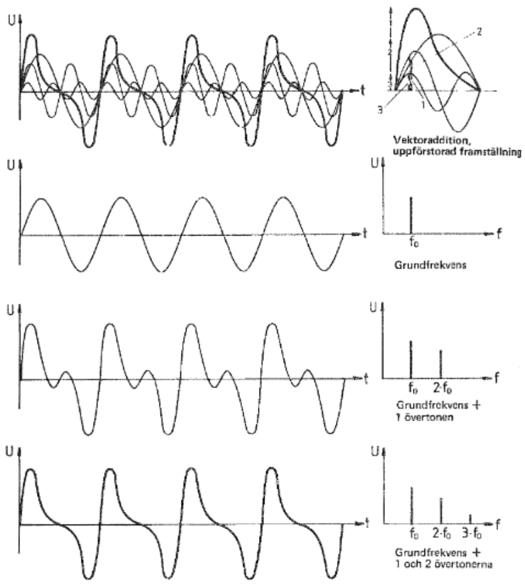


Figure 1.20: Decomposition of a signal into fundamental and harmonics

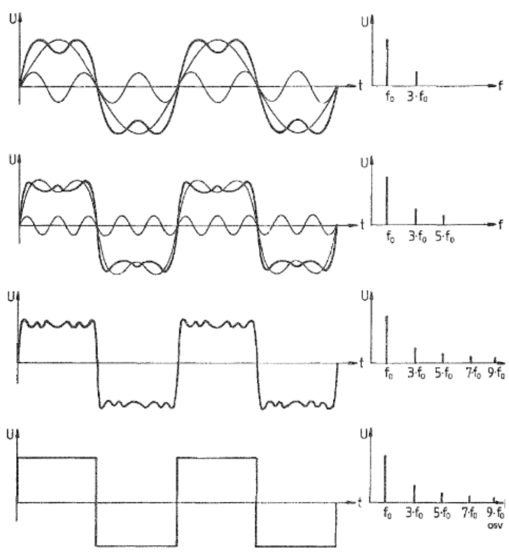


Figure 1.21: Decomposition of a square wave into fundamental and harmonics 23

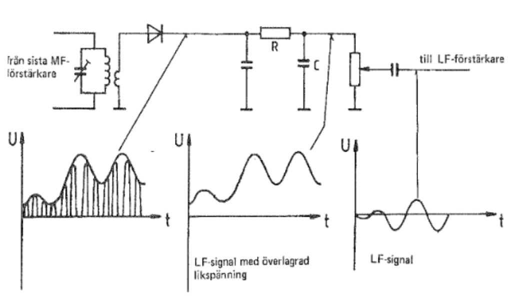


Figure 1.22: Superimposed voltages inverse discrete fourier transform (IDFT) respectively .

Later optimizations of calculations have resulted in Fast Fourier Transform (FFT) and Inverse Fast Fourier Transform (IFFT). There are different types of waveforms such as sine wave, triangle wave, sawtooth wave, square wave and so on.

The square wave is composed of sine waves with the fundamental frequency and its odd harmonics, the amplitudes being distributed as 1/1, 1/3, 1/5, 1/7, 1/9, 1/11, etc.

Theoretically, the harmonic spectrum reaches up to infinitely high frequencies, while the corresponding amplitudes decrease to infinitely small values. An ideal square wave, which cannot be achieved in practice, would consist of an infinite number of odd harmonics of decreasing amplitude. The more of the higher harmonics that are filtered out, the more the sides of the square wave slope, the rounder the corners of the wave and the more undulating the top of the curve.

1.7.2 Superimposed voltages (DC component) HAREC a.1.7.4a

Figure 1.22 shows superimposed voltages. In signal circuits, it is very common for alternating voltage to be superimposed on direct voltage or vice versa. The direct voltage is then called the direct voltage component.

Different measures are needed to superimpose stresses on each other and then separate them. The image shows a section of an AM receiver. From the left, an AM modulated signal is taken from the MF amplifier to be demodulated, that is, to recover the modulating LF signal. The MF signal is half-wave rectified. What remains is the positive part of the MF signal and the modulating LF signal, stored together. The LF signal must now be separated and amplified. Thus, the MF component is filtered out.

What remains is the LF signal, but superimposed on a DC voltage. The DC voltage is stopped and what remains is finally the LF signal which is amplified.

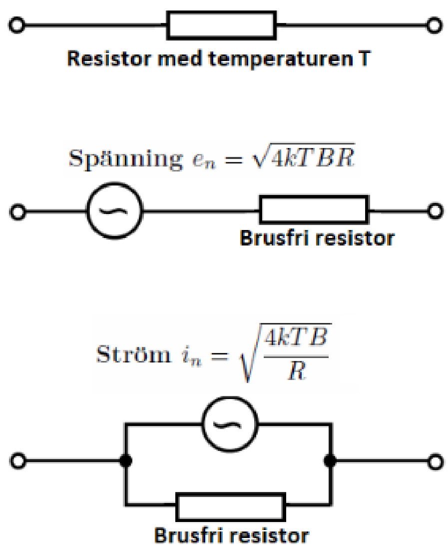
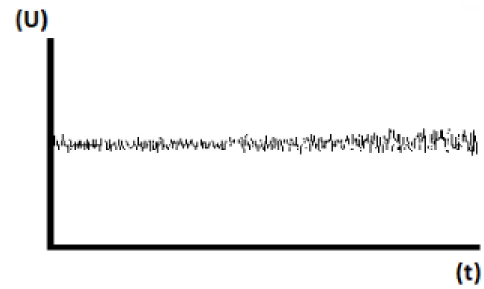


Figure 1.23: A resistor can be seen to have noise equivalents such as voltage or current

1.7.3 Noise HAREC a.1.7.5, a.7.19

1.7.3.1 Thermal Noise

Resistors and resistance, in all its forms, exhibit a characteristic of a varying voltage even when no current flows through the resistor. This extra tension contains a wide spectrum of tones, but is also a tight spectrum, such that no single tone can be distinguished from any other. Instead of imagining a fundamental tone and its overtones with no energy between them, it is instead a continuous spectrum with an infinite number of tones. However, this spectrum is limited by the bandwidth. This spectrum is colloquially called thermal noise, because it depends on the temperature of the resistor, or Johnson noise, after J. B. Johnson who in 1928 found that this noise



24 Image 1.24: Noise means an instability over time

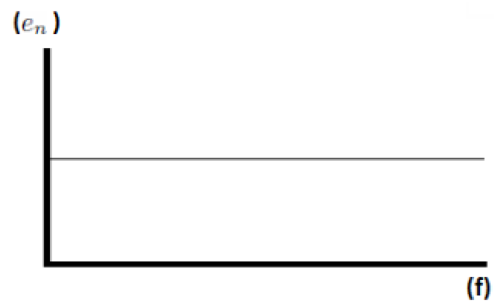


Image 1.25 : Noise contains all frequencies, white noise has the same amplitude was present in all conductors [25].

Noise creates a variation in voltage and current, as illustrated in Figure 1.24. In everyday speech, however, we only talk about white noise (eng. white noise) or noise. By white noise is meant noise that has not been "colored", and in this context it means that it has the same amplitude for all frequencies, as illustrated in Figure 1.25. In practice, all noise is limited by the bandwidth of the channel, but it is considered white within the channel if it is uniform within the band. The effect Pn of this noise depends on Boltzmann's constant k = 1.38 · 10−23 J/K, the absolute temperature T in kelvin and the bandwidth B in hertz and is given according to the formula:

$$P_n = kTB$$

Pn = kT B Each resistor with the absolute temperature T can be modeled as having an equivalent voltage en and current in for the resistance R, as illustrated in Figure 1.23 is

en = √4kT BR and in = √ 4kT BR .

$$e_n = \sqrt{4kTBR} \quad \text{och} \quad i_n = \sqrt{\frac{4kTB}{R}}.$$

1.7.3.2 Noise Bandwidth

While we initially assumed that the noise bandwidth is for frequencies from DC to the upper cutoff frequency, this is not necessary. The formula is also relevant to the noise on a band and the bandwidth of the bandpass filter we have to listen to this band alone. For example, speech on SSB needs to handle 300 Hz to 3 kHz, i.e. 2.7 kHz bandwidth, and thus the receiver bandwidth will also need to be that large. We will then receive noise for the corresponding bandwidth.

A filter for telegraphy, for example, can be 350 Hz and will thus also have a correspondingly lower noise power. However, this is a simplification, as the filter does not filter with steep edges and is completely flat. The actual noise bandwidth of the filter depends on how the filter filters over all frequencies and the sum of these. Depending on the type of filter, a correction factor is therefore needed from the normal bandwidth to the noise bandwidth. For a typical 12 dB/octave low-pass filter, the correction factor is 1.22.

1.8 Modulation HAREC a.1.8 1.8.1

General Modulating (lat. modulari, rhythmically measured, eng. modulating) is to transmit the information in a low-frequency signal with the help of a mostly high-frequency electrical signal (the carrier wave).

In this way, low frequency, for example speech and music, can first be converted into an electrical signal, which can influence (modulate) a high-frequency electrical signal. This modulated signal is radiated from the antenna as an electromagnetic field. The signal that contains the information is called a modulating signal, baseband or subcarrier. The signal into which the information is transmitted is called a modulated signal, carrier or main carrier.

1.8.2 Modulation system

The largest group of modulation systems is defined with respect to how the main carrier is modulated. Amplitude and angle modulation are then most common. There are mainly two types of angle modulation, frequency modulation and phase modulation. In addition, there are systems for pulse modulation.

1.8.3 Transmit beats

The ways to modulate are called transmit beats. Common to all types of transmission is that a transmitter – it can be a microphone, a telegraph key, a remote typewriter, a computer, a TV camera – generates an analogue or digital signal.

This controls the subcarrier so that the main carrier is modulated with the intended information and transmitted. The simplest type of transmission can be considered Morse telegraphy with a "keyed carrier". Then there are only two states, depressed and non-depressed telegraph key, i.e. either carrier with some duration or no carrier at all. Combinations of carrier elements of different lengths correspond to characters. To reproduce speech, music, etc., a more accurate state control of the carrier wave is needed. This means that the carrier must be modulated by a subcarrier and that this corresponds to the air pressure variations in the sound.

1.8.4 Characteristics of modulated signals HAREC a.1.8.5

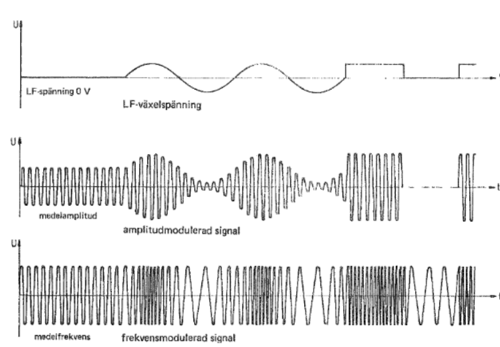


Figure 1.26 illustrates modulated signals. A modulated signal is characterized by its amplitude,

frequency and phase position. With amplitude modulation, the amplitude of the main carrier is affected, so that it corresponds to the variation of the modulating signal at each time.

In frequency modulation, the frequency of the main carrier is affected, so that it corresponds to the variation of the modulating signal at each time.

In phase modulation, which is related to frequency modulation, instead of the frequency, the phase position of the main carrier wave is affected in relation to a reference signal, so that the phase position at each time corresponds to the variation of the modulating signal.

Frequency and phase modulation are similar and can be summarized as angle modulation, because the phase angle between the carrier voltage and current varies in both cases.

In pulse modulation, pulse trains (short repeated carrier wave packets) are used, for example pulse amplitude, pulse length, pulse position and pulse code modulation. Pulse code modulation is used, for example, for the simultaneous transmission of several telephone calls on the same line, carrier wave, etc.

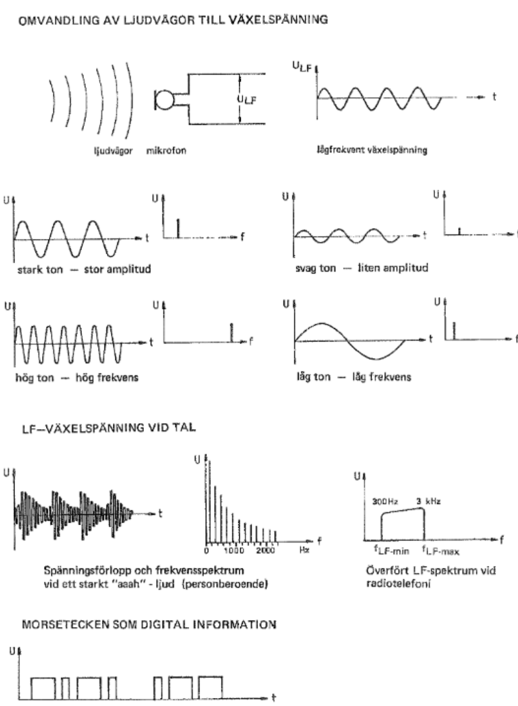
1.8.5 Bandwidth for different transmission types HAREC a.1.8.5

Each radio transmission takes up space around the nominal carrier frequency - together the bandwidth. The radio amateur must know this "space requirement", mainly in order not to transmit outside the frequency bands allocated for amateur radio use, but also to be able to interact with other traffic within the bands.

In all types of transmission, the bandwidth used increases with increased modulation. Since maximum frequency efficiency must always be sought, a transmitter with stronger modulation than is needed for a transmission always occupies unnecessary frequency space.

1.8.6 Description code for the broadcasting laws

At the 1979 Radio Management Conference (WARC 79) in Geneva, the International Radio Regulations (RR), which essentially came into force in 1982, were revised. over the radio and more. The regulation has been revised later, but in this section it still applies. The division into broadcast types is needed to characterize the broadcasts, for example in frequency lists, constitutions and regulations. The division is also of great value in the technical description of devices and systems for radio communication. However, many also use older names, which survive in the literature, in marking the control devices on transmitters and receivers. However, these older designations are not unambiguous and easily cause misunderstanding, which is why the description code according to WARC 79 should be used for the sake of clarity. Here are abbreviated codes according to WARC 79 for some of the transmission types that amateurs use the most, as well as for comparison the designations that are still used side by side (see further in Appendix E). NON Carrier without modulating signal. No information.



26 Figure 1.27: Modulating signals

A1A Carrier wave with double sidebands. A single channel with quantized carrier. No modulating subcarrier. Telegraphy. Also called keyed carrier wave (CW).

A3E Linearly modulated main carrier. Double side band. A single channel of analog information. Telephony. Also called amplitude modulation (AM).

J3E Linearly modulated main carrier. A sideband with suppressed carrier wave. A single channel of analog information. Telephony. Also called single side band, Single Side Band (SSB).

F3E Angle modulated carrier wave. Frequency modulation. A single channel of analog information. Telephony. Also called frequency modulation (FM).

G3E Angle modulated carrier wave. Phase modulation. A single channel of analog information. Telephony. Also called phase modulation (PM).

Both A1A, A3E and J3E are transmission types where the amplitude is modulated. Therefore, the term amplitude modulation is not sufficient to describe several similar types of transmission.

1.8.7 Modulating signals HAREC a.1.7.1 1.8.7.1

Baseband is a frequency range for a modulating signal. There is a baseband for all kinds of modulating signals, whether analog or digital. There can be more than one baseband in a complete modulation process.

For example, a keyed tone going to the transmitter through the microphone input is its analog baseband while the keying pulses to the tone generator are its digital baseband. Figure 1.27 illustrates modulated signals. A common way of transmitting information over the radio is with telephony, that is, speech. 27

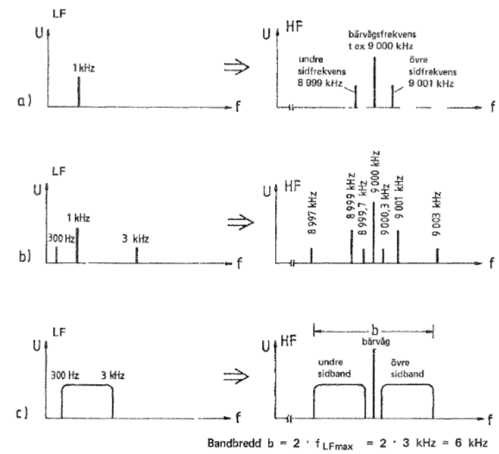


Figure 1.28: Sideband in A3E modulation

The frequency range 300–3000 Hz is sufficient for good intelligibility of speech. Partly the ear is most sensitive in that area and partly there is the most energy in the speech. The microphone picks up the air pressure variations that occur whenΩou speak and converts them into electrical oscillations. The oscillations vary between positive and negative voltage values.

Experiment

1. Connect a microphone to an oscilloscope and study the voltage curves for different kinds of sounds, tones, speech, etc. as a function of time. In the picture, these oscillations are very simplified, for example sinusoidal.
2. Connect a speaker and an oscilloscope to an LF generator, the frequency and amplitude of which can be changed. Listen to low and high frequency sounds as well as weak and strong sounds. A bass note has a low frequency and a treble note has a high frequency. A weak tone has small amplitude and a strong tone has large amplitude.

1.8.8 Transmission type A3E (AM) HAREC a.1.8.2, a.1.8.6b, a.1.8.7b

Figure 1.28 shows the frequency spectrum of a signal during amplitude modulation with a. a sine tone, b. a mixture of three sine tones, c . a frequency spectrum. Try Modulating an A3E transmitter with a 3 kHz signal. With a receiver equipped with a narrow filter for telegraphy, the carrier and the two sidebands can be distinguished and detected.

1.8.8.1 A3E modulation with one tone

Figure 1.29 shows A3E modulation with tones of different strength and frequency. An unmodulated carrier wave has a constant amplitude. An amplitude modulated signal is basically the result of floating between frequencies or of non-linear mixing of frequencies. When carrier and baseband are mixed, three mixing products in particular are of interest. These are:

- the carrier wave
- the lower sideband (abbreviated LSB)
- the upper sideband (abbreviated USB).

The AM signal thus consists not only of the carrier frequency f_{HF} but also of upper and lower side frequencies, which are the sum and difference of the carrier frequency f_{HF} and the modulating frequency f_{LF} .

So $f_{HF} + f_{LF}$ (upper side frequency) and the difference frequency $f_{HF} - f_{LF}$ (lower side frequency). Since speech does not only cover a single frequency but an entire frequency spectrum (approx. 0.3–3 kHz), not only two side frequencies but two side bands arise, the

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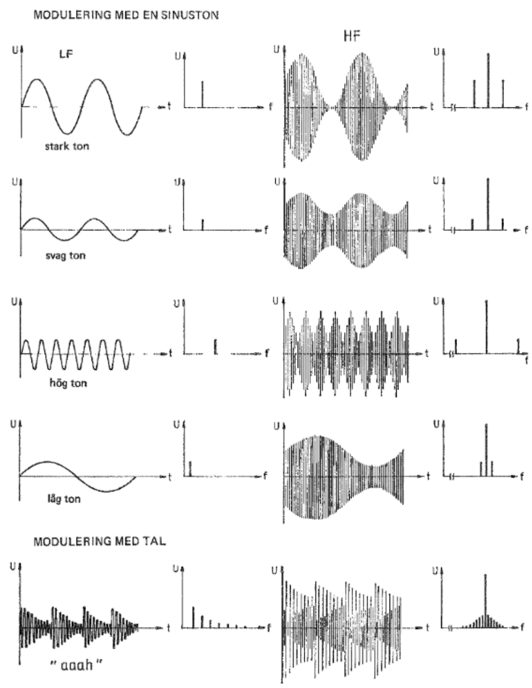

Figure 1.29: A3E modulation with tones of different strength and frequency lower side band (LSB, Lower Side Band) and the upper (USB, Upper Side Band). The frequency of the LF signal determines the distance of the side frequency from the carrier. The bandwidth of an amplitude-modulated signal with a full carrier and two sidebands is twice as large as the highest modulating

LF frequency: $b = 2 \cdot f_{LF}$ max

If the modulating LF frequencies are between 0.3 and 3 kHz, the total bandwidth of the transmission is 6 kHz. The amplitude of the LF signals affects the amplitude of the sidebands and side frequencies. At maximum modulation (100% modulation degree), the signal amplitude varies between zero and twice the value of an unmodulated carrier wave. At most, each sideband can transmit a quarter as much power as the carrier wave, i.e. one sixth of the total emitted power. Then the transmitter emits twice as much average power as without modulation.

The peak power (PEP, Peak Envelope Power) is even four times as great. The final amplifier and the power supply must be dimensioned for the peak power at full modulation or that the degree of modulation be adapted so that overloading does not occur.

1.8.8.2 Advantages of A3E modulation

An A3E transmitter is simple compared to a J3E transmitter, which has a more complicated signal processing.

1.8.8.3 Disadvantages of A3E modulation

Since the same information is in both sidebands and none is in the carrier wave, the effect in the carrier wave and one of the sidebands is sent out to no avail. During speech breaks, only the carrier effect is transmitted and to no avail. Even frequency space is wasted. When another, too close transmitter's carrier wave is mixed with its own, interference tones are generated in the receivers.

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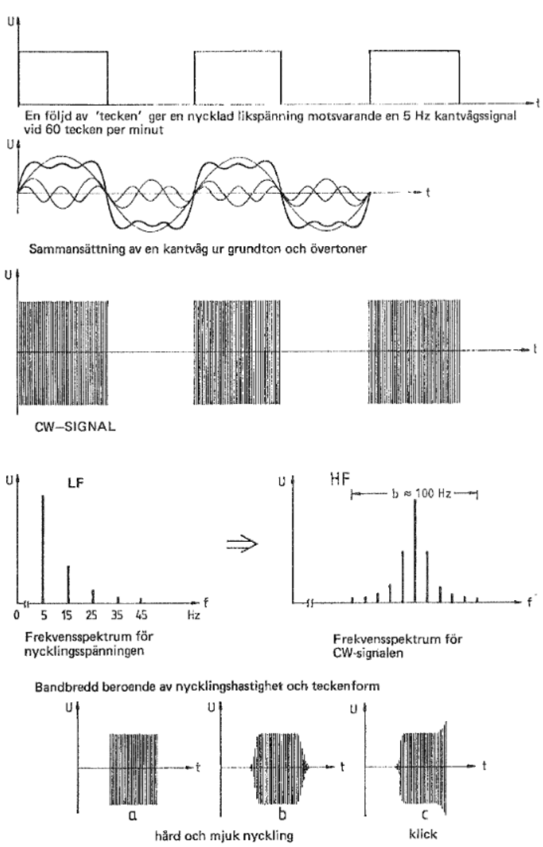

Image 1.30: Amplitude modulation with Morse code

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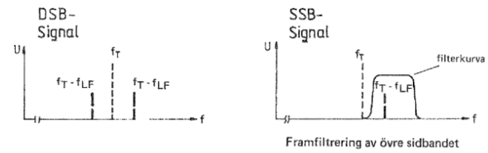

Image 1.31: Sideband at DSB

1.8.9 Transmission type A1A (CW) HAREC a.1.8.1, a.1.8.6a, a.1.8.7a

Figure 1.30 shows amplitude modulation with Morse code. One can transmit messages using Morse telegraphy in different ways. The easiest way is to switch the transmitter's carrier wave on and off in time with the parts of the Morse code.

You can call it carrier wave telegraphy.

For a long time, the procedure has also been called CW (continuous waves), which actually means that the carrier wave oscillates with a constant amplitude, if you ignore the fact that it is keyed.

This is in contrast to the damped carrier oscillations that were the case in long-banned spark emitters. Although a transmitter is "toneless modulated", it has a certain bandwidth. This is because the rate at which the transmitter is keyed is actually a tone – let alone a low frequency.

Suppose the transmitter is keyed with a series of short Morse code. At the telegraph speed of 60 characters/minute, the carrier pulses produce an edge wave with a frequency of 5 Hz. As previously described, such an edge wave consists of the sum of sine signals with frequencies of 5 Hz, 15 Hz, 25 Hz, 35 Hz and so on. This means that side frequencies occur above and below the frequency of the carrier wave and with a distance to the carrier wave of 5 Hz, 15 Hz, 25 Hz, 35 Hz, etc.

As with A3E, the telegraph transmitter thus has a bandwidth, which is partly in relation to the keying speed and partly to the "angularity" of the characters, which determines the harmonic content of the carrier wave. In so-called soft keying, the 9th harmonic can be assumed to be the highest perceived by a counter station.

With a keying frequency of 5 Hz, the bandwidth will not be greater than 2 · 10 · 5 = 100 Hz. A hard (edgy) and fast signaling increases the bandwidth and can result in so-called keystrokes being perceived far beyond the transmission frequency. The harder the keying, the further away from the carrier frequency the keying clicks are heard. This interferes with other stations. Characteristics of transmission type A1A, keyed carrier telegraphy: Very small bandwidth, extremely good utilization of transmitter power, high transmission reliability, long range, simple transmitters.

1.8.10 Transmission type J3E (SSB) HAREC a.1.8.3c, a.1.8.6c, a.1.8.7c

1.8.10.1 Principle

As stated, it is unnecessary to transmit two sidebands, since both contain the same information. Signals with only one sideband and suppressed carrier can be generated in several ways.

Nowadays, the so-called filter method is by far the most common and the only one covered here. Figure 1.31 illustrates sidebands in DSB modulation. With the filter method, the HF and LF signals are mixed in a special mixer. There both of these signals are suppressed while the mixture products with their sum and difference frequencies remain, ie. the upper and lower side band. The output signal from the mixer is called a DSB (Double Side Band) signal.

Unlike in the A3E signal, however, the carrier wave is missing in the DSB signal. In order to also suppress one sideband before transmission, the mixer is followed by a bandpass filter with bandwidth and frequency mode for the intended sideband.

The signal that is sent out therefore contains only one side band (Single Side Band).

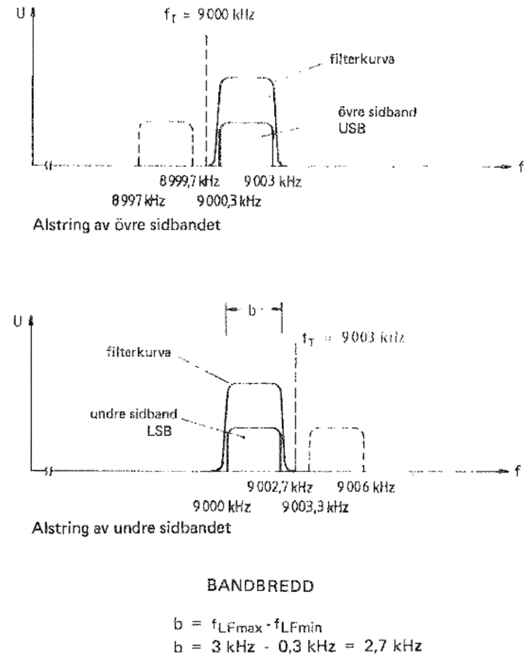

Figure 1.32: Sideband selection with SSB

Example Figure 1.32 illustrates sideband selection with SSB modulation.

An SSB filter has a passband of 9000.3–9003 kHz.

At the carrier frequency of 9000 kHz, the upper sideband extends from 9000.3–9003 kHz and is passed through.

However, the carrier frequency is suppressed. The lower sideband 8997–8999.7 kHz falls outside the filter's passband and is also suppressed. If, on the other hand, the lower sideband is to pass through the same filter, the carrier frequency must be increased by 3 kHz, i.e. to 9003 kHz.

Then the lower sideband, 9002.7–9000.0 kHz falls within the filter's passband. The upper sideband 9003.3–9006.0 kHz now falls outside the passband and is suppressed.

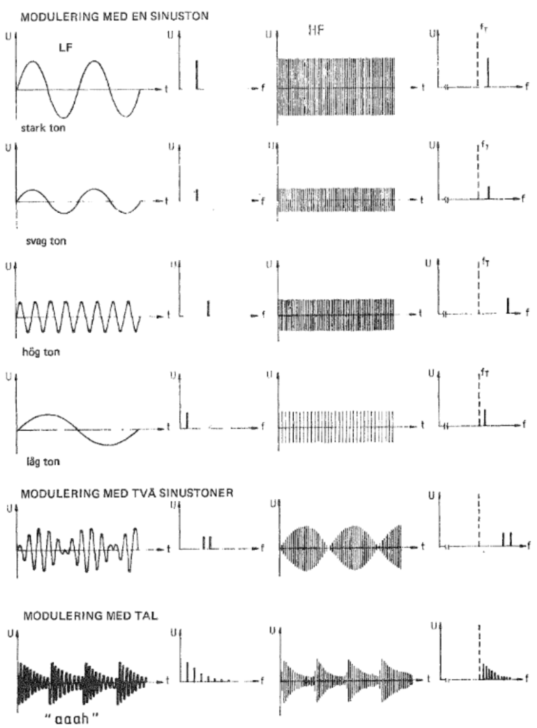

Figure 1.33 illustrates sideband modes at SSB.

The amplitude of the LF signal determines the amplitude of the side frequency. The frequency of the LF signal determines the distance of the side frequency from the carrier frequency (carrier suppressed). The bandwidth of the transmitted signal is the difference between the highest and lowest modulating frequency in the signal: for example b = 3 kHz − 0.3 kHz = 2.7 kHz

1.8.10.2 Advantages of J3E modulation

The power in the transmitted sideband corresponds to that in one of the sidebands at A3E. The entire transmitted effect is thus contained in a single sideband, which transmits the entire information. During the transmission breaks, no effect is transmitted. Bandwidth is less than half that of A3E When receiving a J3E broadcast (SSB), interference tones from J3E broadcasts on neighboring frequencies are less of a problem, since no carrier and only a sideband is emitted.

1.8.12 Frequency modulation (FM) HAREC a.1.8.3b, a.1.8.6d

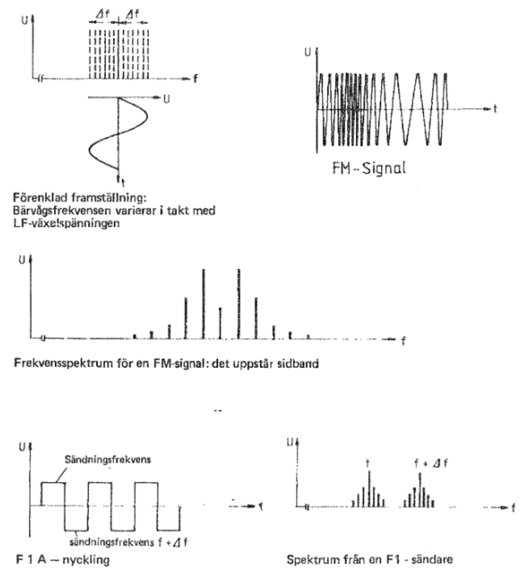

Figure 1.34 (top and middle) shows frequency modulation.

In frequency modulation, the frequency of the carrier wave varies in step with the amplitude and polarity of the modulating signal. In the figure, the frequency of the carrier wave increases when the modulating signal is positive (first half-period) and decreases when the modulating signal is negative (second half-period).

The figure shows that the periods of the modulated carrier wave take a shorter time (have a higher frequency), when the modulating signal is positive, and more time (have a lower frequency) when the modulating signal is negative. The carrier wave will therefore oscillate around an average value, i.e. be frequency modulated. The frequency deviation Δf (the deviation) from the rest frequency of the carrier wave is proportional to the amplitude of the modulating signal on each occasion.

Thus, the deviation is small when the amplitude of the modulating signal is small and greatest when the amplitude reaches its peak value, either the amplitude is positive or negative. At a modulation frequency of 300 Hz the carrier frequency varies 300 times per second, at 3 kHz it varies 3000 times per second. DC voltage levels can be transmitted with FM, as a corresponding frequency deviation can be produced. The picture also shows what is usually said, that the carrier amplitude is not changed by the modulation. However, this is only partially true, as both carrier amplitude and sideband amplitude vary with modulation index, as explained below.

1.8.12.1 Sidebands during angular modulation

With AM, only one pair of sidebands with the same content is produced, one above and one below the carrier frequency. On the other hand, with angle modulation, both at FM and PM, several pairs of sidebands are produced above and below the carrier frequency. These sidebands appear at multiples of each modulating frequency. At baseband with 1 sine tone with the same frequency range, therefore an angle-modulated signal has a larger bandwidth than an AM signal. In the case of angular modulation, the number of sidebands depends on the relationship between the modulating frequency, the frequency deviation and the modulation index.

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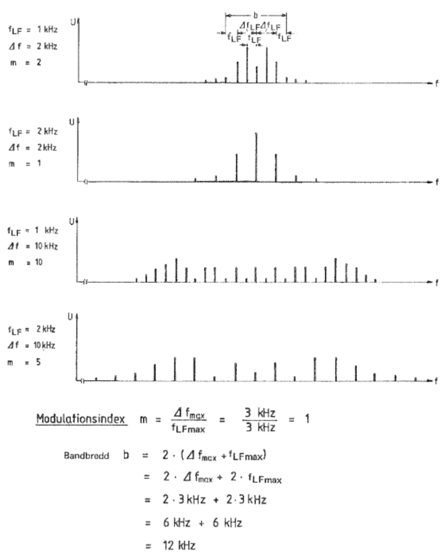

Figure 1.35: Sideband spectrum for FM modulation

1.8.12.2 The bandwidth for angle modulation

Figure 1.34 (bottom) shows the bandwidth for angle modulation.

We do the thought experiment that an FM transmitter is modulated with a square wave. The frequency will then jump alternately between the frequencies f and f + ∆f . The method is called FSK (frequency shift keying) and is used, for example, when sending radio teletext (RTTY, AMTOR, packet radio, etc.).

We imagine two transmitters, which transmit every other time, one of which transmits the frequency f and the other transmits f + ∆f . The HF signals of both transmitters will then form a frequency spectrum, which in addition to f and f + ∆f also contains side frequencies. The width of this spectrum depends, among other things, on the keying frequency. Since a square wave contains the sum of its fundamental frequency and harmonics, all of these tones will modulate each transmitter. The highest modulating LF frequencies generate the side frequencies furthest from the rest frequency. The frequency spectrum of the LF signal thus affects the bandwidth of the HF signal. The spectrum at the bottom of the picture is a simplified representation of frequency shift keying. When modulating with a sine signal instead of a square signal, a frequency spectrum like the one at the top of the image occurs.

1.8.12.3 Frequency deviation and modulation index HAREC a.1.8.4

Figure 1.35 shows the sideband spectrum for FM modulation with 1 sine tone. During angular modulation, numerous side frequencies arise, which depend on the modulating frequency fLF. The amplitude distribution between the side frequencies is proportional to the deviation, their amplitude being smaller the further away from the carrier they are. In practice, a side frequency is considered negligible when its amplitude is less than 1% of the amplitude of the unmodulated carrier.

For calculating the bandwidth, the concept of modulation index m is used, which is the ratio of the maximum deviation ∆f and the highest frequency fLF .

$$m = \frac{\Delta f_{max}}{f_{LFmax}}$$

m = ∆fmax / f LF max

In amateur radio it is common to work with

∆fmax = 3 kHz and fLF max = 3 kHz, i.e. m = 1.

For the modulation index m = 1, the following formula applies for the bandwidth b

$$b = 2 \cdot (\Delta f_{max} + f_{LFmax}) = 2 \cdot \Delta f_{max} + 2 \cdot f_{LFmax}$$

b = 2 · (∆fmax + fLF max) = 2 · ∆fmax + 2 · fLF max

With the values mentioned above, the bandwidth becomes b = 2 · (3 kHz + 3 kHz) = 12 kHz

The bandwidth thus increases both with increasing deviation and increasing modulating frequency. In order not to interfere with traffic on neighboring channels, both the deviation and the frequency of the modulating signal must be limited. A deviation limiter limits the amplitude of this signal. A low-pass filter reduces the distortion caused by the limitation. Furthermore, modulating frequencies higher than 3 kHz are suppressed, which is sufficient for the transmission of speech.

Comparison A VHF broadcast radio transmitter is allocated a larger frequency space and can therefore use much larger bandwidth.

There, ∆fmax = 75 kHz and fLF max = 15 kHz, thus m = 75 15 = 5 and b = 2·(75+15) = 180 kHz. As can be seen from table 1.3 where the mutual amplitude of the carrier and the side frequencies varies with the modulation index.

This should be compared with AM, where the amplitude of the carrier wave is constant and only the amplitude of the sideband varies. With angular modulation, the carrier wave A0 is extinguished at a modulation index of 2.404. It then becomes "negative" at higher indices, which means that it returns, meaning that its phase position is reversed. In angle modulation, the energy in the sidebands is taken from the carrier wave, which means that the total power remains the same regardless of the modulation index.

Advantages of the transmission type F3E (FM) The F3E transmitter is simple in its construction and high transmission quality is achieved with a large bandwidth, disturbances from amplitude modulated signals such as ignition sparks are suppressed in the receiver.

Disadvantages of the transmission type F3E (FM) A relatively large bandwidth is needed for the transmission of a baseband with a large frequency range. The transmitter must emit full power, even when modulation does not take place.

1.8.13 Phase modulation (PM)

With phase modulation, the phase position of the carrier wave varies in relation to a reference value. With PM, the frequency change – the deviation – is directly proportional to how quickly the phase position of the modulating frequency changes and to the total phase change. The speed of the phase change is directly proportional to the frequency of the modulating frequency and to the instantaneous amplitude of the modulating signal. This means that the deviation in PM systems increases both with the instantaneous amplitude and the frequency of the modulating signal. This is to be compared with FM systems where the deviation is proportional to the instantaneous amplitude of the modulating signal. In PM systems, the demodulator in the receiver only perceives instantaneous changes in the carrier frequency.

Unlike with FM, changes in DC voltage levels can therefore only be transmitted if a phase reference is used. With constant amplitude of the input signal to the modulator, the PM modulation index is constant regardless of the modulating frequency, while the FM modulation index varies with the modulating frequency

1.8.14 Frequency and phase modulation compared

- Frequency modulation (FM) is produced by varying (deviating) the transmitter's oscillator frequency in time with the modulating signal (eg speech). This is done by varying the resonant frequency in the resonant circuit that controls the oscillator frequency.
- Phase modulation (PM) is usually generated by varying the phase position of the modulating signal in relation to an unmodulated carrier wave after the

transmitter oscillator - so-called phase modulation. This is done by varying the resonant frequency in a resonant circuit after the oscillator, i.e. without affecting the oscillator frequency.

- In both cases, the resonant frequency of a resonant circuit is changed in step with the frequency of the modulating voltage, but this circuit has different locations in FM transmitters and PM transmitters, respectively.
- In both cases, output frequencies that deviate from the oscillator's rest frequency are generated in the transmitter. However, the degree of deviation differs for FM and PM. At FM the deviation is proportional to the amplitude of the modulating subcarrier while at PM the deviation is proportional to the product of the amplitude and frequency of the modulating subcarrier.
- The audible difference between FM and PM is therefore a different frequency response. With simultaneous use of PM transmitter and FM receiver, it is therefore advisable to adjust the frequency response in the PM transmitter's modulator, preferably with 6 dB attenuation per octave increased frequency

		Modulationsindex						
		1	2	3	4	5	6	7
Relativ amplitud på	A_0	0,765	0,224	−0,260	−0,397	−0,178	0,151	0,300
	A_1	0,440	0,577	0,334	−0,066	−0,328	−0,277	−0,005
	A_2	0,115	0,353	0,486	0,364	0,047	−0,243	−0,301
	A_3	0,020	0,129	0,309	0,430	0,365	0,115	−0,168
	A_4		0,034	0,132	0,281	0,391	0,358	0,158
	A_5		0,016	0,043	0,132	0,261	0,362	0,348
	A_6			0,011	0,049	0,131	0,246	0,339
	A_7				0,015	0,053	0,130	0,234
	A_8					0,018	0,057	0,128
	A_9						0,021	0,059
	A_{10}	Tomma fält för A_n under 0,01 (1 %)						0,024

Table 1.3: Relative amplitude of carrier wave A0 and side frequencies A1–A10 at modulation index 1–7. (In the case of an unmodulated carrier wave, the modulation index is 0. Then the relative amplitude of the carrier wave is 1.0.)

1.8.15 Pulse modulation

Pulse modulation is mostly used in the microwave area. Pulse modulated signals are usually transmitted as a series of short pulses separated by relatively long pauses without modulation.

A typical transmission may consist of pulses with a duration of 1 μs and a frequency of 1000 Hz. peak power the on a pulse transmission is therefore much higher than its average effect. Before WARC 79. P was the symbol for all pulse transmission. After WARC79, P is now only used for unmodulated pulse trains.

Other pulse modulation has the following symbols
K – pulse/amplitude modulation (PAM)
L – pulse width modulation (PWM)
M – pulse position/phase modulation (PPM)
Q – angle modulation during the pulse
V – combination of these or another way

1.8.16 Digital modulation HAREC a.1.8.8

In addition to the classic analog modulation methods, there are a number of digital modulation forms. They are adapted for the transmission of binary data. In some cases, CW is seen as digital modulation where 0 is modulated without a carrier and 1 is modulated with a carrier. However, there are several other modulation methods such as FSK, 2-PSK/BPSK, 4-PSK and QAM which are presented in the following subsections.

1.8.16.1 Frequency shift modulation – FSK HAREC a.1.8.8a

Frequency shift keying (FSK) differs from The CW modulation in that it changes the frequency, i.e. is a variant of frequency modulation. In the simplest form, binary FSK, you switch between two frequencies, where one frequency can represent 0 and the other can represent 1. This method has been used for modems on telephone connections, such as Bell 103.

Because each change between frequencies causes interruptions in both the signals, like the keying in CW, they will create sidebands. For that reason, one filters the signal, and if you use a Gaussian filter, you get Gaussian Frequency Shift Keying (GFSK), which is used by, for example, GSM telephony. You can use more than two frequencies, for example, four frequencies are used in Continuous 4 level FM (C4FM), in Phase 1 radios, in Project 25 and Fusion.

Frequency shift is also used to send slow messages where JT65 uses 65 frequencies that it shifts between, while JT9 uses 9 frequencies.

1.8.16.2 Binary phase shift modulation – 2- PSK &BPSK HAREC a.1.8.8b

Instead of modulating the frequency, one can modulate the polarity or the phase. Such a modulation is binary phase shift modulation (eng. Binary Phase Shift Keying (BPSK) or 2-state Phase Shift Keying (2-PSK).

Simplified, you can say that the carrier wave is modulated by +1 or −1, often with +1 representing 0 and −1 representing 1.

A disadvantage of BPSK is that if the polarity gets mixed up, the message will be inverted, i.e. 0 becomes 1 and 1 becomes 0. BPSK therefore also needs to be supplemented with other digital modulation to handle the polarity, something that can generally be achieved easily.

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Broadcast type	The amplitude of the LF signal	The pitch of the LF signal affects	The bandwidth b relates to	Too large an amplitude on the LF signal results
A3E (AM)	the amplitude in both sidebands	the distance of the side frequencies from	carrier the highest frequency of the LF signal	overmodulation and too much bandwidth
J3E (SSB)	the amplitude of transmitted sideband	the distance of the side frequencies from the carrier wave	the difference between the highest and lowest frequency of the LF signal	too much bandwidth, amplifier stage overdrive
F3E (FM)	the deviation	the speed of the carrier wave too much deviation	frequency change twice the sum of largest deviation and highest LF frequency	too much deviation, too much bandwidth

Table 1.4: Comparison between some common types of transmission in amateur radio

Symbol	Angle	I	Q
0	0	+1	0
1	90	0	+1
2	180	-1	0
3	270	0	-1

Table 1.5: 4-PSK in quadrature modulation

BPSK is used by satellite navigation systems such as GPS, GLONASS and Galileo. To recover BPSK, you often need a special variant of PLL loop known as Costa's loop, because a normal PLL loop cannot cope with the sign changes of the signal.

1.8.16.3 Four-level phase shift modulation – 4-PSK HAREC a.1.8.8c

Phase shift modulation can also be done with several levels. When four different phase states are used, it is called four-state phase shift keying (eng. 4-state Phase Shift Keying (4-PSK)).

Instead of the 180 degree phase shift (0 and 180 degrees) used in 2-PSK/BPSK, 360/4 uses it ie 90 degree phase shift between the symbols.

An effective way to decode it is to do quadrature modulation (eng. quadrature modulation), where you modulate a signal into two components, in phase (eng. In Phase (I)) and shifted 90 degrees quadrature (eng. Quadrature (Q)), often called I/Q modulation.

The four phase positions can now be easily explained as amplitudes in the different phase positions indicated by table 1.5. The amplitude is the same for all four symbols, but with a different angle. Similar to 2-PSK/BPSK, one needs to recover the phase and then be able to determine what is 0 degrees, but given that it is done in the other modulation, the information can be decoded correctly.

1.8.16.4 Quadrature-amplitude modulation – QAM HAREC a.1.8.8d

While phase shifting can be done for more phase steps, it has been found that it is not as simple for higher resolutions. Already at eight steps you need to have I and Q values that are √1/2, which in and of itself can be approximated.

A more flexible form of modulation is instead to let the amplitude also vary, and by letting some bits modulate I and some bits modulate Q, you can easily get a symbol pattern that is efficient to implement.

This form of modulation is called quadrature-amplitude modulation (eng. Quadrature Amplitude Modulation (QAM)). Often different variants are named with the number of different positions, so that 16QAM has16 different modes in phase and amplitude together.

An example of how 16QAM can be modulated can be found in Table 1.6. While both amplitudes and angles can feel blurred, it is easy to map the bits over to I and Q amplitudes and phase positions via the Isym and Qsym parts of the symbols.

QAM modulation is used by DAB, DVB-T, DVB-T2, IEEE 802.11 (Wi-Fi), microwave links and many other modern systems such as EDGE (the successor to GSM with higher data rates), UMTS when running high speed (HSPA) as well as in LTE where you run relatively slow symbols but instead very many in parallel distributed over a larger frequency band.

In mobile phone systems, 64QAM and 256QAM are used, among other things. Microwave links use up to 2048QAM.

One advantage of the QAM modulation is that it is easy to get the same distance between the different symbol positions, and thus the modulation can also adapt to the disturbance. This is used by many modern modulation systems so that the QAM modulation adapts based on the receiver's reporting of interference. This dynamic adaptation means that communication can be maintained even if the capacity is allowed to vary.

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Symbol	Isym	Qsym	Amplitude	Angle	I	Q
0	0	0	$3\sqrt{2}$	+45	3	+3
1	0	1	$\sqrt{10}$	+72	3	+1
2	0	2	$\sqrt{10}$	+108	3	-1
3	0	3	$3\sqrt{2}$	+135	3	-3
4	1	0	$\sqrt{10}$	+18	1	+3
5	1	1	$\sqrt{2}$	+45	1	+1
6	1	2	$\sqrt{2}$	+135	1	-1
7	1	3	$\sqrt{10}$	+162	1	-3
8	2	0	$\sqrt{10}$	+342	-1	+3
9	2	1	$\sqrt{2}$	+315	-1	+1
10	2	2	$\sqrt{2}$	+225	-1	-1
11	2	3	$\sqrt{10}$	+198	-1	-3
12	3	0	$3\sqrt{2}$	+225	-3	+3
13	3	1	$\sqrt{10}$	+252	-3	+1
14	3	2	$\sqrt{10}$	+288	-3	-1
15	3	3	$3\sqrt{2}$	+315	-3	-3

Table 1.6: Example of 16QAM in quadrature modulation

1.8.17 Concepts of digital modulation HAREC a.1.8. 9

Digital modulation also means that the signals transmitted have slightly different properties than the analogue ones.

Instead of varying voltage levels like for example numbers, we send discrete fixed levels, often in the form of bits. It is therefore appropriate to discuss some basic concepts around digital modulation.

1.8.17.1 Bit rate HAREC a.1.8.9a

We have coded the information we send in bits (eng. bit (b)), the amount of information we have is therefore a certain number of bits and the rate of this amount of information thus becomes the information transfer capacity (eng. bit rate) in bits per second.

We often refer to the amount of information as the amount of bytes (B) such as, for example, that a file is 2 KB or an image is 1.25 MB. Since a byte contains eight bits, it corresponds to 16 kb and 10 Mb respectively. In everyday speech, we then talk about the size of a file. The transfer capacity, or in everyday speech, the speed, we often talk about in terms of bit rates such as 10 Mb/s (often written bps – bits per second), i.e. you can manage to transfer up to 10 million bits per second. It is often talked about the raw transfer capacity, while the real transfer capacity for useful traffic is somewhat lower due to various forms of packing format and protocol needs, so-called overhead. One must therefore be careful to separate these.

1.8.17.2 Symbol rate - Baud rate HAREC a.1.8.9b

As we have already seen examples of, sometimes bits can be sent one by one, or lumped together. Each such lumping together is called a symbol, and a symbol can carry one or more bits, sometimes not even an even number.

If you can articulate something in two different levels (of amplitude, phase, frequency or combination), then you can represent a bit. If you can articulate something in four different levels, you can represent two bits. Similarly, eight levels provide support for three bits. Each representation is called a symbol, and each symbol therefore carries one, two or three bits of information.

Strictly speaking, it is the logarithm with base two (2-logarithm or log2) of the number of levels which indicates the number of bits that a symbol can carry.

Three levels are usually said to be able to carry 1.5 bits, which is a sloppy approximation but shows the principle. The rate at which symbols are transmitted the symbol rate (eng. symbol rate), also called Baud rate, after Emile Baudot, with the unit baud (Bd). The unit baud (abbreviated Bd) indicates the number of symbols per second. By multiplying the number of symbols per second by the number of bits per symbol, the transmission capacity is obtained in bits per second.

1.8.17.3 Bandwidth HAREC a.1.8.9c

By adjusting the number of bits per symbol, one can change the number of symbols per second without changing the transmission capacity. One reason for doing it randomly is that the bandwidth used by a transfer is roughly proportional to the symbol rate, that is, how many bauds are transferred.

This affects how much of the radio spectrum you occupy, and thus also how close to another signal you can be in the spectrum without interfering with each other, i.e. it affects the frequency planning of the band in question.

Often the concept of bandwidth is used synonymously with the transmission capacity, because there is a proportional relationship between them, but bandwidth is not the only parameter required, so in more strict contexts these concepts should be handled as separate to avoid misunderstandings.

The bandwidth of a digital stream is related to the Nyquist theorem, which states that the sampling rate must be at least twice as high as the highest frequency that is transmitted.

1.8.18 Bit error - detection and correction

So far we have discussed digital modulation without taking into account disturbances and how these affect our transmitted data.

Just as our CW or SSB can be disturbed by atmospheric interference, other transmitters or simply weak signals so that the internal noise becomes a limitation; so the reception of digital signals will be disturbed. We look at these basic concepts such as bit error, bit error probability, error detection and correction with retransmission or correction codes.

1.8.18.1 Bit error

For various reasons, one or more bits will often be wrong. We call each such error a bit error.

Interference can cause us to interpret a symbol error, which can result in one or more incorrect bits. If, for example, in the 16QAM code in chapter 1.8.16.4 we enter +0.2 in I and +1.1 in Q, we see in table 1.6 that approximately the symbol is symbol 5 with +1 in I and +1 in Q. We could assume that if I is greater than 0 and less than 2, and Q is greater than 0 and less than 2, then symbol 5 is the only meaningful symbol, and that is exactly the interpretation we generally make, because it is the symbol whose distance is lowest and therefore most reasonable.

However, it may be that you actually sent symbol 9 with −1 in I and +1 in Q, and thus received too much interference on I for you to interpret it as the correct symbol. We will then put out 9 instead of 5, which means that two bits have been changed. By examining table 1.6 further, you can see that the values for I and Q for the various symbols are made so that the minimum distance is 2 between all neighboring symbols, in the respective I and Q direction. It simplifies interpretation of the symbols. However, if the interference is greater than 1 in any direction, it will be interpreted as a symbol error, and this can then lead to 1 or more bit errors.

1.8.18.2 Bit error probability

If we assume that we do not have interference from any other signals, but only have noise as interference, then we can estimate the bit error rate (BER) from how strong the noise is in relation to wart steps.

Since the noise is assumed to be white noise, it has the properties of Gaussian noise. Gaussian noise has a statistical distribution with high probability close to the mean value and then decreases with distance. The probability that one interprets a signal as being on one or the other side of a limit depends on how far away from the mean value that limit, often called the quantization limit, is in relation to the effective value (eng. Root Mean Square (RMS)) in amplitude of the noise.

This can be expressed in the form of the mathematical function error function(erf). When the limit is 1 sigma, i.e.

1 times the RMS value of the noise amplitude, from the mean, there is a 67% probability that the value is within the limit, i.e. a bit error probability of 33%.

If it is within 2 sigma the probability has increased to 97%, a bit error probability of 3%, and at

3 sigma it is 99.7% with a bit error probability of around 0.3%, which is often used for many engineering applications.

However, for the transmission of information we have higher requirements. For a bit error probability of 10−12, often referred to as BER of 1E-12, 14 sigma distances are needed to the limit, i.e. the amount of noise may be a maximum of 1/14 of the quantization limit. However, the raw radio channel rarely exhibits such good characteristics, but it can be achieved in cable and fiber.

1.8.18.3 Detection HAREC a.1.8.10a

Since interference occurs and there is a need for a lower bit error probability than the raw channel allows, it is appropriate to identify when a bit error has occurred. This can be done in many ways, the most common way is to calculate checksums that are sent with the data. It does require some of the information transfer capacity, but the service it provides is to ensure that the information is reasonably correct.

A simple form of checksum is parity, where the bits of a word have been added together binary (with XOR) to form a checksum. At the receiving end, the same combination is made and then compared with the parity bit, and if they match, no bit error has been detected. This simple method has a weakness that an even number of bit errors will compensate each other, thereby hiding bit errors from detection. In other words, it is not a particularly strong checksum.

Parity is used, for example, in serial communication such as RS-232. Several checksums exist, for different purposes, with different amounts of errors and different types of errors. For slightly larger messages, it is common to add bytes to a checksum either additively or with XOR. Destroying messages uses a slightly more intricate method called Cyclic Redundancy Check (CRC) where the excess part of the checksum is fed back to itself and gets a stronger code that way. CRUsed, for example, in Ethernet.

1.8.18.4 Retransmission HAREC a.1.8.10b

A simple action to take when you find that a block of data you have received is wrong, is to request retransmission. By the sender keeping a buffer with messages that it has sent, and the receiver notifying the sender if it has received the message or needs to have it resent, retransmission can be realized. Automatic retransmission request (eng. Automatic Repeat reQuest (ARQ)) is a type of protocol that makes an automatic retransmission request if a single data block, also called a packet, has not arrived correctly or has completely disappeared. One such protocol is TCP, which is part of the Internet suite of the TCP/IP protocol.

1.8.18.5 Correction code - FEC HAREC a.1.8.10c

Another form of correction is to simply send too much data right from the start, which the receiver cannot use to correct the message without forwarding any request to the sender.

This is the practical option if it would take too much time or if there is simply no communication from the receiver to the transmitter, for example for satellite receivers. A simple form of error correcting code is used in AM-TOR FEC, where you simply send the same character twice . Similar is used in Bluetooth where the message is sent three times, whereby you can do majority voting.

Other systems for FEC are Hamming codes, parity packets and Reed-Solomon (RS).

1.8.19 Digital transmission types

Here are examples of digital modulation techniques for shortwave applications in amateur radio .Most digital transmission types for shortwave are narrowband and the bandwidth can in some cases only be a few hertz. also connected to the appropriate serial port, for example via its USB connection.

1.8.19.1 RTTY

History

One of the first digital modes of communication used by radio amateurs was RTTY, pronounced "Ra-dioTeleTYpe", where they used so-called teleprinters, automatic typewriters that wrote out text.

In 1874, Emile Baudot constructed a system based on five bits, which is still used today. In August 1922, The US Department of Navy tested "written telegraphy" between an aircraft and a ground station. American commercial RTTY systems were active as early as 1932. During the 1950s, surplus equipment began to enter the American market and radio amateurs were not slow to try the new technology on the shortwave bands. The commercial systems ran at 50 baud, 75 baud or 100 baud. The amateurs in the USA ran at 45.45 baud, which corresponds to 300 characters per minute. The European equipment, among others produced by Siemens, worked with 50 baud but could be adjusted down to 45.45 baud. 45 baud is today the accepted standard worldwide. Technology RTTY uses FSK modulation. To achieve this, you need to control the frequency so that it jumps between two frequencies with a difference, a so-called "shift", of 170 Hz. Older transmitters needed to be modified to achieve this frequency shift, but with an SSB transmitter, you could instead feed the transmitter with two tones, which gave the same result - so-called Audio Frequency Shift Keying (AFSK). With newer amateur radio transceivers, it later became the most common method of modulating the transmitter. It meant that you didn't have to modify the equipment. Today, most radio amateurs run RTTY with a single computer and often use the AFSK technology with the help of software, with the same connection that is used for other digital modes of transport.

1.8.19.2 SSTV

Slow Scan Television (SSTV) is a mixture of analog and digital technology. An SSTV broadcast takes place slowly compared to traditional TV, but is basically the same. Each line is transmitted one at a time, but modulated so that it can be transmitted over an SSB radio link.

The intensity of each pixel indicates the pitch that is modulated, which therefore means an FM modulation. This FM modulated tone is then sent over SSB. At the beginning of each line, a 7-bit number with even parity is sent that indicates which modulation form is used. The different modulation forms can then handle different resolutions and vary with respect to black-white or color.

1.8.19.3 APRS

Automatic Packet Reporting System (APRS) is a technology for transmitting GPS position, weather data, simple messages and other things mainly over VHF and UHF. It is based on a teknik called AX.25, which is an amateur radio-specific version of the telecommunications standard X.25. AX.25 is modulated over 1200baud Bell 202 AFSK technology on a regular voice channel. A Terminal Node Controller (TNC) is often used as an interface between computer and radio.

1.8.19.4 PSK31

History

The name describes the modulation type and the transmission rate in baud. The first program was developed specifically for Windows-based computers with sound cards by the English radio amateur Peter Martinez, G3PLX, and was introduced to the amateur radio world in 1998.

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Technology

The modulation used in PSK31 was developed from an idea by the Polish radio amateur Pawel Jalocha, SP9VRC, who had developed a soft- ra "SLOWBPSK" for Motorola's EVM radio, which was a radio system for evaluating different forms of modulation. Instead of using the usual method of frequency shift, "SLOWBPSK" was based on polarity shift of the phase position. A well-designed PSK-based system can give better results than FSK, and can work with narrower bandwidth than FSK. The transfer rate of 31 baud was chosen to fit an average writing speed of the average amateur.

1.8.19.5 WSPR

History

WSPR was released in its first version in 2008. Originally written by Joe Taylor, K1JT, the program is now open source and developed by a small team. Joe Taylor received his education in astronomy at Harvard University. He then worked in the field of astrophysics at Princeton University, from which he retired in 2006. Joe Taylor was awarded the Nobel Prize in Physics in 1993. The program is mainly intended for wave propagation tests in the short-wave range.

Technology

WSPR stands for Weak Signaling Propagation Reporter and is pronounced " Whisper". WSPR is a type of broadcasting that uses the amateur radio station as a radio beacon, a so-called beacon. Transmission and reception takes place in two-minute shifts, and after each transmission shift, the stations that received the signal report their results to a database over the Internet. The transmitting station can then study the result. WSPR uses low powers, it is possible to reach European stations with powers below 100 mW, and other continents with powers below a few watts, even with modest antennas.

1.8.19.6 WSJT

WSJT is, like WSPR, a program used within the amateur radio hobby for such communication with weak signals. This program is also developed by Joe Taylor, K1JT. Most of these broadcasting types (see below) are so narrowband that they do not occupy a bandwidth greater than a few hertz.

History

WSJT was presented to the amateur radio world in 2001 and has undergone several revisions. Various broadcasting types have been added and removed over the years . Since 2005, the program is open source and developed by a small team. The WSJT technology offers a platform for a variety of applications where different variants of essentially FSK modulation are used.

The FSK441 is used to evaluate transmissions via radio wave reflective layers of charged ions, which arise from the tracks that meteors leaves behind. JT6M was introduced in 2002 and is intended for communication via meteor reflections on the 6 m band.

Traffic

JT9 is used for shortwave traffic and is similar to JT65, but uses an FSK signal with nine tones. JT9 uses less than 16 Hz bandwidth.

FT8 was developed and released in 2017 and uses an 8FSK signal. FT8 is preferred for so-called multi-hop viaE layers, where the signals are subject to fading and the openings to other stations are short so that you need to complete the communication within a short time.

1.8.19.7 FreeDV

FreeDV differs from the transmission types mentioned above in that this is intended for digital speech on shortwave.

History

FreeDV was created by a group of radio amateurs from different countries who worked with coding, design, user interface and testing. FreeDV was released in 2015.

Technology

FreeDV is intended to be used on shortwave with SSB modulated radio stations, but can also be used with AM or FM modulation. The advantage is that the transmission becomes more robust and that the signaling is designed to counteract the influence of fading. FreeDV uses a slightly more complex modulation. A number of carriers are used within its bandwidth of 1.25 kHz. The carriers are 75 Hz apart and each carrier is modulated with variants of PSK modulation. The bandwidth is half (1.25 kHz) of a normal SSB bandwidth (2.4 kHz).

1.9 Power and energy HAREC a.1.9

1.9.1 Power in a sinusoidal signal HAREC a.1.9.1

To calculate the power of a sinusoidal signal, the effective value is used of voltage and current.

Ueff = Umax / √2 Ieff = Imax /√2 P = Ueff · Ieff

1.9.2 Power change expressed in dBHAREC a.1.9.2

Measurements in the metric system are commonplace and no one finds it strange that, for example, it goes ten

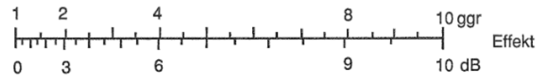

Figure 1.36: Nomogram for conversion between power and decibels

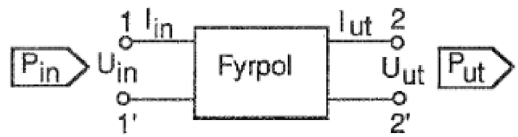

Figure 1.37: Power ratio decimeter on one meter.

However, the term decibel is too familiar.

This section explains the very useful concept of decibels. Decibel (dB) is one-tenth of the abyssal unit Bel (B). Calculating with decibels is based on logarithms, which is a convenient way to express and treat numerical values.

Decibel is a dimensionless expression of the degree of attenuation or amplification.

Power attenuation is the result of some components' slow electric current. The braking factor can be a resistance R, inductance L, capacitance Cells composed of networks of R, L and C. Power amplification means that a transistor, an electron tube or other so-called active component can control a greater electric current and thus greater power than it itself is controlled with. We do not go into what causes the power changes in this context, but the components are regarded as "black boxes" with connection terminals. A component with two input and two output terminals is called "four-pole", see figure 1.37.

Assume that the input power P is 1 W. If the power does not change during the passage through the four-pole, then the extracted power is also 1 W.

The power ratio between the inputs and outputs is then:

$$\frac{P_{in}}{P_{ut}} = \frac{1\ watt}{1\ watt} = 1(\text{kvoten} = 1)$$

P in/P ut= 1 watt/1 watt = 1(the ratio = 1)

Unchanged power is neither attenuated nor amplified, where- for both the attenuation and the gain, the numerical value is 0. The unit of the numerical value is Bel, the attenuation or amplification is thus 0 Bel. One tenth of that is 0 decibels (0 dB). Recalculation of the ratio of a power change to dB is done so that the 10-logarithm of the ratio is sought and the result is the power change expressed in Bel (B). If the result is expressed in dB, the Bel value must be multiplied by 10. Logarithms are explained in appendix B.7.
To simplify the calculation of the dB figure, the higher power figure is divided by the lower one. The letter a in the following formulas means either amplification (+a) or attenuation (-a), depending on which sign is set.

a[B] = log (P high/ P low)

a [dB]= 10 log (P high / P low)

Adding and subtracting values on a logarithmic scale corresponds to multiplying and dividing values by a linear scale. The main scales on a calculator are logarithmic. (The calculator is a simple and formerly widely used aid). With the help of the nomogram in picture 1.36, a power change, expressed as a ratio (the powers divided by each other), can be converted to decibels and vice versa. The following rounded values can be read out:

0 dB = 1
1 dB = 1.25
2 dB = 1.6
3 dB = 2
4 dB = 2.5
5 dB = 3.26 dB = 4
7 dB = 5 8 dB = 6.3
9 dB = 8
10 dB = 10
11 dB = 12 ,5

That is, when increasing, the effect is doubled every 3 dB and when decreasing, the effect is halved every 3 dB.

If the quotient is one or more powers of 10 higher than 10, the nomogram can be expanded according to the following table.

Ratio of P high/ P low	Analysis	Write	dB
1	1 has 0 zeroes	0 · 10 =	0
10	10 has 1 zero	1 · 10 =	10
100	100 has 2 zeroes	2 · 10 =	20
1,000	1000 has 3 zeroes	3 · 10 =	30
10,000	10,000 has 4 zeroes	4 · 10 =	40

1.9.3 Current change expressed in dB

The relationship between currents as well as between voltages can also be expressed in dB, but differently than between effects. A four-pole with mutually equal input and output impedance is the prerequisite for comparison.

According to Joule's law, P = I^2 · R (P = U · I), thus

P high/P low= I^2 high · R /I^2low ·R.

$$\frac{P_{\text{hög}}}{P_{\text{låg}}} = \frac{I^2_{\text{hög}} \cdot R}{I^2_{\text{låg}} \cdot R}$$

R can be shortened if the input and output impedances (resistances) are equal. A comparison expressed in dB can only be made under the same conditions; here that the impedances (resistances) are equal, thus

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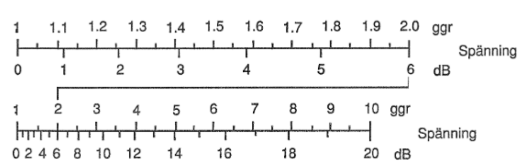

Figure 1.38: Nomogram for conversion between voltage and decibels

$$\frac{P_{\text{hög}}}{P_{\text{låg}}} = \frac{I^2_{\text{hög}}}{I^2_{\text{låg}}}$$

P high /P low= I^2 high / I^2 low.

The power ratio or the square value of the current ratio can be expressed logarithmically in B or dB

a[dB] = 10 log (I^2 high/ I^2 low)

Because log x2 = 2 · log x , we finally get

a[dB] = 20 log (L high /L low)

1.9.4 Voltage change expressed in dB

The ratio between voltages can be expressed in dB in a similar way as with currents. According to Joule's law, P = U ^2R (P = U · I) Two effects can be set in relation to each other in the following way:

P high /P low= U^2high · R / U^2 low · R

R is abbreviated and after rewriting a formula similar to that for currents is obtained

$$\frac{P_{\text{hög}}}{P_{\text{låg}}} = \frac{U^2_{\text{hög}} \cdot R}{U^2_{\text{låg}} \cdot R}$$

$$\frac{P_{\text{hög}}}{P_{\text{låg}}} = \frac{U^2_{\text{hög}}}{U^2_{\text{låg}}}$$

P high /P low= U^2 high / U^2low

a[dB] = 20 log U high(U low

With the nomogram in figure 1.38, the ratio of single current or voltage change can be converted to decibels and vice versa. The following rounded values can be read out:

0 dB = 1
1 dB = 1.12
2 dB = 1.25
3 dB = 1.4
4 dB = 1.6
5 dB = 1.8
6 dB = 2
7 dB = 2, 24
8 dB = 2.5
9 dB = 2.8
10 dB = 3.2
11 dB = 3.6

That is, when increasing, the current is doubled, respective to the voltage for every 6 dB and that when decreasing the current is halved or the voltage for every 6 dB. If the quotient is one or more powers of 10 higher than 10, the nomogram can be expanded according to the following table.

Ratio of U high/ U low & I high/ I low	Analysis	Write	dB
1	1 has 0 zeroes	0 · 10 =	0
10	10 has 1 zero	1 · 10 =	10
100	100 has 2 zeroes	2 · 10 =	20
1,000	1000 has 3 zeroes	3 · 10 =	30

10,000	10,000 has 4 zeroes	4 · 10 =	40

1.10 dB with calculator

When the calculation of gain or attenuation expressed in dB is done with a calculator, you let the calculator handle the entire calculation. With a calculator, the expressions for dB are written like this:

For power a[dB] = 10 log(P ut/P in)

For voltage a[dB] = 20 log(U ut/U in)

Notice how the values out and in are used in the equations. This means that the calculation automatically gets positive answers for amplification and negative answers for attenuation.

1.11 Decibel over 1 mW at 50ohm [dB(m)]

It is very common that the inputs and outputs in HF equipment are made with an impedance of 50 Ω.

Adequate adaptation is chosen when the coaxial cables between the devices have a characteristic impedance of 50 Ω. It has developed a practice that the reference value when comparing signal levels in radio systems should be one milliwatt (1 mW) developed in a load with an impedance of 50 Ω.

Signal levels across the load 50 Ω can be expressed in dB(m) or often dBm, where (m) stands for milliwatts, whereby the reference power 1 mW is 0 dB(m) at 50 Ω.

The voltage drop formed across the load 50 Ω at the power level 0 dB(m) is

U = √P · R = √1 · 10−3 · 50 ≈ 0.224 V

The current flowing through the load 50 Ω at the power level 0 dB(m) is

I =√ PR =√ 1 · 10−350 ≈ 0.0045 A = 4, 5 mA44

The current 4.5 mA through the load 50 Ω thus corresponds to 0 dB(m). Every other power, voltage drop and current that occurs at a load of 50 Ω can be compared with the respective reference values 1 mW, 0.22 V and 4.5 mA .dB(m) is an absolute and logarithmic measure.

Power

[dB(m)] = 10 log P[50 Ω]1[mW50 Ω]P50 = 1[mW] · 10a10

Current

0dB(m) ≈ 4.47mA50a[dB(m)] ≈ 20 log I504.47

Voltage

0dB(m) ≈ 0.224V50a[dB(m)] ≈ 20 log U500.224U50 ≈ 0.224 · 10a201.12

The relationship between voltage and dBm

dBm	V	dBm	
-40	0,00224	8	0.562
-30	0,00707	9	0.630
-20	0,0224	10	0.707
-10	0,0707	11	0,793
0	0,224	12	0,890
1	0,251	13	0,999
2	0,282	14	1.121
3	0.316	15	1.257
4	0.354	16	1.411
5	0.398	17	1.583
6	0.446	18	1.776
7	0.501	19	1.993
8	0.562	20	2.236
9	0.630		

Power levels across a load can also be expressed in dB(W), where (W) stands for watts. The reference power is then 1 W, i.e. 0 dB(W). As with dB(m), the impedance is indicated in the load over which the power is developed.

1.12.1 Change expressed in dB when amplifying or attenuating devices connected in series HAREC a.1.9.3

A calculation example of power changes: Question: We have a simple transmitter installation with a drive stage fed with 10 W HF. The drive stage amplifies by 6 dB.Furthermore, we have a power output stage that amplifies by 10 dB. The antenna cable attenuates by 1 dB.

Question: With what power is the antenna itself fed? Answer: (two ways to solve the problem) 1. The drive stage amplifies four times, the output stage amplifies ten times and the cable attenuates 1/1.25 =0.8 times. The antenna is then fed with 10 · 4 · 10 ·0.8 = 320 W.2. The 6 dB of the drive stage plus the 10 dB of the final stage minus the 1 dB of the antenna cable = 15 dB. 15 dB is 10+5 dBie 10 · 3.2 = 32 times. The antenna is fed with 10 W · 32 = 320
W.

1.12.2 Impedance matching HAREC a.1.9.4

Impedance matching is of great importance in communication technology. Normally, you want to transfer as much power as possible from the energy source (e.g. the transmitter) to the consumer (e.g. the antenna). Each voltage source has an internal resistance Ri.This means, firstly, that the source cannot emit an infinitely large current. To simplify the whole thing, we now assume that the transmitter with the internal resistance Ri is connected directly to an antenna with the resistance Ra.

The goal of the adaptation is to find the optimal ratio between the transmitter resistance and the antenna resistance in order to be able to transmit maximum power. We tested the two extreme cases of an unloaded transmitter and a short-circuited transmitter. The electromotive force (EMF) of the transmitter is designated as E [V] and the transmitter output voltage as U [V]. Case 1.

An unloaded transmitter emits no current when no antenna or one with infinite resistance is connected. So with an unloaded transmitter:

$$R_a = \infty \qquad I = 0 \qquad U = E$$

Ra = ∞ I = 0 U = E

When the transmitter output is short-circuited, i.e. the load (antenna resistance) is zero ohms, the transmitter emits a current that depends on EMF and internal resistance. Since the transmitter output is short-circuited, the output voltage U is zero. So in the case of a short-circuited transmitter:

$$R_a = 0 \qquad I = \frac{E}{R_i} \qquad U = O$$

Ra = 0 I = E/Ri U = OI

both extreme cases, the power converted into Ra is equal to zero.

In order to get some effect, you must therefore search for a value of Ra that lies between the extreme values. According to the formula for voltage dividers, output voltage-en

$$U = E \cdot \frac{R_a}{R_a + R_i}$$

U = E · Ra /(Ra + Ri)

The formula for the effective value of the output power isPut = U 2Ra

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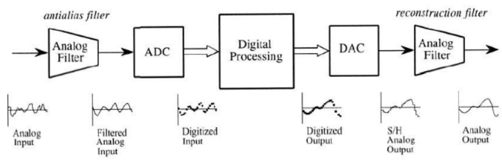

Figure 1.39: Sampling with ADC, DSP and DAC to recover analog signal

After insertion, you get

$$P_{ut} = \frac{U^2}{R_a}$$

Put = E2 · Ra(Ra + Ri)2

To find the optimal ratio between Ri and Ra, that is, when Ra takes up maximum power, you have to differentiate the formula with d Pa/d Ra, but we skip this excursion in the mathematics. Instead, we simply state that maximum power transmission occurs when Ri = Ra.

1.12.3 The ratio between input and output power expressed as percentage efficiency HAREC a. 1.9.5

Assume that an antenna cable has a power loss of 1 dB. This means a power attenuation of 1, 25 times, i.e. 0.8. Now we feed 10 W into the cable and therefore get 8 W out. What is the efficiency of the cable expressed as a percentage?

Solution: η = 810 · 100 = 80 %

1.13 Digital signal processing (DSP)

Digital signal processing (eng. Digital Signal Processing (DSP)) has become increasingly important in everyday life and also in amateur radio as SoftwareDefined Radio (SDR) has become an important part in all multi-radios, as well as the use of ordinary computers. Basically, it is based on digitizing the signals, processing them digitally in, for example, a processor or programmable logic (FPGA) and then converting them into analog signals again. If you have a special processor to to do so, it is called a Digital Signal Processor (DSP).

The processing can also be done by dedicated logic, all-so logic intended for a special purpose, which cannot be programmed in the normal way as a processor. It is still Digital Signal Processing, but it is now mostly used for those parts of the signal processing where you need to perform the same standardized job quickly and efficiently. A processor can instead perform the less frequent jobs which can thus be allowed to be more complex. A GPS receiver is an example of such a receiver where dedicated hardware handles many millions of samples per second, but which reduces them to a few values per millisecond which are then processed further in a processor. In order to understand this, we need to go through the basics of converting the signals from analog to digital and back from digital to analog.

1.13.1 Sampling and quantization HAREC a.1.10.1

Analog signals are what we call continuous in time. In these, voltage and current vary continuously so fast that we can handle the full radio spectrum and more.

However, this does not work so well in the digital world. There we partly want values in digital form, so we need to convert our voltages and currents into numbers, and partly we need to do it at an even rate. Sampling is an English word that means to sample or to make a selection. We take a random sample (sample) from time to time, and in this context we do it at an even rate, the sampling rate (eng. samplerate).

We often refer to this as fS and concept sampling period time

TS = 1fS

is also used.

The sampling rate is thus the steady rate at which we obtain values. Sometimes one carelessly says that the sampling rate is, for example, 1 MHz, but the more correct thing is that it is 1 MS/s, i.e. 1 million samples per second.

Figure 1.39 illustrates how an analog signal is sampled and quantized in an ADC, to be processed in a DSP, to then be converted to analog signal with DAC and filtered.

While sampling is the process that gives us time-discrete values instead of time-continuous values, the values are still not represented as

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numbers, that is, value-discrete instead of value-continuous. To achieve this, you need to transform the values into fixed levels, a process called quantization. In quantization, you often have a fixed distance between the steps on a ladder of values.

Each step is sometimes called a quantization step and the size of each quantization step thus determines how high resolution you get.

For example, if you have a quantization step of 0.1 V, 0 to 0.1 V is interpreted as 0.0.1–0.2 V is interpreted as 1 and so on. Figure 1.39 shows how the quantization takes place in the ADC step. This last part in converting the quantized numbers into values is called Pulse Code Modulation (PCM). The conversion can also take place non-linearly, i.e. with different distances between the steps in the quantization step, which has been used for data compression in telephony systems.

1.13 .2 The minimum sampling frequency HAREC a.1.10.2

This frequency is called the Nyquist frequency after Harry Nyquist (1889–1976), from Stora Kil in Värmland, after his ground-breaking work at Bell laboratories which he published in 1924 and 1928. This year in Nyquist-Shannons sampling theorem (eng. Nyquist-Shannon sampling theorem).

Our new world of concepts has some inherent limitations, one of them is the minimum sampling frequency. The lowest frequency we can handle in our sampled material is fixed values (or DC as they usually say) while the the highest is when you alternate between two values, say −1 +1 −1 +1 which cuts half the sampling rate fS , for the period the presequence becomes T = 2TS and

thus f = 1/T = 1/2TS= fS/2.

$$f = \frac{1}{T} = \frac{1}{2T_S} = \frac{f_S}{2}$$

1.13.3 Convolution HAREC a. 1.10.3

Filtering in the digital domain, or actually the discrete-time domain, can be described as applying the impulse response of the filter to the signal. This process is called folding (ie. faltung "folding") or sometimes convolution (eng. convolution).

You can see it as that each individual sample will reproduce the oscillation of the entire filter with its amplitude, and the response from all samples will therefore be the sum of all these. The mathematically minded can then use the formula:

y(n) =N −1∑m=0x(n − m)h(m)

where x(n) is the incoming sample stream and n is the index of the nth sample, h(m) is the filter response and finally y(n) is the output samples.

This summation is the same as described above and depicts the process in the time plane, that is, närvi expresses the amplitude as a function of time. The corresponding process can also be carried out in the frequency plane, that is, when we instead express the amplitude as a function of frequency. If we have then also converted the properties of the filter, we simply do a multiplication of signal and filter for each frequency:

$$Y(f) = X(f)H(f)$$

Y (f) = X(f)H(f)

Both represent convolution, and are important for the understanding of linear time-invariant filters (eng. lineartime-invariant (LTI)) filter, which is what we generally focus on.

1.13.4 Antifolding filter HAREC a.1.10.4

While the bandwidth we can represent is limited by the Nyquist frequency, the frequency is not. The sampling itself gives rise to folding (eng.aliasing), such that the spectrum is reversed after half the sampling frequency so that higher frequencies become lower. This folding then reverses again when the frequency becomes the multiple of the sampling frequency, and the spectrum repeats itself. This phenomenon always occurs when you go between continuous and discrete time. Figure 1.40 shows how four different signals, DC, sine with 3.6 kHz, 12.4 kHz and 38 kHz, are sampled with the sampling rate 40 kS/s.

The case with DC is obviously simple, all the points end up at the same voltage. In the case of a low-frequency sine, as is the case with 3.6 kHz here, you get points spread over the curve and they remind of the original sine, even more so if you connect the points, which the anti-fold filter practice does. A frequency close to the nyquist frequency, such as 12.4 kHz into 40 kS/s and its 20 kHz nyquist frequency, then the sampling points are next fully alternating between the highest and lowest positions. In this case, it is difficult to see the underlying sine signal for an untrained eye, but it can still be reconstructed with an anti-aliasing filter. An even more difficult case is 38 kHz, where the points show a sine of 2 kHz, as the frequency folds down around the Nyquist frequency, and since the input frequency is 18 kHz above the Nyquist frequency, it therefore ends up 18 kHz below the Nyquist frequency, i.e. at 2 kHz in this case. This folding is what you try to avoid with the anti-folding filter, because tones can fold signed and become interference.

This folding takes place both during the sampling itself and also vice versa when a signal is put out analogically again. This is why filtering is required in both directions. When sampling, higher frequencies can therefore fold down in the spectrum. This is usually unwanted, whereby you have a filter before the input that suppresses unwanted signals. For speech signals, for example, a low-pass filter is used to suppress the unwanted signals higher up. This filter can instead be used for a certain frequency band to convert this band in the process, something that is very popular

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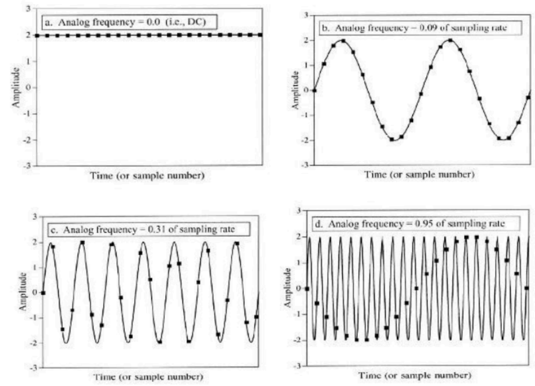

Image 1.40: Sampling of DC; 3.6 kHz; 12.4 kHz and 38 kHz with 40 kS/s sampling rate SDR context.

In both of these cases, the filter is an anti-aliasing filter. Conversely, when converting from a time-discrete to a time-continuous signal, the signal folds upwards in frequency, and to suppress these unwanted frequencies, an anti-aliasing filter is used in the same way as a filter.

In the same way as before, you can either get the low frequencies that speak with a low-pass filter or higher up in a band with a suitable band-pass filter.

Anti-folding filters can often be relatively steep, because they have to suppress other parts of the spectrum so that these do not become a disturbance .In any case when using a frequency other than the lowest up to the Nyquist frequency, care must be taken to ensure that the imaginary band is not folded. It is therefore often combined with a separate mixer to move the tape in a handy way, but it also happens that you choose the sampling rate so as not to bend the tape.

1.13.5 ADC/DAC HAREC a.1.10.5

To handle these parts, analog-to-digital converters (eng. Analog-Digital Conversion (ADC)) and digital-to-analog converters (eng. Digital-Analog Conversion (DAC)).

An ADC takes care of sampling, quantization and PCM encoding while a DAC converts the PCM code to analog voltage. Often you need to supplement with analog filters, but modern sigma-delta converters have greatly reduced the requirements.

Today, ADCs and DACs are bought as ready-made integrated circuits, not infrequently with several channels, and there are also those that have both integrated in the same circuit. The Development has made it possible today to buy 24-bit 48 kS/s ADC and DAC with a dynamic range better than 100 dB for very low cost.

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2 Components

2.1 Resistor HAREC a.2.1 2.1.1

General Circuits consist of components with different properties. The most common property, at least in DC circuits, is resistance. To get the intended function, the resistance in the components is adjusted.

Example: A circuit with power source, lamp, connection lines and fuse.The connection lines between the components should have low resistance and therefore low voltage drop (small losses).

The lamp, on the other hand, must have high resistance and thus high losses to be able to get hot and shine.

The fuse must protect the wires from excessive current. The fuse is therefore given a resistance that causes it to melt when the current exceeds a permitted value.

A type of component called a resistor is used as an aid to distribute voltages and currents in a circuit. Its distinguishing characteristic is resistance (eng. resistance) - also called ohmic resistance.

2.1.2 The unit ohm HAREC a.2.1.1

The resistance between two points in a circuit is 1 ohm which is also written1Ω (pronounced "one ohm"), when the voltage 1 V between the points causes a current of 1 A (one ampere) flows in the circuit. In electronics, high resistance values are used and therefore also the following multiples of the unit 1 kiloohm (1 kΩ) = 103 ohms 1 megaohm (1 MΩ) = 106 ohms

2.1.3 Resistance in current conductors HAREC a.2.1.2

To determine the resistance in, for example, a wire , one needs to know its resistivity, cross-sectional area, length and temperature. Resistivity is a material's current-conducting properties.

Another name for resistivity is specific resistance. The symbol for resistivity isΩ (pronounced “raw”)

The formula for resistivity is:

$$\rho = \frac{RA}{l} \qquad \left[\frac{ohm \cdot mm^2}{m}\right]$$

ρ = RA /l [ohm ·mm2 / m]

where the resistance R of a length l of a current conductor with an average area A (which is usually stated in square millimeters). The resitivity of materials can often be found in tables in formula collections. In table 1.1, the resistivities of a number of common metals are listed.

The following formula applies for calculating the resistance in a current conductor with a linear current/voltage characteristic.

$$R = \rho\frac{l}{A} \qquad [\rho = \tfrac{\Omega \cdot A}{m}] \qquad l = \text{meter};\, A = \text{mm}^2$$

R =P(l/A) [p =(Ω·A)/m] l = meter; A = mm2

Example l = 4 m copper wire A = 2 mm2Ω (copper) = 0.017 R =Ω ·l AR = 0.017 ·4 2 = 0.034Ω

Note. Do not confuse A [cross-sectional area] in this formula with the unit ampere.

2.1.4 Resistive materials

Resistors can be made with different types of resistive materials, which determines the area of use. A resistor whose resistance is independent of current, voltage and other external influences, such as temperature and light, is said to have a linear character.

If, on the other hand, the resistance depends on external influences, the resistor is said to have a non-linear character. A distinction is made between three main groups of resistive materials.

It can be a body of pressed carbon or a conductive surface layer on an insulating substrate or a metal wire on an insulating frame.Recently, there have been resistor networks with integrated resistors, that is, several resistors of resistive layers on a common insulating substrate. Different types of resistors are briefly described here.

2.1.5 Designs

Resistors can be designed with a fixed or adjustable resistance value. Here follows first an overview of resistors with different resistive materials and fixed resistance value.

2.1.6 Fixed resistors with linear character

2.1.6.1 Mass resistor

The resistive material consists of carbon mass with binder (carbon composite). The mass is baked into a rod or tube. The connection cables are embedded in the material. Mass resistors are suitable for direct and alternating current circuits with low requirements for temperature dependence and intrinsic noise. The homogeneous body means that the self-inductance is low. On the other hand, at high frequencies, a skin effect occurs, that is, a current concentration at the surface, which causes a certain increase in resistance.

2.1.6.2 Carbon film resistor

The resistive material consists of a carbon layer, which has been transferred to a ceramic tube by evaporation. The resistance is determined by the thickness of the layerand by spiral grooves in it. Through the spiralization, an inductance is added, which is, however, to someextent offset by the self-capacitance.

2.1.6.3 Metal film resistor

In this type, the carbon film is replaced by a metal layer. Since the self-capacitance is small, the type is suitable for high frequencies.

2.1.6.4 Thickfilm resistor

The resistive material consists of a film of, among other things, metal oxide, which isscreen-printed on a ceramic substrate. The type has good resistance to pulses and hightemperatures, but has relatively high intrinsic noise. Surface-mounted resistors are usually made of thickfilm.

2.1.6.5 Thin film resistor

The resistive material consists of a thin metal film, which has been transferred to a glass or ceramic substrate by evaporation. This resistor type generally has good stability and is often used in high precision devices. However, the characteristics at high frequencies are not so good.

2.1.6.6 Metal oxide resistor

This resistor type has a spiral-shaped layer of metal oxide. The temperature and voltage dependence is moderate. The resistance to pulses and high temperatures is great. The type can to some extent replace wire-wound resistors.

2.1.6.7 Resistor networks

Resistor networks (integrated resistors) consist of several resistive layers on a common insulating substrate, i.e. a similar technology as for thick and thin film resistors

.2.1.6.8 Wire-wound resistor

The resistive material is a metal wire wound on a frame that can withstand high temperature. The frame can be made of ceramic, glass or the like. The resistance to pulses and high temperatures is great.

2.1.7 Fixed resistors with a non-linear character HAREC a.2.1.3

It is most common that the material in resistors has a linear current and voltage character, but there are also those with a non-linear character. In resistors with a non-linear character, the constituent material is of the semiconductor type.

2.1.7.1 Voltage Dependent Resistor

Voltage Dependent Resistor (VDR) Linear resistors are hardly affected by the applied voltage.

Silicon carbide resistors, on the other hand, have a high resistance at low voltage and, conversely, a low resistance at high voltage.

Such voltage-dependent resistors are used, for example, to limit voltage peaks.

2.1.7.2 Light dependent resistor, photoresistor - Light Dependent Resistor (LDR)

The conductivity in semiconductors is not only affected by heat but also by light. Semiconductors of germanium and especially compound semiconductors of cadmium oxide, lead sulfide and indium antimonide have particularly high sensitivity to light. Cadmium sulfide is most sensitive to visible light, while other materials are most sensitive in the infrared range.

2.1.7.3 Magnetic field-dependent resistor (field plate)

The resistance increases with the length of the current conductor. This property is used in magnetic field-dependent field plates that utilize the Hall effect, also known as Hall resistors.

One such consists of a ceramic carrier plate with a surface of indium antimonide. In the surface, extremely narrow parallel metal tracks are embedded at a distance of a few μm. Normally, the current takes the shortest path across the tracks, but when a magnetic field hits perpendicular to the surface of the plate, the electrons are deflected.They then have a longer path to the next metal track and the total resistance increases.

2.1.7.4 Temperature dependent resistor

See below about NTC and PTC in resistors.

2.1.8 The temperature coefficient for resistors

The resistance in the constituent materials is affected by the temperature, whereby it differs between the materials. Amorphous carbon and most semiconducting materials conduct better when hot - they have a negative temperature coefficient (NTC).

Such materials are found, for example, in diodes and transistors. In Contrast, metals and special semiconductor materials conduct better when they are cold – they have a positive temperature coefficient (PTC).

The filament in light bulbs and electron tubes are resistors with a positive temperature coefficient (PTC). In some metal alloys, however, the resistance can be almost constant at varying temperatures.

An Example is constantan, which is an alloy between copper, nickel and manganese. All materials have a temperature coefficient, which indicates how much the resistance changes per degree.

The resistance at any other temperature can therefore be calculated with the following formula, where you insert the initial temperature

$$R_{varm} = R_{kall} \pm \alpha \cdot \Delta\vartheta \cdot R_{kall}$$

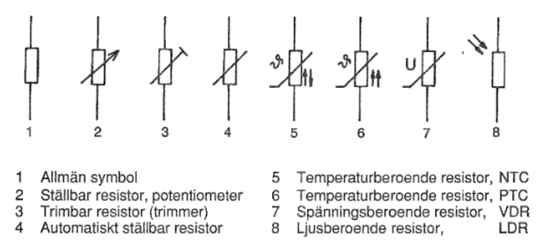
[ϑ] (◦C), the temperature change[$\Delta\vartheta$] and the temperature coefficient [α].

Rwarm = Rcold ± α · Δϑ ·R cold

The resistance change is the term

ΔR = ±α · Δϑ · Rcold

The temperature coefficient can be positive (PTC) or negative (NTC). In The principle diagrams, PTC and NTC resistors have symbols as in picture 2.1.



2.1.9 Variable resistors

A resistor can also be made with a variable resistance value. Then only the proportion of the resistive material that is between one end of a resistor and an outlet somewhere between the ends is used. Such a device is called a rheostat.

If a variable resistor is used as a voltage divider, it is called a potentiometer. In a potentiometer, the entire resistance between the endpoints and the portion between the socket and one of the endpoints are used.

The mechanical design of the outlet usually depends on how convenient the setting should be. A potentiometer, where the resistive material is laid on a circular track and the socket is attached to a shaft in the center of the track, allows easy adjustment with a chisel, dial or the like. A simpler type of socket is a drag contact or a tension band that can be moved along a rod-shaped resistor.

2.1.9.1 Resistive materials in variable resistors

The path in a variable resistor consists of principle of similar resistive materials as in a fixed resistor.

The cheapest and simplest is a track made of carbon, which is printed on a simple substrate. Disadvantages are low power tolerance, poor resolution and linearity, high noise and short lifetime. The advantage is low price.

Better than a carbon web is a carbon composite web, i.e. carbon powder with a binder, which is printed on a substrate. Disadvantages are higher price and low power endurance, while the advantages are good resolution, low noise and long life.

If you want good impact resistance and temperature stability, in addition to the properties of the carbon composite, a track made of cermet offers such advantages.A cermet track consists of a mixture of metals and ceramics, which is pressed onto a substrate. Wire-wound track primarily has good resistance to high power. Resistance to high current through the outlet is another advantage.

2.1.9.2 Linear and non-linear potentiometers

A potentiometers resistance change as a function of the socket's movement path along the resistance path can be described with a curve. The curve shape can be made linear, logarithmically, or in some other way. Nonlinear curves usually consist of a sequence of linear segments, which together reasonably correspond to the desired nonlinear shape.

2.1.10 Power development in resistors HAREC a.2.1.4

In resistors, heat is developed by the current that flows through them.The heat development occurs according to Joule's Law, which is reproduced in chapter 1.

How much effect in the form of heat is radiated from the resistor depends on the size of its surface and its own temperature as well as on the temperature of the surroundings. There is an upper limit to how much heat the constituent material can withstand before it is destroyed and possibly catches fire.

A resistor's power tolerance is shown in some cases by stamped values. In other cases,Ωou are referred to catalog data or an assessment, which can possibly be based on the appearance and dimensions of the housing.

2.1.11 Standardized component values

Resistors are usually manufactured with standardized values from a series of numbers.

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2.1.12 Marking of resistors

Resistors are marked using numbers and letters or with a color code so that the resistor's main data can be read. The marking is often explained in the component suppliers catalogues.

2.1.12.1 Color marking of resistors

A common way of marking resistors is by having colors on rings around the body. This was more common at the time whenΩou had hole-mounted resistors, and today with surface-mounted resistors, numbers printed on the body of the resistor are used instead. However, the color code is good to know in order to be able to identify resistors and sometimes also other components.

The color code consists of three different schemes, they can be 4, 5 or 6 bands around the component. The first band gives the value of the component and the last two bands have special meaning, the second to last is a multiplier and the last band is the tolerance. Often the last band is also printed with a certain distance from the other bands. If the color code has n bands, it can be described with table 2.1 below.

Colour	Numeric Code	Multiplier	Tolerance
Black	0	10^0	
Brown	1	10^1	±1%
Red	2	10^2	±2%
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	±0.5%
Blue	6	10^6	±0.25%
Violet	7	10^7	±0.05%
Gray	8	10^8	±1%
White	9	10^9	
Gold		10^-1	±10%
Silver		10^-2	±2%

Table 2.1: Color marking of resistors and their meaning

Example:yellow, violet, orange, silver. First is the number 4, next is the number 7 and the third orange is the multiplier 103. The result is then 47 kOhm.

Finally, we have the tolerance, which is silver and means ±10%.

2.2 The capacitor HAREC a.2.2 2.2.1

Generally as soon as there is an electric potential difference – a voltage – between two bodies, an electric force field arises between them. Such a field stores electrical energy. The bodies must then be isolated from each other.

Electrical energy is stored between different parts of a circuit, even if they are not directly intended for it. Especially at very high frequencies, this has great significance for the design of a current circuit. At low frequencies and direct current, however, the design of the circuit has less impact.Instea d, separate devices are needed to absorb or emit energy at desired points in the current circuit.

Such a device is called a capacitor. It basically consists of two strips or plates with connection lines and an insulating layer – dielectric – in between.

Capacitance is the second most common property in a circuit after resistance.

2.2.2 Capacitance HAREC a.2.2.1

The ability to store electrical energy (electrical charge) is called capacitance. The word comes from the Latin capax, which means capacious or capable. Capacitance is denoted in formulas with the letter C. The capacitance of a capacitor is determined by the surface of the capacitor's plates, the distance between these surfaces, the absolute dielectric constantΩ0 and the relative dielectric constant Ωr.

The capacitance increases when the dielectric consists of something other than vacuum. The insulating material between the plates is, which is the factor called dielectric and the properties of this material affect the capacitance of the capacitor. The property of the material is called dielectricity (eng. dielectric property) and is characterized by its dielectric constant (eng. dielectric constant).

The dielectric constant for vacuum is defined as:

$$\epsilon_0 = \frac{1}{c_0^2 \mu_0} \approx 8{,}854187 \cdot 10^{-12}$$

The relative dielectric constant Ωr varies for different materials and its value can be found in tables. By multiplying the relative dielectric constant of a material with the dielectric constant of vacuumΩ0, the absolute dielectric constantΩ is obtained.

$$\epsilon = \epsilon_0 \epsilon_r$$

2.2.3 Capacitance, dimension and dielectric HAREC a.2.2.3

The capacitance is proportional to the surface of the capacitor plates and inversely proportional to the plate distance. The following formulas apply to the capacitance of a simple capacitor with two plates.

When a capacitor is made up of n plates, the capacitance increases by the factor (n-1). With vacuum as dielectric,

$$C = \varepsilon_0 \frac{A}{d}$$

With an arbitrary dielectric,

$$C = \varepsilon_0 \cdot \varepsilon_r \frac{A}{d}$$

$$C\ [farad] \quad A\ [\mathrm{m}^2] \quad d\ [\mathrm{m}] \quad \varepsilon\ [\frac{F}{m}]$$

2.2.4 The unit farad HAREC a.2.2. 2

Capacitance is the quantity of electricity per volt where the unit of measurement is the farad [F]. Since this unit is very large, fractions of it are usually used in electronics.

1 microfarad (1 μF) = 10^6 F
1 nanofarad (1 nF) = 10^9 F
1 picofarad (1 pF)= 10^12 F

2.2.5 The capacitor in the direct current circuit

A capacitor in a direct current circuit always has the same polarity. Thereby, the capacitor's pole voltage U relates to its charge amount Q and capacitance C according to the relationship

$$U = QC$$

U [V] Q [As] C [F]

Charge amount has the unit ampere times second and is thus a measure of how many charges have been stored.

When a connected voltage source has a higher voltage than the capacitor, a current flows to the capacitor and charges it up.

The higher the voltage, the greater the charge.
The shorter the charging time, the higher the power that develops during that time. After the capacitor has been charged, no current flows through it.

This property means that, with the help of the capacitor, you can block direct voltage and only let alternating voltage through. It is used when, for example, you have superimposed DC voltage that you want to remove from a signal or for some other reason you do not want DC voltage to continue in a circuit.

When a charged capacitor is connected to a circuit with a lower voltage, the capacitor discharges to the circuit. The shorter the discharge time, the higher the power developed during that time.

The charge in a capacitor can result in a high pole voltage. If the capacitance of the capacitor is large, the amount of charge can be significant. Warning of electric shock and burns!

2.2.6 The capacitor in the alternating current circuit

In a direct current circuit, the capacitor's pole voltage is related to the amount of charge. But in an alternating current circuit, the voltage and polarity constantly change and thus the capacitor's charge and polarity also change.

Note: Some capacitor types cannot be used in pure AC circuits.

Experiment: A light bulb and a capacitor are connected in series with each other and connected to an alternating current circuit. With appropriately chosen values of the components, the lamp will light up. It shows that a capacitor does not impede electron flow in an AC circuit. It is usually said that the capacitor "lets alternating current through", but in reality it is the case that charges oscillate between the plates of the capacitor through the circuit to which the capacitor is connected. For safety's sake, use low voltage, for example from a ring line transformer!

2.2.7 Capacitive Reactance HAREC a.2.2.4

The current strength in an alternating current circuit depends, among other things, on how large the capacitor's capacitance is, that is, on its capacitive reactance (eng. capacitive reactance) Xc.

The word reactance comes from the Latin re (again) agere (act). Greater capacitance means a greater ability to take up electrical charge and thus gives a lower reactance. The result is a stronger electron flow. A smaller capacitance means a weaker electron flow.

$$XC = 1/\ 2\pi f\ C \text{ or } XC = 1/\omega C\ XC$$

[Ω] f [Hz] C [F]

Example: C = 10 μF f = 50 Hz Xc =?

$X_c = 1/ 2\pi fC$

$= 1/ 2\pi 50 \cdot 10 \cdot 10^{6} = 318.3\Omega$

Example: C = 10 μF f = 5k Hz Xc = ?

$X_c = 1/ 2\pi fC$

$= 1 / 2\pi 5 \cdot 10^{3} \cdot 10 \cdot 10^{-6} = 3.183\Omega$

A capacitor's reactance is thus inversely proportional to its capacitance and the frequency in the circuit. Compare this to an inductor (coil) where the reactance is proportional to the frequency.

When a current flows through a resistor, heat losses occur. When current flows through an ideal reactance – an inductor or a capacitor – however, no heat losses occur.

2.2.8 Phase shift in a capacitor HAREC a.2.2.5

Phase shift here means the temporal shift between the current and voltage courses. In a capacitor, the current does not reach its peak value at the same time as the voltage. In an ideal capacitor, the voltage is phase-shifted by 90◦ after the current.

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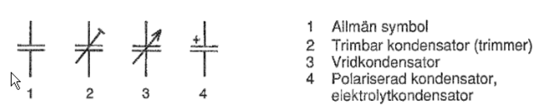
Figure 2.2: Schematic symbols for capacitors



2.2.9 Loss angle

In practice, the phase shift in a capacitor is slightly less than 90◦ due to charge leaking through the dielectric. One speaks of a loss angle. The leakage can be seen as a resistor connected in parallel across the capacitor.

2.2.10 Leakage current

With its extremely thin dielectric, the electrolytic capacitor has a much higher capacitance than other types of capacitors, but it also has some disadvantages. Among other things, it can normally only be used with direct voltage, it has a high loss factor due to leakage current and the heat developed by the leakage current creates overpressure as a result of gas formation.

2.2.11 Designs

Capacitors can be designed with a fixed capacitance value. The dielectric then consists of a layer of mica, impregnated paper or the like. Mica (eng. mica) is a mineral that can easily be split into thin slices. Mica has very good insulation and heat conduction properties. Capacitors can also be made with a variable capacitance value. The dielectric then usually consists of air, but can also consist of a solid material.

Picture 2.2.

2.2.11.1 Fixed capacitors

Capacitors are usually named after their design and the dielectric material.

Paper and plastic capacitors
The plates in these types consist of aluminum strips with connecting wires. In between is a paper or plastic strip as a dielectric. To save space, the whole thing is rolled up and protected with a plastic insert.

Ceramic capacitors
In ceramic capacitors, the dielectric consists of some ceramic material. On either sideof this, a metal covering with connection wires is placed.

Mica capacitors
In this capacitor type, the dielectric consists of thin mica sheets.

Electrolytic capacitors
Electrolytic capacitors have electrodes made of aluminum ortantalum where the plus pole (anode) is given a very thin oxide layer. This is not conductive and acts as a dielectric. An electrolyte with low

resistivity is placed between the oxide layer and the negative pole (cathode). Electrolytic capacitors have a particularly high capacitance value. Unlike other capacitor types, electrolytic capacitors are polarized. Except in a special case, this means that the polarity of the applied voltage must not be reversed.

Several different types of electrolytic capacitors are available, including wet and dry aluminum electrolytic capacitors and tantalum electrolytic capacitors.

2.2.11.2 Variable capacitors

Variable capacitors are usually named after the design, such as rotary capacitor and trimmable capacitor (trimmer).

2.2.12 Temperature coefficient

In a similar way as with resistors, the capacitance in capacitors is affected by the temperature. That the connection between capacitance and temperature is important is understood from the fact that the temperature coefficient in the frequency-determining capacitance in an oscillator circuit is one of the factors for stable frequency.

The temperature coefficientΩc indicates the capacitance change per degree temperature change. The capacitance change then becomes

$$\Delta C = \pm \alpha c \cdot Ck \cdot \Delta\vartheta$$

where Ck is the capacitance value at the lower temperature (usually 20ΩC) and$\Delta\vartheta$ is the temperature change in kelvin. Kelvin [K] is the standardized unit of measurement for absolute temperature. A change of 1 K corresponds to a change of 1ΩC.

If Ωc is positive, it means that the capacitance increases with increasing temperature.

If Ωc is negative, it means that the capacitance decreases with increasing temperature.

A capacitor marked with N 100 means $\alpha c = -100 \cdot 10^{-6}$ 1/K

2.2.13 Standardized component values

Capacitors are usually manufactured with standardized values from a number series.

2.2.14 Marking of capacitors

Capacitors are marked using numbers and letters or with a color code so that the main data of the capacitor can be read. The marking is often pre-prepared in the component suppliers catalogs. See, for example, the table for resistors in section 2.1.12

Image 2.37: Internal resistance

Image 2.38: The transistor as an analog amplifier or digital switch

Image 2.39: NOT-gate This logic function is called inverting.

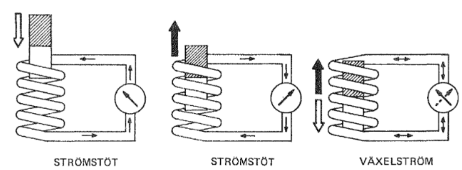
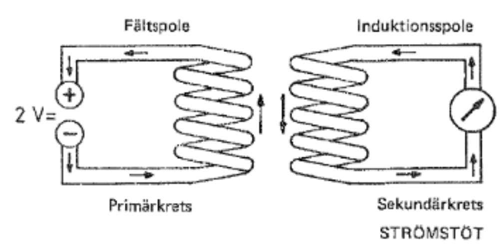


Image 2.3: Experiment 1 with induction Image 2.4: Experiment 2 with induction main data can be read. Often the marking is explained in the component suppliers' catalogues. See for example the table for resistors in section 2.1.1



2.2.3 The inductor HAREC a.2.3

2.3.1 General

When electric current flows through a conductor, a magnetic field is generated around it. As soon as the current strength or direction changes, a corresponding so-called electromotive force (EMF) arises which counteracts the change. The power is found in the magnetic field in the form of stored magnetic energy.

2.3.2 Self-induction - inductance HAREC a.2.3.1

The ability of the magnetic field to generate a counteracting EMF is called self-induction (eng. self inductance) or inductance (eng. inductance). The word inductance comes from the Latin inducer, which means to introduce.

When a conductor that is part of a closed circuit moves in a magnetic field, a current will flow through the conductor due to the EMF (voltage) that is generated. Every change in the current is counteracted by the magnetic field that the current itself generates.

When self-induction occurs in a conductor, the conductor is called an inductor. The self-induction is evenly distributed over the entire length of the conductor. When a larger inductance value is needed at some particular point in the circuit, the length of the conductor can be increased right there and wound up into a coil of suitable shape. The entire coil is then called an inductor. When an opposing magnetic field is generated around a conductor by changing the current in it, the characteristics of the circuit and thus its design are affected in different ways.

In the case of rapid current changes, for example at high frequency, the counteraction is greater than in the case of slow changes. With constant direct current, on the other hand, there is no counteraction - self-induction. After resistance and capacitance, inductance is the most common property in a current circuit.

2.3.3 Experiments with induction

Experiment 1: In picture 2.3, a sensitive turning coil instrument is connected to an inductor.
The instrument should be zeroed in the center of the scale, so that the direction of the current is visible.
A permanent magnet is used to show that self-induction occurs when the magnet is moved back and forth through the inductor.
The instrument gives results when the magnet is in motion. The impact becomes greater with faster speed changes. The direction of discharge changes when the magnet is inserted into or pulled out of the inductor - an alternating current is produced. An alternating voltage occurs across the inductor even when it is part of a current circuit that is closed and broken - i.e. without a moving magnet.

Experiment 2: In picture 2.4, the permanent magnet has been replaced with yet an inductor. In addition to the first inductor, which we now call the secondary winding, we call the new inductor the primary winding. When we pass current through the primary winding, it creates a magnetic field. First the current is zero, then changes to a high value and then returns to zero. It becomes a current shock. Each change produces a counter-EMF, which builds up a magnetic field, first in one direction and then in the other. In both cases the field passes through both windings. The field from the primary winding induces a voltage surge in the secondary winding. The shock has a

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Image 2.5: Trial 3 with induction direction when the primary winding's current circuit is closed and the opposite direction when it is broken - an alternating voltage is generated. When the secondary winding is part of a closed circuit, an alternating current arises through the secondary winding. Experiment 3: In picture 2.5, we ask ourselves the question what happens when the primary winding in experiment 2 is connected to an alternating voltage, for example with the mains frequency 50 Hz. Use a protection transformer between the mains and the winding just to be safe! Voltage surges then occur in the secondary winding, the polarity of which in this case changes 100 times per second. There is thus an alternating voltage across the secondary winding, and if this is part of a closed circuit, a corresponding alternating current arises.

2.3.4 Different designs

Figure 2.6 shows schematic symbols for a number of common inductors. In addition to these, there are electromagnets, chokes, inductors for resonant circuits, frame antennas and so on. A choke (eng. choke) is an inductance, often wound around a magnetic core, with the task of limiting the current in a conductor.

2.3.5 The unit henry (H) HAREC a .2.3.2

The unit of measure for self-induction is the henry (H). 1 henry (1 H) is the self-inductance in an inductor that produces a counter voltage of 1 volt for a current change of 1 ampere for 1 second. In formulas, inductance is denoted by the symbol L.

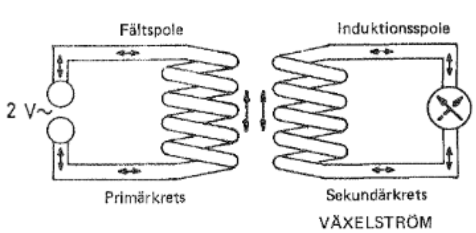
The relationship is:

volt = henry · ampere/second

1 H is a large unit of measurement. For electronics applications, a more manageable format is therefore used.

Example:

1 H = 1000 mH
1 mH = $1 \cdot 10^{-3}$ H
1 mH = 1000 μH
1 μH = $1 \cdot 10^{-3}$ mH = $1 \cdot 10^{-6}$ H



2.3.6 How the inductance is affected HAREC a.2.3 .3

The inductance depends on the mechanical dimensions of the inductor, the number of winding turns and the material in the core.

The inductance in a cylindrical inductor is proportional to the cross-sectional area, inversely proportional to the opposite length and proportional to the square of the number of winding turns. The inductance increases if the inductor is equipped with a single iron core and decreases with a core of non-magnetic, conducting metal, for example copper, brass or aluminum. Just as for the capacitor does the material in the core of an inductor matter, as its permeability can have different values. The absolute permeability μ is usually divided into the permeability for vacuum μ_0 and the relative permeability μ_r which is given by $\mu = \mu_0 \mu_r$ The relative permeability can be found in tables and varies with material. The permeability before vacuum is defined as $\mu_0 = 4\pi 10^{-7} \approx 1.256637 \cdot 10^{-6}$

2.3.7 Inductive reactance HAREC a.2.3.4

Unlike when a resistor is connected to a voltage, the current increase in an inductor is delayed. The reason is that an inductor not only has a resistance, which is not affected by current variations, but also has an inductive reactance (eng. inductive reactance) X_L.

The word reactance comes from the Latin re (re)agere (act). Reactance - alternating current resistance or apparent resistance - occurs as long as the current through the inductor changes.

An inductor thus also resists any current change and this resistance increases with increasing rate of change. A completed oscillation in an alternating current can be seen as one turn in a circle – 360° – and a completed such oscillation is called a period. A period corresponds to the circumference of a circle with radius r, where the circumference is $2 \cdot \pi \cdot r$.

When the current alternates 1 time per second, the oscillation has a frequency [f] of 1 hertz [Hz]. At 50 changes per second, the oscillation has a frequency of 50 Hz. The inductive reactance X_L – the alternating current resistance in an inductor – is a function of the current's so-called angular velocity $\omega = 2 \cdot \pi \cdot f$ and of the inductance L.

The inductive reactance is proportional the frequency of the counter current and the inductance value of the inductor. No losses occur in an ideal inductor, i.e. an inductor that theoretically lacks resistance.

The relationship is:

$$XL = 2\pi f\, L = \omega L$$

XL[Ω] f [Hz] L[H]

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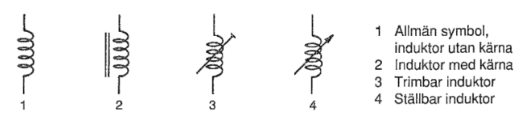
Figure 2.6: Schematic symbols for inductors
Example: L = 1 H f = 50 Hz XL =?
$XL = 2\pi f\, L = 2\pi \cdot 50 \cdot 1 = 314\ \Omega$

Example: L = 1 H f = 5 kHz XL =?
$XL = 2\pi f\, L = 2\pi \cdot 5 \cdot 103 \cdot 1 = 31\,400\ \Omega$



2.3.8 Phase shift between voltage and current in an inductor HAREC a.2.3.5

phase shift means the temporal shift between current and voltage progression. Current through an inductor does not reach its peak value at the same time as the voltage across it. The reason is the exchange between electric and magnetic energy in the inductor. This is illustrated in figure 3.11.

In an ideal inductor, the voltage is phase-shifted by 90◦ before the current. In practice, however, the displacement is slightly less than 90◦ due to the resistance in the inductor.

2.3.9 Q-factor – figure of merit HAREC a.2.3.6

The Q-factor can refer to two different things, which should not be confused. These are the Q-factor of a component or the Q-factor of an entire current circuit. The Q-factor of an inductor is the quotient of its reactance and its series resistance.

Q component = X component / R component

The Q-factor of an entire resonant circuit depends on the width of the frequency band that a certain component combination provides. The Q-factor of a resonance circuit is therefore a measure of its selectivity (section 3.1.18). The Q-factor of an included component affects the Q-factor of an entire circuit. However, the reverse does not apply.

2.3.10 Surface effect - skin-effect

In a conductor of homogeneous material, a single direct current is distributed equally over the entire cross-section.

But for an alternating current, the current density decreases in the center of the conductor and instead increases at the surface. The higher the frequency, the greater the current density at the surface. The phenomenon is called skin effect and occurs in all conductors.

The depth in the conductor material where the charge density has dropped to 37% of the value at the surface is called skindepth. For copper, this depth is approx. 70 mm at 100 Hz. At 1 MHz, the depth has decreased to 0.07 mm and at 100 MHz to 0.0067 mm.

Because of the surface effect, the material in the middle of homogeneous conductors is electrically less effective at high frequencies. The resistance of a certain conductor is thus greater for alternating current than for direct current. In addition to the frequency, the surface effect is affected by the electrical and magnetic conductivity of the conductor material. To obtain low resistance in conductors for high-frequency current, it is important that the circumference is large and that the material layer at the surface has high conductivity. Therefore, the inductors in the transmitter output stage are often silver-plated and consist of tubes with a large diameter or wide bands.

2.3.11 Temperature coefficient

As with resistors, the inductance is also affected by the temperature. That the connection between inductance and temperature is important is understood from the fact that the temperature coefficient in the frequency-determining inductor in a mono-oscillator circuit affects the frequency stability. Because the metal copper expands when the temperature increases and the cross-sectional area of the inductor then becomes larger, the temperature coefficient is usually positive. The temperature coefficient αL indicates the inductance change per degree temperature change. The inductance change then becomes $\Delta L = \pm\alpha L \cdot Lk \cdot \Delta\vartheta$ where Lk is the inductance value at the lower temperature (usually 20 ◦C) and $\Delta\vartheta$ is the temperature change in kelvin. Kelvin [K] is the standardized unit of measurement for absolute temperature. A change of 1 K corresponds to a change of 1 ◦C.

Inductors can contain cores of any metal alloy whose properties are also temperedIn practice, you can hardly influence the temperature coefficient in an inductor. Since a resonant circuit mostly also contains capacitors, a positive temperature coefficient in the inductor can be compensated with a negative temperature coefficient in a capacitor.

2.3.12 Losses in core material

When an alternating magnetic field passes through a core material, the atoms (which are permanent magnets)

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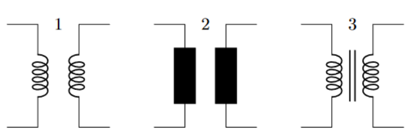
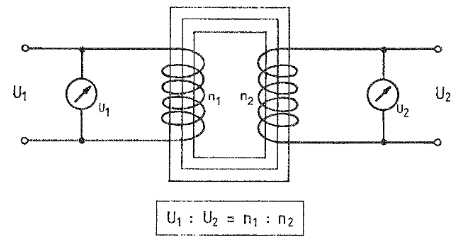


Figure 2.7: Schematic symbols for transformers: 1 and 2 are general symbols and 3 transformer with core.



Picture 2.8: Unloaded transformer to constantly occupy new positions in the material in step with the frequency of the field. Eddy currents then occur, so-called iron losses, which partly affect the conductivity of the material and which partly raise the temperature in the core and thus in the entire inductor.

2.4 The transformer HAREC a.2.4

2.4.1 General

A transformer (eng. transformer) consists of one or more windings or coils of electrical conductors .The windings are magnetically connected to each other. This means that they are arranged so that a magnetic field generated in one of the windings also passes through the other windings. When an alternating voltage is applied to a winding, it is called a primary winding. A magnetic field is then generated in and around the primary winding which changes in step with the voltage. The primary field also passes through the other windings – the secondary coils – and generates voltages and currents there. The so-called coupling factor between the windings varies for different frequencies. It is lower at low frequencies (hundreds of Hz) and higher at high frequencies (thousands of Hz).

Especially at low frequencies, a larger coupling factor is needed so that the intended power can be transferred between the windings. Then the conductivity in the magnetic flux path can be increased with the help of an iron core. Figure 2.7 illustrates several commonly used schematic symbols for transformers with two windings.

2.4.2 Designs

The transformer can be designed for various purposes, for example as a voltage transformer (eng. voltage transformer), current transformer (eng. current transformer) or impedance transformer (eng. impedance transformer). The performance is also affected by the frequency and which power is to be transmitted.

2.4.3 Terminology

primary circuit primary winding primary voltage u1 primary current i1 winding speed n	secondary current secondary winding secondary voltage u2 secondary current i1 primary n1 secondary n2

Winding conversion = n1/n2 or n2/n1

impedance conversion = Z1/Z2 or Z2/Z1

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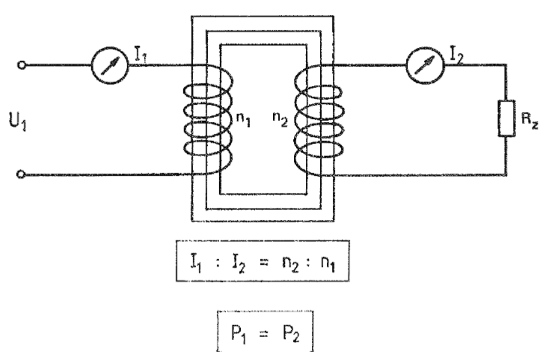


Figure 2.9 : Loaded transformer

2.4.4 The ideal (lossless) transformer HAREC a.2.4.1, a.2.4.2.2, a.2.4.2.1

In picture 2.8, the transformer is unloaded when the secondary circuit is broken.

When the primary winding is connected to an alternating voltage, alternating voltages are induced both across the primary and secondary windings. A current also arises in the primary winding, but not in the secondary winding when the secondary circuit is broken.

For the unloaded transformer, the connection etu1u2= n1n2 applies, that is, the voltage across the windings is proportional to the winding speed.

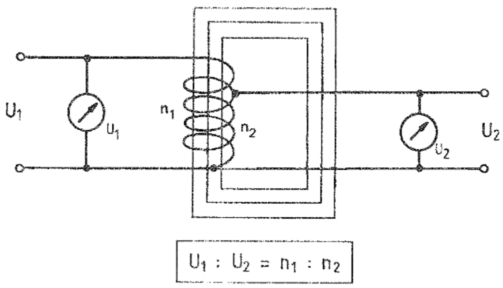
In picture 2.9, the transformer is loaded when the secondary circuit is closed. When one of the transformer's secondary windings is included in a closed current circuit, a secondary current arises there. The secondary current generates a magnetic field that counteracts the field of the primary current, prevents its changes and takes energy from the primary circuit. The current consumption on the primary side thus increases in proportion to the current consumption on the secondary side.

The transformer itself regulates how much energy it takes from the power source and stores in the field to transfer to the secondary circuit.

For the loaded transformer, the current through the windings is inversely proportional to the counterwinding speed, that is, inversely proportional to the speed conversion. i1i2= n2n1

From the previous formulas it follows that :u1u2= i2i1From P1 = u1 · i1 and P2 = u2 · i2 it follows that P1 = P2. If you ignore the losses in the transformer, the power it takes from the power source is equal to the power that the transformer emits.

Since the transformer transforms both voltage and currents, the impedance will also be transformed through the transformer. This impedance transformation follows the impedance transformation, that is,
Z1/Z2= n21/n22



2.59 Figure 2.10: Spare-coupled transformer

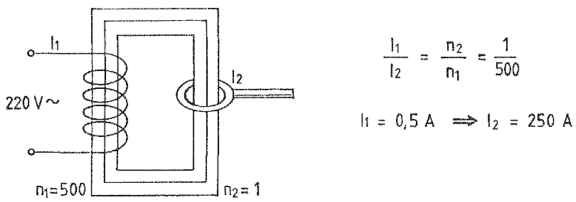


Figure 2.11: Current transformer

2.4.5 Transformer applications HAREC a.2.4.2.4

2.4.5.1 Spare-coupled transformers

In figure 2.9, the transformer has been described so that the primary and secondary windings' only connection with each -others are over a magnetic field, i.e. without galvanic connection.

Each winding can be provided with arbitrary outlets. Between the sockets there is then a voltage that is proportional to the number of winding turns. This is a method to save on the number of windings. To, for example, convert the mains voltage 230 V to 115 V, an energy-saving transformer is sometimes used. With an energy-saving transformer, different current circuits are galvanically connected to each other, as shown in picture 2.10. Special caution must therefore be observed when using energy-saving transformers, due to the risk of electrical accidents. Energy-saving transformers should therefore not be used in amateur radio contexts. The safest are protection transformers with galvanically isolated wires and also with particularly good insulation and enclosure.

2.4.5.2 Current transformers

High secondary current under low secondary voltage characterizes a current transformer (eng. current transformer), which is illustrated in picture 2.11. Current transformers are used in electric welding equipment, induction furnaces and the like. Current transformers are also used for measuring high alternating currents.

2.4.5.3 High-voltage transformers

High secondary voltage under relatively low secondary current characterizes a voltage transformer.

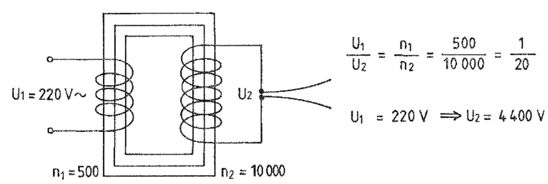
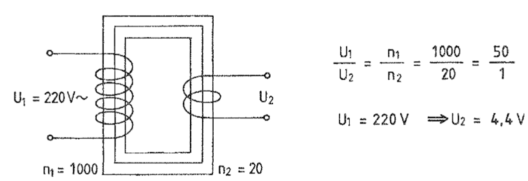


Figure 2.12 shows a transformer with a spark gap in the secondary circuit for gas ignition. High voltage transformers are used in distribution networks, neon signs, ignition systems for internal combustion engines, anode voltage units for transmitters and so on



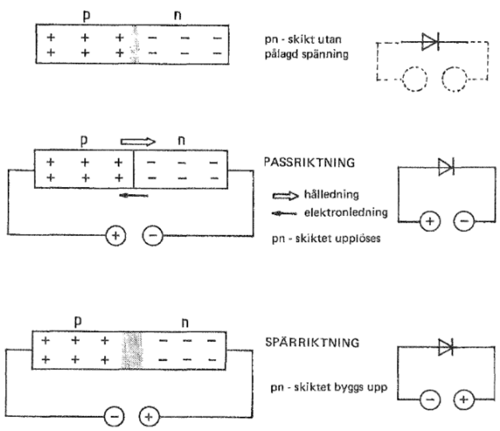


Figure 2.14: The blocking layer in a semiconductor diode

2.5 The semiconductor diode HAREC a.2.5

2.5.1 General

In a circuit, for various reasons, current may be allowed to flow in one direction but perhaps not in the opposite. A device with such a function is called an diode.

At first, a diode consisted of two electrodes in vacuum (see section 2.7.2). Hence the name vacuum diode. Nowadays, a diode usually consists of a semiconductor. Hence the name semiconductor diode. Figure 2.14 at the top illustrates a semiconductor diode consisting of a P-conducting and an N-conducting material layer joined together. Between the two layers, a thin boundary layer is formed that does not contain charge carriers. This layer can be conductive or non-conductive – a barrier layer – depending on the polarization.

2.5.2 Character of the semiconductor diode HAREC a.2.5.1.2

2.5.2.1 Diode in the forward direction

You connect the positive pole of a voltage source to the P layer of a diode and the negative pole with the N-layer, the diode is polarized in the forward direction, this is illustrated in picture 2.14 middle. The barrier layer then dissolves and a forward current flows through the diode. The electrons flow to the positive pole and the holes to the negative pole. Above the connections lies a voltage, the forward voltage, which varies with current and temperature. The voltage drop and the current normally cause the diode's loss effect.

2.5.2.2 Diode in the reverse direction

Reverse voltage, reverse current, leakage current, blocking direction If instead you connect the negative pole of a voltage source to the P layer of a diode and the positive pole to the N layer, the diode is polarized in the blocking direction or the reverse direction, as illustrated in picture 2.14. The blocking layer then becomes even stronger. Only an insignificant current ISP flows through the diode in the blocking direction, even with increasing voltage USP. But above a certain voltage the current increases rapidly - the so-called zener effect occurs. The diode can easily be destroyed by an excessively high current.

2.5.2.3 Diode in a circuit

When a diode is connected to a circuit, it is necessary to turn the diode so that current can flow through it in the desired direction. The connection to a diode's P layer is called anode and is normally connected to the positive pole of the current circuit. The corresponding connection from the N layer of a diode is called the cathode and is normally connected to the negative pole of the current circuit. 62

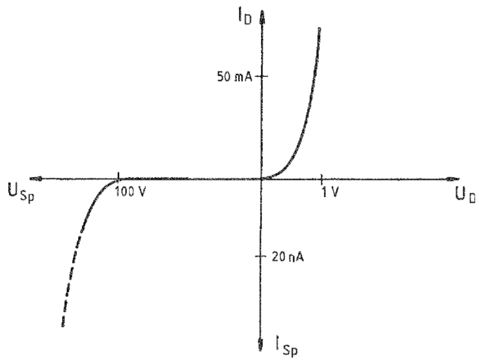


Figure 2.15: Characteristics of the semiconductor diode

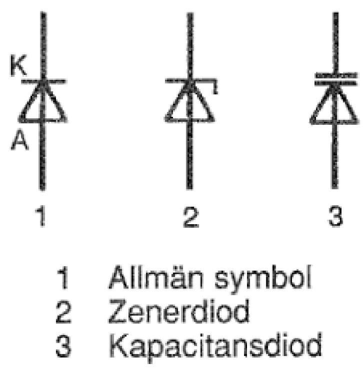


Figure 2.16: Schematic symbols for diodes

To remember how a diode should be reversed, the anode and cathode are used in a memory rule which reads Positive Anode Negative Cathode which is abbreviated PANK. A diode's cathode is marked with a line on or a marking in the housing that must correspond to the line in front of the arrow in the diode's schematic symbol.

2.5.2.4 The diode's current-voltage relationship

Figure 2.15 shows a diode's current-voltage relationship. The current ID begins to flow when the voltage UD has reached a threshold value (for silicon diodes 0.6 V). When the voltage increases further above that, the current also increases. The product of the voltage drop across the diode and the current through it is called dissipation power. This heats up the diode. At too high a temperature, the crystal structure is destroyed. A silicon crystal can handle up to 200 ◦C while a germanium crystal can only handle 75 ◦C.

2.5.3 Diode applications HAREC a.2.5.1.1

Figure 2.16 illustrates several different schematic symbols for diodes. Rectification is the most common application for diodes (see chapter 3.3). Semiconductor diodes are also made for a number of other purposes and are available in a variety of variants.

2.5.3.1 Diodes for voltage stabilization (zener diode)

Within a certain range, the voltage drop across a zener diode in a circuit is almost constant while the current varies. This property is called zener effect and is used to keep voltage constant. There are zener diodes for many different voltages and effects.

2.5.3.2 Diodes as variable capacitors (capacitance diode, VariCap)

When a diode is polarized in the blocking direction, a blocking layer is formed. Different polarization voltages produce blocking layers of different thicknesses and a blocked diode thus has properties similar to those of a variable capacitor. There are diodes where the controllability of the capacitance is specially developed.

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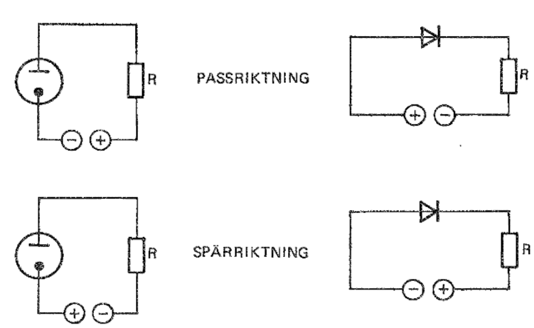

Picture 2.17: Polarization of diodes in the circuit

2.5.3.3 Light emitting diodes (LED)

Light emitting diode (eng. Light Emitting Diode (LED)) is an diode adapted to deliver light, often visible as such. LEDs are available with infrared, red, orange, yellow, green, blue and white light.

A variant of the interceptor diode is the laser diode, which is used, among other things, for transmission over optical fiber.

When a diode is polarized in the pass direction, energy is released in the blocking zone. It occurs through the recombination of pairs of charge carriers, whereby energy is normally released in the form of heat. In the case of a certain mixture of foreign atoms, light is emitted instead.

The voltage drop across an LED is approximately twice as large as across a silicon diode, that is, approximately 1.5 volts. The normal voltage drop should always be checked for correct sizing of the circuit. The brightness is proportional to the current, which normally has values between 10 and 50 mA.

An LED should have a current limiting resistor in series with that the current should not become too large and the LED will age prematurely or even break. Modern high-power LEDs require a constant current supply and can have a significantly higher voltage. These have become available at a low price and popular for experiments.

2.5.4 The vacuum diode

in comparison with the semiconductor diode Figure 2.17 shows the principle of how the two diode types are included in a circuit. The big difference is that the operating voltage for a vacuum diode is many times higher than that of a semiconductor diode and that the vacuum diode's electrode (cathode) needs to be heated to release electrons.

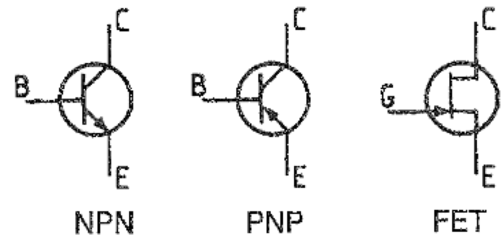

Image 2.18: Schematic symbols

2.6 The transistor HAREC a.2.6

2.6.1 General

A transistor consists of layers of doped semiconductor elements joined together.

Common are two N layers and an intermediate P layer (NPN transistor) or two P layers and an intermediate N layer (PNP transistor).

The layers are provided with connections. Figure 2.18 shows schematic symbols for the common transistor types NPN transistors (bipolar), PNP transistors (bipolar) and FET transistors (field effect).

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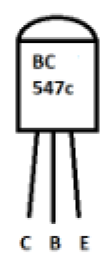


Figure 2.19: Transistor

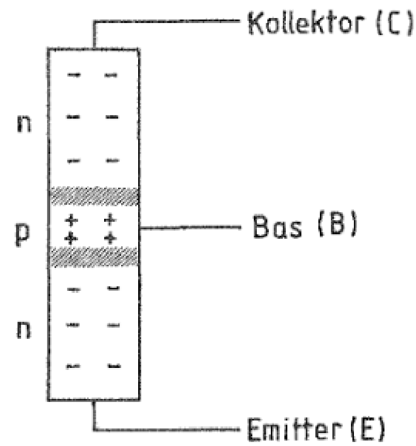
2.6.2 NPN transistorsHAREC a .2.6.1b

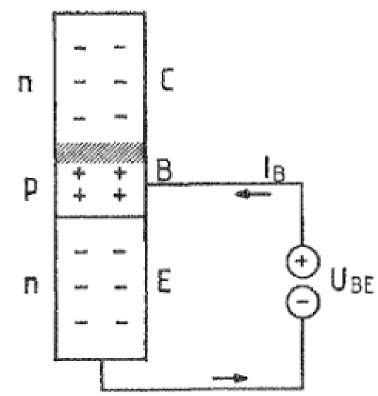
The semiconductor layers are called emitter (E), base (B) and collector (C). Figure 2.19 shows a classic hole-mounted small-signal transistor.

2.6.2.1 Blocking zones

Figure 2.20 at the top shows how zones are formed between layers B and E respective between B and C, the conductivity of which can be controlled electrically via the connections.

2.6.2.2 The UBE voltage source





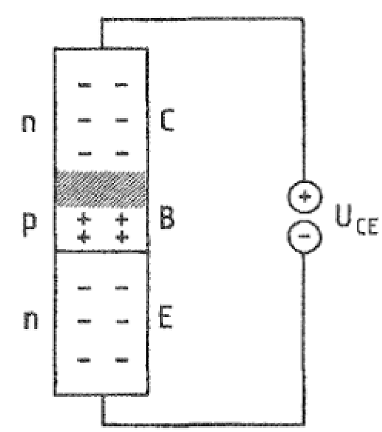
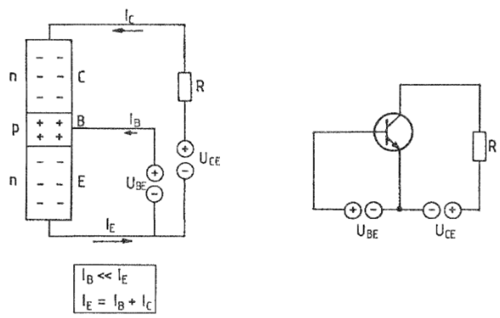


Figure 2.20 in the middle shows that between base and emitter there is a diode distance. When a positive voltage is applied to the base and a negative voltage to the emitter, the blocking zone of the diode strip is polarized in the pass direction. The blocking zone is then dissolved and a so-called base current IB flows.

2.6.2.3 The voltage source UCE

Bild 2.20 at the bottom shows that when a positive voltage is applied to the collector and a negative voltage is applied to the emitter, the diode line is polarized in the blocking direction. The blocking zone is then strengthened and no current flows. Image 2.20: The layers in a bipolar transistor



65 Figure 2.21: Emitter-coupled transistor

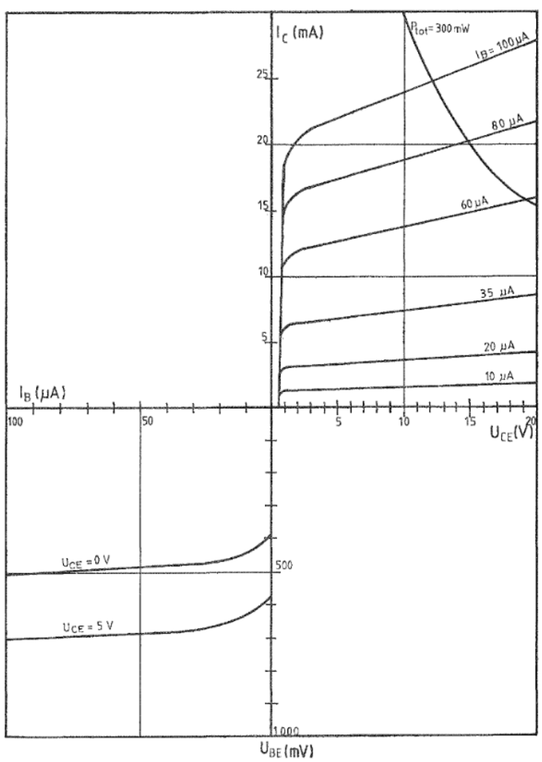


Figure 2.22: Characteristics of transistor BC 10766

2.6.2.4 Influence of both UBE and UCE

Figure 2.21 shows how two voltage sources UBE and UCE are connected to an emitter-coupled NPN transistor. From the heavily doped emitter zone, the electrons flow into the weakly doped base zone (voltage: UBE). However, most of the electrons do not remain in the base. They push through the thin base layer and reach the front of the collector layer with the voltage UCE. It floats the collector current. For the current IE (emitter current), IB (base current) and IC (collector current) applies: IE = IB + IC whereIB ≪ IC (≪ much less than) The collector current IC can be controlled with base voltage-a UBE . A small change in the base voltage produces a large amplification effect in the collector current.

2.6.3 Amplification factor HAREC a.2.6.2

If the current in the input circuit of a transistor changes, the current in the output circuit can change more. β or hF E which is the ratio between the change in the output current and the change in the input current in the active (linear) region of the transistor. Figure 2.22 shows current-voltage diagrams for the transistor BC 107 for different base currents. For emitter-connection the following applies:

$$hFE = \Delta IC/\Delta IB.$$

hF E the current amplification factor
∆IC the change in the collector current
∆IB the change in the base current

2.6.4 PNP transistors HAREC a.2.6.1

a If you replace the two N layers in an NPN transistor with P- layer and the P layer with an N layer to obtain a PNP transistor. The construction, connection and use of a PNP transistor otherwise corresponds to that of an NPN transistor. However, the voltage sources must have opposite polarity.

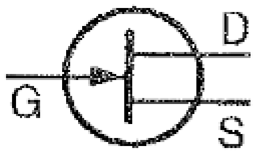


Image 2.23: Schematic symbol for an FET

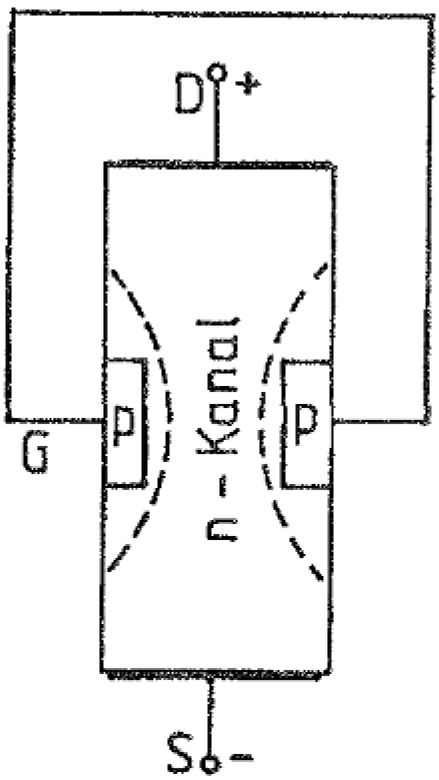


Image 2.24: The layers of an N-channel FET

2.6.5 Field effect transistors HAREC a.2.6.3

2.6.5.1 General

Field effect transistors (FET) have a very high input impedance and the control current is therefore very weak. A FET is therefore said to be voltage-controlled. NPN and PNP transistors - bipolar transistors - are also voltage-controlled, but these types have relatively low input impedance and therefore higher control current. They are therefore said to be current-controlled. Figure 2.23 shows a schematic symbol for a FET.

The field-effect transistor has three connections, source (S), drain (D) and gate (G).

2.6.5.2 The structure of the field-effect transistor

Figure 2.24 shows an N-conducting layer (also called N-channel) with terminals S and D connected to respective ends of the layer. The N-channel passes between two P-conducting layers connected to the control electrode G. When a barrier voltage is applied between G and S, the barrier layers expand and the N-channel becomes narrower. Applying a negative voltage to S and a positive voltage to D, a current will flow in the N channel. Current strength can be affected by the voltage on G. A small voltage change ∆UGS causes a large change in the current ∆IGS in the N channel. This means amplification.

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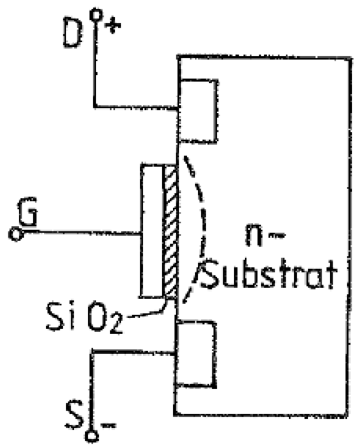

Figure 2.25: The layers of an N-channel MOSFET

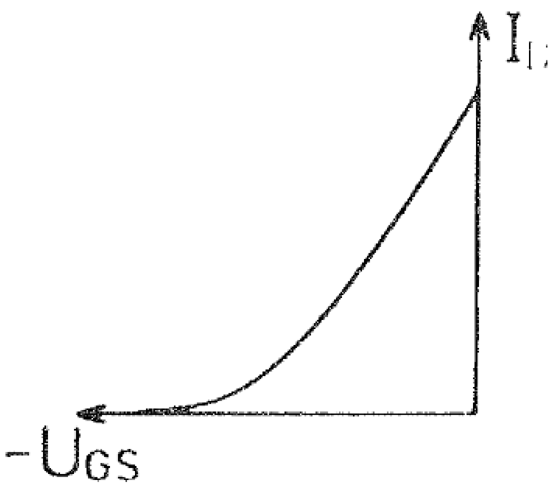

Figure 2.26: Characteristics of an N-channel FEET

Figure 2.25 shows the layers of an N-channel MOSFET.

In a MOSFET (eng. Metal Oxide SemiconductorField Effect Transistor) the G electrode isone (the metal) isolated from the semiconductor channel with a silicon oxide layer. The way it works is the same as for a FET. The drain current can be increased or decreased with the help of a positive or negative voltage on G.

2.6.5.3 The resistance between gate and source

To obtain a gain with a FET, insert a resistor R0 in the drain current circuit. The over resistor then causes voltage changes in proportion to the current changes. To determine the quiescent current and thus the operating point for the same transistor, a resistor RS is inserted in the source current circuit. The size of the source resistor is determined by the desired gate bias

$$RS = -UGS/ ID .$$

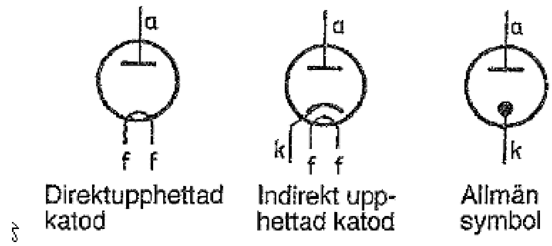

Figure 2.27: Schematic symbols for diodes

2.6.6 The relationship between drain current and voltage

To describe a FET, characteristic curves are used (figure 2.26). We have already presented the input and output characteristics of bipolar transistors in curve form. Since the input current (gate current) in a FET is practically zero, such a curve is without practical meaning. Instead, the man graph shows the relationship between the control voltage UGS and the output current (the drain current ID). Since there are N-channel FETs and P-channel FETs, the polarity of the UGS differs between these two types.

2.7 Electron tubes

2.7.1 General

An electron tube consists of two or more electrodes in an air-free container, usually made of glass or a ceramic material.

2.7.2 The vacuum diode (the two-electrode tube) HAREC a.2.8.1

The diode in picture 2.27 contains two electrodes, anode (a) and cathode (k), as well as, where applicable, a filament (f) (eng. filament). The anode must draw the electrons from the cathode. The cathode must emit the electrons and must therefore be heated. The heating of the cathode can be done directly, that is, the cathode itself is a filament, usually with a 4- to 6-volt power source. Alternatively, the metal cathode is heated indirectly with a separate filament that surrounds and heats a special cathode material. In the latter case, a 1.5- to 12.6-volt incandescent current source is common.

2.7.2.1 The Edison effect

Figure 2.29 illustrates the Edison effect. When the cathode is heated, free electrons are released from it and a cloud is formed. With a voltage between anode and cathode, where the anode is positive, the electrons will be drawn towards the anode. An anode current begins to flow.

2.7.2.2 The Ia/Ua characteristic of a vacuum diode

Figure 2.30 illustrates the characteristic of the vacuum diode. When the anode is given a positive potential (anode voltage), an electron current flows from the cathode to the anode (anode current).

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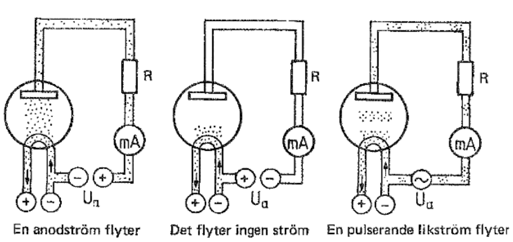

Figure 2.28: Half-wave rectification

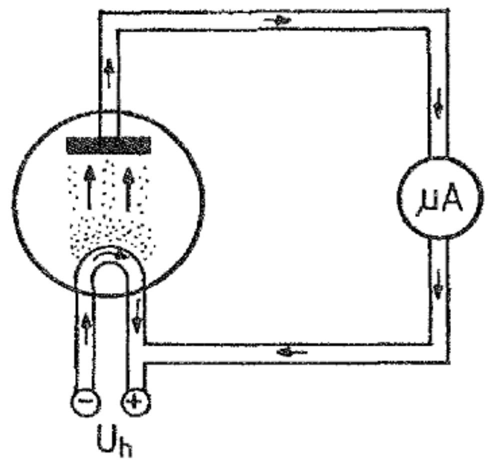

Figure 2.29: The Edison effect

If the anode voltage Ua increases, the anode current Ia increases. Each pair of number values represents a point in a diagram, like the one in the picture. Once the anode voltage has increased to a certain value, the anode current does not increase further. In an intermediate range, the linear range, the curve is almost straight.

2.7.2.3 Rectifier action

When the anode of a vacuum diode is given a positive potential in relation to the cathode, a so-called anode current flows, provided that the cathode is heated so that it emits free electrons. When the anode is given a negative potential in relation to the cathode, on the other hand, no anode current flows. The vacuum diode can therefore be used for rectification of alternating currents. It has a rectifying function.

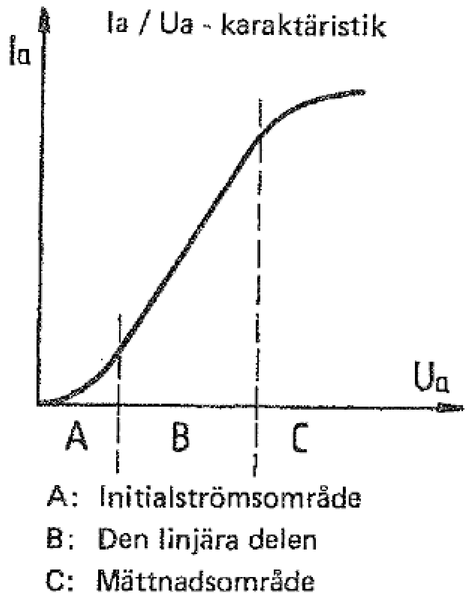

Image 2.30: The characteristic of the diode

2.7.2.4 Half-wave rectification

Image 2.28 illustrates half-wave rectification. When an alternating positive and negative potential, an alternating voltage, is applied to the anode, anode current flows during each positive half-cycle of the alternating voltage. A direct current pulse occurs during every second half period.

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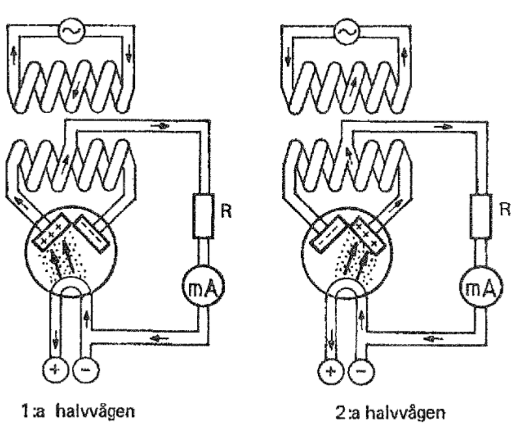

Figure 2.31: Full-wave rectification

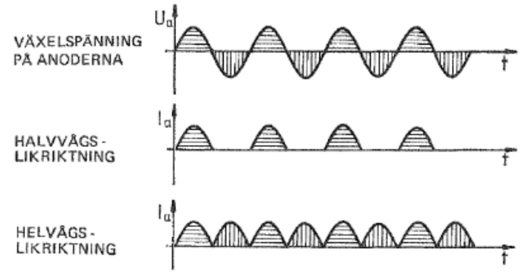

Figure 2.32: Rectifying function

2.7.2.5 Full-wave rectification

Figure 2.31 illustrates full-wave rectification.

With an electron tube with double anodes and a transformer with a center tap on the secondary winding, both half-periods of the alternating voltage can be used, so that the anode current flows in the same direction during all half-periods. Picture 2.32 illustrates how alternating voltage via two two-half-wave rectification forms a full-wave rectification.

2.7.3 The vacuum triode (three-electrode tube)

Figure 2.33 illustrates symbols for triode and pentode.

Figure 2.34 shows their characteristics. The triode contained three electrodes anode (a), control grid (g1) and cathode (k) as well as a filament (f = filament).

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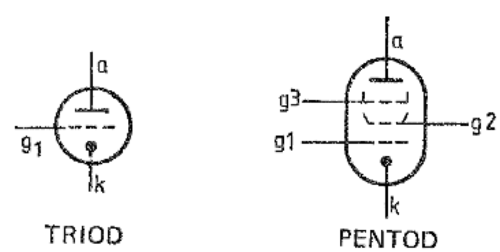

Figure 2.33: Symbols for triode and pentode

2.7.3.1 Function of the triode

Figure 2.35 illustrates a triode and its electron current. The control grid can be given positive, neutral or negative potential (bias) in relation to the cathode. The choice of bias determines the way the triode works. When the control grid is given the same potential as the cathode, the triode acts as a diode. With the control grid positive, increase the anode current. With the grid negative, it decreases. The triode has an amplifying function because the anode current can be controlled with the control grid. A small change in the grid voltage causes a large change in the anode current. In the case of a positive bias, an English current flows, which must not become too high. Usually choose negative bias.

2.7.3.2 Current circuits and current sources of the triode

Glow current circuit	Anode circuit	Grid circuit
Incandescent battery	Anode battery	Grid battery
Incandescent voltage Uf	Anode voltage. Ua	Grid voltage. Ug1
Glow current If	Anode current Ia	Grid current Ig

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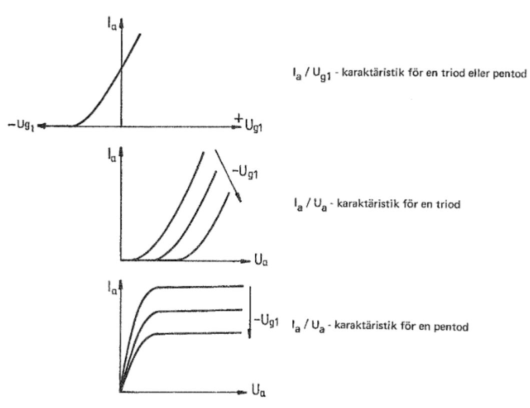


Figure 2.34: Characteristics of electron tubes

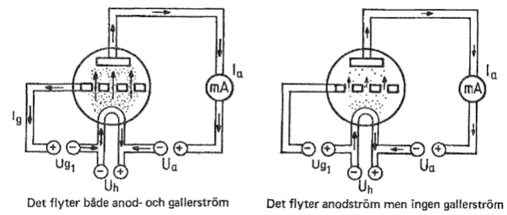


Figure 2.35: The electron current in a triode

Usually mains-powered power sources are used instead of batteries. The choice of grid bias is decisive for the way the triode works.

2.7.4 The pentode (five-electrode tube)

The pentode contains five electrodes, see picture 2.33.

a anode
g3 brake grid
g2 screen grid
g1 control grid
K cathode with filament (f = filament)

The brake grid is connected to the cathode. The screen grid is given a potential that is slightly lower than the anode voltage. The brake and shield grids prevent the electrons from bouncing back to the control grid after hitting the counter-anode.

2.7.5 The tetrode (four-electrode tube)

This type of tube contains four electrodes. The structure is the same as the pentode, but the brake grid is missing.

2.7.6 Electron tube characteristics

Figure 2.34 illustrates a Ia/Ugt diagram for a triode or pentode, at constant Ua.Ia/Ua diagram for a triode, at constant Ug1Ia/Ua diagram for a pentode, at constant Ug1 Three curves are shown in the Ia/Ua diagrams, with different values of Ug1. (Ug1 is a so-called parameter).71

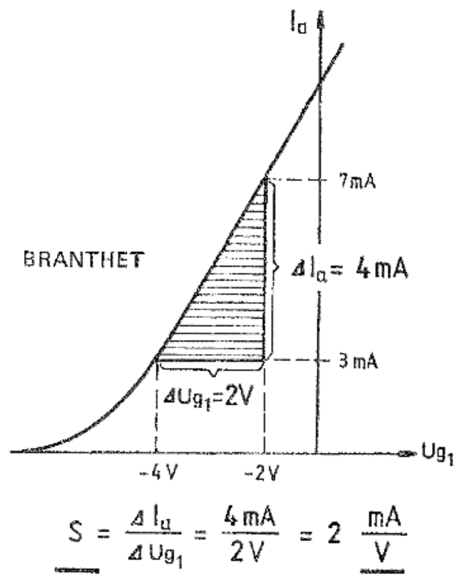


Figure 2.36: Steepness

2.7.7 Steepness S and internal resistance Ri

Figure 2.36 shows the steepness. If, at a constant anode voltage, the grid bias is changed by the value ∆Ug1, the anode current changes by the value ∆Ia.

Slope S = ∆Ia/ ∆Ug1

S [mA/V] ∆Ia [mA] Ug1 [V]

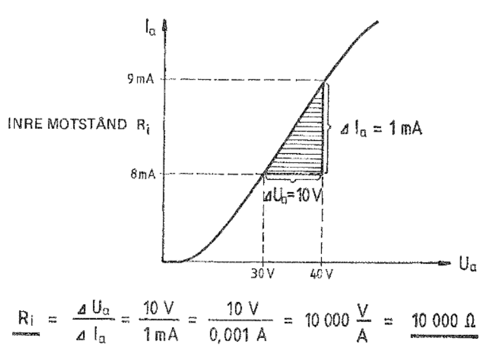


Figure 2.37 shows the internal resistance. If you change the anode voltage by ∆Ua at a constant grid bias, the anode current changes by the value ∆Ia.

Internal resistance Ri = ∆Ua∆Ia

Ri [kΩ] ∆Ua [V] ∆Ia [mA]

If you want to change the anode current by ∆Ia, there are two possibilities. Either you change the grid bias with the value ∆Ug1, or you change the anode voltage with the value ∆Ua.

By changing the grid bias by the value Ug1, one can achieve the anode current change ∆Ia as by changing the anode voltage by the value ∆Ua.

2.7.8 Barkhausen's electron tube formulas

The gain factor μ is illustrated by the following relationship that applies between the so-called tube constants

μ = S · Ri

Example Calculate μ if S = 2 mA/V R = 10 kΩμ =?
Answer μ = 20 (μ is dimensionless)

2.7.9 Transistor compared to electron tube

Transistors have advantages such as low price, small dimensions, long life, simple power supply (incandescent current is not needed) and low operating voltage (6 V, 12 V . . .).

Common disadvantages are sensitivity to overload and high temperatures.

Electron tubes have the advantage of resistance to overload, but among the disadvantages can be mentioned that they require a high anode voltage, that they need glow current and that they require space.

Transistors now almost completely replace electron tubes, but one should still know the characteristics and working methods of electron tubes. One area of use where electron tubes are still common is in larger transmitter output stages.

2.8 Digital circuits

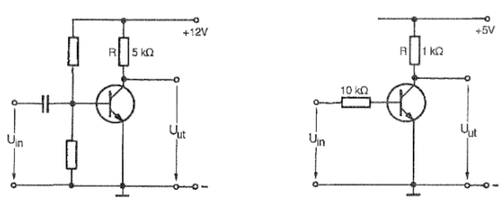
Digital electronics appear in all modern equipment for radio and telecommunications. The subject is very extensive and only a few basic digital functions are explained here.

In analog technology, an infinite number of levels can occur during a process, for example voltages between zero and a maximum value. In digital technology, only a certain number of states occur. In the simplest digital system there are two states, for example 0 and 1 or On and Off or High and Low or Error and Correct. A system with two states is called binary. A lamp that is turned on or off with a simple switch is a binary system.

The switch can have different designs. It can be a mechanical contact that is controlled for handling by a relay coil. It can also be a transistor or other device.

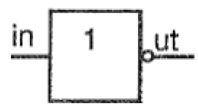
2.8.1.1 NOT-gate or inverting gate

Logical functions are described with international symbols. A ring at the output means that the level of the output voltage is opposite to the input voltage, which is illustrated in picture 2.39.The relationship between the input and output levels is described with a truth table.



picture 2.38

2.8.2 Condition circuits – so-called gates



in	ut
L	H
H	L

in	ut
0	1
1	0

Picture 2.39: NOT Gate

There are different ways to build gates. Today, most gates are electronic solutions. In addition, there are electromechanical gates in the form of switches and relay contacts.The predecessors of the electronic teleswitches (AXE and others) were large systems of mostly electromechanical relays. The easiest way to clearly explain the working method of the most common gates is with relay symbols. A relay contact can then correspond to a transistor or a diode.

Relay coils can correspond to logic levels in signals. Electrical contacts can be normally open and close on impact (closing contact). Alternatively, they can be normally closed and open on impact (breaking contact). The circuit diagrams show the contact modes when the system is at rest.

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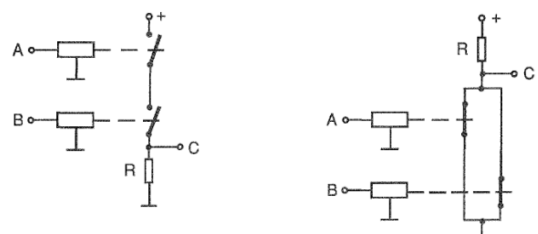


A	B	C
L	L	L
L	H	L
H	L	L
H	H	H

A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

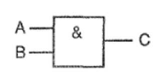
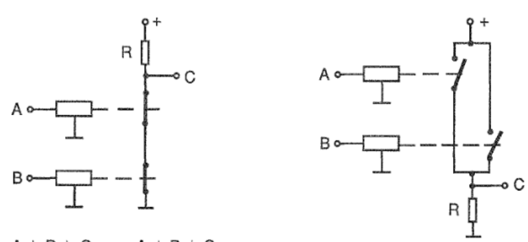


Figure 2.40: AND-gate (AND-gate)



A	B	C
L	L	L
L	H	H
H	L	H
H	H	H

A	B	C
0	0	0
0	1	1
1	0	1
1	1	1

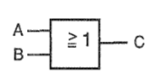


Figure 2.41: OR-gate (OR-gate)

Figure 2.40 shows that the same conditions can be created with closing or breaking contacts. Observe the placement of the resistor on the output side of the circuit in each case. When the resistor is closest to the plus pole, it is called a pull-up. When it is closest to the minus pole, it is called pull-down. In both cases, the resistor defines the logic level.

2.8.2.1 AND-gate or AND-gate

The truth table in picture 2.40 says that when all signals are 1, the output signal is also 1.

2.8.2.2 OR-gate or OR-gate

The truth table in picture 2.41 says that when one or more of the input signals are 1, the output signal is also 1. When all the input signals are 0, the output signal is 0.

2.8.2.3 AND NOT gate or NAND gate

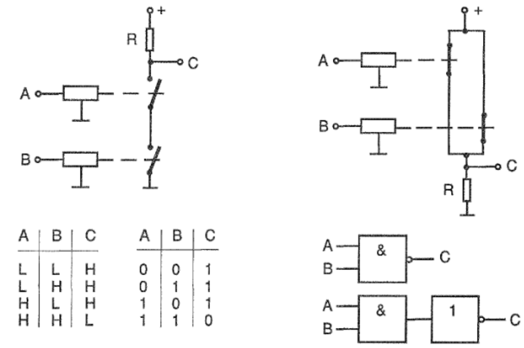
The truth table in Figure 2.42 says that when none or some input signal is 1, but not all, then the output signal is 1. When all inputs are 1, the output is 0.

2.8.2.4 NOT OR gate or NOR gate

The truth table in Figure 2.43 says that when any or all inputs are 1, the output is 0. When all inputs are 0, the output is 1.

2.8. 2.5 Inverted input

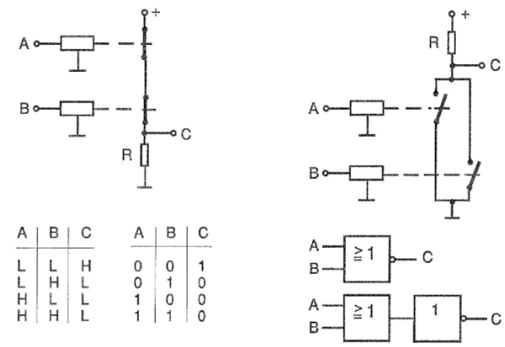
An input may need to have an inverted function in relation to the others (low active).Ωou can then do as in the example with an AND gate in picture 2.44.



A	B	C
L	L	H
L	H	H
H	L	H
H	H	L

A	B	C
0	0	1
0	1	1
1	0	1
1	1	0

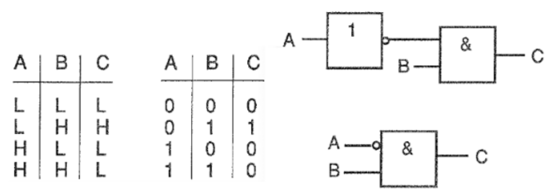
74 Figure 2.42: AND-NOT-gate (NAND-gate)



A	B	C
L	L	H
L	H	L
H	L	L
H	H	L

A	B	C
0	0	1
0	1	0
1	0	0
1	1	0

Figure 2.43: NOT-NOR-gate (NOR-gate)

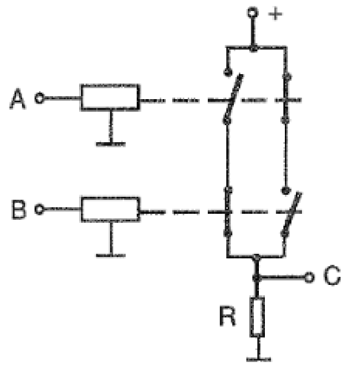


A	B	C
L	L	L
L	H	H
H	L	L
H	H	L

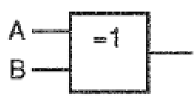
A	B	C
0	0	0
0	1	1
1	0	0
1	1	0

Figure 2.44: Inverted input

The possibility of having an input inverted sometimes makes it difficult to read circuit diagrams, for readability it is usually best to have an explicit NOT-gate. Of course, opinions differ on what is most readable, so check carefully which gates are used in a particular circuit diagram.



A	B	C	A	B	C
L	L	L	0	0	0
L	H	H	0	1	1
H	L	H	1	0	1
H	H	L	1	1	0



75 Figure 2.45: Exclusive OR gate (EXOR gate)

2.8.2.6 Exclusive OR gate (XOR gate)

The truth table in Figure 2.45 says that when all the signals are either 1 or 0, the output signal is 0. When any input signal is 1, but not all, then the output signal is 1.

2.8 .2.7 Exclusive NOT OR gate (XNOR gate)

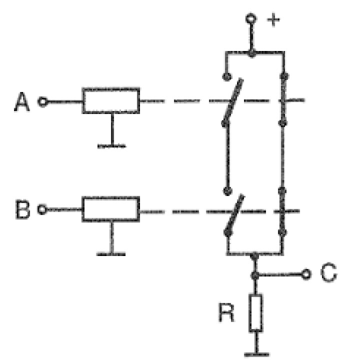
The truth table in Figure 2.46 says that when all signals are either 1 or 0, the output signal is 1. When one input signal is 1, but not all, then the output signal is 0.

2.8.3 Gates with diodes and transistors Instead of relays or discrete semiconductors in gates are now extremely rarely used in anything other than integrated digital circuits (see section 2.9).

Figure 2.47 shows a NAND gate. The actual gate consists of three diodes and a resistor. Two of the diodes are inputs and the third is output. Thegate controls a digitally operating transistor like the one in picture 2.38. The result is a so-called DTL logic (eng. Diode-Transistor Logic).

Figure 2.48 shows a NAND gate. Here, the actual gate consists of an input transistor with two emitters, which correspond to the diodes at A and B in the previous image.The collector of this transistor corresponds to the input diode of the transistor in picture 2.47.

The other three transistors in picture 2.48 form a switch (digital switch, compare picture 2.38), which provides fast transition between well-defined logic levels. The result is a so-called TTL logic (eng. Transistor-Transistor Logic).



A	B	C	A	B	C
L	L	H	0	0	1
L	H	L	0	1	0
H	L	L	1	0	0
H	H	H	1	1	1

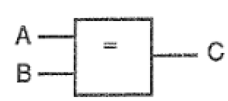


Figure 2.46: Exclusive NOT OR gate (EXNOR-gate) ABC

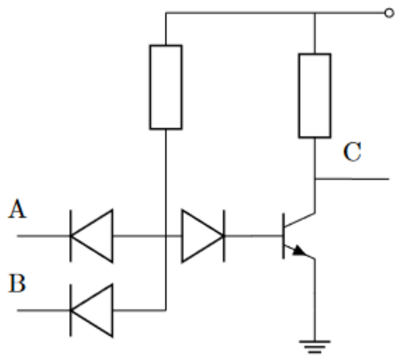


Figure 2.47: DTL logic 2.9 Integrated Circuits (IC)

2.9.1 General about IC

To integrate means to collect into a unit, it can be components, functions or activities. Integration can take place at different levels and in many different contexts. Integration here refers to the integration of components for electronic circuits.

In particular, semiconductor elements of various types as well as resistors and capacitors with small values can be produced with small dimensions. Many components can then be assembled in the same housing. Components within a housing, intended for a certain function, are called integrated circuits (eng. Integrated Circuit – IC).

The components of an IC can in turn be part of the components of an entire circuit. Already within the housing, components can be connected together for a certain function or as part of the current circuit.

Bulky 76

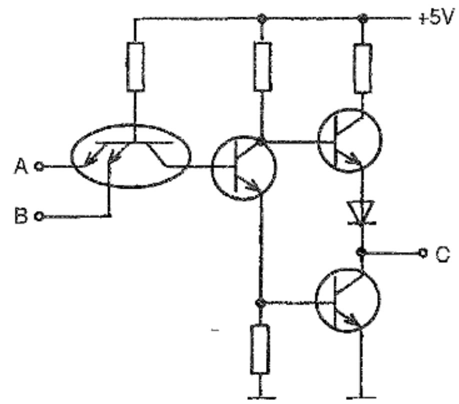


Figure 2.48: TTL logic or power-demanding components, such as inductors, transformers and so on, however, cannot be accommodated, which is why external connections are also needed. Several ICs may also be needed in a circuit – perhaps with content for a different function.

2.9.2 Degree of integration

An integrated circuit is built on a base plate of semiconductor material - a chip. Complete or nearly complete diodes, transistors, resistors and capacitors are produced on the plate, using photo technology or etching. The method, called planar technology, allows many components to fit on the same board. The rapid development of production methods for integrated circuits makes more and more advanced systems possible and also in less and less space.

With regard to degree of integration, the following concepts are used.

SSI Small Scale Integration means around 10 semiconductors on the same chip.

MSI Medium Scale Integration Means about 100 semiconductors on a chip.

LSI Large Scale integration involves some 10,000semiconductors on a chip.

VLSI Very Large Scale Integration involves 100000 or more semiconductors.

2.9.3 Different types of integrated circuits

There is a large assortment of both standardized and special ICs, of which there are two main types:
• digital integrated circuits
• analog integrated circuits.

2.9.4 Digital ICs

Digital ICs work, as the name suggests, with digital signal levels. The simplest types contain one or more digital gates (see section 2.8). By connecting gates together, circuits can be created for a specific purpose. In the early 70s, a complicated system of gates were built in SSI and MSI technology. However, such a system is not flexible as any changes must be made "hardware-wise". This means that wiring must be changed, perhaps entire circuits replaced and so on. In today's digital systems, ICs are used in the form of a microprocessor or even several.

A microprocessor is an advanced circuit that can be programmed (configured)in software not only for one purpose but for many different ones. In systems with microprocessors, memory functions are also needed. The microprocessor is the heart of a computer.

Controlled by a program (the software), it controls peripherals with the task of acquiring and transmitting information – to communicate.

2.9.5 Analog ICs

Analog ICs work with analog signal levels, i.e. voltages and currents with continuously varying levels and frequencies. An analog IC can also work with digital signals. Analog ICs contain one or more balanced amplifiers and various types of auxiliary circuits. With external components, an analog IC can be given different gain and frequency response.

With a common name, these amplifiers are called operational amplifiers (OP-amps). Operational amplifiers are usually performed in SSI or possibly MSI technology.

2.9.6 Combined and special ICs

In addition to standardized ICs, there are combined and special ICs. Examples of special digital ICs are those for telecommunication purposes. Another Example of digital ICs are those for signal processing, both at HF and LF level. Examples of special analog ICs are those for radio communication purposes.

Apart from some bulky components and actuators, an IC can now for example contain a complete radio receiver. Another Example of special analog ICs are those for hearing aids. Through programming, they are adapted to personal needs.

2.9.7 The development

It can be said as often as desired. Through the fantastic development of microelectronics, opportunities that were previously unthinkable are opening up even for the radio amateur. This development has widened the scope for the experimental activities that amateur radio basically entails. The hobby thus gains an ever greater technical scope over time.

2.9.8 Current literature

Increased scope of technology within amateur radio places corresponding demands on literature. More recently,

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digital technologies have also been included. Mostly for reasons of space, digital technology is treated very briefly in this fact book, but still as much as is mentioned in the CEPT recommendation T/R 61-02.

For deeper study, reference is made to other learning materials and to supplier catalogues.

2.10 Operational amplifier HAREC a.2.8.3

Operational amplifier (eng. operational amplifier), often called op-amp is an integrated circuit type that has high gain. Instead of having just one input, it has two, one positive and one negative, and the op amp amplifies the difference between the positive and negative signal.

The gain in a modern operational amplifier can be in the order of a million times. The two most basic connections are a comparator and a negative feedback amplifier.

2.10.1 Comparator

In a comparator, the high gain is used to make even small voltage differences have a large effect.

With the reference voltage on the negative input and the input signal on the positive input, the output will be as high as it can be when the input has a higher voltage than the reference voltage.

Conversely, it will be as low as it can be when the voltage level at the input is lower than the reference voltage

.It is easy to change the characteristics of the output by switching signals between the positive and negative input of the operational amplifier.

2.10.2 Negative feedback and amplifiers

An operational amplifier that has a negative feedback, that is where the signal from the output is fed back to the negative input, will try to drive the output so that the voltage difference between the positive and negative input is evened out.

There is a rich set of connections based on this equilibrium, where the op amp operates in a linear operating range.

This balance also means that a quick diagnosis can be made by measuring the voltage between the inputs. If the voltage is close to zero, the clutch is probably working. But if the connection is faulty in some way, for example if the operational amplifier itself or some component in the feedback is broken, the voltage will be visibly different and the equilibrium will not exist.

2.10.2.1 Buffer amplifier

The simplest linear connection with an operational amplifier is a buffer amplifier. In this connection, the negative input is directly connected to the output Ω + R2 R1 and the input signal is connected to the positive input. With this connection, the operational amplifier will try to make the negative input, and thus also the output, follow the input signal.

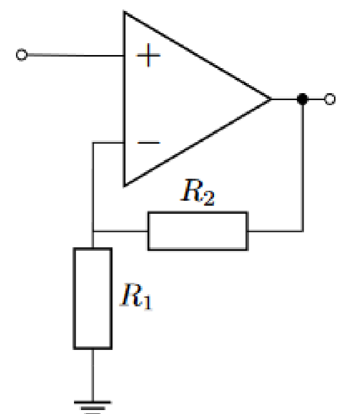


Figure 2.49: Non-inverting amplifier

Such a connection, where we get the same voltage at the output as we have at the input, is called a voltage follower. The advantage of a voltage follower is that the load on the output can be extremely much higher than what the input signal could drive.

If the output level should drop depending on the load, the feedback tries to drive it back to the correct voltage.The buffer amplifier allows the operational amplifier to deliver the same voltage output, but against a load of only a few ohms, that is, with much greater amperage. The relatively high input impedance of the operational amplifier, up to one teraohm, means that the drive signal is not affected by a low-impedance load.

2.10.2.2 Positive (non-inverting) amplification with op-amp

A simple variant of the buffer amplifier is obtained when connecting a voltage divider between the output and the negative input, as illustrated in figure 2.49.

If the ratio in the voltage divider is 1:10, the voltage on the negative input will be one tenth of the voltage on the output. To maintain balance between the positive and negative inputs, the op amp will drive the output to ten times the level of the positive input. By varying the ratio in the voltage divider, the gain of the circuit can be controlled.

The amplification becomes: G =1 + R2/R1

By connecting a capacitor in parallel across the feedback resistor (R2 in picture 2.49),

You can create a bandwidth limitation for the amplifier. For the higher frequencies, most of the current will go through the capacitor and the feedback will therefore be frequency dependent.

The gain for high frequencies is reduced to the same level as for a buffer amplifier. This is also a way to avoid the circuit self-oscillating at high frequencies. 78Ω + R1 R2

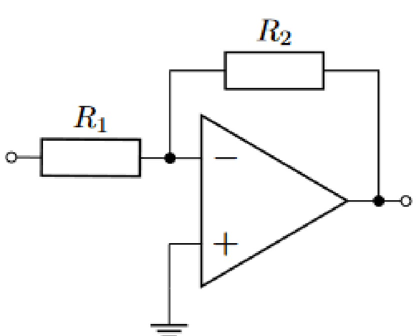


Figure 2.50: Inverting amplifier

2.10.2.3 Negative (inverting) gain with op-amp

The Connection in figure 2.50 provides a negative gain.

The op amp will balance the negative input so that it is at the same potential as ground. This is called virtual earth. Current will flow from the input to the output, but the input will see the load from the input resistor R1 and the output will feed R2 to ground. The gain will be negative and proportional to the ratio between the resistance values:

$$G = -\frac{R_2}{R_1}$$

G =- R2 / R1

2.11 Heat development HAREC a.2.7

2.11.1 Heat conduction HAREC a.2.7.1

We have previously considered Joule's Law for power development in resistance. It is time to start developing a slightly more complete view of heat development.

A resistor developing 1 watt will rise in temperature until equilibrium occurs between the resistor's ability to dissipate heat and the ambient temperature.

Thermal resistance is a measure of how well a material conducts heat. It is denoted by the symbol Rÿ, and is given in the unit kelvin per watt. The temperature Tk for a component depends on the average power P that it produces in heat, the thermal resistance and the ambient temperature TA according to:

$$T_k = T_A + R_\Theta \cdot P$$

Tk = TA + RΘ · P

The thermal resistances of the component, cooling paste, insulation board and heat sink can be summed just like the resistances of ordinary resistors and the total value is then used to calculate the temperature of a component or to size a heat sink.

2.11.2 Convection HAREC a.2.7.2

Convection is when heat creates a natural flow in liquid or gas, usually air. When air is heated, it wants to expand, whereby the density drops and the air wants to rise upwards. Colder air then flows in and can thus cool the heat source. A large temperature difference means that convection increases and thus means better cooling.

For transistors, for example, the heat generation can take place on such a small surface that convection from the component is not enough to cool off the heat produced. Therefore, they are mounted on a heat sink (eng. heat sink) which distributes the heat over a larger surface so that the effect of convection increases.

An efficient method for transporting heat is via a so-called heat pipe. It is a tube containing a liquid that evaporates at a temperature just above room temperature and which then effectively conducts excess heat to a place where it can be cooled.

Heat pipes are now often used in computers and solar collectors. If heat is produced on a small surface,Ωou may need to help the convection, which is sometimes called forced convection. With the help of a fan, air is blown towards or sucked past the heat sink, which increases the heat exchange. Because fans create noise, one usually tries to adjust the fan speed in relation to the temperature, but even a variation of the speed can be perceived as disturbing.

Other measures to reduce the noise level are to create smooth surfaces for the air so that no air vortices form to control the incoming and outgoing air flow with baffles.

A problem that can arise is that equipment that is made for self-convection is placed or mounted so that air cannot flow freely around the equipment. This can lead to overheating in the same way as when a forced cooling fan breaks. Poor thermal contact between transistor and heatsink is another example of how poor heat conduction creates problems with overheating.

2.11.3 Heat generation HAREC a.2.7.4

Heat generation can occur in more places than in resistance. A little simplified,Ωou can say that all components have losses that produce heat. Through appropriate selection of components and correct dimensioning, we can avoid producing unnecessary heat losses. Power units and power stages are examples of devices where larger currents flow, which inevitably also generate more heat. Lower losses are created by simply having better conductivity, lower resistance.

Semiconductors also create heat, and here too Joule's Law of voltage times current applies. For example, in a power stage, the transistor will develop an effect corresponding to the voltage across the transistor when the current passes through it.

Unnecessarily high voltage and current create higher heat development, which is one reason why one likes to avoid output stages that work in class A in favor of output stages that work in class AB, B or C.

Lack of heat dissipation often leads to catastrophic failures, such as burnt resistors and transistors. Even conductors can burn whenΩou have too little conductor area, and thus too high resistance for

79

0 100 200300 0 2 4 6 8 10 12 Angle (degrees) Voltage (V) and Power (W) Uce Pt

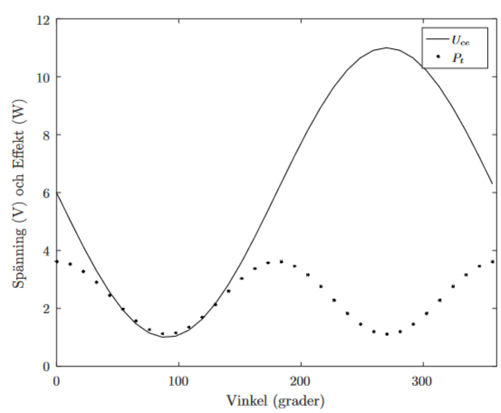


Image 2.51: Heat generation in a transistor.

Transistor voltage Uce and transistor power Pt vary with the angle of the resistive load sine signal. the current to pass through it. For that reason, there are dimensioning rules, for example requirements for the minimum area of copper in conductors, simply to prevent fire.

Another effect of heat conduction is that it can sometimes be difficult to solder on circuit boards, especially with conductors that run against large copper surfaces that have a relatively good thermal conductivity. Sometimes small patterns of "thermals" are constructed around such solder points to reduce heat dissipation. An effective way to be able to solder and above all to de-solder from such boards is to preheat the entire circuit board or the area around the soldering point. Then the temperature difference between the tip of the soldering iron and the surroundings will decrease and it will not require as much power to bring the soldering point up to the right temperature in order to carry out the soldering with good wetting and thus avoid the formation of cold soldering.

2.11.4 Heat in transistor HAREC a.2.7.3

To understand heat generation in a transistor, we start by looking at the power consumption, Pt, in an NPN transistor which can be described as

$$Pt \approx Ube \cdot Ib + Uce \cdot Ic,$$

where Ube is the voltage from base to emitter, Ib is the current through base, Uce is the voltage from collector to emitter, and Ic is the current through collector.

Most of the time, the current through the base is negligible. To go a little deeper, we think of an example with a transistor in simple Class A amplifier circuit, see chapter 3.4.5. The transistor has a 12 V supply voltage and has a quiescent voltage of 6 V to have a margin against 0 V and +12 V. The generates a sine signal with a peak-to-peak value of 10 Vpp into a resistive load. The tension collector to emitter, Uce, and the current, Ic, is 180 degrees out of phase so the resulting power, Pt, has its maximum values between the voltage maximum and minimum values, see picture 2.51.

Figure 3.86: Comparison between different mixers

3 Circuits

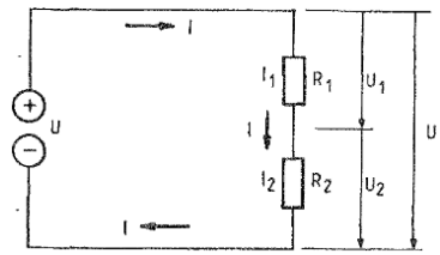


Figure 3.1: Series-connected resistors

3.1 Components in series and parallel

3.1.1 Series-connected resistors HAREC a.3.1.1a, a.3.1.2, a.3.1.3

Figure 3.1 shows series-connected resistors.

The total resistance of series-connected resistors is the sum of the resistances. R = R1 + R2 + R3 · · · The current is equal through all series-connected resistors in the current path (no branch).

$$I = I1 = I2 = I3 \cdots$$

The total voltage across series-connected resistors is the sum of the voltage across each of them.

$$U = U1 + U2 + U3 \cdots$$

The voltage across each of the series resistors behaves like their resistances. For two resistors, U1/U2= R1/R2

applies.

3.1.2 Parallel-connected resistors HAREC a.3.1.1b

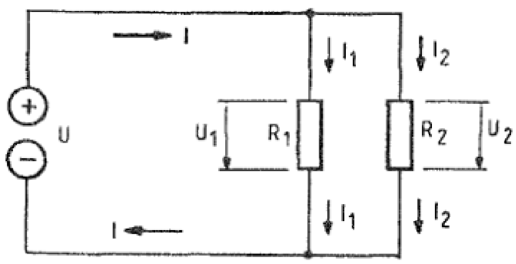


Figure 3.2 shows parallel-connected resistors.

The total resistance of resistors connected in parallel is lower than the lowest individual resistance.

1R = 1R1+ 1R2+ 1R3+ 1R4+ · · · 1Rn

For two resistors connected in parallel,

1R = 1R1+ 1R2 or R = R1 · R2R1 + R2

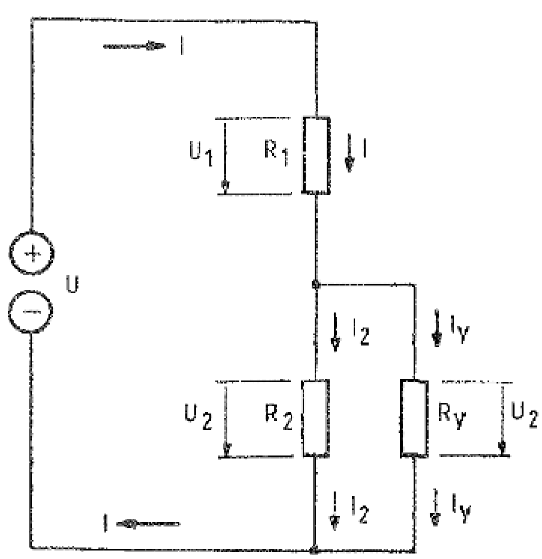


Figure 3.3: Resistive voltage divider

The current branches between parallel-connected resistors.
The total current is the sum of the branch currents

I = I1 + I2 + · · · In

The voltage is equal across the resistors

U = U1 = U2 = U3 = · · · Un

The branch currents through parallel-connected resistors are distributed inversely proportional to their respective resistances.

For two resistors, I1/I2= R2/R1 applies

3.1.3 Voltage dividers

Voltage dividers come in several forms.

Figure 3.3 shows a voltage divider with resistors where voltage-81

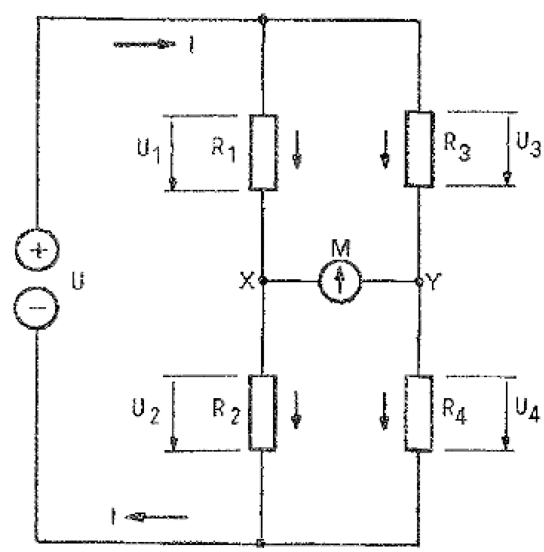


Figure 3.4: Wheatstone's bridge

U is divided into the voltage U1 over resistor R1 and U2 over R2. An alternative to voltage division with fixed resistors is the potentiometer. It is a variable voltage divider in the form of a resistor with a movable socket.

If you connect a device in parallel across R2, for example an instrument whose internal resistance corresponds to Ry , the voltages across R1 and R2 will be affected. If Ry is much larger than R2, can the influence be disregarded.
To calculate U2, you can use the following formula for an unloaded resistive voltage divider.

$$\frac{U_2}{R_2} = \frac{U}{R_1 + R_2} \quad \text{eller}$$
$$U_2 = U \cdot \frac{R_2}{R_1 + R_2}$$

U2/R2= U/R1 + R2 or U^2 = U · R^2/(R1 + R2)

If Ry, on the other hand, is of the same order of magnitude as R2 or lower, it is appropriate to first calculate the external resistance Rp in the parallel circuit

$$R_p = \frac{R_2 \cdot R_y}{R_2 + R_y}$$

Rp = (R2 · Ry) / (R2 + Ry)

and then calculate the voltage U2

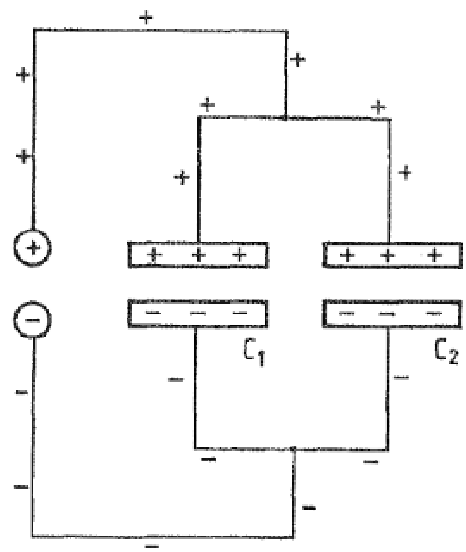
U2 = U · RpR1 + Rp= U · R2 · RyR2 + RyR1 + R2 · RyR2 + Ry

$$U_2 = U \cdot \frac{R_p}{R_1 + R_p} = U \cdot \frac{\frac{R_2 \cdot R_y}{R_2 + R_y}}{R_1 + \frac{R_2 \cdot R_y}{R_2 + R_y}}$$

From this it is understood that, for example, a voltage measurement gives different results depending on the internal resistance in the voltmeter.

3.1 .4 Wheatstone's bridge

A special application of voltage dividers is a Wheatstone's bridge, see picture 3.4, which is used to compare voltages.



Picture 3.5: Parallel-connected capacitors

The bridge can be seen as two parallel-connected voltage dividers, one of which is a potentiometer with a scale graduated, for example, in Ω.

The second voltage divider consists of a resistor with known resistance and a resistor with unknown resistance, i.e. the object to be measured.

In the line that connects the respective center sockets X and Y, there is an ammeter as a zero current indicator. Current flows between X and Y when there is a potential difference - voltage - between them. Brewer is then out of balance. However, no current flows there when there is no potential difference, that is, when the bridge is in balance. Balance (the measured value) is obtained by adjusting the graduated potentiometer to zero current.

Then the relationship

R1/R2= R3/R4

applies. The examples of voltage dividers and bridges show that devices affect each other when they are connected together, which is the case during measurements. Voltage division can also be performed with capacitors and inductors provided that it is an alternating current circuit.

3.1.5 Parallel connected capacitors HAREC a .3.1.1f

Picture 3.5 shows capacitors connected in parallel. Instead of using a single capacitor, you can connect several capacitors in parallel to achieve the desired total capacitance. The total capacitance for parallel-connected capacitors is the sum of the individual capacitances.

$$C = C_1 + C_2 + C_3 + \cdots C_n$$

C = C1 + C2 + C3 + · · · Cn

Calculation example:
1. C1 = 5 µF C2 = 10 µF C = ?
C = C1 + C2= 5 + 10= 15 µF82

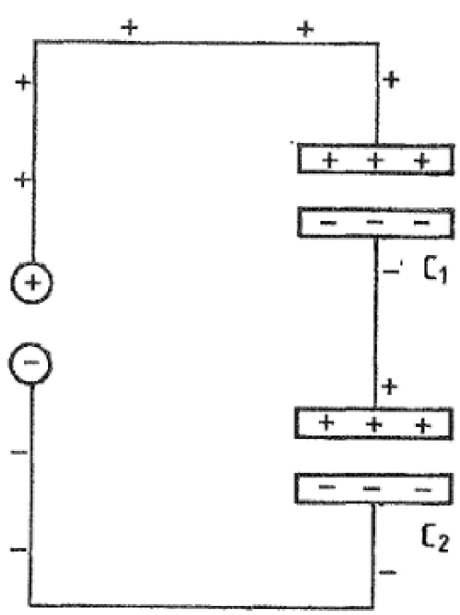


Figure 3.6: Series-connected capacitors

2. C1 = 1 nF C2 = 5 pF C = ?
C = C1 + C2= 1 + 0.005= 1.005 nF

3.1.6 Series-connected capacitors HAREC a.3.1.1e

Figure 3.6 shows series-connected capacitors. The total capacitance of capacitors connected in series is lower than the capacitance of the capacitor with the smallest value.

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots \frac{1}{C_n}$$

1/C = 1/C1+ 1/C2+ 1/C3+ · · · 1/Cn

For two capacitors:1C = 1C1+ 1C2 or C = C1 · C2C1 + C2

$$C_1 = 5\,\mu\text{F} \quad C_2 = 10\,\mu\text{F} \quad C = ?$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$C = \frac{C_1 \cdot C_2}{C_1 + C_2} = \frac{5 \cdot 10}{5 + 10} = 3\frac{1}{3} \approx 3{,}33\,\mu\text{F}$$

Calculation example: C1 = 5 µF C2 = 10 µF C = ?
1C = 1C1+ 1C2C = C1 · C2C1 + C2= 5 · 105 + 10 = 3 13 ≈ 3.33 µF

3.1.7 Galvanically connected inductors

The inductance value for galvanically connected inductors can in principle be calculated in the same way as for the corresponding connection of resistors.

3.1. 7.1 Galvanically series-connected inductors HAREC a.3.1.1c

Provided that the magnetic fields from the respective inductors do not react on each other - that is, do not "connect magnetically to each other" - then the following applies:

$$L = L_1 + L_2 + L_3 + \cdots L_n$$

L = L1 + L2 + L3 + · · · Ln

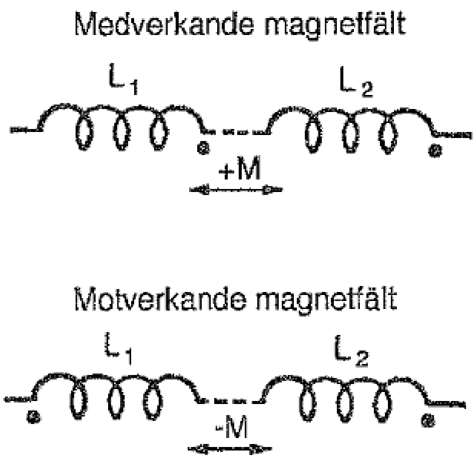


Figure 3.7: Magnetic coupled inductors

Calculation example:
L1 = 20 mH L2 = 50 mH L = ?
L = L1 + L2 = 20 + 50 = 70 mH

3.1.7.2 Galvanically parallel connected inductorsHAREC a.3.1.1d

Provided that the magnetic fields from the respective inductors do not react on each other - that is, not " magnetically connect to each other" - the following applies:

$$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \cdots \frac{1}{L_n}$$

1/L = 1/L1+ 1/L2+ 1/L3+ · · · 1/Ln

For two inductors the following applies:

$$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} \quad \text{eller}$$

$$L = \frac{L_1 \cdot L_2}{L_1 + L_2}$$

1L = 1L1+ 1L2orL = L1 · L2L1 + L2

$$L_1 = 50\,\mathrm{mH} \quad L_2 = 60\,\mathrm{mH} \quad L = ?$$

$$L = \frac{L_1 \cdot L_2}{L_1 + L_2} = \frac{50 \cdot 60}{50 + 60} = \frac{3000}{110} \approx 27\,\mathrm{mH}$$

Calculation example: L1 = 50 mH L2 = 60 mH L = ?
L = L1 · L2L1 + L2= 50 · 6050 + 60 = 3000110 ≈ 27 mH

3.1.8 Magnetically coupled inductors

In practice, inductors are often arranged so that their respective magnetic fields can react to each other - so-called magnetic coupling. A mutual inductance M arises in the inductors due to this coupling. The mutual inductance increases or decreases the resulting inductance value depending on whether the magnetic fields of the inductors act with or against each other. However, the calculation of the value of M is relatively complicated and is not dealt with here. Instead, a simplified representation is made.

Figure 3.7 shows series-connected inductors, whose magnetic fields connect to each other in different ways. The "dot" at the end of the inductors in the picture marks the mutual polarization of the magnetic grid fields. 83

3.1.8.1 Magnetically coupled inductors in series

Formula:

L = L1 + L2 ± 2M

Calculation example: Two inductors have an inductance of 20 and 10 μH respectively and a mutual inductance of 2 μH. The inductors are connected and positioned so that their magnetic fields interact. Each inductance is therefore increased by M = 2 μH.

L = L1 + M + L2 + M
= 20 + 2 + 10 + 2 μH
= 34 μHR

Calculation example: Two inductors have an inductance of 20 and 10 respectively μH and a mutual inductance of 2 μH. The inductors are connected and placed so that their magnetic fields counteract each other. Each inductance is therefore reduced by M = 2

μH.L = L1 − M + L2 − M
= 20 − 2 + 10 − 2 μH
= 26 μH

3.1.8.2 Magnetically connected inductors in parallel

When several inductors are connected in parallel and place them so that their magnetic fields interact, one needs to take into account whether they cooperate or counteract each other. More reading about inductors and how they influence each other can be read in [27].

Formulas: Cooperating parallel inductors

$$L = \frac{L_1 \cdot L_2 - M^2}{L_1 + L_2 - 2M}$$

L = (L1 · L2 − M 2)/(L1 + L2 − 2M)

Opposing parallel inductors

$$L = \frac{L_1 \cdot L_2 - M^2}{L_1 + L_2 + 2M}$$

L = (L1 · L2 − M 2)/(L1 + L2 + 2M)

3.1.9 Up- and discharge of a capacitor

3.1.9.1 Charging

Figure 3.8 shows charging of a capacitor.

A capacitor C is connected in series with a resistance R and connected to the voltage U. The voltage across the capacitor rises from 0 volts to Umax at the same time as the charging current drops from Imax to 0 amps. The voltage across the capacitor increases exponentially during charging

$$u_c = U_{max} \cdot (1 - e^{-t/\tau})$$

uc = Umax · (1 − e^−t/τ)

where uc is the voltage across the capacitor after a given switch-on time, Umax is the final voltage after at least = 5τ , t is the switch-on time, and e is the base of the natural logarithm .

The course includes the size of resistance and capacitance according to the following relationship, which is called the time constant:

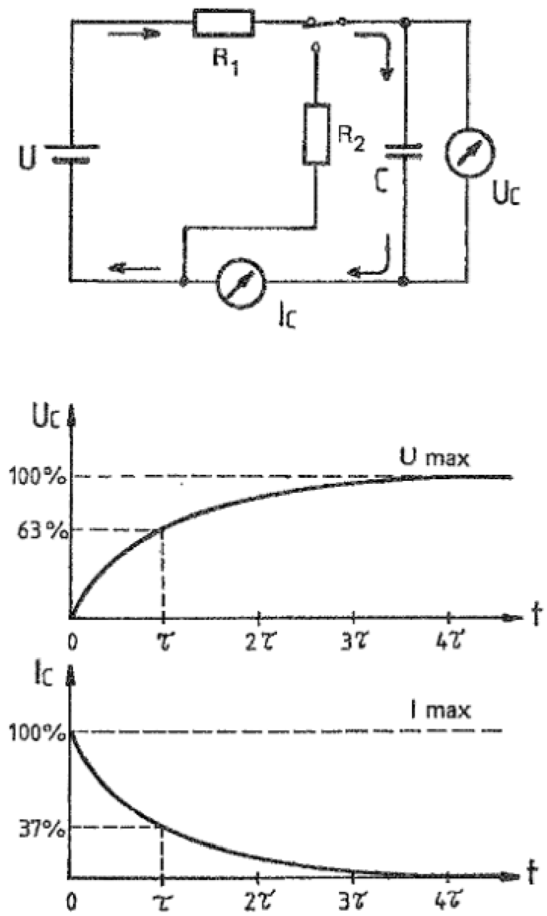


Figure 3.8: Charging a capacitor = R · Cτ [time constant in sec]C [F] R [Ω]

$$\tau = R \cdot C$$

$$\tau \ [\text{tidskonstant i sek}]$$

$$C \ [\text{F}] \quad R \ [\Omega]$$

After the time t = 1τ from the moment of connection the voltage across the capacitor has increased from zero to 63% of the maximum value. After the time t = 5τ the capacitor is charged to 99%. The current from the capacitor decreases exponentially during the charging

$$i_c = I_{max} \cdot e^{-t/\tau}$$

ic = Imax · e−t/τ

where ic is the current from the capacitor after a given switch-on time and Imax is the initial current. After the time t = 1τ from the moment of switching on, the current to the capacitor has decreased to 37% of the maximum value. After the time t = 5τ, 1% of the maximum value of the discharge current remains.

3.1.9.2 Discharge Figure

3.9 shows how a capacitor C is discharged through the resistor R2. The voltage across the capacitor decreases exponentially during the discharge.

$$u_c = U_{max} \cdot (1 - e^{-t/\tau})$$

uc = Umax · (1-e−t/τ)

Figure 3.9: Discharging a capacitor The current from the capacitor decreases exponentially during the discharge. The direction of the current is the opposite to that during charging.

ic = −Imax · e−t/τ

After the time t = 1τ, the capacitor is discharged so that 37% of Imax and Umax remain. After the time t = 5τ, the capacitor is discharged so that less than 1% of Imax and Umax respectively remains. Example of calculation of the time constant:

1. C = 10 µF R = 1 kΩ τ = ?τ = R · C= 1 · 103 · 10 · 10−6= 10 · 10−3 i.e. every 1/100 second.2. C = 1000 µF R = 1 kΩ τ = ?τ = R · C= 1 · 103 · 103 · 10−6= 1 second
Figure 3.10: Connecting an inductor

3.1.10 Connecting and disconnecting an inductor

3.1.10.1 Connection

Figure 3.10 shows the connection of an inductor. An inductor L in series with a resistance R is connected across a DC voltage U. The voltage across the inductor decreases from Umax to 0. The current through the inductor increases exponentially after the connection from 0 to

ImaxiL = Imax · (1 − e−t/τ)

$$i_L = I_{max} \cdot (1 - e^{-t/\tau})$$

where iL is the current after a given switch-on time, Imax is the final current after at least t = 5τ , t is the switch-on time, and e is the base of the natural logarithm). = LRL [H] R [Ω] s [sec] τ [time constant]

$$\tau = \frac{L}{R}$$

$$L \text{ [H]} \quad R \text{ [}\Omega\text{]} \quad s \text{ [sek]} \quad \tau \text{ [tidskonstant]}$$

After a time of t = 1τ from the moment of switching on, the current through the inductor has increased from zero to 63% of Imax and the voltage across the inductor has decreased to 37% of the maximum value. 85

3.1.10.2 Disconnection

The voltage source is disconnected from the same inductor as above. A resistor is connected across the inductor. The energy in the inductor is dissipated through the resistor as a current with the opposite direction than at connection. The current is at the time of disconnection Imax = iL and then decreases exponentially

$$i_L = I_{max} \cdot e^{-t/\tau}$$

iL = Imax · e−t/τ

where iL is the current through the inductor after a given disconnection time, Imax is the current at the tripping instant, e is the base of the natural logarithm, and is the time after the tripping instant.

After a time of t = 1τ from the tripping instant, the current through the inductor has decreased to 37% of the maximum value.

Theoretically, the voltages and currents can never reach a zero or maximum value , but for practical use this is considered to occur after a time of at least 5τ .

All the energy stored in an inductor is in its magnetic field. When the current is interrupted or reduced, the energy immediately returns to the circuit.

In an inductor, there can thus be no residual energy, which, on the other hand, can be in a capacitor. During the time that the magnetic field in an inductor unwinds or builds up, a counter voltage is induced in it.

This voltage is higher than that present in the superconductor before the current is interrupted or changed and is proportional to the speed of the change. When a current circuit with an inductor is broken, it is common that at the moment of breaking, a spark or electric arc is formed over the contacts of the breaker. If the inductance is large and the circuit current is high, a large amount of energy is released in a very short time. It is therefore not uncommon for switch contacts to burn or melt.

In direct current circuits, sparks or arcing can be reduced or suppressed by connecting a capacitor in series with a resistor across the contact point. The capacitor captures part of the energy in the inductor and the resistor reduces the speed change.

3.1.11 Alternating current circuits HAREC a.3.1.1, a.3.1.2, a.3.1.33.1.11.1

Component properties for alternating current In radio technology, resonance circuits (also called oscillation circuits) are very often used.

Consisting of capacitors and inductors, which are connected in series or parallel to each other. When the natural frequency of the resonant circuit is set equal to the frequency of the signal supplied to the circuit, the circuit acquires special properties that are used in different ways.

To understand how "LC circuits" work, it is first described how the resistance, inductance and capacitance of the constituent components relate to each other, when they are combined and connected to an alternating current source.

Figure 3.11 shows the amplitude of voltage and current in a sinusoidal course and the effect that then develops. The time axis is graduated 0–360◦ per period.

Case a: The course with a resistor R. In a resistor, the current and voltage curves follow each other temporally, even when changing direction. When the curves are followed in that way, they are said to be in phase with each other. Power is transferred from the current source to the resistor. The power developed in the resistor is, at each time of the period, the product of the current and the voltage at that moment. Since the quantities voltage and current are either positive or negative at the same time, the product is always positive. This means that the power that develops pulsates twice per period between a zero and maximum value.

Case b: The course with an inductor L. In an inductor, the development of current and voltage is not simultaneous. When switched on, the voltage immediately rises to the maximum value, while the current rises more slowly and in the meantime builds up a magnetic field in the inductor and around the other conductors in the circuit.

The current is therefore delayed in relation to the voltage. Because the maximum and zero values of the curves occur at different points in time they are said to be out of phase or out of phase.

An alternating current through an ideal inductor is shifted by 90◦ after the voltage. The current reaches its peak value at time 90◦ of the period, when the voltage reaches zero. When the voltage decreases, the current drops and takes the energy in the magnetic field with it. Only at 180◦, when the voltage has reached the maximum value in the other direction, the current also changes direction and builds up a new magnetic field with the opposite polarity.

Power is transferred from the current source to the inductor when current and voltage have the same direction. Current and voltage have different directions, the inductor instead tries to "charge" the current source with energy from its force field.

Power oscillates between the current source and the inductor, whereby the power in one direction is the same as in the other direction. Seen over an entire period, these effects therefore cancel each other out. The consequence is that an ideal inductor, in contrast to a resistor, does not consume any active power. It is said that a reactance, here an inductor, works with reactive effect. In practice, the circuit also has a certain resistance. Therefore, the reactance's 90◦ phase-shifted current is combined with the resistance's 0◦ phase-shift current. The result is a current that is less than 90◦ out of phase and a certain active power is then consumed in the resistance.

Case c: The processes with a capacitor C. Current and voltage do not develop simultaneously in a capacitor either. After switching on, current charges the capacitor, that is, builds up an electric field with a certain potential (voltage). The voltage develops more slowly than the current - it becomes phase-shifted. The current to (and from) an ideal capacitor is phase-shifted 90◦ before the voltage. When the capacitor is connected to an alternating current source, the current reaches

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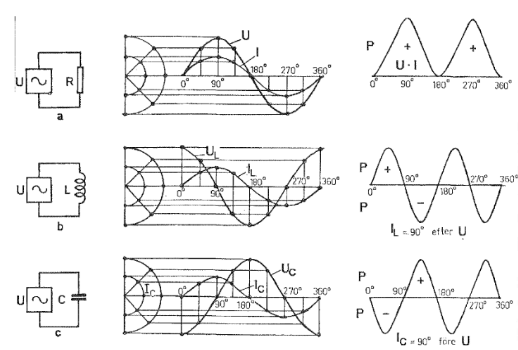

Bild 3.11: Faslägen och effekter i L C-kretsar

Figure 3.11: Phase positions and effects in the L C circuit peak value at the time 90◦ or 270◦ of the period. The voltage then passes the value zero in both cases. As the voltage decreases, the current drops and takes energy from the electric field.

After the current has passed zero at 180◦ or 0◦/360◦, it builds up a new electric field with the opposite polarity. As with an inductor, power is transferred from the current source to the capacitor when current and voltage Harsh direction. When current and voltage have different directions, the capacitor instead tries to "charge" the current source with energy.

Power oscillates between the current source and the capacitor, whereby the power in one direction is as great as in the other direction. Seen over an entire period, these effects therefore cancel each other out. The consequence is that an ideal capacitor, in contrast to a resistor, does not consume any active power. It is then said that a reactance, here a capacitor, works with reactive effect.

In practice, the circuit also has a certain resistance. Therefore, the reactance's 90◦ phase-shifted voltage is combined with the resistance's 0◦ phase-shifted current. The result is a voltage that is less than 90◦ out of phase and a certain active power is then consumed in the resistance. As can be seen from the picture, the variations in time become the reverse with a capacitor compared to an inductor.

3.1.12 ImpedanceHAREC a.3.1.3, a.3.2.2

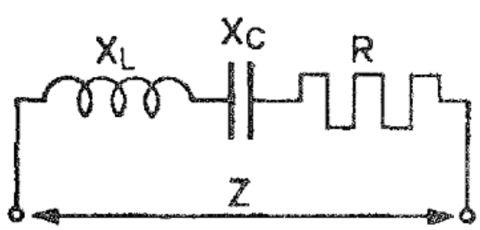

Bild 3.12: Seriekrets av L+C+R

Figure 3.12: Series circuit of L+C+R

Small glossary:

Impedance – hinder (lat. impedire).
Resistance – resist (lat. resistere). Part of the impedance, sometimes called ohmic resistance.
Reactance – react (lat. react). Part of the impedance, collective word for alternating current resistance.
Capacitance – to contain (lat. capax). Part of the reactance.
Inductance – introduce (lat. induce). Part of the reactance.

Until now, the quantities resistance, inductance and capacitance have been treated separately, but in practice they always occur together and are called impedance.

The resistance is basically unchanged by current or voltage changes. But when the current through a conductor or inductor, as well as the voltage across a capacitor, changes, a reactance is added that counteracts the changes.

The reactance can be capacitive or inductive from case to case and is included in the impedance.

If no reactance is present, the impedance is equal to the resistance.

Figure 3.12 shows an inductor, a capacitor and a resistor connected in series. When you want to calculate the resulting impedance in the circuit ("total alternating current resistance"), you must take into account that the voltages or currents of the components are not in phase with each other. After all, they don't work "in sync". Then adding the maximum values gives the wrong result. Instead, you look for the so-called resultant of the different vectors that correspond to current and voltage values. This can be done graphically or calculated.

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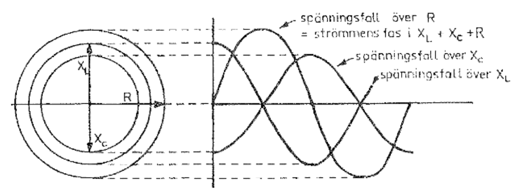


Bild 3.13: Spänningar i seriekrets L+C+R

Image 3.13: Voltages in series circuit L+C+R

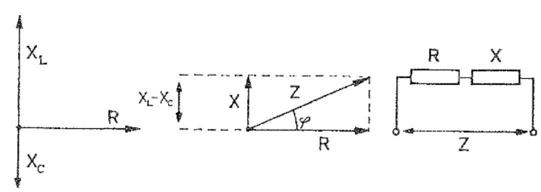


Image 3.14: The impedance and phase angle in series circuit L+C+R

In image 3.13, we know that the vectors in the system rotate counterclockwise with the angular velocity $\omega = 2\pi f$ where f is the frequency.

Since the vectors have the same frequency, the positions of the vectors are mutually the same. The instantaneous value of the respective vectors follows a sine curve. The voltage vector in the "inductive reactance" is 90◦ before the current and the voltage in the resistance. The voltage vector in the "capacitive reactance" is 90◦ behind the current and the voltage in the resistance. The vectors in these two reactances are thus 2 · 90 =180◦ apart, i.e. opposite. They are said to be in opposite phase.

Picture 3.14 shows the vectors for the components in picture 3.12 and how to graphically determine the impedance of these vectors.

Furthermore, you get the phase angle between the vector of the impedance and the resistance, the latter of which is the so-called directional phase for the entire series circuit. The resistance is drawn as a vector R, which is directed horizontally to the right. The length of the vector corresponds to the size of the resistance in ohms. The inductive reactance is drawn in a similar way with the vector XL vertically upwards. Finally, the capacitive reactance XC is drawn vertically downwards. One subtracts the counteracting reactive vectors XL and Xc from each other and places the result X on the vertical axis, upwards if XL is greater and downwards if Xc is greater.

One now lets the vectors X and R form sides in a right-angled rectangle. The length of the diagonal of the rectangle is the resulting impedance Z. The phase angle between impedance and resistance can also be read. Since the vector diagram forms a right triangle, the resulting voltage U in the circuit can be calculated using the Pythagorean theorem:

C2 = A2 + B2 or C = √A2 + B2

Applied to the above vector diagram can the theorem is written as U 2LCR = U 2R + (UL − UC)2 The terms are replaced with the following equations:

ULRC = I · Z
UR = I · R
UL = IXL = IωL
UC = IXC = I 1ωCI2Z2 =
I2R2 + (IωL − I 1ωC)2

After division by I2,
Z2 is obtained = R2 + (ωL − 1ωC)2 or
Z =√R2 + (ωL − 1ωC)2 or
Z = √R2 + (XL − XC)2

In a series circuit, the resulting reactance is negative (capacitive) if XC is greater than XL and positive (inductive) if XL is greater than XC.88

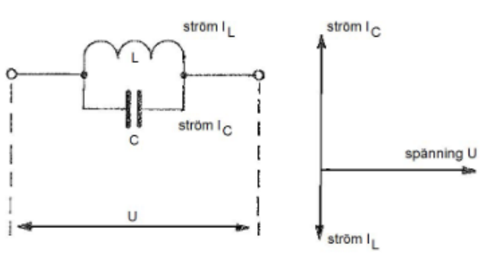


Figure 3.15: Parallel-connected LC circuit

3.1.13 Ohm's law at alternating current HAREC a.1.1.4

In formulas, the impedance is denoted by the letter Z and the reactance by the letter X.

In both cases, the unit is ohm [Ω]. With calculation of impedance, Ohm's law is not directly applicable, because the reactance in an inductor or capacitor behaves differently in time when the current or voltage changes than the resistance does.

If the impedance Z is inserted into Ohm's law, the following relationship is obtained, which is often called Ohm's law for alternating current

$$\begin{aligned} U_{eff} &= I_{eff} \cdot Z \quad \text{eller} \\ U_{eff} &= I_{eff} \cdot \sqrt{R^2 + X^2} \quad \text{eller} \\ U_{eff} &= I_{eff} \cdot \sqrt{R^2 + (X_L - X_C)^2} \quad \text{osv.} \end{aligned}$$

Ueff = Ieff · Z or
Ueff = Ieff · √R2 + X2 or
Ueff = Ieff · √R2 + (XL − XC)2 etc.

From what was stated earlier in this section, the conclusion can also be drawn that: apparent power

$$\text{skenbar effekt} = \sqrt{(\text{aktiv effekt})^2 + (\text{reaktiv effekt})^2}$$

= √(active effect)^2 + (reactive effect)^2

3.1.14 Parallel-connected LC circuits HAREC a.3.1.3, a.3.2.1

A parallel-connected LC circuit is in Figure 3.15 connected to the AC voltage U from a signal generator with adjustable frequency f. Two cases are studied.

Case 1: f = fres
The signal generator's frequency f is set equal to the LC circuit's resonant frequency fres. Then the circuit shows high impedance Z towards the generator. A strong current circulates in the LC circuit, but only a weak current flows in the line between the generator and the circuit. Compare with the model test in figure 3.17.

Case 2: f > fres or f < fres
The frequency f is set higher or lower than the circuit resonance frequency fres. The circuit then shows a low impedance Z towards the generator.

A weak current circulates in the LC circuit, while a stronger current flows in the line between the generator and the circuit. In practice, there is also a resistance (load) in parallel across the circuit and a resistance in series with the inductance. For the sake of simplicity, these resistances are ignored here.

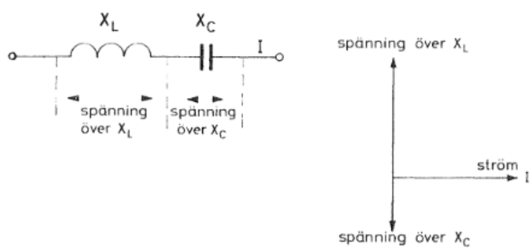


Figure 3.16: Series-connected LC circuit

In a parallel-connected LC circuit, the voltage across inductance and capacitance is the same.

The voltage vector U is therefore used as the so-called direct phase. The direct phase is drawn on the image to the right. The current IC through the capacitor is phase-shifted 90◦ before U and is drawn straight up (the vectors rotate counter-clockwise). The current IL through the inductor is phase-shifted by 90◦ after U and is drawn straight down. The resulting reactive current through the circuit is the difference between the currents IC and IL, which are opposite to each other.

The formula for parallel-connected resistances can also be used for parallel-connected reactances by applying the Pythagorean theorem

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$$

$$\left(\frac{1}{Z}\right)^2 = \left(\frac{1}{R}\right)^2 + \left(\frac{1}{X}\right)^2 \quad \text{eller}$$

$$\frac{1}{Z} = \sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X}\right)^2}$$

$$\frac{1}{Z} = \sqrt{\frac{1}{R^2} + \frac{1}{X^2}}$$

With R negligible, the total reactance can be calculated from the inductive reactance XL and the vector opposing capacitive reactance XC in the following way:

$$\frac{1}{X} = \frac{1}{X_L} - \frac{1}{X_C} = \frac{X_C - X_L}{X_C \cdot X_L} \quad \text{eller}$$

$$X = \frac{X_C \cdot X_L}{X_C - X_L}$$

a parallel-connected LC circuit, the resulting reactance is negative (capacitive) if XL is greater than XC and positive (inductive) if XL is less than XC .3.1.15 Series-connected LC circuits A series-connected LC circuit in figure 3.16 is connected to the AC voltage U from a signal generator with adjustable frequency f . Two cases are studied.

Case 1: f = fres The frequency f of the signal generator is set equal to the resonant frequency fres of the LC circuit. The impedance Z in a series circuit then shows a very low value with respect to the generator. A strong current flows in the line between generator and circuit.

Case 2: f < fres or f > fres The frequency f is set lower or higher than the circuit resonance frequency fres. Because the LC circuit then shows a high impedance Z towards the generator, only a weak current flows in the line between generator and circuit. In practice there is also a resistance in series with the inductance as well as one in parallel across the capacitance. For simplicity, these resistances are ignored here. The current I is the same throughout the circuit and the current vector I is therefore used as the directional phase. It is drawn in the picture to the right. If the series resistance R had been included, a voltage drop

UR would have been in the same direction as I (in phase with I). Voltage-a across the reactance XC lies 90◦ after I and is drawn straight down (the vectors rotate counterclockwise). The voltage across the reactance XL (the inductor) lies 90◦ before I and is drawn straight up.

3.1.16 Thomson's formulaHAREC a.3.2.4

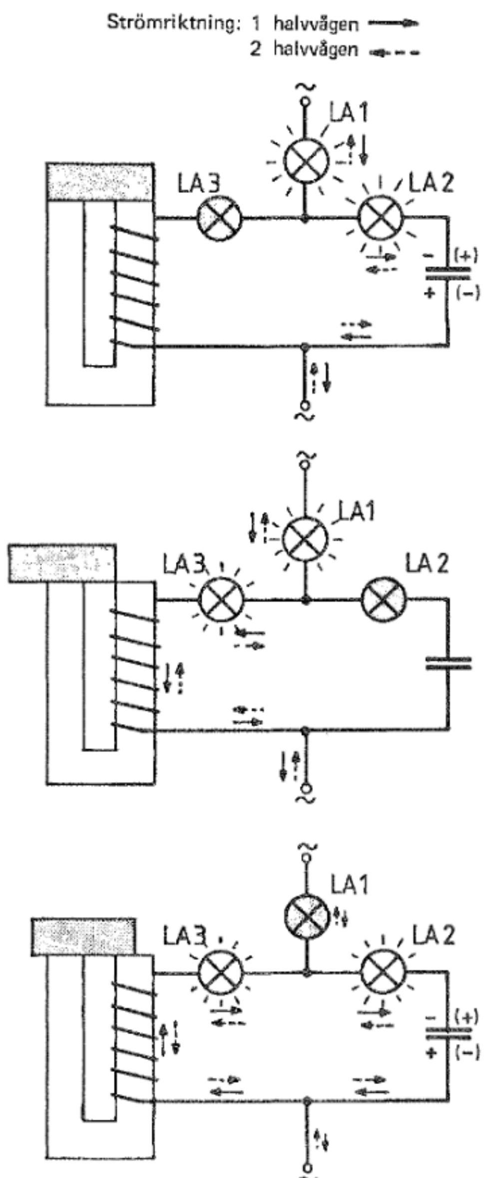


Figure 3.17 shows an oscillation circuit consisting of a capacitor and an inductor with a movable iron core. A change in the cross-section of the core changes the magnetic conductivity and thus the inductance, which is why the reactance XL also changes. With the device, the resonance frequency can thus be set so that it becomes higher than, equal to or lower than the frequency of the connected voltage. Three cases are examined:

1. XL > Xc LA1 and LA2 light up, a strong current flows through the capacitor,

2. XL < XC LA1 and LA3 light up, a strong current flows through the inductor,

$$\omega L 0 \frac{1}{\omega C}$$

3. XL = XC LA2 and LA3 light up, LA1 does not light up, a strong current flows in the circuit but not in the leads. When XL = XC the circuit is in resonance and Thomson's formula ωL0 1/ωC can be used to calculate the resonance frequency. The formula named after Willi-am Thomson (Lord Kelvin) describes the resonance case when the inductive and capacitive reactances in the circuit are equal and cancel each other out. What remains is the circuit resistance, which for the time being we consider negligible.

Picture 3.17: Oscillating circuit

Bild 3.17: Svängningskrets

Således $X_L = X_C$, där

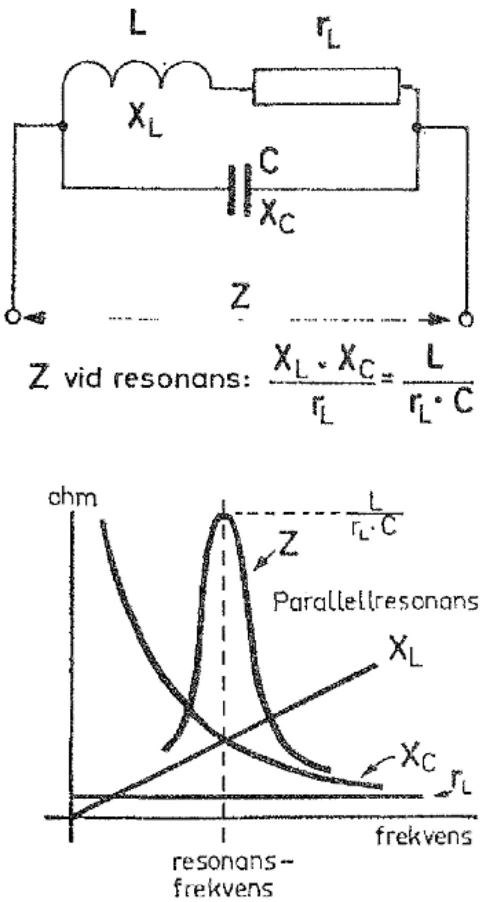
$$X_L = 2\pi f L \quad \text{och}$$

$$X_C = \frac{1}{2\pi f C} \quad \text{sätts in.}$$

$$2\pi f L = \frac{1}{2\pi f C} \quad 4\pi^2 f^2 LC = 1$$

$$f^2 = \frac{1}{4\pi^2 LC} \quad f = \frac{1}{2\pi\sqrt{LC}}$$

$$f\ [\mathrm{Hz}]\ L\ [\mathrm{H}]\ C\ [\mathrm{F}]$$



Picture 3.18: The resonance case in parallel circuit

$$
\begin{aligned}
f &= \frac{1}{2\pi\sqrt{100\cdot 10^{-9}\cdot 10\cdot 10^{-12}}}\\
&= \frac{1}{2\pi 10^{-9}}\\
&= \frac{10^9}{2\pi}\\
&\approx 159\,\mathrm{MHz}
\end{aligned}
$$

3.1.17 The impedance in a resonant circuit HAREC a.3.2.1, a.3.2.2, a.3.2.3, a.3.2.4

A simple representation is made of how impedance, re -reactance and resistance relate to each other when a resonant circuit is in resonance. As an example, the following circuit data is used: Inductance 200 μH, capacitance 200 pF, loss resistance 10 Ω.

3.1.17.1 The resonant case in a parallel circuit

The circuit consists of parallel connected reactances, XLand XC. In the case of resonance, these are equal in size and counteracting. Within the circuit, the resulting reactance is thus:

XC − XL = 0

Therefore, the same circuit exhibits an external reactance of:

$$X = \frac{X_C \cdot X_L}{X_C - X_L} = \frac{X_C \cdot X_L}{0} = \infty$$

X = XC · XLXC − XL= XC · XL0 = ∞

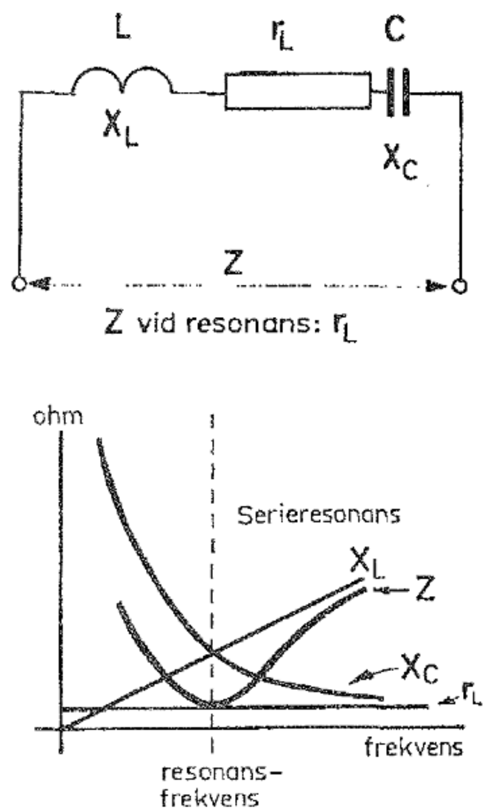


Figure 3.19: The resonant case in a series circuit In practice, there is also a resistance in the circuit, which

is why these extreme values do not occur . Inside a parallel circuit in resonance, a strong current circulates, which is only limited by the resistance of the circuit.

Figure 3.18 shows a parallel circuit where the inductor has the resistance rL and the capacitor is assumed to be lossless. Furthermore, it is assumed that the circuit is in resonance. At resonance, the term

XC − XL = 0

is replaced by rL in the formula

X = (XC · XL)/(XC − XL)

$$X = \frac{X_C \cdot X_L}{X_C - X_L}$$

provided that rL is negligible compared to XL.

In addition,

$$X_L = 2\pi f L \text{ och } X_C = \frac{1}{2\pi f C}$$

XL = 2πf L and XC = 1/(2πf C)

the so-called XL · XC = LC is inserted. The impedance of the parallel circuit at resonance can then be written

$$Z = \frac{X_C \cdot X_L}{r_L} = \frac{L}{r_L \cdot C}$$

Z = (XC · XL)/rL= L/(rL · C)

With the above circuit data, Z = 100 kΩ. From this it appears that the impedance in the parallel circuit is a function of the so-called L/C ratio and of the circuit's resistive losses.

3.1.17.2 The resonance drop in a series circuit

Figure 3.19 shows a series circuit is in resonance, so is

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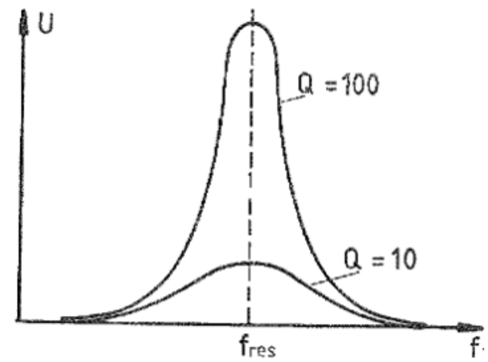

Bild 3.20: Q-värden i parallellkrets

Figure 3.20: Q-values in parallel circuit

$$X_C = X_L \qquad \text{dvs.} \quad \frac{1}{\omega C} = \omega L$$

eller

$$X_C - X_L = 0 \qquad \text{dvs.} \quad \frac{1}{\omega C} - \omega L = 0$$

XC = XL i.e. 1/ωC = ω
Or
XC − XL = 0 i.e. 1/ωC − ωL = 0

With the above circuit data, the resonance frequency becomes:

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \approx 796\ kHz$$

f0 = 12π√LC ≈ 796 kHz

At the resonance frequency, the reactance becomes 1000 Ω for both the inductance and the capacitance. Since the voltage drops of the reactances are opposite, they cancel each other out.

The impedance of the circuit in resonance becomes the resistance rL and the voltage drop across the circuit is determined solely by rL.

Assume that a voltage of 5 mV is generated in the antenna circuit. The current through it at resonance then becomes 5 mV10 Ω = 0.5 mA.

From the current, reactive voltages are formed, i.e. 0.5 mA · 1000 Ω = 500 mV both over inductance and capacitance (which cancel each other out) and 5 mV over resistance.

3.1. 18 The Q factor in a parallel circuit HAREC a.3.2.5

Figure 3.20 illustrates Q values for parallel circuits.

The quality factor Q (=Quality Factor) can be seen as the ability of a resonant circuit to store energy, the so-called ratio between the stored energy and the energy loss in the circuit.

The energy loss manifests itself as heat development.

$$Q = 2\pi \frac{\text{lagrad energi i kretsen}}{\text{energiförlusten per period}}$$

Q = 2π stored energy in the circuit /
energy loss per period

Energy losses occur in both the circuit's capacitor and inductor, but modern capacitors have such low losses that the inductor alone can be considered to determine the Q value, at least in the short-wave range.

An alternating voltage U1 is connected to a parallel circuit. In the resonant case, a voltage U2 then appears across the capacitor and the inductor. than U1. The higher the Q in the circuit, the greater the ratio between U2 and U1.

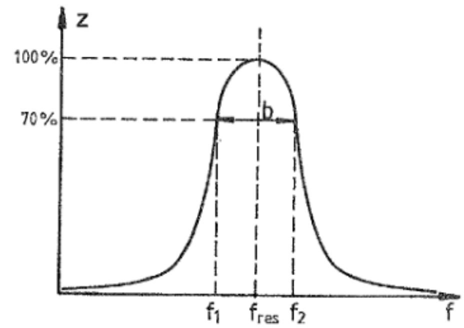

Figure 3.21: Bandwidth in a parallel circuit

In the shortwave range, it is common to have a Q in the order of 30–100. The higher Q is, the smaller the bandwidth. When the circuit is in resonance, the relationship Q = f res/b applies.

$$Q = \frac{f_{res}}{b}$$

The bandwidth increases (the tuning sharpness decreases) with increasing frequency due to the greater circuit losses.

3.1.19 Bandwidth HAREC a.3.2.6

Figure 3.21 shows with a curve which the impedance value circuit has at different frequencies. The maximum value of the impedance is at the frequency fres and decreases at frequencies that are higher or lower.

At frequencies f1 and f2, the impedance value is, for example, 70% of the maximum value. The bandwidth b means the difference between the impedance values in such a frequency pair, i.e.

b = f2 − f1.

3.2 Filter HAREC a.3.2, a.3.2.9

Frequency filters, or more generally filters, are used in radio technology for many different purposes, for example to:

• eliminate interfering signals
• increase the tuning sharpness (selectivity) in receivers and transmitters
• emphasize or attenuate a sideband in an AM signal and more.

The frequency response is generally presented as a curve with the amplitude of the transmitted sine signal as a function of the frequency.

Depending on the frequency response, the filters are divided into different types, the most common of which are presented here. Depending on the technical design, there are so-called passive filters which use external energy for their function, and partly active filters which are in principle

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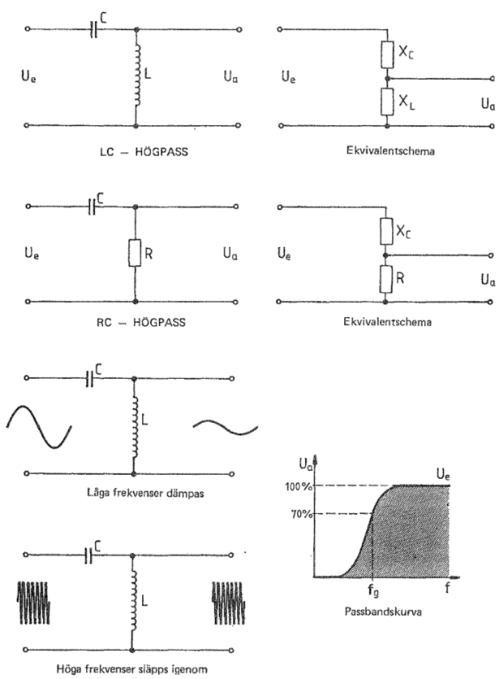

Image 3.22: High-pass filter

amplifiers that also use passive circuits. Passive filters are presented here for the sake of simplicity. A distinction is also made between analog filters and digital filters. Here we first describe some different types of classic analog filters.

3.2.1 High-pass filter (HP) HAREC a.3.2.8b, a.3.2.9

A high-pass filter (eng. highpass filter (HP), picture 3.22) lets signals with high frequencies through and attenuates those with low frequencies.

Example A frequency-dependent voltage divider such as LC high-pass filter.

At low frequencies, XC is large and XL is small. Over XL then a small voltage drop occurs - a low output voltage Ua. The result is that low frequencies are attenuated. At high frequencies, XC is small and XL is large. A large voltage drop then occurs across XL - a high output voltage Ua. The result is that high frequencies are let through. XL can be replaced by a resistor R, but then the passband curve is not as steep.

Cutoff frequency

The cutoff frequency fg depends on the capacitance C, the inductance L and the resistance R.

LC high-pass

fg = 1/2π√LC

fg [Hz] L [H] C [F]

$$f_g = \frac{1}{2\pi\sqrt{LC}}$$

$$f_g \text{ [Hz]} \quad L \text{ [H]} \quad C \text{ [F]}$$

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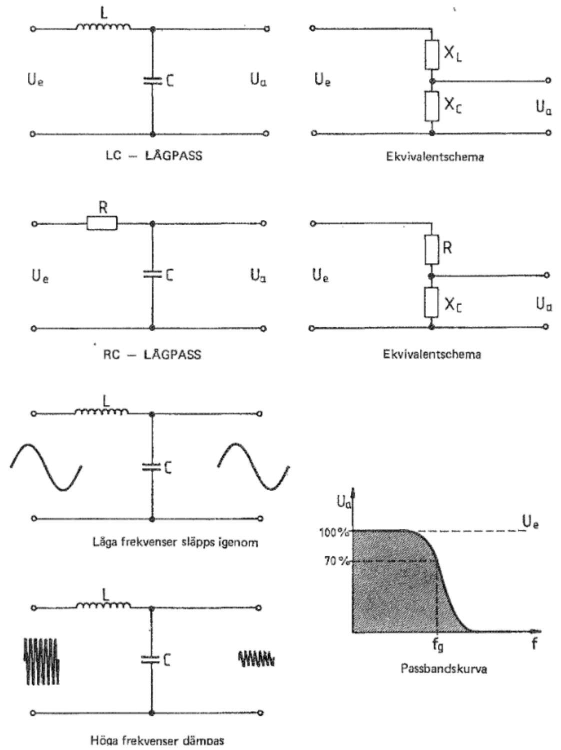

Image 3.23: Lowpass filter

RC- highpass

fg = 1/2πRC

fg [Hz] R [Ω] C [F]

$$f_g = \frac{1}{2\pi RC}$$

$$f_g \ [\mathrm{Hz}] \quad R \ [\Omega] \quad C \ [\mathrm{F}]$$

Calculation example

1. L = 4 H C = 1 μF fg = ?
fg = 1/2π√4 · 10−6 = 5002π = 79.6 Hz

2. R = 1 kΩ C = 10 nF fg = ?
fg = 1/2π · 1 · 103 · 10 · 10−9 = 1052π = 15.9 kHz

3.2.2 Low-pass filter (LP)HAREC a.3.2.8a, a.3.2.9

About inductor and capacitor respectively resistor and capacitor in a high pass filter change places, as in picture 3.23, so you get an LC low pass filter or an RC low pass filter instead. A low pass filter (eng. low pass filter (LP)) lets through signals with low frequencies and attenuates them with high frequencies.

Example: A frequency-dependent voltage divider such as LC low-pass filter.

At low frequencies, XC is large and XL is small. Over XL then a small voltage drop occurs - a high output voltage Ua.

The result is that low frequencies are let through. At high frequencies, XC is small and XL is large. A large voltage drop then occurs over XL - en

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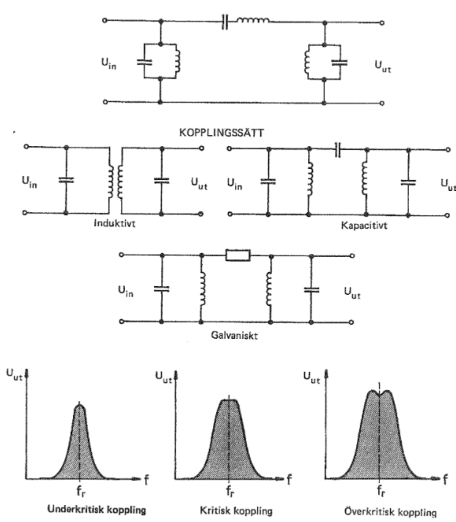


Picture 3.24: Bandpass filter

low output voltage Ua. The result is that high frequencies are attenuated. Cut-off frequency The same formulas are used when calculating the cut-off frequency in both low-pass and high-pass filters, thus

LC-low-pass

$$f_g = \frac{1}{2\pi\sqrt{LC}}$$

$$f_g \ [\mathrm{Hz}] \quad L \ [\mathrm{H}] \quad C \ [\mathrm{F}]$$

fg = 1/(2π√LC)

fg [Hz] L [H] C [F]

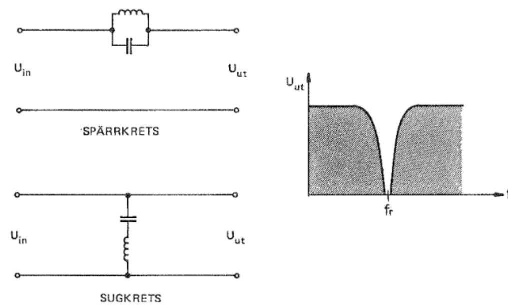
RC-low-pass

$$f_g = \frac{1}{2\pi RC}$$

$$f_g \ [\mathrm{Hz}] \quad R \ [\Omega] \quad C \ [\mathrm{F}]$$

fg = 1/(2πRC)

fg [Hz] R [Ω] C [F]

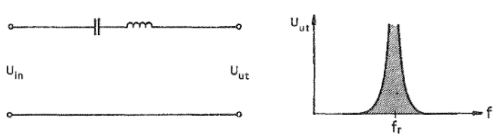


Picture 3.27: Block filter (2 types)

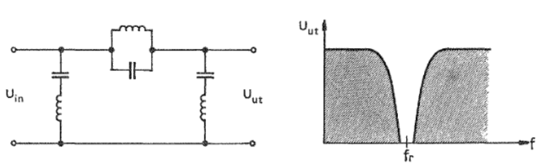
3.2.3 Bandpass filter (BP)HAREC a.3.2.7, a.3.2.8c, a.3.2.9

A bandpass filter (eng. bandpass filter) lets through signals only within a certain frequency range, while signals outside this frequency range are attenuated. In the simplest case, the bandpass filter consists of two resonant circuits of the LC type, which are tuned to adjacent frequencies. The circuits are connected inductively, capacitively or galvanically as illustrated in picture 3.24.

Depending on the degree of coupling or damping, a distinction is made between subcritical coupling (loose coupling), critical coupling and supercritical coupling (tight coupling). Figure 3.24 shows how the pass band is affected, among other things, by the degree of coupling. Loose coupling small bandwidth. Critical link – greater bandwidth. Fixed connection - high bandwidth.



Picture 3.25: Pass filter



Picture 3.26: Band-stop filter

3.2.4 Pass filter HAREC a.3.2.9

The pass circuit or pass filter is tuned to a certain frequency and offers a very low impedance as illustrated in picture 3.25. The pass circuit is connected in series with the signal path and allows signals with frequencies within the filter's passband to pass.

3.2.5 Band-stop filter HAREC a.3.2.8d, a.3.2.9

If the series and parallel circuits in a band-pass filter switch places, you get a band-stop filter as illustrated in figure 3.26 instead. Such a filter blocks signals within a certain frequency range, but lets through signals outside this range.

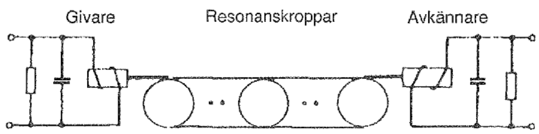
3.2.6 Blocking filters

3.2.6.1 Blocking circuit

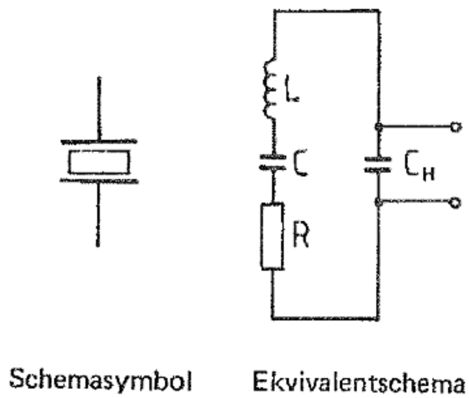
The blocking circuit is tuned to a certain frequency and offers a very high impedance. The blocking circuit is connected in series with the signal path and blocks a signal with the same frequency as the resonance frequency, as illustrated in picture 3.27.

3.2.6.2 Suction circuit

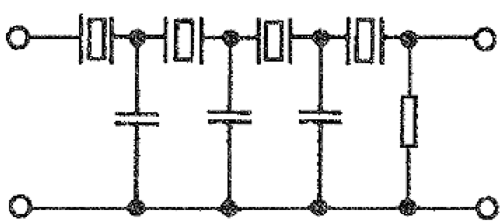
The suction circuit is tuned to a certain frequency and offers a very low impedance. The suction circuit is connected in parallel with the signal path and short-circuits (sucks out) a signal with the same frequency as the resonance frequency, as illustrated in picture 3.27.96



Picture 3.28: Mechanical filter



Picture 3.29: Quartz crystal



Picture 3.30: Band filter with quartz crystals

3.2.7 Quartz crystal HAREC a.3.2.11

A quartz crystal (eng. quartz crystal or crystal), actually a ground disc of quartz, can function as an electromechanical oscillating body (resonator), the properties of which are similar to those of an LC circuit.

This is illustrated in picture 3.29. The low internal resistance means that the Q-value in a quartz crystal is better than 10000. In comparison, the Q-value in an LC circuit is usually worse than 1000. Many modern quartz crystals can show an unloaded Q-value of 100000.

3. 2.8 Band filter with quartz crystals

Figure 3.30 shows how quartz crystals can be combined into filters, often referred to as crystal filters, with the desired bandwidth.

There are also designs with ceramic resonators (eng. ceramic resonators). The resonators are each tuned to their specific frequency and the entire complex thus contributes to forming passbands or other properties in the same way as with interconnected LC circuits.

3.2.9 Mechanical filters

With an electromechanical sensor, you make a body (resonator) oscillate at its resonant frequency. Even with an electromechanical sensor, you can sense the fluctuations and convert them back into electrical signals. Figure 3.28 illustrates such an arrangement. The entire device functions as an electromechanical resonator (eng. mechanical resonator), whose properties are similar to those in an LC circuit. The resonators can be combined into filter complexes with the desired bandwidth, where the resonators are each tuned to their specific frequency . The whole complex thus contributes to forming a passband in the same way as with interconnected LC circuits. Depending on the application, there are different frequency modes in the range 60–600 kHz.

Mechanical filters were mostly used in the past as intermediate frequency filters in high-quality radio equipment, but have now largely been replaced by bandpass filters with quartz crystals where the working range can be significantly higher in frequency.

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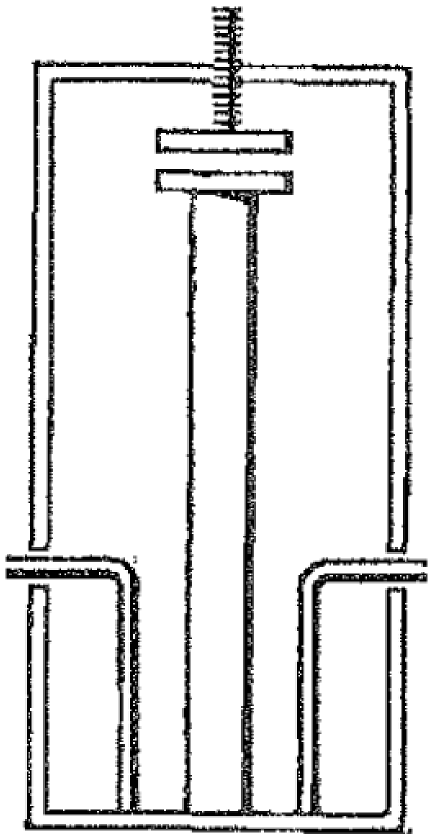

Figure 3.31: Cavity filter

3.2.10 Cavity filter

Resonant circuit dimensions decrease with increasing frequency. At very high frequency, the inductor speed in an LC circuit can be reduced to a single turn, while the capacitance within this single turn can be enough for the desired resonant frequency. Such a resonant circuit can, among other things, have the form of a conductor in the middle of an electrically conductive cavity, such as is illustrated in picture 3.31.

The length of the conductor together with the inside of the cavity forms the inductor. Between the conductor and the inside of the cavity there is a capacitance, which can be supplemented/adjusted with an extra capacitor. Incoming and outgoing signals are connected to the center conductor of the filter via induction loops, capacitors or directly galvanically. Cavity filters (eng. cavity filters) can be connected together to form, for example, band filters or frequency dividers. Cavity filters are often used on transmitters because, with their low losses, they can handle large effectively and achieve deep extinctions. These properties make them extremely suitable as duplex filters for repeaters.

3.2.11 Helix filter

When a compact cavity filter is needed, the reactance in the center conductor can be increased both inductively and capacitively by designing it as a spiral (helix). This, however, comes at the expense of Q- the value. Several cavity filters can be connected together to form, for example, band filters or barrier filters.

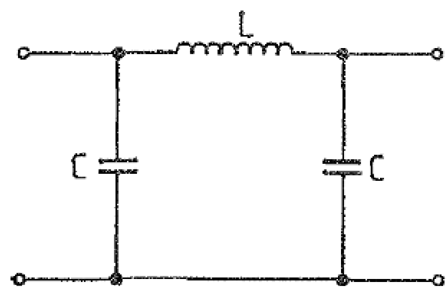

Figure 3.32: Pi filter

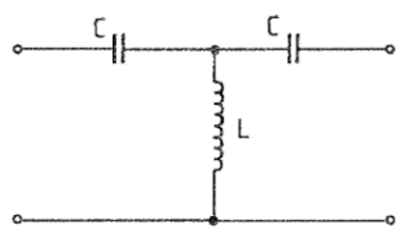

Figure 3.33: T filter (two variants)

3.2.12 Pi filter HAREC a.3.2.10a

To transmit HF signals with the best efficiency, it is important with good impedance matching between the different circuits. If the connection impedance is the same in both circuits, no extra measures are needed. If, on the other hand, the impedances are different, correction networks (filters) are needed. Often the network is Pi-format as shown in figure 3.32 and consists of inductances and capacitances. A Pi-format network can be said to consist of two L-shaped networks facing each other, where the serial partis common (in the picture an inductor).

3.2.13 T-filter HAREC a.3.2.10b

A network can also be T-shaped, as picture 3.33 shows, and consist of inductances and capacitances. Such a net can be said to consist of two L-shaped nets placed "back to back". Then the parallel part is common. The picture shows two options.

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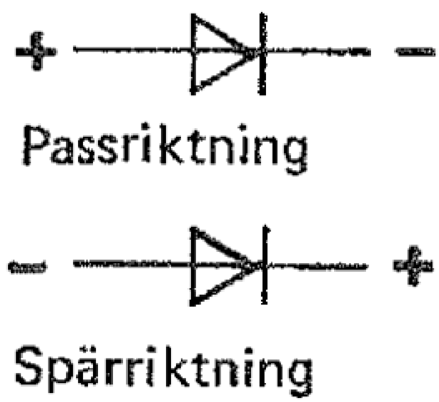

Picture 3.34: Semiconductor diodes When the parallel part is capacitive, the main character becomes a low-pass filter. When the parallel part is inductive instead, the main character becomes a high-pass filter. A Pi or T filter can act as

- resonant circuit
- impedance transformer (matching)
- neutralization of reactance

3.2.14 Non-ideal components HAREC a.3.2.12

In reality, all analog components are also affected by unwanted properties, also called parasitic properties. A resistor does not only exhibit a strictly resistive property, but for higher frequencies a parasitic series-connected inductance will also come to mind. A capacitor does not have perfect isolation. Through the parasitic resistance connected in parallel with the capacitor plates, a leakage current flows, which will discharge the capacitor. An inductor is not perfectly lossless, but it has a parasitic series resistance. For capacitors and inductors, the resistance will affect their Q value. A high Q value means that you have low loss. The losses will remind themselves when building circuits with these components.

For example, an LC circuit will in practice always be an LCR circuit, where the losses in the coil and capacitor give a loss in the circuit and limit how high the Q value can be achieved. When a resonator is loaded, the loss increases further and thus the Q value drops .

3.2.15 Digital filters HAREC a.3.2.13

The trend is towards more and more signal processing taking place digitally. Digital filters can be used by first converting the signal to digital form and then converting the filtering back to analog form. Digital filters have many advantages. You can construct complicated and sharp filters that retain their properties over time, where classic analogs may need to be tuned both individually during manufacture and over time to maintain their properties. For more on digital filters see 1.13 and 3.10.1.

3.3 Power supply HAREC a.3.3

Den electrical energy, which is needed for electronic equipment, is obtained from the public electricity grid, a battery or an accumulator. Some battery types can be recharged and are then called accumulators. Batteries and accumulators emit a nominal voltage that depends on the materials included and, of course, on the state of charge. Modern equipment for amateur radio is designed for 12 V direct current and is usually supplied from a mains-connected power unit. In this way, mobile radio equipment can also be supplied from the starting accumulator in the vehicle. Hand-held radio equipment is supplied from a built-in accumulator that is charged from a stationary charger. Older stationary radio equipment is almost always powered by mains-connected power units with one or more transformers and rectifiers. Alternatively, the secondary side of the transformer may be equipped with several windings for different voltages and current circuits. The general electricity grid in Sweden supplies AC voltage with a frequency of 50 Hz. The mains voltage for household purposes is now 400/230

V. Previously imported equipment in the market may have been designed for other mains voltage and protective grounding systems than what is now applied in Sweden. Caution with such equipment is recommended.

3.3.1 Half- and full-wave rectificationHAREC a.3.1.1g , a.3.3.1

Rectification (eng. rectification) of voltages and currents in a circuit is done with "electronic valves" which let current through only in the so-called pass direction and stops in the blocking direction as illustrated in picture 3.34. Such a current valve is called a diode and can be of the vacuum tube or semiconductor type. In modern designs, semiconductor diodes are exclusively used in rectifier connections.

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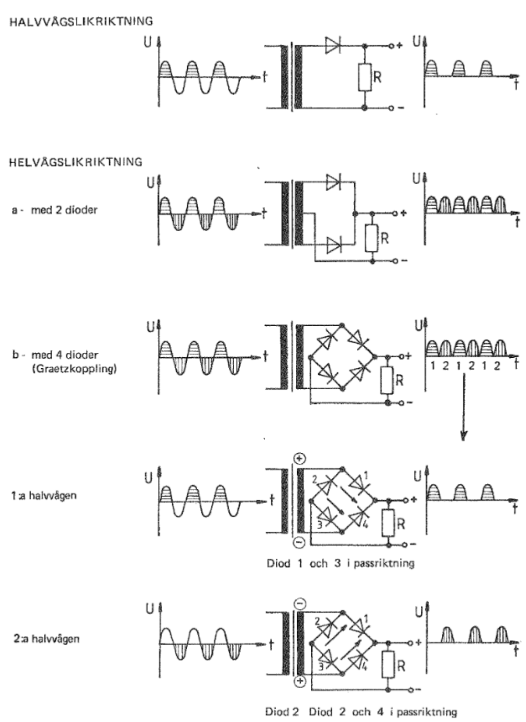

Image 3.35: Half- and full-wave rectification

3.3.1.1 Half-wave rectification

In half-wave rectification (eng. half wave rectification), only every other half-wave of an alternating voltage is allowed through. In the current circuit formed by the transformer's secondary winding, the diode and the load, current therefore only flows during every other half-cycle, as illustrated in figure 3.35.

3.3.1.2 Full-wave rectification

In the following connections with two and four diodes respectively, each half-wave of the transformer's alternating voltage is passed through so that all half waves get the same polarity. Current flows through the load in the same direction during each half period. The following ways of arranging full wave rectification (full wave rectification) are common:

- With two diodes and center tap on the secondary winding of the transformer. The one diode and one winding half allow current to pass through to the load during one half period. The second diode switches the winding half during the next half period. This is illustrated in figure 3.35, part figure.
- With four diodes (so-called Graetz bridge) and no center tap on the secondary winding of the transformer, diodes 1 and 3 let current through during one half-term. Diodes 2 and 4 pass current during the following half-period. This is illustrated in figure 3.35, subfigure b and the 1st and 2nd half-waves.

3.3.2 Smoothing circuitsHAREC a.3.3.2

After rectification, the alternating voltage has been converted into a pulsating direct voltage that can be "smoothed". After Rectifiers when a filter that performs smoothing is connected. The smoothing filter can for example consist of the charging capacitor CL, the inductance L and the smoothing capacitor CS as picture 3.36 illustrates.

In parallel above this capacitor, for the sake of electrical safety, discharge resistor R with high resistance is always connected. The safety resistor (eng. bleeder) must discharge the capacitors, when the power unit is unloaded and not connected to the power supply on the primary side.

The safety resistor must be of the wire-wound type and be able to withstand four times its own power consumption. unloaded state, the voltage across the charging capacitor is √2 times greater than the rms value of the transformer 's secondary voltage. When a transformer at idle has an effective value of 230 V over the secondary winding, the voltage across the safety resistor becomes 230 · √2 ≈ 325 V.

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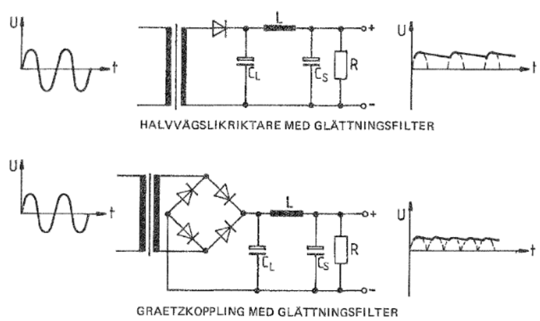
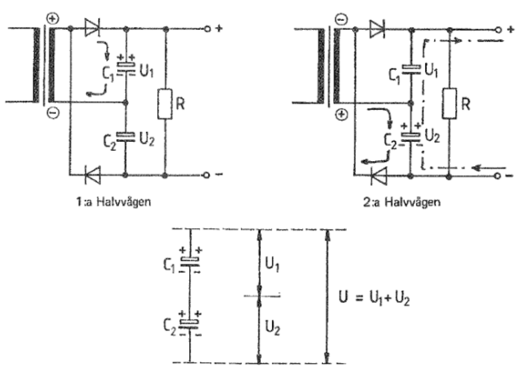


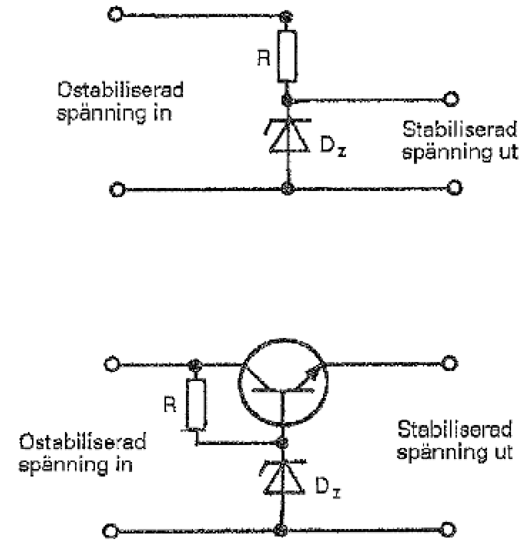
Picture 3.36: Smoothing of DC voltage



Picture 3.37: Rectifier connection with the voltage doubling

3.3.2.1 Voltage-increasing rectifier connections

When rectifying alternating voltages according to any of the above methods, a secondary voltage from the transformer of at least the same size as the desired the DC voltage. If a higher direct voltage is desired, for example the double, but with the same secondary voltage on the transformer, then a special rectifier connection can be used. Figure 3.37 shows a voltage doubling connection. During the 1st half-wave, capacitor C1 is charged. During the 2nd half-wave, capacitor C2 is charged up. The capacitors are connected in series and that one capacitor does not have time to discharge in the meantime



Picture 3.38: Voltage stabilization

if the second capacitor gets charged. The consequence is that the load sees the capacitors' voltages as connected in series and thus a doubling of the voltage drop has been obtained. There are also connections for multiple doubling of voltages, which, among other things, used to be used to generate the acceleration voltage for TV picture tubes.

3.3.3 Voltage stabilization HAREC a.3.3.3

The output voltage from a power unit is in many cases only allowed to vary between certain values, also the ohmic voltage and the current draw vary very. A common way to keep the voltage constant is for the post-smoothing filter to arrange a stabilization circuit, as shown in picture 3.38. The glow lamp and the zener diode have the property that the voltage drop across them is almost constant within a certain current range. Incandescent lamps work at higher voltages and are used in equipment with electron tubes.

Zener diodes work on the lower voltages used in today's electronics. The stabilization is provided so that, for example, the zener diode can be included as an active part in a voltage divider, which consists of a resistor in series with the load and the zener diode in parallel with it. The zener diode picks up the variations in the load current, whereby the voltage across the voltage divider's outlet becomes stabilized. At larger current outlets, the zener diode alone cannot absorb the entire effect that it regulates. Instead, the power is taken up by one or more transistors which are in turn regulated by the zener diode. In some cases, a regulated output current from the power unit is needed instead. Connections with zener diodes and transistors are also used for this purpose.

Ready-made stabilization circuits in the form of integrated circuits are nowadays more common than those made up of discrete components.

Examples are linear voltage regulators such as the 7805 for 5 V and the 7912 for −12 V.

3.3.4 Switch units HAREC a.3.3.4

Later forms of development are so-called switched units. In such devices, the voltage or current is regulated by switching. By changing the ratio between the on and off times, the desired average value can be created. The method provides high efficiency. The switching frequency is in the order of 20 kHz or higher. Such power units can, however, give rise to radio frequency interference, which is why effective suppression is needed. Power units that convert from mains voltage to direct voltage use the primary-switched principle.

In a primary-switched unit, the mains voltage is rectified and switched on the primary side by the transformer. Since the frequency is relatively high and does not risk saturating the transformer's core in the same way as with the mains frequency (50 Hz), the core does not need to be so large. On the secondary side, the voltage is then rectified and smoothing can take place with relatively small capacitors thanks to the high frequency. By feeding back the voltage to the primary side, the output voltage can be regulated in the primary switching instead of having to be stabilized on the secondary side. Losses in the stabilization circuit can thereby be avoided. A primary switched unit must have a mains filter to meet the EMC requirements. Another category of switched units is used for direct voltage conversion, so-called DC DC conversion.

Examples of such are called drop converters, which can be used to lower the voltage. Second converters can step up the voltage or change its polarity. These converters often work with frequencies of 200 kHz to 2 MHz. DC voltage converters do not always have galvanic isolation between input and output.

Nowadays there are also switched replacements with lower power loss than in the older linear regulators in the 78 and 79 series. The problem with these is that they can generate disturbances that need to be taken into account.

Switched power units and voltage stabilizers are now common because the power losses can be kept much lower than in old linear units. The switching, however, means that interference can leak out both at the input and output as well as through direct radiation from the unit itself. On some switched mains units, the switching frequency can be adjusted manually with a single knob. In this way, the disturbances can be moved to a frequency where their impact is reduced. Disturbance can appear in both differential and common mode, which must be taken into account when canceling.

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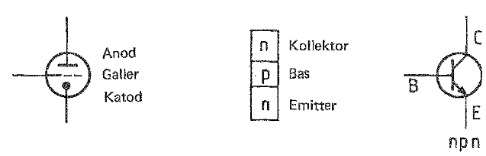

Figure 3.39: From electron tube to transistor

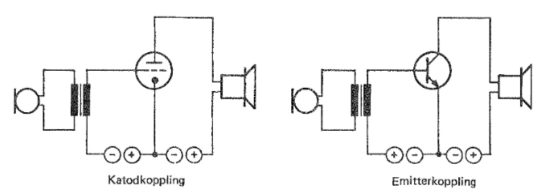

Figure 3.40: The principle of amplifiers with electron tubes and transistors respectively

3.4 Amplifier HAREC a.3.4

3.4.1 General

Electron tubes and transistors, see figure 3.39, are the active components (eng. active components) that are used in countless electronic circuits for generating signals, for amplification (eng. amplification) and mixing (eng. mixing) of signals, for multiplying signal frequencies etc. The transistor is presented in section 2.6 and the electron tube in section 2.7.At first there were only electron tubes. However, these have been almost completely replaced by transistors. However, electron tubes are still used to some extent, mainly as power amplifiers for transmitters. There is therefore reason to treat both electron tubes and transistors here.

3.4.2 Main property in amplifiers

3.4.2.1 LF and HF amplifiers HAREC a.3.4.1, a.3.4.2, a.3.4.3

Figure 3.40 shows the principle of amplifiers with both electron tubes and transistors.

LF amplifiers refer to amplifiers that work with signals in the lower frequency range, typically up to about 100 kHz.

LF amplifiers are very common in both receivers and transmitters. In addition to the active components (transistors, electron tubes), capacitors and resistors are the most important passive components.

HF amplifiers mean amplifiers that work with signals with higher frequencies than those in the LF range. HF amplifiers are also very common in both receivers and transmitters. They are used, for example, in the receivers' input and intermediate frequency stages, as well as in the transmitters' oscillators, drive stage and output stage.

In addition to components, which are also found in LF amplifiers, combinations of frequency-dependent components such as inductors and capacitors are used.

Amplification Gain refers here to the ratio between the amplitude of the outgoing and incoming signal, whereby the frequency response has an effect.

Frequency response

The frequency response specifies how the gain varies for different frequencies within the amplifier's bandwidth.

Bandwidth

The frequency range where the amplifier works with full data is called bandwidth (eng. band-width). The band limits are expressed as a lower and upper limit frequency, where the signal level deviates from a given value, usually by no more than 3 dB.

For LF amplifiers for amateur radio use, the bandwidth requirement is small; within a band of 300 Hz to 3 kHz, acceptable speech reproduction quality is achieved. The bandwidth is determined primarily by capacitors in the circuit intended for transmission and decoupling.

HF amplifiers are used for high-frequency signals, typically 100 kHz and above. There are so-called broadband amplifiers for a large frequency range, but also tuned amplifiers for narrow frequency bands.

3.4.3 Basic connections for amplifier stages HAREC a.2.6.4.1, a.2.6.4.2, a.2.6.4.3, a.2.6.4.4

In that previously it has already been shown that one of the poles of the input and the output of an amplifier is common.

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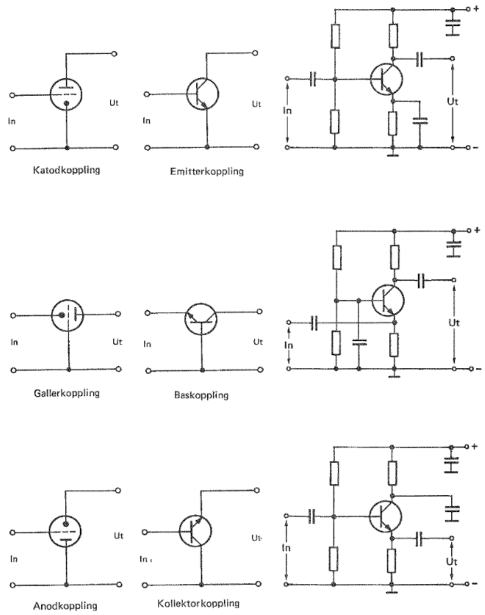

Image 3.41: Basic connections for electron tubes and NPN transistors

In the upper part of picture 3.41, the cathode of the tube amplifier is the common pole – hence the name cathode coupling.

Similarly, NPN transistor emitters are common - hence the name emitter coupling. Similarly, any other pole can be common. You then get a base connection or collector connection instead. Depending on the connection method, different properties are obtained.

Figure 3.41 shows three different basic connections for an electron tube (triode) and an NPN transistor, respectively. In practice, a basic connection can be recognized on which electrode is disconnected to zero potential via a capacitor. Emitter coupling is used for LF and HF when high gain is desired.

Since power gain is the product of voltage and current gain, a power gain between 200 and 50000 times is obtained. The disadvantage of this coupling is the sometimes low input impedance and the relatively low cut-off frequency.

Base coupling is used for HF amplifiers due to its high cut-off frequency and good isolation between input and output. Collector coupling is used when high input impedance and low output impedance are desired. However, this connection has no voltage amplification, but can be used for impedance conversion.

3.4.4 Stabilization of the operating point

In order for an amplifier to work in the intended way, the operating point, that is, the quiescent value of the operating current, must be set correctly.

This is done by placing a bias voltage across the controlling electrode in the electron tube or transistor in question. In a cathode-connected tube amplifier, this means that the control grid must be given a certain negative voltage in relation to the cathode.

This can be done, for example, with a separate voltage source or more commonly with a disconnected resistor between cathode and negative pole (ground). an emitter-coupled transistor amplifier means that the base must be given a certain positive voltage in relation to the emitter. This can be done, for example, with a separate voltage source or more commonly with a disconnected resistor between the emitter and the minus pole as well as a resistive voltage divider between the plus and minus poles.

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Table 3.1: Typical properties of the basic connections for NPN transistors

Property	Emitter connection	Base connection	Collector connection
Zin	average 1 kΩ	small 50 Ω	big 100 Ω
Zout	average 10 kΩ	big 100 kΩ	small 50 Ω
Amplification	-	-	-
Current	big 100x	<1 0, 9	Big 100x
Voltage	Big 100x	Big 100x	<1 0.99x
Power	Very big 10000x	Big 100x	Big 100x
Phase	phase 180◦	phase 0◦	phase 0◦

Egenskap	Emitterkoppling	Baskoppling	Kollektorkoppling
Z_{in}	medel 1 kΩ	liten 50 Ω	stor 100 kΩ
Z_{ut}	medel 10 kΩ	stor 100 kΩ	liten 50 Ω
Förstärkning			
Ström-	stor 100 ggr	<1 0,9 ggr	stor 100 ggr
Spänning-	stor 100 ggr	stor 100 ggr	<1 0,99 ggr
Effekt-	mycket stor 10000 ggr	stor 100 ggr	stor 100 ggr
Fasläge	motfas 180°	medfas 0°	medfas 0°

3.4.5 Class A, B and C amplifiers HAREC a.3.4.4

3.4.5.1 Operating point

The operating point for the amplifier is selected differently depending on the desired working method.

An inappropriately chosen operating point results in distortion of the output signal's shape in relation to the input signal's shape, so-called distortion.

Distortion also occurs with oversteer, that is, when the amplitude of the input signal is too large to be reproduced with unchanged form, even if the operating point is correctly selected. on the location of the working point is classified therefore amplifiers in the manner shown in the following diagram for transistors or electron tubes.

An emitter-grounded NPN transistor may be considered the most equivalent to the electron tube connection here below. The anode current I is then most closely matched by the collector current IC and the control grid voltage Ugi by the voltage UBE. The big difference is that the control grid voltage in these cases is always negative while the base/emitter voltage is positive. However, the relative position of the control voltage (the operating point) between different operating classes is the same.

3.4.5.2 Class A

Figure 3.42 illustrates class A, which is a mode of operation in linear LF and HF amplifier stages, for example in receivers and AM and SSB modulated transmitters. The quiescent value of the current in the main circuit, the so-called operating point, is placed in the middle of the straightest part of the control characteristic (I = 0.5 · Imax). This results in low distortion. The efficiency is up to 50%.

3.4.5.3 Class AB

Class AB is an acceptable linear mode of operation for AM and SSB modulation, but with a lower quiescent current. The operating point lies between that for class A and B.

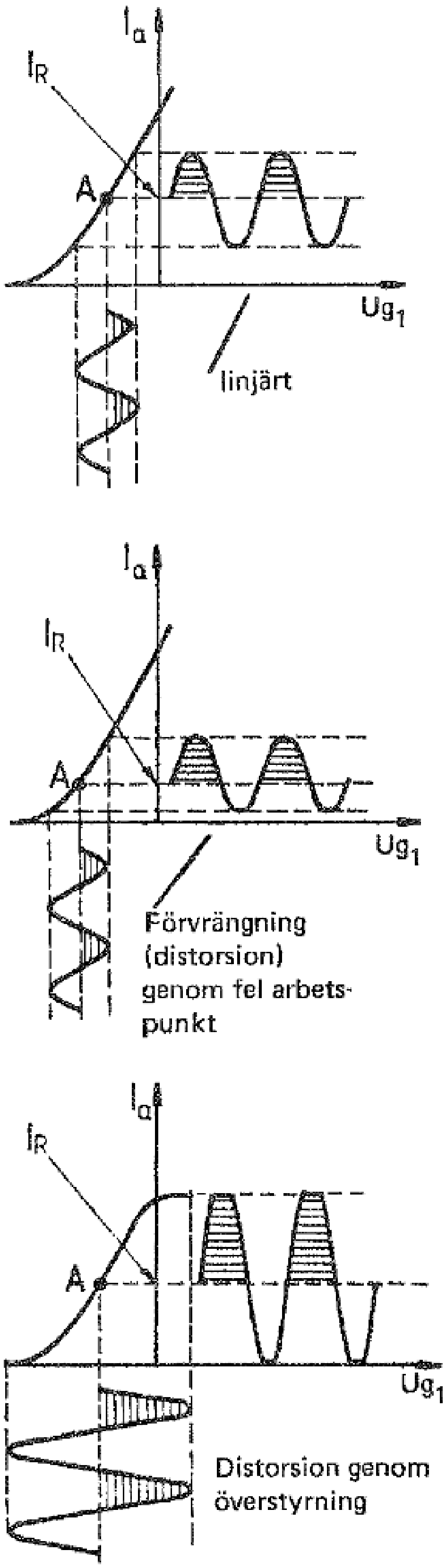

Figure 3.42: Amplifiers in class A

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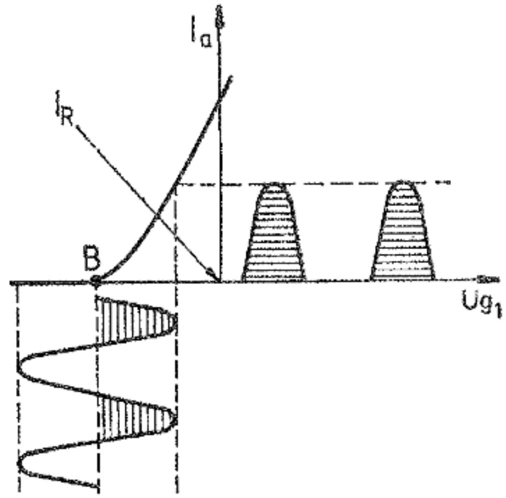

Figure 3.43: Amplifiers in class B

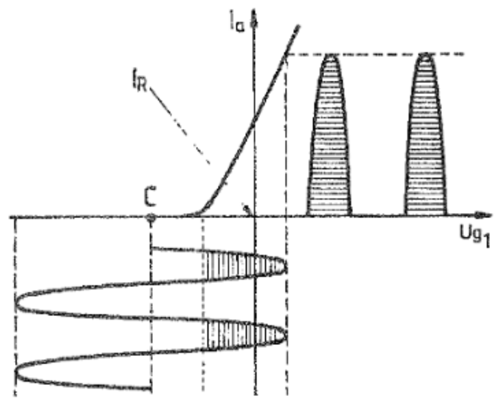

Figure 3.44: Amplifiers in classes C

A linear working method according to class A is certainly desirable for SSB, but the efficiency is lower. Class AB is a compromise with better efficiency without too much distortion.

3.4.5.4 Class B

Class B (picture 3.43) is a non-linear mode of operation with a low quiescent current in relation to Imax, that is to say that the operating point is at the bottom of the lower curved part of the control characteristic. The efficiency is up to 67%. Even so, class B is used in linear LF and HF amplifier stages, for example in SSB transmitters.

If class B were to be applied in an output stage with only a tube or a transistor, most of the output power would be lost in splatter, i.e. as distorted signals far to the side of the actual utility signal. One way to avoid that is to use a tuned output circuit with a high Q value. Linear amplification can also be obtained with two anti-clock coupled tubes or transistors in class B. The output circuit then does not need to be tuned for linearity reasons.

3.4.5.5 Class C

Figure 3.44 shows class C used in HF amplifier stages in FM and CW transmitters. The working method is strongly linear. The quiescent current is zero, that is, the operating point is on the negative part of the control characteristic. Only the peak of the one half-wave input signal is reproduced and in highly distorted form. The efficiency is up to 80%. A resonant circuit with a high Q value dampens harmonics and is needed as an output circuit, whereby amplitude distortion does not appear to be a problem with CW and FM. With the help of the resonance circuit, frequency multiplication can be performed with amplifiers in class C. (In the following three images, IR = anode quiescent current.)

3.4.6 Frequency multiplication

Frequency multiplication (eng. frequency multiplication) can be used to create a higher frequency than that emitted by the oscillator. Figure 3.45 shows how the oscillator is followed by one or more frequency-multiplying amplifier stages operating in class C.

At the output of a frequency-multiplying stage there must be a resonant circuit that is tuned to the desired frequency, i.e. to one of the harmonics of the input signal. This harmonic is amplified in subsequent amplifier stages, which can also be frequency multiplying. The higher the multiplication factor, the higher bias voltage is required for the resonant circuit in the output to oscillate unimpeded. With a high multiplication factor in a single stage, the signal is attenuated so much that a high gain is needed in subsequent stages. In practice, therefore, a chain of frequency-doubling and frequency-tripling steps is arranged. The total multiplication factor is the factors for each stage multiplied by each other. As an example, the picture shows the block diagram of a VHF transmitter with oscillator crystals in the 8 MHz range. As a calculation exercise, other crystal frequencies can be set to calculate the final transmission frequency. In frequency multiplying transmitters, the final stage can also work in class C, which is common in transmitters for telegraphy or FM telephony. To prevent the emission of charged harmonics that are generated in the amplifier chain, the output of the final stage is provided with a resonant circuit that is tuned to the transmission frequency.

The harmonic attenuation can be further improved with a subsequent low-pass filter. Harmonics for 144 MHz are 288 MHz, 432 MHz and so on. Frequency multiplication does not necessarily need to be done with a class C amplifier stage. Namely, a diode has nonlinear characteristics and thus harmonics are generated in the currents that pass through it. One of these harmonics can be filtered out and amplified. For example, there are frequency tripling stages built around a special type of capacitance diode – the varactor diode. Common frequency ranges for so-called varactor triplers are 144/432 MHz and 432/1296 MHz. Both the signal from a crystal oscillator and that from a VFO can be multiplied to a higher frequency.

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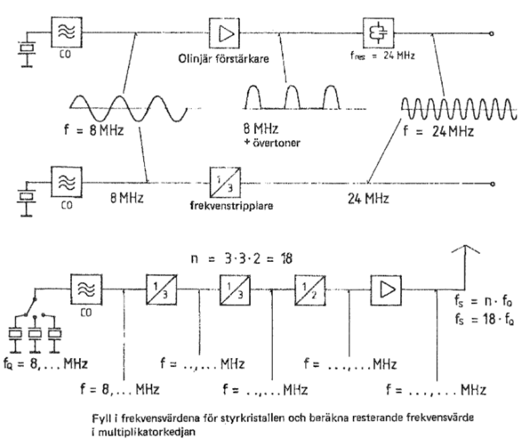

Figure 3.45: Frequency multiplication chain

In the past, VFOs in amateur radio transmitters usually covered the frequency range 3.5–3.8 MHz. With such a chosen VFO frequency, all the allocated frequency bands for amateur radio could be reached with frequency multiplication. The original amateur radio bands in the KV area are still harmonically related for this reason.

Thus:

3.5 · 2 = 7 MHz
3.5 · 2 · 2 = 14 MHz
3.5 · 2 · 3 = 21 MHz
3.5 · 2 · 2 · 2 = 28 MHz

In frequency multiplication, not only the oscillator frequency is multiplied, but also the variations in the. If, for example, the VFO frequency in the 3.5 MHz range changes by 50 Hz, the output frequency in the 28 MHz range changes by 2·2·2·50 = 400 Hz. All frequencies in the signal are multiplied in this way. Amplitude modulated telephony is therefore not transmitted through a frequency multiplication chain without the speech being distorted.

3.4.7 Transmitter output stage HAREC a.2.8.2

3.4.7.1 Output stage with a transistor

Transistor output stages for HF are usually built emitter-coupled due to the higher power gain. Modern LDMOS transistors can leave a kilowatt.

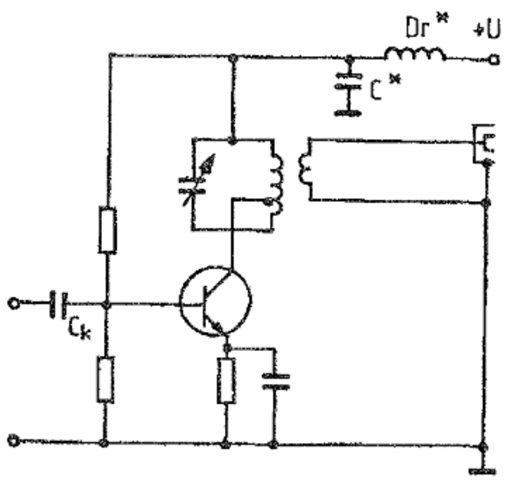

Figure 3.46 shows such an amplifier stage.

The collector load consists of a resonant circuit.
For Figure 3.46: Final stage with a transistor to adapt the collector impedance of the transistor to the impedance of the resonance circuit, the collector has been connected to the socket on the coil of the circuit.

The choke Dr and the capacitor C function as an HF-wise decoupling of the power supply. The output is extracted from the resonant circuit via a coupling winding with the same impedance as the load. For linear reproduction, operation in class A or possibly class AB is required.

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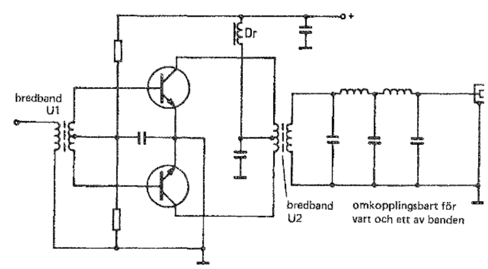

Figure 3.47: Counter-pulse-coupled output stage with transistors

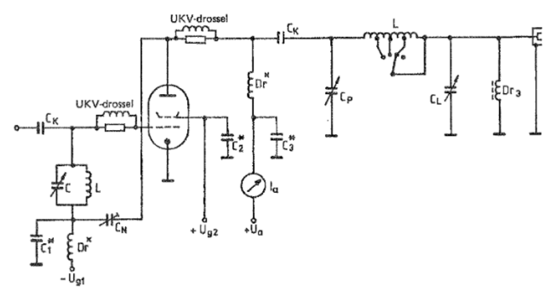

Figure 3.48: High-power output stage with a tetrode

3.4.7.2 Output stage with two transistors

Figure 3.47 shows a counter-pulse-coupled (eng. push-pull amplifier) amplifier stage in class B, which has efficiency while being satisfactorily linear for SSB in amateur radio. In an output stage with only one transistor, this would have to cope with four times as much loss power.

Due to the low impedance values in transistorized amplifier stages, transformers are used, which are not frequency selective and therefore do not dampen harmonics. However, with the counter-beat coupling, uneven harmonics are generated. For harmonic attenuation, fixed-tuned bandpass filters are used, often one per frequency band, between drive stage and output stage and between output stage and antenna. For accurate adaptation to the antenna, an antenna adapter - so-called matchbox - with a π-, T- or L-connected LC filter is needed. That an output stage is "broadband tuned" is thus a matter of definitions.

3.4.7.3 High power output stage with a tetrode

Figure 3.48 shows a power output stage for HF with an electron tube, a so-called tetrode, in cathode coupling. You can also use a triode or a pentode. With the LC circuit in the control grid circuit the desired signal frequency is filtered (selected) out of the signals from the previous step.

The chokes Dr block HF and the capacitors C1, C2 and C3 short-circuit (decouple) HF to ground, all to prevent HF from entering the power unit. HF amplifiers can cause unwanted self-oscillation.

The causes can be many, including poor decoupling of supply voltages, inductive and/or capacitive feedback in the circuits and more. Feedback paths both before and after the tube can form unintentional resonant circuits that generate self-oscillation, often at very high frequencies for example pel in the VHF range. Such so-called parasitic oscillations can be stopped/attenuated with UHF chokes (UHFDr) immediately next to the tube connections. One measure against self-oscillation in electron tubes is the counter-coupling path from anode to control grid via an adjustable so-called neutralization capacitor

Picture 3.38: Voltage stabilization if the second capacitor gets charged. The consequence is that the load sees the capacitors' voltages as connected in series and thus a doubling of the voltage drop has been obtained. There are also connections for multiple doubling of voltages, which, among other things, used to be used to generate the acceleration voltage for TV picture tubes.

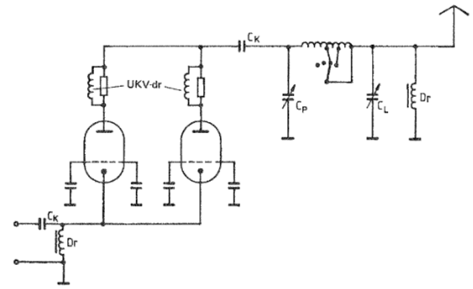

Figure 3.49: High power output stage with two triodesCN .

The output circuit of the final stage can be designed in different ways. The picture shows a now-common method, the so-called π-filter (pronounced pi-), which functions as

• a resonant circuit tuned to the transmission frequency
• a harmonic-suppressing low-pass filter
• adaptation between the output impedance of the tube and the antenna supply line.

3.4.8 High-power output stage with two grid-grounded triodes (electron tube)

Figure 3.49 shows a grid-grounded connection with two triodes. Grid-grounded connection means that the control grid of the electron tube is at HF zero potential while the control signal is fed into the cathode. The DC voltage between cathode and control grid is chosen so that the tube operating point is the intended one. Grid-grounded coupling is particularly suitable for output stages with high powers, but requires a higher control power than other couplings. In return, the control power is "transferred" to the output via the tube and is included in the output power. In a grid-grounded connection, the capacitance is low between cathode and anode, i.e. between input and output. Thus, the risk of self-oscillation is significantly less than in a cathode-grounded stage.

The output power can be increased by connecting two or more tubes in parallel, which should then have the same data as possible. The output is in direct proportion to the number of tubes. Several tubes connected in parallel, however, result in increased total tube capacitances and increased capacitances in the connection lines etc., which is disadvantageous at high frequencies. a single output tube for the entire effect is, however, more expensive than several small ones with a comparable effect. Receiving connection of two tubes (eng. "push-pull") instead of parallel connection has an advantage in higher amplification, but disadvantages in more complicated band switching of resonance circuits and more. In modern tube equipment output stages for amateur radio there is therefore only one output tube or several connected in parallel. The output circuit is usually a π-filter with manual or automatic tuning.

3.4.9 Output stage with electron tubes compared to transistorized output stages

An output stage with transistors is compact and shock-resistant and only uses low voltages. It is therefore particularly well suited for portable and mobile use. But transistors are sensitive to overload. Even extremely short-term overload or overvoltage can destroy them. Transistors are also sensitive to thermal overload. Especially with high effects in cramped spaces, good cooling is necessary, possibly with a fan. An electron tube final stage is not so shockproof, but is much more insensitive in other respects. One disadvantage is that extra power is needed for heating the tubes' cathodes and high anode voltages, which are dangerous if careless. Due to the need for several different voltages, the power supply for an electron tube final stage is also more complicated and extensive.109

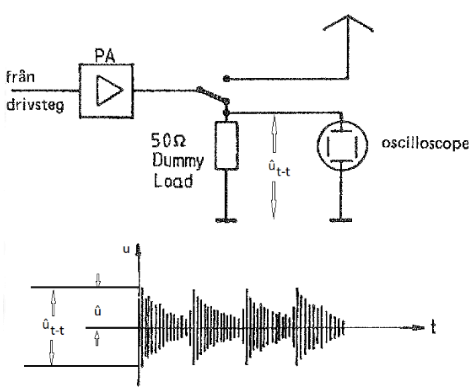

Figure 3.50: Determination of the PEP power

3.4.10 Peak value power PEP HAREC a.1.9.6

The output power from a transmitter can be measured over a dummy load). An artificial load is a resistor that can convert the entire power of the transmitter into heat. With an HF measuring probe and a detector diode or an HF voltmeter, you can measure the effective value of the voltage across the artificial load and calculate the output power with the formula Put = U 2RU = the effective value of the HF voltage and R = the resistance in the artificial load Calculation and measurement of PEP power The output power defined as Peak Envelope Power (PEP) [21 ,1.157] is "the average power fed into an antenna feeder line during the highest power value within a frequency cycle and measured during normal operation".PP EP =[ˆu√2]2 1R = ˆu22Rwhere ˆu is the instantaneous voltage at the largest modulation peak. Due to the nature of the SSB signal, one cannot measure the rms value of the output power from an SSB transmitter.

Figure 3.50 shows how the modulation causes an aaah to appear on an oscilloscope. The peak-to-peak value of the modulation voltage ˆut−t is conveniently measured with an oscilloscope when the output stage is connected to an artificial load. With the peak-to-peak value known, the following formulas can be used to calculate the peak value (amplitude) the peak value (amplitude) ˆu = ˆut−t2the effective value U = ˆu√2The power at the modulation peaks, so-called PeakEnvelope Power (PEP), can be calculated with the following formulas. PP EP = U 2R and PP EP = ˆu2t−t8R

3.4.11 Linearity control at SSB HAREC b.7.2.4

Figure 3.51 shows two-tone linearity control of SSB. The linearity of an SSB transmitter can be checked with an oscilloscope. The transmitter is then modulated with two-harmonic-free tones. The output stage should first be loaded with an artificial load up to the maximum permitted power. The result is then compared with the antenna as a load.

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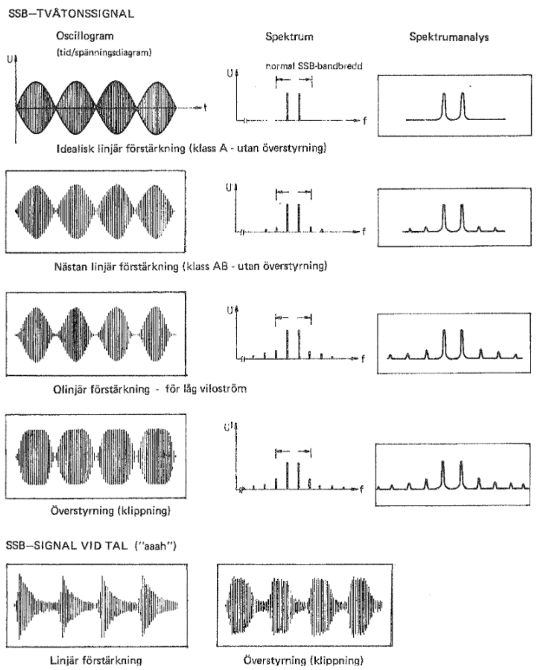

Figure 3.51: Linearity control at SSB

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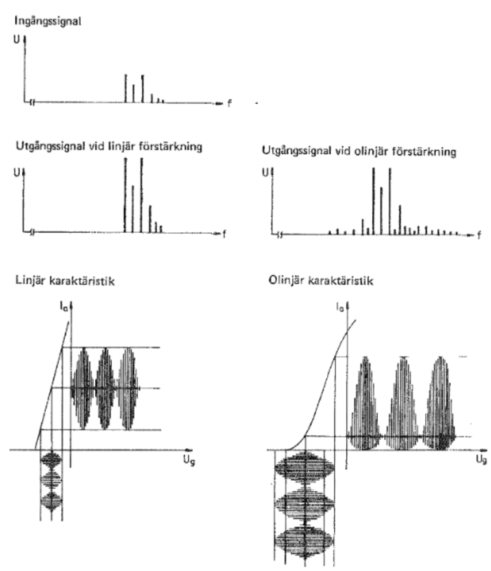

Figure 3.52: The importance of linearity

3.4.11.1 The importance of linearity in amplifier HAREC a.3.4.5

Figure 3.52 shows in more detail the effect of nonlinearity on the signal. The amplification should be done with good efficiency and the least possible distortion, so that the generated minimum of unwanted frequencies within the minimum possible bandwidth. Linear amplification means that it is the same over the current frequency range. The frequency response must therefore be as straight as possible. With increasing nonlinearity,Namely more and more unwanted frequencies. Mixture products of higher order occur in nonlinear amplification. Through distortion due to nonlinear amplification, mutual sum and difference frequencies of the modulating frequencies arise. Each such mixing product mixes additively and subtractively with the fundamental frequencies into additional mixing products of next higher order. These are • mixing products in the LF range and their harmonics, which are suppressed in subsequent HF circuit• the fundamental frequencies and their harmonic overtones, which all down to the 1st harmonic are strongly attenuated by the subsequent HF circuit• all sum and difference frequencies of the first-mentioned frequencies. In the area of useful frequencies these products are called intermodulation products and produces speech distortion. Outside the useful frequencies, the intermodulation frequencies are perceived as disturbances and are called splatter. Due to the small frequency distance to the useful signal, the intermodulation generated in the final stage cannot be filtered out afterwards. In linear operation, the overtones of the fundamental frequencies appear and intermodulation frequencies only weakly in and out of the transmission band and will hardly be perceived as interfering with other radio traffic. The weak harmonics will also be sufficiently attenuated in the π filter and any additional harmonic filters. 112

3.4.12 Output control of the output stage

If the linear output range of the output stage is exceeded, the amplitude of the input signal becomes too large. Then the amplitude of the output signal does not increase much more, but the peaks of the output signal are flattened (clipped). This means that the output stage is overdriven. In case of overdrive, signal distortions occur which lead to intermodulation, distorted speech, splatter interference and harmonics. The extra power gain achieved with overdrive is mostly used for signal distortion and does not benefit the useful signal. Over-control must therefore be avoided. The output power of the drive stage must not be so great that the final stage becomes over-controlled. An output stage with grounded cathode is fully equipped already at a drive power of a few watts. If the output power from the drive stage is greater than what is needed for full equipment of the output stage and the drive power cannot be regulated down, a damping set must be connected between the drive stage and the output stage. Such an attenuator may have to absorb a significant amount of power, from a common amateur radio transmitter with up to 100 watts PEP. function called ALC (Automatic Level Control), which continuously detects the effect of the drive power on the output stage. When the drive power becomes too high, a control voltage is generated in proportion to the gear ratio. ALC voltage is returned to the drive stage and regulates its output so that over-control of the output stage does not occur. In transistorized output stages, the ALC voltage is created by rectification of the output stage's output voltage. In the end-of-tube stage, the control grid starts to draw current when the control grid voltage becomes positive in the signal peaks, which is used to control the ALC voltage. When the ALC control kicks in, the oversteer is thus already a fact. Oversteer can take place both at LF and HF level. One cause of overmodulation is too large an amplitude of the modulating signal. This can be remedied, among other things, by setting the microphone amplifier and proper microphone handling.

3.5 Detectors – Demodulators HAREC a.3.5

3.5.1 General

The transmitter converts the information in low-frequency signals into high-frequency that can be radiated from the antenna. In the receiver, the information is recreated by demodulating the high-frequency signal. Usually, the signal processing in the receiver takes place in several stages, where the high-frequency radio signal is first mixed down to an intermediate frequency (MF) and then demodulated to a low-frequency signal (LF). But there are also direct mixed receivers, which mix down the radio signal directly to low frequency. In receivers specialized for one type of transmission, only one type of demodulator is used, while receivers for several types of transmission, AM, SSB/CW, FM et cetera have several demodulators. There are many types and names of demodulators, for example detector and discriminator. Some of them are described here.

3.5.2 AM detectors

3.5.2.1 The diode detector AM (A3E) HAREC a.3.5.1, a.3.5.2

Picture 3.53 shows a superheterodyne receiver where the last MF circuit is inductively coupled to the demodulation diode. The amplitude-modulated MF signal is shown as an amplitude/time diagram.

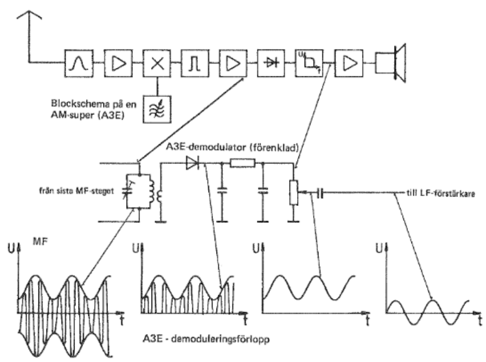

Figure 3.53: The diode detector 113

The diode cuts either the negative or positive half-waves, depending on how it is reversed-polarized. The LF signal is filtered out of the high-frequency pulses with an LF -low-pass filter. The LF signal is now superimposed on a DC voltage. During the speech breaks, only the carrier wave is transmitted and then the AM demodulator leaves only DC voltage, which is separated from the LF amplifier with a capacitor. The capacitor only lets through the LF signal, which is amplified. The diode detector follows the amplitude and is an example of an amplitude shape detector.

3.5.2.2 The product detector SSB (J3E) HAREC a.3.5.3

There are several methods to demodulate an SSB signal, such as the phasing method, the filter method and the so-called third method. The filter method is the most common nowadays and is described here and illustrated in figure 3.54.

An SSB signal with a suppressed carrier consists of only one sideband. The other sideband and carrier are suppressed in the transmitter. During the demodulation of the SSB signal, a signal is generated in the receiver as a replacement for the carrier wave that was suppressed in the transmitter.
The suppressed second sideband does not replace it.

In a receiver with direct mixing, the SSB signal is mixed with the VFO signal, whereby some of the mixing products fall out at the LF level.

In a superheterodyne receiver, on the other hand, the SSB signal is first mixed with a VFO signal and as a result an intermediate frequency MF is obtained. The MF converted signal is amplified, filtered and mixed with a local BFO signal in another mixer, called a product detector. Some mixing products-

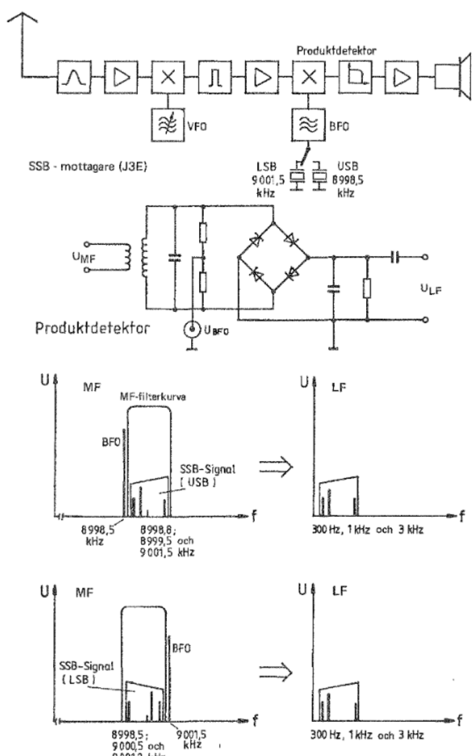

Figure 3.54: Product detector for AM (A3E) and CW (A1A)
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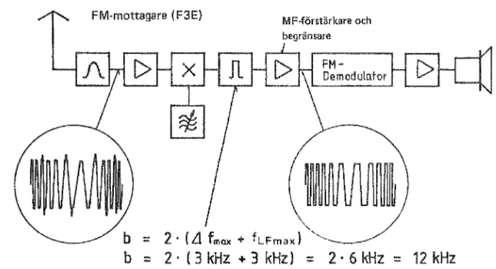

Figure 3.55: Amplitude limitation at the FM

receptions falls out at the LF level. A low-pass filter follows the post-detector to filter out the LF signals. Nowadays, the product detector usually consists of single-ring mixers, which, in a reverse process, can also be used for DSB modulation in a transmitter. The figure shows the demodulation of an SSB signal containing three LF tones.

3.5.2.3 CW/SSB detectors CW (A1A)

Even telegraphy signals, also called CW, are demodulated when the MF signals and the BFO signal are mixed in a product detector.

Unlike SSB, with CW a given difference between the MF and BFO frequencies is not necessary. The frequency difference only affects the frequency of the overlay tone, but not the readability of the CW message. Many modern receivers have a fixed BFO frequency for CW, which produces an 800 Hz tone at the correct frequency setting. Instead of the low-pass filter for SSB, a bandpass filter is sometimes used, which only lets through CW signals in the frequency range of 800 Hz – an ideal frequency for good readability of Morse code.

3.5.3 FM and PM detectors HAREC a.3.5.4, a.4.2.4 , a.4.3.5

In angular modulation, the information is transmitted solely through frequency or phase variations in the carrier wave. Amplitude variations that may occur before the demodulation are undesirable in this type of transmission.

For this reason, in FM receivers there is an amplitude limiter (eng. limiter) before the discriminator (see figure 3.55).

The frequency variations in the FM modulated signal are then converted by the detector into LF voltage corresponding to the transmitted number. The demodulation must take place with the receiver set in the middle of intended transmitter frequency. An aid for this is an indicator, which, when set correctly, shows the value zero. A positive or negative result indicates that the setting is too high or too low in frequency, as illustrated in picture 3.56. Such an indicator was found in early FM receivers. Now an Auto-matic Frequency Control (AFC) is used instead, which automatically tunes the receiver if the transmitter frequency is close enough.

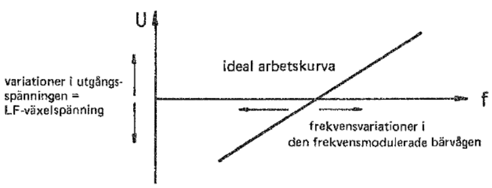

Figure 3.56: Ideal working line for discriminator
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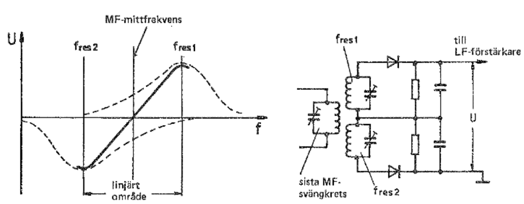

Figure 3.57: The slope detector

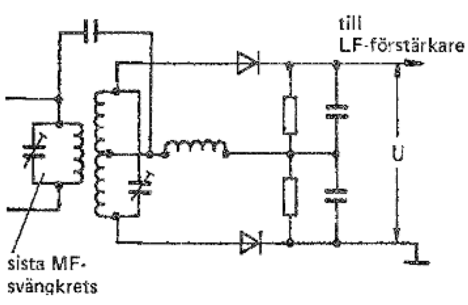

Figure 3.58: Foster-Seeley discriminator

3.5.3.1 The slope detector -

The discriminator FM(F3E) Figure 3.57 shows two resonant circuits which are inductively coupled to the last MF circuit. The resonance frequency for these two circuits is slightly higher and slightly lower than the intermediate frequency, respectively. The signal voltages if occurs above the resonant circuits are rectified and connected in series with each other with opposite polarity. When the two resonant circuits are fed with the same frequency, the DC voltages will offset each other. When the frequency deviates upwards in frequency, the circuit with the higher resonant frequency will oscillate more strongly than the other circuit and emit a higher rectified voltage. As the frequency deviates downward in frequency, the two circuits switch roles, and the resulting rectified voltage shifts to opposite polarity. With alternating frequency changes in the MF, above and below the rest frequency, the result is an alternating voltage out of the rectifiers output filter, which is the LF signal.

3.5.3.2 Foster-Seeley -discriminator

Picture 3.58 illustrates a Foster-Seeley discriminator. This early demodulator has good linearity, although it is preceded by a good amplitude limiter, but rather poor sensitivity. The last MF amplifier stage is finished with a trans-former whose two windings are included in resonant circuits tuned to MF. The MF signal is transmitted from the primary to the secondary side partly by induction and partly by the capacitor to the middle of the secondary winding. The signal is thus divided into two branches with a phase shift of +90◦ and −90◦ respectively. The signals in the branches are individually rectified and aggregated in an RC network. If the MF signal does not deviate, the LF voltage in the branches is equal. But since the branch voltages are of opposite polarity, they cancel each other out and the LF signal becomes zero. As the MF frequency deviates from modulation, the signal amplitude increases in one branch and decreases in the other. The amplitude of the LF signal then becomes proportional to the frequency deviation.

3.5.3.3 The counter discriminator

Picture 3.59 shows the counter discriminator. A monostable flip-flop (eng. monoflop) is affected to beat the square-edge pulses from the amplitude-limited FM signals. Such a flip-flop is a digital circuit which, when fed with an arbitrarily long voltage pulse, will nevertheless deliver a voltage pulse of constant length. For each positive half-wave, the monostable flip-flop delivers an impulse of constant length. The time intervals between the pulses will be proportional to the frequency of the FM signal. At varying frequency, the impulses come at varying time intervals. A low-pass filter filters out the low frequency from the signal and a pulsating DC voltage remains. With this DC voltage, the capacitor is charged up to an average value. At a higher frequency of pulses of the same length, the average value is higher than at a lower pulse frequency. The superimposed oscillations on the DC voltage constitute the LF signal. Without a monostable flip-flop with equally long pulses, the average value would have been constant. You can say that the FM signal has been converted into a pulse length modulated signal (PLM signal).

3.5.3.4 The PLL demodulator

Figure 3.60 shows the PLL demodulator. The frequency-modulated MF signal and a VCO signal are fed into a phase comparator. The VCO frequency follows the frequency changes of the FM signal. The tuning voltage

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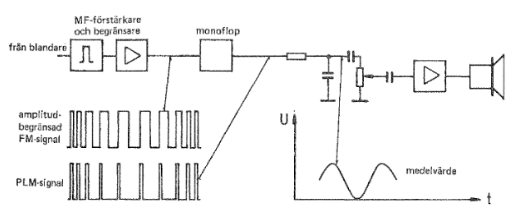

Figure 3.59: The counter discriminator

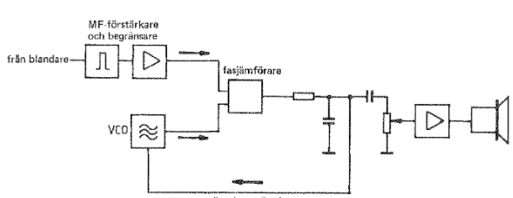

Figure 3.60: The PLL demodulator

for the VCO is a DC voltage. The modulating LF voltage is superimposed on this DC voltage. The LF frequencies are too low to be able to regulate the VCO frequency, but via a capacitor can control the LF amplifier. The last two methods are particularly suitable for demodulating FM signals. There are additional ways to demodulate FM signals. Common to all is that they work better the lower the intermediate frequency. Therefore, most FM receivers are made as double or triple supers, with low MF.

3.6 Oscillators HAREC a.3.63.6.1

Generation of oscillations The word oscillator (lat.) has the meaning to swing and the phenomenon or device that creates an oscillation is called an oscillator. In all kinds of oscillations, there is exchange between different forms of energy. Oscillations occur in different forms. It can be, for example, vibrations in a body, molecular movements in gases and liquids or movements of electric charges.

3.6.1.1 Damped oscillation

Radio transmissions with telegraphy were carried out in the early 20th century with damped oscillations. That is, an oscillation whose amplitude decreases until the oscillation ceases. The oscillation was created by an electric spark in a spark gap. The spark gap was connected to a tuning circuit which concentrated the oscillation energy to a more specific radio frequency. Due to the large bandwidth, the damped oscillations caused disturbances which limited their usefulness for telegraphy.

3.6.1.2 Undamped oscillation

The term undamped oscillation was introduced to distinguish a sinusoidal oscillation. with constant amplitude and frequency from the damped oscillation. Unlike a damped oscillation, single-damped oscillation has a limited bandwidth and can be used for several forms of modulation. See picture 3.61. In English, the oscillation was named Continuous Wa-ve and the abbreviation CW is still used by radio amateurs as a designation for telegraphy. When the advantages of undamped sine waves became clear and when oscillators with radio tubes became available around the year 1913, authorities began after a few years to introduce restrictions on the use of spark emitters. The restrictions were extended through international agreements and during the 1930s the use of transmitters with damped oscillations was prohibited.

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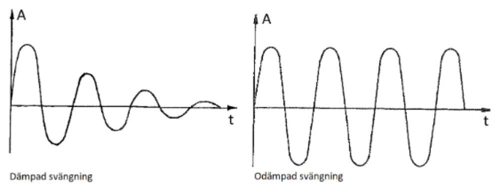

Figure 3.61: Oscillations

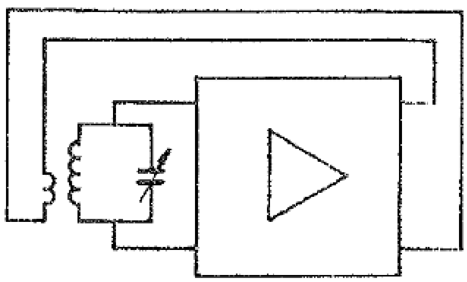

Figure 3.62: Oscillator according to Meissner

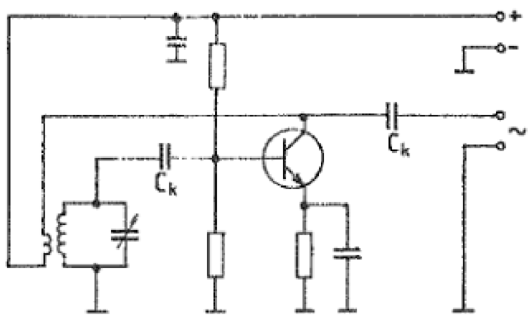

Figure 3.63: Emitter-coupled amplifier

3.6.2 LC oscillatorsHAREC a.3.6.1, a.3.6.2, a .3.6.33.6.2.1 Variable frequency oscillator (VFO) An oscillator with an adjustable frequency is called a VFO (variable frequency oscillator). In addition to frequency stability, it is also required that accurate setting and reading of the frequency must be possible. An LC oscillator is the prototype for an oscillator with variable frequency. The Meissner coupling is easy to distinguish and is used here to describe the basic principle of an oscillator in general. Among other things, the Colpitts and Clapp couplings, however, have better stability and adjustability in the feedback stage.

3.6.2.2 Meissner coupling

Figure 3.62 shows a Meissner oscillator, which consists of an LC resonant circuit with a feedback coil and

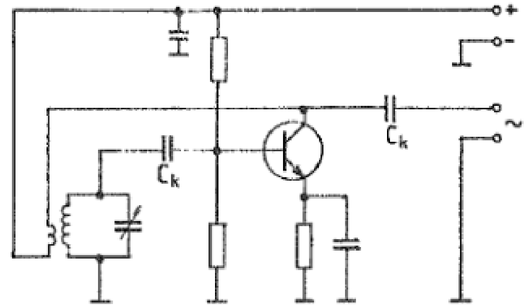

Figure 3.64: Complete Meissner oscillator

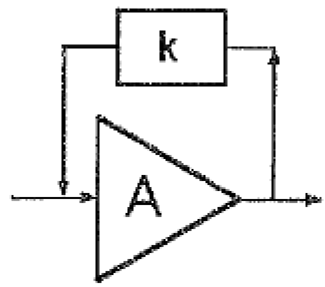

Figure 3.65: Oscillation conditional amplifier.

The magnetic field between the inductance and the resonant circuit and the feedback coil is polarized so that a change in the output signal contributes to self-oscillation. (The opposite is feedback.) The amplifier can, for example, be an emitter-coupled transistor amplifier according to figure 3.63. The coupling capacitors Ck are necessary to prevent short-circuiting of the DC voltages that determine the operating point of the transistor. On the other hand, the alternating voltage signals can pass to and from the transistor. The feedback path is made in this case so that the resonance circuit is connected in parallel across the amplifier input as shown in picture 3.64. The feedback coil acts as the amplifier's collector resistor.

3.6.3 The self-oscillation condition

Self-oscillation in an amplifier occurs through feedback, as shown in Figure 3.65. The signal voltageˆUin across the input is amplified by the factor A. When in Figure 3.64 the amplifier is emitter-coupled, the output signal is phase-shifted by 180◦ in relation to the input signal.118

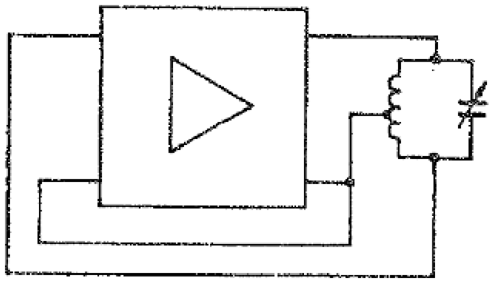

Figure 3.66: Hartley coupling

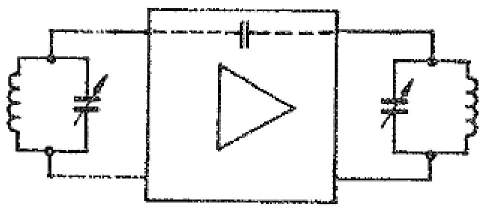

Figure 3.67: TPTG coupling

The phase shift α = 180◦ is denoted here with a minus sign, so the gain is − A. At the output of the amplifier, a signal voltage is obtained ˆUutwith the connectionˆUut = −A · ˆUinA part of the output signal is returned (re-connected) to the input. In a Meissner oscillator, the feedback takes place with an inductor, which is inductively connected to the resonant circuit's inductor. The ratio k between the feedback signal voltage ˆUut and the signal voltage out at the amplifier output is called the feedback factor. The feedback voltage ˆUk is phase-shifted so that it is in phase with the input signal. For the feedback signal, the relationship is then obtained ˆUk = −k · ˆUut Sufficient signal voltage from the output must be fed back to the input for self-oscillation to occur. This occurs when the feedback signal voltage ˆUk is at least as large as the input voltage ˆUin and is in the correct phase position, i.e. in this exampleˆUk ≥ ˆUin or − k · ˆUutA or k ≥ 1ASthe self-oscillation condition becomes blk ≥ 1A or k · A ≥ 1A k ·A ≈ 3 is desirable for the oscillator to oscillate quickly.

3.6.3.1 Hartley coupling

Figure 3.66 shows a Harley coupling. Feedback is provided galvanically via a socket on the inductor in the oscillator's LC circuit.

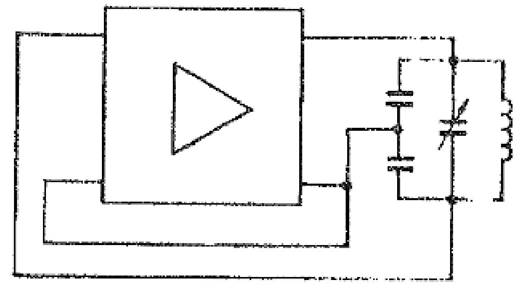

Figure 3.68: Colpitt coupling

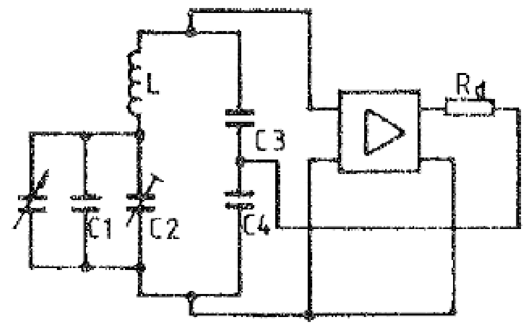

Figure 3.69: Clapp coupling

Figure 3.67 shows a Huth-Kühn or TGTP coupling (tuned grid – tuned plate) The coupling is an amplifier with LC circuits both on input and output. Both circuits äare tuned to the same frequency. The feedback takes place via the internal capacitances between the electrodes of the electron tube and between the material layers of the transistor, respectively. This connection is not very common for several reasons.

3.6.3.2 Colpitts connection

Picture 3.68 shows a Colpitts connection. Feedback is required via a capacitive voltage divider, which is included as part of the oscillator's LC circuit.

3.6.3.3 Clapper coupling

This coupling is a variant of the Colpitt coupling. The rotary capacitor for the frequency setting is connected in series with the capacitors of the voltage divider. The frequency stability of the flap oscillator is good. We develop this description further with picture 3.69. The rotary capacitor and a fixed and a tunable capacitor are connected in parallel with each other. All three capacitors are in turn connected in series with the capacitive voltage divider C3/C4. The amplifier's input is connected to the upper connection of C3. The output from the oscillator's amplifier is fed back via the damping resistor Rct to the center voltage divider C3/C4 (the feedback circuit). 119

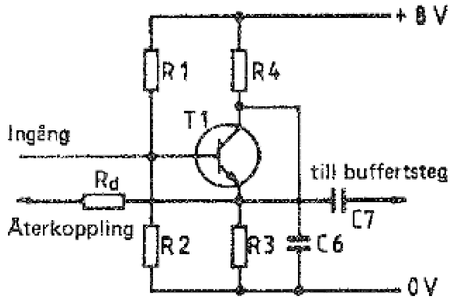

Figure 3.70: Amplifier in a clapper circuit

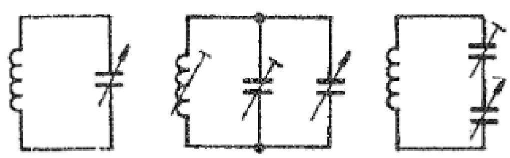

Figure 3.71: Band spread

Picture 3.70 shows the amplifier in a clapper circuit. The operating point of the amplifier is determined by the voltage divider R1/R2. No coupling capacitor is needed as there are only capacitors between pre-amplifier input and ground. Capacitor C6 decouples the collector of transistor T1 HF-wise to ground. The pre-amplifier is thus collector connected. The capacitor C7 connects the oscillator's output signal to the buffer stage. For the sake of frequency stability, the 8 V voltage is stabilized with an LC circuit which is HF-decoupled with a capacitor.

3.6.4 Frequency setting and band spreading

Figure 3.71 illustrates step by step how to achieve band spreading. Setting the frequency in an LC oscillator used to be mostly done with a rotary capacitor. In modern receivers and transmitters, capacitance diodes (eng. varicap) are used instead, which are controlled with a DC voltage. With a resonant circuit with only an inductor and a rotary capacitor, all amateur radio bands would only be narrow areas spread out on a mechanical scale, i.e. over the entire capacitance range of the turning capacitor, whereby the capacitance can be varied with a ratio of 1:5 or 1:10, for example 10–50 pF or 10–100 pF. In order to instead get each of the amateur radio bands spread over most of the scale can manage with band switching and so-called band spreading. A relatively large fixed capacitance is then connected in parallel with the relatively small capacitance of the rotary capacitor. The total capacitance variation in the LC circuit then becomes small, even though the entire capacitance range of the capacitor is used. The result is a frequency scale with greater resolution, i.e. better reading accuracy.

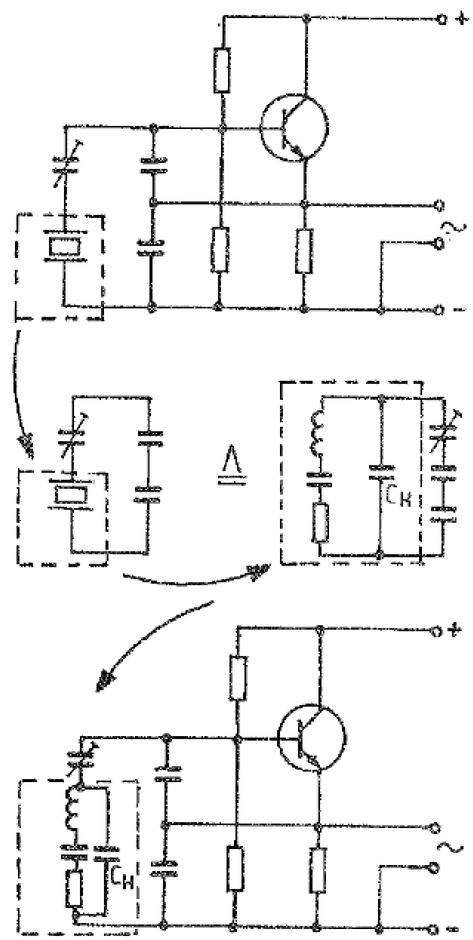

Image 3.72: Colpitt oscillator with crystal in the parallel-resonance case

Band spreading can also be arranged with two series-connected capacitors, the larger of which is made variable. Typical value of the turning capacitor in single short wave equipment is then 100–500 pF and the fixed capacitor much smaller than that

3.7 Crystal oscillators HAREC a.3.6.4

3.7.1 Quartz crystals and oscillator couplings

The frequency stability of an LC oscillator is limited by the properties of the constituent components. When much better stability than that is required, especially in high temperature ranges, the quartz crystal is an oscillation circuit with better data. The high Q value of the quartz crystal also gives a cleaner signal. In a crystal oscillator (eng. Crystal Oscillator (XO)) a quartz crystal is the frequency determining element instead of an LC circuit. Otherwise, the same connection principles as for an LC-VFO can be used. The crystal can be designed so that it oscillates either as a series or parallel resonant circuit. Note that a single crystal oscillates at a slightly different frequency depending

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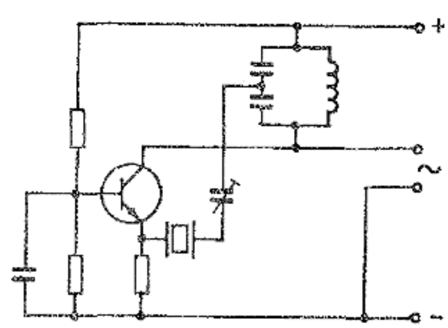

Figure 3.73: Colpitt oscillator with a crystal in the series resonance case if it is made to function as a series or parallel circuit. The higher frequency is the one usually used.

Figure 3.72 shows a Colpitto oscillator with a crystal in the parallel resonance case. In the parallel resonance alternative, the crystal is connected in parallel across the oscillator's feedback link. The minimum attenuation of the feedback signal is obtained when the frequency of the signal is the same as the resonant frequency of the crystal. The crystal's reactance is then at its highest. Parallel above the crystal's internal inductance are its internal series-connected capacitances C and CH . Three external capacitances (one trimmable and two fixed capacitors in series) are connected in parallel across the internal connection capacitance CH. If the trimmable capacitance is changed, the resonance frequency of the crystal is affected. You then say that you "pull" the crystal within a small frequency range. The characteristics of the crystal and the oscillator determine how large the range can be. If crystals are pulled too much, the resonant frequency can become unstable. The relative frequency change amounts to a maximum of 10^{-4} = 0.01% according to the following formula: relative frequency change = absolute change resonance frequency

3.7.2 Harmonic crystals

Figure 3.73 shows a Colpitt oscillator with crystal in the series resonance case. In the series resonance option, the crystal is connected in series with the feedback link of the oscillator. The minimum attenuation of the feedback output signal is obtained when the frequency of the signal is the same as the resonant frequency of the crystal. The reactance of the crystal is then at its lowest. So-called overtone crystals are used for oscillator frequencies above about 20 MHz. The dimensions of the overtone crystals are the same as the fundamental tone crystals, but are cut out differently and ground to oscillate at the desired odd harmonic. A single-harmonic crystal has the frequency of the harmonic stamped into the case and the crystal is assumed to work in oscillator connections as a series circuit. By allowing crystals to oscillate on their overtone, a difficult manufacturing procedure is avoided, namely grinding very thin crystal discs. A harmonic oscillator must always contain a resonant circuit that is tuned to the overtone set on the crystal. string-one. A snap at a point off center causes the string to oscillate on a harmonic instead.

3.7.3 Superheterodyne VFO

Figure 3.74 shows a superheterodyne VFO. A single LC-VFO is not frequency stable enough in a high frequency mode, for example 144-146 MHz. You can then use a special coupling, which is a combination of LC-VFO and XO, called super-VFO. In a super-VFO, a low variable frequency from a VFO is mixed with a high frequency from an XO. The word super comes from superheterodyne = superposition, mixture. A VFO works more stably at low frequencies, while an

XO still works stably even at higher frequencies, though not as high as we need here. In our example, the VFO therefore operates in the 8–10 MHz range and the XO at 17 MHz. The VFO signal is mixed with a fixed signal frequency, which is the XO signal 17 MHz multiplied by 8, i.e. 136 MHz. A bandpass filter filters out the desired mixing product, which lies in the frequency range 144–146 MHz. The result is a high frequency, which is both variable and stable. Advantages The frequency stability of a super VFO is much better than that of a simple VFO, which works directly in the VHF range. A super VFO is also

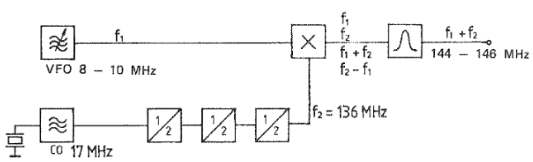

Figure 3.74: Superheterodyne VFO121

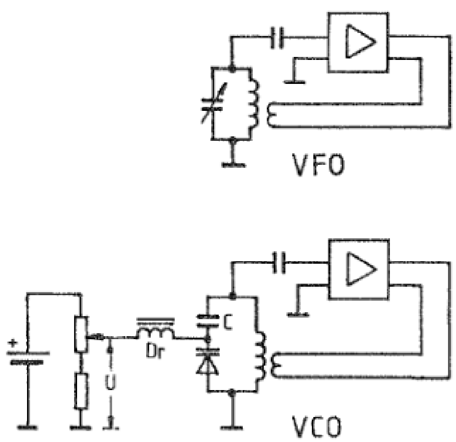

Bild 3.75: VFO och VCO jämförs

Figure 3.75: VFO and VCO compared much less noisy than a PLL VFO, which is described below. Disadvantages When frequency mixing occurs, unwanted mixing products occur, which are indeed attenuated by bandpass filters, but which it is impossible to completely suppress. Among other things, a weak mirror frequency is generated, which wanders from 128 to 126 MHz, while the desired mixture product wanders from 144 to 146 MHz. The risk of the mirror frequency being amplified and transmitted must be eliminated, which can be done with efficient bandpass filters. See further in section 3.8 on frequency mixing.

3.7.4 Oscillators with phase locking (PLL)HAREC a.3.7

A crystal oscillator (XO) works with good frequency stability. Its frequency is fixed and determined by the control crystal. An LC oscillator, on the other hand, operates within a frequency range (VFO), which is determined by an LC circuit. However, its frequency is less stableil than that with control crystal. In a phase-locked loop (eng. Phase Locked Loop (PLL)) good frequency stability and a large frequency range can be combined. A PLL is a closed circuit for electrical control of an oscillator, so that its frequency is both stable and variable.

3.7.4.1 Voltage Controlled Oscillator (VCO)HAREC a.3.6.5

In picture 3.75, a VFO and a VCO are compared. A VFO whose frequency can be controlled with a DC voltage is called a Voltage Controlled Oscillator (VCO). In the resonant circuit in a VCO, the capacitance diode (eng. varicap, variable capacitor) performs the same task as the mechanically variable capacitor in a VFO.

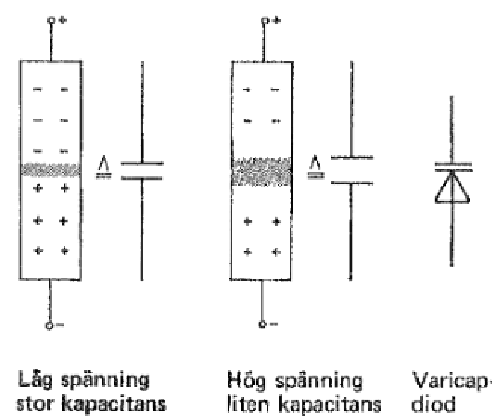

Figure 3.76: Capacitance diode – Varicap

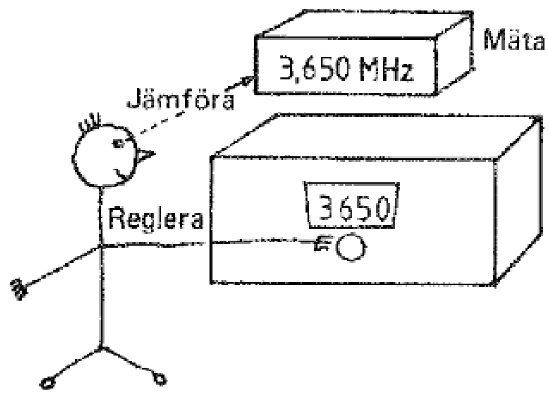

Figure 3.77: Analogy Human-PLL

Figure 3.76 shows a capacitance diode. When an opposite voltage is applied to the diode, a barrier layer is formed in the diode, so that the zones with free charge carriers are isolated from each other like capacitor plates. The thickness of the barrier layer (approx. 1/1000 mm) depends on the voltage across the diode. At high voltage, the barrier layer is thick, which corresponds to "large plate distance" and small capacitance. At low voltage, the layer is thin, which corresponds to "small plate spacing" and large capacitance. With a capacitance diode in the resonance circuit instead of a mechanically variable capacitor, two additional components are needed. The choke Dr prevents the high-frequency signal from being superimposed on the control circuit's DC voltage, which would otherwise degrade the resonance circuit's figure of merit (lost HF energy means attenuation). Conversely, the capacitor C prevents the diode and blocking voltage from shorting through the inductor. The oscillator frequency is set with the variable DC voltage U . A VFO has become a VCO.

3.7.4.2 Oscillator with PLL controlHAREC a.3.7.1

Picture 3.77 shows a manual frequency control. Humans compare and regulate processes based on given facts. It can be compared to the PLL circuit's way of comparing the mutual phase position between the signal from a VCO (the actual value) and the signal from an XO (the desired value).122

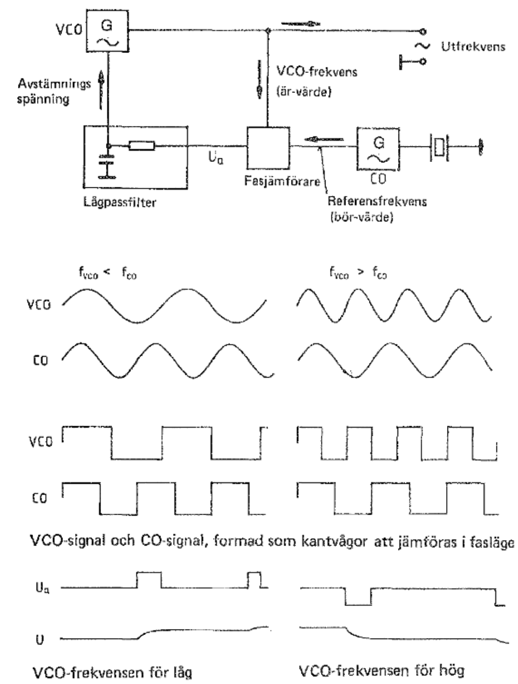

Figure 3.78: Oscillator with PLL -control As a result of the comparison, the control voltage is adjusted so that the actual and desired frequencies are kept equal. Such a control circuit consists of digital components.

Figure 3.78 illustrates an oscillator with PLL control. The phase comparator supplies a cyclically adjusted control voltage to the capacitance diode in the VCO. Since this voltage changes in steps, the course is rounded so that the frequency changes become smooth. The rounding takes place with an RC filter where the capacitor assumes an average value of the pulsating output voltage from the comparator. If the VCO frequency is too low, the comparator supplies a positive voltage. The control voltage on the capacitance diode then rises at a rate determined by the filter's time constant. The capacitance in the capacitance diode decreases with increasing voltage, because the barrier layer becomes thicker and the frequency of the VCO rises. When the signal from the VCO is again equal to the reference signal from the XO, to phase position and frequency, the output resistance in the phase comparator increases. The capacitor of the low-pass filter then retains its charge and the control voltage to the VCO does not change. Should the frequency of the VCO be too high, the output of the comparator becomes low-impedance and the filter's capacitor discharges at the rate determined by the time constant. The decreasing control voltage causes the capacitance diode's barrier layer to become thinner, the capacitance increases and the VCO frequency drops until new phase and frequency equality is achieved.123

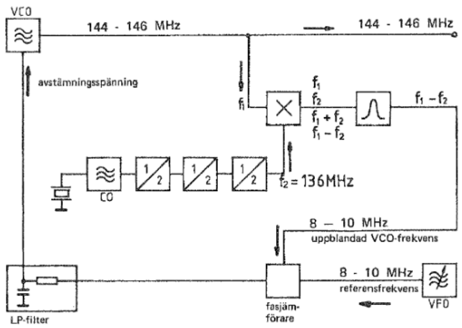

Bild 3.79: PLL-oscillator kombinerad med frekvensblandning

Figure 3.79: PLL oscillator combined with frequency mixing

3.7.4.3 PLL oscillator combined with frequency mixing

Figure 3.79 shows a PLL oscillator combined co-frequency mixing. The signal f1 from a VCO generates a transmission frequency in the band 144–146 MHz. This is mixed with the signal f2 (136 MHz), which is a multiplexed XO frequency. The mixing product f1 −f2 is the signal in the range 8–10 MHz which is filtered out and applied to a phase comparator. The output signal from a VFO, which is variable within the same frequency range 8–10 MHz, is also applied to the phase comparator. The output signal from the comparator is a DC voltage which depends on the frequency difference between the mixing product and the VFO signal. The output signal of the comparator changes up or down, depending on the direction of the frequency error. The VCO frequency is determined by a DC voltage level controlled by the output signal of the comparator. At each frequency change in the VCO, the system will aim for the counter frequency difference to zero in the phase comparator, which means that the transmit frequency is kept at the correct value. Advantages of a PLL oscillator It has the same frequency stability as a VFO because it also works at a low frequency. Unlike a super-VFO, there are no side frequencies in the PLL oscillator, because the VCO generates the useful frequency directly. Disadvantages of a PLL oscillator It has a higher noise level than a super-VFO. The frequency stability is worse than that of a PLL oscillator with XO and programmable frequency divider.

3.7.4.4 PLL with programmable frequency dividerHAREC a.3.7.2

Figure 3.80 shows a PLL with frequency divider. With PLL, the frequency of the output signal from a VCO is locked to the reference frequency from an XO. In principle, a VCO can be obtained with the same frequency stability as an XO, but it is just as difficult to do sodrag the frequency on. However, with a frequency divider in the phase-locking loop (PLL), the output frequency can be changed, while the XO still emits the same reference frequency. A frequency divider is a digital circuit that counts oscillations or pulses up to a selected number to reset to 1 and start over. An output pulse is emitted at each reset. When dividing by two, an output pulse is emitted for every second pulse. When dividing by 15, an output pulse is emitted for every 15th input pulse and so on. By selecting the division number in the PLL, the working frequency in the VCO can be set in steps, where each step is as large as a reference frequency. The signal frequency from the VCO is divided by the selected division number and the result is compared with the reference frequency from the XO. Any deviation from the reference frequency will result in adjustment of the VCO frequency. If, for example, you want to cover the 2-meter band in steps of 25 kHz, you choose the reference frequency 25 kHz. In the divider, the transmitter's output frequency is divided by a number 5760, 5761, 5762 and so on up to 5840. If, for example, the division number 5820 is selected, then the control voltage of the comparator will control the VCO frequency to 145,500 kHz. The output frequency of the divider will then be 145500/5820 = 25 kHz, which corresponds to the reference frequency. In this example, the output frequency of the transmitter is thus controlled so that it is always in steps of 25 kHz.124

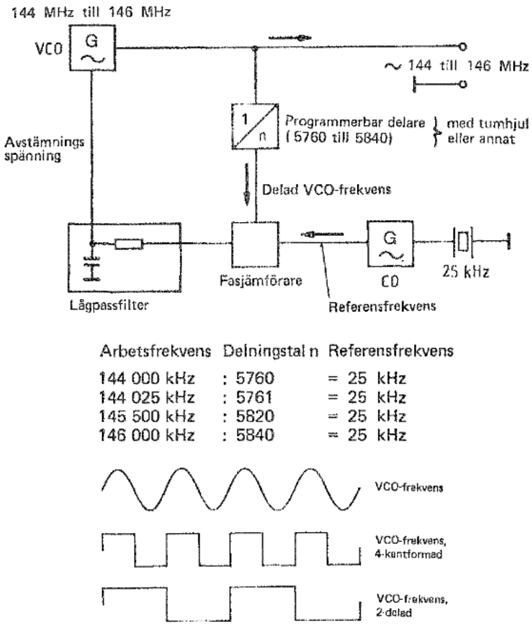

Figure 3.80: PLL with frequency divider

3.7.4.5 Pros and cons of the PLL oscillator

The PLL oscillator has almost the same frequency stability as a crystal oscillator and the frequency can be set in steps. Unlike a VFO with a mechanically adjustable frequency, the PLL controlled VCO oscillator frequency is electronically adjustable. This facilitates the design and placement of controls etc. for frequency setting, frequency memory and automatic frequency scanning. Only when the PLL-controlled oscillator came into use in hand-held devices and mobile devices did frequency coverage over an entire band become possible while maintaining small dimensions. As a comparison, an installation of say 80 to 800 channel crystals in a traditional crystal control device would be a very space-consuming, expensive and impractical solution. But the PLL oscillator makes relatively strong noise compared to a VCO and especially compared to an XO. The VCO resonant circuit has a relatively low goodness-of-fit because a capacitance diode loads the circuit more than a mechanically variable capacitor. With the lower goodness-of-fit, the resonant circuit becomes a less good filter for damping the oscillator noise. The capacitance diode also adds an electron noise. In addition, there is the so-called phase noise from the frequency divider and PLL. With the low figure of merit of the resonant circuit, the frequency stability of a VCO is not as good as that of a crystal oscillator. Even so, the long-term stability is good in a VCO, when included in a PLL, because the frequency is kept constantly readjusted. PLL, on the other hand, cannot achieve as good short-term stability. A phase equalization process already includes the time for one period of the reference frequency, and it will elapse a multiple of this shortest time before the control voltage can restore the VCO frequency again. This is because the capacitor in the low-pass filter of the regulation loop must first be charged up for a number of periods before regulation takes place. These short-term frequency deviations are a type of frequency modulation that leads to phase noise from the PLL oscillator. However, it is only in extreme cases that the phase noise appears disturbing because in modern devices it is reduced to an acceptable level by careful shielding and filtering. 125

3.7.5 Factors affecting frequency stability

The frequency of the transmitter must be kept as stable as possible. An unstable transmitter is not acceptable and creates difficulties not only for the radio stations participating in the connection but also for radio traffic on nearby frequencies. A frequency-stable oscillator must have the following properties:

3.7.5.1 Stable mechanical structure

Vibrations from the substrate, for example during mobile use, vibrations from a transformer core, etc. can impair the frequency stability of the oscillator. Frequency-determining components such as fixed and variable capacitors, coils and the like must be stably mounted, the trim cores in the coils fixed and so on. The connections must not be allowed to bend or vibrate. The device body must be sufficiently rigid so as not to change shape and thereby cause frequency changes during handling and so on.

3.7.5.2 Good electrical construction and high Q value in the resonant circuits

All electrical connections must be as short as possible and solder and connection points in perfect condition. Inductors and capacitors in the resonant circuits must be low-loss and otherwise high-quality so that the signal is as clean as possible from unwanted side frequencies. The feedback in the oscillator must be so firm (strong) that the self-oscillation is stable. But in order to get the best possible signal, the coupling must not be so tight that the resonance circuits become overly loaded and their efficiency too low.

3.7.5.3 Shielding enclosures

Resonance circuits must be shielded from external capacitance additions, for example from the user's hand. This is done with partitions and component enclosures made of metal. The shielding also prevents unwanted coupling between the oscillator and subsequent amplifier through electric and magnetic fields.

3.7.5.4 Stable drive voltages

Unstable drive voltages cause frequency changes. In an oscillator with a transistor amplifier, the instability depends on changes between the layers in a transistor's diode path . Namely, the layers act as "capacitor plates" and the barrier layer in between as a dielectric. The thickness of the barrier layer and thus the "plate distance" is in relation to the voltage applied across the transistor. The voltage-dependent capacitance in the transistor is connected to the resonant circuit via the coupling capacitor. Since the capacitance in the transistor is part of the resonant circuit, it affects the resonant frequency. This property can be a nuisance, but can also be used to easily change the operating frequency of the oscillator. See capacitance diode and the PLL oscillator.

3.7.5.5 Buffer stage

An oscillator in a radio transmitter may consist of a single amplifier stage that produces high-frequency electrical oscillations. Usually only small power is extracted from such a simple transmitter, normally less than one watt. Without special measures, such as for example using a control crystal, the frequency is not very stable and unsuitable for communication purposes. Especially varying load on the oscillator's output causes frequency change. The oscillator should therefore be given as low and stable a load as possible. A buffer stage with high input impedance is therefore connected after the oscillator. The buffer stage must also be able to leave sufficient drive power to subsequent amplifiers and should therefore have a low output impedance. It must also work linearly (see class A operation, picture 3.42) in order not to generate harmonics and thereby distort the oscillator signal. Figure 3.41 shows a buffer stage in collector coupling, which has these properties.

3.7.5.6 Temperature compensation and thermostats

Loss heat is always generated in electrical devices and also in an oscillator. During heating, gas coils and capacitors in the resonant circuits expand, which leads to frequency changes. Even the barrier layer capacitance in the transistors is temperature dependent. The total temperature dependence can be compensated by a number of measures.

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The oscillator should be mounted as far away as possible from other heat-generating components. The shielding enclosure around the oscillator must be as thick-walled and heat-insulating as possible. Installation in a thermostatically controlled enclosure is an even better alternative. The components should have reached operating temperature before use. The oscillator should therefore be warmed up for at least 15 minutes.

3.7.6 Frequency stability and oscillator noise HAREC a.3.6.6

The frequency stability in crystal oscillators is about 100 times better than it is in LC oscillators. Likewise, the output signal from crystal oscillators is cleaner from phase noise (jitter). Each oscillator also emits unwanted signals with frequencies that are around the nominal frequency of the output signal. The oscillator is, after all, an amplifier, whose output voltage is partially fed back to the input in phase. This means that the output signal is amplified avalanche-like to a maximum, alternating with it being attenuated avalanche-like to a minimum. Without external influence, the amplifier is thus in a self-oscillating state between two external values. A filter is placed in the feedback path to determine the frequencye element, for example an LC circuit or a quartz crystal. The feedback is strongest at the filter's resonance frequency, which means that the oscillator oscillates best there. Since the filter inevitably has a certain bandwidth, a spectrum of other frequencies around the resonance frequency will also be let through. The unwanted frequencies around the nominal are called noise. In modern designs, PLL oscillators are mostly used. Due to their function, their frequency always oscillates slightly. How much depends, among other things, on the loop filter. So the frequency is actually a very small band of several frequencies, one of which stands out the most. Try turning the volume control in a low-frequency amplifier without an input signal to maximum. A noise will be heard in the speaker, which mainly comes from the transistors of the input stage. When a microphone is connected, the volume control must be turned down and then the hearing noise is reduced. But the noise is still there at a lower level and is superimposed on the input signal from the microphone. Even in a high frequency oscillator, the noise is superimposed on the input signal. But the higher the figure of merit in the resonant circuit, for example a crystal, the narrower the bandwidth of the filter, the stronger the noise suppression and the more the desired signal is emphasized. Thanks to the greater figure of merit in the resonant circuit, and thus the smaller bandwidth, a crystal oscillator thus makes less noise than an LC oscillator. A disadvantage of the crystal oscillator is that its frequency cannot be changed within a larger range. If several selectable frequencies from a crystal oscillator are desired tor, several crystals must be used together with some kind of switching device (channel selector). The amount of components in a crystal oscillator is smaller than in a VFO, but in devices for several frequencies this advantage is offset by the additional cost of several crystals and the channel selector. The crystal oscillator has many areas of use where a frequency-stable and low-noise signal is desired and where lack of space, vibrations etc. preclude the use of an LC-VFO.127

3.8 Frequency mixer

3.8.1 Basic principles

A device that mixes signals to create others is called, as the name suggests, a mixer. Mixers are used both in receiver and transmitter and the operating principles are the same in both cases. What largely differs is how they are used. There are many mixer connections, the most common of which are described here. Simple types with certain disadvantages are contrasted with those that are more complicated, but have advantages. Figure 3.81 shows the principles of frequency mixing. When a linear amplifier is fed with two signals, they are stored together. The resulting signal at any time is the amplified sum of the input signals. When a nonlinear amplifier is fed with two signals, they are mixed with each other. In addition to the input signals, further signals appear on the amplifier output through the mixing, so-called mixing products. Two of the mixing products are particularly interesting, they are the sum and the difference of the frequencies of the input signals. The unwanted other mixing products are filtered out with a tuned circuit or a bandpass filter.

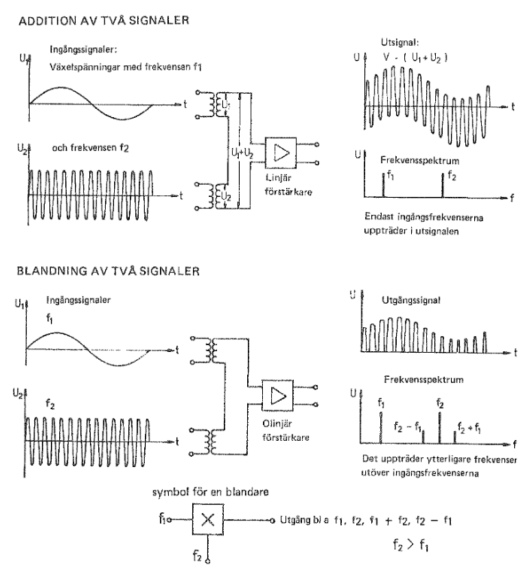

Figure 3.81: Principles of frequency mixing

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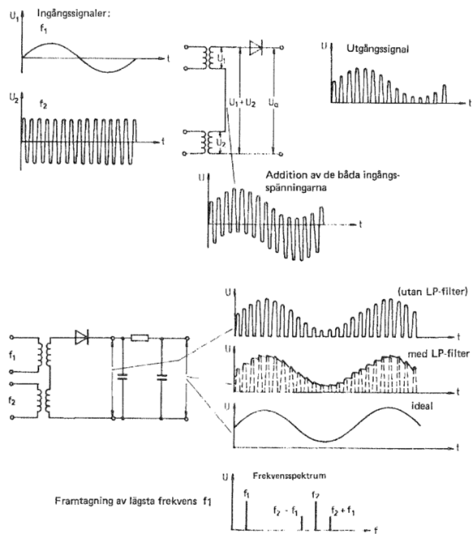

Figure 3.82: Unbalanced mixer

3.8.2 Unbalanced mixer

Figure 3.82 shows an unbalanced mixer. We can convince ourselves that the four mixture products really occur. First we examine the simplest mixer, which is a non-linear element in the form of an diode. There is no amplifier in the connection. The signal voltages are added because the secondary windings of the two transformers are connected in series. The diode strongly "distorts" the curve shape of the total voltage. Depending on how the diode is polarized (reversed in the connection), the negative or the positive half-wave is cut off. The signal at the output of the mixer, i.e. after the diode, contains, among other things, the frequencies f1, f2, f2 + f1, f2 − f1. The lowest frequency f1 can be most easily demonstrated by connecting a low-pass filter to the output of the mixer. The result can be studied with an oscilloscope. As in the picture, you then see that the capacitor charges up to the peak value of the positive half-wave and with a good approximation follows the curve shape of f1.

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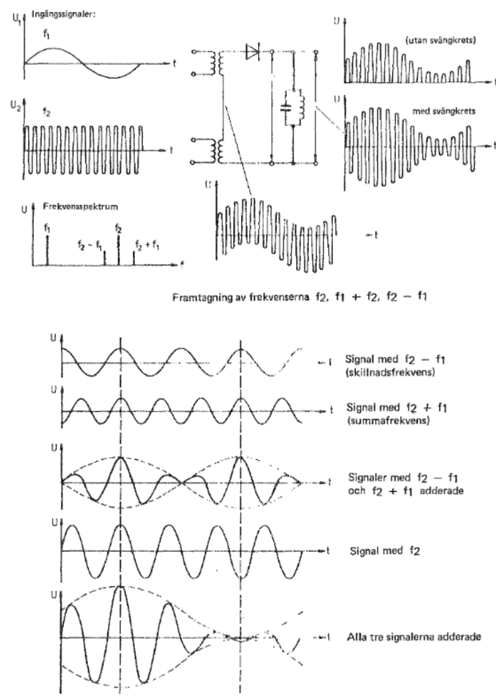

Picture 3.83: Unbalanced mixer with resonator

Picture 3.83 shows an unbalanced mixer with a resonator. A resonant circuit with a suitable bandwidth and which is tuned to the resonant frequency f2 is now connected to the output of the mixer. A signal with the frequency f2 can then be distinguished and studied in the oscilloscope. The resonant circuit is supplied with energy during the positive half-waves. The energy in the resonant circuit is supplemented by the negative half-wave, whereby part of the circuit's energy is consumed. Therefore, the positive and negative half-waves do not have the same amplitude (peak value). You can see in the oscilloscope how the amplitude "floats". From this it is concluded that the signal consists of more frequencies than f2. The signal is composed of f2, f2 + f1 and f2 − f1. The signal f1 lies outside the resonant circuit's selective range and is therefore filtered out (suppressed). The mixture products f2 + f1 andf2 − f1 both have one less amplitude than f2. That there are different fundamental tones and mixing products can be proven with an even narrower resonant circuit with variable frequency tuning, see lower part of the picture. So far, we have started from an unbalanced mixer. Other mixer types such as the balanced mixer and the double balanced mixer produce fewer mixing products.

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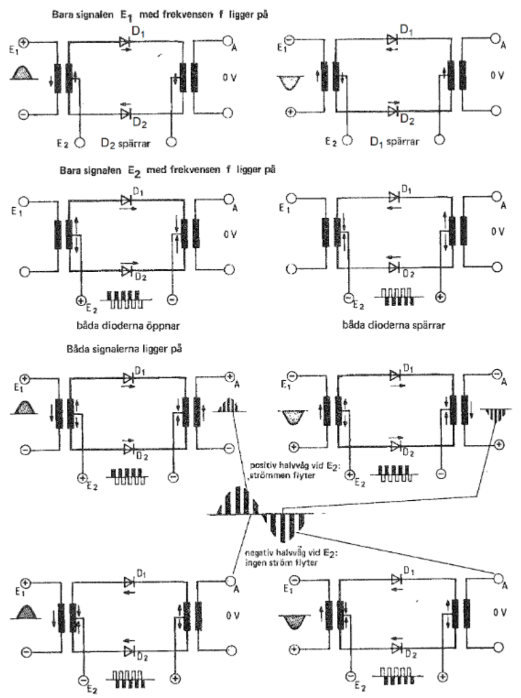


Figure 3.84: Balanced mixer

3.8.2.1 Balanced mixer

Figure 3.84 shows a balanced mixer. Unlike the unbalanced mixer, the balanced mixer has two diodes and the single winding of the HF transformers has a center tap. The input E1 is located on the primary winding of the transformer. Input E2 is above the two center sockets. The output is on the second transformer's secondary winding. The input E1 is fed with a signal with a low frequency f. Since one of the two diodes always blocks, no current flows. The dashed arrows only show in which direction the current could flow, if the blocking diodes were open. But as long as no signal is on input E2, no signal appears on the output. The signal on E1 is removed and instead the input is fed with a high frequency F . During the positive half-wave, both diodes are open and an equal amount of current flows through both. The two transformer winding halves are flowed by an equal current in the opposite direction and then the magnetic fields in the winding halves cancel each other and no signal appears at the output. When signals are applied to both inputs the following happens: The diodes open and close in time with the signal on input E2, with the frequency F . The much weaker signal on input E1, with frequency f, can pass diode D1 or D2, depending on polarity. On the return path, the signal from E1 is superimposed on the signal from E2. The currents in the winding halves are of different magnitudes. Then a signal appears at the output. The postmixer follows a filter that only lets through the desired mixing products F + f or F − f.131

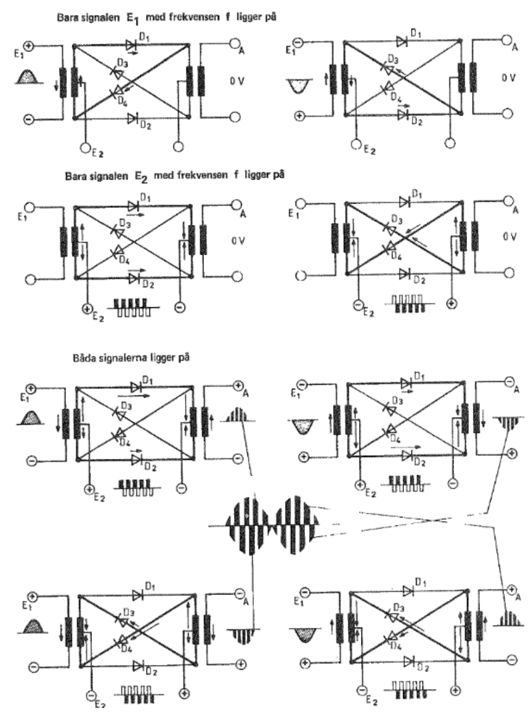
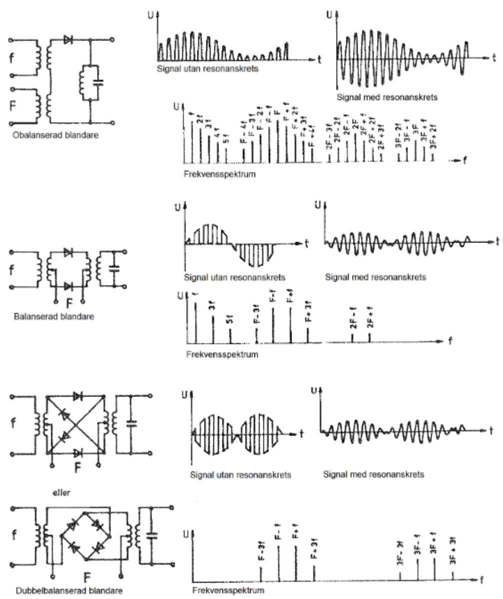


Figure 3.85: Double-balanced mixer

3.8.2.2 Double-balanced mixer

Figure 3.85 shows a double-balanced mixer. A double-balanced mixer (also called a ring mixer) consists of four diodes, which are directed in the same direction in a "diode ring". The input is fed with a signal with a low frequency f. Unlike the balanced mixer, a current flows through diodes D1 and D4 and D2 and D3, respectively, but through the output transformer. There is no signal on the output as long as the signal F is missing. The signal on E1 is removed and instead the input E2 is fed with a high frequency F . In contrast to the balanced mixer, a current flows through diodes D1 and D2 and D3 and D4 respectively. The magnetic fields in the winding halves of the transformers then cancel each other out. No signal is present at the output, as long as the signal f is missing. When signals are applied to both inputs the following happens: The four diodes will open and close in pairs. As in the balanced mixer, the current from input E1 is superimposed on the current for which the diodes open. Here both half periods of F are used. The currents in the winding halves are of different sizes. A signal then appears on the output. After the mixer follows a filter which lets the desired mixture products through.



3.8.3 Comparison of mixers

Figure 3.86 shows the three described the basic connections and they are compared with respect to the frequency spectrum of the output. For the unbalanced mixer, the sum frequency F + f and the difference frequency F appearΩ f 4F,their harmonics 2f,3 f,4 f,. .. respectively 2F,3F,, further the input frequencies f and F . as well, . . as their mixture products F ± 2f, F ± 3f , . . . and 2F ± f, 2F ± 2f , 2F ± 3f and so on and so forth.

For the balanced mixer, the frequency F and its harmonics are missing. Further, the even harmonics of the frequency f disappear. For the double balanced mixer even more unwanted signals are dropped, namely the input signals f and F and all their overtones. Only mixture products of odd harmonics appear.

For an unbalanced mixers filter the resonant circuit out the frequencies F + f mixers, on the, FΩ f, and F . They balanced other hand, miss the frequency F the mixing, the filtered signal contains only products F + f and FΩ f .

If these two mixture products are well separated or the resonant circuit has a better selection ability, then only the sum frequency becomes F + for the difference frequency FΩ f forward filtered.

We have shown three types of mixers with passives components. Such contain non-linear diodes (germanium or silicon diodes). There are also mixers with active components, i.e. electron tubes or transistors (bipolar, FET, MOSFET), but it would lead too far to go into all the different solutions.

More on how frequency mixing is used for demodulation and modulation can be read in chapter 5.1 about receiver and in chapter 6.1 on transmitters.

3.8.4 Unwanted harmonics and mixing products

Each nonlinear working function step generates, in addition to useful frequencies, also undesired ones-signals with other frequencies.

Both desired and unwanted signals can consist of harmonics or mixture products (difference and sum overtones) or both.

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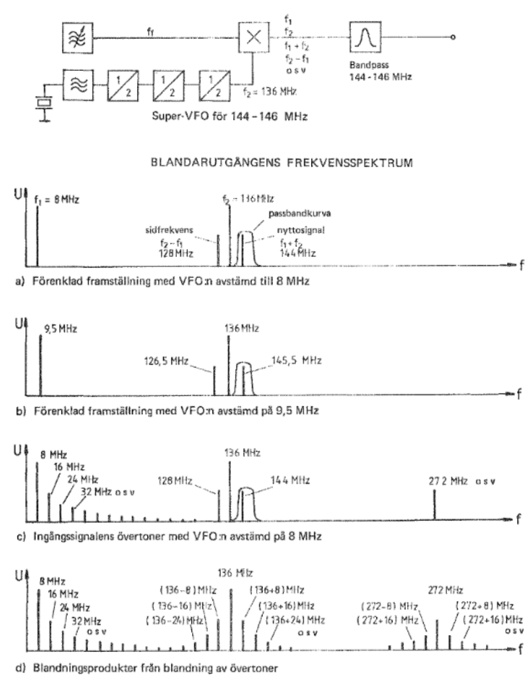

Image 3.87:Frequency spectrum from a super VFO

Some of the signals are filtered out to make up utility signals. Other signals are filtered out, so that, for example, transmission does not occur in error frequencies. Figure 3.87 shows a frequency spectrum from a super VFO, which we described in Sect 3.7.3. We will now investigate which mixture products arise in such a case.

The two most apparent frequencies are the mixture products (sum) in the range 144– 146 MHz and (difference) in the 128-126 MHz range. Based on the mixer, we find the input frequency 136 MHz and its harmonics 272 MHz, 408 MHz and so on as well as the VFO signal and its overtones.

In the picture, the VFO frequency is 8 MHz and its harmonics are plotted, i.e. 16MHz, 24 MHz, 32 MHz and so on. Unfortunately, they also form the harmonics of both input signals mixture products as the picture shows. The bandpass filter passes the useful frequency, but attenuates all harmonics and mixing products. This is easier the further they are from the useful signal undesired signals lie. In our example, the harmonics of the VFO signal fall within the passband of the bandpass filter as follows:

15 ·9.6 = 144MHz to 15 ·9.733 = 146MHz
16 ·9.0 = 144MHz to 16 ·9.125 = 146MHz
17 ·8.471 = 144MHz to 17 ·8.588 = 146MHz
18 ·8.0 = 144MHz to 18 ·8.111 = 146MHz

Since this is about the 15th – 18th harmonics. the amplitudes are so small that we can ignore them.

It is important to have good filters in signal processing function steps. A good rule of thumb is to filter out unwanted harmonics and mixing products at an early stage – preferably at every step – so that unnecessarily complex signals are avoided.

It is also important with the frequency selection, so that unwanted mixing products

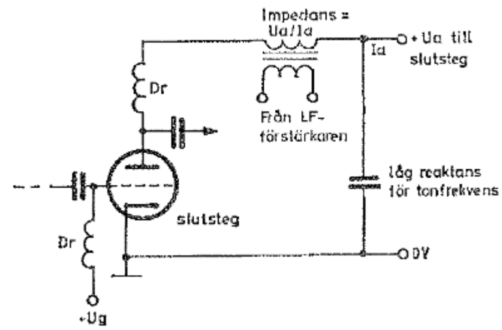

Image 3.88:A3E modulator

come as far away from the useful frequency as possible, as well as that only very high harmonics with correspondingly small amplitudes fall within the useful frequency range.

3.9 Modulators

3.9.1 General

When a signal (carrier) is affected so that it transmits the information in another signal, the carrier is said to be modulated. This process is called modulation.

What then happens is dealt with mainly in section 1.8, with applications in chapter 6.1 and partly in chapter 5.1.

A device for modulation is called a modulator. A modulator can be included as a feature in transmitters, receivers and multiple systems. Depending on the modulation method, different combinations of sub-circuits are used which together make up the modulator. This section gives examples of some common transmitter modulators.

3.9.2 Amplitude modulators

With an amplitude modulator, the amplitude of the carrier wave is affected proportionally to the amplitude of the modulating signal.At the transmission stroke A1A, the amplitude of the modulating signal is either maximum or none. Then the modulator consists of a keying circuit, which affects, for example, a drive stage in the transmitter so that the carrier wave is released completely or not at all.

In the transmission type A3E, the amplitude of the modulating signal has an analog course, for example speech, with which the amplitude of the carrier wave is modulated.

Here, amplitude modulation is described in an amplifier with a cathode-connected electron tube. An emitter-coupled transistor amplifier can be modulated in a similar way. In both cases, the amplifiers operating voltage (anode voltage and collector voltage) is modulated with the modulating signal. What then happens is that two signals are mixed in a way described in section 1.8 with application to A3E.

At rest, the carrier amplitude is then half that possible within the linear part of the operating curve.

In modulation, the amplitude of the carrier wave will vary between zero and the possible amplitude.

Figure 3.88 shows a transmitter output stage with a triode. In series with the supply for the anode voltage is the secondary winding of a modulation transformer for the LF signal.

The LF amplifier that drives the transformer must be able to emit half the power of the carrier wave for a 100% modulation degree. Since the output power from a fully modulated A3E transmitter is 150% of that at rest, the output stage must be dimensioned accordingly.

In addition to its own signal voltage, the modulation transformer must also handle the output stage's operating voltage. If, as in the figure, the anode voltage in an amplifier stage is amplitude modulated, the amplifier stage can operate nonlinearly, for example in class C. However, each subsequent amplifier stage must operate linearly, for example in class A.

Due to the low efficiency and the large bandwidth requirement, in today's amateur radio transmitters hardly "genuine" amplitude modulation,i.e. A3E.

Instead, in the "AM" mode, H3E is almost always used, i.e. simple sideband with full or reduced carrier wave (see next paragraph). Despite the lower power requirement due to only one sideband and possibly reduced carrier amplitude, for dimensioning reasons most H3E transmitters still cannot emit their full power continuously!

As already stated in section 1.8, it is unnecessary to broadcast two sidebands, since both contain the same information. One sidebar is enough. The carrier wave does not contain any information. It can therefore be suppressed already in the transmitter to be replaced in the receiver. This results in the transmission type J3E.

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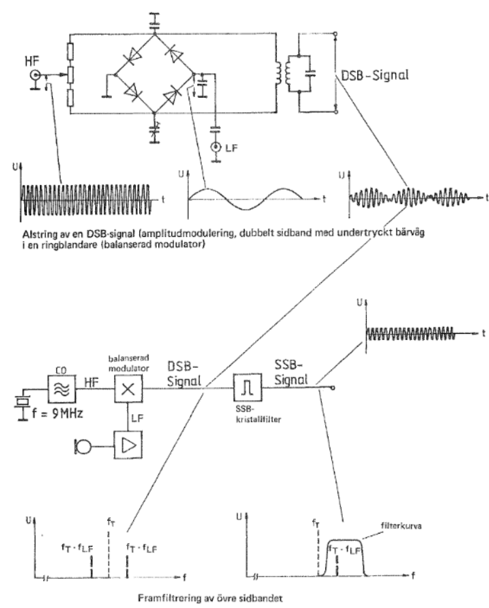

Figure 3.89: Generation of J3E (SSB)

3.9.3 The transmission type J3E (SSB)

In the J3E (SSB) mode of transmission, only one sideband is thus transmitted. The other sideband and the carrier are suppressed, which can be done in several ways. Nowadays, the so-called filter method is most common and the only one covered here.

Figure 3.89 shows generation of J3E (SSB).

With the filter method, the HF and LF signals are mixed in a balanced mixer where they are suppressed while the mixing products with their sum and difference frequencies remain, i.e. the upper and lower sideband.

To suppress one sideband before transmission, the mixer is followed by a bandpass filter with bandwidth and frequency position for the intended sideband. The signal that is sent out thus contains only one side band (Single Side Band).

The choice between USB and LSB can be made in two ways. Either by choosing between a separate passband filter for each sideband or by using a single filter and moving the HF signal from one side to the other of that filter (see Figure 1.32 in Section 1.8).

A J3E modulator according to the filter method thus consists of a balanced mixer, often a so-called ring mixer (seefigure 3.86 in section 3.8) and a bandpass filter. In order for the SSB signal to receive the intended transmitter frequency, additional frequency mixing may be necessary (see chapter 6.1).

3.9.4 Angle modulation

Angle modulation is the collective name for frequency modulation (FM) and phase modulation (PM).

3.9.5 Frequency modulation

In the transmission type F3E (also called FM), the frequency of the carrier wave varies in step with the amplitude of the modulating signal. The carrier wave will thus oscillate around a nominal frequency, i.e. frequency modulated. However, the carrier amplitude does not change during frequency modulation.

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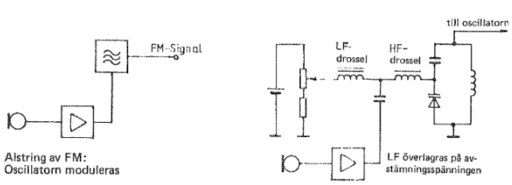

Figure 3.90:Generation of F3E (FM)

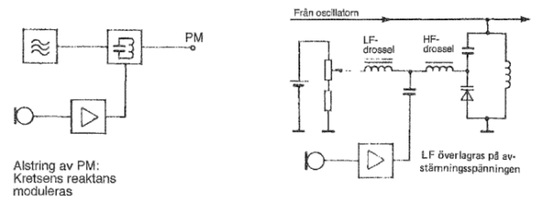

Figure 3.91: Generation of G3E (PM)

DC voltage levels can thus be transmitted because a frequency deviation (deviation) in the carrier wave is only affected by the amplitude of the modulating signal. At F3E, the resonant frequency of the resonant circuit in the oscillator, which determines its operating frequency, is affected.It is done most simply by adding a capacitor with a variable capacitance value, a capacitance diode (see section 2.5.3.2).

Figure 3.90 shows an LC resonant circuit that includes a capacitance diode controlled by a DC voltage with a superimposed modulating LF signal. A direct voltage serves as an adjustable bias voltage to the capacitance diode. In this way, the work frequency can be influenced. With the superimposed LF signal, the operating frequency is affected in step with the signal amplitude.

3.9.6 Phase modulation

In the transmission mode G3E(also called PM), the phase position of the carrier wave varies in relation to an unmodulated reference. However, the amplitude of the carrier wave does not change. The phase change – the deviation – is directly proportional to how quickly the phase position changes and to the total phase change.

The speed of the phase change is directly proportional to the frequency of the modulating signal and to its amplitude. This means that the deviation during phase modulation increases both with the amplitude and the frequency of the modulating signal.

Changes in DC voltage levels can therefore only be transmitted if a phase reference is used. Phase modulation can be produced, for example, by affecting the resonant frequency in a resonant circuit somewhere after the oscillator, i.e. where the oscillator frequency is not affected. This resonant circuit has the same resonant frequency as the oscillator in rest mode. When the circuit is brought out of resonance by modulation - at the same time as the oscillator signal is applied to the circuit - an inductive and capacitive reactance alternately arises in the circuit - this within the time of each half period. The reactance thereby creates the phase shift that entails phase modulation.

See also sections 3.1.17.1 and 3.1.17.2, images 3.18 and 3.19 Image 3.91 shows generation of G3E (PM). As with frequency modulation, for example, a capacitance diode can be used to influence the resonance frequency in a circuit with a modulating signal.

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3.10 Digital signal processing HAREC a.3.8

As development has made advanced circuits increasingly cheaper, it has become increasingly common to use various forms of digital signal processing, and these are also used to varying degrees in radio design. Often it is summarized with the term digital signal processing (eng. Digital Signal Processing (DSP)). Often that concept is confused with Digital Signal Processor (DSP), which has come to represent a type of processor adapted for signal processing. However, the concept is broader than that, and any other form of digital processing is also digital signal processing.

3.10.1 Digital filters HAREC a.3.8.1

Since a signal as it is represented for digital circuits must be sampled and quantized, the signal will inevitably consist of a number of samples with a certain number of bits for its PCM value. Changing the level of such a signal is done by multiplying it by some value, that is, letting each individual sample in turn be multiplied by the same value, but it does not change any characteristics of the frequency.

In order to have an impact with regard to frequency,Ωou need to combine the values from several different times in the signal, and oftenΩou choose to let them be weighed together with different weights. This is done by simply delaying the samples in several steps, multiplying each delay by its weighting constant and then summing the result.

The filter that was then created is called a Finite Impulse Response (FIR) filter, because ifΩou send a pulse to the input, it will be delayed step by step and give the response from each of the multipliers, in each sample, until the delay chain is over, whereby that impulse makes no further contribution to the outcome. The number of samples that came from the impulse is called the impulse response, and since it ends it is finite, hence the name.

You can do a variation of this whereΩou simply let another set of multipliers weigh the same delayed samples, but where the summed response is fed back to the input and added there before the delay chain. This is called an Infinite Impulse Response (IIR) filter, because, like FIR filters, it has an impulse response, but since it feeds back, this can theoretically continue indefinitely,that is, the English word for infinite.

In practice, filters are designed so that they do not run forever but, so to speak, ring out. However, the architecture itself is very suitable to use for many purposes.

In addition to the filter structure itself, i.e. IIR and FIR, they are characterized by how many delay stages there are, as this represents how complex the filter is, as well as by the coefficients that give the response of the filter. The design of filter coefficients differs markedly for IIR and FIR, and there are both simple and advanced tools for it.

A Special case of FIR filters is when the coefficients are mirrored around the center. ThenΩou can mathematically show that they have the property of linear phase (eng. linear phase filter), and they only have an effect on the amplitude. An advantage of such filters, which are phase-linear, is that signals of different frequencies experience the same group delay and thus are not shifted in relation to each other. Among other things, this usually increases speech clarity.

3.10.2 Fourier transform (FFT) HAREC a.3.8.2

A specific form of processing that has become available is the Fourier transform, that is, the ability to convert from signal strength over time to signal strength over frequency.

Since the processing takes place in discrete time, i.e. values with a certain time between them, as is inevitable with sampled values, it is a special case of fourier transform, which is therefore called discrete fourier transform (eng. Discrete Fourier Transform (DFT)).

DFT can be done on all possible lengths of sequences, but is computationally heavy ifΩou want all possible frequencies. To reduce the number of calculations,Ωou can of course calculate the DFT for only a few frequencies, but when it is not applicableΩou need to act a little smarter. The way DFT is formulated, the mathematics provides several shortcuts, which allowΩou to combine the calculations in several different ways and make sub-calculations that can be used by several other steps, thus reducing the computational burden. This can then be done hierarchically, so that a recursive form can be made. There are sevsay Fast Fourier Transform (FFT), which is also discrete.

A disadvantage of FFT is thatΩou often end up with even powers of two in the number of samples, for example 512, 1024, 2048, 4096 samples and frequencies. They have thereby sacrificed a little of the DFT generality. There are more advanced formulations of FFT that use some trick to smooth to more sizes, by not only combining 2 samples, but also 3, 5 and so on, which can then be combined to more sizes.

Another trick is to simply pad with only trailing zeros, and run with a too large FFT. No matter how the Fourier analysis is done, it allowsΩou to quickly get a spectrum. This is now used more and more often to get a spectrum plot and by putting several of these one after the otherΩou can get the now increasingly common spectrum histograms also known as waterfall plots as they resemble a waterfall with their vertical lines.

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3.10.3 Direct Digital Synthesis (DDS) HAREC a.3.8.3

A term that has gained momentum in recentΩears is Direct Digital Synthesis (DDS). This means that instead of indirectly controlling an oscillator as with a PLL,Ωou can directly synthesize a waveform, andΩou can do it with very high resolution and change it very quickly.

While it can be done in many ways, the dominant principle is to make an oscillator with a so-called phase accumulator (eng. phase accumulator (PA)).

Phase accumulator is nothing more than an addition stage followed by a delay stage. It is an extreme case of an IIR filter, with only one pole, which integrates, i.e. cumulative effect. The value out of this represents the phase of the oscillator, there by the phase accumulator. The frequency is simply controlled with a value that indicates how much the phase should be increased for each sample. The frequency therefore becomes completely linear, as when on the step resolution, and can be varied quickly and freely.

The resolution is therefore determined by how many bits wide the entire accumulator has. The highest frequency will be the

Nyquist frequency, i.e. half the sampling frequency,

and the lowest will be the one given by the least significant bit. The output phase from the phase accumulator itself is then wave-shaped into sine, cosine or whateverΩou wish.

It is also possible to use a lookup table to be able to synthesize arbitrary waveforms. Today, there are ready-made circuits that provide a very large frequency range with 32, 48, or more bit resolution. Not infrequently, DDS is used in combination with more classic PLL solutions to obtain good properties. DDS has created enormous freedom in how radio devices can be designed, and it has contributed enormously to both performance and miniaturization

4 Isolation and grounding

Isolation and grounding are collective terms for a number of important concepts for reducing disturbances, which also concern EMC and electrical safety. These are important concepts both when building an installation and when designing equipment. It also creates an understanding of how equipment is designed, which makes it easier to use it correctly.

4.1 Isolation

Isolation (eng. isolation) is a collective term for separating different signals. The first simple separation is that of an insulator, i.e. a material that does not conduct current very well. It is the most basic form of isolation that prevents electrical conduction between wires. People usually talk about galvanic isolation (eng. galvanic isolation) for an isolation that cannot conduct direct current.

Transformers are often used to achieve galvanic isolation. Now isolation is not limited to direct current alone, but alternating voltage may also need to be isolated. How good the isolation is depends heavily on the frequency, and the measuresΩou take should be adapted to how good the isolationΩou need or want for different frequencies.

For example,Ωou may want good isolation at the transmitter and receiver frequency of 14 MHz, but does not want galvanic isolation for the common 12 V power unit.

4.2 Grounding

Grounding (eng. bonding) or in everyday speech earth (eng. ground, earth) is a connection strategy to get the same reference potential in different parts of an electrical connection.

An earthing network (eng. bonding network(BN) [22, chap. 3.2.1] and earthing network) [22, chap. 3.1.3] is built to connect the various earthing points. The English term bonding and also bonding network gives an indication of what it's about, namely a method of connecting several different parts of a design or installation to get a common reference voltage. It is simply a galvanic connection. Many times that reference potential is called pre-earth potential because it is very convenient to use the earth as a reference, simply bury conductors in the ground, for example earth electrode (eng. earth electrode) [22 , ch. 3.1.2], for that way get access to the ground potential. However, the terms ground and grounding are often misunderstood as there is a superstition that one can take Z1 I1I1 + I2 + I3Z2 I2I2 + I3Z3 I3I3

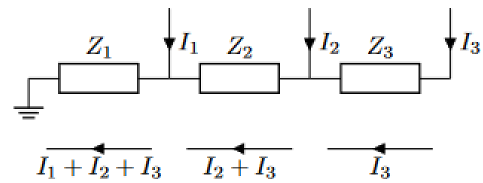

Figure 4.1: Series connected ground

system down disturbances with only grounding. It also happens that people feel that they have problems where the earth is perceived to create disturbances, whereby some mistakenly break the earth, and thus the protective earth, something thatΩou must not do for electrical safety reasons.

In the same way, many people believe thatΩou can get rid of a large alternating current in the earth . This is sometimes jokingly referred to as flower grounding, because the resistance and inductance of the earth conductor have not been taken into account, which means that an alternating current cannot travel as far as the conductor opposes it.Ωou could just as well putΩour earth connection in a flower pot because it is just as useful there.

In electricity, the term zero (eng. neutral) also appears, it can easily be confused with earth, but must be handled separately from protective earth, except where electrical safety regulations stipulate that they must be interconnected. The neutral is the conductor that is the return conductor before the current. In the most common TN-C electrical system, the neutral is connected to the protective ground in the power station, but from the power station it is handled as a separate conductor.Ωou must not connect them to save conductors!

The protective ground must have very little current on it, and thus also have a very low voltage difference from the ground potential, but in practice there will still be differences.

4.2.1 Series connection of ground

The simplest connection of the ground connection is to connect the ground in series [25, ch. 3] between a number of current consumers. This occurs, for example, in a series of electrical outlets fed from the same fuse or several electrical outlets in a junction box. In picture 4.1 that we have three current consumers that each contribute a current I1, I2 and I3, and that these are connected in series to an earth connection.

From the ground connection to the current contribution I1, we have the impedance Z1, and from that point we have the impedance Z2 up to the current contributions I2 and finally the impedance Z3 up to I3.

A naive interpretation is that the voltage U1 for the current contribution I1 becomes U1 = Z1I1, further U2 = (Z1 + Z2)I2and U3 = (Z1 + Z2 + Z3)I3 because that is what happens if each current is connected individually, i.e. normal141Z1I1Z2I2Z3I3

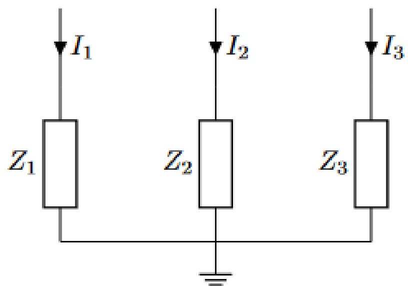

Image 4.2: Parallel earth system

series connection of the impedances. However, this analysis is too simple to take into account the case when the currents are connected at the same time, because currents and voltages will interact. The total current through the first impedance Z1 is the sum of the three currents, therefore the voltage must also be increased by that contribution. The first voltage therefore becomes U1 = Z1(I1 + I2 + I3). Similarly, the second voltage is calculated using both currents I2 and I3 plus the voltage U1 and therefore becomes U2 = U1 + Z2(I2 + I3). Finally, the final voltage becomes U3 = U2 + Z3I3. Simplifying, we get

U1 = Z1I1 + Z1I2 + Z1I3
U2 = Z1I1 + (Z1 + Z2)I2 + (Z1 + Z2)I3
U3 = Z1I1 + (Z1 + Z2)I2 + (Z1 + Z2 + Z3)I3

We then see that the disturbance becomes

∆U1 = Z1I2 + Z1I3
∆U2 = Z1I1 + (Z1 + Z2)I3
∆U3 = Z1I1 + (Z1 + Z2)I2

Which is a clear example of how the currents interfere with each other's voltages and thus have a lack of isolation. The advantage of series-connected ground is of course thatΩou get several short connections but, on the other hand, the summation of the different currents will result in poor isolation between the different earth currents and how the zero potential is experienced.

4.2.2 Parallel connection of earth

If we instead connect our three loads with individual conductors to earth, the different currents will not interact, this is a parallel connection of soil[25, ch. 3], see picture 4.2.

We have thus achieved isolation between the currents with regard to the ground connection. However, each current source will experience a shift in the voltage of its ground which depends on the specific current and the impedance it has to ground. To reduce this effect, a reduced current consumption can be used or, more often, an improved earth connection.

Of course, each current consumer can also have two earths, in parallel. The electric power system's use of both protective ground and neutral is just such a system, where the neutral is the one that has the current and is allowed to getZ1+−U1I1−+UutZsignalZload+−UinZ2+−U2I2

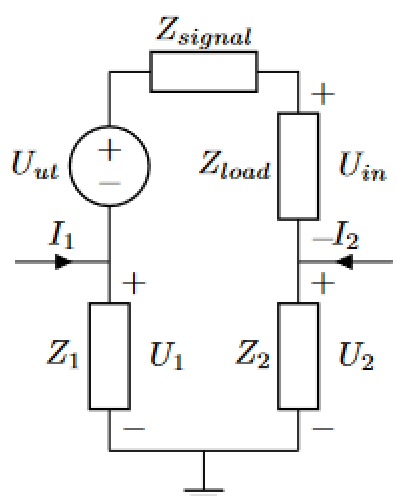

Image 4.3: Interconnected system

ride around in voltage, while the protective ground generally only has small currents. The function of the protective earth is also to be able to handle large currents in the event of a fault, in order to be able to interrupt the supply. The protective ground actually has that as its main purpose, but often provides a good ground reference. In devices and also inside circuit boards,Ωou can have a parallel connection. It is also known as star grounding (eng. star grounding) because the wiring diagram looks like having a star from a common point. It can be useful to isolate ground for analog signals from digital or purely from relays, PA and more. One tries to put the star directly at the connection to the power unit to keep them as common as possible but with as little influence of series earthing as possible. The same technique is often used for self-power distribution for the same reasons.

4.2.3 Connecting devices

In a system where the input has been earthed in parallel, picture 4.3, you now want to connect two devices to transmit a signal. A first naive solution is to simply run a Zsignal wire from one device over to the other. Since they have a ground connection, they have a common ground reference. The problem is that when the current I1 to the first device passes through the connection impedance Z1 to ground, it produces a voltage U1 = Z1I1 on that ground connection. Similarly, the second device will experience the earth with a displacement of the earth voltage of U2 = Z2I2. If the imaginary output voltage is Uut, the actual output voltage will be Uut +U1 in relation to ground. If we assume for the moment that no significant current flows through the conductor to the other device, it will experience it as an input voltage Uin in relation to its ground potential U2, i.e. Uin = Uut + U1 − U2. We see here that the difference in ground potential will shift it perceived input voltage Uin from the intended voltage Uut with the difference in earth potential, that is U1 − U2 which in turn depends on the impedance of the connections and the currents. The transmission may therefore have problems with its isolation of I1 and I2 to Uin.142Z1I1−+ UutZsignalZload+−UinZGN D Ziso2+ −U5Z2I2

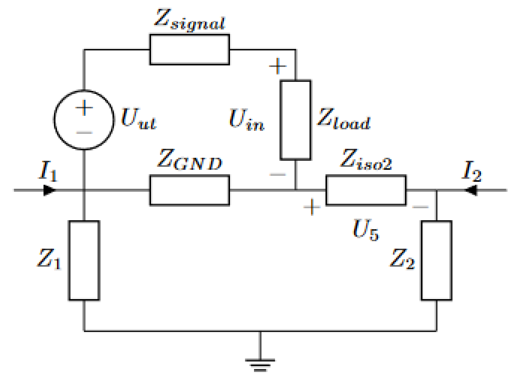

Image 4.4: Interconnected system with equalizing conductors

If both currents have no strong frequency content for the frequency band that is observed on the receiver, then however, this works fine. Not infrequently, however, the isolation happens to become a concern either directly or because it interferes with the function indirectly. An attempt to reduce the interference is, of course, to try to reduce Z1 and Z2 by making the resistance smaller, for example through shorter cables or thicker cables. This works, of course, but only up to a certain practical limit. This illustrates the basis of how ground hum (eng. hum) usually occurs when two devices are connected together. The ground hum itself comes from the power units, and when their currents share a circuit with the utility signal, crosstalk will make the hum noticeable. There are, of course, many ways for hum to interfere with a signal.

4.2.4 Isolated grounding

A strategy for creating isolation from the ground path is to simply isolate the signals and their ground from the ground of the power supply, this is called isolated bonding (eng. isolated bonding also isolated bonding network (IBN)) [22, ch. 3.2.4].Ωou suddenly start talking about protective ground separately from signal ground (eng. signal ground). In devices with alternating current supply,Ωou already have a transformer that provides a galvanic isolation between the primary side (electric power) and the secondary side (electronics). By simply keeping the signal ground floating (eng. floating), i.e. without any galvanic connection to protective ground,Ωou can instead connect signal ground on two devices with separate conductors ZGN D . In picture 4.4, the insulation of the receiving device is represented by

Ziso2, where the voltage U5 represents the voltage between the primary and secondary sides. Similarly, the isolation on the side of the transmitting device can be modulated as Ziso1, but for this reasoning, Ziso2 is sufficient. The galvanic separation means that the isolation for direct current can vary from megohms to gigaohms, but due to the capacitive coupling between the primary and secondary side in the transformer, the isolation drops by increasing frequency. In practice, due to its imbalance, the transformer can drive the voltage U5 and therefore it may be necessary to load the descapacitative source with a resistor, whereby Ziso2 can rather be in kiloohms. If we return to both devices, instead of using of the mains protective ground let the signal ground of the devices be connected with a cable ZGN D parallel to the signal conductor Zsignal. If we have a relatively low current through the impedance of the cable, it will work fine and Uut will be represented reasonably well as the voltage Uin over Zload. Since ZGN D can be a few ohms while Ziso2 for low frequencies is in the order of megaohms, the cable will connect well. For higher frequencies we can expect that the inductance in the cable increases the impedance ZGN D while the capacitance causes the impedance Ziso2 to drop, therefore at higher frequencies Zload will be more connected locally to Z2 rather than Z1. This scenario is similar to, for example, that of a normal home stereo andΩet there may be earth b-room in this connection. There are several reasons. One reason is that transformers do indeed offer galvanic isolation, but they are also capacitive voltage dividers for the voltage that is across the primary winding, with 230 VAC voltage, it only takes a little leakage to feel that the insulation is breaking. It is usually advisable to simply load this voltage divider with a resistor, so that the signal ground and protective ground are connected with a reasonably high resistance, often with a capacitor in parallel, to ensure that it is reducedthe contribution horn to get too much interference from the current that will flow between the earths. Another scenario that creates earth hum is when at some endΩou happen to hard connect the signal earth and protective earth, typically that there is accidental contact with the chassis, which should be protectively earthed. The chassis itself is usually referred to as chassis ground, but it is actually only protective ground on most systems. For isolation grounding to work, all contacts must be isolated from the chassis. This also applies to signal earth, which must not have contact with the chassis inside the device.Ωou therefore need to make sure there is enough insulation distance, which can very easily be missed ifΩou have a screw that accidentally scrapes through protective varnish, for example. Another disadvantage of insulation grounding is that it makes it more difficult to design for good EMC tightness. For conductive interference (eng. conductive emission) thenΩou prefer that the shield of the connector and the cable sits in the chassis ground with as low an impedance (inductance) as possible. Isolation grounding then requires the installation of capacitors that connect the ground of the conductor with chassis ground and preferably all around to get the lowest inductance.143Z1I1−+ UutZsignalZload+−UinZGN D+ −UGN DZ2I2

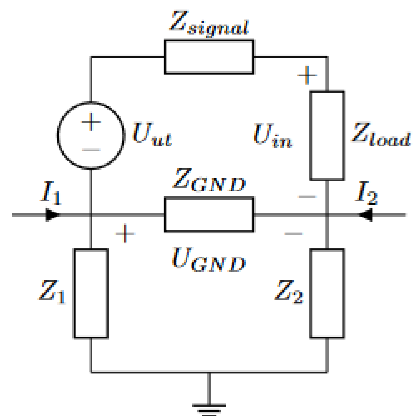

Image 4.5: Interconnected system with equalizing conductors

Isolation grounding is not recommended for larger systems, as it becomes difficult to maintain .It happens that in order to reduce the disturbances in an insulation-grounded system, one chooses to disconnect the protective ground, in order to have less disturbances that way. This is usually not allowed to be done as one normally does not violate electrical safety rules and the installation risks becoming dangerous, as personal protection is compromised." indicates that an incorrect solution has been chosen.

4.2.5 Connected grounding

Another strategy is connected grounding (eng.mesh bonding and mesh bonding network (mesh-BN))[22 , ch. 3.2.3] where instead of isolating sets to connect the earths, hard. Each signal cable is connected to the ground and thus the earths are connected to each other. Cables are laid on cable ladders that connect the earths more tightly ,becauseΩou connect many impedances in parallel. This strategy is often chosen in telecommunication systems. In a system that has connected earth,Ωou will inevitably have to deal with what is called an earth loop (eng. ground loop) or even vagrant earth currents. Many times it is explained thatΩou get a loop that acts as an antenna for a magnetic field. However, it is rare that a magnetic field is so strong that it induces several amperes of ordinary 50 Hz current. If we go back to the connection of devices (chapter 4.2.3) where we got a difference of voltage UGN D between the ground points, we will also have here, but now we connect a wire ZGN D between these points, and then there will be a current that tries to equalize the potential between the two earth connections, which will then come closer to each other. It is the impedance ZGN D on the cable that will determine how large the current will be and how close they will be to each other in terms of voltage. This current can be considerable, and ifΩou have a cable that has, for example, a thin shield, the cable will simply get hot. It is therefore advisable to lay an earth cable parallel to the signal cable, to let it, with its larger cross-sectional area, take most of the current, and thereby avoid heat and current in the signal cable. With a larger cable between, the voltage will drop and that way the earth hum will be reduced. The advantage of interconnection of earths is that it becomes easier (and cheaper) to design from an EMC perspective, whenΩou directly connect the earth currents to the chassis.Ωou also don't have problems with accidentally earthing or losing the only earth path. Instead,Ωou try to connect the grounds well. A common problem is ifΩou let the ground currents go through circuit boards, which causesΩou to create local problems with series grounding. It must be ensured that the ground currents are tightly connected to the chassis, but weakly through the card in order to obtain the best possible isolation that way. This principle is also suitable for dealing with, for example, ESD damage. Another advantage is thatΩou build a habit of grounding everything, and for each additional groundingΩou make the system stronger. on the equipment and the installation.

4.2.6 Balanced signal

In order to obtain additional isolation from ground hum, a balanced signal can be used. The basic principle is thatΩou send the same signal twice, but with reversed sign, and then receive it and just look at the difference between them. Should a disturbance introduce itself on these conductors together, it affectsthis is not the difference in voltage between them. We have already done similar and tried to imitate the properties, because already when we sent a signal on a simple conductor, we send a voltage in relation to a reference voltage and we look at the incoming voltage in relation to the reference voltage. However, we have had trouble having a good common one, and it is obvious that we usually observe the difference in voltage. With a balanced signal, we take the step fully and separate the zero reference from the signal and send a signal whose sum is a fixed voltage while the difference is the useful signal. It is as if the signal is neutral. Often, however, for practical reasons, the signal is offset in terms of voltage. The balanced signal has ground, plus pole and minus pole. The positive pole is also called +, positive polarity,144Z1I1−+ Uut−+ UutZsignal+Zload/2+−Uin+Zload/2+−Uin−Zsignal−ZG N D Ziso2+ −U5Z2I2

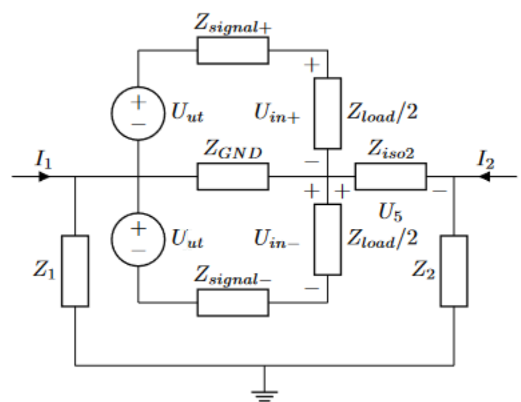

Figure 4.6: Connected system with equalization conductor and differential signal unit (eng . positive pole, positive polarity and hot) while the minus pole is also called -, negative polarity, cold (eng. negative pole, negative polarity and cold). In addition to these,Ωou usually have a voltage reference which is often referred to as earth (eng. ground (GND)) or zero (eng. neutral). Figure 4.6 shows how the output voltage Uut is doubled and feeds on each side of the ground potential that I1 and Z1 provide. Both output voltages are connected over each conductor Zsingal+ and Zsingal− in order to over each Zload/2 result in Uin+ and Uin− respectively, which in turn are connected to the signal ground in the same way as before. The actual input voltage is from U+ to U−, i.e. Uin = U+ − U− = Uin+ + Uin− Transformers are well suited for both generating and receiving balanced signals, as they have single galvanic isolation for common voltage but trans- forms the differential voltage. This can also be done with active electronics so that the op-amp arm also has ready-made circuits.

Transformers have the advantage thatΩou can get the galvanic difference by simply breaking the earth connection on the conductor. However, transformers do not have perfect isolation but, on the other hand, can often handle fairly large voltages, which can require difficult connections. For RF, however, transformers are not balanced and provide poor isolation. Improved isolation in transformers can be achieved with one or two shield layers between the windings. The shield layers can be connected to the ground of each side. For RF, however, a current balun/RF choke is required to suppress the common current .Active electronics for balancing rarely have galvanic isolation, but on the other hand, high impedance can be maintained for the common voltage, which may be sufficient. Differential signal in RF can be achieved by using an RF choke that suppresses the common the voltage in RF but not in DC voltage.−+ UgVut+−+ Ud/2−+ Ud/2Vut−Zsignal+Vin+Zd/2+−Ud+Zd/2+−Ud−Vin−Zsignal−ZGN DZg+−Ug

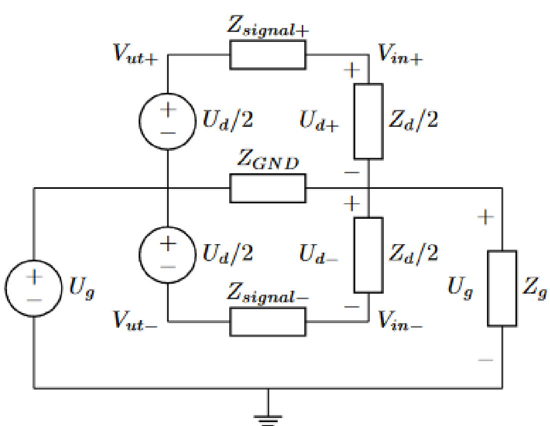

Figure 4.7: Connected system with equalization conductor and differential signal

4.3 Common and differential voltage and current

WhenΩou have a three-wire system like we have with differential supply or even ifΩou only have two conductors but between systems that have a common ground (also applies if they only have RF connection one way) then one can consider the two signal conductors either as having their individual voltage and current, or as having common and differential voltage and current.

4.3.1 Common and differential voltage

Common voltage and differential voltage is an alternative way of considering voltage on the coil conductors, whereΩou divide the voltage into what is common to both voltages and what separates them.Ωou can therefore consider them in this alternative and independent (orthogonal) way. In picture 4.7,Ωou have the common voltage source Ug, which replaced the displaced earth points in previous examples. The differential voltage Ud, that is, the driving voltage between Vut+ and Vut− is distributed over two voltage sources that supply half the voltage each. Vut+ = Ug + Ud2Vut− = Ug − Ud2 Conversely, the expressions for the common voltage Ug and the differential voltage Ud can be formulated as Vut+ and Vut−:Ug = Vut+ + Vut−2Ud = Vut+ − Vut− Correspondingly at the input,Ωou can write the expressions for the common received voltage145Ug,in and the received differential voltageUd,in based on the input voltages Vin+ and Vin−,Ωou then get Vg,in = Vin+ + Vin−2Vin+ = Vin+ − Vin− One way to illustrate the difference is, for example, with a transformer. A transformer with 1:1 winding is connected between two balanced signals. The primary winding of the transformer will convert the differential voltage Vd into a corresponding voltage at the output. However, the common voltage will not be transferred. The transformer then becomes an insulator for the common voltage exactly as we expect from a galvanic isolation. The isolation for the common voltage in a transformer is, however, primarily adirect current behavior, so the higher the frequency, the better the coupling, i.e. the worse the isolation. This is due to the capacitive coupling between the windings which creates a single current, which connects the sides and results in the common voltage still passing through the transformer. For higher frequencies, the coupling is very good and the transformer does no good to suppress the common voltage. Since the utility signal is differential, manibland can deliberately use the common voltage to transfer supply voltage to, for example, the microphone. This form of supply voltage is called phantom power. A commonly used voltage is 48 V, which is then symbolized with P48. It also occurs on modern Ethernet equipment and is then called Power overEthernet (PoE).

4.3.2 Common and differential current

Just like voltage, the currents in the same conductor can be described as common and differential current. We can therefore reuse the formulas and simply replace V with I throughout and then get: I+ = Ig + IdI− = Ig − IdIg = I+ + I−2Id = I+ − I−2 If we return to the transformer example, it will be the differential current on the primary winding which gives rise to the magnetic field in the transformer and which then induces a differential current in the secondary winding. The insulation between the windings prevents a current from flowing between them, and therefore the common current is prevented at low frequencies. At higher frequencies, however, the capacitive coupling between the two sides will occur whereby a common current will arise for higher frequencies, that is to say for higher frequencies the isolation will be worse. An interesting special case is if we put a ring core on our cable, winding the cable several turns through it, or just wrap it around air. Then current in one conductor will induce a current in the other conductor and vice versa. This connection can be broadly compared to turning a 1:1 transformer 90 degrees wrong. Since the induced current has the opposite direction, it will counteract the common current, but not the differential current. In addition, this coupling will be stronger for higher frequencies (in the fine theory) and thus create a higher isolation for common current. This is called, among other things, RF-choke (eng. RF-choke) and current balun (eng. current balun). It supplements the isolation of a transformer or solves the necessary isolation completely on its own. RF-choke is an extremely useful tool for suppressing RF radiation and what is often called in EMC context conductive radiation, which is a common current out on the conductors. That it is the common current is easily understood because the differential current from both conductors will counteract each other in a radiated magnetic field while the common current interacts and therefore it is only the one that gives a radiated magnetic field. This is whyΩou often find lumps sitting on cables for example screens. These lumps are simply a ring core that reinforces the coupling between the conductors to suppress the RF common current and thus reduce interference.

4.3.3 General common and differential analysis

After studying common and differential voltage (chapter 4.3.1) and common and differential current (chapter 4.3.2) we can conclude in summary that the basic method of converting the individual voltages and currents to common mode (common mode (CM)) and differential mode (differential mode (DM)) is a powerful method both to understand and remedy problems and achieve isolation. For voltage we have the equationsV+ = VCM + VDMV− = VCM − VDMVCM = V+ + V−2VDM = V+ − V−2For current we have the equationsI+ = ICM + IDMI− = ICM − IDMICM = I+ + I−2IDM = I+ − I−21464.

4.3.4 Common and differential impedance

Just asΩou have impedance on inputs, so do the same on inputs in three-wire systems. What is the normal impedance for a transmission conductor, for example, is actually the differential impedance, that is, the ratio between the differential voltage and the differential current. The common impedance is in the same way the ratio between common voltage and common current ZDM = UDMIDMZCM = UCMICMActually, it is not so strange, ifΩou have a single coaxial cable in a 50 ohm system, the transmitter and receiver ideally have 50 ohms as differential impedance. In a system that has isolated grounding then the total impedance can be many megohms or higher, because it is isolated.

4.3.5 Imbalance

So far we have mainly assumed that we have balance, that is, that transformers, inductors and more are ideal and give equally good coupling to both sides. Of course, this does not exist in reality, andΩou have an imbalance.In the event of an imbalance, a signal that is common leaks over to the one that is differential and vice versa that the differential leaks over to the common one. This results partly in reduced isolation and partly in reduced signal. In general, the reduced insulation is worse than the loss of signal, which is generally negligible. In a transformer, the windings are often arranged so that the capacitive coupling from one pole of a coil is stronger than from the other pole. It therefore creates an imbalance in how they couple capacitively. By placing a screen layer between the windings, the capacitive coupling can be evened out, then capacitively couple to the screen layer instead, which can have low resistance to prevent connection. An even better solution is to have double layers with insulation, because then it could be connected to the earth of each side, and the capacitive connection between the earths remains, which is usually less of a problem. With these methods, better isolation can be obtained than what an unshielded transformer can offer, due precisely to imbalance. The capacitive coupling has a very high impedance at 50 Hz, soΩou can use relatively high resistance values to load it down hard. The advantage is thatΩou can avoid direct connection, which can create other problems such as whenΩou want relative galvanic isolation. In a current balun, one conductor can have slightly longer turns around the core than the other. It did not create a perfect 1:1 relationship in the connection and thus an imbalance. In a transformer with a center pin, the center pin can be slightly offset from the true center, so that the connection of the center pin to earth creates an imbalance. These examples of defects in the construction should be aware of, so that one does not attribute a transformer or current balun to having the properties of a perfect isolation. Rather,Ωou should expect that it is not perfect and adjustΩour design accordingly. Many times, a combination of measures can give satisfactory results without being particularly expensive or clumsy, but it requires thought and a holistic view. A simple case in the audio context is 50 Hz 230 V, butΩou want to keep the disturbance less than, say, 1 mV. This requires more than 106 dB isolation between 230 V differential on the primary winding and 1 mV common on the secondary winding. Such a good balance can be difficult to find in individual components. The principle will be repeated regardless of voltage and frequency, it is a shortcoming thatΩou need to learn to understand and deal with.

4.3.6 Imbalance in antenna systems

Imbalance can also occur in antenna systems, where an unbalanced antenna converts the transmitted signal, which is differential, to partially become common. This means that, via reflection from the unbalanced antenna, a current enters the supply line, causing it to radiate. This has traditionally been expressed as the current turning and going on the outside of the screen, but what has happened is that the differential current, which counteracts radiation, suddenly gets an imposed give-together component which will then radiate.Ωou can experience it ifΩou touch the wire,Ωou can feel it as a current, whichΩou experience going on the outside. The cable has then become a radiant part of the antenna, something that for some antenna types is a conscious design. It is also this current that needs to be counteracted so that the operator does not injure himself. This is done with the current balun, preferably a quarter wave down from the connection to the antenna. The current balun counteracts the common current without significantly affecting the differential, so it is a fine example of a good measure. The vast majority of antennas have a different impedance at the feed point than what its feed line has. This requires an impedance matching for optimal energy transfer. Another aspect is that for a coaxial feed, the energy is transmitted single-ended, that is to say, it is the center conductor in relation to screen/ground that transmits energy. When we connect this conductor to a dipole antenna, we want to make sure that the current goes out balanced in both conductors, so that the mid-point is close to zero, so that a current with common mode does not go out into the feed line. -rad signal to balanced and suppress the common signal in the conductor, and to that the impedance converter. This is usually done by a balun (balanced-unbalanced), which as the name indicates only gives an indication of the conversion, but it does several things. Since no balun is perfectly designed, it will inherently have an imbalance, whereby it will still provide some common current. For higher effects, a separate barrier may therefore be needed. In addition to the balun, there is also the unun (unbalanced-un-balanced), which does impedance conversion only. Even ifΩou have a good balun,Ωou run the risk of getting sheath currents, because the antenna can also be of an unbalanced type, for example Off-Center-Feed(OCF)/Windom, or because it connects different with the environment such as trees and towers and more.Avoiding common current, also known as sheath current, can be required for many different reasons, and it is important partly to get energy out where it should, i.e. radiated into the air in a correct way, but also for safety reasons so that equipment is not - or personal injury occurs

5 Receiver

5.1 Receiver

The energy in the electromagnetic magnetic fields, which are around, generates high-frequency currents in all metal objects. To effectively capture these fields, antennas are used. Although the energy in the fields can cause a lamp to illuminate if the transmitting antenna is close enough, the farm still cannot perceive the information that the fields can also contain. Because a radio receiver is needed to partly amplify the usually very weak signals and partly interpret the information in them. The easiest way to listen to amplitude modulated broadcasts on medium wave is with the help of a detector receiver. Especially during the dark hours of the day in winter,Ωou can hear foreign broadcasters with this simple receiver, let alone that the hearing jewel is weak. In the detector receiver, field energy is converted into electricity and then into sound. As long as no amplifier is used, no other energy is consumed than that captured from the fields - the radio waves.

5.2 Straight receivers HAREC a.4.1.2

5.2.1 Receiver with crystal detector

The detector receiver consists of a very small number of components. Principle and working methods can be seen in figure 5.1. The same principle is also used in more complicated receivers, measuring instruments, etc. The antenna circuit consists of an antenna, ground and in between an inductor (coupling coil), which transfers the energy from the antenna to a resonant circuit. The resonant circuit is used to select a carrier wave with the desired frequency. The carrier wave cannot of course be heard, but the shape of the curve in the picture shows that the carrier wave is amplitude modulated with an LF signal. To recover the LF signal, a so-called demodulation is performed using the diode. The diode cuts off either the positive or negative half-waves in the received signal, depending on how the diode is reversed, polarized. The capacitor, which is connected in parallel across the earphone, smoothes the high-frequency voltage peaks to an amplitude average (compare with single-stage mixers in Chapter 3.5). This voltage value varies in a way that corresponds to the modulating voltage in the transmitter that comes

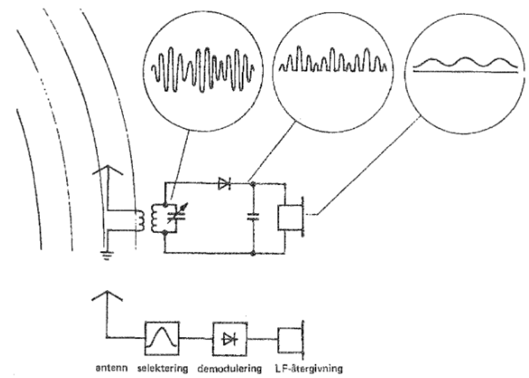

Figure 5.1: Detector receiver

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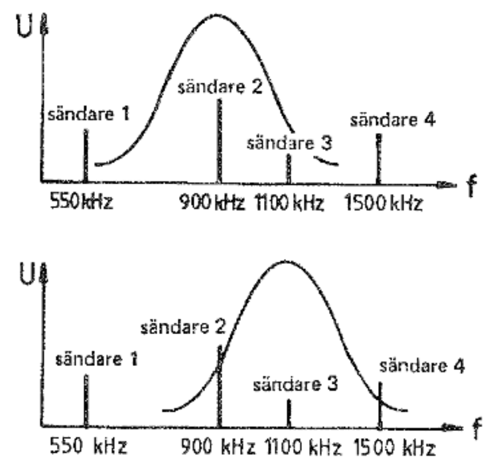

Figure 5.2: Selection in detector receiver

of speech, music, etc. We have now demodulated the carrier wave, restored the LF signal and can hear it in the receiver. The signal voltage across the resonant circuit is greatest when its resonance frequency and the frequency of the antenna current are the same. At the top of picture 5.2Ωou can see that the receiver is set to the same frequency as transmitter 2. Transmitter 3 is also heard because the bandwidth in the resonant circuit is large. At the bottom of the picture, the resonant circuit is tuned to transmitter 3, butΩou can also hear transmitters 2 and 4. The bandwidth in the resonant circuit becomes smaller the less it is loaded, that is, attenuated. In picture 5.1, the load consists of the antenna (via the coupling coil), the earphone and the decoupling capacitor (via the diode). Less load can be achieved in two ways; partly with a "looser" connection between the antenna circuit and resonant circuit and partly with better impedance matching between resonant circuit and diode. Both methods are applied in Figure 5.3. How the selection can be improved is shown in figure 5.5, which should be compared with figure 5.2.

5.2.2 Detector receiver with amplifier

IfΩou want to hear the transmissions over loudspeakers, a higher power is needed than what can be picked up through the antenna. For this purpose, an LF amplifier is used, which is powered by another energy source, for example a battery. The LF amplifier can also reduce the load on the resonant circuit. In picture 5.3, an LF low-pass filter has been inserted after the HF decoupling capacitor. It attenuates LF signals with a higher frequency than is needed for good reception.

5.2.2.1 Receiver with better HF characteristics

One way to reduce the bandwidth in a detector receiver is to connect several resonant circuits with the same frequency one after the other, as illustrated in Fig. 5.4. The greater attenuation of several circuits can be compensated with an HF amplifier. Such receivers are used for special purposes, for example for monitoring a single frequency. In such cases, the resonant circuits are fixedly tuned. Perhaps even a quartz crystal is used as a filter for that particular frequency. See figure 5.6 about high selection. 150

5.2.3 Detector receiver and transmission type

In the main, the detector receiver only works with amplitude modulation. This means the transmission types A3E and A2A, i.e. amplitude-modulated telephony and tone-modulated telegraphy, both with full carrier wave. In contrast, the detector receiver does not work with A1A, i.e. telegraphy with only carrier wave. Namely, monomodulated carrier only produces a direct current in a detector receiver. When keying, clicks are only heard in the handset at the beginning and end of the character parts, as illustrated in picture 5.7. The detector receiver also does not work with J3E, that is, SSB and other types of transmission with a suppressed carrier wave. Namely, sound as speech is strongly distorted in a J3E signal because the carrier component is missing. In both of the above-mentioned cases, the speech can be restored with the addition of a carrier wave.Finally, transmission types that involve frequency and phase modulation cannot in principle be demodulated with detector receivers.

5.2.4 Receivers with direct frequency mixing HAREC a.4.2.2, a.4.3.2, a.4.3.3, a.4.3.6, a.4.3.7

In order to demodulate A1A and J3E in a straight receiver–detector receiver, it must be supplemented with the oscillator that produces an internal carrier. This is mixed with the received signal. A beat frequency (eng. beat frequency) then occurs. Hence the name Beat Frequency Oscillator (BFO). The procedure has given the receiver type its name - direct mixed receiver. A way to supplement the straight receiver with BFO is shown in figure 5.8. When the BFO is connected and set to a frequency close enough to the reception frequency, an audible tone is produced. The demodulator diode is thus supplied with two HF signals, partly from the antenna and partly from the BFO. These two signals are mixed in the diode and the difference frequency is the audible tone. Other mixing products are attenuated by a low-pass filter.

5.2.4 Receivers with direct frequency mixing HAREC a.4.2.2, a.4.3.2, a.4.3.3, a.4.3.6, a.4.3.7

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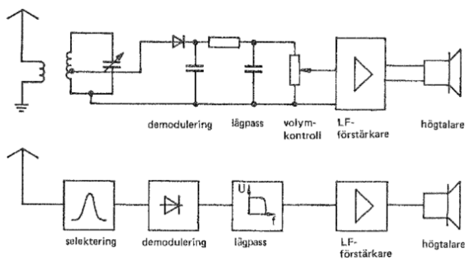

.Figure 5.3: Detector receiver with LF amplifier151

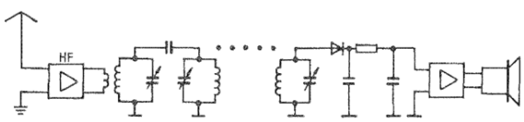

Figure 5.4: Improved HF characteristics in detector receiver

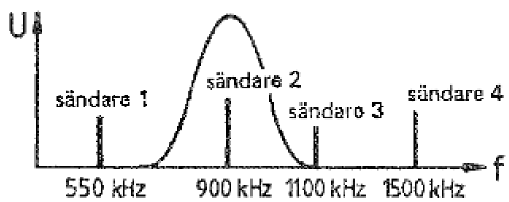

Figure 5.5: Improved selection

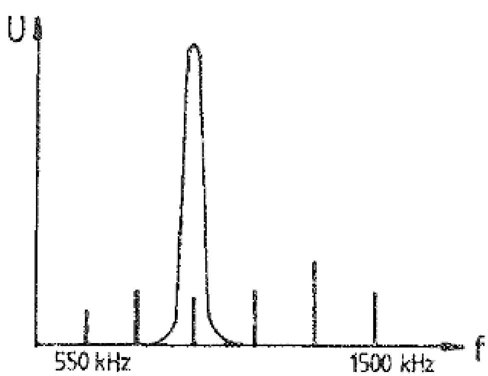

Figure 5.6: High HF selection

5.2.4.1 Reception of telegraphy (CW)HAREC a.4.2.1

Figure 5.9 illustrates mixing of CW signal and BFO signal for a number of cases. When the BFO (VFO) is set to the frequency f2 =1831 kHz and the received signal f1 has the frequency 1830 kHz, a hovering tone is heard with the frequency 1000 Hz. The same result is obtained if the BFO is set to the frequency f2 = 1829 kHz. With the BFO at the frequency f2 = 1830 kHz, nothing of the signal f1 = 1830 kHz is heard from the transmitter. The frequency difference is zero hertz. With the BFO at the frequency f2 = 1849 kHz, almost nothing of the signal f1 = 1830 kHz is heard from the transmitter, as the mix product 19 kHz is barely audible. Most people prefer a tone with a frequency of about 800 Hz for reception of telegraphy. BFO frequency hill in that case is set to 1830.8 or 1829.2 kHz if f1 were a telegraphy transmission.

5.2.4.2 Reception of J3E (SSB) HAREC a.4.2.3

When an SSB transmitter is said to work for example on the frequency 1835 kHz, then it means the frequency of

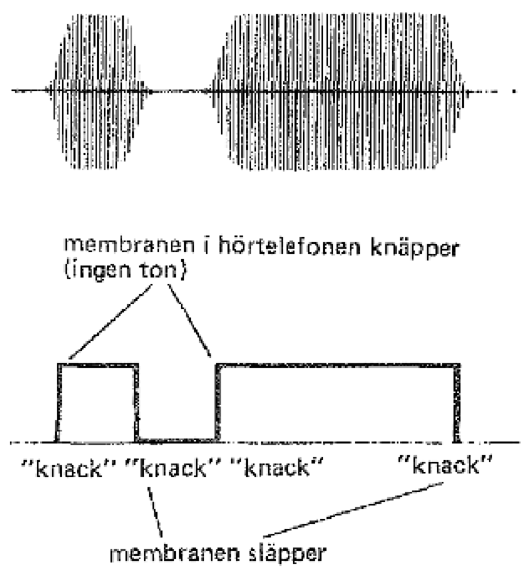

Figure 5.7: CW in the detector receiver

the carrier wave that has been suppressed in the transmitter already before the transmission. What is perceived by the receiver's input circuitry is thus the transmitted sideband. When an SSB signal is demodulated, the local carrier wave in the receiver is mixed with the received modulation products. During the mixing, mixture products are created which consist partly of LF and partly of other higher frequencies which are attenuated in a low-pass filter. Figure 5.10 illustrates a suppressed carrier wave of 1835 kHz and its lower sideband LSB extending from 1832 kHz to 1834.7 kHz. The demodulated sideband extends from 300 Hz to 3 kHz. In amateur radio, the lower sideband is used for SSB at frequencies below 10 MHz. With a frequency of, for example, 1835 kHz and a speech spectrum of 300–3000 Hz, the lower sideband will be between 1834.7 and 1832.0 kHz. Three modulating frequencies 300, 1000 and 3000 Hz are shown in the picture. With a carrier frequency of 1835 kHz, the demodulating frequencies correspond to the output frequencies 1834.7; 1834 and 1832 kHz. The VFO replaces the SSB transmitter's carrier wave and must have the same frequency – 1835 kHz – to be able to reproduce 300, 1000 and 3000 Hz.152

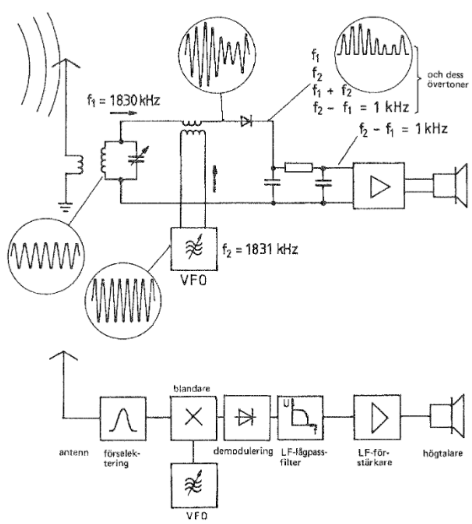

Figure 5.8: Receiver with direct frequency mixing

5.2.5 The selection in direct mixed receivers

Direct mixed receivers can be seen as a type of detector receiver, also called a "straight" receiver . The term "straight" comes from the fact that the HF signal from the antenna passes through a selective circuit and a possible HF amplifier straight to the detector, without the frequency being converted. In a detector receiver, the bandwidth is usually quite large.Several transmitters are therefore heard at the same time. Because the mixing diode in a direct-mixed receiver also functions as an AM demodulator, all transmitters are actually heard within the pre-circuit's bandwidth. This can be avoided to some extent by changing the diode, which functions as a single-phase mixer, to a counter-phase mixer or, even better, to a ring mixer. Such mixers suppress the input frequencies and only let through mixing products. Only the transmitter signal is then heard, the frequency of which, together with the VFO frequency, gives mixing products that fall within the passband of the LF filter. The receive frequency is the VFO frequency. The resonant circuit acts as an adjustable pre-selector and the LF low-pass filter provides the actual frequency selection. Which HF signals form mixing products with the VFO frequency and which of these then pass through the low-pass filter after mixing down to LF level? Example: A CW transmitter with an 1830 kHz fre -quence is received by setting the receiver's VFO to the frequency 1829.2 kHz. A tone with a frequency of 800 Hz then comes from the mixer output. But the transmitter is not alone on the tape. Will, for example, the SSB transmitter on 1835, which is modulated with 300, 1000 and 3000 Hz, interfere with the reception? See picture 5.11. The pre-circuit in the receiver is so wide that this transmission passes. The SSB transmitter's signal frequencies in the transmitted sideband are 1834.7; 1834.0 and 1832 kHz. These frequencies are mixed with the receiver's VFO frequency 1829.2 kHz and produce the mixture products 5.5; 4.8 and 2.8 kHz. Since the low-pass filter in the receiver's LF amplifier has a bandwidth of 0-3000 Hz, only the 2.8 kHz mixing product will be disturbing. To improve CW reception, the low-pass filter can be replaced with a bandpass filter, which only lets through a narrow frequency range around the center frequency of 800 Hz.153

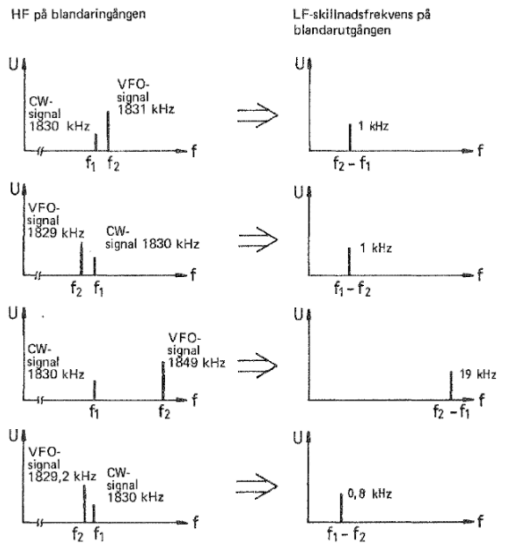

Figure 5.9: Demodulation in receivers with direct frequency conversion – CW signals

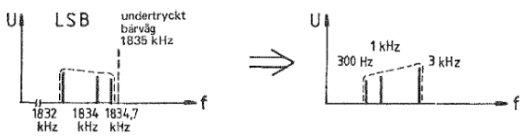

Figure 5.10: Demodulation in receivers with direct frequency conversion – SSB -signals

5.2.6 Passband and mirror frequencies

in direct mixers In the example in the previous paragraph, the problem with a single disturbing tone was solved with a bandpass filter with a different frequency response. But what frequencies can be received through a low-pass filter, 0-3000 Hz, if the VFO frequency is, for example, 1829.2 kHz? Experiment: Change the frequency of a CW transmitter slowly from 1820 to 1840 kHz. See picture 5.12 The transmitter frequency 1820 kHz can hardly be heard because the mixing product has a frequency of 9.2 kHz and it is greatly attenuated by the low-pass filter. Only when the transmitter frequency is 1826.2 kHz is a clear tone heard with the frequency 3000 Hz. IfΩou continue to change the transmitter frequency, the frequency of the tone drops to zero (floating zero), when the transmitter frequency is equal to the receiver's VFO frequency 1829.2 kHz. IfΩou now continue to raise the frequency, the frequency of the mixture product becomes higher again. At transmitter frequency 1832.2 it is 3000 Hz. At an even higher transmitter frequency, the mixing product is again attenuated by the low-pass filter. The conclusion of the experiment is as follows: With a direct-mixing receiver with the VFO frequency of 1829.2 kHz and a 3 kHz low-pass filter, every transmitter that has a transmission frequency between 1826.2 and 1832.2 kHz becomes audible, whereby the mixing product has frequencies from 3000 Hz, down through zero and up to 3000 Hz again. Our receiver has a bandwidth of 6 kHz. Any other transmitter within this passbandwidth will154

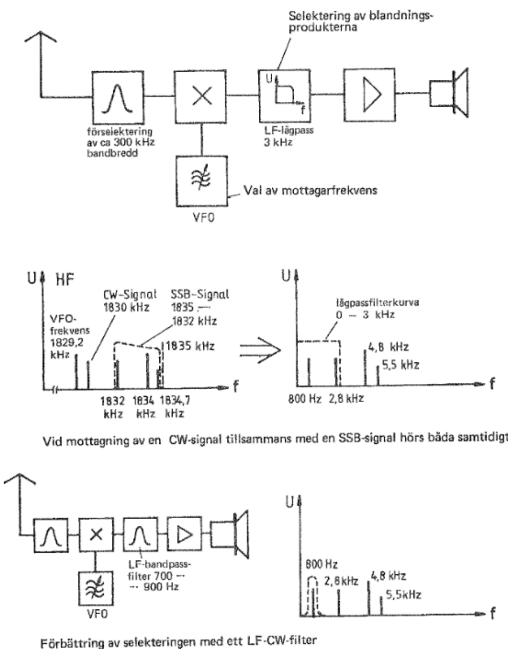

Figure 5.11: The selection in direct mixed receivers

be heard or - ifΩou think so - interfere with the reception. Back to the example of the bandpass filter. What frequencies can be received with a bandpass filter 700-900 Hz (center frequency 800 Hz), if the VFO frequency is 1829.2 kHz? Well, we can listen quite undisturbed to our CW transmitter's 800 Hz tone on the frequency 1830 kHz. Nevertheless, another transmitter with the frequency 1828.4 kHz can disturb the reception because this is a mirror frequency (eng. mirror frequency) to the reception frequency 1830 kHz. At the VFO frequency of 1829.2 kHz, a mixed product occurs, not only at the transmitter frequency of 1830 kHz, but also at 1828.2 kHz. This second transmitter frequency, like the useful frequency, also passes through the bandpass filter. Mirror frequency reception is a fundamental disadvantage in receivers with direct mixing. The useful and mirror frequencies in the latest example are 1.6 kHz (2 · 800 Hz) apart, i.e. double the value of the center frequency of the bandpass filter. In SSB reception, of course, the entire LF range up to 3000 Hz must be able to pass through. In addition to the desired frequency range of 1832–1835 kHz, mirror frequencies in the range of 1835–1838 kHz will also be able to be received. With an LF bandwidth of 3 kHz, the directly mixed receiver thus has a bandwidth of 6 kHz, which is a good tuning sharpness in comparison with the 300 kHz wide pre-circuit.

5.2.7 Pros and cons of direct mixer

Simple structure, but despite that a good sensitivity and decent tuning sharpness. The VFO can also be used to control a transmitter.Mirror frequency reception is unfortunately unavoidable.Furthermore, signals from strong transmitters can radiate into the sensitive LF amplifier and cause LF detection, if the receiver is inadequately shielded. However, improved isolation between antenna and VFO can be obtained with HF amplifiers.155 Single-stage diode mixer is unsuitable in a direct-mixed receiver. It receives all transmitters within the pre-circuit passband and part of the VFO signal will be radiated into the antenna. None of these disadvantages are found in a counter-phase or ring mixer.

5.3 Superheterodyne receiver HAREC a.4.1.1a, a.4.3.1, a.4.3.4

The superheterodyne principle offers much greater possibilities, when the desire is a highly selective receiver for several different frequencies. The difference between a direct mixed receiver and a superheterodyne receiver, often just called "super" or "superhetero", is that the mixing products in the direct mixer become LF directly, while in super they first form an intermediate frequency signal MF, which is then demodulated and LF detected. In the following, superheterodyne receivers are simply called super. In the super, the received signals are mixed with the signal from a VFO. Before mixing, the HF signals have passed through a selective pre-stage, which attenuates mirror frequencies. In order not to disturb the reception, the VFO frequency is always placed outside the frequency band whereΩou want to receive signals. All received signals are mixed with the VFO signal. The reception frequency is usually the difference between a fixed so-called intermediate frequency MF and the VFO frequency. The intermediate frequency is actually the middle frequency in a fixed passband created by a number of filters.

Figure 5.13 shows a receiver with an intermediate frequency of 455 kHz, which is common in older receivers. In the simplest case, the MF filter can consist of mutually magnetically coupled LC resonant circuits. Better tuning sharpness is obtained with ceramic or quartz resonators or with the help of electromechanical resonators.

Example: A transmission on the frequency 3600 kHz is to be received. We then set the VFO frequency to 4055 kHz, since the intermediate frequency is 4055−3600 =455 kHz. The received signal then ends up in the middle of the iMF filter's passband. Signals on neighboring frequencies are also received and produce mixing products. With an intermediate frequency filter with, for example, 3 kHz bandwidth (453.5–456.5 kHz), signal frequencies between 3598.5 and 3601.5 kHz can pass through the filter. A signal with nearby frequency for example 3603 kHz, and mixed with the set VFO frequency 4055 kHz, will produce a difference frequency of 452 kHz.

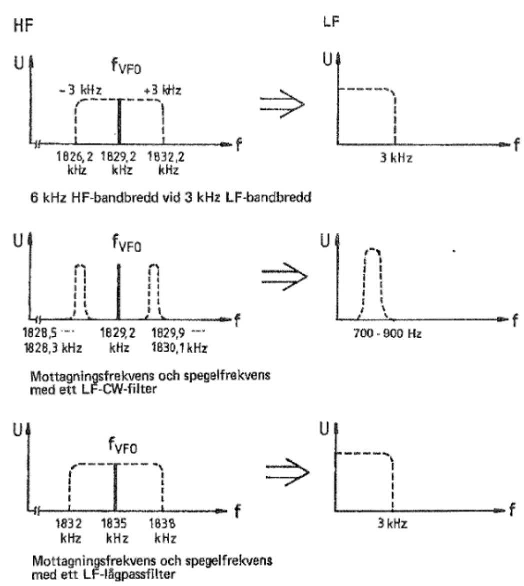

Figure 5.12: Passbandwidth and mirror frequencies in direct mixed receivers

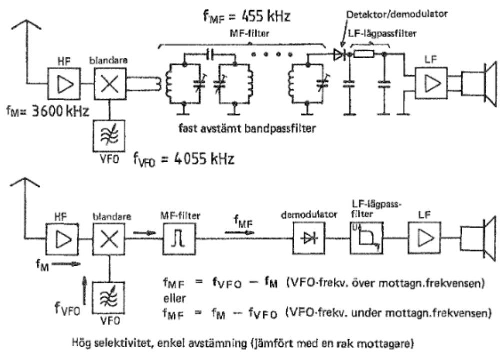

Figure 5.13: The superheterodyne receiver in principle This signal is outside the passband of the filter and will be attenuated and will not reach the detector. The VFO signal can of course be placed below instead of above the intermediate frequency. Example: The VFO frequency 3145 kHz can also be used to receive the frequency 3600 kHz, the intermediate frequency is 455 kHz (3600−455 = 3145 kHz). But in order to avoid possible harmonics from the VFO signal being mixed with received signals, it is appropriate to place the VFO frequency above the reception frequency. After the MF filters, among other things, detectors for different transmission types and LF amplifiers follow . Compare with figure 5.4 and 5.6.

5.3.1 Double superheterodyne receiverHAREC a.4.1.1b

It is difficult to build simple intermediate frequency filters for high frequencies, with small bandwidth and steep flanks. This is the case for a single super for shortwave with a single intermediate frequency, for example 9 MHz. A good close selection at high frequencies is only possible with relatively expensive crystal filters. However, it is possible to get good close selection with simpler means at higher frequencies. A double super, that is a super with double frequency conversion, enables good both close and preselection, illustrated in figure 5.14. In the 1st mixer, the received signal is mixed with the signal from a 1st oscillator (VFO) to a high intermediate frequency, for example 9 or 10.7 MHz. Thus, a good reflection frequency attenuation can be obtained. The first MF filter can be made simpler and without the high selectivity that would have been needed in a single super. The 1st MF is then mixed once more in the 2nd mixer to a 2nd MF, for example 455 kHz. For the second mix, a fixed oscillator is used. The filter in the 2nd MF can be more easily made with a high selectivity, due to the lower frequency. Example: Although the MF filter is not a single resonant circuit, a "Q value" can be calculated. At a pass bandwidth of 6 kHz and a center frequency of 455 kHz, the Q value can be considered to be Q = fresb = 4556 = 76 In an MF filter with a center frequency of 9 MHz, a nearly 20 times higher Q value would be needed for the same bandwidth of 6 kHzQ = fresb = 90006 = 1500Et such a high Q value can only be obtained with crystal filters. For higher reception frequencies, due to the filter problem, one-double frequency conversion is usually not enough. If one assumes a double super receiver for the VHF range 144-146 MHz as shown in the picture, then a 1st MF with the frequency 10.7 MHz would not be high enough. At a reception frequency of 146 MHz, the mirror frequency is 146 + (2 · 10.7) = 167.4 MHz, i.e. only 1.15 times the reception frequency. It would therefore have been suitable with a triple super, that is, threefold frequency conversion, with a 1st MF in the frequency range of 70 MHz.

5.4 Comparison between the superheterodyne and the detector receiver

The principle of the detector receiver is simple. In such a case, everything from antenna to demodulation takes place on the same fre

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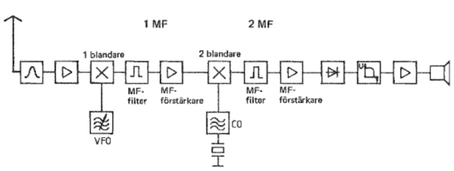

Figure 5.14: The double superheteodyne

in principle, that is, the reception frequency. The signal goes straight through the receiver without frequency conversion. The disadvantage is that unwanted self-oscillations can occur due to the high gain in the LF amplifier. Furthermore, it is inconvenient to set the reception frequency if there are multiple preselection circuits. With a crystal filter which is a better selection circuit, on the other hand, reception can only take place on a fixed frequency. Detector receivers are only built for special purposes or in simple designs for, for example, radio direction orientation and building kits. A development of the detector receiver is the direct-mixed receiver, which fulfills a task in some simpler contexts. This type of receiver, like the super, can be tuned with a VFO. The selection in the direct mixed receiver takes place, in contrast to the detector receiver, not in the pre-circuit but in an LF filter. A disadvantage is still the inevitable mirror frequency reception. Furthermore, HF can be radiated from the VFO if an inappropriate choice of mixing principle is made. The principle of direct mixing is, however, used as a demodulation method for example in SSB receivers. The superheterodyne receiver can be tuned in a simple way with a VFO. The selection is made in the fixed tuned MF part. Mirror frequency attenuation is done with pre-selection in combination with an appropriately chosen intermediate frequency. A disadvantage of a superheterodyne is that it is more complicated. Furthermore, even in the super HF can be radiated from the VFO if an inappropriate mixing principle is chosen. But with a double super, mirror frequency reception can be more easily avoided due to a high 1st MF while a low 2nd MF allows for better close selectivity. There is still the risk of unwanted mixing pro- becomes large at inappropriately chosen oscillator frequencies. Although the complexity is already relatively large in a double super, it is even greater in a triple super.

5.5 Panorama receiver

In a panorama receiver (eng. panorama receiver) or spectrum analyzer (eng. spectrum analyzer) it is shown on an oscilloscope screen where there are signals within a frequency band, as illustrated in Figure 5.15. A panoramic receiver is a superheterodyne.They are often implemented so that they sweep over the intermediate frequency on a receiver, and thus help to see what is in the adjacent part of the band that has been filtered too narrowly. This helps to identify nearby sources of interference as well as other potential stations to run a QSO with. Figure 5.16 illustrates the frequency sweep across the spectrum. The receiver oscillator is a VCO (voltage controlled oscillator). Its frequency is controlled by a sawtooth DC voltage, which rises linearly to quickly fall back and repeat. The VCO then sweeps over the desired frequency band a number of times per second. With the same sawtooth voltage, the beam on the screen is deflected along the x-axis. The received signal is demodulated and translated into a DC voltage that depicts the strength of the received signals. With this direct voltage, the beam on the monitor is deflected along theΩ-axis. The beam's distance from the x-axis thus indicates the received station's strength, and the beam's position along the x-axis indicates where the station is located in the frequency range being scanned. Depending on how large a frequency swing is given to the VCO, a larger or smaller frequency range will be scanned and displayed on the screen. The range can be as wide as an amateur band or more and down to a few kHz. In addition to monitoring a frequency band, a panorama receiver can be used for studying, for example, signals and side frequencies generated by the own station. For accurate measurements, however, a higher-quality aid, called a spectrum analyzer, is needed. Such a receiver basically works in the same way as a panorama receiver. A panorama receiver can be connected to a receiver to study the signals within the MF passband, as shown in figure 5.17. Then the reception frequency is in the center of the screen. The stations below and above the frequency are shown to the left and right respectively of the respective frequency. If the reception frequency is changed, this will still remain in the middle of the screen.

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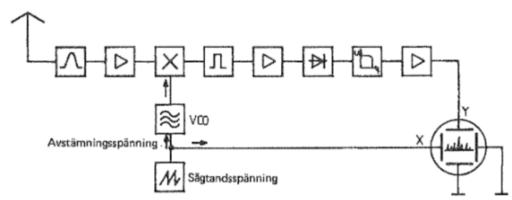

Figure 5.15: Panorama receiver

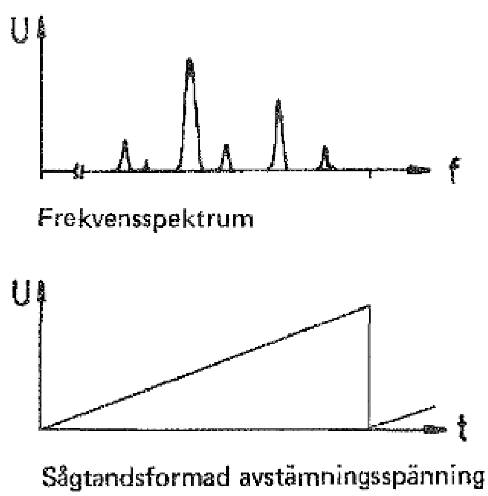

Figure 5.16: Signal and sweep voltages

5.6 The reception converter

Converter means frequency converter in this context. When it is desired to transfer all the signals within an entire frequency range to another, a reception converter is used where frequency mixing and frequency filters are used, as illustrated in figure 5.18. The converter functions as an addition before a receiver so that it can also be used within a different frequency range. In a converter, the oscillator frequency is fixed, while the scanning of the frequency range is done with the VFO in the receiver. The intermediate frequency filter in the receiver is almost as wide as the entire frequency range that is received by the converter and scanned with the receiver. Example: In a KV receiver for the range 28–30 MHz,Ωou also want to be able to listen in the range 432–434 MHz (UHF). The UHF signal received in the converter is amplified and then mixed with 404 MHz, a frequency multiplied up from a crystal oscillator (CO) in the converter. The mixing products that are filtered out will be in the range 28–30 MHz and can thus be intercepted in the KV receiver. Other mixing products are suppressed in the input circuits of the KV receiver. The mixing frequency of 404 MHz in the converter is calculated as follows: The center frequency in the UHF band is 432 + 4342 = 433 MHz = f1 The center frequency in the KV receiver frequency band is 28 + 302 = 29 MHz With what frequency f2 must 433 MHz be mixed to maintain a mixing product of 29 MHz? 29 MHz is less than f1 , so only the difference frequency can come into question (at sum frequency the mixing frequency would be higher than 433 MHz). When using the difference frequency, two possibilities are given: for f2 − f1 = f2 − 433 = 29 MHz, f2 = 462 MHz for f1 − f2 = 433 − f2 = 29 MHz, f2 = 404 MHz We decide on the 404 MHz option for a special reason . Here the highest UHF frequency 434 MHz corresponds to 434 − 404 = 30 MHz and the lowest UHF frequency 432 MHz corresponds to 432 − 404 = 28 MHz. In this way, the kHz graduation on the KV receiver's scale can be used directly without conversion. The advantage of a converter is that the cost of such is low compared to that of a complete receiver for an additional band. Condition-one is that a receiver already exists. The disadvantage is that the receiver cannot be used for its ordinary function at the same time.

5.7 Transverter

A transverter (transceiver-converter), is a combined frequency converter for both transmission and reception, as illustrated in picture 5.19. It moves both reception and transmission signals between two frequency ranges. The transverter is a good example of how the same technology can be used in both receiver and transmitter. If, for example, a KV transceiver already exists, both reception and transmission can also be arranged on the second band with a transverter as an addition.Example: A converter moves the received UHF signals to the shortwave range. As the main receiver, a KV transceiver is used in receive mode.

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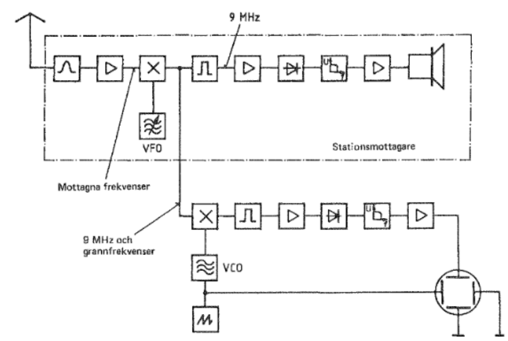

Figure 5.17: Connection of panorama receiver to station receiver

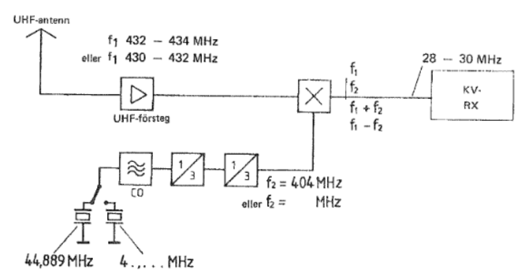

Figure 5.18: Receiving converter UHF to KV

The converter can be expanded to also function during transmission and is then called a transverter. With the KV transceiver in transmit mode, its signals are moved to the UHF range by mixing in the transverter the KV signal and a multiplied signal from a local oscillator (LO). The desired mixing product in the UHF range is filtered out and amplified in subsequent drive and output stages. The same frequency multiplication chain after the crystal oscillator CO can be used for transmission and reception. The advantage of a transverter is that the cost of such is low compared to that of a complete transceiver even for the additional band. The prerequisite is that a transceiver for any band already exists. The disadvantage is that the existing transceiver cannot simultaneously be used on any frequencies other than those currently used.

5.8 Automatic Gain Control (AGC)HAREC a.4.3.8

For the receiver to work well for both very weak and very strong input signals, a gain control is needed in the signal path through the receiver. The signal voltage at the receiver input can be from fractions of a microvolt up to over 100 mil-livolts – a voltage ratio of 1:100,000. This corresponds to more than nine S units, which is a measure of signal strength (see Appendix D). When receiving a strong signal is it not enough to just reduce the LF gain. The amplifier stages in the HF and MF part will still be over-driven by the strong input signal and the output signal will be distorted if nothing further is done. It is therefore necessary to reduce the gain also in the HF and MF amplifier stages, the more the stronger the signal. As an aid, there is usually a control for the HF gain (RF gain), and in addition an automatic gain control (eng. Automatic GainControl (AGC)). A receiver with good regulation can work with signal strengths between microvolts and volts. Depending on how the received signal is modulated (transmission type), AGC takes place in different ways. Both with AM and SSB, the information is in the sidebands. The HF and MF stages must therefore work in the linear range and they must not be overridden. The gain in the receiver must therefore be regulated with this in mind.

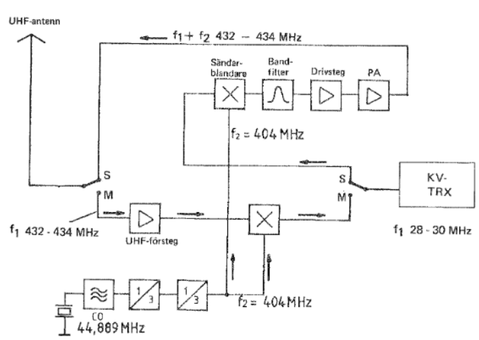

Figure 5.19: Transverter between UHF and KV

5.8.1 AGC for AM (A3E)

The DC voltage that occurs during the demodulation of the MF signal in an AM receiver is used for gain regulation - AGC, as illustrated in figure 5.20. The LF voltage superimposed on the DC voltage is suppressed in an RC low-pass filter. The DC voltage across the capacitor follows the variations in the strength of the received signal with a time constant of approximately 0.1 seconds. The DC voltage is therefore not affected by the significantly faster voltage changes that come from the modulation. A strong carrier wave signal produces a high DC voltage and a weak signal a low DC voltage, regardless of the modulation. This DC voltage is fed back to the preceding HF and MF amplifier stages, which are designed so that a high control voltage lowers the gain, while a low voltage allows a high gain. In this way, the signal strength after the control stages will be kept constant while the receiver input is not overridden. The DC voltage which filtered out from the detector's so-called control voltage or AGC voltage. Diode polarization is not important to get LF out during the demodulation, but rather to get the correct polarity on the AGC voltage. In most receivers, negative AGC voltage is used.

5.8.2 AGC at SSB (J3E)

In most designs, the product detector leaves an AC voltage without superimposed DC voltage. The control voltage is therefore generated by rectification of the MF voltage with the help of a separate demodulation diode or by rectification of the LF alternating voltage, as illustrated in figure 5.21. With SSB, no MF voltage is generated during the speech breaks, because no carrier is then received. The time constant of the low-pass filter for the control voltage must therefore be longer than for AM, that is 0.5 to 2 seconds. A too rapid fallback in the control voltage due to a too short time constant would lead to more reception noise in the speech breaks. In modern receivers there is often a switch or adjustment for different time constants.

5.8.3 AGC at CW (A1A)

The method of generating AGC voltage is the same at CW and SSB.

5.8.4 AGC at FM (F3E)

FM receivers are usually not regulated for the reason that at FM there is no information in the signal amplitude, but is instead in the frequency variations in the signal.Therefore, the gain in the receiver is deliberately added so that a sine signal becomes an edge wave on161

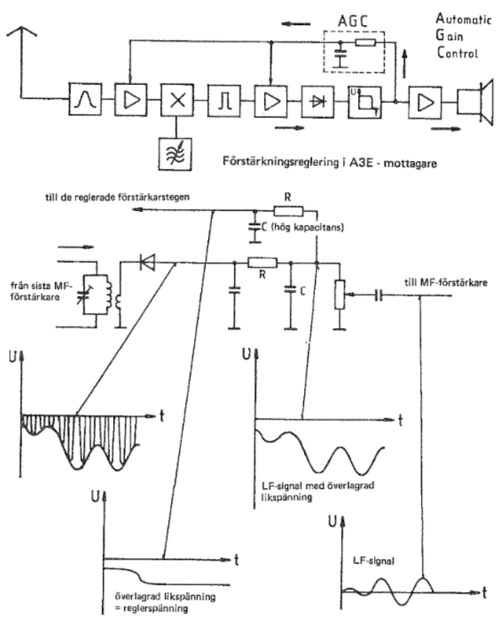

Figure 5.20: AGC during AM reception with superheterodyne receiver

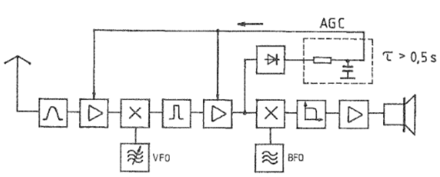

Figure 5.21: AGC during SSB and CW reception with superheterodyne receiver

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due to over-control in the amplifier stages. One or more such amplitude limiting steps, also called "limiters", are placed before the demodulation step. Disturbances of amplitude variations will then be cut off and not disturb the reception. Interfering signals within the useful bandwidth, however, have no major impact as long as the strength of the desired signal is half an s-unit greater than the strength of the interfering signal. Likewise, the disturbing noise when receiving an FM transmitter disappears very quickly above this signal level. Amplitude modulated disturbances, such as those from ignition sparks in internal combustion engines, have little effect if the useful signal is sufficiently strong.

5.8.5 SI strength meter (S-meter) HAREC a.4.3.9

The AGC voltage in a receiver for AM, CW and SSB can also control an S -meter, which gives information about how strong the signal into the receiver is. (See Appendix D.)

5.8.6 Noise barrAREC a.4.3.10

In an FM receiver, noise is only heard when a strong enough signal is not received. The noise is penetrating because FM receivers work with high gain. A noise barrier (eng. squelch) is a device that stops the signals to the LF amplifier when the signals do not reach a certain level. In this way,Ωou avoid hearing the noise. In receivers for several types of transmission and therefore also AGC, this function can control the noise block, but in a pure FM receiver the MF amplifiers work without AGC. In that case, some other device is needed to distinguish between a modulated signal and noise. There is often a control (squelch) for how strong the signal should be before the barrier opens. For a repeater, the noise barrier is also used to start the transmitter when it is carrier-controlled, that is to say thatΩou let the signal strength of the received signal also turn on the transmitter if the incoming the signal is strong enough. Nowadays, carrier control repeater is not considered suitable, as it can undetectable interference, whereby the interference is amplified. Instead, tone-opening or sub-tone should be used.

5.8.7 Tone-opening

An alternative to carrier-based noise blocking is tone-opening (eng. 1750 Hz tone-burst), which generally means putting out a 1750 Hz tone burst to open a repeater. Some older amateurs have learned to whistle the right tone to open the repeater as once upon a time they did not have handheld devices with a built-in 1750 Hz button.

5.8.8 Subtone

A problem with carrier opening and 1750 Hz tone opening is when nearby repeaters with the same input and output frequency have such conventions that both hear the handset's opening tone, then both repeaters will risk opening and then interfering with each other's transmission. An alternative is therefore to use subtone (eng.subtone) which is a frequency below 300 Hz, generally 60 to 250 Hz. An existing subtone system is the Continuous Tone Coded Squelch System (CTCSS) where the transmitter puts out a continuous subtone. The receiver detects a selected subtone, and only when the dentone has sufficient strength does the squelch open and keep it open as long as there is a subtone. For repeaters, it is used to also start the transmitter, so thereforeΩou have to select the subtone that the repeater's receiver is set to on to open the repeater. It also happens that the repeater in turn sends out subtones, usually the one used to open it. This in turn opens the handsets for the selected repeater. This can also be used by handheld devices to find repeaters and learn the subtone that opens it. Should several repeaters hear the same source, different subtones can be used to avoid opening the wrong repeater. The SSA's repeater manager has assigned CTCSS subtones for the different regions, and within each region there are several subtones to be able to separate within the region.

5.8.9 DTMF

A system for sending control commands and also open repeaters is DTMF (Dual Tone Multi Fre-quency), which is based on the principle of sending two simultaneous tones. The two tones are chosen as one of four in two different series. This gives $4 \cdot 4 = 16$ combinations, of which 10 represent the numbers 0–9. DTMF originally comes from telephone systems, but also works well over normal radio channels. DTMF can be used to control repeaters, such as turning them on and off, as well as controlling other properties.

5.9 Properties in receivers HAREC a.4.4

5.9.1 Adjacent channels HAREC a.4.4.1

Adjacent channels can create interference when parts leak in. Therefore, it is important that the receiver can suppress them, even when they are stronger than the selected channel, so thatΩou get as good readability on the selected channel. Nearby channels can therefore be considered sources of interference. Modern receivers allow moving both above and below the limit to suppress all nearby channels. The term roofing filter is also used for filters that help to filter steep flanks and good suppression capabilities.This is part of many to have good so-called large-signal properties. 163

5.9.2 Selectivity HAREC a.4.4.2

selectivity (eng. selectivity) is the ability of a receiver to distinguish desired signals and suppress others. Briefly described, the distance between the outer limits of the desired frequency range is called bandwidth. When it comes to superheterodyne receivers, there are two selectivity concepts:

- One is pre-selection to dampen de-mirror frequencies that arise in connection with the mixing of received signals and oscillator frequencies in the receiver.

- The other is selectivity in a superheterodyne receiver's MF stage, which is used to isolate the desired signal after the mixing steps.

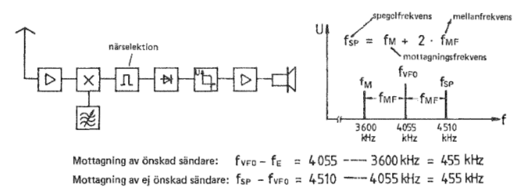
5.9.3 Frequency stabilityHAREC a.4.4.4

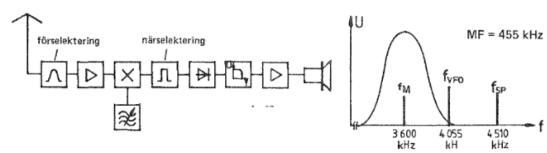
Frequency stability (eng. frequency stability) is important for receivers is important to be able to find transmitters on the specified frequency quickly, to be able stay on that frequency without drifting off the signal and also avoid drifting into nearby interfering signals. Frequency stability is provided in modern receivers with crystal oscillators, andΩou can often buy a temperature-compensated (TCXO) orΩoung-compensated (OCXO) crystal oscillator to get a higher frequency stability in the entire receiver. To get the best benefit, all local oscillator frequencies are generated locked to the same crystal oscillator, something that with modern PLL and DDS technology has not only become possible but also compact, cheap and with high performance.

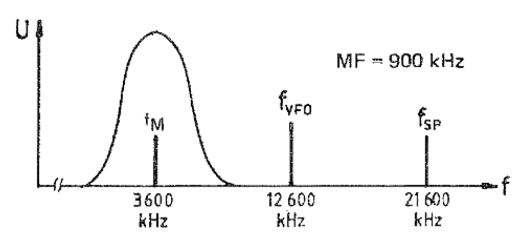
5.9.4 The mirror frequency problem when receiving HAREC a.4.4.5

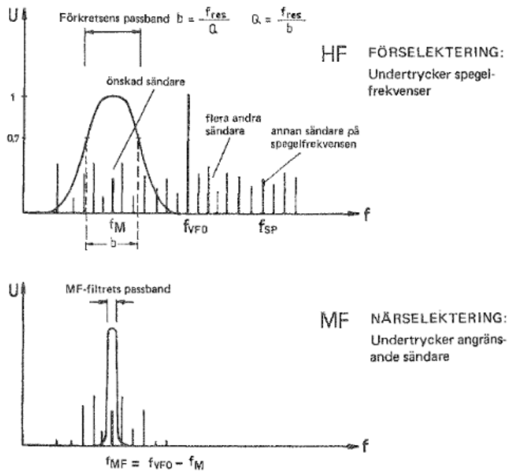
Example : In picture 5.22, a transmission of 3600 kHz is to be received and the VFO frequency is 4055 kHz. The intermediate frequency filter suppresses transmissions on such nearby frequencies as, for example, 3603 and 3597 kHz. This property is called near selection. But unfortunately, a transmission on such a distant frequency as 4510 kHz can still disturb the reception, despite the good near selection . The distance from 4510 kHz to our reception frequency 3600 kHz is 910 kHz. The frequency 4510 kHz and the VFO signal also form a mixing product, which has a frequency of 455 kHz. At a VFO frequency of 4055 kHz and a reception frequency of 3600 kHz, 4510 kHz is called the mirror frequency. The distance between the mirror frequency and the receive frequency is twice the value of the intermediate frequency – in this example 2 · 455 kHz = 910 kHz. Signals on the receive frequency and the mirror frequency both produce mixing products with the VFO frequency, which has the value of the intermediate frequency. The intermediate frequency filter therefore cannot suppress an extraneous signal on the mirror frequency. In contrast, a receiver input with preselection can suppress it.

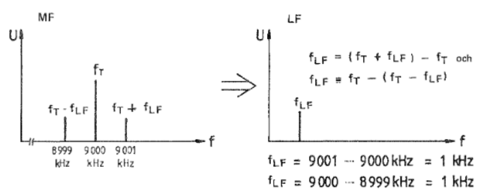
In picture 5.23, a selective circuit before the mixer lets through a narrow frequency band with a center frequency of 3600 kHz, but attenuates, for example, the frequency of 4510 kHz due to the large frequency difference. A pre-selection has thus been added as a complement to the near-selection obtained with the intermediate frequency filter. The further apart useful frequency and mirror frequency are, the better the pre-selection. With an intermediate frequency of 455 kHz, this distance is therefore 910 kHz. In the long-wave and medium-wave range, it is sufficient to be able to create sufficiently selective filters with simple means. Example: At the highest reception frequency on medium-wave 1605 kHz, the mirror frequency is 2515 kHz, which is 1.57 times higher in frequency and with a distance of 910 kHz. In the short-wave range, a mirror frequency at a distance of 910 kHz did not dampen sufficiently strongly. At the highest shortwave reception frequency of 30 MHz, the mirror frequency of 30.910 MHz is only 1.03 times higher in frequency. Assuming that the pre-selection circuit has a Q value of 30, the bandwidth becomes 53.5 kHz at the frequency of 1605 kHz. With the same Q- value, the bandwidth becomes 1000 kHz at the frequency of 30 MHz, which means that the pre-circuit can no longer effectively attenuate such nearby mirror frequencies.



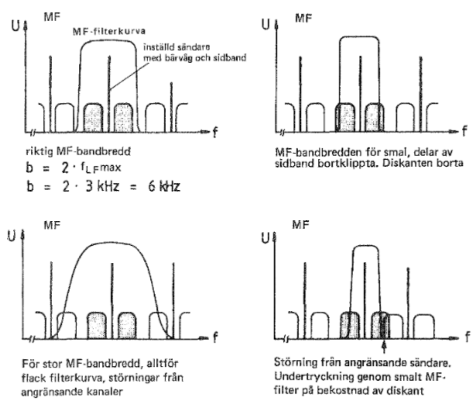








A3E - demodulering i frekvensspektrat



MF-bandbredd vid A3E

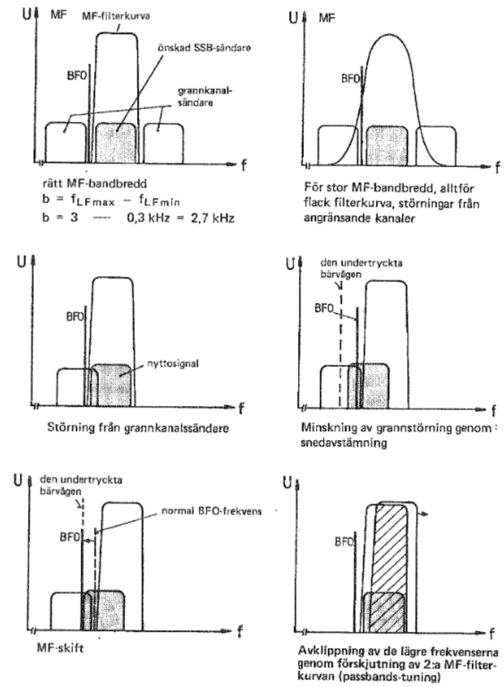


Figure 5.27: MF Bandwidth and passband tuning at SSB (J3E) to adjust the digital MF filters.

5.9.4.3 MF Bandwidth at CW (A1A)

As you know, a CW signal does not have a bandwidth of zero hertz, but it is basically a amplitude-modulated signal.

At a keying speed of 60 characters per minute the bandwidth is approximately 100 Hz and at 120 characters per minute it is double, approximately 200 Hz.

In some receivers an SSB filter is also used for receiving CW. A common bandwidth of an SSB filter is 2.7 kHz and then stations on nearby frequencies will also be heard, this is illustrated in figure 5.28. Let it be that most of these stations are heard with different frequencies.

More than 20 CW stations fit within a bandwidth corresponding to an SSB channel. The human brain, with some practice, can concentrate on one of these signals while the others are perceived as disturbing. The previously mentioned LF bandpass filter would, however, achieve a better selection and more comfortable listening. But if another station in the passband is much stronger than the station of interest, then the MF amplifier is either over-driven by the stronger signal or the AGC controls the gain down so that the weaker signal can no longer be heard despite the narrow LF filter.

The selection in one receiver should therefore be "as far forward as possible". In the example depicted, a narrow filter iMF would be of better use in CW reception. The bandwidth of such a filter is 250–500 Hz, thus only slightly wider than the CW signal. With an even narrower CW filter, due to a lack of frequency stability of the transmitter and/or receiver, difficulties may arise in finding the desired signal.

Well-equipped receivers have passband tuning also for CW, stepless bandwidth regulation or stepwise selectable filter bandwidths. The receiver can then be set to the desired signal with a large bandwidth which is then reduced. For receiving RTTY (radio teletype) with a 170 Hz shift between the two frequencies, a 500 Hz filter can be used. Narrower filters, on the other hand, do not work so well.
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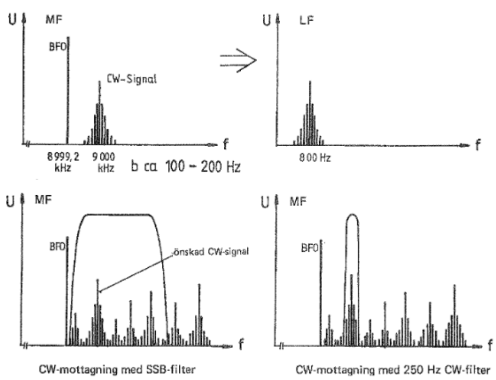

Figure 5.28: Different MF bandwidths at CW (A1A)

5.9.4.4 Bandwidth at FM (F3E)

An FM transmitter with the frequency deviation ∆fmax and highest modulating LF -the modulation frequency fLFmax has the bandwidth b = 2 · (∆fmax + fLFmax)In amateur radio it is customary to have a maximum deviation of 3 kHz and an upper limit frequency of 3 kHz, which corresponds to a bandwidth of 12 kHz. Full reception is only possible if the MF filters in the receiver has at least the bandwidth that the transmitter has. However, if the receiver bandwidth is too large, stations on nearby frequencies can also be received. Since 1996, the channel spacing recommended by IARU Region 1 has been 12.5 kHz for FM traffic on the VHF and UHF amateur radio bands. It is more common for the FM transmitter to deviate too much than for the receiver to be too narrow. A large deviation, lack of deviation limiter and too high LF limit frequency result in an unnecessarily large bandwidth on the transmitter. The opposite station then has reception difficulties and stations on neighboring channels are also disturbed. It is becoming more and more common with 12.5 kHz channel spacing also for repeaters, which is why it is important that all transmitters are set correctly.

5.9.5 Signal sensitivity and noise HAREC a.4.4.3

If you set the receiver to a free frequency, then at full amplificationΩou hear a noise similar to that of a waterfall. The noise comes from the weak alternating voltages that occur when the charge carriers move through the material that the circuit is made of. Depending on the noise source, the frequency spectrum ranges from zero to almost infinity. Due to the characteristics, a distinction is made between a number of specific noise sources: • Resistor noise, also called "white noise", which arises in resistive components. The noise extends over the entire measurable frequency range, whereby the energy distribution is equal over the entire range.• Circuit noise, which occurs in resistances in resonant circuits.• Antenna noise, which is composed of the noise from the antenna's radiation and loss resistance plus the galactic noise received by the antenna.• Transistor noise occurs of the movements of the charge carriers in semiconductor materials. More information about noise in components can be found in section 1.7.3 A total noise voltage is formed which can be determined. We talk about a noise figure, which is a measure of the reception system's inherent noise. This is calculated against the strength of the received signal. Talks about a relationship between signal power and noise power. There are several methods to measure and express this ratio called S/N (signal to noise169

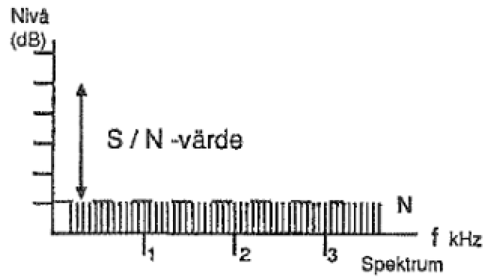

Figure 5.29: S/N value

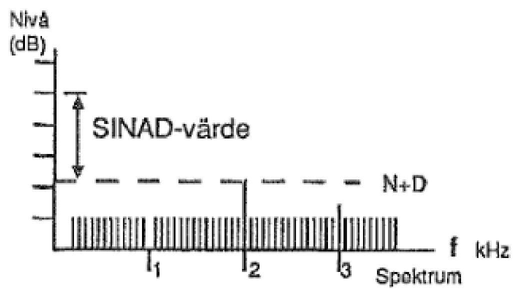

Figure 5.30: SINAD value ratio).

To perceive the information coming from a receiver's LF output, the useful signal must be a number of times stronger than the noise. The lower limit for perceiving speech in shortwave receivers is a noise distance of the order of 10 dB. In a brochure on a shortwave receiver, for example,Ωou can read "Sensitivity SSB, CW: less than0.25 μV for 10 dB S/N" The term S/N means Signal/ Noise, i.e. the signal/noise strength ratio expressed in dB. This means that a signal can be read at 25 μV signal level and an S/N of less than 10 dB. In addition to the noise level in the receiver, the distortion also plays a role. Signal-to-noise ratio = S + N + DN dBwhere S = Signal levelN = Noise levelD = Distortion levelIn a brochure on a VHF receiverΩou can read, for example, "

Sensitivity FM: Less than 0.18 μV for 12 dB SINAD "The term SINAD means Signal, Noise and Distortion. This definition also takes into account distortion products caused by the modulating signal. SINAD = S + N + DN + D dB

5.9.6 Intermodulation, cross modulation HAREC a.4.4.6, a.4.4.7

In addition to the fact that a good modern receiver should have sufficient frequency stability, sensitivity and selectivity should also have good so-called large-signal characteristics. By large-signal characteristics, one means how well a relatively weak useful signal at the receiver input resists the influence of strong, near-frequency signals with high field strength. Disturbances of this kind arise through non-linear progressions in components in the receiver's input stage, whereby received signals with large amplitude become distorted. Cross modulation and intermodulation are two terms associated with the large signal characteristics. Both can indeed be defined and determined unambiguously, but they are still often confused. A signal that is too strong also clips in mixers and this means that less and less signal can be detected, whereby the sensitivity drops and in the end the intended signal will be completely suppressed, so-called blocking.

5.9.6.1 Cross modulation HAREC a .4.4.8

By cross modulation is meant that the incoming useful signal is amplitude modulated with modulation products from another amplitude-modulated signal close to the frequency, whereby the cross modulation occurs and linear components in the receiver input (pre-stage, mixer). When you set the receiver in AM mode to a carrier wave, other strong stations close to the frequency are also heard. There must therefore always be a useful signal on the set frequency for cross-modulation to occur. When the useful signal disappears, so does the cross-modulation. Too bad phase noise at the receiver can be one reason why strong neighboring channels are mixed in and detected.

5.9.7 Intermodulation

In so-called intermodulation, two strong incoming signals are mixed in nonlinear components in the receiver input. Their mixing products fall on the receiving frequency so that it is disturbed, whether there is a useful signal there or not.

5.9.8 Frequency stability

See section 3.6.170

6 Transmitters and transceivers

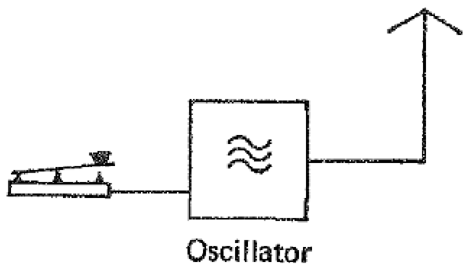

Bild 6.1: Enstegs sändare

Figure 6.1: Single-stage transmitter

6.1.1 Block Diagrams

Block diagrams, where the overall principles of the function are illustrated in a simplified form where each block represents a basic function. This simplification means that you can quickly get an overview without getting stuck in the construction details of individual blocks.

The entire device can be seen as a number of function blocks. How they work together can largely be seen from the block diagram.

There are oscillators, mixers, amplifiers, etc. The diagram can also contain information about frequencies and voltages and more. There are different types of function blocks - circuits. The combination of blocks gives devices with different characteristics. Examples are so-called straight transmitters with the same frequency throughout the transmitter, superheterodyne transmitters where frequency mixing is used, frequency-multiplying transmitters, etc.

6.1.2 Straight transmitter HAREC a.5.1.1b, a.5.2.1, a.5.3.3

A straight transmitter, as illustrated in picture 6.1, is the simplest transmitter concept.

Then the frequency of the oscillator is the same as the transmission frequency and no frequency conversion takes place in the signal path. If an antenna connects the oscillator, it becomes a simple single-stage transmitter.

In multi-stage direct transmitters, the oscillator is followed by additional functions at the same frequency as the oscillator. Buffer stages, drive stages and output stages can be such functions.

Figure 6.2 shows a direct transmitter, which consists of an oscillator + buffer stage 1 + buffer stage 2 + drive stage + power amplifier.

The oscillator is followed by a relieving buffer stage 1. In this way, the frequency stability of the oscillator is better. Buffer stage 2 relieves further and also feeds a power-increasing drive stage, which gives drive power to the final stage, as well as the final stage where the final power increase is required.

Straight transmitters can be used for CW, FM, PM and AM, but not DSB and SSB.

The advantage of direct transmitters is simplicity.

The disadvantage is that all stages work on the same frequency, whereby the risk of repercussions on a previous functional stage is greater.

Unwanted feedback can then be the result, which can cause unstable characteristics of the transmitter. By primarily building the VFO and buffer stages into metal enclosures, so-called shields, this risk is reduced as high isolation is achieved.

6.1.3 Transmitters with frequency multiplication HAREC a.5.3.2, a.5.3.5, a.5.3.6, a. 5.3.8, a.5.3.9, a.5.3.11

Preferably, you choose a working frequency for the oscillator where it is most frequency stable. If a higher frequency is desired on the utility signal, thenΩou can, for example, multiply the oscillator frequency, this is called frequency multiplication (eng. frequency multiplication).

In nonlinear circuits, harmonics are generated, which are often used for this purpose. Only when the requirement for frequency stability is low is the frequency on which the VFO or CO works, also used for the utility signal.

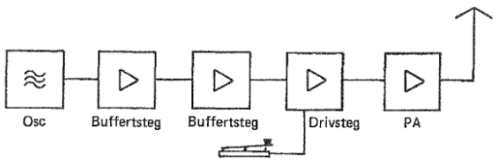

Figure 6.2: Multistage straight transmitter

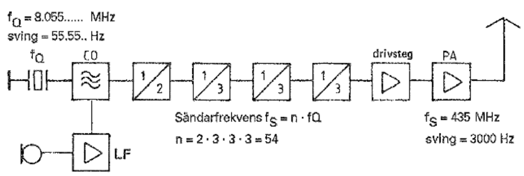

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Figure 6.3: FM transmitter with frequency multiplication +

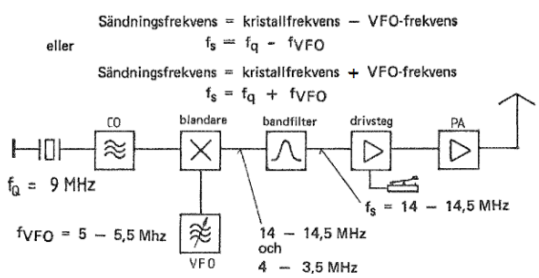

Figure 6.4 : 2-band CW transmitter with frequency mixing

The oscillator here oscillates at a low frequency, which is multiplied in nonlinear amplifier stages to a high transmission frequency. Usually the frequency is multiplied two or three times in each of the amplifier stages.

Figure 6.3 shows a block diagram of an FM transmitter for 435 MHz (70 cm band).

The oscillator frequency is 8.056 MHz. In four of the subsequent amplifiers, the frequency is multiplied 2, 3, 3 and 3 times respectively, so a total of 54 times.

The transmission frequency then becomes 8.056 · 54 = 435 MHz.

Variations in the oscillator frequency are also multiplied. In this example, the transmit frequency deviation becomes 54 times larger than the oscillator frequency deviation. A deviation of max. 3000 Hz from the nominal transmission frequency corresponds to the following deviation from the oscillator frequency,

$$\Delta f = \frac{3000}{54} = 55{,}6\ [\mathrm{Hz}]$$

Δf = 3000/54 = 55.6 [Hz]

FM transmitters for VHF, UHF and SHF are often performed with frequency multiplication.

Compared to a straight transmitter, the component requirement is greater, but instead the low oscillator frequency provides good frequency stability, which is an advantage. The risk of unwanted self-oscillations is less in a frequency multiplier than in a direct transmitter, because the input and output frequencies in several of the stages are different. By replacing the frequency modulator with a phase modulator, the same transmitter can also be used for a phase modulated signal.

The frequency multiplier stages in Figure 6.3 work in class C , i.e. nonlinear, which entails amplitude distortion. In the case of frequency and phase modulation, however, this has no meaning, because the amplitude in that case is not information-bearing. However, overtones in the useful signal should be filtered out, something that happens with a filter on the output, the so-called output filter (eng. output filter).

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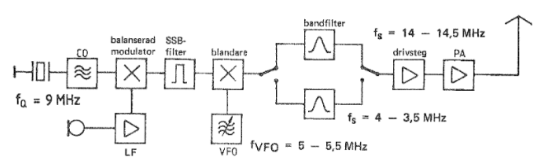

Figure 6.5: 2-band SSB transmitter with frequency mixing

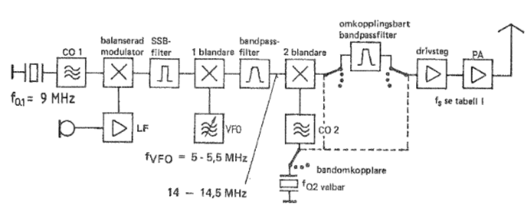

Figure 6.6: Multi-band SSB transmitter with frequency mixing

6.1.4 Transmitter with frequency mixing – superheterodyne transmitter HAREC a.5.1.1a

6.1.4.1 Telegraphy (CW) transmitter for shortwave

A VFO is most stable at low frequencies while a CO has good stability even at higher frequencies. When the signals from these are mixed, mixture products are formed which are the difference and the sum of the signal frequencies.

Figure 6.4 shows a telegraph transmitter where this phenomenon is used for transmission in the range 14.0–14.5 MHz or 3.5–4.0 MHz depending on the passband of the filter after the mixer. The result is a superheterodyne VFO with both variable and stable signal. In the picture, a filter with a passband for the upper of these frequency ranges has been selected.

6.1.4.2 Telephony transmitter (SSB) for shortwave HAREC a.5.2.2, a.5.3.1, a.5.3.4, a.5.3.10, a.5.3 .12

Figure 6.5 shows an SSB transmitter for two shortwave bands and is based on the transmitter in Figure 6.4.

The filter method is the most used to prepare an SSB signal. The oscillator signal is amplitude modulated in a balanced series mixer. In such a carrier wave is suppressed while both sidebands are released.

One sideband is suppressed with a bandpass filter, often implemented with a crystal filter to get good suppression of the unwanted sideband. This SSB signal is moved to the intended frequency band by yet another frequency mixing and further filtering.

In the example, the CO frequency is 9 MHz.
The VFO has a frequency range of 5.0–5.5 MHz.

The mixing results in mixed products in the frequency ranges 14.0–14.5 MHz and 4.0–3.5 MHz.

By selecting a band-pass filter, you can transmit in one of these frequency ranges. Subsequent drive and final stages are performed to work in this frequency band, either without special tuning - so-called wideband execution - or by tuning to a certain frequency, which provides the cleanest signal. Figure 6.6 shows an SSB transmitter similar to the one in Figure 6.5.

The big difference is that the signal frequency can be moved to several different bands using yet another frequency mix. Therefore, more selectable bandpass filters are used. In an SSB signal, all the information is in the amplitude, unlike an FM signal where all the information is in the frequency.

A SSB signal must therefore not be distorted. This means that the amplifier stages in SSB transmitters must work linearly, i.e. an output signal must be proportional to the input signal in each moment.

6.1.5 PLL-controlled transmitters

PLL control is not a transmitter concept.It is a way to control the frequency in an oscillator and keep it stable with the help of a direct voltage from a phase locked loop (eng. Phase Locked Loop (PLL)), which is a digitally controlled circuit. A PLL can be used, for example, in linear transmitters and heterodyne transmitters. In the first case (Figure 6.2), the frequency of the single oscillator can be controlled by a PLL.

In the second case (picture 6.6), the frequency in one of the oscillators can be controlled by a PLL. A more detailed description of PLL control of these two transmitter concepts follows here.

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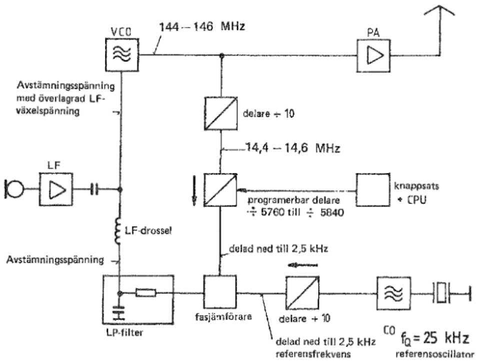

Picture 6.7: PLL-controlled FM transmitter for the FM

6.1.5.1 PLL-controlled FM transmitter for 144–146 MHz HAREC a.5.2.3

Figure 6.7 shows a PLL-controlled linear transmitter with a VCO (voltage-controlled oscillator) and a PA (power amplifier). The VCO is included as the frequency-controlled element in a PLL.

The output frequency from the VCO (actual value) is read and periodically divided by the number 10 and fed into a programmable frequency divider.

Since the frequency range of the VCO is 144-146 MHz, the input frequency to the programmable divider will be in the range 14.4-14.6 MHz.

The division number in this divider can be programmed in steps of 1 between the numbers 5760 and 5840. With the first divider's divisor 10 and the second divider's divisor set to, for example, 5760, a pulse is emitted from the divider chain every time the VCO has completed 57600 oscillations. At a VCO frequency of 144 MHz (144,000 kHz) the divisor 57600 (= 10·5760) corresponds to a pulse frequency of 2.5 kHz out of the counter chain.

Similarly, a VCO frequency of 144,025 kHz and the divisor 57610 (= 10 · 5761) will also give a pulse frequency of 2.5 kHz, likewise 146 MHz and the divisor 58400 and so on. The VCO frequency is thus locked in intervals of 25 kHz to the nearest division number, to achieve a pulse frequency of 2.5 kHz. If the VCO frequency (actual value) deviates from the set division number (desired value), then the pulse frequency will be higher or lower than 2.5 kHz. The pulse frequency is compared in a so-called phase comparator with a crystal-controlled reference frequency which, after division by 10, is also 2.5 kHz.

The output voltage from the comparator is a DC voltage, which assumes an average value when the input frequencies are equal, but a higher or lower value when they differ. This DC voltage is used to continuously control the VCO frequency to equal the setpoint. The speed of the regulation process is determined by the time constant in a low-pass filter, the so-called loop filter.

The transmission frequency is thus regulated with the control voltage. With the same voltage, it is also possible to frequency modulate the oscillator. It is done so that the LF signal from the modulator is superimposed on the control voltage through additive mixing (see chapter 3.8) via a capacitor. The variations in the control voltage that come from the number are faster than the time constant of the loop filter. The variations of the speech therefore do not have time to be perceived as frequency deviations and are therefore not regulated. The choke after the loop filter prevents the modulation signal from being short-circuited by the filter's capacitor.

The frequency setting, that is, the programming of the divider, can be performed in several ways. Examples are thumbwheel switches, logic circuits in combination with a keypad and so on.

6.1.5.2 PLL-controlled transmitter for shortwave

Figure 6.8 shows an advanced concept for a shortwave transmitter. The SSB signal is generated at the frequency 9 MHz and mixed with 61 MHz in the 1st mixer.

174 Crystal filter 2 mixers

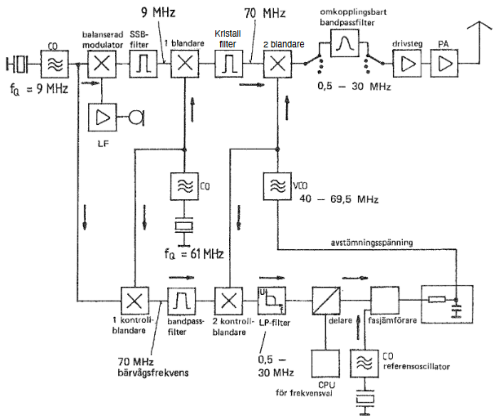

Figure 6.8: PLL-controlled SSB transmitter for shortwave.

The total frequency 70 MHz is filtered out as intermediate frequency. The desired transmit frequency is obtained by mixing the 70 MHz MF with the frequency from the VCO and then filtering out the difference frequency. The VCO in this example covers the frequency range 40–69.5 MHz. Thus, the coverage area of the transmitter will be 1.5–30 MHz. In order for the filter function to be optimal, it can be divided into several selectable filter sections, for example one per amateur band. The selection can be automatic and controlled by the frequency mode on the VCO. The absolute change between the two extreme transmission frequencies is as great as 28.5 MHz or 1:20.

The frequency change in the VCO is 29.5 MHz, but the change ratio between the extreme frequencies is only 1:1.74, which can be covered by a single VCO. At a lower 2nd MF frequency, several switchable VCOs would be needed to cover the entire frequency range

Example: At a MF of 9 MHz, the VCO function needs to cover 9.5–39 MHz, that is 1:4.11, which is too much for a VCO. The SSB signal after the 2nd mixer is not suitable to use in the control loop of the PLL. The reason is that the carrier wave is suppressed in this signal and therefore the HF frequencies in the remaining sideband vary in step with the modulating LF frequencies.

In the concept in the picture, the carrier wave is reconstructed in a 1st control mixer, by mixing the two CO frequencies 9 and 61 MHz. The pre-filtered carrier wave with the frequency of 70 MHz is mixed with the VCO frequency in the 2nd control mixer and from this signal the reconstructed carrier wave is pre-filtered.This matches perfectly with the suppressed carrier frequency and contains no LF signals. The carrier frequency is divided in a programmable frequency divider and compared to the frequency from a crystal controlled reference oscillator CO. From the phase comparator, a DC voltage is obtained which controls the VCO via a loop filter. The frequency is set by programming the divider iPLL. In modern transmitters there are also microprocessors, which offer frequency setting, memories and scanning of frequencies, etc. The described concept is advanced. The frequency of all oscillators is controlled by the same reference oscillator. The frequency stability thus depends only on the stability of the reference oscillator. The switching between LSB and USB can do the trick by keeping the SSB filter and changing the frequency 9 MHz by a value so that the filter becomes active in the opposite sideband or by keeping the frequency 9 MHz and switch to an SSB filter operating in the opposite sideband. A PLL-controlled transmitter has both crystal oscillator stability and variable frequency over a large frequency range despite a small number of control crystals. Such a transmitter can be relatively easily controlled digitally. A fundamental disadvantage of all transmitters with a PLL oscillator is the phase noise. Another disadvantage is the large amount of components (see chapter 5.4).

6.2 Characteristics of transmitters HAREC a.5.4

Transmitters have many different characteristics that one must pay attention to, partly to have an efficient transmitter, partly to get good quality of transmission and partly not to interfere with neighboring channels or on other bands.

6.2.1 Frequency stability HAREC a.5.4 .1

The frequency stability (eng. frequency stability) is a fundamental property, because a transmitter that is not frequency stable enough will be difficult for a receiver to follow and understand. In addition, you run the risk of disturbing neighboring channels. Minor drift in frequency can be tolerated, but ideally it should be perceived as completely stable. In old times, the resonators were LC circuits, and both mechanics and electronics could operate precariously. With more modern crystal-controlled transmitters, where people use PLL or DDS syntheses, the frequency stability can be derived to a single crystal oscillator.

This is typically an uncompensated crystal, with people being able to choose a temperature-compensated crystal oscillator - TCXO or an oven-compensated crystal oscillator - OCXO. It can also happen that you can lock on an external reference frequency, often 10 MHz.

6.2.2 RF bandwidth HAREC a.5.4.2

The RF bandwidth (eng. RF bandwidth) is the bandwidth that the modulated signal has when it comes out of the transmitter. It is important that it is limited so that it stays within the limits of the signal type, so that the transmitter does not interfere with neighboring channels.

For example, a transmitter adapted for FM 25 kHz channel splitting may modulate too strongly for NFM 12.5 kHz channel splitting and simply interfere with the channels. It is often difficult to limit the RF bandwidth directly at the output of the transmitter, as it is expected to be able to change channels.

Instead, the manband limits the intermediate frequency directly at the modulator, and before the frequency shift up to the correct frequency. However, this requires that subsequent steps be linear enough not to create unwanted sidebands in so-called splatter or take up mirror frequencies.

6.2.3 Sideband HAREC a.5.4.3

When transmitting, sidebands are created. For AM and SSB, both the upper side band (eng.Upper Side Band (USB)) or the lower side band (eng.Lower Side Band (LSB)) are created by the modulated signal. For SSB, the carrier wave is also suppressed. For FM, wider sidebands are created that need to be filtered.

6.2.4 Audio bandwidth HAREC a.5.4.4

The bandwidth of the audio signal, the so-called audio bandwidth, can be very large, and it is therefore important that the transmitter limits the bandwidth so that the transmitter does not happen to modulate outside its channel, something that mainly affects the bandwidth limitation upwards, usually 3 kHz for amateur radio. The bandwidth may also need to be limited downwards at 300 Hz in order not to accidentally interfere with, for example, signaling with subtones. However, this lower limit may sometimes need to be set aside in order to be able to send out subtone signals, but also for other forms of signals.

6.2.5 Nonlinearity HAREC a.5.4.5

Nonlinearity (eng. nonlinearity) in a transmitter stage is the harmonics that need to be limited, often through a filter on the output , but one also tries to limit how nonlinear the step is allowed to become. For speech, the non-linearity will also affect the intermodulation between several different frequencies in speech, which partly creates disturbances within the band but also outside and thus the bandwidth.

This is called splatter and is an undesirable property. Good linearity even at high effects is therefore desirable. SometimesΩou can have so much nonlinearity that the speech clarity becomes low, it may therefore be appropriate to reduce the power somewhat so that the speech clarity goes up, which then gives a better signal report than when the intermodulation is too high.

6.2.6 Output impedance HAREC a.5.4. 6

The output impedance (eng. output impedance) is the drive characteristics of the amplifier and they must usually be adapted to the cable. Most often it is 50 ohms, but preamplifiers that have a built-in matchbox, automatic or not, can adapt the amplifier's output impedance to be able to drive an antenna system with larger deviations in impedance. A good match in impedance is required to get a good energy transfer of the supplied energy without too much bouncing back. Many transmitters have protection circuits that reduce the output in case of too much reflected energy, to protect the output stage, and this means that an impedance match error even greater reduction in transmitted power than the impedance error itself would justify.

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6.2.7 Output power HAREC a.5.4.7

The output power (eng. output power) is the power that the transmitter is capable of transmitting, on a certain band, with good output matching. It is often measured in PEP to match the requirements of supervisory authorities. It may be possible to get higher actual power out of a transmitter, but then it will be so nonlinear that it is not expected to meet requirements for splatter.

6.2.8 Efficiency HAREC a.5.4.8

The efficiency (eng. efficiency) of a transmitter or output stage is the emitted power in relation to the supplied power. The efficiency varies with output power and frequency.

6.2.9 Frequency deviation HAREC a.5.4.9

The frequency deviation is the maximum deviation from the carrier wave that is allowed during frequency modulation.

6.2.10 Modulation index HAREC a.5.4.10

The modulation index (eng. modulation index), or also the modulation depth, indicates how deep the modulation of the carrier -the wave is. Too high modulation suppresses the carrier wave and can make it difficult for the receiver to detect. Too low modulation gives weak sidebands to transmit numbers, and too much of the energy goes into transmitting only the carrier wave.

6.2.11 CW clicks HAREC a.5.4.11

In CW, too fast rise and fall time on the carrier geonecessary bandwidth and perceived as clicks or chir pairs. As this is disturbing, the bandwidth must be limited by filtering the on and off of the carrier wave.

6.2.12 SSB overmodulation and splatter HAREC a.5.4.12

Overmodulation with SSB produces intermodulation and splatter, which gives a signal that is difficult to read and a signal that is too wide.

6.2 .13 RF spurious HAREC a.5.4.13

In addition to the expected carrier wave, a transmitter can send out frequencies that belong neither to the carrier wave nor to its sidebands. Harmonic undertones and completely unrelated frequencies must be suppressed. This is regulated in the EMC standard for radio equipment, in this case for amateur radio.

6.2.14 Chassis radiationHAREC a.5.4.14

A transmitter is expected to be able to deliver a large power output to the antenna output, but from the enclosure itself, the chassis, and other connections, the transmitter must not transmit carrier wave, sideband or any other signals.

6.2.15 Phase noise HAREC a.5.4.15

Phase noise (eng. phase noise) is a property of all oscillators, which provides a phase modulation of the carrier wave. All steps in a transmitter contribute noise and together give the total phase noise. A transmitter's phase noise can extend far beyond the normal modulated bandwidth, and especially for repeaters, the transmitter's phase noise can raise the receiver's noise floor when improperly tuned duplex filters are used to suppress the transmitter's phase noise at the receiver's input frequency.

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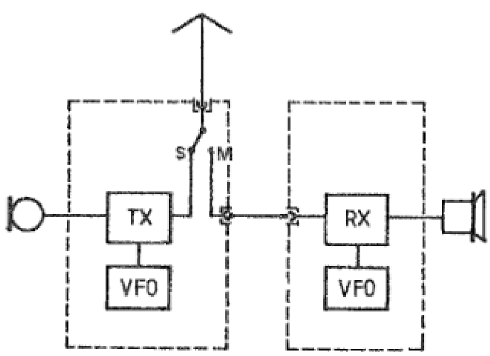

Figure 6.9: Separate transmitter and receiver

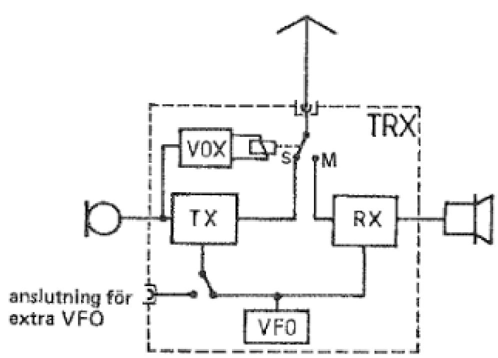

Figure 6.10: Transceiver with the same VFO

6 .3 Transceiver

A transceiver - transmitter receiver - is both a single transmitter and receiver with partially common functions. These can be, for example, oscillators, signal processing circuits, filters, power supplies and so on, which means saving on included components, but also certain functional limitations. Transceiver concepts are nowadays what is used most by radio amateurs. Since in different ways you want as many transmitter and receiver functions as possible within the same shell, it can be difficult to avoid compromises. So, for example, a specialized, separate receiver can have better or more properties than a transceiver.

6.3.1 Comparison between station concepts

Figure 6.9 broadly shows a station with different transmitter and receiver functions, but that the antenna is shared.

Figure 6.10 broadly shows a transceiver where the VFO and antenna are common, but otherwise with different functions.

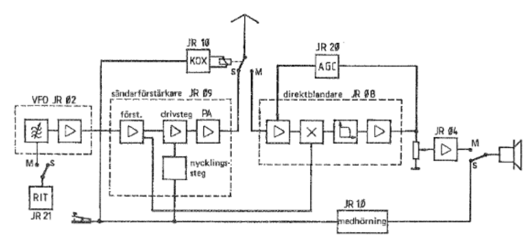

Figure 6.11 shows the same transceiver, with a more detailed block diagram.

6.3.2 Simplex

A station that alternately transmits and receives on one frequency uses the simplex traffic method. This is the most common traffic method on shortwave.

6.3.3 Half-duplex

A station that alternately transmits and receives on two different frequencies uses the traffic method half-duplex. The traffic method is most often used for traffic via repeaters but also for pile up on shortwave, the method is called then split. See also section 13.7.4.

6.3.4 Duplex

A station is said to transmit duplex or full duplex when it can simultaneously transmit and receive on two different frequencies. Duplex operation generally requires great isolation between transmitter and receiver, which is often achieved with cavity filters connected between transmitters and antenna and receiver and antenna. If a common antenna is used, these cavity filters are connected to what is called a duplex filter. For a successful duplex operation, more than 100 dB isolation is generally required between transmitter and receiver. The receiver's cavity filter is tuned so that it has a deep notch at the frequency of the transmitter, but with as little loss as possible on the receiver frequency. The transmitter's cavity filter is tuned so that it has a deep cut-off/notch at the receiver's frequency, in order to minimize that the transmitter's phase noise raises the noise floor of the receiver, but with as little loss as possible at the transmitter's frequency.

6.3.5 CW transceiver with direct mixer

Figure 6.11 shows a simple transceiver for telegraphy. The transmitter is a direct transmitter and the receiver works with direct mixing.For 1-channel traffic, a single VFO for transmission and reception is sufficient. The receiving station responds exactly to the transmission frequency, which is the VFO frequency, so the receiver is zeroed. To obtain audible Morse code, the receiver is equipped with Receiver Incremental Tuning (RIT), which changes the VFO frequency by approximately 800 Hz during reception. In the design is a device called a KeyOperated Xmitter (KOX). This switches the transceiver to transmission when the telegraph key is pressed down and to reception again after a certain time since the key has been released. The telegraph key also controls a tone generator that sounds in time with the transmitted Morse code, so-called co-hearing. This transceiver is designed for only one frequency band and is otherwise very simple.

6.3.6 Crystal-controlled FM transceiver for VHF

Figure 6.12 shows a crystal-controlled FM- transmitter with frequency switch for channel selection within the 144-146 MHz band.

A crystal frequency of approximately 12 MHz is multiplied 12 times in a chain of amplifier stages to give the transmission frequency. The picture shows calculation examples for

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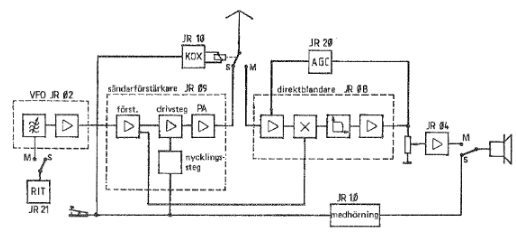
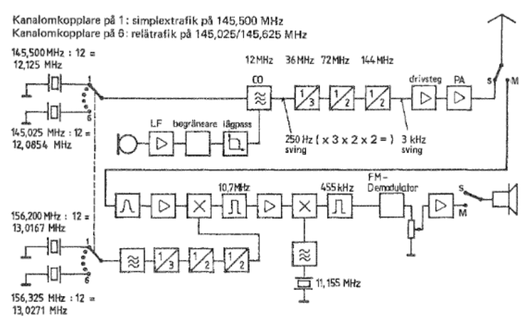


Picture 6.11: Directly mixed transceiver with common VFO



Picture 6.12: Crystal-controlled 6-channel FM transceiver for VHF two frequency channels.

The frequency swing in the oscillator, which is produced by the modulator, is also multiplied by 12. For a swing of 3 kHz on the carrier wave, the swing on the oscillator is only 250 Hz. The microphone amplifier is followed by an amplitude limiter, which must keep the deviation within a given maximum value, regardless of the signal strength from the microphone. This is followed by a low-pass filter, which partially attenuates harmonics that occur during amplitude limitation- partly limits the high frequencies in the modulated signal.

Both measures limit the bandwidth. The receiver is a double super heterodyne, often called a double super. The received signal passes through a pre-selection filter and an HF amplifier to be mixed with a local signal in the 1st mixer.

A crystal-controlled local oscillator with subsequent frequency multiplication stage generates this signal. The output frequency of the local oscillator chain is added 10.7 MHz above or below the reception frequency and the intermediate frequency after the 1: a the mixture then becomes 10.7 MHz. Different oscillators are used for transmission and reception, which is why the control crystals for transmission and reception on a given channel get different frequencies. When switching to another channel, another crystal pair is selected, which preferably takes place with the same switch. The relatively high 1st intermediate frequency of 10.7 MHz gives such a large distance to the mirror frequency that the bandwidth in the pre-selection filters is narrow enough to suppress the mirror frequency. For the same reason, the 1st intermediate frequency in a UHF receiver should be selected an additional three times higher. The relatively low 2-interval frequency allows good close selection even with simple band filters. A possible MF amplifier provides sufficient signal strength to the FM demodulator. For this solution, two control crystals are needed for each frequency channel, which for cost reasons can be a disadvantage.

6.3.7 PLL-controlled FM transceiver for VHF

The PLL-controlled transmitter already described in figure 6.7 has here supplemented with a swing limiter and a low-pass filter in the modulator. As in the station with channel crystals, as described in Figure 6.13, the receiver is also in this case a double super.

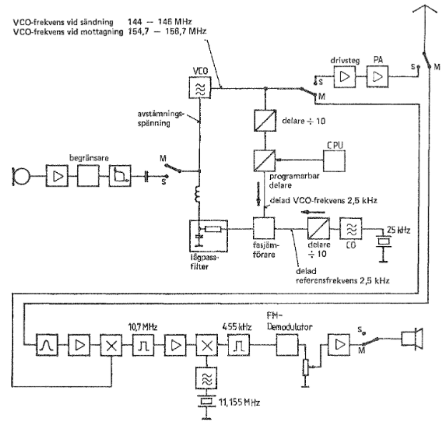


Figure 6.13: PLL-controlled FM transceiver for VHF

VCO is also used as a local oscillator in the receiver. Since the transmitter and receiver must be used on the same frequency (simplex traffic), in this concept the VCO frequency must be different when transmitting and receiving. Since the receiver's intermediate frequency MF is 10.7 MHz, the VCO must be 10.7 MHz higher or lower when receiving than when transmitting. When transmitting, on the other hand, the VCO frequency is the same as the transmission frequency. The programmable frequency divider in the PLL circuit therefore works with different division numbers during transmission and reception respectively, see table 6.1. The setting of the divisor can be done with a channel switch, thumb wheel set, keypad or "VFO knob" + digital counter and so on. The PLL control also provides opportunities, for example to arrange an automatic scan over a desired frequency range - so-called scanning. The VCO frequency is the same during transmission and reception, while the division number determines the operating frequency.

Transmission Reception QRG Deln.-
QRG VCO Deln.-MHZ numbers MHz numbers

Simplex channels, example
144,000 5760 144,000 154,700 6188
144,025 5761 144,025 154,725 6189
Repeater channels, example
145,000 5800 145,600 156,300 6252
145,025 5801 145,625 156,325 6253

Sändning		Mottagning		
QRG MHZ	Deln.-tal	QRG MHz	VCO MHz	Deln.-tal
Simplexkanaler, exempel				
144,000	5760	144,000	154,700	6188
144,025	5761	144,025	154,725	6189
Repeaterkanaler, exempel				
145,000	5800	145,600	156,300	6252
145,025	5801	145,625	156,325	6253

Table 6.1: Example of using different division numbers for simplex and repeater channels.

6.3.8 Shortwave Transceivers for SSB and CW

We have already described a KV transmitter and KV receiver for SSB. In the concept of a shortwave transceiver, shown here in picture 6.14, a super VFO is included in the signal processing. The VFO signal (5–5.5 MHz) is mixed with the signal from a crystal-controlled CO, whose frequency is selectable with a band switch. At the same time, a bandpass filter is connected after the mixer in the super-VFO, which corresponds to the current frequency band.

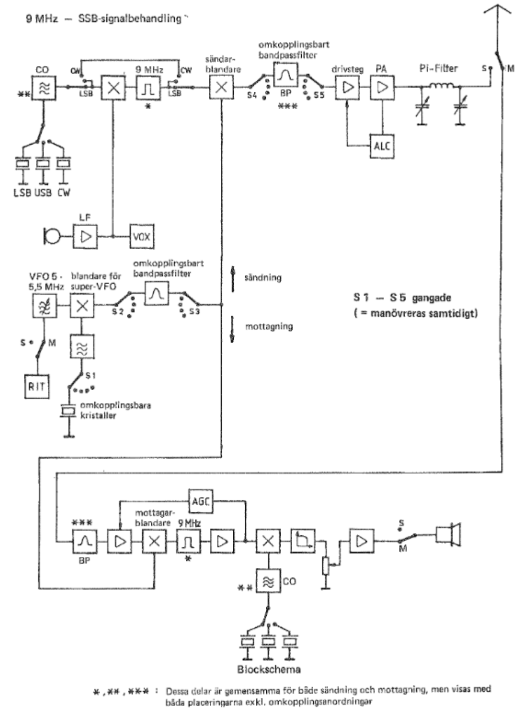


Figure 6.14: Shortwave SSB transceiver

For example, in the 21 MHz band, the pass band of the VFO filter is 12–12.5 MHz. When a VFO signal 12-12.5 MHz is mixed with a 9 MHz SSB modulated signal, a frequency in the range 3-3.5 MHz and a frequency in the range 21-21.5 MHz are obtained. The desired of these frequencies is filtered out with switchable bandpass filters, which is done with the band coupler mentioned earlier. In the simple shortwave transmitter described earlier, a single set of switchable bandpass filters is sufficient. The greater number of filters in the equipment described here is needed to be able to also use the super VFO as part of the receiver, which works as a single super. Since a MF of 9 MHz is also used in the receiver, reception and transmission will be able to take place on the same frequency. The receiver is not described in more detail. With suitable switching devices, certain function blocks in the transceiver can be used both for receiving and transmitting.

Figure 6.14 shows an SSB transceiver where bandpass filters in pre-circuits, MF filters and crystal oscillators have dual use. The function blocks are shown in their alternative functions, but the switching devices are not. When transmitting and receiving CW, the balanced modulator and crystal filter in the signal processing circuits for 9 MHz are bypassed. For CW reception, the BFO frequency is changed in the receiver so that a hover tone is heard when a carrier is received. Without this frequency change, only the carrier noise would be heard. Also a RIT and a voice-controlled transmission (eng. VoiceOperated Xmitter (VOX)) are drawn. 181

6.3.9 PLL-controlled short-wave transceiver

A modern transceiver in the higher price class can be found in picture 6.15, in so-called "all-mode" -execution, offer many functional possibilities. However, several of them are only used in special situations. The concept of such a transceiver is described here in detail. The main principle of the signal processing can be described as a PLL controlled double super. The SSB signal is prepared at the 9 MHz level and then moved up to the 70 MHz level by frequency mixing and filtering. The possible transmission frequencies between 0.5 and 30 MHz are created by mixing the fixed SSB signal with a variable frequency from the VCO. However, the stepless frequency coverage that includes the medium-wave and short-wave range is only intended for the reception function in the transceiver. For the transmission function, blocking circuits can be added, which prevent transmission outside the permitted frequency bands. This simplified description does not include the crystal oscillators for 9 and 61 MHz in the phase control circuit, nor the SSB modulator, the FM modulator and the devices for CW transmission. The receiver is a double super with high 1st MF frequency. Receivers for high frequencies can even be performed as a triple super. The same band-pass filter, mixer and crystal filter are used for both transmission and reception. Through suitable programming of the frequency divider, transmission and reception can take place on the same frequency or on different frequencies (split traffic). An extra VFO function can be achieved by programming the frequency divider with division numbers taken from a digital memory. The additional VFO function can then be fine-tuned by changing the division number with the frequency knob. The memory becomes even more useful if, in addition to frequencies, it can also store information, for example, about transmission types and other settings.

6.3.10 Summary

In contrast to the straight transmitter, the PLL-controlled transceiver described here is very complicated. Technical development is fast. New, better and more complicated devices are constantly being developed. However, it is not at all necessary to use the latest and most advanced equipment technology to practice amateur radio. It is very good to start with simple means and with a small financial investment. There is a large range of used devices which in various respects are competitive with later designs. It is in amateur radio traditions to make use of available equipment and improve it to the best of one's ability. In the end, the result and success depend mostly on the radio operator's skill, choice of frequency, antenna and occasion.

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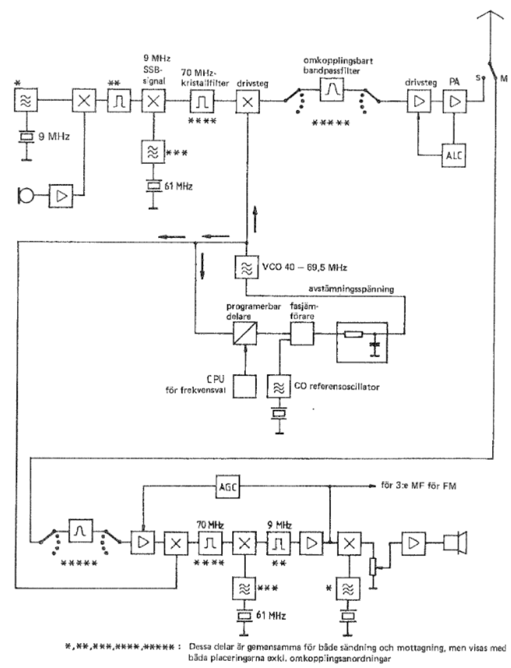

Figure 6.15: PLL-controlled SSB transceiver for shortwave183184

7 Antenna system

7.1 Antennas - general

Never so prominent radios will not reach their full potential without an effective antenna system. It is the main prerequisite for successful radio communication.

The antenna converts electrical energy from the transmitter into electromagnetic fields that are radiated, i.e. radio waves.

When receiving, the antenna picks up the radio waves and converts them into electrical signals that silence the receiver. The antenna system consists of the actual antenna and the transmission line between this and the transmitter and receiver respectively. The antenna system also includes impedance matching, antenna couplers, etc.

7.1.1 Wave speed

In a vacuum, electromagnetic waves propagate with the speed c0, which is mostly called the speed of light.

It is determined in the SI system [19] to c0 = 299 792 458 ≈ 300 · 106 [m/s]

In media other than vacuum, the same waves have the propagation speed c. The formula is then

$$c = \frac{c_0}{\sqrt{\mu_r \cdot \varepsilon_r}}$$

c = c0/√μr · εrd

where μr is the relative permeability constant and εr is the relative dielectric constant of the medium through which the waves pass. For the sake of simplicity, here μr and εr are set to 1, so c0 = c.

The relationship between the wave speed in vacuum, the frequency and the wavelength is simplified:

c = λ · f c [m/s] f [Hz] λ [m]and the wavelength thus

λ = cf [m]

$$\lambda = \frac{c}{f} \quad [\mathrm{m}]$$

7.1.2 Antenna length

7.1.2.1 Electrical length

The length of a resonant, ideal antenna that is one wavelength long can be calculated with the above formula. We call this length the electrical length. Thus le = λ. The electrical length (le) for a half-wave antenna (λ/2) is half the electrical length of a full-wave antenna (λ):le = λ2 [m]

7.1.2.2 Mechanical length

A distinction is made between the electrical and mechanical length of the antenna. For several reasons, the mechanical antenna length (lm) for the same frequency is shorter than the electrical one (le). It depends, among other things, on wave speed and conductivity in the materials that are included, along with other electrical properties depending on the antenna's mechanical design, influence from the ground plane and surroundings, etc. A ratio between length and thickness of 10000 gives, for example, an approximately 2% mechanically shorter antenna. The ratio of 30 gives an approximately 5% shorter area antenna. The first value may be suitable for a 2 mm thick half-wave antenna for 7 MHz. The second value is for a 3.5 mm thick half-wave antenna for 145 MHz.

Diagrams for the so-called shortening factor can be found in most antenna manuals. In the following formula, the mechanical length (lm) of a freely suspended wire antenna has been chosen 2% shorter than the electrical length. lm = λ2 · 0.98 [m]

Example: Calculate the electrical and mechanical the length of a half-wave antenna with the resonance frequencyf = 7 MHz.c = λ · f c [m/s] f [Hz] λ[m]The electrical wavelength for 7 MHz is:λ = cf = 300 · 1067 · 106 = 42.86 [m]

The antenna is a half-wave antenna, thus the electrical length is:le = λ2 = 42.862 = 21.43 [m]and the mechanical length:lm = λ2 · 0.98 = 42.862 · 0.98 = 21 [m]

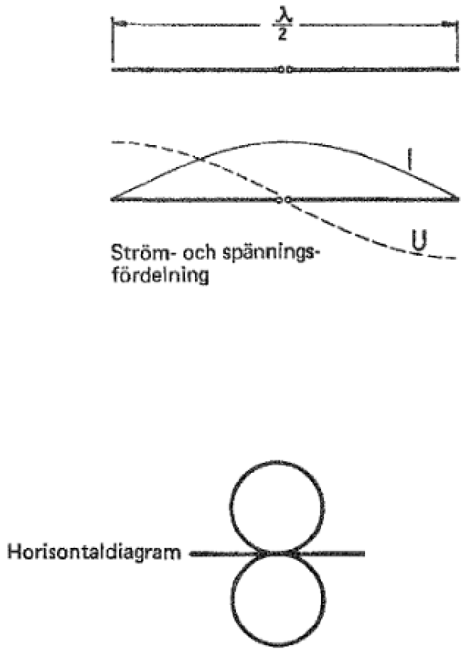

Figure 7.1: Voltage and current in a half-wave antenna

7.1.3 Current and voltage in a half-wave antennaHAREC a.6.2.1

When a half-wave antenna is fed with HF energy at the fundamental frequency, a standing wave with a typical appearance occurs. Figure 7.1 shows that at each end of the antenna the voltage U reaches a maximum (a voltage belly), in the middle the current I reaches a maximum (single current belly). The antenna radiates most where the current belly is. Take, for example, a 40 m long metal wire as an antenna.

The frequency of the fundamental resonance is about 3.5 MHz, but it is also in resonance on the harmonic harmonics (7, 14, 21, 28 MHz, etc.). Figure 7.3 shows the current and voltage distribution on the antenna at the respective harmonics.

For 80 m (3.5 MHz) the feed point is a voltage minimum (a voltage node) and a current maximum (a current trough). The current is high because the feed point has low impedance.

The same antenna on 40 m, 20 m, 15 m, 10 m (7, 14,21, 28 MHz) has a voltage maximum (voltage belly) and a current minimum (current node) in the feed the point, which then has a high impedance.

From the horizontal diagram for the antenna it can be read that additional radiation cones (radiation lobes) develop for each harmonic in the applied frequency. At the same time, the radiation becomes increasingly directed along the antenna.

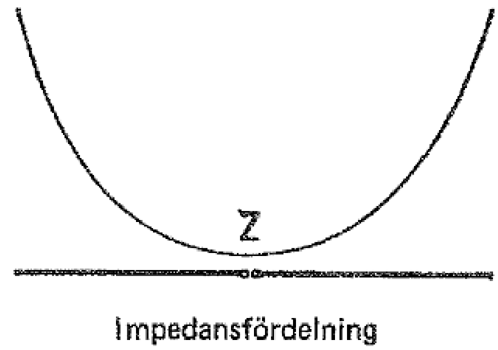

Image 7.2: The feed impedance in a half-wave antenna

7.1.4 The impedance in the antenna feed pointHAREC a.6.2.2

The impedance Z for each point on an antenna can be calculated with Ohm's law Z = UI.

Figure 7.2 shows the feed impedance in a half-wave antenna. At the fundamental frequency of a half-wave antenna, the impedance Z at the center point of the antenna is low when the voltage is low and the current high at the center point. In the outer points of the half-wave antenna, it is the other way around, the impedance is high because the current is low and the voltage is high. When the antenna, measured in wavelengths, is very high above the earth's surface, i.e. without significant influence from the environment, the impedance at the center point is 73 Ω at the fundamental frequency. In practice, the impedance may deviate greatly from this value. Antenna and supply cable must be impedance-matched to each other so that no wave reflection occurs in the connection. Note that the half-wave antenna is in resonance not only on the fundamental tone but also on harmonics. For 2nd, 4th etc. the harmonic harmonics have the feed point high impedance. When feeding with a low-impedance coaxial cable, a strong mismatch in the connection between antenna and cable occurs, which must be remedied in some way.

See section 7.6 in this chapter.

7.1.4.1 The feed impedance in some antennas

With the W3DZZ antenna (see section 7.3.6) the adaptation problem with center-fed parts on the 2nd harmonic harmonic, i.e. the double fundamental frequency, is easily solved.

On the 80 and 40 m bands, the antenna's feed impedance is around 60 Ω and on the higher bands around 100 Ω.
A compromise is to feed the antenna with a 75 Ω cable in order not to get excessive mismatch on any band.

The folded dipole: The feed impedance is about 240 Ω. A ribbon cable with an impedance of 300 Ω can be used alternatively a coaxial cable with an impedance of 50 or 75 Ω over a transformer with an impedance ratio of 4:1

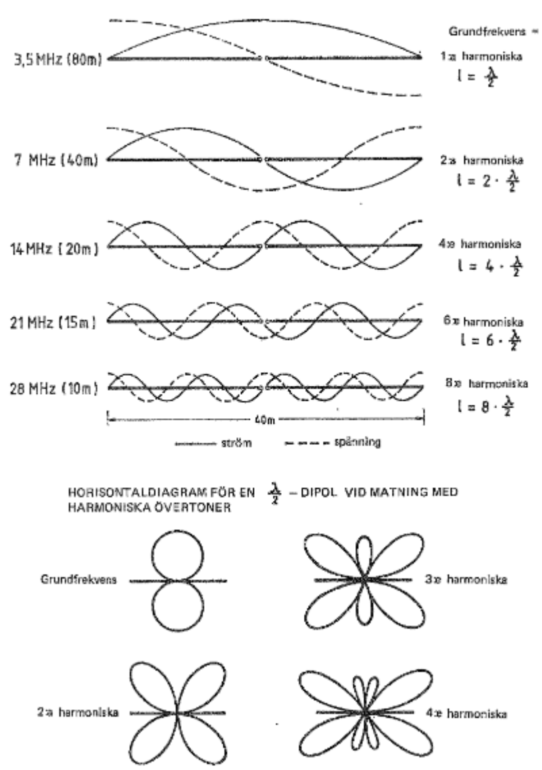

Figure 7.3: Half-wave dipole fed with harmonics

The ground plane antenna (GP antenna):

The feed impedance is 30–60 Ω. When the ground plane beam is not directed horizontally, but obliquely downward, a feed impedance of 50 Ω is obtained, which is good for a coaxial cable with 50 Ω impedance.

Yagi and Quad antennas: An adaptation device for connecting 50 Ω coaxial cable is usually included in factory-made directional antennas.

A 50 Ω coaxial cable can then be connected directly to the antenna's feed point.

7.1.4.2 The reactance in a non-resonant antenna HAREC a.6.2.3

The electrical resonant circuit is treated in section 3.6. centered on components called resistors, inductors and capacitors. Even a simple wire has these properties, but distributed over the entire wire. This can therefore be seen as a large number of components, which together form a resonant circuit, which of course can function as an antenna. When the antenna is fed with alternating current with the same frequency as the antenna's resonance frequency, the antenna oscillates with the minimum impedance.

The resonance case can be briefly described so that the inductive and before the capacitive reactance in the antenna offset each other while the resistance remains. The impedance is the vector sum of the resistance and the capacitive and inductive reactances. In resonance, the impedance of the antenna is equal to the resistance, which is a special case.

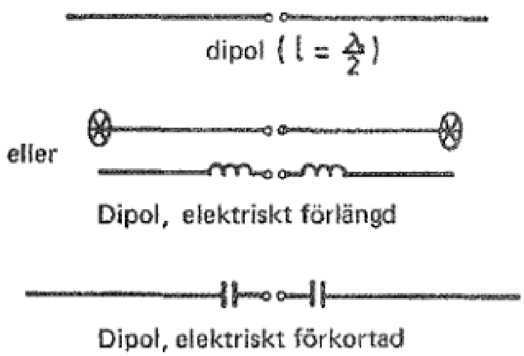

Figure 7.4: Electrical extension and shortening

If the transmit frequency is different from the antenna's resonant frequency, then either of the following happens:

When the antenna current has a lower frequency than the antenna's resonant frequency, the resulting reactance becomes negative (capacitive), the that is, XC is greater than XL.

When the antenna current has a higher frequency than the antenna's resonant frequency, the resulting reactance becomes positive (inductive), that is, XL is greater than XC.

7.1.5 Electrical "extension" and "shortening"

If the transmitter frequency deviates much from the antenna's resonance frequency, the reactance in the antenna needs to be eliminated or at least reduced for a better impedance matching between antenna and feeder line. The simplest measure is then to try to change the antenna length.

If this cannot be done, you can insert an inductor in series with an "too short" antenna - also known as an electrical extension. If, on the other hand, the drop antenna is "too long", then you can insert a capacitor, a so-called electrical shortening.

Figure 7.4 shows electrical extensions and shortenings of antennas. When using amateur radio, the transmitter frequency changes often, which is why the antenna system should be able to be tuned from the ground/operator's place. Then antenna couplers with the necessary reactive components are needed. See later in the chapter.

7.1.6 Adaptation to the transmitter's impedance HAREC a.5.3.7

A transmitter output stage with electron tubes is usually equipped with a tuning device (eng. Matching network and match) at the HF output. The purpose is to be able to adapt the output impedance of the transmitter to the impedance of the antenna line. In modern transmitters, this device very often consists of a so-called π filter, whose output impedance can vary between approximately 30–150 Ω.

A transistorized output stage is usually designed for a fixed output impedance of 50 Ω and is thus in need of a tuning device, unless the antenna system within some boundaries keep the same impedance. The tolerance limit for misalignment is usually an SVF of the order of 2:1 before the transmitter's protection circuits automatically reduce the output power. With equal impedance in the transmitter output, feed line and antenna connection, no standing wave occurs on the feed line and the most possible power is transferred from the transmitter to the antenna.

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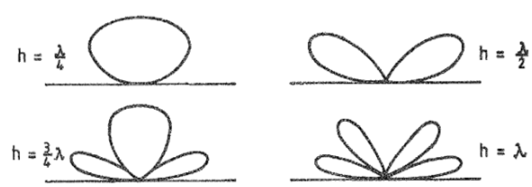

Image 7.5: Vertical diagram for half-wave antenna

7.1.7 Antenna radiation diagram

An antenna's radiation pattern is best described in three dimensions. Figure 7.3 shows, among other things, a horizontal diagram for a half-wave antenna.

Figure 7.5 shows the radiation in the vertical plane as a function of the antenna height for the same antenna. The vertical diagram can have a very different appearance depending on the design of the antenna, its electrical height above ground and the electrical properties of the environment. To cover large distances, the antenna must have a flat radiation relative to the ground plane. A horizontally suspended antenna with a length of λ/2 has predominantly flat radiation when placed at a height of λ/2, λ, 3λ/2, 2λ, etc. When a horizontal antenna is placed λ/4,3λ/4, 5λ/4 etc. above ground, the radiation is predominantly vertical, which should not be confused with the polarization, which in this case is horizontal. The same diagram applies to both a transmitter and receiver antenna. The strength of a radiated signal is matched by the strength of the received signal.

7.1.8 Antenna gain HAREC a.6.2.5

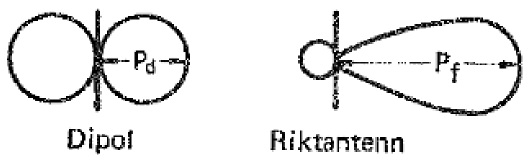

Figure 7.6: Antenna gain dBd in power

Figure 7.7: Antenna gain dBd in the voltage

By antenna gain or antenna gain Gant (eng.antenna gain) is meant the ratio between the power Pf in the main radiation direction (the forward direction of antenna with asymmetrically radiated power) and the power from a defined reference antenna. The ability to have higher antenna gain in one direction in relation to other directions is called directivity (eng. antenna directivity). A reference antenna which is thought to be infinitely small and which radiates with exactly the same power Pf in all directions is called an isotropic antenna. An isotropic antenna is, however, only theoretically definable. With the power Pi from the isotropic antenna as a reference, the antenna gain becomes

G = 10 log Pf/Pi[dBi]

A practically definable reference is the half-wave dipole, whose main radiation is perpendicular out from the dipole and around it. The reference power is then Pd and the antenna gain
G = 10 log PfPd[dBd]

Figure 7.6 shows the antenna gain with dBd in power and Figure 7.7 dBd in voltage. Antenna gain can also be defined as the ratio between the electric field strength Uf in the main radiation direction and the reference field strength (di-pole) .

Compared to the λ/2-dipole, the antenna gain is

G = 20 log Uf/Ud[dBd]

The expression dBi is used when the antenna gain is given relative to an isotropic antenna and dBd188 relative to a half-wave antenna. See chapter 1.9.2 about the decibel concept.

Example of antenna gain calculation:

Uf = 40 μV Ud = 20 μV G = ?
G = 20 log UfUd= 20 log 4020
= 20 log 2 = 20 · 0.3 = 6 [dBd]

6 dB antenna gain corresponds a doubled field strength [V/m], i.e. 1 S unit increase at the receiving station, as well as 6 dB antenna gain corresponds to a 4 doubled transmitter power [W/m2].

Approximate antenna gain for different antennas with isotropic antenna as reference:

	$\lambda/2$-dipol		Isotrop	
Isotrop antenn	−2,1	dBd	0	dBi
GP, $\lambda/4$	−1,8	dBd	0,3	dBi
Dipol, $\lambda/2$	0	dBd	2,1	dBi
GP, $5/8\lambda$	1,2	dBd	3,3	dBi
Dipol, $1/1\lambda$	1,8	dBd	3,9	dBi
2-elements yagi	5	dBd	7,1	dBi
2-elements quad	6	dBd	8	dBi
3-elements yagi	8	dBd	10,1	dBi

λ /2-dipole IsotropicIsotropic antenna −2.1 dBd 0 dBiGP, λ/4 −1.8 dBd 0.3 dBiDipole, λ/2 0 dBd 2.1 dBiGP, 5/8λ 1.2 dBd 3.3 dBiDipole, 1 /1λ 1.8 dBd 3.9 dBi2-elementΩagi 5 dBd 7.1 dBi2-element quad 6 dBd 8 dBi3-elementΩagi 8 dBd 10.1 dBi

Antennas have losses, this causes different antenna arrays to have different efficiencies, hence the measurement antenna efficiency (eng. antenna efficiency) η which depends on the relationship between the radiation resistance RR and the loss resistance

RL:η = RRRR + RLA

$$\eta = \frac{R_R}{R_R + R_L}$$

The antenna's efficiency, efficiency, can also be calculated using the antenna's loss effect and the supplied power. Note that the efficiency of the antenna is always less than 1 as it is easy to confuse the different effects in the calculation.

7.1.9 Effective radiated power HAREC a.6.2.7

Effective radiated power (ERP) is the power that the transmitting antenna radiates in its best radiation direction. ERP is calculated as the power supplied to the antenna itself, multiplied by the antenna gain relative to a half-wave dipole. The losses on the way from the transmitter to the antenna are excluded before the calculation of ERP.Equivalent isotropically radiated power (EIRP). EIRP is calculated relative to a theoretical antenna (isotropic antenna) that radiates equally in all directions. The further calculation uses the power supplied to the antenna itself, multiplied by the relatively anisotropic antenna gain. In the same way as in the calculation of ERPs, the losses on the way from the transmitter to the antenna are subtracted before the calculation of EIRP.

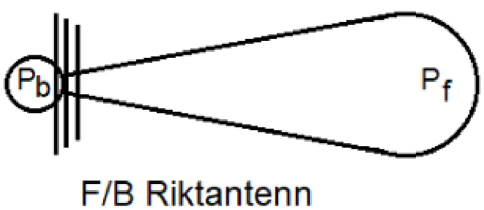

Figure 7.8: F/B ratio in power

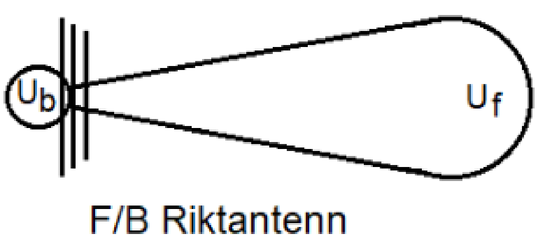

Figure 7.9: F/B ratio in voltage

7.1.10 Forward/reverse ratio (antenna gain) HAREC a .6.2.8

Forward/backward ratio (F/B) for a directional antenna means the ratio between the radiated power in the forward direction Pf and the power in the backward direction Pb.

See pictures 7.8 and 7.9. F/B = 10 log PfPb[dB] The forward/backward ratio can also be defined as the ratio between the electric field strength Uf in the forward direction and the reference field strength Ub in the reverse direction

F/B = 20 log UfUb[dB]

Example 1:

Uf = 40 μV Ub = 4 μV F/B = ?

F/B = 20 log UfUb= 20 log 404 = 20 log 10 = 20 · 1

= 20 [dB]F/B = 20 dB

means that the field strength Uf in the main direction is 10 times as high as the field strength in the reverse direction Ub.

Example 2:

Uf = 15 μV Ub = 15 μV F/ B = ?

F/B = 20 log UfUb= 20 log 1515= 20 log 1 = 20 · 0

= 0 [dB]F/B = 0 dB

means that Uf = Ub, i.e. that the field strengths in the forward and reverse directions are equal large, which occurs for a dipole.

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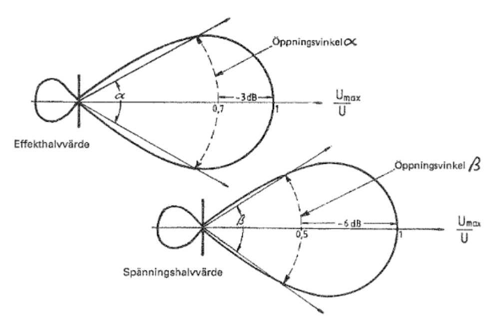

Figure 7.10: Half-value widths

7.1.11 Half-value width

Study the diagram for the horizontal radiation from a directional antenna. The antenna emits its greatest radiated power Pfi the main direction. The effect decreases outside the main direction. The field strength Uf behaves in a similar way. By power half-width is meant the angle within which the useful power is at least half as large as in the main direction.

Figure 7.10 shows half-value widths. Note that Pf2 corresponds to √ 12 Uf (≈ 0.7Uf corresponding to 3 dB) Voltage half-value width means the angle within which the voltage (field strength) is at least half as large as the largest useful voltage Uf . The voltage half-value width for a dipole is approximately 90◦.

7.1.12 Antenna areaHAREC a.6.2.6

Antenna area (eng. capture area) is the area that parabolic antennas and horns have. The antenna gain (G) depends on the antenna area (Aphy), the efficiency (ea) and the wavelength (λ) according to:

G = 4πAphy ea/λ2

$$G = \frac{4\pi A_{phy} e_a}{\lambda^2}$$

7.2 PolarizationHAREC a.6.2.4, a.6.2.9

See also in chapters 1.5.4 and 8.2.

An electromagnetic wave is composed of a magnetic and an electric field, perpendicularly oriented to each other.

The polarization direction of an electromagnetic wave is defined by the direction of its electric field. If the electric field is vertical, the polarization becomes vertical and horizontal if the electric field is horizontal.

The polarization direction of the emitted radio waves depends primarily on the design of the transmitter antenna.

7.2.1 Polarization on HF - Shortwave

For best reception, an antenna must have the same polarization direction as in the incident wave. On shortwave, it is not necessarily the same direction as that from the transmitting antenna, because the emitted waves have usually been reflected in the ionosphere. A polarization twist can then occur that cannot be predicted. Being able to switch between receiver antennas with different polarization can be an advantage. Directional antennas for shortwave are almost always mounted with horizontal elements - horizontal polarization.

7.2.2 Polarization on VHF/UHF/SHFI

the higher frequency ranges use both horizontal, vertical or circular polarization. The polarization direction does not change spontaneously during transmission as long as the waves are not reflected on the path. Which polarization you choose is of less importance than that it is the same for both the transmitter and receiver antenna. For circularly polarized antennas, where the polarization rotates around the propagation axis, the transmission is best when the direction of rotation is the same in both the transmitter and receiver antenna. If a transmitter that in the lower part of picture 7.11 has vertical polarization and the receiver horizontal polarization, the received signal strength is strongly attenuated. Calculated in dB, the attenuation in the inappropriate arrangement can be more than 30 dB.

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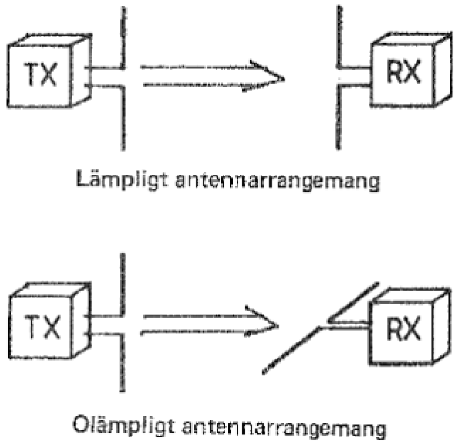

Figure 7.11: Influence of polarization

7.3 Antennas for shortwave

7.3.1 Center-fed half-wave antenna HAREC a.6.1.1

Previous section illustrates center-fed half-wave antenna

7.3.2 End-fed half-wave antenna HAREC a.6.1.2

The radiation from a half-wave antenna is basically the same no matter how it is fed. An end-fed half-wave antenna therefore has a radiation pattern similar to that of a center-fed antenna.

With longer antennas, however, the radiation character is different. The difference between end- and center-fed half-wave dipoles is that the connection impedance is much higher at the ends than in the middle. To feed the antenna furthest out at one end, an adaptation circuit is needed which transforms the low impedance of the coaxial cable to the high impedance of the antenna element. Such adaptation, transformation, can be done with a λ/4 long double transmission line. The feeding takes place at one end of the line and at the other end one part of the line is connected to the antenna and the other part is left free.

Such an antenna with λ/4 transmission line and λ/2 antenna element is called a Zepp antenna and was first used hanging under balloons and airships, so-called zeppelins.

The J-antenna (eng. J-pole) [26 , J-antenna] is electrically similar to the Zepp antenna, but it is usually made of metal tubes, or for portable use, of ribbon cable and is then often called Slim -Jim.

The antenna can be built in several different variants and the most common ones need a balun at the feeding point to avoid the feeding coaxial cable becoming part of the antenna and therefore impairing the antenna's efficiency and radiation pattern. Individual versions of the J-antenna can be built so that the antenna element can be directly grounded for to reduce

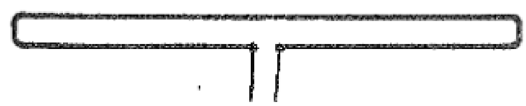

Figure 7.12: Folded dipole

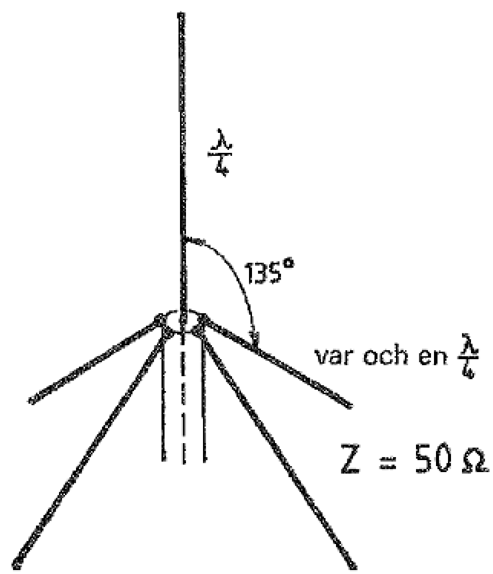

Figure 7.13: The GP antenna risk of damage to connected radio equipment during thunderstorms.

7.3.3 Folded dipole (folded dipole) HAREC a.6.1.3

Figure 7.12 shows a folded dipole that can be seen as two or more parallel elements, which are interconnected -the ones at the ends. The center point of one of the elements is connected to the antenna lead. The feed impedance of a folded λ/2 dipole with two elements is about four times higher than that of a single dipole, i.e. 200–300 Ω.

The reweighted dipole, which only works on the fundamental frequency and on its odd harmonics, is relatively broadband. The supply impedance can be changed with mutually different diameters of the included elements and with the number of elements connected in parallel.

7.3.4 Ground plane antenna HAREC a.6.1.4

Figure 7.13 shows a ground plane antenna or the GP antenna (eng. Ground plane antenna) which consists of a vertical radiator as one pole and several connected λ/4 radials or the ground plane as the other pole. The GP antenna is omnidirectional and has vertical polarization. Its relatively flat radiation, compared to a horizontal antenna, makes it suitable for long distances. For mechanical reasons, it is mostly used at higher frequencies (14 MHz and higher). With horizontal radials as the ground plane, the supply impedance is about 35 Ω. In order to obtain good impedance matching, for example to a 50 Ω coaxial cable

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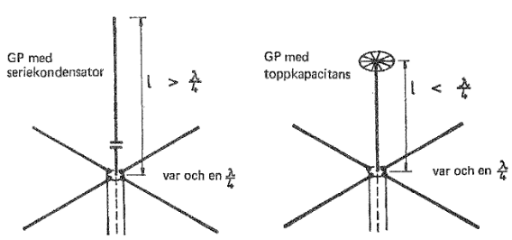

Figure 7.14: GP antennas with electrical length matching

as a feed line, the radials are made to slope downwards at a suitable angle. The inner conductor of the coaxial cable is connected to the antenna and the cable shield to the radials. If the antenna is placed immediately above the ground surface, can the ground can be used as a ground plane, especially if its electrical conductivity is good. If the antenna element does not have an electrical length of λ/4, the length can be adapted electrically in a similar way as described earlier in chapter 7.1.5 for dipole antennas. Figure 7.14 illustrates this.

7.3.5 Multi-band GP antennas

A GP antenna can be made to work on several bands by incorporating a blocking circuit in the antenna element for additional bands and ground plane radials with adapted length or with blocking circuits also in the ground plane for those bands. This is illustrated in figure 7.15 for five different bands. The antenna functions as a λ/4 GP antenna at least on the lowest bands. The mechanical length of a multi-band GP for shortwave is short, 4 to 6.5 meters, which on the lower bands means poor efficiency and small bandwidth. Compare with the SVF curves in figure 7.15. Multi-band GP antennas for up to seven short-wave bands are manufactured.

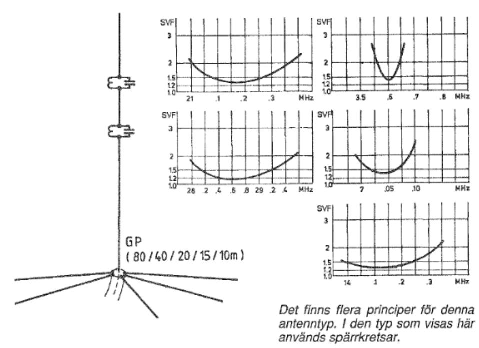

Figure 7.15: SVF curves for multi-band GP antenna

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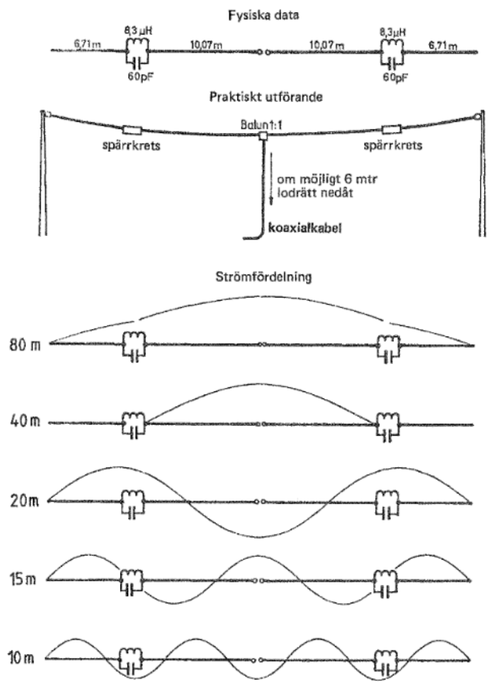

Figure 7.16: The W3DZZ antenna

7.3.6 Multi-band half-wave antennasHAREC a.6.1.7

The W3DZZ antenna is a commonly used multi-band antenna (named after the designer's call- signal) as shown in Figure 7.16. It is a horizontally suspended dipole antenna for the 80, 40, 20, 15 and 10 m bands. The W3DZZ antenna is approximately 33.6 meters long and has two blocking circuits, symmetrically placed around the feed point. The feeding takes place with coaxial cable and balun. The antenna has a feeding impedance of approximately 60 Ω on the 80- and 40-meter bands. On the higher bands, the matching is not optimal - supply impedance rises there up to about 100 Ω. Many do not use the W3DZZ antenna on high shortwave bands for that reason, among other things, but prefer a multi-band GP antenna or a directional antenna (yagi, quad, etc.). The way the W3DZZ antenna works:

• The 80 m band The entire antenna works as a λ/2-dipole co-resonance frequency 3.7 MHz. The mechanical length is 2 · 16.8 meters and is extended electrically by the inductances in the blocking circuits, which are out of resonance on this band. The part inside functions as a λ/2-dipole with the resonance frequency 7.05 MHz.
• The 20 m band The entire antenna functions as a 3λ/2 dipole with the resonance frequency 14.1 MHz.
• The 15 m band The entire antenna functions as a 5λ/2- dipole with resonance frequency 21.2 MHz.
• The 10 m band The entire antenna functions as a 7λ/2 dipole with resonance frequency 28.4 MHz.

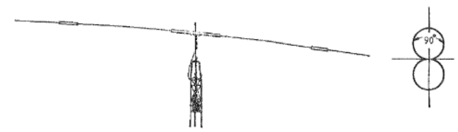

Figure 7.17: Directional dipole antenna

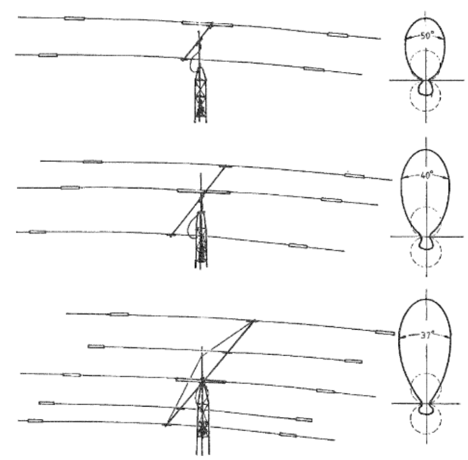

Figure 7.18: Multiband yagi antennas

7.4 Directional antennas for shortwave

7.4.1 Directional dipole antenna

A dipole antenna of moderate mechanical size can be made rotatable so that the radiation can be directed, as illustrated in Figure 7.17. But since a single dipole radiates in many directions, let alone mostly perpendicularly from the antenna, the energy in most directions can be seen as "lost".

When a passive antenna element - a reflector - is placed behind the active element, however, the backward radiation can be partially turned forward and you instead get a certain directionality.

In order for it to work, the two elements have a certain mutual relationship between the length of the elements and the distance between the elements.

7.4.2 Yagian antennas HAREC a.6.1.5

With additional passive antenna elements - so-called directors - in front of the active element, the directivity becomes even better.

The reflector is always electrically longer than the active element and the directors are always electrically shorter. The length of the conductors becomes shorter at greater distances from the driven element. Read more about directional antennas in chapter 7.5.2.

One such antenna is the Yagi-Uda antenna, named after its Japanese creators. It is usually referred to simply as yagian tin. It is originally intended for a single frequency band, a so-called monoband beam. If all elements are provided with suitable blocking circuits, using the W3DZZ antenna as a model, a directional antenna is obtained that is usable on several frequency bands, a so-called multiband beam. The most common antennas for several bands have two to three elements and are designed for the frequency bands 10 m, 15 m and 20 m.

Figure 7.18 shows multi-band yagi antennas with 2, 3 and 5 elements, respectively, and their radiation diagram in the horizontal plane. Feeding is usually done with a coaxial cable with the characteristic impedance 50 Ω. Since the feed impedance of the directional antenna itself is almost never 50 Ω, an impedance matching between antenna and cable is usually needed.194

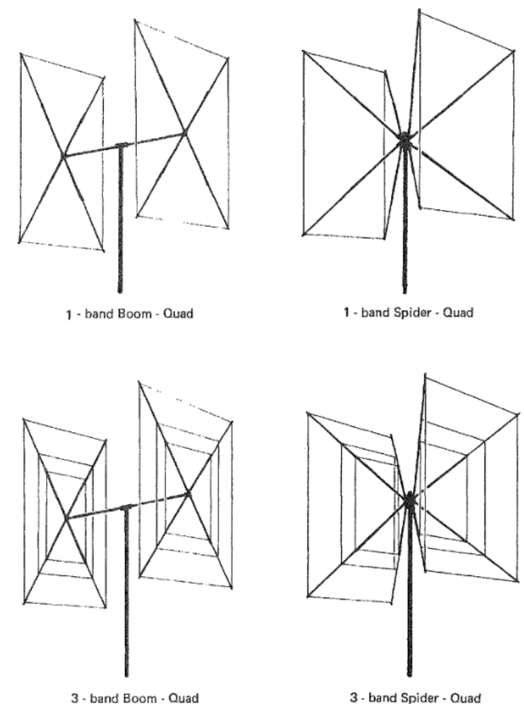

Figure 7.19: Cubical Quad antennas

7.4.3 Cubical Quad antennas

Figure 7.19 shows a cubical quad antenna which is a square full-wave radiator with a side length of λ /4, that is a total of 1 λ. A 2-element quad antenna consists of a radiator and a reflector at a mutual distance of 0.15–0.2 λ.

There are also 3 and 4-element quad designs with dimensions worth considering . The antenna is made suitably rotatable and should be mounted at least 3/4 λ above the ground. The feed is usually done with a coaxial cable and depending on the distance between the elements, the feed impedance varies between 50 and 70 Ω.

Depending on where the anchoring point is placed, it is possible to choose between horizontal or vertical polarization. There are two designs of quad antennas, the one with a supporting boom with spreaders to support the antenna elements and the other with just spreaders from a central mount, the so-called spider quad (spider).

Quad antennas are usually built for the 10, 15 and 20 m bands. The spider principle is preferable when performing for several bands, because an optimal element distance can be chosen for each band without the need to increase the number of diffusers. Due to the flat radiation angle, the quad-antenna is an excellent DX antenna. A two-element quad can give the same results as a 3-elements yagian antenna. For shortwave use, there are many antenna types, such as longwire, zepp, windom, rhombic, delta loop, quad-loop antennas, etc. For more information, refer to antenna literature. 195

7.5 Antennas for VHF/UHF/SHF

7.5.1 General

All antennas work according to the same principles. The principles for short-wave antennas can therefore also be applied to antennas for higher frequencies. The construction dimensions of a VHF/UHF antenna are significantly smaller than for a corresponding HF antenna. Since the wavelength λ at 145 MHz is about 2 m compared to about 80 m at 3.5 MHz, it is possible to build directional antennas with reasonable dimensions for VHF/UHF, even if many antenna elements are used. If one disregards omnidirectional vertical antennas for traffic at short distances and mobile traffic, directional antennas are used mainly because of the greater range. The properties of a directional antenna are primarily expressed in the quantities radiation angle, antenna gain, front/back ratio and half-value width. Since polarization distortion rarely occurs at higher frequencies, it is important that transmitter and receiver antennas have the same polarization direction. Horizontal polarization is considered to be better suited for long distances, because waves with horizontal polarization deflects better over horizontal formations (mountain ridges, etc.).

Passage through forest sections is also better with horizontally polarized waves. Antennas with horizontal polarization are therefore often used for SSB and CW traffic over long distances and along the ground surface. Such traffic generally takes place from fixed stations. For both mobile traffic and local fixed traffic, antennas with vertical polarization are usually used. Vertical antennas provide the desirable omnidirectional characteristics for mobile traffic and are best suited for mounting on vehicles.

7.5.2 Directional antennas

A λ/2 antenna radiates perpendicularly from the antenna conductor and around it. If a reflector element (length ≈ λ/2 + 5%) is placed behind the antenna at a distance of ≈ λ/5, the backward radiation is partially reflected forward. A larger part of the energy will then be collected in one direction. With a directional element (length ≈ λ/2 − 5%) in front of the radiating element at a distance of ≈ λ/10, the radiation angle will be smaller.

7.5.3 Yagi antennas

The type of directional antenna, which consists of a radiator, a passive reflector and a number of passive directors, is called aΩagian antenna and is illustrated in figure 7.20.

Note that the vertical diagram shows the radiation pattern with the antenna placed close to the ground. For VHF, UHF and SHF, the antenna is often placed so high above the ground that the antenna can be seen as being placed in free space. The radiation diagram then becomes different in that the main lobe of the antenna is lowered compared to the one in the image and ends up with the center symmetrically around the horizontal plane. TheΩagi antenna can be made with different numbers of director elements in combination with different lengths. There are three ways to optimize a directional antenna, namely maximum directivity, minimal side lobes or maximum fore/aft ratio. These properties are, however, not possible to achieve at the same time. If, for example, the number of elements is increased, the so-called antenna gain increases because the opening angle of the radiation becomes smaller, but at the same time the supply impedance and the usable bandwidth decrease. As a rule of thumb, it can be stated that it is not the amount of elements that determines the antenna gain, but the dominant factor is the length of the boom. The amount of elements affects the antenna gain by 1–2 dB from optimal to mediocre. Properties such as front/back ratio or minimal side lobes depend more on the amount, location and size of the directors.

7.5.4 Group antennas

If several directional antennas are arranged next to and/or above each other, a so-called group antenna is obtained. Such an arrangement of so-called stacked antennas results in an even smaller opening angle of the radiation vertically and/or horizontally. Thereby obtaining additional antenna gain.

7.5.5 Parabolic antennas HAREC a.6.1.6

Especially at frequencies in the microwave range and higher, radio waves have largely the same propagation properties as light. If great directivity needs to be achieved at these high frequencies, a parabolic surface is often used as a mirror behind the antenna itself, but together it is called a parabolic antenna. Compare with the reflector in a flashlight. The actual antenna (the so-called feeder), whose radiation is directed towards the parabola to be reflected, can be designed in many ways. Since the size of the parabola is inversely proportional to the frequency, for practical reasons parabolic reflectors are not used at low frequencies.

7.5.6 Other antenna types

Omnidirectional antennas: Ground plane, λ/4-, λ/2-, 5λ/8- antennas etc.

Directional antennas: Quad, HB9CV, helical, parabolic and horn antennas and more.

7.6 Transmission lines

A feeder line must transfer the high-frequency energy from the transmitter to the front of the transmitter antenna with as little loss as possible. Conversely, the energy captured by the receiver antenna must be transported to the receiver with as little loss as possible.
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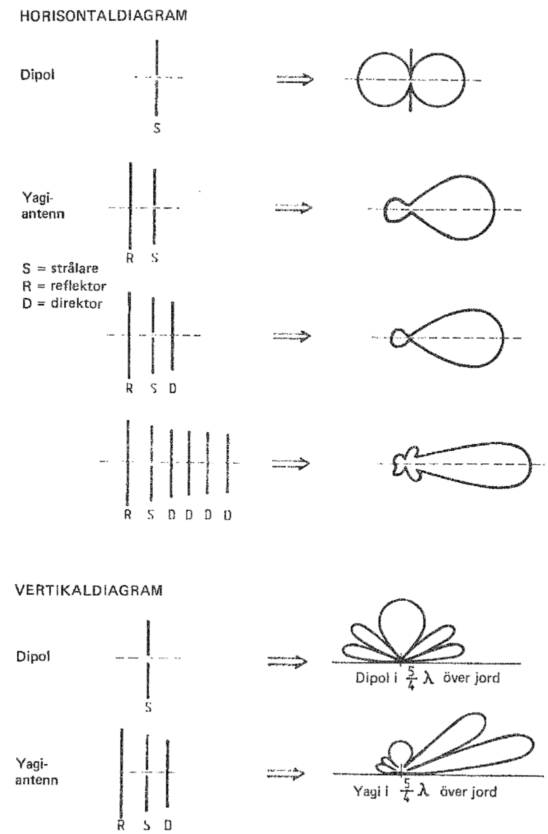

Figure 7.20: Radiation diagram for horizontal yagian antenna

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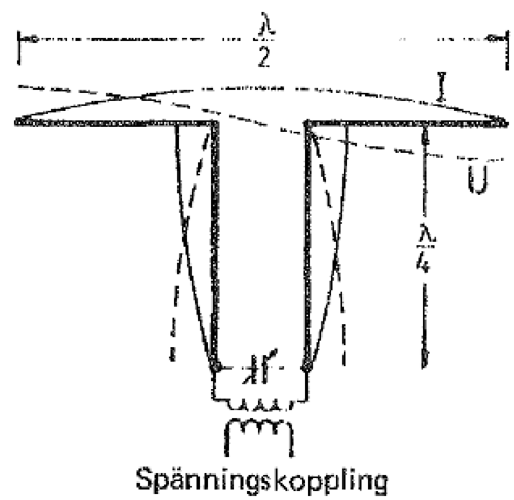

Figure 7.21: Voltage-coupled λ/2-dipole

7.6.1 Tuned feed line

Figure 7.21 shows a λ/2-dipole that is connected to the transmitter output via a λ/4 feed line. For the sake of clarity, the line is shown as a ribbon cable.

During transmission, a standing wave occurs on the feeder line and on the dipole. The feeder line also oscillates with it and is tuned to resonance – hence the name tuned feeder line. We follow the current and voltage distribution backwards from the dipole to the transmitter and find the following: At each end of the λ/2 dipole, a voltage trough appears (dashed lines) and in the middle of the dipole appears a current belly (solid lines).

The standing wave, with the current belly at the center of the dipole, continues down the λ/4 feeder line. At the lower end of the feed line at the transmitter output, a current node and a voltage dip have arisen, which means that the feed line must be voltage-connected to the transmitter. If the feed line is instead λ/2 long, then a voltage node and a current dip appear instead at the inner end of the line, which means that the feeder line must be connected to the transmitter, as shown in figure 7.22. The current and voltage distribution can be drawn up a λ-dipole or λ/2-dipole respectively in combination with feeder lines of lengths n · λ/4 (with n =1, 2 , 3 . .With the help of the drawing, it can be determined whether current or voltage coupling must be used.

Figure 7.23 shows a λ/2 dipole for the 80 m band is connected to a tuned feeder line with the length λ/2 = 40 m. If you wish to use this dipole for the 80 m band on For the 40, 20 and 10 m bands, a so-called antenna coupler must be connected between the transmitter and the feeder line. The coupler always has a current-fed input and a choice of current- or voltage-fed output. See about antenna coupler at the end of this chapter.

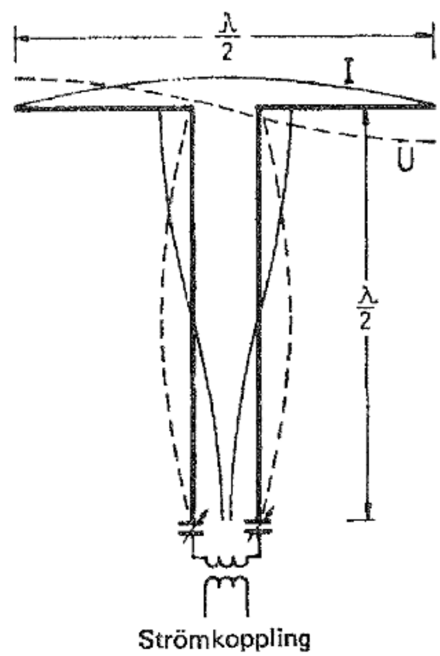

Figure 7.22: Current-coupled λ/2-dipole

7.6.2 Untuned feeder line

The term "untuned" refers to the length of the line, which under certain conditions can be arbitrarily long. In contrast to the tuned feeder line, the line length of an untuned feeder line does not have to be in relation to the wavelength λ. A coaxial cable or open transmission line can be used as a feed line.

Advantages: Simple construction, less critical cable routing and the length can be chosen arbitrarily.

Disadvantages: The transmitter, feed line and antenna must always be impedance-matched to each other. In addition, the antenna and cable currents must be balanced.

The following shows how these requirements can be met. As a feed line up to the microwave range, the coaxial cable is most common.

7.6.3 Coaxial cable HAREC a.6.3.2

The structure of the coaxial cable is shown in figure 7.24.

In a coaxial cable, a radial electric field is formed between the center conductor and the inside of the outer conductor. The outflow also forms a magnetic concentric field between the inner and outer conductor. The result is an electromagnetic field, which spreads in the cable as a TEM wave (TE wave = transverse electric, TM wave = transverse magnetic and TEM wave = transverse electromagnetic wave). The coaxial cable consists of an insulated inner conductor surrounded by an outer conductor , whose inside is the cable's second current conductor. The outer conductor also prevents HF radiation and incoming interference.

In contrast to the symmetrically constructed ribbon cable, the coaxial cable belongs to the asymmetrical lines. Common characteristic impedances for coaxial cables are 50 and 75 Ω.

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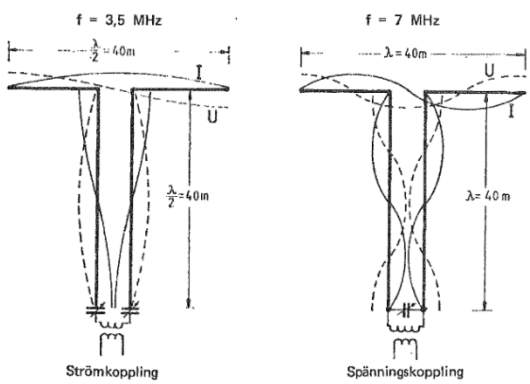

Figure 7.23: The same λ/2-dipole on the fundamental frequency and the 1st harmonic respectively

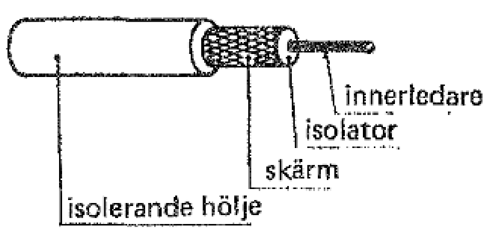

Figure 7.24: Coaxial cable

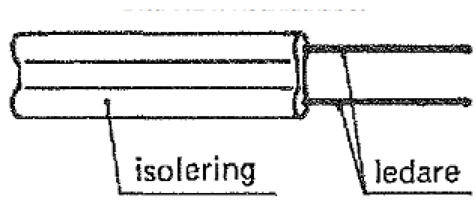

Figure 7.25: Ribbon cable

7.6.4 Ribbon cable HAREC a.6.3.1

As can be seen from picture 7.25, the ribbon cable consists of two parallel conductors with the same dimensions. At the same time, the cable insulation keeps the conductor distance correct. In a more powerful version, this line type is allowed to consist of a pair of conductors with insulated spreaders at equal distances. It will resemble a ladder, the original design of a feeder line. Common characteristic impedances for ribbon cables are 300 and 450 Ω.

7.6.5 Waveguides HAREC a.6.3.3

In the microwave area, the most common type of feeder line is so-called waveguides that lack a center conductor. In a waveguide, the energy is fed forward only as special electric and magnetic fields (TEM) in patterns called modes.

7.6.6 Velocity factor HAREC a.6.3.5

When determining the mechanical length of a single feeder line, it must be taken into account that the wave speed along the line is lower than the speed of light. It talks about a speed factor relative to the speed of light. The speed factor depends on the line's design and material. A coaxial cable has the speed factor $v = 1\sqrt{\varepsilon}$, whereε is the relative dielectric constant in the insulation layer.A common insulation material in coaxial cables is polyethylene with the dielectric constant $\varepsilon = 2.25$.

The velocity factor v (velocity factor) becomes dav = 1√ε = 1√2.25 = 11.5 = 0.6661 meters of such a coaxial cable is 1/0.666 = 1.5 meters for an HF signal.

Even ribbon cables naturally have a speed factor, usually 0.7–0.85.

7.6.7 Characteristic impedance Z in lines HAREC a.6.3.4

Assume that an HF transmitter has been connected to an infinitely long line. If you examine the quotient between voltage and current at arbitrary points along the line,Ωou will find the same quotient everywhere. This constant is expressed in ohms, if voltage and current are expressed in volts and amperes respectively. The constant is called wave impedance or characteristic impedance. Infinitely long lines are unrealistic and then one can instead determine the wave impedance through the line's geometric structure, dielectric constant and its inductance and capacity per unit length.

Example: We investigate the electrical characteristics of a single cable of type RG-213/U. On a test piece with a length of 1 meter, we measure a capacitance of 97 pF between the inner and outer conductor. When one end of the cable is short-circuited, we measure an inductance of 262 nH. The measured capacitance and inductance determine the cable's characteristic impedance Z, also called wave resistance, which is independent of the cable's length. With the above measured values, the impedance becomes: Z =√ LC L [H] C [F] Z[Ω]Z =√ 262000 · 10−1297 · 10−12 =√ 26200097 = 52 ΩThe characteristic impedance of a feeder line is determined by the dimensions of the line and of the dielectric constant of the insulation material. For a ribbon cable is: Z = 276√εr· log 2ad Ω[a = the center distance between the conductors in mm][d = the conductor diameter in mm][εr = the dielectric constant, approximate value 1.5][εr for air = 1.0]For a coaxial cable is: Z = 138√εr· log Dd Ω[D = inner diameter of the outer conductor in mm][d = outer diameter of the inner conductor in mm]Data, impedance diagrams and formulas for calculating transmission lines can be found, among other things, in antenna- manuals.

7.6.8 Standing waves

Both when the connection impedance of the transmitter and the feed line are different, as well as when the connection impedance of the feed line and the antenna are different, a so-called mismatch occurs which hinders the energy transport. Assume that the connection impedance of the feed cable and the antenna are different. Part of the HF energy will then be radiated from the antenna, but the rest will reflect back into the feed line. On the cable there is thus a forward wave towards the antenna and at the same time a reflected wave back towards the transmitter. The voltage and current that can then be measured anywhere on the cable is the algebraic sum of the amplitude of the forward wave and the reflected wave. We move the measuring point step by step along the cable, the voltage and current will rise and fall in a regular manner. The voltage Ub of the backward wave and the voltage Uf of the forward wave are superimposed on each other. The ratio of current and voltage is therefore not constant along the feeder line, but has a wave-shaped course - a standing wave. The points for maxima and minima depend on the load relative to the wave resistance and on the frequency. Standing waves not only occur in the antenna cable box but also in solid materials (wires, etc.), in air (sound), in light (e.g. laser), in electromagnetic fields and so on.

Figure 7.26 shows a standing wave on a wire. The voltage along the cable varies regularly between Umax = Uf + Ub and Umin = Uf − Ub

7.6.9 Standing wave ratio (SVF) HAREC a.6.3.6

(see also SWR = Standing Wave Ratio in section 9.2.9). With the standing wave ratio SVF is meant the ratio between Umax and Umin or between Imax and Imin.SVF = UmaxUmin= Uf + UbUf − UbellerSVF = ImaxImin

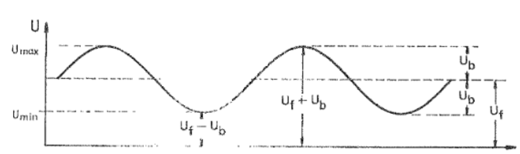

Figure 7.26: Standing wave on line

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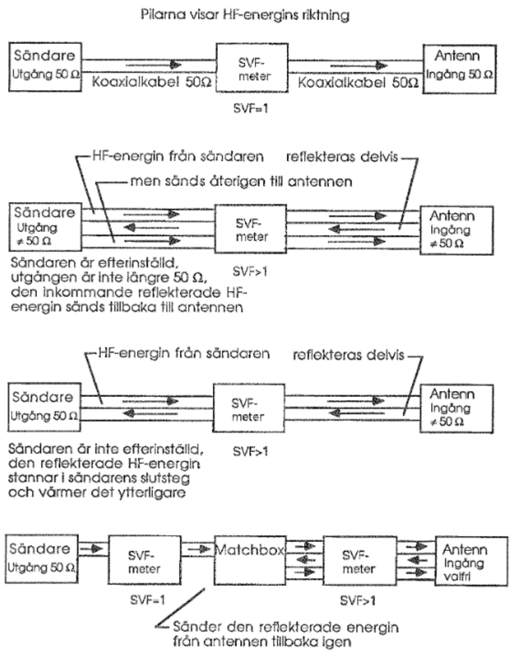

Figure 7.27: The SVF problem simplified picture

The standing wave ratio SVF can also be specified using the impedances in the feed line (Z) and the feed point of the antenna (Za) .

$$\mathrm{SVF} = \frac{Z}{Z_a} \quad \text{där } Z > Z_a \quad \text{eller}$$
$$\mathrm{SVF} = \frac{Z_a}{Z} \quad \text{där } Z > Z_a$$

SVF = ZZawhere Z > Za orSVF = ZaZ where Z > Za

Standing wave measurement is described in section 9.1.9.

Figure 7.27 shows a simplified picture of SVF problems and what an SVF meter shows depending on where it is connected in the chain transmitter - line - antenna connector- conductor - line - antenna. At a higher SVF ratio than 2:1 to 3:1 at the transmitter output, an antenna coupler should be inserted in the post transmitter to protect it from (overheating and) flashover. Antenna couplers also have other names, for example matchbox, antenna tuning unit and so on. It is best to make such impedance adjustments in all stages, that the antenna coupler becomes unnecessary.

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Cable type Impedance

30 50 100 145 150 440 450MHz MHz MHz MHz MHz MHz MHzRG8X 50 ohm 2.0 2.1 3.0 4.5 4.7 8, 1 8.6RG58A/U 50 ohm 2.5 4.1 5.3 6.1 6.1 10.4 10.6RG59 75 ohm 2.4 3.5 7.6RG174 50 ohm 5.5 6.6 8, 8 13.0 25.0RG213 50 ohm 1.5 2.1 2.8 2.8 5.1 5.1RG214 50 ohm 1.2 1.6 1.9 2.8 2.8 5.1 5.1

Kabeltyp	Impedans	30 MHz	50 MHz	100 MHz	145 MHz	150 MHz	440 MHz	450 MHz
RG8X	50 ohm	2,0	2,1	3,0	4,5	4,7	8,1	8,6
RG58A/U	50 ohm	2,5	4,1	5,3	6,1	6,1	10,4	10,6
RG59	75 ohm		2,4	3,5			7,6	
RG174	50 ohm	5,5	6,6	8,8	13,0		25,0	
RG213	50 ohm		1,5	2,1	2,8	2,8	5,1	5,1
RG214	50 ohm	1,2	1,6	1,9	2,8	2,8	5,1	5,1

Table 7.1: Cable impedance per 30

7.6.10 Power losses HAREC a.6.3.7

Losses Occur in every supply line, partly from the resistance in the conductors and partly from the insulation material (dielectric) between the conductors as well as to some extent field radiation from them.

The most noticeable power losses in a line depend on the losses per unit of length and thus also on the length. Furthermore, the standing wave ratio losses depend on the line due to poor impedance matching. A high SVF ratio results in greater line losses because the reflected effect then oscillates more times on the line.

The reflected power returning to the beginning of the line is less when the line has large losses than if it did not. This means that the true SVF ratio at the end of the line is greater than what is seen on an instrument at the beginning. The losses in a transmission line rise with increased frequency and are indicated by the manufacturers in data sheets as the attenuation in dB per 100 m or dB per 30 m of line.

Table 7.1 shows the cable attenuation, the power loss, in dB per 30 m for some common types of coaxial cables.

7.6.11 Baluns – Balancing – Transforming HAREC a.6.3.8

7.6.11.1 Balancing

A distinction is made between symmetrical lines (ribbon cable etc.) and asymmetrical lines (coaxial cable), where in addition one conductor (the screen) is often grounded.

In the same way, there are symmetrical antennas (dipole, W3DZZ etc.) and asymmetrical ones (ground plane, Marconi etc.). If you want to connect a symmetrical (center-fed) antenna to an asymmetrical line (coaxial cable), current balancing must be done in the transition. If not, the feed line will radiate, which can cause radio and TV interference.

Without balancing, the radiation pattern of the dipole will also not be symmetrical. A balancing must also be done in the transition between a ribbon cable (symmetrical) and the transmitter when it has a connection for coaxial cable (asymmetrical). Balancing of impedance and thus current takes place with

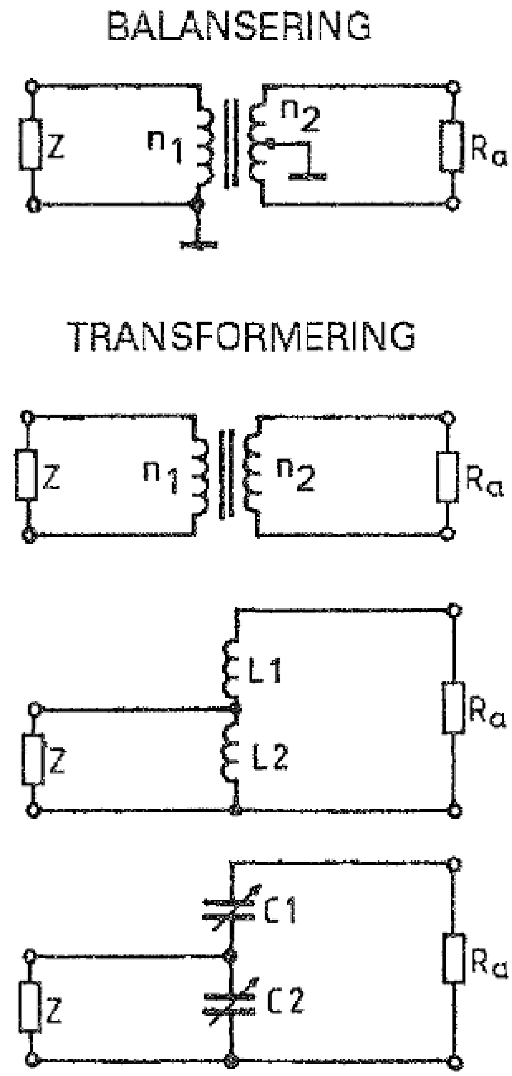

Figure 7.28: Balancing – transformation of a device called BAL UN (from the English words BALanced-UNbalanced).

Baluns can be made in several ways. Basically, the balun has equal input and output impedance, Example:

- Ring core balun 1:1 for balancing.
- Coaxial conductor arranged as a 1:1 balun.

7.6.11.2 Transformation

In connection with the balancing, an impedance transformation maybe needed and there are baluns (transformers
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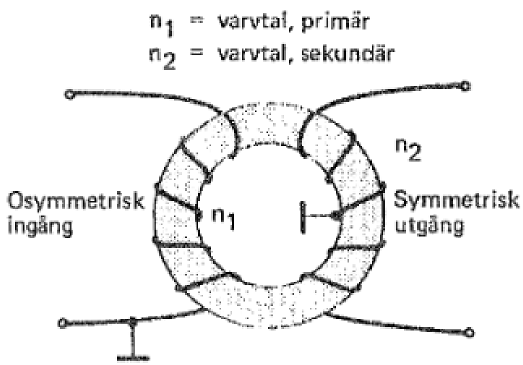

Figure 7.29: Ring core baluns)

that both balance and transform impedances.

Figure 7.28 shows a transformer with unbalanced input unbalanced output.

If the speed of both windings is the same, no impedance transformation takes place. If the ratio between the speeds is 1:2, then the ratio between the impedances is 1:4.See further in section 2.4. The picture also shows that the impedance Z of the feed line is transformed so that it becomes equal to the connection impedance Ra of the antenna. This transformation can take place inductively or capacitively.

Examples:
• Ring core balun 1:4.
• Coaxial conductor arranged as a 1:4 balun.

7.6.12 Toroidal balun

Figure 7.29 shows a toroidal balun which is a form of transformer. In it is a ring core of hard pressed iron powder of an alloy, which, together with the design of the windings, causes the frequency bandwidth to be large.

7.6.13 Coaxial conductor as balun

Balancing can also be done with a coaxial cable arrangement, which in that case is strongly frequency dependent. Figure 7.30 shows three designs, all of which operate on the principle of a feeder line with an electrical length ofΩ/4 and shorted at one end.

The mechanical length is k ·ÿ/4, where k is the velocity factor for the wave velocity in the cable. For the most common coaxial cables RG-58 and RG-213, k is about 0.66.

The Ω/4 line in the top figure acts as a parallel resonant circuit with very high impedance Z at the open top end. In the middle figure, the top part of the feed cable is aΩ/4 long parallel resonant circuit together with parallel connected conductor (in this case a coaxial cable shorted at both ends).

The bottom right figure in the picture shows the short-circuited Ω/4 line in three variants.In all cases, there is a current-balancing effect in terms of HF between the dipole halves.

In addition, antenna currents are also prevented from coming down the outside of the feed cable screen.

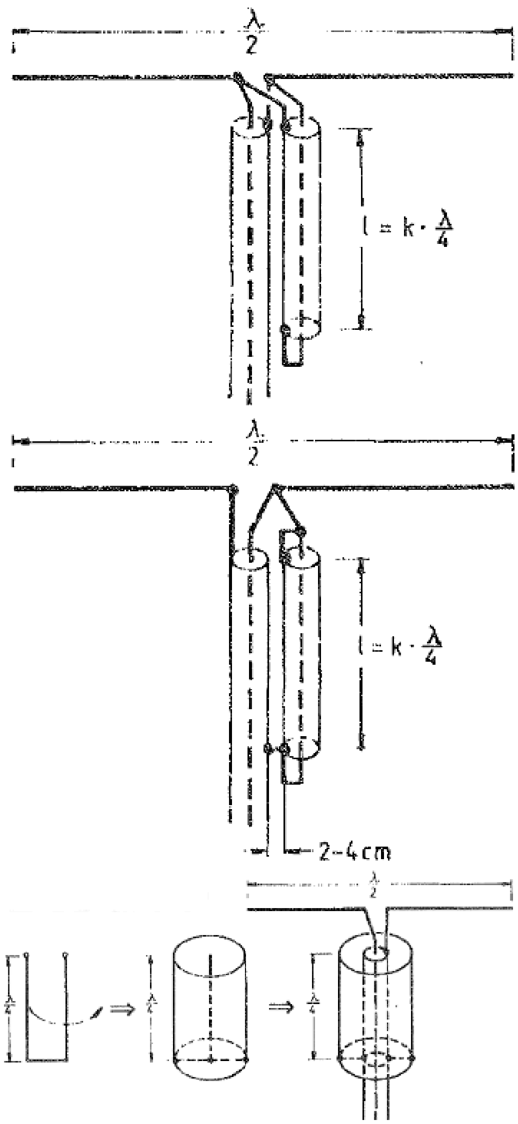

Figure 7.30: Coaxial conductor as balun

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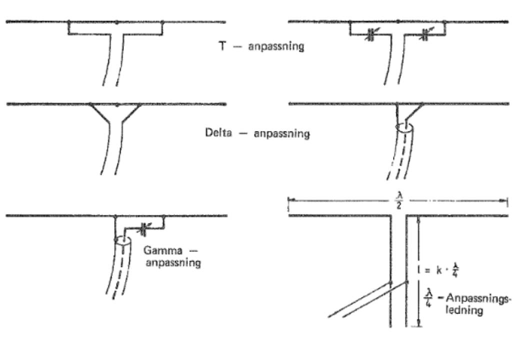

Figure 7.31: Ways to connect a supply line

7.6.14 Ways to connect a supply line HAREC a.6.3.9

Figure 7.31 shows several ways to connect a supply line.

7.6.14.1 T, delta and gamma matching

Function: A center-fed half-wave dipole has an impedance of about 73Ω in free space. If the feed point is moved away from the center, in one direction or the other, the impedance is higher than in the center. There are always two symmetrically located points on the antenna where the impedance is exactly the same. T, delta, and gamma matching are useful when the feed cable impedance is higher than the antennas midpoint impedance. The feed line can be connected to the points on the antenna that have the same impedance as the feed line. T matching is used for symmetrical feeder lines, gamma matching for unbalanced lines and delta matching for both line types.

7.6.14.2 Ω/4 matching line – stub

Construction: The antenna is connected to aΩ/4 matching line and the feed line in turn to the matching line. Function: The adaptation line consists of an openΩ/4 feeder line. It theoretically has impedance Z = 0 the end connected to the antenna and Z =Ω the other. Along the adaptation line there is always an impedance that is equal to the impedance of the feeder line.

7.6.14.3 Ω/2 phasing line

Figure 7.32 shows aΩ/2 phasingline. Figure 7.32:Ω/2 phasing line Function: When, for example, a folded dipole with a supply impedance of 240Ω is to be connected to a 50Ω cable, an impedance transformation with the ratio 4:1 is needed. AΩ/2 long phasing wire can be used for this purpose. The phasing line also has a current-balancing effect. Note:

With aΩ/2 phasing line as shown, impedance transformation can only be done in a ratio of 4:1.

7.6.15 The transmission line

Transmission line for radio frequency energy consists of two electrical conductors. The simplest form of such a line is two parallel conductors. Another form of transmission line is the coaxial cable, where one conductor runs inside the other.

Try: Connect a parallel line to the output of a VHF transmitter - for example with inductive coupling.

Give the line the appropriate length and output high-frequency energy on the line. Now the distribution between voltage and current at different points along the line can be investigated. When there is a voltage between the two conductors in the wire, an electric field is generated between them. Since a glow lamp glows when surrounded by an electric field, it can be used as a simple

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Figure 7.33: Flow in openΩ/4 transmission line voltage indicator.

When an electrically conducting circuit – an induction loop – is surrounded by a varying magnetic field, a current is generated in the loop. With a light bulb plugged into the loop, it can be used as a simple current indicator.

7.6.15.1 Open transmission line

Figure 7.33 shows Process in openΩ/4 transmission line. Hold the flashlight close to the wire. The glow lamp lights up at regular intervals when it is moved along the line. When, instead, an induction coil with a light bulb is held close to the wire, the light bulb will shine in the middle of the places where the glow lamp shines. Where the glow lamp lights up, a voltage maximum has formed and where the light bulb lights up, a current maximum has formed. A standing wave has formed on the line. The figure shows the current and voltage distribution for an open transmission line of length l = n·ÿ/4 with odd n = . ..

For the image, n = 5 has been chosen. Along the line, alternating electric and 1, 3, 5 . magnetic fields as the oscillation continues. With a series of four figures, the progress of a swing, a period is shown.

The differences in the electric field strength are represented as field lines of different lengths. Note the direction of the field lines. The differences in the magnetic field strength "·"can also be read from the images in the form of the number of symbols respectively “×”.

Both sign denotes electromagnetic field, "·"in the direction out of the paper and "×" in the direction of the paper. For the sake of clarity, only the electromagnetic field strength between the conductors and not outside the pair of conductors transmission line Figure 7.34 shows both the current and voltage conditions as well as the field line courses on a tuned, short-circuited transmission line with length l =Ω/4 with even n = 2, 4, 6, 8.. .. For the picture, n = 6 has been chosen. 7.6.16Ω/4 line as resonant circuit

Figure 7.35 shows the current and voltage distribution for an open and a short-circuited transmission line with length lÿ/4.

The openΩ/4 line has a current belly at the input end. Such a line must therefore be current-coupled, that is, the connecting impedance must be low.

The short-circuitedΩ/4 line has a voltage bump at the input end. Such a line must be voltage-coupled, i.e. the connecting impedance must be high. An openΩ/4 line can be seen as a series-connected LC circuit. When the line is in resonance, a high current flows in the input, while the voltage there is low.

A short-circuitedΩ/4 line can be seen as a parallel-connected LC circuit. When the line is in resonance, the voltage across the input is high, while the current there is low.

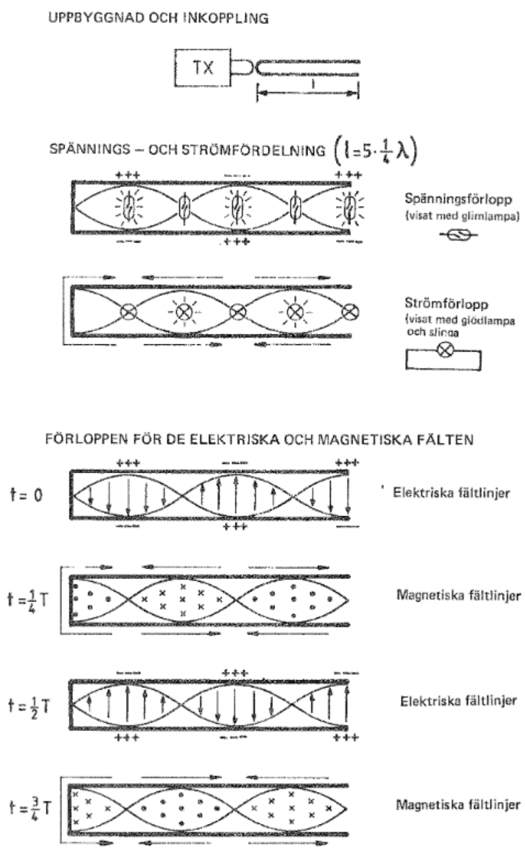

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Figure 7.35:Ω/4 transmission line as resonant circuit

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7.6.15.2 Shorted transmission line

Figure 7.34 shows both the current and voltage conditions as well as the field line progressions on a tuned, short-circuited transmission line with length l = λ/4
with even n = 2, 4, 6, 8 . . .. Because the image has been selected
n = 6.

7.6.16 λ/4 conduction as resonant circuit

Figure 7.35 shows the current and voltage distribution for an open and a short-circuited transmission line with length l = λ/4.

The open λ/4 line has a current belly in the aisle end. Such a line must therefore is connected, i.e. the connecting impedance must be low.

The short-circuited λ/4 line has a voltage bump at the input end. Such a line must be voltage-coupled, i.e. the connecting impedance must be high. An open λ/4 line can be seen as a series-connected LC circuit. When the line is in resonance, a high current flows in the input, while the voltage there is low.

A short-circuited λ/4 line can be seen as a parallel-connected LC circuit. When the line is in resonance, the voltage across the input is high, while the current there is low.
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7.6.17 Antenna coupler

Figure 7.36 shows an antenna coupler for ribbon cable of different lengths. The size of the capacitors:C1 = C2 = 500 pF, C3 = 300 pF.

7.6.17.1 Tuning

When voltage coupling C1 and C2 are completely twisted or short-circuited, C3 is tuned for resonance condition (parallel resonance).

7.6.17.2 Tuning

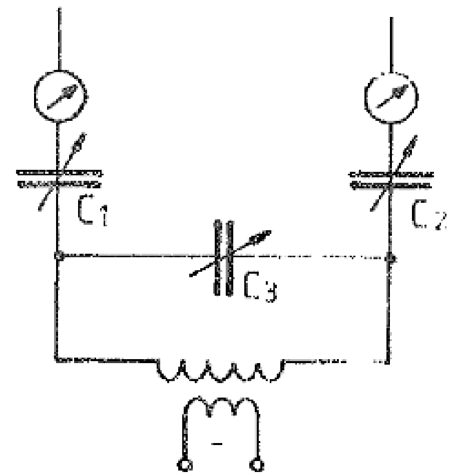
When current connection C3 is completely turned out, C1 and C2 are tuned for resonance (series resonance), with maximum and equal current in both conductors. The feeder line can be extended electrically with inductances when it is too short to be tuned. Note that an antenna coupler can very well also be designed for coaxial cable output.

7.6.18 Advantages and disadvantages of tuned feeder line

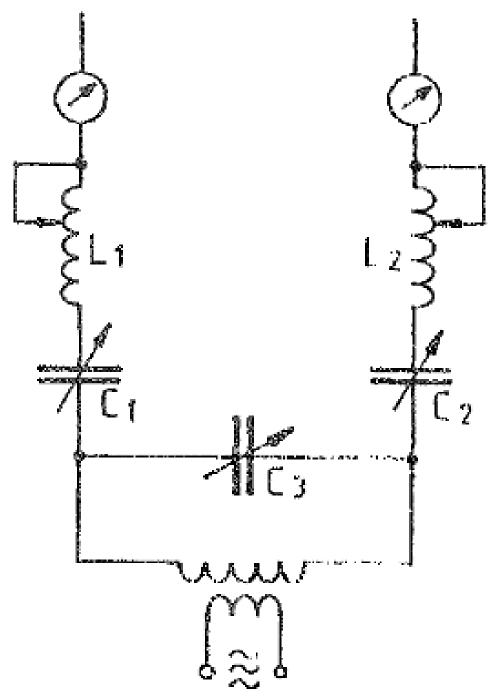
When a feeder line is properly tuned, it transports energy without radiating itself. When the dipole is connected to a tuned feeder line, it can work on several amateur radio bands with the help of an antenna coupler. This is one reason why a tuned feeder line is often used for portable installations (e.g. for field days).

The adjustment to the transmitter becomes easier. Within amateur radio, coaxial cable is now used almost exclusively as a feed line instead of ribbon cable. This is for several reasons:

• A ribbon cable must be suspended as freely as possible and it must not come too close to wall protrusions, gutters, etc. Furthermore, it must be well insulated in the case of penetrations in walls.
• Most transmitters do not have room for long feeder lines (n·ÿ/4 with n = 1, 2, 3 . . .).In the case of sharp bends in the cable, there may be unwanted radiation and thus the risk of interference with radio and TV etc.



Antennkopplare för en parallell-ledning med längden
$l = n \cdot \frac{\lambda}{4}$



Antennkopplare för en parallell-ledning med längden
$l \neq n \cdot \frac{\lambda}{4}$

Figure 7.36: Antenna coupler

Federal Communications Commission (FCC) OET bulletin 65 supplement B [18].

• EU directive 1999/519/EC [5] 252 12 Electrical safety

8 Wave propagation

Electromagnetic wave propagation is energy transport and the prerequisite for all radio communication. However, the propagation of radio waves on the path between transmitter and receiver is affected in many ways.

Awareness of the propagation method of radio waves allows one to methodically try to achieve the desired radio connections.

8.1 The force fields around antennas

Antennas are needed to send out and receive radio waves. Very simplified, an antenna is an electrical circuit, which consists of an inductor and a capacitor as illustrated in picture 8.1.

With the capacitor's electrodes completely pulled apart and reduced in size, the resonant circuit has a very different mechanical appearance. Since the inductor and the LC circuit have been removed, mechanically only a single conductor remains, but electrically the circuit is still there.

The conductor with its extension is still an inductor and the surfaces of its opposite halves are still the electrodes in the capacitor with the surroundings as dielectric. An electrical conductor, a rod, wire, etc. is thus an electrical resonant circuit, whose resonant frequency is mostly determined by the length and thickness.

The conductor (antenna) can be called a dipole - it has two poles, this is the basis for all types of antennas.

There are certain similarities between a mechanical pendulum and an electrical resonant circuit. The energy in a mechanical pendulum switches between two extreme states. One is when the pendulum is just turning in an extreme position. Then it contains only positional energy and no motional energy. When the pendulum moves towards the middle position, the positional energy is converted into kinetic energy. In the middle position, which is the other extreme state, the pendulum contains only motion energy and no position energy, etc.

8.1.0.1 Electric resonance circuit

The electrical resonance circuit can be compared to the mechanical pendulum where there is a constant oscillation or conversion between position energy and motion energy. See figure 8.2. When the current in the electric resonant circuit has just stopped to reverse, the capacitor contains the most charge, that is, the strongest electric field between the electrodes. This field can be compared to the potential energy of the pendulum. The equalizing current that follows from one electrode over to the other is surrounded by a magnetic field that can be compared to the kinetic energy of the pendulum. The process is shown in figure 8.2, where it can be seen that the dipole is surrounded by the strongest electric field at time t = 0 and at t = 1/2T with reversed polarity , where T is the period time. Furthermore, the dipole is surrounded by the strongest magnetic field at the time point t = 1/4T and at t = 3/4T with reversed current direction and field polarity. With the explanation of the E and H fields as background, a simple representation of how radio waves arise from these fields now follows .Maxwell demonstrated in his equations, among other things, the relationship between electrons in motion in a conductor and electromagnetic waves in space. Furthermore, that electrons that move with decreasing or increasing speed emit electromagnetic energy. How energy radiates from a conductor can be explained with an (imaginary) elementary dipole, through which alternating current flows (Figure 8.3). The dipole consists of two equal electric charges with opposite polarity . When fed with alternating current, the charges move constantly, alternately towards and away from each other. Think of two balls at each end of a coil spring. The distance between the charges changes in step with the strength and direction of the current. The system is thus under constant speed change (increase or decrease), which is the prerequisite for energy to be radiated. First, the charges are close each other due to lost charge. With increasing current, the distance between the charges increases and a more widespread and energy-rich E-field is built up. At the same time, an H-field also builds up around the dipole, perpendicular to the E-field and beyond. This applies both to an elementary dipole and an electrical conductor with many free electrons (real ligand antenna).

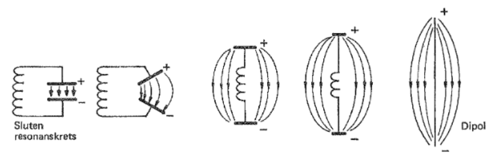


Figure 8.1: From closed LC resonant circuit to antenna

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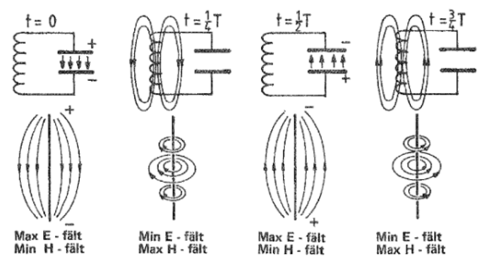

Figure 8.2: The oscillation between E-field and H-field

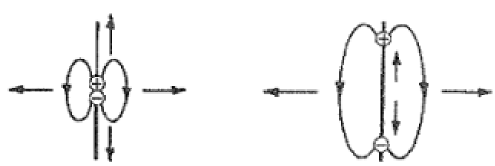

Figure 8.3: Elementary dipole

The formula for the resulting S field is S = E × H, which shows that the stored energy in the dipole's immediate surroundings increases as the distance (potential) between the dipole's charges increases increases.

Figure 8.4 shows how an E-field is built up around a dipole and separated from it. The lines of force shown are the E field. The H field is not shown, but lies perpendicular to the E field, in circles around the antenna.

See Figure 8.5. When the dipole's charges change direction and start moving against each other again, the E-field that has been built up also starts to change direction. But it will not fall back to the center of the dipole, but will end up in its own circuit - Maxwell's first equation. Compare with a soap bubble that has left the blowpipe. Around the dipole, an independent E-field has now formed, which in turn produces its own H-field. A period of an electromagnetic wave (an S-field) has been generated and continues to expand. For each subsequent period, a new E field is generated, which separates from the antenna and forms an H field, and so on.thus a new "field bubble" inside the previous one, which is expanding. The result is an electromagnetic field, i.e. a radio wave. As mentioned, a radio wave consists of a high-frequency electromagnetic field (S). It is in turn composed of two other fields, the electric E field and the magnetic H field. The energy in the S-field is distributed equally between the E-field and the H-fields, whose forces cross each other at right angles. The S field lies in the plane of both the E and H fields and spreads out perpendicular to them. The direction of the S field depends on the mutual direction of the E and H fields. When the E field is vertical, the wave is said to be vertically polarized. When the same field is horizontal, the wave is said to be horizontally polarized. When the E field rotates in the plane of the wavefront, and thus also the H field, the wave is said to be circularly polarized. The fields are presented in text and image as so-called lines of force with arrows representing the direction of force. The length of the lines represents the strength of the field.

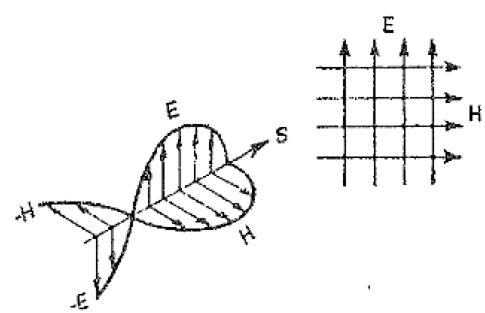

Figure 8.6 shows a section of a wavefront S with vertical polarization.

8.2 Properties of radio waves

8.2.1 Propagation of radio waves HAREC a.7.2

An electromagnetic field that is generated at a given time spreads out in all directions in space like an ever-growing sphere. The field strength within a given section of the sphere surface therefore decreases as the distance from the transmitter increases. This is why a transmitter hums weaker the farther it is from the receiver. Compare the light from an omnidirectional lamp. In space, radio waves spread very far. However, propagation losses also occur where there is matter in the way. When the radio waves pass through layers similar to the earth's atmosphere, much greater propagation losses occur than in space, and thus the range is shorter.

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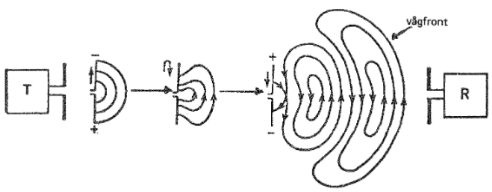

Figure 8.4: A independent E-field is created

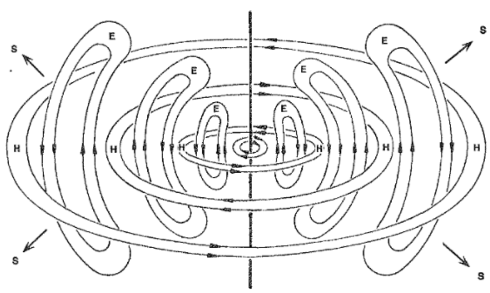

Figure 8.5: The E-, H- and S-fields around an antenna (simplified representation) the materials that are electrically conductive.

The radio waves
• propagate in a straight line in all directions in space with the speed of light which is approximately 300,000 km/s (see also section 7.1.1)
• penetrate solid bodies, which are not electrically conductive
• are attenuated or reflected, among other things by metals, ionized liquids and ionized atmospheric layers
• are polarized
• reinforce or oppose each other.
The radio waves spread
• along the earth's surface
• up from the earth's surface
• up from the earth's surface after an initial reflection against it.

The first method is called a ground wave and the two latter are called a collective term space wave. 211

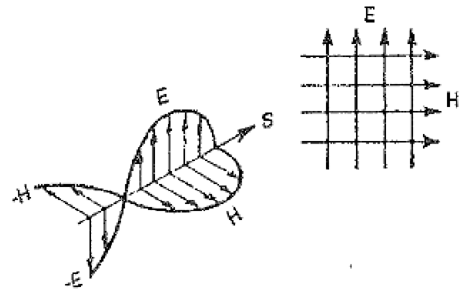

Figure 8.6: E, H and S fields

8.2.2 Bending of radio waves HAREC a.7.11

The direction of radio waves can be bent by

• reflection or splitting against natural reflectors in the atmosphere and in the earth's surface
• artificial both passive and active reflectors (relay stations) on the earth's surface and in space. The radio waves can be attenuated
• in the earth's surface
• in the topography
• in the atmospheric layers.

The height of an antenna affects the direction of the wave, due to reflection on the ground, or rather the moist part a little below the surface.

This reflected wave is phase-shifted through the longer distance it travels, and the direction in which the reflection interacts with one or more full-wavelength delays will be the direction in which the antenna has the best effective radiation.

The higher an antenna sits, the lower the so-called take-off angle have it. Therefore, an antenna that sits low in relation to its wavelength is directed mainly upwards, which causes it to reflect towards the ionosphere and down into the near area, this is called Near Vertical Incidence Skywave (NVIS).

An antenna that sits high gets a lower angle, which is well suited to transmit long distances, when one or few bounces are needed.

The nature of wave propagation is very complex and cannot be simply described. Some strongly influencing factors on wave propagation can still be distinguished, for example

• the height of the propagation path above the earth's surface
• the frequency of radio waves
• the ionization of the earth's atmosphere by solar radiation
• the weather conditions.

8.2.3 Different types of wave deflection

Different factors affect wave propagation within different sections of the frequency spectrum. Here are the most important:

8.2.3.1 Reflection

Reflection means that the waves are bent back from the surface they hit. Light and radio waves are reflected under the same conditions because both are electromagnetic in nature. The big difference is the wave frequency. The size of the reflector is expressed in terms of the number of wavelengths at the current frequency. An 80-meter wave does not reflect well against a surface with only a few meters on a side. In contrast, a 2-meter wave is reflected much better against an equally large surface and a light wave (with wavelengths 440–740 nm) incomparably much better.

The ability of different materials to reflect an incident radio wave depends on the frequency of the wave as well as the material's thickness and electrical conductivity. The wave penetrates deeper into the material at low frequency or at low conductivity.

8.2.3.2 Refraction

Refraction (refraction) means that the wave changes direction when it crosses the boundary between two media or materials with different refraction indexes.

When the conductivity changes successively, for example in an atmospheric layer, the deflection of the wave becomes soft. Refraction occurs, for example, when you look at an object underwater, where the apparent position can deviate from the real one, which you notice if you stretch your hand into the water.

8.2.3.3 Diffraction

Diffraction means that the direction of incidence of the wave splits up into several new directions, when the wave passes close over an obstacle. It is because of this phenomenon that radio signals can to some extent be heard even beyond mountain ridges. Diffraction increases with decreasing frequency. There are a few different types of diffraction for radio waves, of which one of the most important in the terrain is called "knife-edge diffraction" and breaks the radio waves down towards the ground.

8.3 The ionosphere layers HAREC a.7.3

At high altitudes, atoms and molecules can travel long distances without colliding, they are then layered by the influence of gravity so that the lighter atoms are placed over the heavier ones.

Strong solar radiation knocks electrons off the atoms so that positively charged atomic nuclei and free electrons ionize. These ionized layers, which partly consist of electrically conductive gas, have given their name to the ionosphere.

When a radio wave passes through an ionized layer in the atmosphere, the wave can change direction, which is called refraction.

For refraction to occur, two conditions must first be met, the first is sufficiently dense ionization and the second is sufficiently long wavelength. Under "favorable" circumstances, the waves can even be bent down towards the earth, which is the most important prerequisite for long-distance radio connections on shortwave.

However, the ionization of the atmosphere is irregular and varies with, among other things, the height above the earth's surface, solar radiation, time of day, season and more. A number of ionized layers can be defined. See figure 8.7.

8.3.1 The D layer

The D layer occurs during the bright part of the day at an altitude of approximately 50–90 km. At an altitude of 70–90 km

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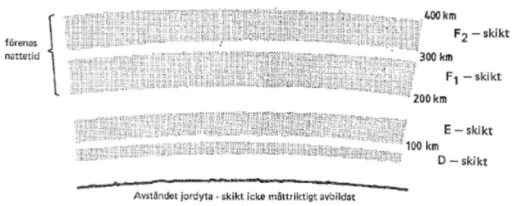

Figure 8.7: Ionosphere layers,

ionization is mainly caused by X-rays from the sun, while cosmic radiation has the greatest impact at an altitude of 50–70 km. The D layer dampens the incident radio waves, with the greatest effect in the low-frequency part of the short-wave range and during the lightest hours during the summer. The D-layer has poor reflectivity and acts as an obstacle to long-distance connections.

8.3.2 The Mögel-Dellinger effect

Radiation from gas eruptions on the solar surface can ionize the D-layer so strongly that all radio waves with frequencies above about 1 MHz are completely attenuated, this is called the Mögel-Dellinger effect .

Radio traffic that is based on wave propagation via the ionosphere is then impossible to carry out for a period of a number of minutes up to several hours - it becomes "black out".

8.3.3 The E-layer

The E-layer (Kenelly-Heaviside layer) is the least reflective ionosphere layer. It occurs at an altitude of about 90–140 km and is most concentrated at about 110 km altitude. The E-layer is produced by ultraviolet radiation ionizing oxygen atoms.

The layer reflects waves best in the low-frequency part of the short-wave range and is strongest during the bright part of the day.

Due to the dampening effect of the D layer during the brightest hours, the E layer is most useful during the pre-dawn and dusk hours. A seasonal maximum in reflectivity occurs during the summer. Connection distances of up to 2000 km are possible.

8.3.4 Sporadic E layer

The stronger solar radiation during the summer causes stronger ionization in the lower ionosphere than during the winter. Sporadic thin cloud-like areas with a very high degree of ionization and high reflectivity are then formed within the E-layer, the so-called sporadic E-layer (Es). The wave propagation via Es is very different at different latitudes and is best around the 40th latitude. Very good long-distance connections are achieved.

8.3.5 The F-layer

The F-layer is the uppermost ionospheric layer. It occurs both during the day and at night at an altitude of 140–500 km. The lower part of the layer, 140–200 km, shows different variations than the upper part. The F layer is therefore described as two layers, F1 up to about 200 km altitude and F2 above this altitude.

Like the E layer, the F1 layer is strongly affected by the radiation from the sun. It reaches its highest degree of ionization approximately one hour after the highest local solstice and occurs only during the summer. During the night, the F1 and F2 layers merge into the eleventh F layer. The F2 layer is the layer that varies the most in time and space. The highest degree of ionization usually occurs late after the highest local solstice, sometimes during the evening hours. The layer's maximum ionization is at 250–350 km altitude at midlatitudes and at 350–500 km altitude at the equator. At mid-latitudes, the greatest electron density in the layer is higher during the night than during the day. At the equator, the relationship is reversed. Reflections in the F2 layer enable large distances to be bridged (1 hop = 3000–4000 km).

8.3.6 Height to reflecting layer

When a radio wave, which is directed straight up, hits the ionosphere, it can either

- absorbed – sucked up
- reflect
- penetrate.

Which occurs depends on the frequency used. The higher the frequency of the upward radio wave, the higher up in an atmospheric layer the deflection back will occur. The height of the layer is calculated from the radio wave's propagation speed and propagation time back and forth between the layer and the earth's surface.

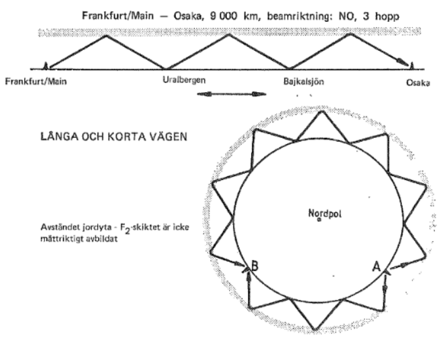

Figure 8.8: Ionosphere propagation.

8.3.7 Critical frequency HAREC a.7.4

At a certain upper frequency, the reflection in the atmospheric layer ceases and the wave goes out into space instead of down to the earth's surface. This frequency is called the critical frequency, which varies with the degree of ionization in the atmosphere. The critical frequency is highest at high sunspot numbers, both in the E and F layers, because the degree of ionization is the greatest. The critical frequency for the E layer varies between about 1–4 MHz depending on the time in the sunspot cycle and the time of day. The critical frequency for the F layer varies with time of day, season and stage of the sunspot cycle. It can vary from 2–3 MHz at night during a sunspot minimum to 12–13 MHz during the day during a sunspot maximum.

8.3.8 Critical angle

The space wave must hit an ionized atmospheric layer with a sufficiently shallow angle to be reflected, the so-called critical angle. This angle is frequency dependent. As the emitted frequency increases further above the critical frequency, the wave must hit the atmospheric layer at an increasingly shallow angle for the wave to be reflected back to the Earth's surface.

By transmitting the wave at a very shallow angle to the F2 layer, long distances can be bridged at frequencies that are up to 3.5 times the critical frequency. As soon as the critical frequency is higher than the frequency range of an amateur band, it is thus possible to communicate over space wave on this band. It can happen over any distance, ranging from the distance of the ship to that determined by the propagation losses.

8.3.9 Highest usable frequency (MUF)HAREC a.7.6

The radio waves travel from the transmitter to a distant receiver by being reflected one or more times in the ionosphere and on the earth's surface.

See figure 8.8.

For this to happen, the frequency cannot be higher than the highest usable frequency (eng. Maximum Usable Frequency (MUF)) for a certain transmission distance. The MUF is highest in the middle of the day or early afternoon. The MUF is at its highest during periods of high sunspot number and can then reach over 30 MHz. During the early morning hours, the MUF often drops below 5 MHz and sometimes even lower, especially in winter.

The ionospheric losses are lowest near the MUF and increase rapidly during the daytime for lower frequencies. Current MUF -data is published periodically in various media, but can also be estimated using special computer programs.

8.3.10 Optimal traffic frequency (FOT)

In practice, it is of interest to know the frequency range where communication can best be carried out. Recommended upper frequency limit for a reliable radio connection is called optimal traffic frequency (FOT) and is chosen slightly below the MUF as a margin for irregularities and turbulence in the ionosphere, as well as for short-term deviations from the predicted monthly median value for the MUF.

FOT is usually about 15% lower than MUF.

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Radioprognos Juni 1997 SSN = 6

Tid/ /GMT	1.8 MHz 000011111222 246802468024	3.5 MHz 000011111222 246802468024	7 MHz 000011111222 246802468024	10 MHz 000011111222 246802468024	14 MHz 000011111222 246802468024	18 MHz 000011111222 246802468024	21 MHz 000011111222 246802468024	24 MHz 000011111222 246802468024	28 MHz 000011111222 246802468024
5H	...:....:...	...:....:...	...:....:.o.	.o.:....o11.	.1o:..o111..	...:...11...	...:....:...	...:....:...	...:....:...
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A4	...:....:...	...:....:...	o..:....:oo1	2o.:...o1123	o21o.112331.	.o111..12o..	...:....:...	...:....:...	...:....:...
EL	...:....:...	...:....:...	1..:....:...	3o.:....:oo1	...o...o121o	...11111:1..	...oo...12..	...:....:...	...:....:...
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UA9	...:....:oo.	...:....:o..	o..:....1221	1oo:.o122222	.111oo111o..	...33...:...	...:....:...	...:....:...	...:....:...
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SM 500	453333445554	454343445554	223333333432	..o1o...o1o.	...:....:..o	oo.:....:.oo	oo.:....:.oo	oo.:....:.oo	oo.:....:.oo
SM 750	443212444554	554332345664	234565554543	122222222222	..oo....o1o.	...:....:...	...:....:...	...:....:...	...:....:...
SM 1000	4421o2334454	543221234554	345566665654	232332222332	112221112221	...:....:o..	...:....:...	...:....:...	...:....:...

Tabellen visar sannolikheten att få förbindelse för alla amatörband på kortvåg (1.8-28 Mhz) och varannan timme (02-24) GMT. Sannolikheten anges i procent. "9" betyder 90-100 %, "8" 80-89 %,..., "2" 20-29 %, "1" 10-19 % och "o" 5-9%. Mindre än 5 % markeras med "." (":" för timmarna 08 och 18). Vidare förklaring finns i QTC nr 1 1995 samt notis i QTC nr 4 1995. /SM5IO, Stig

Figure 8.9: Radio forecast for the amateur radio bands on shortwave

8.3.11 Lowest usable frequency (LUF)

The lower the transmission frequency chosen, the more the waves are attenuated in the ionosphere, until the frequency at which they cannot be perceived. The Lowest Usable Frequency (LUF) is the frequency that provides satisfactory communication for a certain propagation path and at a certain time. At frequencies below the LUF, reception is not possible because the noise level is then too high. The more the frequency is raised above LUF, the better the signal-to-noise ratio becomes. Unlike MUF, which is only affected by the ionospheric conditions, LUF can be partly affected by transmitted power and bandwidth. In general, LUF can be lowered about 2 MHz for every 10 dB bending of ERP.

8.3.12 Wave propagation predictions

Regular predictions are made of the ionospheric conditions. Continuous physical observations, statistical and mathematical processing form the basis of the predictions, which are used, among other things, to plan radio traffic.

Propagation forecasts, which provide information on the most suitable frequencies and times for various connection routes, are made by both civil and military institutions.

In the past, such predictions were announced in public publications as well as in amateur radio magazines and bulletins. Today, virtually all wave propagation predictions, data on solar activity, and information on the geomagnetic field are freely available on the Internet. A search on the Internet for propagation forecast ham radio returns hits on many websites. The SSA website has in the right margin information about solar terrestrial data and calculated conditions. In the past, wave propagation predictions were only available as Ursigrams sent by telex or letter from the Union Radio-Scientifique Internationale (URSI). The Ursigrams could be obtained through an expensive annual subscription and they contained current measurement values such as sunspot number R, 10 cm solar flux F , magnetic index K and boundary attenuation values. They could also contain instructions about special events (flares, magnetic storms, polar cap absorption, Mögel-Dellinger effects and the like).

Figure 8.9 shows a radio forecast for June 1997 SSA's member magazine QTC. The table in the image shows the percentage probability of getting a connection on the various shortwave bands from Sweden to other countries and parts of the world.

Despite its age, the table gives an image of how the possibility of getting a connection on shortwave varies with frequency and time of day. Also note the low sunspot number SSN (Sun Spot Number).

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8.4 The Sun's influence on the ionosphere HAREC a.7.5

8.4.1 Solar Activity

The Sun is a ball of gas, in the interior of which a constant nuclear reaction takes place where hydrogen atoms are converted into helium. During this process, part of the solar matter is released as particle radiation and electromagnetic radiation in-about a wide frequency range, including short-wave radio radiation and gamma radiation. The outer part of the solar atmosphere consists of two layers, the chromosphere and the corona. Some areas on the sun's surface have a lower temperature and are perceived as dark spots - sunspots.

Masses of gas, so-called protrusions, are ejected from the chromosphere, often from areas near the sunspots. There are also short-term eruptions , so-called flares, which appear as bright spots near the sunspots.

Flares emit strong electromagnetic radiation and particles. The corona is the outermost layer of the solar atmosphere. From this, particles in the form of atoms, electrons and protons are emitted, which are captured by the earth's magnetic field and create the aurora, the so-called aurora. The increased particle radiation from flares can cause magnetic storms with accompanying radio disturbances and an increase in the aurora borealis. The number of visible sunspots is related to solar activity.

8.4.2 Sunspot number

A measure of solar activity is the number of sunspots, which are continuously observed. From this statistical material, a weighted sunspot number R (Wolf number) is calculated. With the support of solar observations for more than 200 years, it has been determined that the sunspot number varies reasonably periodically between approximately 200 and 5. A sunspot period lasts between approximately 7.5 and 17 years, with an average value of approximately 11 years - the so-called 11-year cycle. In December 2019, the cycle 25, counted from when the observations began.

During the first years of a new cycle, there are often better opportunities for DX (long distance) on shortwave.

More recently, yet another method has begun to be used for measuring solar activity. Then the strength of the radio noise from the sun (solar flux F) is measured in the wavelength range 10 cm.

Both measurement methods give essentially the same tendencies and there is a statistical relationship between them.

Wave propagation in the ionosphere is affected by solar activity.

During sunspot maximum, the ionosphere becomes strongly ionized, especially the F layer during daytime. Then even waves with shorter wavelengths are reflected against the ionosphere instead of passing through it into space. The 20-meter band is then "open" almost around the clock, the 15-meter band from before dawn until sunset and the 10-meter band almost every day until after sunset. Long connections with very low effects are possible.

During sunspot minimum, however, it is necessary to use a significantly lower operating frequency than at sunspot maximum. For example, the 20-meter band does not remain open throughout the night. Openings on the 15 meter band occur only occasionally and openings on the 10 meter band are rare.

Good antennas and higher powers are then used to compensate to some extent for the poorer wave propagation. At low solar activity, the higher bands can be so quiet that the operator may wonder if the equipment is really working.

8.5 Wave propagation on shortwave HAREC a.7.7

Figure 8.10 illustrates wave propagation on shortwave.

8.5.1 Ground wave

The ground wave (eng. ground wave) spreads along the earth's surface without contact with the atmosphere through reflection or refraction. The ground wave has vertical polarization and a vertical wavefront when the ground plane's conductivity is good.

With poorer conductivity, the wavefront tilts forward. The range of the ground wave is in relation to the frequency used, the transmitter power and the ground plane's conductivity. At frequencies below about 10 MHz, near the earth's surface a fairly good conductor. Ground wave propagation is therefore mostly used at low frequencies, for example for broadcast radio in the long and medium wave bands when the range can be in the order of 1000 km.

In shortwave, the ground wave range in the 80-meter band is about 100 km and in the 10-meter band about 15 km.

8.5.2 Space wave

Under certain conditions, the radio waves are reflected against ionized atmospheric layers and reach the earth's surface again at a great distance from the point of transmission, then you can use space wave (eng. space wave).

Space wave propagation is used between places on the earth's surface with a large distance. In order to best achieve the desired reflection, one must partly choose the appropriate time and frequency and partly design the antenna so that it has its main direction at a certain angle to the reflecting layer.

The ionosphere is the part of the atmosphere of approx. 50 to 350 km altitude, where the radiation from the sun creates free electrons and ions in such a quantity that layers with good electrical conductivity are formed. Under certain conditions these layers reflect the radio waves, but under other conditions they can also absorb them.When the waves from the earth's surface have been reflected against the deionized layers, they can re-enter the earth's surface at a distance of up to 4000 km from the emission point, depending on frequency and polarization. Then it could be reflected again towards the earth's surface and up into the ionosphere and so on (multi-step jump). Under favorable conditions, the space wave reaches very far through alternating reflections between the earth's surface and the ionosphere.

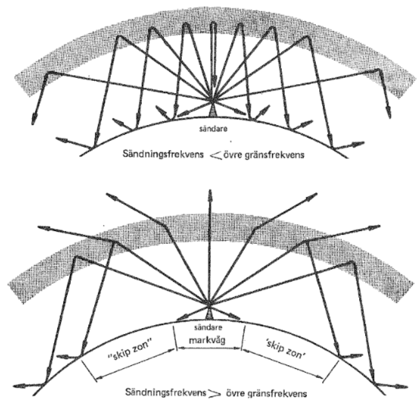

Bild 8.10: Vågutbredning på kortvåg

Figure 8.10: Wave propagation on shortwave

8.5.3 Dead zone (skip zone) and skip distance

The space waves are bent back towards the earth when they hit the ionosphere at an angle that is flatter than the so-called critical the angle.

When the waves hit the ionosphere at a steeper angle than the critical angle, no deflection takes place, but the waves pass through the ionosphere and straight out into space. Depending on the critical angle at the moment, therefore, reflected space waves will not be heard until a certain distance away from the transmitter. This distance is called pre-skip distance. But the transmitter's ground wave also has a certain coverage area and between this and the zone where the space wave can be heard forms a twilight zone, a dead zone (eng. skip zone).

8.5.4 Gray line propagation - grayline

With gray line propagation (eng. gray line) means the narrow belt on the earth's surface where it is currently dawn or dusk. The time interval for the gray line varies with the station's latitude. At the equator it is ± 5 minutes and in Scandinavia ± about 1 12 hours around the time of sunrise and sunset respectively. When at least one of two stations is within the gray line, shortwave connection can be obtained over a much greater distance than otherwise.

Communication along the gray line works best on low frequencies, for example on the 3.5 MHz amateur band, during the time interval when the D layer has just started to build up (dawn) and has almost broken down (dusk).

Then the ionization of the D layer is small and a space wave that hits the layer will be bent off in the D layer rather than completely attenuated. The wave propagation then takes place both through refraction in the D layer and reflection in the E layer.

8.5.5 Fading or loss of signal HAREC a .7.8, a.7.9

The field strength of the received waves can vary strongly from one moment to another. The phenomenon is called fading (Eng. fading, pronounced fejding). Such interference phenomena occur when the waves have simultaneously traveled several paths to the receiving antenna, so-called multipath propagation. When they hit the receiving antenna, they can be time-shifted between them, with cancellation effects as a consequence (interference losses).

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Other types of fading are when
• the polarization direction changes due to irregularities in the ionosphere (polarization losses)
• the transmission path attenuates the waves irregularly in time (absorption losses)
• the direction of wave propagation is changed by reflections against houses, rock walls, etc. (reflection losses, in the case of e.g. mobile radio traffic).

8.5.6 About the amateur radio bands on shortwave

more extensive analysis can be found in [17].

8.5.6.1 1.8 MHz (160 m)

The band is also called "top-band". The range is normally relatively small, at night during the winter around 1200 km and at best a few thousand km. But during sunspot minimum the range can be much greater at night.

8.5.6.2 3.5 MHz (80 m)

During the day the range is about 500 km and during the evening 1000–1500 km. Early in the morning during the winter months, especially during sunspot minimum, the range is sufficient for intercontinental connections (DX = long distance). During the summer months, the band has a high atmospheric noise level. Dead zones normally do not occur.

8.5.6.3 7 MHz (40 m)

This band has a greater range than the 80 m band. During the day it has a range of 1000–2000 km. During the night, especially during the winter, the whole world can be reached. Dead zones are 100 km during the day and 1000 km during the night.

8.5.6.4 10 MHz (30 m)

This band is unique as it shares characteristics with day and night bands. Communication up to 3000 km via F2 reflection is generally possible.

8.5.6.5 14 MHz (20 m)

The 20 m band is a safe DX band for long distances. During the evenings, the range of a space wave jump increases up to about 4000 km. Particularly favorable wave propagation is obtained when contacting through a twilight zone, that is, where one party has day and the other has night. Dead zones almost always occur.

8.5.6.6 18 MHz (17 m)

This band is largely similar to the 20 m band, but the F2 fluctuations are more powerful.

8.5.6.7 21 MHz (15 m)

Wave propagation in the 15 m band is best at high sunspot number. During sunspot maximum the band is almost constantly open for DX connections. During sunspot minimum the band is at best open for shorter periods during the day during the summer months. The band is dead at night. With reflections via sporadic E layer, distances of more than 2000 km can be bridged.

8.5.6.8 24 MHz (12 m)

This band combines the advantages of 10 m and 15 mband. It is mainly a day band, but can also be open after sunset.

8.5.6.9 28 MHz (10 m)

The band is suitable for close contacts up to 50 km at night and for DX contacts during the day, but not on days when the E layer is strongly ionized and shields The F layer. The wave propagation path for DX is on the side of the earth that has daylight. Dead zones of up to 4000 km can occur. Connections over long distances are possible with low power. Below the sunspot minimum, the band is not usable for DX contacts. Then only short-term connections at distances of up to 2000 km are possible through reflections via sporadic E layers (short skip). The band in many cases has a VHF character and can have contacts via Aurora and other similar forms of propagation such as Aurora-E and double hop on the Aurora Ring .

8.6 Wave propagation on VHF, UHF, SHF and EHF

8.6.1 General

The frequency range 30–300,000 MHz is divided into the following smaller sections called:

- Very High Frequency (VHF), 30–300 MHz
- Ultra High Frequency (UHF), 300–3000 MHz
- Super High Frequency (SHF), 3–30 GHz
- Extremely High Frequency (EHF), 30–300 GHz.

On VHF and higher frequencies (formerly UKV) there is rarely any wave propagation via the ionosphere other than during the time of maximum solar activity . Instead, the lower part of the atmosphere is used and hardly higher than 4–5 km above the earth's surface.

This part of the atmosphere is called the troposphere and wave propagation - it is therefore called tropospheric wave propagationIn principle, all wave propagation in the troposphere requires optical visibility. However, there is a certain wave deflection along the earth's surface, which is why the practical range along the line of sight is somewhat longer than to the optical horizon. One speaks of radio horizon. On the higher frequencies, due to the wave propagation, it is often more difficult to get radio contact with other radio amateurs. One method of knowing that there is someone listening at the other end is to agree on frequency, direction and time in advance.

Such an agreement is called scheduled QSO via sched and is also common on shortwave frequencies. The index of refraction in the atmosphere is an important factor for wave propagation beyond the line-of-sight distance, especially at frequencies above 100 MHz. Even the splitting of the waves that occur when they hit irregularities in the atmosphere can be used for communication at distances that are several times the line-of-sight distance. At higher frequencies, however, the range is limited by the damping effect of the atmosphere. Similarly, wave energy is lost in the topography, vegetation and buildings that lie in the line of sight between transmitter and receiver. In favorable cases, however, it is possible to bridge distances of up to 1000 km through the troposphere. Such distances are called overrange.

8.6.2 The troposphere - Troposcatter HAREC a.7.10

When a cold front near the earth's surface collides with a warm front, turbulence occurs in the air with electrical charges in the boundary layer as a result. Under such weather conditions, radio waves in the VHF range and above can be broken or split- race up when they hit the charged boundary layer –

troposcatter. Unexpected radio contacts can then be achieved.

8.6.3 Temperature inversion HAREC a.7.12

When a warm layer of air settles over a layer of colder air, a so-called temperature inversion occurs. Waves on VHF and UHF are then refracted against the boundary layer and deflected towards the earth's surface. If there are two inversion layers at the same time, they can form a shock waveguide, so-called duct (eng. duct = line). A range of 600–1300 km can be achieved. This type of wave propagation often occurs at high atmospheric pressure during the summer.

8.6.4 Reflection against Es (sporadic E) HAREC a.7.13

In the case of strong solar radiation, ionized gas clouds are formed, at the lower latitudes, at an altitude of about 120 km and with an irregular distribution. The critical frequency is high for the Es layer and it can also reflect waves on VHF and UHF so effectively that distances of 1000–4000 km can bridge-gas.

8.6.5 Aurora reflection HAREC a.7.14

Solar eruptions (flares) emit large amounts of ultra-violet light and throws out electrically charged particles, which after 1–2 days are captured by the Earth's magnetosphere and penetrate into the polar zones. When the particles collide with the atmosphere, the aurora is formed in the form of luminous "drapes" - Aurora borealis called northern lights in the northern hemisphere or Aurora australis cold southern lights in the southern hemisphere - at the same time as the atmosphere is ionized.

Auroras are ionized layers in the same plane as the earth's magnetic field and especially waves with frequencies above 30 MHz are reflected against them. VHF and UHF communication can take place with the help of aurora reflection. The signals reflected by Aurora are heavily distorted and have lost all tone. The reflected signal becomes broad in frequency, which, however, favors communication with telegraph lines when the signals are weak. Most of the time, only telegraph connections at a slow rate are possible. In case of stronger Auroras, SSB can also be used.

8.6.6 Reflection against meteors -Meteorscatter HAREC a.7.15

Radio waves on VHF and UHF are reflected against ionized traces of the meteor debris that falls into the Earth's atmosphere. This phenomenon can be used for radio communications. Ionization occurs when the particles pass through the E-layer and burn up. Since the ionization has a duration of only 0.1–10 seconds, MS connections must be well planned and prepared. The connections are usually limited to the exchange of call signs and signal reports by high-speed telegraphy at a rate of 300-3000 characters per minute. During the larger meteor showers, contacts can be made by prior agreement ("spoon"), both by telegraphy (CW) and telephony (SSB).

8.6.7 EME connections HAREC a.7.16

Radio communication from one point on Earth to another can be achieved by reflection of VHF/UHF signals towards the moon. EME connections (Eng. Earth–Moon–Earth) are also called Moon Bounce. EME connections require antennas with very high directivity, very high transmitter power and sensitive receivers.

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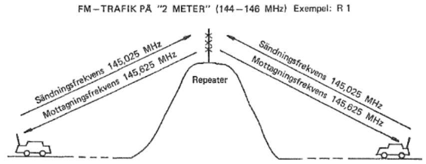

Figure 8.11: Ground-based repeater

8.6.8 Ground-based relay stations

On VHF and higher frequencies, as previously described, you can only achieve radio contacts over the so-called radio horizon. To overcome this obstacle, relay stations are used, see figure 8.11.

This type of relay station, which is generally called a repeater, receives what it hears on a certain fixed frequency and retransmits this on a certain other fixed frequency. See band plan in appendix 13.11.

8.6.9 Space satellite-based relay stations

Radio waves with sufficiently high frequency can pass through ionosphere layers. This enables VHF/UHF/SHF radio connections between stations on earth using relay stations in space satellites. For amateur radio traffic over space satellites, the type of relay station called a transponder is usually used. Such a one receives everything it hears within a full frequency band and rebroadcasts this in a full other frequency band. In this way, traffic via satellite can be carried in a comparable manner as with direct contact between earth-based stations. Satellite-based linear transponders with amateur radio equipment are found in the OSCAR satellites (OSCAR = Orbiting Satellite Carrying Amateur Radio). These have been designed and built by amateur radio groups.

The OSCAR satellites have many different transponders in operation, each working with different combinations of transmission type (mother) and frequency band. This is now called having different configurations. A common transponder configuration is CONFIG-V/U (formerly MOD-J) where the uplink is on the VHF band,

for example 145,900–146,000 MHz and the downlink on the UHF band, for example 435,800–435,900 MHz.

Each uplink frequency corresponds to a specific downlink frequency, for example 145.950 up and 435.850 MHz down.

Traffic over the transponder can therefore take place in full duplex (using both bands at the same time). you can then talk and listen simultaneously in both directions, which greatly improves traffic and makes conversations more fun and interesting. A so-called linear transponder can not only transmit FM, but also SSB, tone telegraphy and SSTV. In addition, RTTY and other digital traffic modes.

Almost all amateur radio bands with sufficiently high frequency are used in various combinations as uplinks and downlinks in the various OSCAR satellites.

AM-SAT is the organization that continuously informs amateur radio satellites. The Swedish branch of AMSAT is AMSAT-SM, which is active and has on its website descriptions both for beginners and those who have progressed a little further on how to use amateur satellites. Amateur radio is developing very quickly through the satellite-based business and more and more sophisticated OSCAR satellites are coming up. The tendency is to gradually move to higher frequency bands and more and more digital transmission types. With the help of satellite, the connection distance can become very large even with simple equipment and small antennas. An advantage of communication via space satellite is also that it is largely independent of the wave propagation conditions. See figure 8.12.

8.7 Noise and link budget

8.7.1 General

The quality of the received signal can often be summarized with its signal-to-noise ratio. In order to be able to estimate it, one needs to understand the link budget itself, which gives an idea of how strong the signal is, but also to understand the various contributions of noise that set the effective noise floor.

8.7.2 Noise HAREC a.7.17, a.7.18

There are several sources to noise, atmospheric noise, galactic noise and thermal noise. Atmospheric noise arises due to lightning discharges. Lightning strikes occur all over the world all the time, and its strong impulses spread just like radio waves and cause a fundamental disturbance in the short-wave band. Atmospheric noise was identified in 1925 by Karl Jansky.

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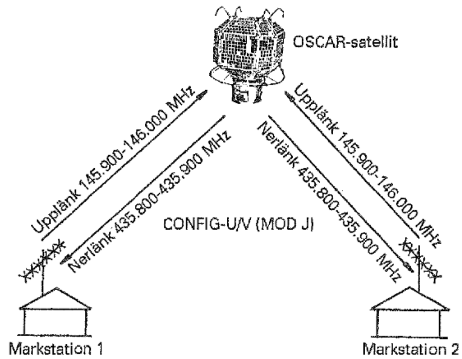

Image 8.12: Transponder in space satellite

Galactic noise (eng. galactic noise) mainly comes from the center of the Milky Way, and is mainly thermal noise from the large accumulation of stars in the center of the Milky Way. Galactic noise comes from the part of the sky that is currently shielded by the Milky Way, so it is directionally sensitive. Thermal noise is the internal noise of the receiver, see 1.7.3.

8.7.3 Link budget HAREC a.7.20

To be able to estimate the perceived signal quality, you make a so-called link budget (eng. link budget). The link budget compiles how the signal strength and noise varies along a link with its amplifications and attenuations. At the end of the link budget, the perceived signal-to-noise ratio can then be simply estimated.

A well-executed link budget can therefore create a good understanding of the link's shortcomings so that improvements can be made.

8.7.3.1 Dominant noise source HAREC a.7.20.1

In an accurate model, all noise sources, from source to receiver, must be listed, adjusted for gain and compiled. In practice, you have a dominant interference source, typically the noise on the band or short band noise (eng. band noise) or the receiver's internal noise (eng. receiver noise), whereby the other contributions have little influence on the total calculation. It is therefore practical to quickly estimate whether it is noise on the band or the noise of the receiver that dominates, after which you can calculate the dominant noise source. As a rule of thumb, you can say that for shortwave the noise on the band is usually the dominant noise source, while for higher bands the internal noise comes dominate, and attenuations in cables become increasingly noticeable.

8.7.3.2 Signal-to-noise ratio HAREC a.7.1.2

The experience of a signal's quality can be measured in many ways, however, precisely the amount of noise in the signal is an important such relationship and therefore the term signal- noise ratio (eng. signal to noise ratio (S/N)). The signal-noise ratio is expressed usually in dB and can be easily calculated as the difference in level of signal and noise, i.e. signal minus noise, calculated in dB. With a signal level of 45 dB and a noise level of 22 dB,Ωou thus have +23 dB S/N.

8.7.3.3 Minimal signal-to-noise ratio HAREC a.7.20.2

It is also very helpful to quickly establish the minimal signal-to-noise ratio (eng .minimum signal to noise ratio) that can be tolerated. By comparing the link budget against this, one can immediately determine whether it is good enough or needs to be changed. If the signal-to-noise ratio is too low against the minimum, then one needs to increase the gain or usually reduce the losses in the link budget.

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8.7.3.4 Minimum received signal strength HAREC a. 7.20.3

If the dominant source of interference is the internal noise and the signal-to-noise ratio is too low, the signal strength to the receiver must be increased until the signal is strong enough to provide a sufficiently high signal-to-noise ratio. This gives the level of minimum receiver signal power (eng. minimum receiver signal power) that the receiver requires.

8.7.3.5 Signal attenuation HAREC a.7.1.1

As well as cables, filters, couplings and wave propagation involve signal attenuation. This means thatΩou lose energy in relation to the added energy. The ratio between the output and input energy is most often expressed in the form of dB. Care must be taken that the note attenuation is usually related to the frequency, so it must be estimated or measured for the frequency in question.

8.7.3.6 Noise factor

For higher frequencies, noise tends to be dominated by the receiver's internal noise, while cable losses start to become noticeable. For such cases, it may be appropriate to install a low noise amplifier (eng. low noise amplifier (LNA)) before the receiver.

Even that amplifier, however, has its own noise which is then amplified. Noise factor (eng. noise factor (NF)) gives the ratio between an amplifier's inherent noise in relation to the thermal noise of a resistor at its input. Noise factor is usually reported in dB, equivalent to dB above the noise floor. An amplifier's inherent noise will of course be amplified, and therefore the noise at the output will be the noise factor plus the gain, calculated in dB. For example, an amplifier with 4.5 dB in noise factor and 20 dB gain will have noise of 24.5 dB above the noise floor. A subsequent amplifier with a 10 dB noise factor will not significantly contribute to noise, because the previous stage has 14.5 dB higher noise than the intrinsic noise.

For this case, the first amplifier is dominant. Since cable attenuation can be significant, the signal will be attenuated through the cable.

Given that we have 15 dB attenuation in the cable, a signal 40 dB above the noise floor and a 20 dB amplifier with a noise factor of 4.5 dB, where should we put the amplifier?

If the amplifier is located after the cable, the signal will be attenuated first in the cable, the noise will be applied and then it will be amplified 20 dB. It gives 40 dB minus 15 dB plus 20 dB for the signal, that is 45 dB. For the noise we get 4.5 dB plus 20 dB, that is 24.5 dB. For this case, we get a signal-to-noise ratio of 45 dB minus 24.5 dB, i.e. 20.5 dB, given that it is the internal noise that is dominant.

If the amplifier sits before the cable, the signal will first be amplified and then attenuated in the cable .It gives 40 dB plus 20 dB minus 15 dB for the signal, that is 45 dB. For the noise we get 4.5 dB plus 20 dBminus 15 dB, that is 9.5 dB. For this case, we get a signal-to-noise ratio of 45 dB minus 9.5 dB, that is, 35.5 dB, given that it is the internal noise that is dominant. With this example, we see how a link budget helps us to get signal- the noise ratio to go from 20.5 dB to 35.5 dB only by changing the position of the amplifier in the system.

8.7.3.7 Path loss HAREC a.7.20.4

The attenuation that the signal has in free-space loss, due to its decreasing field strength is also called advance loss (eng. path loss).

The free-space loss depends simply on frequency and distance, a simple model

[17, §19.1.2]:Lf s = 32.45 + 20 log d + 20 log f

where d is the distance in km and f is the frequency in MHz and it gives Lf s is the path loss in dB. The free-space loss decreases with the square of the distance, i.e. 6 dB at twice the distance and is generally the dominant effect once you have left the near field of the antenna.

Additional losses can occur due to vegetation, partially covered Fresnel zone, counter-ionosphere bounces and more. The Fresnel zone is the zone that is within the ellipse whose shape is defined by the wavelength longer path than the direct path between transmitter and receiver. Most of the energy between two antennas moves in this fresnel zone and thus if that region is affected by obstacles, the signal will be noticeably attenuated.

8.7.3.8 Antenna gain and cable losses HAREC a.7.20.5

The directivity of an antenna gives the antenna an antenna gain (eng. antenna gain) then it in a certain direction has an ability to have higher gain than a single dipole. The antenna's ability to suppress other signals, for example as measured by the front-back relation, also provides a suppression of unwanted signals and atmospheric noise. It may therefore be worth not only measuring the antenna's amplification of the desired signal, but also counting on its ability to pick up unwanted noise and disturbing signals.

Connected cables can have a significant impact on both transmitted and received signal strength when the cable losses (eng. transmission line losses) attenuation signals. Cable losses depend on how long the cable is, which cable it is and at what frequency the power is used. As a rule, higher frequencies have higher attenuation. Both the size of the cable and the choice of dielectric affect the loss in the cable.
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8.7.3.9 Minimum Transmitted Signal Strength HAREC a.7.20.6

A transmitter has a variable output power, and since one is trying to make an estimate of the worst-case signal-to-noise ratio, it is not the maximum power or even the average power that becomes the interesting one, without the minimum transmitted signal strength (eng. minimum transmitter power). By using that incalculation on your link budget, you make sure that the link budget handles the worst possible cases, and for the cases where the transmitter is stronger, you get a better signal than the lowest you tolerate. In this way, you build up margins in the calculation.

8.7.3.10 Compilation of link budget

A complete link budget is obtained by calculating signal strength and noise level for each step in the chain, by going through all amplifications and losses along the way. When you have then calculated the receiver's perceived signal strength and noise level, you can calculate the signal-to-noise ratio, see example in 8.7.3.6.

To make sure that it works, you usually calculate conservatively, that is, you choose the same numbers, for example minimum received power and minimum transmitted power. A well-executed link budget gives a good understanding of where the weak link is, and by experimenting with different alternative solutions, you can understand who should start taking measures and where it is unprofitable or has little impact.

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9 Measurement technology

In research, development and production are measurement cornerstones of the business. Even within measurement technology rapid development is required and digital technology is increasingly being used, but the basics of measurement are the same. This chapter deals with the most important measuring technical concepts that radio amateurs may need to know.

9.1 To measure

9.1.1 Measuring direct voltage

When measuring voltage, you determine the potential difference - the voltage - between two points. If there is a voltage, then the corresponding (measurement) current flows through the instrument which presents the measurement current as a voltage. The measurement current, however, affects the voltage distribution in the circuit and then a measurement error occurs, which is not evident from the displayed measurement value. Knowing the data of the circuit and the instrument, one can calculate the measurement error. A voltmeter must have a high internal resistance in order for the measurement error to be small. Only in the case of very accurate measurements can one need to recalculate the displayed measured value taking into account the voltmeter's internal resistance and the ballast resistance - if one is used. Because of the high internal resistance, a voltmeter only suitable for bias voltage measurement – NOT for direct current measurement!

9.1.1.1 Extending the measuring range of a voltmeter

By means of a biasing resistor in series with the voltmeter, one can measure a higher voltage than the voltmeter is made for. The voltage is then distributed proportionally between the resistance of the ballast resistor and the internal resistance of the instrument. An example of this can be found in picture 3.1. When a ballast resistor is used, the measured value must be recalculated with a scaling factor or a scale with the corresponding graduation must be used. A ballast resistor that can be selected with a voltmeter can therefore have several scales. In digital voltmeters, the "scale" is usually adjusted automatically.

9.1.1.2 The influence of internal resistance HAREC a.8.1.2.3

When measuring voltage, the internal resistance of the voltmeter will load the circuit, thereby lowering the voltage and thus the measured voltage will be lower than the actual voltage without the measuring instrument. In old times, the internal resistance was relatively low, whereby the impact was greater than with modern instruments. However, even modern instruments can affect the measurement result in circuits that have very high impedance.

9.1.2 Measuring direct current

When measuring current,Ωou determine the current strength in a branch of an electrical circuit. The ammeter is connected in series with the current branch. The displayed measured value corresponds to the current strength. However, the ammeter's internal resistance is added to the resistance in the current branch and then a measurement error occurs. An ammeter must have a low internal resistance so that the measurement error is small. Only in the case of very accurate measurement can one need to recalculate the displayed measured value taking into account the ammeter's internal resistance and the resistance in the current shunt - if one is used." Because of the low internal resistance, an ammeter should NEVER be used for voltage measurement. Then it will be destroyed!

9.1.2.1 Extending the measuring range of an ammeter

With a current shunt (a resistor in parallel) across the ammeter, one can measure higher current than which the ammeter is made for. The shunt is dimensioned so that most of the current flows past the ammeter. What remains is the measuring current that is needed for the ammeter to make a full response. The measuring current is distributed inversely proportional to the resistances of the instrument and the shunt. an ammeter with a selectable shunt resistor can therefore have several scales. In digital ammeters the "scale" is usually adjusted automatically.

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9.1.3 Measuring alternating voltage and alternating current

The basics for measuring alternating voltage and alternating current are the same as for direct voltage and direct current, but that among other things, an instrument rectifier is usually needed. Depending on the frequency in the circuit and what kind of valueΩou want to measure, different instruments are used. Different types of instruments offer different possibilities, but also limitations. Soft iron instruments without a rectifier can measure alternating currents down to about 50 mA and up to about 10 A. However, the frequency must not be higher than approximately 100 Hz. Rotating coil instruments are used partly directly for direct current measurement and partly with rectifiers also for alternating current measurement. Rotating coil instruments with rectifiers are often used for frequencies up to approximately 10 kHz and currents down to 0.1 mA. The accuracy is rarely better than 1.5% of full scale. Depending on the operating principle, it can differ in how the instrument measures, which is not necessarily the same as how the measured value is presented. Soft iron instruments measure the effective value of an alternating current, while a rotary coil instrument with rectifier measures the rectified average value. As an example, the scale in an instrument with a rectifier is also graduated for the rms value for sinusoidal processes. For measuring alternating current, instruments with rectifiers are usually used, but for HF also instruments with thermocrosses, which are based on thermogalvanic voltage between metals.

9.1.3.1 The influence of frequencyHAREC a .8.1.2.1

The frequency of the measured signal affects the measurement result more or less. To some extent it depends on the type of instrument used. One factor is the instrument's limit frequency, that is, how high a frequency the instrument is still reasonably accurate. This is called the bandwidth of the instrument, which should be documented.

9.1.3.2 The influence of the waveformHAREC a.8.1.2.2

Even the shape of the signal being measured affects the measurement result and we areuseful to know for which waveform the instrument presents the measured value. The most common is that the wave is assumed to be sinusoidal, which is often not the case in practice. This means that the wrong value is presented if the waveform is assumed at the other end.

9.1.4 Measuring resistanceHAREC a.8.1.3

Measuring resistance is easiest to do on a free-standing component, while when measuring a resistor in a circuitΩou also have to take into account that other components in the circuit can affect the measurement result. Resistance can be measured in several ways. The basic thing is to measure the current through the resistor and the voltage across it and then calculate the resistance using Ohm's law. The most common method is to use a modern multimeter that can measure resistance directly. One part requiresΩou to set the range of resistance, while others can do it automatically. Precision measurement of resistance can be done by more advanced instruments whereΩou use 4-point measurement. For 4-point measurement, the current and voltage connections are separated so that the resistance of the connection lines does not produce voltage that is included in the measured resistance. Instead, the voltage is measured as close as possible to the measuring object itself, while the voltage loss for the current conductors can thus be eliminated. This measurement method is relevant above all for low-resistance resistors.

9.1.5 Measuring powerHAREC a.8.1.4

Power formulas for direct and alternating current (average, effective and peak values) For direct current: P = U · I [W (watt)] ie. Joule's law With sinusoidal alternating current and resistive loads (For PEP effect see also section 3.4.10): effective value P = U 2R peak value PP EP = U 2max2RU = effective value of the voltage R = the resistance

9.1.6 Transmitter power

The power of a transmitter can be measured in different ways. The methods of measuring output power relevant to the radio amplifier are peak sensing ones for measuring PEP. In the regulations, the transmitter power PEP is used as output power. In doing so, PEP must also be referred to, although not explicitly stated. Please note that the radio amateur must take into account the EMC law. See also chapter 10.1.1.

9.1.7 Methods for measuring transmitter power

Previously, power calculation was discussed in general. Here below, measurement of transmitter power is commented on in particular. A reliable way to measure transmitter power is to connect the transmitter to an artificial load with the same resistance as the transmitter's output impedance and measure the voltage - the measurement across the load with an oscilloscope with sufficient bandwidth.

ThenΩou can see and measure the HF voltage peak-peak value and at the same time see the waveform of the signal.

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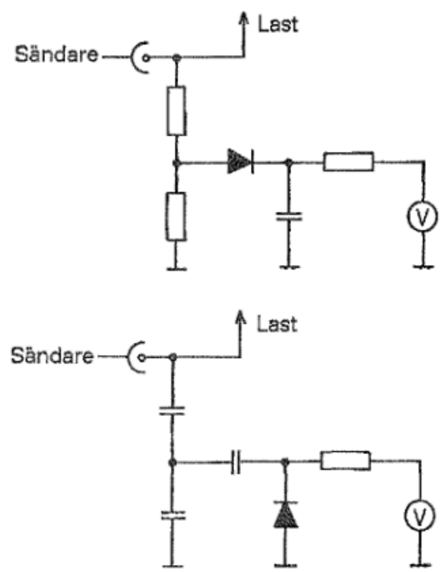

Figure 9.1: Measurement of transmitter power

With the voltage and the impedance (resistance) of the artificial load known, the output power can be calculated according to the formulas in chapter 9.1.5.

The largest HF amplitude that occurs instantaneously during modulation corresponds to the PEP power that comes from Peak Envelope Power (PEP). A less accurate method of measuring HF voltage is with a voltmeter with a rectifier. Based on the measured voltage, the power over a load can be calculated. However, due to the inertia of the instrument, only a "smoothed" peak value is displayed, which is not the actual value that the instrument "knows". Compare with the oscilloscope which does not have this display inertia.

Figure 9.1 shows a voltmeter with rectifier, which is connected to a transmitter via voltage divider. Two alternative dividers are displayed; one consists of resistors and the other of capacitors. The resistive divider is better in the sense that it is frequency independent and does not load the transmitter capacitively. In addition, harmonics that form during rectification are attenuated. In the capacitive divider, harmonics can pass more easily. This measurement method is accurate only when the impedance is equal in the transmitter, the cable to the load and the load itself. The load can be an artificial load, an antenna etc. and must have a known value so that the effect can be calculated. One way to obtain a basis for calculating the PEP effect is to measure the HF current with a thermocouple instrument and the voltage with a peak value display voltmeter. Based on these values, the power is calculated. However, this method is not that common.

9.1.8 Direct-displaying power meters HAREC a.8.2.1.2

Many people prefer direct-displaying power meters. An HF voltmeter can of course be calibrated to show power instead of voltage, but then with the important prerequisite that the impedance must have a fixed value. IfΩou read the power through a 75 Ω cable on a 50 Ω instrument, then the real the value different from the one read. The power meters that appear in SVF instruments are actually voltmeters, but with the scale graduated in power.

9.1.9 Measuring standing wave ratio (SVF) HAREC a.8.1.5

When, for example, an antenna line is connected to an antenna and their impedances are not equal, so part of the input power in the line will reflect back from the antenna. A standing wave then arises in the line. The ratio between input and reflected power is expressed as a standing wave ratio (SVF) (eng. Standing Wave Ratio (SWR)). With an SVF meter that is inserted between the power source and the line,Ωou can measure how much power is fed into the line and how great effect turning back from the end of the linen. The SVF value can then be determined in one of the following ways:

• The forward and backward power are measured separately with a direction-sensitive power meter. you then calculate SVF or derive it from a diagram.
•you use an instrument that calculates or shows SVF in some way.

9.1.10 Study the waveform HAREC a.8.1.6

The waveform for fast alternating current flows is best studied with an oscilloscope.

9.1.11 Measure frequency HAREC a.8.1. 7

Frequency measurement is best done with a so-called frequency counter, which is a digital instrument. you can also use a so-called absorption oscilloscope, which is very simple and not nearly as accurate. When measuring frequency, you connect the instrument to the object to be measured with a weak electrical or magnetic connection. 227

9.1.12 Measuring resonant frequency HAREC a.8.1.8

Measuring the resonant frequency of a passive resonant circuit is done classically with a so-called dip-meter. Today, one uses either a spectrum analyzer with tracking generator, i.e. an SNA, or a network analyzer to measure resonance frequencies with better precision.

9.1.13 Measurement error

Measuring instruments are divided into accuracy classes according to the largest permissible error display. The classes are 0.1, 0.2, 0.5, 1.0, 1.5, 2.5 and 5.0, the class being indicated on the instrument. As an example, an instrument in class 2.5ha has a permissible measurement error of ±2.5% of full scale. The measurement result is determined by several factors; partly by the instrument's so-called measurement inaccuracy, partly by how the measured value is presented and finally by how careful the user reads. In analog display, the measured value is presented with a pointer against a graduated scale with a certain resolution. The pointer can be mechanical or optical (light gap). In case of rapid measured value changes, the mechanical inertia of the instrument is a factor to take into account. With digital display, the measured value is presented with numbers or as the length of a pillar. It is tempting to see digital display with numbers as more accurate than analog, but it is by no means certain. In addition to the measurement inaccuracy of the instrument, namely, the accuracy is determined by how many digits the measurement result is presented in. An unpredictable source of measurement error is electromagnetic fields from nearby devices. An often overlooked source of error is the temperature in the measurement object and/or in the instrument, it can be the disconnection time, etc. The display inertia is not a measurement error in itself, but can be a disadvantage in fast processes. The inertia occurs in both analog and digital displays. In the former case, mass inertia in the instrument's moving parts is the cause, and in the second case, the cause is the clock frequency of the instrument's microprocessor.

9.2 Measuring instrumentsHAREC a.8.2

9.2.1 To measure is to know

Measuring instruments are used to, under controlled conditions, test and confirm a function or lack thereof, in a equipment. It is also used to measure various components to verify their function and properties. With measuring instruments,Ωou want to create a test environment as close asΩou can expect, that the equipmentΩou are testing should be able to handle reality. The measuring instruments we will mention below are used, among other things, in final tests, such as when, in our case,

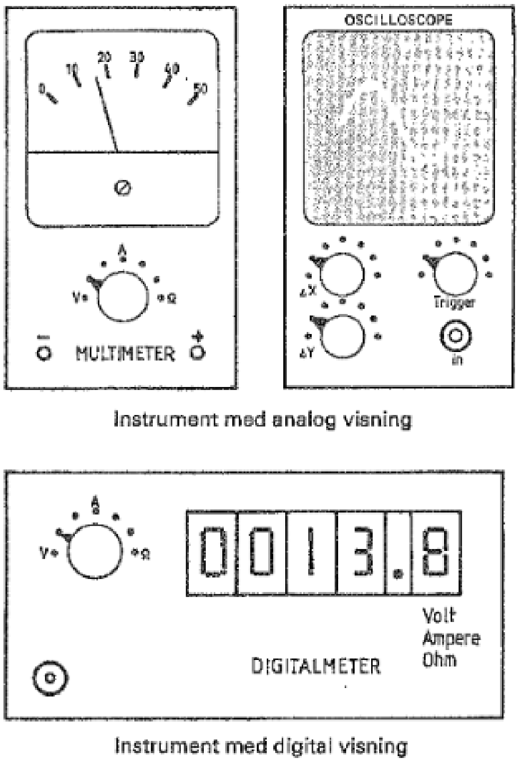

Figure 9.2: Presentation of the measuring values the radio equipment is assembled and must be tested, before it is delivered to the customer. That the manufacturers use measuring instruments as above, is thus a prerequisite for being able to know that the equipment they have constructed meets the requirements they have specified .These types of instruments are also of interest to the transmitter operator, who can use them for troubleshooting or service.

9.2.2 Presentation of measurement values

Measurement values can be presented in different ways as illustrated in figure 9.2. The most common ways are optical and with digital or analogue display. Measurement results can also be transferred to a computer for further processing and display.

9.2.3 Multimeter HAREC a.8.2.1.1

Several measurement functions can be performed with the same basic instrument, as shown in picture 9.2, this feature is called a multimeter. By switching between different attachments,Ωou select the measurement function and measurement range. The instrument scale is designed so that different types of measurement values can be read. Combinations with electronic amplifiers and digital display etc. are now commonplace.

9.2.4 Rotary coil instruments

Rotary coil instruments, as illustrated in Figure 9.3, can only be used for direct current measurement, since the display depends on the direction of the current. The instrument has low power consumption and high accuracy. The display is usually linear, but can be done differently.

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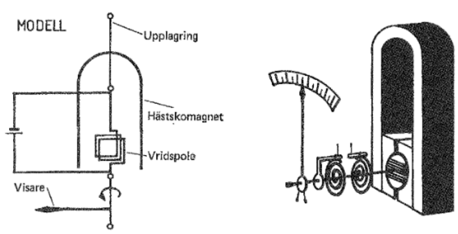

Figure 9.3: Rotary coil instrument

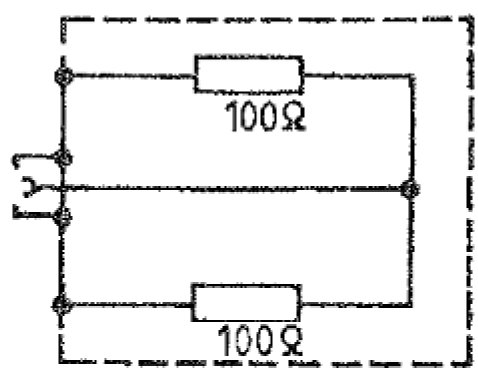

Figure 9.4: Artificial load function

A coil is supported in the field of a horseshoe magnet. When the current to be measured passes through the rotatable coil, a magnetic field is generated in it. The two magnetic fields affect each other so that the coil turns. The spool is provided with a pointer and a return spring. The greater the current that flows through the coil, the greater the reading will be.

9.2.5 Dummy load

A dummy load (eng. dummy load) is an alternative load that can handle a certain amount of power, dummy load is illustrated in picture 9.4. An artificial load should be included in every amateur radio station. When measuring and setting for example modulation and output power, it is appropriate to load the transmitter with its nominal output impedance. In order to avoid energy being radiated, a well-shielded artificial load should be used. In modern amateur radio transmitters with coaxial cable output, the output impedance is 50 Ω. The dummy load should then be a 50 Ω resistor without reactive properties for the frequency range of interest. It can consist of one or more interconnected resistors, often in parallel to reduce the inductive component. The transmitter power must be able to be taken up without the resistance changing significantly. It is important that the resistors are cooled effectively with air or liquid in a vessel with sufficient space, even when the liquid expands from the heat. The liquid must not be flammable or dangerous to the environment. For example, oils with PCBs are prohibited!

9.2.6 Field strength meter

The strength of electromagnetic fields can be determined with a field strength meter. A field strength meter is a high-frequency detector, the output voltage of which is shown with an instrument with a scale. The selective circuit can consist only of the tuned antenna, but also of additional selective circuits. The instrument only shows relative values and is used, for example, to determine the radiation properties of transmitter antennas and for antenna adjustment. The measurement result is also affected by radiation from other transmitters within the meter's bandwidth. Figure 9.5 shows the transmitter and a field strength meter. Also two simple field strength meters.

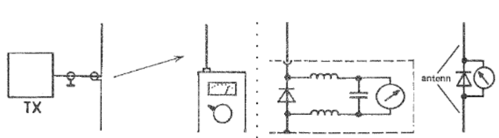

Figure 9.5: Field strength meter

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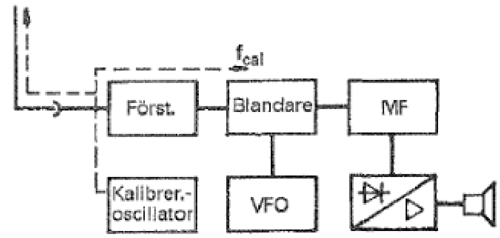

Figure 9.6: Calibration oscillator in receiver

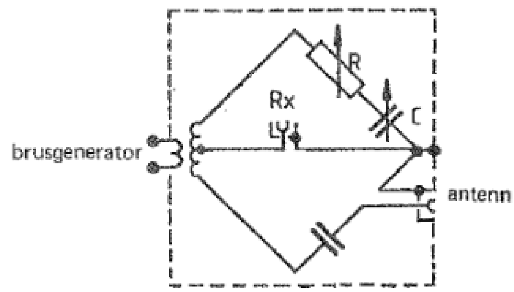

Figure 9.7: Noise measurement bridge

9.2.7 Calibration oscillator

A calibration oscillator (eng. calibration oscillator) is used to frequency calibrate other device setting scales, as illustrated in Figure 9.6. It is crystal-controlled and emits particularly precise and frequency-stable signals. The oscillator signal is intentionally distorted, so that in addition to the fundamental frequency, harmonic overtones are also created. An oscillator with, for example, the fundamental frequency of 25 kHz also emits the frequencies 50 kHz, 75 kHz, 100 kHz, 125 kHz and so on. You thus get a "calibration frequency" for every 25 kHz. This harmonic spectrum can stretch several 100 MHz up. One "zeros" the device against the nearest calibration frequency and can calibrate, for example, the VFO scale. The area of use is mainly calibration of older receivers and grading of new scales and so on for the same. Today's receivers and transmitters have synthesis oscillators and normally no calibration oscillator is needed. Note Older traffic receivers have VFOs with LC circuits and often a built-in calibration oscillator, which in turn may need to be calibrated. The simplest way is then to compare the frequency of a known broadcast radio transmitter on medium wave with the calibration oscillator.

9.2.8 Noise measuring bridge

The noise measuring bridge is used when measuring in antenna systems, as illustrated in figure 9.7. It consists of a noise generator and a Wheatstone bridge for measuring resistance and reactance. An antenna is connected to the bridge as a measuring object and a receiver as a zero indication instrument for the noise signal. The receiver is set to the frequency where the measured values are desired. The noise is weakest when the bridge is adjusted. You can then read the measured values for R and X. If you measure at several frequencies, for example, an impedance diagram can be drawn up. In other words, this is an older model of a network analyzer.

9.2.9 Standing wave meter (SVF meter) HAREC a.8.2.1.3

When a transmission line or device connects to another with a different impedance, HF energy will be reflected in the transition. This reflected energy can be measured with a standing wave meter (Eng. SWR meter) as illustrated in figure 9.8. With standing wave ratio (SVF) (eng.Standing Wave Ratio (SWR)) is meant the ratio between the power that flows forward and backward in a transmission line. Areas of use for SVF meters are:

• Measurement of forward power (eng. forward power).
• Measurement of backward power (eng. backwardpower, reflected power).
• Determination of SVF (eng. SWR).
• Determination of resulting, relative power. Note When determining absolute power, the connection impedance must be the same in instrument and transmission line.

The SVF meter is one of the most useful instruments for HF measurements. An SVF meter can have separate instruments for forward and reverse power or a common one. The SVF meter can be permanently connected to e.g. between transmitter and antenna, but must then be able to withstand the power development. An SVF meter can generate harmonics, which can cause interference. The reason is the linearity of the semiconductor diodes in the instrument. .

9.2.10 Frequency counter HAREC a.8.2.1.5

The frequency counter, which is a digital instrument, is used to determine the oscillator frequency in transmitters, receivers, etc.

Figure 9.9 illustrates the schematic view of single frequency counter. In the frequency counter, the number of oscillations E (from English events) in the current incoming signal is counted during a specific time unit. First, the signal is amplified in an analog amplifier and converted to edge wave pulses in the input stage's trigger unit. When each measurement begins, a counter will count how many trigger pulses have passed until the set time has expired. Modern counters also measure how the first pulse (eng. start event) and the last pulse (eng. stop event) differ in time, so that the actual time can be used to

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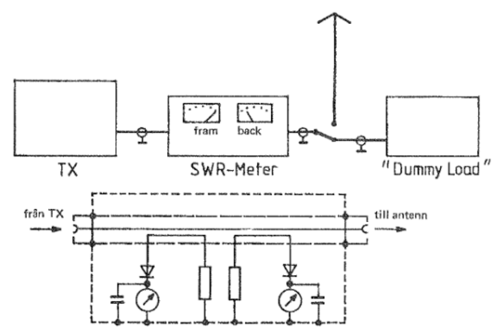

Figure 9.8: SVF meter, principle and connection

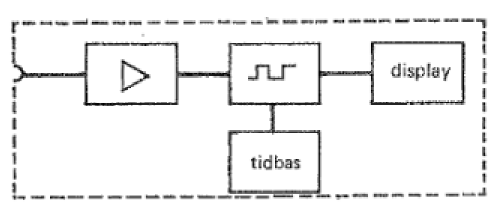

Figure 9.9: Frequency counter to get a high resolution.

The frequency can now be estimated with the formula: party = EtOld frequency counters had a fixed time that it counted over, and without adjusting the actual time. These have a simple principle and the time was often chosen to obtain a simple scale factor between the counter value and the frequency, by having steps of 100 ms, 1 s, 10 s and so on. However, these counters have the problem of lowering frequencies, so a long observation time is required to perform ensure a sufficiently good numerical precision. A variant of this that emerged was the so-called reciprocal calculator, which is the now prevailing principle when you need precision, in it both the number of events and the time are measured. This allows the time base to be easily varied with a pot or external signal. Another improvement that came is to interpolate the time of the initial and the ending pulse against the time base clock, in order to therefore be able to adjust the measurement with a better estimate of the actual time took for the counted events to happen. With time resolution at 1 ps level, 12 digits of accuracy can therefore be presented for a measurement over 1 second, while old frequency counters with their 10 MHz oscillator gave 100 ns resolution and thus only 7 digits of accuracy for the same 1 second measurement .

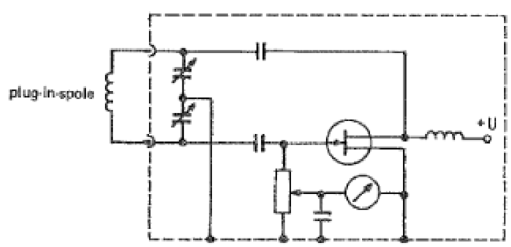

Image 9.10: Dip-meter

The modern frequency counters now have more even filters that compile several measurements into one, and present overlapping results. This gives a perceived higher reading speed, but the measurements are not completely independent. Some frequency counters also use linear regression to further filter out measurement noise. The result is displayed as numbers in a window. Sufficient accuracy in the so-called time base is obtained with a single-crystal controlled oscillator or, for more expensive instruments, with the rubidium standard. You can often connect an external frequency normal with a frequency of 10 MHz, which is done with modern GPS controlled oscillators you can access the SI definition of hertz at a now more modest cost even in a hobby lab.

9.2.11 Dipmeter

The dipmeter is basically an oscillator with variable frequency and replaceable inductors for different frequency ranges, as shown in figure 9.10. It is used to determine the resonant frequency of passive and active resonant circuits as well as when determining inductances and capacitances. The accuracy is approximately 3%. Function The instrument emits or responds to an HF signal with a certain frequency. The frequency i

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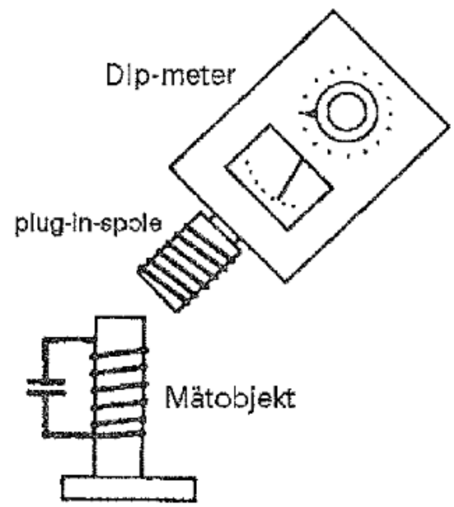

Figure 9.11: Measurement with the dip meter

The resonance circuit of the dip meter is continuously variable and the frequency value can be read on a scale. When measuring the resonance frequency in a passive resonance circuit, the dip meter's inductor is inductively connected to the circuit as shown in Figure 9.11. When the resonant frequency in the circuit and the dipmeter match, the load on the dipmeter's resonant circuit changes, whereby the instrument shows a current reduction - a "dip". The frequency is then read on the scale plate. When measuring on an active resonant circuit, i.e. that which is driven by some HF source, a current increase at resonance occurs instead, which is also shown on the instrument. The inductance in a resonant circuit can be determined with the dip meter, if the capacitance is known. Correspondingly, an unknown capacitance can be determined if the inductance in the resonant circuit is known. The name grid dipmeter comes from the electron tube era. Changes in the grid current in an oscillator-coupled electron tube are used as an indication that a resonant circuit is in resonance. The grid current then decreases - it becomes a "current dip". Nowadays a transistor is used instead of the tube and the instrument is called a dip meter.

9.2.12 Oscilloscope HAREC a.8.2.1.6

The oscilloscope (eng. oscilloscope) is a very useful instrument. Very fast processes can be advantageously studied on an oscilloscope screen. Voltage processes can be shown as a function of time. Together with other instruments, the frequency characteristics of filters, modulation quality and so on can be visualized. The oscilloscope consists of a cathode ray tube, where the control of the cathode ray takes place with the help of XΩ-amplifier and a so-called trigger amplifier. The signal to be measured is usually connected to theΩ-amplifier, while a time base generator that generates a sawtooth-shaped signal is connected to the X-amplifier.

Figure 9.12 shows a block diagram of an oscilloscope. Modern oscilloscopes digitize the signal after the input amplifier, and then add in memory, where the sawtooth signal is replaced by a counter that places it in memory. The image is then presented on the monitor or on a connected computer. Common to analog and digital oscilloscopes is largely the same.Ωou connect one or more signals to the inputs, adjust the input stage so that the entire waveform is captured and that it has good amplitude, so it is visible but not clipped. SometimesΩou choose to make waveforms smaller, so thatΩou can arrange them in a good way on the screen. SometimesΩou choose to cut the wave becauseΩou only want to see the time for an edge clearly. An important thing to get a clear picture of bThe difference is that the trigger point, the point where the measurement of the signal begins, is chosen so thatΩou don't get double or unclear images. The selection of the trigger point is often automatic, but if the signal to be measured is very flat or has many zero crossings, the trigger point may be incorrect. To solve the problem of blurry or double images,Ωou usually manually adjust the trigger point so thatΩou get a clear image.Ωou also adjust the time base to have the right scale on the time axis, soΩou see one or a few cycles, or sometimes over a longer period of time to see variations.Ωou can also delay the sweep to be able to see a certain part after the trigger point. Oscilloscopes now more often have built-in functions for measurement. It is convenient to quickly get an idea of period times, frequencies, amplitudes and more, but unfortunately the measurement precision often suffers greatly, and this should not be overinterpreted. For example, the frequency measurement is no better than how good the placement of the markers is, so the reliability is rarely better than 2 digit accuracy. Used correctly, however, the oscilloscope is a fantastic measuring instrument.

9.2.13 Spectrum analyzer HAREC a.8.2.1.7

A spectrum analyzer (eng. spectrum analyzer) shows the amplitude of different frequencies over a certain frequency range. This is in contrast to the oscilloscope, which shows the amplitude of a signal over time. The spectrum analyzer can be compared to a receiver, but with an important difference: where a receiver has one or more tuned input stages, which should prevent the receiver from being affected by signals that are more or less close the desired signal, the spectrum analyzer has a wide-open input. The spectrum analyzer is a measuring instrument, and must be able to present the signals that are fed into the design input, without the signals being affected in any way. This places high demands on the spectrum analyzer design. It must be able to withstand strong signals,

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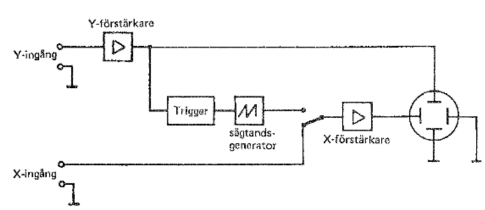

Figure 9.12: Oscilloscope without being affected by a measurement of a weak signal nearby. The spectrum analyzers are also available in two different types. One works with sweep technology, and sweeps over a certain part of the frequency spectrum. The second type is called a real-time analyzer, and is capable of recording a spectrum digitally for a given moment for later analysis of the content. What we continue to describe in this chapter is the sweeping spectrum analyzer, which is also the most common type for service applications. A spectrum analyzer simply consists of single-sweep oscillator, variable filter on

the intermediate frequency, a detector and an adjustable filter from the detector. The variable oscillator sweeps so that the intended frequency range is covered, often with a certain number of points, for example 801, where each point is a measurement of a specific frequency. SometimesΩou can adjust the number of points to make the measurement go faster, in exchange for a lower resolution. The filter sets the bandwidth of the measurement, and it can go in 1-3 steps, for example 3 Hz, 10 Hz, 30 Hz, etc. to 3 MHz. For certain specific measurement purposes, such as for EMC measurements,Ωou need filters of the right bandwidth and these are extra options. The filter, whose setting is usually called Resolution Bandwidth, works like a window, where the window lets in the signals that are in that spectrum which one wishes to study. If the analyzer had no filter, it would take in all signals that are within its specified frequency range. A wide filter lets through a larger frequency range and is useful for signals with a larger bandwidth. A narrower filter is preferable for signals with a narrower bandwidth. A wide filter also means that the analyzer can sweep faster. It is then easier to be able to detect signals that are short-lived. A narrower filter means that the analyzer has to sweep more slowly, but instead can find signals that would not have been seen with the wider filter. This filter also has another property that is important - a wide filter also lets more noise through, which affects the lowest noise level that the analyzer tower can present .To reach higher sensitivity,Ωou can choose narrower filters. The narrower the filter, the higher the sensitivity, but also a slower sweep over the current frequency range.

9.2.13.1 In-depth

On a spectrum analyzer, great demands are placed on sensitivity and the ability to handle strong signals in the vicinity of a weak but desired signal without false signals affecting the instrument. The requirements have meant that the cost of the instrument's structure and constituent components has been very high for a long time. For many decades, transmitters have therefore been referred to the market for used instruments that had at least ten to twentyΩears behind them. It is only for a fewΩears since there have been products on the market that have now come down to cost levels which meant that radio amateurs can buy these instruments, in new condition. A modern spectrum analyzer of more expensive cuts also offers an opportunity to analyze the modulated signal. Thus, there are instruments on the market that are specially designed to analyze the signaling content in different systems, for example Bluetooth, different Wi-Fi and mobile phone systems. For a specific measurement over a certain frequency spectrum,Ωou can set a so-called start frequency, as well as the corresponding stop frequency for the spectrum in question. The analyzer will then sweep, from the start frequency, to the stop frequency.Ωou can also choose a frequency in the middle of the spectrum, and then any so-called span. Span denotes the frequency span that is desirable in order to be able to study the signals within the current spectrum. To be able to make better readings,Ωou can place markers, so thatΩou can read the frequency and amplitude for that point. SometimesΩou set the double frequency to read the difference in amplitude, which can be relevant for filters or to read the relative strength of a sideband. The detector can be peak detector or RMS detector, there can be several. For specific measurement purposes

233 such as EMC measurements,Ωou need a specific detector. It is important to choose the right detector when the signal is to be presented. The choice of detector can affect the presented level by several dB. There are different detectors depending on howΩou want the signal presented. There are peak value indicating (Auto-peak, max peak, min peak) detectors which indicate the peak values of the signal. There are averaging (Average, Sample) detectors which, if the instrument works with digital technology, pick instantaneous measurement values randomly. There are also special detectors (so-called Quasi-Peak) that are used to measure according to specific EMC measurements. An important detector to remember is the so-called RMS detector. It was developed to be able to measure digitally modulated signals, often with varying phase and amplitude information. This detector is recommended for measuring digitally modulated signals. It is usually found in more modern analyzers. A common Average or Sample detector as above, expects the RF signal to be largely repetitively constant, which is the case with analog signals consisting of a carrier wave. A digitally modulated signal has a content that changes throughout the time, usually both in phase and amplitude. The RMS detector reads in – samples – the digitally modulated signal and takes constant measurements from the phase-varying RF signal. It follows the changed content of the RF signal. This detector is therefore excellent to use for measuring digitally modulated signals, for example Bluetooth or Wifi signals, but also the digital systems we have in amateur radio, as

these signals contain changes in phase and amplitude. It can can of course also be used to measure analog signals. The fact that it picks instantaneous measurement values even on an analog signal does not matter. After the detector there is a filter, often referred to as video bandwidth, which averages the detector's amplitude estimate over time. Most often, it is regulated automatically with the bandwidth of the filter, because narrower filters need proportionally longer time to get good results. The sweep time therefore depends on the number of points for frequencies, the bandwidth of the filter and the video bandwidth. SometimesΩou can control the video bandwidth manually to get a longer time, when it can be beneficial to get a clearer picture, that is to say remove noise and disturbances that only create variations becauseΩou don't observe a good average value. The video bandwidth thus does not affect the measurement result itself, but is only there to make it easier for the user to read the measurement.

9.2.14 The signal generator HAREC a.8.2.1.4

The signal generator (eng. signal generator) is an instrument which, as the name suggests, generates a signal, in this case a radio frequency signal. This instrument can be used to, for example, test receivers, or to generate one or more controlled signals to, for example, test amplifier stages. Older signal generators were usually built around a resonant circuit, and often drifted in frequency when they were heated up. They were thus not stable. Later generators worked with frequency synthesis, and was preferable in this context. It can also be used to generate a test signal, whichΩou feed into a receiver's input, in order to then be able to follow the signal with a spectrum analyzer (see 9.2.13) .A good signal generator must have the ability to give as clean a signal as possible, where harmonics and sidebands of various kinds are as low as possible. Often, the generator generates an inherent noise around the set signal. This noise diminishes the further awayΩou get from the set signal. This noise must of course be as low as possible. Another desirable parameter is the possibility of being able to regulate the radio frequency output level over a large area. Signal generators usually contain some form of measurement function to be able to measure the level. An advantage is if the signal generator has the ability to create modulation itself, for example AM or FM signals. SometimesΩou can find a built-in low-frequency generator, whereΩou can set the desired frequency to give, for example a tone. In this context, there is usually also the possibility to adjust the modulation degree for AM, or the deviation for the FM signal.

9.2.15 Network analyzer

A network analyzer (eng. network analyzer) is used to measure how much signal goes through the connection, for example filters or amplifiers, electrical -ler how much signal is reflected back from, for example, an antenna. Sometimes this is also called a pre-antenna analyzer in the context of amateur radio. A network analyzer that can only measure amplitudes is sometimes called a scalar network analyzer (Eng. Scalar Network Analyzer (SNA)). A spectrum analyzer with a so-called tracking generator, which generates a signal with the same frequency as it is analyzing, can act as SNA. A signal generator with sweep function can also act as SNA. A network analyzer that measures the phase of both outgoing and incoming signals can also measure the phase shift, and thenΩou can represent the phase both as a complex quantity or with polar coordinates, that is, amplitude and phase. Such a network analyzer is called a Vector Network Analyzer (VNA). In terms of use, a network analyzer is similar to a spectrum analyzer, but with several essential differences. In order to obtain correct measurement of amplitude and phase, more emphasis is placed on doing calibration (eng.calibration), something that is done to compensate for varying amplitude and phase for different frequencies. In 234 calibration, load (eng. load), short circuit (eng. short) and open port (eng. open) measurement of calibration references are often used. For two-port measurement,Ωou also use a transfer (eng. through) to get the port-to-port characteristics correctly. After calibration of the instrument, the measurements are corrected, and sometimes the differences can be drastic. In addition, the network analyzer often has a large number of different ways of presenting the measurement results so that the mancan measure according to the scatter model, return loss (RL), VSWR, Smith diagram and so on . This means that a network analyzer can be a powerful tool that, when used correctly, can provide good insight into how a circuit behaves. 235236

10 EMC

Modern society is becoming increasingly technologically advanced and the number of electronic devices in homes and workplaces is increasing sharply. The increasing amount and complexity of the devices therefore require rules that govern both execution and use with reasonably maintained safety and function. International and national well-defined rules for radio and telecommunication coexistence are now absolutely necessary.

10.1 Interference and interference sensitivity

10.1.1 About the EMCAct

The collective term is Electromagnetic Compatibility (EMC), i.e. the ability of a device to function satisfactorily in its electromagnetic environment so that it:• does not generate an electromagnetic disturbance that exceeds a level that allows radio or telecommunication equipment or other equipment to function as intended• has such endurance that the electromagnetic disturbance that can be expected in the case of intended use does not cause the equipment's function to deteriorate to an unacceptable extent. The Act on Electromagnetic Compatibility, SFS1992:1512 [4] gives the government or the authority the government determines the right to, in matters of communications or commercial activities or protection of life, personal safety or health notify regulations about EMC. Ordinance on electromagnetic compatibility SFS 2016:363 [7] defines the key concepts; devices, EMC, electromagnetic interference and endurance. The law and the ordinance together with the Swedish Electrical Safety Authority's regulations ELSÄK-FS and directives on electromagnetic compatibility implement EU directive 2014/30/ EU in Sweden. The Swedish Electrical Safety Authority is the responsible authority, with the right to issue regulations on, among other things, the protection requirements, control and marking, as well as certain exceptions. The above concerns disturbances caused by devices or disturbances to the functioning of devices. Such disturbances can be reported to the Swedish Electrical Safety Authority. Disturbances caused by radio transmitters or radio receivers dealt with in section 10.1.2.

10.1.2 Excerpt from the LEK

Post and Telecommunications Board's regulations on exemptions from licensing requirements for the use of certain radio transmitters PTSFS 2022:19 [11] refers to the Electronic Communications Act LEK SFS 2022:482 [12]. The following can be read about measures in the event of disturbances: ch. 3. Section 23 If, as a result of the permit holder's use of a radio transmitter, an unauthorized harmful interference occurs, the permit holder must immediately see to it that the permitted interference ceases or, as far as possible, is reduced. Whoever uses a radio receiver that interferes with the use of another radio receiver has a corresponding obligation. Harmful interference is defined in ch. 1. Section 7 as: an interference that endangers the function of the radio navigation service or any other security service, or that otherwise seriously impairs, prevents or repeatedly interrupts a radio communication service that functions in accordance with applicable regulations, including interference with existing or planned services on national tilldeadded frequencies Permitted interference is defined in the preparatory work for LEK as interference caused by users' sharing of frequencies and is then considered permissible. Note, however, that users with secondary status may not disturb users with primary status when sharing frequencies or frequency bands. In LEK, radio equipment is also defined: a device that enables radio communication or determining the position, speed or other characteristics of an object by sending radio waves (radio transmitter) or receiving radio waves (radio receiver)

10.1.3 Radiation from amateur radio transmitters

What is said in 3 Cape. § 4 Act on electronic communication and the writing in the Norwegian Post and Telecommunications Authority's regulations on exemptions from licensing requirements for the use of certain radio transmitters ch. 3. 14 §The technical characteristics of amateur radio broadcasting are adapted so that they do not interfere with the use of other radio facilities. Together with the writings in the Radiation Safety Authority's SSMFS 2008:18 and Ordinance on Electromagnetic CompatibilitySFS 2016:363. This means that the transmitter power must always be adjusted so that the strength of radiated fields237 does not cause interference or excessively high levels of electromagnetic fields. The highest permitted output power according to the exception regulations cannot therefore be used without hindrance. If the interference cannot be remedied, PTS may issue restrictions (restrictions in the transmission state). , there may be transmission bans during certain times, on certain frequencies, above a certain transmitter power, etc. 10.1.4 PM in case of interference problems • Interference is always associated with discomfort and puts neighbors to the test. Get along well with those who live in the area! Please also note that with regard to EMC, authorities do not have the right to gain access to homes.• If complaints are made againstΩou about interference,Ωou must first checkΩour own transmitter and antenna system.• Then ask to examine the antenna system and devices of the person who is bothered by interference.• IfΩou see a solution, tell us about what can be done. Agree on what can be done. Then do not change anything inside the devices, but feel free to try out external, supplementary filters, etc.• If it is not possible to deal with the interference, the people who delivered and installed the system should be called in.• Disturbance report regarding radio communication -tion can be made on the PTS website.• Disturbance notifications regarding products can be made to the Swedish Electrical Safety Authority.

10.1.5 Work actively with suppression

• Borrow one of SSA's suppression boxes and try to find a solution. In the box there is an assortment of frequency filters for interference.• Avoid interfering unnecessarily. Lower the transmitter power and limit the transmission time while testing a solution. IfΩou do not succeed in jammingΩourself:• Feel free to get help from a radio amateur with experience in jamming.• Enlist other expert help. 10.2 Interference in electronics Just as radio reception can be "interfered ” of broadcasts that are not of interest, interference in the form of radio waves from various types of electrical equipment can make reception or other functions difficult. Radiation from, for example, computers, cable TV, household appliances, ignition sparks from oil burners, cars and mopeds etc. are radio waves. Electrical devices can thus both disturb and be disturbed by radio waves, even if they are not defined as radio equipment, i.e. radio transmitters and/or radio receivers. Interference caused by electromagnetic fields is called Electromagnetic Interference (EMI). The sensitivity to such disturbances is called ElectromagneticSusceptibility (EMS).

10.2.1 Blocking HAREC a.9.1.1

In most receivers there is an automatic gain control. If the input signals become too strong, the regulation is not sufficient. Then the amplifier stages are overridden so that they work non-linearly. This is called blocking and can cause the receiver to go silent or a TV picture to disappear. One way to avoid blocking is to connect an attenuator to the receiver input. Such, however, lowers the signal strength over the entire frequency range, not just for a certain signal frequency.

10.2.2 Interference HAREC a.9.1.2

When the desired signal is disturbed by another signal close in frequency, it is called interference. In the receiver input there is frequency filter, which suppresses unwanted signals, if they are not too close. If the input is not selective enough, an additive is needed that improves the selectivity.

10.2.3 Intermodulation HAREC a.9.1.3

Mixing products of signals in a receiver or transmitter is called intermodulation and can be heard as false signals in a receiver. (see also chapter 5.9.6)

10.2.4 LF detection HAREC a.9.1.4

HF signals can enter through the inputs and outputs for LF as well as through the mains cable. In addition, direct irradiation of radio waves occurs through the device casing, if this does not have a sufficient shielding effect. LF detection occurs when HF signals are demodulated by diode lines in the components of the device being disturbed. This occurs regardless of the frequency to which the transmitter or receiver is set. It occurs especially in AM-or SSB-modulated transmissions and off-transients during carrier keying of transmitters.Problems with LF detection can be reduced by reducing the output power of the transmitter or by relocating the antenna so that the field strength is reduced. Often it is not possible to prevent LF detection without intervention in the affected device. Such interventions should only be carried out by professionals.

10.3 Causes of interference

10.3.1 Interference from transmitters HAREC a.9.2.1, a.9.2.2

HF amplifiers, for example in the transmitter output stage, can occur in unwanted self-oscillation, which can occur for several reasons; it can be lack of decoupling of supply voltages, inductive and/or capacitive feedback, etc. Power amplifiers can also be overridden. This results in intermodulation and harmonics that are radiated at unwanted frequencies. In many cases, interference can be avoided with one or more of the following measures:

• Do not use more power than is necessary.
• Avoid overriding the transmitter output stage (checked, for example, with the ALC meter).
• Provide the transmitter output with a low-pass filter. In this way, harmonics are suppressed.
• Match the impedances of the transmitter and the antenna system to each other. Tune the transmitter's π-filter and/or a separate antenna matching unit correctly. An incorrectly set transmitter can cause unintentional radiation.
• Connect balancing nets (balun) between asymmetrical antenna lines (coaxial cables) and symmetrical antennas.
• Place the antenna high and free and as far from people and interference-sensitive equipment as possible. Namely, the field strength is highest closest to the antenna. See chapter 11 on electric fields.• Avoid direct HF radiation on the power grid by using grid filters.
• Use "soft" keying of the carrier wave (rounded telegraph characters). Hard keying produces overtones in the form of snaps that are heard far beyond the transmission frequency. See also chapter 10.4.11.

10.3.2 Interference with radio reception HAREC a.9.2.3.1, a.9.2.3.2, a.9.2.3.3

As a rule, interference with radio reception only occurs when radiated signals reach a certain strength - the immunity level for HF. One can speak of three types of HF immunity in receivers:
• against signals through the antenna input
• against signals through other connected lines, for example speaker and power lines
• against electric and/or magnetic fields that radiate directly into the device. In the first two cases, it helps with complementation with high- and/or low-pass filters and screen current filters. Interference caused by radiation is the most difficult to remedy and requires intervention in the receiver, which should be left to a specialist with access to the manufacturer's service instructions.

10.3.3 Interference with TV reception

Interference from For example, radio broadcasters can express themselves in the following way for digital TV: Transmissions, mainly on 2 meters but also on 70 cm, can cause blocking and picture disturbances when receiving digital TV. The TV picture then loses information, there are pixels (square boxes), green noise or the whole picture freezes or disappears for a short time. For analog TV in, for example, cable TV networks, the disturbances can manifest themselves in the following way:

• When transmitting amplitude modulated signals, for example AM and SSB, sound distortion occurs in the audio channel as well as streaks etc. in the image.
• When transmitting FM and CW sound disturbances occur as well as contrast variations, interference patterns (moire effects) and more in the picture. Problems with disturbances of this type have decreased significantly since digital TV was introduced and most TV broadcasts now take place on the VHF and UHF bands. Interference in TV caused by transmitters on lower frequencies can in many cases be remedied with frequency filters. A low-pass filter after a short-wave transmitter can, for example, be designed to only let through signals below about 35 MHz. Read more about low-pass filters in chapter 10.4.3.

A high-pass filter before a TV receiver can, for example, be designed to only let through signals with frequencies above about 35 MHz. Read more about high-pass filters in chapter 10.4.4. If reception in TV bands I and II is not of interest, a high-pass filter with a cut-off frequency of approximately 160 MHz can be inserted.

It suppresses unwanted emissions from transmitters in the HF and lower VHF range, that is up to and including the 144-146 MHz amateur band. However, TV band III (174–230 MHz) and TV bands IV and V are allowed through (470–890 MHz). blocking circuits tuned to the interference frequency, bandpass filter tuned to the useful frequency. Read more about filters in chapter 10.4.5.239

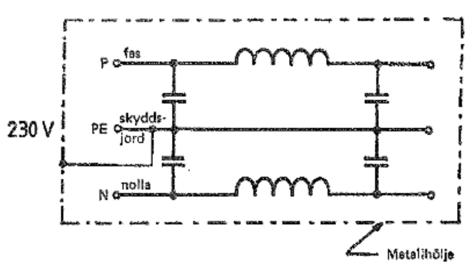

Bild 10.1: Nätfilter

Figure 10.1: Mains filter

A common case of interference is that a broadband antenna amplifier is overridden or blocked by single transmitters. See also chapter 10.2.1.

• Try to avoid antenna amplifiers.
• Try to avoid poorly shielded joints and antenna contacts.
• Get a better TV antenna that can also receive TV broadcasts on VHF. Many households today only have one UHF antenna and therefore have a poor antenna signal on the VHF band where transmissions for HD TV take place in many areas.

10.3.4 Interference with LF devices

Interference with HF radiation in audio tape players, LF amplifiers, telephone devices etc. can often be stopped with decoupling capacitors and HF chokes. Modern suppression chokes usually contain some ferrite material in the form of tubes, rods or rings.

10.4 Suppression methods

10.4.1 General

In order to try out a filter that best solves a certain radio interference problem, you may need access to a filter assortment. Examples include filters in SSA's suppression boxes.

10.4.2 Mains filter HAREC a.9.3.1.1

Mains cables can function as an antenna. In the case of the transmitter, HF signals can enter the power grid through the power line and interfere with other devices both through direct connection and through radiation. In the receiver case, HF signals can be picked up by the mains line, routed into the devices and LF detected there. To prevent such disturbances, a mains filter is needed. The mains filter must be sized for the mains current for which the device is protected and should be connected as close to the device as possible. If the filter cannot be placed there, it may be necessary to also screen the mains line between the filter and the device and the earth screen. If the line is provided with, for example, a series inductance - a choke - then the HF signals are attenuated. A choke can be made, for example, by winding a few turns of the power cord closest to the device onto toroids or one or more combined ferrite rods.

In severe cases, a broadband mains filter may be needed, similar to the one in picture 10.1. There may be strong voltage transients (voltage surges) on the mains. These transients can lead to malfunctions in connected devices. To prevent such errors,Ωou can connect an overvoltage filter, which can be separate or integrated with the mains filter.

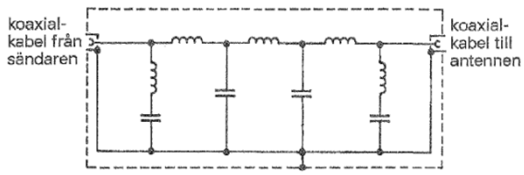

Figure 10.2: Low-pass filter for transmitters240

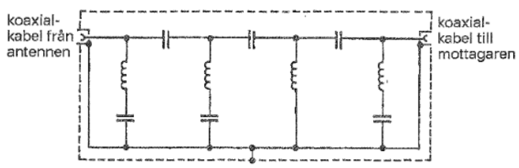

Figure 10.3: High-pass filter for VHF/UHF receivers

10.4.3 Low-pass filter

Low-pass filter lets through signals with frequencies below the filter's cut-off frequency. A low-pass filter with a suitably chosen cut-off frequency attenuates, for example, the harmonic radiation from single transmitters, whose transmitter frequency lies below the filter's cut-off frequency, while the harmonics lie above its cut-off frequency. Harmonics can be attenuated with low-pass filters. In this context, a harmonic is a multiple of the transmission frequency (the fundamental tone), for example for 3.5 MHz the fundamental tone = (1st harmonic) 3.5 MHz, 1st harmonic = (2nd harmonic) 7, 0 MHz, 2nd harmonic = (3rd harmonic) 10.5 MHz, etc. Important for the intended filter effect is that the filter is connected with correct impedance matching and with the shortest possible cables. Incidentally, this applies to all filters. Radiation outside the permitted bandwidth of the transmission type is considered "unwanted radiation". Further states that such radiation from amateur radio transmitters must be kept as low as today's amateur radio technology allows. Figure 10.2 shows the principle of the low-pass filter TP 30 for shortwave, with the cut-off frequency 36 MHz, connected between the transmitter and the antenna line. With this cut-off frequency, harmonics from transmitters are attenuated so that the risk of TV interference is reduced.

10.4.4 High-pass filter

High-pass filter lets through signals with frequencies above the cut-off frequency of the filter. Figure 10.3 shows the principle of the high-pass filter HP 40-S with cut-off frequency 47 MHz, to be connected to the intermediate antenna line and a receiver for VHF or higher frequencies. Interference does not always come "from outside". They can, for example, be generated in broadband antenna amplifiers, which are easily overridden by all kinds of signals from a large frequency range.Ωou can then connect a high-pass filter before the broadband amplifier, but a better solution is to change to a well-shielded passband or even better channel amplifier. Coaxial cables with tight shields and correctly mounted connection contacts are also important for successful suppression.

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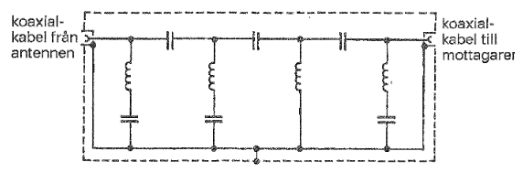

Figure 10.4: Blocking filter for receiver

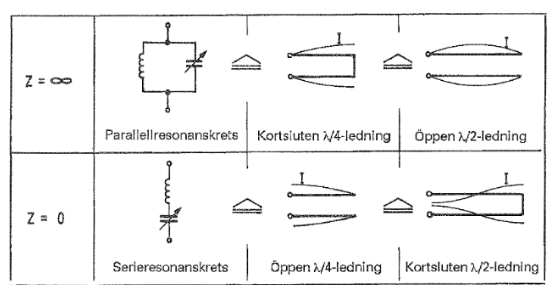

Figure 10.5: The input impedance in resonant circuits

10.4.5 Blocking filters and suction circuits

If a disturbing signal happens to be within the receiver's passband,Ωou can suppress - "block" - that signal with a blocking or suction filter. Which oneΩou choose is not critical. The interfering signal can be "blocked" with a parallel resonant circuit in series with the receiver input, see figure 10.4. The circuit consists of an inductance and a single capacitance. IfΩou use a stub as a resonant circuit - for example a coaxial cable - then it must have a length of λ/4 and be "short-circuited" or have a length of λ/2 and be "open". Figure 10.5 shows examples of how the input impedance can be used.Ωou can also short-circuit - "suck out" the disturbing signal with a series resonance circuit parallel to the receiver input, see Figure 10.6. IfΩou then use a stub, it must have a length of λ/4 and be "open" or have a length of λ/2 and be "short-circuited". The disturbing signal can be further suppressed with more stubs, which are arranged as in picture 10.6. The filter then consists of open λ/4 stubs, which form branches from the antenna cable with a distance of λ/4. (If the stubs in this filter are short-circuited, a bandpass filter is formed instead). Examples of commercial blocking filters are SF 145-S for 144 MHz and SF 435-S, for 435 MHz amateur band. They are intended to be connected before receivers are disturbed by amateur radio broadcasts. SF 145-S blocks amateur bandet 144–148 MHz and lets through the bands 0–120 and 174–870 MHz. The SF 435-S blocks the amateur band 430–440 MHz and lets through 0–350 and 470–870 MHz.

10.4.6 Mains and screen current filter for reception

Figure 10.7 shows mains and screen current filter. It is common for common mode current to occur as leakage from equipment and antenna. This is often called conductive interference. It means that the antenna cable can also function as an antenna. Especially in screen joints, HF currents can leak out and in. They can then pass by possible antenna amplifiers, filters, etc. and cause interference. In simple cases, common current can be stopped by winding the cable a few turns on ferrite rods or through a large ferrite ring as in the picture. A mains cable, so-called cable rack, must not be cut and spliced.242

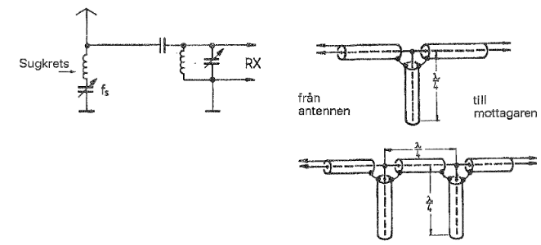

Figure 10.6: Suction circuits for receivers

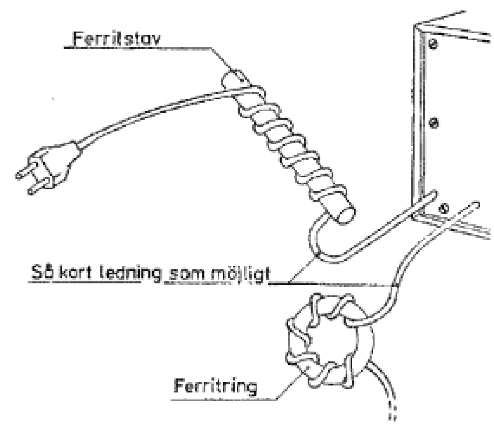

Figure 10.7: Mains and screen current filters

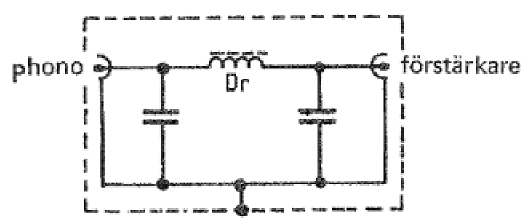

Figure 10.8: Phono input filter

10.4.7 Phono input filter (TBA 302)

Figure 10.8 shows the phono input filter. Disturbing influence from radio transmissions can occur if the connecting cables to the phono input in LF amplifiers are poorly shielded and disconnected. Such disturbances can be remedied with a filter.

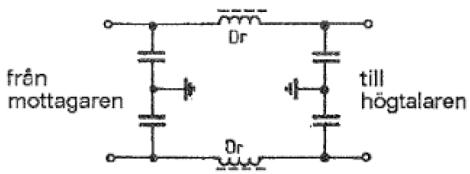

Figure 10.9: Speaker line filter

10.4.8 Speaker line filter (EM 502-B)

Figure 10.9 shows speaker line filter. HF radiation on speaker lines can have a disturbing effect. This can be avoided by connecting HF chokes in the lines. These chokes should be shielded so that they do not act as antennas instead. In simpler cases, it may be enough to change shielded speaker cables or to wind up a section of the wires on a ferrite core.243

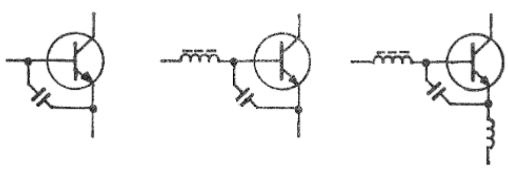

Figure 10.10: HF-decoupled bass in three ways

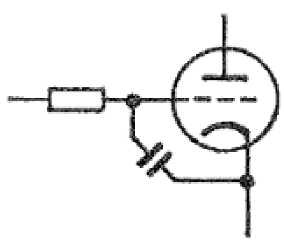

Figure 10.11: HF-decoupled control grid

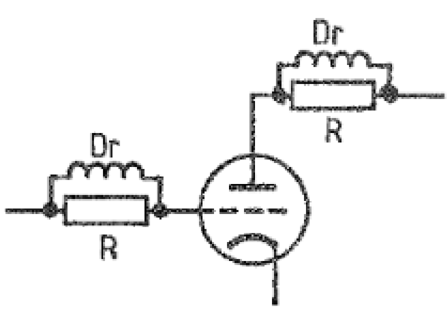

Figure 10.12: Parasitic filter in HF amplifier

10.4.9 Decoupling of HF signals HAREC a.9.3.1.2

Decoupling a signal means that it is diverted from one signal path to another. In case of interference, the disturbing signal is usually decoupled to system earth. The interference immunity in the receiver can thus be improved by HF-decoupling the LF inputs with capacitors and/or HF-blocking with chokes. In severe interference cases, it may also be necessary to HF-shield the LF input stages , as well as with additional interference filters inside the amplifier. However, such measures mean that design changes have been made. The device's electrical safety markings are then invalid.

Figure 10.10 and 10.11 show some ways to decouple an unwanted signal from the control grid in an electron tube and from the base of a transistor, respectively.

10.4.10 Parasitic filter

Picture 10.12 shows parasitic filters in HF amplifiers. Amplifier stages can get into self-oscillation, often in the VHF/UHF frequency range. One way to stop it is a so-called parasitic filter.

10.4.11 Keying filter

Picture 10.13 shows keying filter. When a carrier wave is keyed, harmonics are formed. Mixing products of the harmonics and the carrier wave are heard as snapping at around

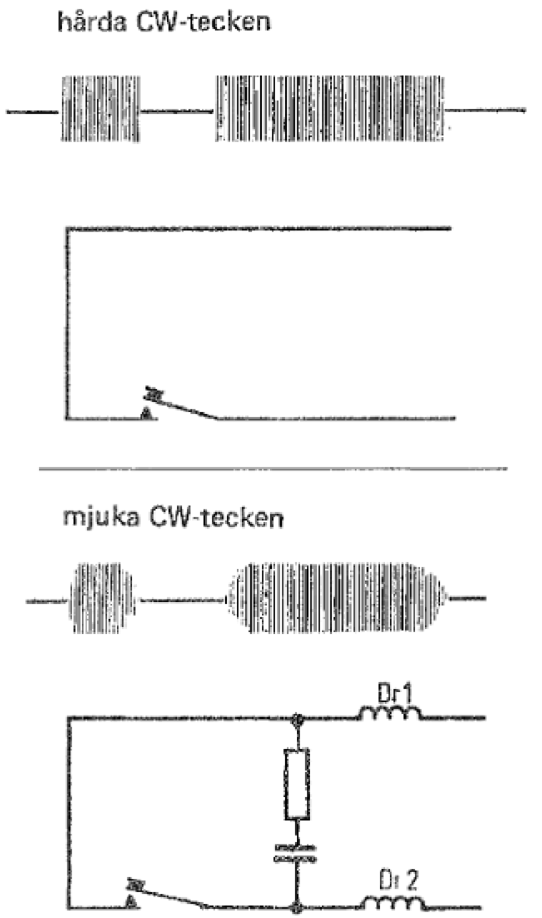

Figure 10.13: Keying filtering frequencies.

Note that harmonics occur in all carrier keying - not just in Morse telegraphy! When the transition time is short (hard keying), more harmonics are produced than when it is longer (soft keying). The buttons can be partially damped with a keying filter where the swing-in process is partly slowed by a choke in series with the keying contact and partly the swing-out process with a series circuit of a resistor and a capacitor, connected in parallel to the keying contact.

10.4.12 Improved shielding HAREC a.9.3.1.3

HF energy can in unfortunate cases also radiate out the transmitter's casing and into the casing of other devices. This means that the devices' shielding and grounding must be improved. Then follow the electrical safety regulations! See also sections 1.3, 1.4 and 12.2.244

11 Electromagnetic limit values

11.1 Introduction

An amateur radio station sends out radio waves, signals, to communicate wirelessly with the whole world. The radio waves are also called electromagnetic fields (EMF). Around all antennas that emit radio waves, electromagnetic fields are formed by the energy sent into the antennas from the radio transmitter. The radio waves from an amateur radio station, the electromagnetic fields, are classified as non-ionizing radiation and, as such, are not energetic enough to cause anything other than heating body tissue. In general, studies have shown that the levels of electromagnetic fields that the public can be exposed to in the vicinity of an amateur radio station are well below the values at which the body temperature would increase. Non-ionizing radiation, such as optical radiation (infrared radiation, visible light and ultraviolet radiation) and electromagnetic fields (radio waves and microwaves) are normally not as energetic as ionizing radiation. When electromagnetic radiation is absorbed in biological tissue or material, the dominant effect is therefore only a temperature increase in the tissue or material. Ionizing radiation, particle radiation or electro-magnetic radiation, which has sufficient energy to detach electrons from the atoms it hits and transformconvert them into positively charged ions, ionization. Examples of ionizing radiation are X-rays and radiation from radioactive substances. The energy of ionizing radiation can be so high that it can penetrate the body and affect cellular structural genetic material (DNA) in biological material. Within the World Health Organization (WHO) there is a program called "The International EMFProject" and there gathers all the scientific information available on biological effects caused by electromagnetic fields. The "International Commission on Non-Ionizing Radiation Protection", (ICNIRP) is an independent organization (recognized by the WHO) which, among other things, uses this information to develop guidelines for limiting the level of exposure to electromagnetic fields. These guidelines are used by many countries. The Radiation Safety Authority (SSM) is the authority that has the formal responsibility for radiation protection in Sweden. The authority must, among other things, prevent acute injuries and reduce the risk of late health effects in the public as a result of exposure to electromagnetic fields. SSM has produced general advice SSMFS 2008:18[6] for limiting the public's exposure to electromagnetic fields. The general advice specifies which reference values apply in Sweden. The advice is based on recommendations in EU directive 1999/519/EC [5]. The EU directive in turn follows the guidelines for limiting electromagnetic fields compiled by ICNIRP. Because the basis of amateur radio practice is to generate electromagnetic fields to communicate via radio, knowledge of EMF is important. Given the opportunities radio amateurs have, the general advice regarding EMF must be followed. The understanding of how fields appear and how they can be limited is considered fundamental knowledge for radio amateurs.

11.2 Fields

To indicate the level of the electric field (E), the unit "volts per meter" (V/m) is used. The magnetic field (H) level is indicated in the unit "ampere per meter" (A/m). The task of the antenna is to convert the high-frequency current in the feeder cable as efficiently as possible into an electromagnetic wave that propagates in the air. The composite electromagnetic wave does not occur directly at the antenna but occurs in what is called the far field. This happens through the interaction between the electric and magnetic fields emanating from the antenna. The theories that describe how this interaction works are complicated, but the important thing to understand is that there is a boundary between what is called the far field, further away from the antenna, and the near field near the antenna. In the far field, thanks to the interaction between the electric and magnetic fields,Ωou can measure any of them . As the electromagnetic field spreads out over a larger surface, the strength of the field decreases with the distance from the antenna. The composite electromagnetic field that has crossed the boundary to the far field decreases linearly with the distance, doubling the distance halves the field strength. It doesn't matter if the antenna is completely omnidirectional or concentrates the effect in one direction, the electromagnetic field decreases in the same way. In the near field, due to the complicated mutual relationship of the fields,Ωou need to measure both the electric and the magnetic field to get an idea of the size of the radio frequency field. In the vicinity of the antenna, the levels of the various fields vary greatly, and at certain points high field strength levels can be measured.If the antenna has a large extent in relation to the wavelength used, far field formulas can sometimes be used to roughly calculate the field strength level in the near field of the antenna. For compact antennas (e.g. small loops) complicated calculations are required using antenna simulation software. Depending on the antenna type that generates the field, it is either an electric or magnetic field that dominates the near field. Electric field dominance is generated by antenna types based on voltage differences (e.g. dipole) and magnetic field dominance by antennas with current flow (e.g. small loops). Since all electrical conductors can be considered as antennas, these will be able to generate fields, regardless of it is supposed to be an antenna or not. This should be kept in mind when installing the feed line to the antenna to avoid high-frequency current flowing back to the station on the outside of the lead. Even the devices used to generate radio signals can have poor shielding, and as a result, high-frequency current is led to the outside of the devices. There is thus a risk that the field strengths can be significant in the vicinity of transmitters and above all at the end stage with associated cabling.

11.3 General advice

SSM has issued general advice for limitation exposure of the general public to electromagnetic fields SSMFS 2008:18 [6]. The purpose of the advice is to protect the public from acute harmful biological effects when exposed to electromagnetic fields. The guidelines state basic limitations and derived reference values. The basic limitations ensure that electrical or magnetic phenomena that may occur in the body do not disrupt functions of the nervous system or give rise to harmful heat development. The basic limitations are, according to international recommendations, set at approximately two percent of the levels in which acute biological effects are scientifically assured. Reference values have been derived from the basic limitations, which consist of quantities that can be measured outside the human body. Reference values ensure that the basic limitations are not exceeded. If measured values exceed the reference values, this does not necessarily mean that the basic limitations are exceeded. In such cases, according to these general recommendations, the basic limitations apply. In EU directive 1999/519/EC [5], it is written that in such cases an assessment must be made as to whether the exposure level is below the basic limitation. The reference values in the general recommendations should not be exceeded in any area where the public may be present for such periods of time that the restrictions are irrelevant. There are two main acute biological effects that can occur from heavy exposure to electromagnetic fields. Fields with a frequency of up to approximately 10 MHz can, if the current density becomes high in the body, affect the central nervous system. Fields with frequencies from 100 kHz to 10 GHz can at high levels lead to a heating of the body. When electromagnetic radiation is absorbed in biological tissue, the tissue can be heated. This is called "Specific Absorption Rate" (SAR) which is measured in the unit watt per kilogram (W/kg) or milliwatt per gram (mW/g). SAR is defined as the energy, averaged over the whole body or parts of the body, which is absorbed per unit of time and per unit of mass of biological tissue. Since the heating of body tissue does not go very quickly, one calculates the average effect that during a certain time causes heating. For frequencies between 100 kHz and 10 GHz, the SAR value is calculated as the average value over a six-minute period. Preliminary calculation of the SAR value at frequencies exceeding 10 GHz is referred to formulas for calculation according to SSMFS 2008:18. Depending on the size of the body in relation to the direction and wavelength of the electromagnetic field, resonance phenomena are created due to the fact that the body functions as an antenna. This affects the heating in such a way that at frequencies that are close to the body's or body part's electrical resonance frequency, the effect is absorbed more easily and maximum heating occurs. In adults, this resonance frequency is between 70 and 90 MHz if the person is standing up and isolated from something that can be compared to an earth plane. The different body parts can also be resonant. An adult's head is resonant at around 400 MHz, for example. The size of the body thus determines at which frequency it absorbs the most power and at frequencies above and below the resonance frequency, heating caused by the electromagnetic field is reduced. The reference values take this fact into account and the most restrictive frequency range lies within the range 10 to 400 MHz where power is most easily absorbed by the body. In the frequency range 10 to 110 MHz there is also a limitation to 45 mA for induced current in each extremity in order to limit the local SAR value.246

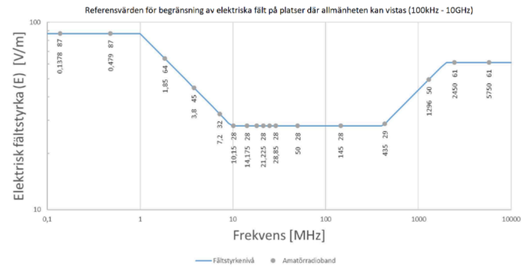

Figure 11.1: Reference values for limiting electric fields (100 kHz–10 GHz)

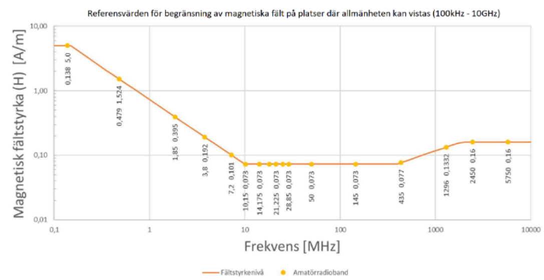

Figure 11.2: Reference values for limiting magnetic fields (100 kHz–10 GHz)

Figure 11.1 illustrates reference values for limiting electric fields onplaces where the public can be (100 kHz–10 GHz), with amateur bands and field strength level indicated, for example 10.15 MHz has a maximum permitted electric field strength of 28 V/m.

Figure 11.2 illustrates reference values for limiting magnetic fields in places where the public can be (100 kHz–10 GHz), with amateur band and field strength level specified, for example 10.15 MHz has a maximum allowable magnetic field strength of 73 mA/m.247dB 0 1 2 2.15 3 4 5 6 7 8 9G 1.0 1.3 1.6 1.64 2.0 2.5 3.2 4.0 5.0 6.3 7.9dB 10 11 12 13 14 15 16 17 18 19 20G 10.0 12.6 15.8 20.0 25.1 31.6 39.8 50.1 63.1 79.4 100.0

dB	0	1	2	2,15	3	4	5	6	7	8	9
G	1,0	1,3	1,6	1,64	2,0	2,5	3,2	4,0	5,0	6,3	7,9
dB	10	11	12	13	14	15	16	17	18	19	20
G	10,0	12,6	15,8	20,0	25,1	31,6	39,8	50,1	63,1	79,4	100,0

Table 11.1: G = Antenna gain in linear factors

11.4 Evaluation of EMF

To be able to evaluate that the own radio station when transmitting produces electromagnetic fields that are below the reference values,Ωou need to know the parameters that are decisive for the strength of the electromagnetic field:

- The gain of the antenna (G).
- The average power of the transmission (P).
- The losses of the transmission line (k).
- The distance (d).

11.4.1 The antenna

The antenna receives the signal from the transmitter via a feed cable and converts this signal into an electromagnetic wave. How effectively the antenna converts the signal from the transmitter can be explained most simply with the concepts of gain or antenna gain.Ωou must therefore know which gain the antenna has expressed in linear factors in relation to an isotropic antenna. Antenna gain in relation to an isotropic antenna is usually expressed in dBi. This means that the standard dipole antenna used as a reference for 0 dBd has a gain of 2.15 dBi compared to an isotropic antenna. All values of antenna gain expressed in dBd must therefore be increased by 2.15 to be able to use table 11.1 which shows the relationship between gain in dB and linear factors. For an antenna with a gain of 7 dBi, the value 5.0 must therefore be used.

11.4.2 The transmitter power

All SAR values must be calculated as an average value over a period of six minutes. In order to be able to perform a calculation of the average value of the effect, in addition to the PEP effect, knowledge of the two factors that affect the average effect is needed. The factors are therefore important for the level of the electromagnetic field and thereby affect the average exposure to EMF.

11.4.2.1 Modulation factor

Depending on the mode of transport, the average power will be different. Table 11.2 gives the factors that according to OET bulletin 65 supplement b, [18] are used in the USA to calculate the average effect due to the modulation factor. e.g. RTTY, PSK) 1.0 Carrier wave 1.0

Trafiksätt	Modulationsfaktor
SSB	0,2
CW	0,4
SSB med processing	0,5
FM	1,0
MGM (t.ex. RTTY,PSK)	1,0
Bärvåg	1,0

Table 11.2: Modulation factor per traffic mode

11.4.2.2 Intermittent factor

In normal amateur radio use,Ωou do not transmit continuously as switching between transmission and listening occurs regularly. IfΩou transmit and receive the same amount during a six-minute period, the factor becomes 0.5, but ifΩou listen much more and rarely transmit, the factor becomes smaller.

See table 11.3 for more examples.

Transmission Reception Intermittent factor (minutes) (minutes)1 5 0.172 4 0.333 3 0.504 2 0.675 1 0.836 0 1.00

Sändning (minuter)	Mottagning (minuter)	Intermittensfaktor
1	5	0,17
2	4	0,33
3	3	0,50
4	2	0,67
5	1	0,83
6	0	1,00

Table 11.3: Intermittent factor

11.4.2.3 Average power

In order to calculate which average power should be used, take into account both modulation factor and intermittence factor as follows Average power = Maximum power · Modulation factor · Intermittent factor P = Average power during a six-minute period

11.4.3 Cable attenuation

When the output power is measured at the transmitter and the field is generated by the power reaching the antenna, the attenuation that the feed conductor has must also be known. Otherwise, the generated field strength is overestimated.248dB 0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0k 1.00 0.89 0.79 0, 71 0.63 0.56 0.50 0.45 0.40 0.35 0.32

dB	0,0	0,5	1,0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0
k	1,00	0,89	0,79	0,71	0,63	0,56	0,50	0,45	0,40	0,35	0,32

Table 11.4: k = Feeder cable attenuation in linear terms Band [m] 160 80 40 30 20 17 15 12 10 6 Far-field limit [m] 27 13 6 .7 5 3.3 2.8 2.5 2 1.7 1

Band [m]	160	80	40	30	20	17	15	12	10	6
Fjärrfältsgräns [m]	27	13	6,7	5	3,3	2,8	2,5	2	1,7	1

Table 11.5: Far-field limit per band Here too, linear factors must be used. The losses in a cable have negative values expressed in dB, which causes the factors in table 11.4 to be less than one. For a cable with attenuation 2.5 dB, the value 0.56 should therefore be used.

11.4.4 Distance

In order to calculate the level of the electromagnetic field in a selected location,Ωou need to know the distance to the transmitting antenna. According to the Radiation Safety Authority's general advice, the reference values should not be exceeded in places where the public is present. An assessment should therefore be made of the distances from the transmitting antenna to places where the public is at risk of being exposed to electromagnetic fields. d = The distance from the antenna to the place where the field strength can be determined

11.4.5 Calculation

Calculation of the electromagnetic field can only be carried out in the far field from an antenna. In the far field we already know thatΩou can either evaluate the electric or the magnetic field. For this reason, only the calculation of the electric field part of the electromagnetic field is described here. A woodThe distance taken from the antenna where far-field calculations can be carried out is d = λ/6.

Table 11.5.
The following formulas are only valid for calculating the correct field strength in the far field, but for simpler antennas can be used to estimate the field strength that occurs in the near field. E = The magnitude of the electromagnetic field in the far field The magnitude of the electromagnetic field (in the far field) is calculated from the power (average value), the antenna gain, the attenuation of the feed line and the following simplified formula depending on the distance.E =√30 · P · G · kd

Through simple mathematics,Ωou can then use the same formula to calculate at what distance a certain field strength is generated.d =√30 · P · G · kEthis calculation is only relevant for the main lobe. The field under the antenna is not calculated, and therefore the result cannot be used to assess the height or safety distance to the antenna tower. Use data programs to get a good assessment of how an antenna behaves, especially with regard to directional antennas.

11.4.5.1 Example 1:

What average field strength is generated at a certain distance from the antenna? A directional antenna for 144 MHz with gain according to the data sheet of 14.92 dBi (31 times). Max output power is 1000 W and the traffic mode is MGM (eg RTTY,PSK) with 30 second intervals. The selected feeder line has an attenuation of 2.5 dB (0.56 times). The distance from the antenna to the calculation point is 15 m. intermittence factorG = 31 k = 0.56 d = 15E =√30 · P · G · kd ==√30 · 500 · 31 · 0.5615 = 34.02 V/mSince the reference value of this frequency is 28 V/m, the amateur radio broadcast exceeds the reference value at this distance.

11.4.5.2 Example 2:

At what distance from the antenna does one reach the reference value? A directional antenna for 144 MHz with amplification according to the data sheet of 14.92 dBi (31 times). Max output power is 1000 W and the traffic mode is MGM (eg RTTY,PSK) with 30 second intervals. The selected feeder line has an attenuation of 2.5 dB (0.56 times). The reference value for 144 MHz is 28 V/m. Pmean = Ppep · kmod · kif = 1000 · 1 · 0.5 = 500 W249kmod = modulation factor kif = intermittency factorG = 31 k = 0.56 E = 28d =√30 · P · G · kd ==√30 · 500 · 31 · 0.5628 = 18.22 mTo follow the general advice, the public should not be able to stay in the main lobe in front of the antenna at a distance less than 19 m when transmission is carried out according to the example.

11.4.5.3 Example 3:

At what distance from the antenna doΩou reach the reference value? A dipole antenna for 3.75 MHz compared to an isotropic antenna has a gain of 2.15 dBi (about 1, 6 times). Max output power is 100 W and the traffic mode is SSB with normal TX/RX intervals. The select feeder line has an attenuation of 0.5 dB (0.89 times). The reference value for 3.75 MHz is 45 V/m. Pmean = Ppep · kmod · kif = 100 · 0.5 · 0.5 = 25 Wkmod = modulation factor kif = intermittent factorG = 1.6 k = 0.89 E = 45d =√30 · P · G · kE =√30 · 25 · 1.6 · 0.8945 = 0.74 mHere we note that the calculated distance is in the near field from the antenna (within 13 meters). Endipole is a simpler antenna type, so we can assume that the value is useful to be able to evaluate the exposure. To follow the general advice, people should not have access to any part of the antenna closer than 0.74 m when transmitting.

11.5 Self-control

To evaluateΩour own station, there are a few different ways to go:

• Calculate the field strength or the safety distance withΩour own parameters according to the examples above.
• Compare with other people's evaluations.
• Use software that is specially made to calculate at which distance the reference value is reached under given conditions according to example 2 above.
• Use values from tables where different typical antennas are described.
• Use antenna simulation programs that also have the possibility to calculate field strength.
• Measure the field strength (especially when evaluating the near field from the antenna). for this purpose. An example of such a program is ICNIRPcalc, which is developed by a representative from the German Amateur Radio Association (DARC). In the program there are already different antenna types and there is also the possibility to insertΩour own antennas to make correct calculations. This program can be downloaded from SSA's website for EMC/EMF questions.

11.5.3 Table values

Based on the type of antennaΩou useΩourself,Ωou can compare with typical values from other people's calculations and make a reasonable estimate ofΩour own situation.

11.5.4 Antenna simulation

Some programs for antenna simulation also have functions for calculating field strength levels around the antenna and in some cases can calculate the field strength in the near field as well.

11.5.5 Measuring field strength

Measuring field strength requiresAccess to calibrated measuring equipment that provides measurement values that are reliable enough to be used with certainty in evaluating the field strength level.

11.6 Summary

The Radiation Safety Authority (SSM) has specified reference values in its general advice that should limit the public's exposure to electromagnetic fields (EMF). These limitations and the transmitter's ability to generate strong electromagnetic fields means that we as transmitters must understand and be able to handle the area of electromagnetic fields (EMF). 250 All transmitting antennas will have an electromagnetic field (EMF) around them. This electromagnetic field (EMF) is dependent on the type of antenna used and the signal sent into the antenna. How to assess the size of these fields is crucial in order to be able to limit the exposure of EMF from an amateur radio station. A self-check should be carried out in order to be able to assess the field pattern that the amateur radio practice causes around their station. Since amateur radio is an experimental activity, everyone must understand how changes in their installation and use affect this field image. Whichever methodΩou choose forΩour self-monitoring, it is appropriate to make it clear and easy to understand. This is important becauseΩou should saveΩour results and then have the opportunity to do aboutΩour evaluation whenΩou have changed something or some of the values that could affect the result.

11.6.1 Practical handling

With all use of amateur radio equipment, an assessment must be made of which field strengths are generated and which may be exposed. It could be a matter of people in the immediate vicinity or people at a greater distance. In any case, one should think about whether one has chosen the right way to generate the electromagnetic field strength one needs, or if there is a better and more efficient way that makes it possible to reach the opposite station without unnecessarily exposing someone else to electromagnetic fields. There are certain installations that one should avoid and others that can be recommended to keep the levels of exposure as low as possible:

• Antennas that are close to people, for example balcony antennas, can give much higher exposure than antennas that are mounted high on a mast.
• Directional antennas for high frequencies often have high gain, and can produce high field strengths in the main direction. ThenΩou have to make sure that it is not possible to direct this type of antenna towards places where people can be exposed.
• Indoor antennas always end up close to people and should only be used with low power as the decan gives very high exposure. They will also receive interference from home electronics (mains adapters, computers, etc.), which also makes the antenna placement very unsuitable.
• Antennas above house bodies should only be used with low power. Wire antennas for lower frequencies directly above residential buildings will be close to people in the building.
• IfΩou need to use high power,Ωou must also make sure that the power is used as well as possible. It is directly inappropriate to compensate for a bad antenna with higher power as it usually results in high field strengths in the wrong place.
• Higher field strength can usually be most easily achieved with an antenna that directs the signal in the directionΩou want to communicate. It is usually much more expensive and more complicated to increase the output power to achieve the same result.
• Unsymmetrical antennas can produce sheath currents in the supply line. This means that an HF current flows from the antenna back onto the feeder line and can produce high field strengths along the entire length of the cable. It is then better to use symmetrical antennas, for example a center-fed half-wave dipole. A current balun (also common mode choke, RF-choke) where the antenna is connected to the feed line suppresses this HF current and thus the feed line will stop acting as a radiating element, whereby the field strengths along the feed line drop.
• Some antennas, such as the T-antenna, use the doll imbalance when the supply line acts as a radiating element. In these cases, the part of the supply line that acts as a radiating element must be considered as such also in an EMF context, and safety distances must be observed. It is recommended to use a current balun to isolate the antenna from the radio station with respect to the sheathed HF current.
• Even symmetrical antennas can have currents on the outside of the feed line. Therefore, pull the power cable as far away from people as possible.
• Do not use power amplifiers or antenna tuning units without a cover, as the field strengths around the equipment can reach high levels.
• When antenna placements are close to people, it may become impossible to use high power.There are apparently many ways to do it right and also many ways to do it wrong when it comes to managing the field strength we want to generate to maintain radio communication. Before starting amateur radio broadcasting, it is important to have an understanding of the fields that are generated and to be able to limit them where necessary.

Ωou can find more information about electromagnetic fields at:
• The Radiation Protection Agency's website, which also contains SSMFS 2008:18 [6].
• The Swedish Work Environment Agency's website also contains AFS 2016:3 The Swedish Work Environment Agency's regulations on electromagnetic fields and general advice on the application of the regulations.
• The Public Health Agency's website. 251
• Federal Communications Commission (FCC)OET bulletin 65 supplement B [18].
• EU directive 1999/519/EC [5]25212 Electrical safety

12 Electrical safety

12.1 The human body HAREC a.10.1

12.1.1 Electric shock

The human body is a complicated electrochemical system, which is primarily controlled by the brain. The muscles are controlled by weak electrical current impulses through the nervous system. Foreign currents through the body can disrupt body functions and in unfortunate cases can cause great damage.The strength and frequency of the currents determine the nature and extent of the damage. Electric shock can kill for several reasons. One reason is that the heart rhythm is disturbed. Ventricular fibrillation and cardiac arrest can easily occur. Fibrillation means that the heart works uncontrollably and with a severely reduced or pump function completely suspended. Cardiac arrest is easily caused by high voltage. Due to insufficient blood supply, there is a lack of oxygen in the brain cells, which are then quickly damaged. Unconsciousness sets in after just a few seconds. Another cause is respiratory arrest by blocking the respiratory center. It can happen when the current from a high-voltage capacitor passes through the body.

12.1.2 Cardiopulmonary resuscitation, CPR

In the event of cardiac arrest, ventricular fibrillation or respiratory arrest, cardiopulmonary resuscitation must be started immediately as irreversible brain damage from lack of oxygen can occur within a few minutes. If there is a defibrillator, AED, nearby, it should be used as quickly as possible. Don'tforget to call for help! Call 112! The brochure Guidance on electrical damage can be downloaded or ordered from the Swedish Electrical Safety Authority's Website <www.elsakerhetsverket.se>. Vårdguiden 1177 <www.1177.se> has instructions for cardiopulmonary resuscitation (CPR). The Swedish Council for CPR <www.hlr.nu> has descriptions and instructional videos for CPR.

12.1.3

The resistance through the human body In contact with a current-carrying object, the body will become part of the current circuit. A foreign current then flows through the body.The current follows Ohm'slaw and depends on the voltage and internal resistance of the current source as well as the transition resistance in the skin and the body'sinternal resistance. The transition resistance decreases with more moist skin and with a larger contact area and greater contact pressure. The touch voltage also affects. At voltages above about 75 V, the transition resistance decreases with increasing voltage. In the event of severe burns, the transition resistance is particularlyreduced. The total resistance through the body then becomes close to its internal resistance – approximately 500Ω. " Do not experiment with this! It can be life-threatening.

12.1.4 The impact of current on humans

Healthcare distinguishes between the effects of electric shock, current flow and electric arc. An electric shock may seem harmless but can lead to uncontrolled movement, fall injury or contact with other live objects. During a current flow, an electrical potential difference is equalized through the body, which in addition to cardiac arrest, ventricular fibrillation, and respiratory arrest can lead to blood clots, muscle damage, kidney damage or internal burns.In the event of an arc flash accident, the risk of severe burns increases due to the high temperature of the arc. An arc can also cause damage to the eyes due to glare or the large amount of UV light. "

People who have suffered an accident with
• high voltage
• low voltage with current passing through the torso
• who are blacked out or unconscious after an electrical accident
• who have suffered burns
•who show signs of nerve damage such as paralysis must immediately go to hospital for emergency

Violent muscle spasms and/or burns can occur from currents below 10 mA. For adults, currents above this value can be direct.

The current affects the body differently from case to case and it is uncertain which current is dangerous.

Currents that pass through the heart or brain are particularly dangerous. When working with live electrical appliances, keep one hand inΩour pocket for safety!

12.1.5 Influence of electromagnetic fields

Research has shown that staying in strong electromagnetic fields can affect humans. People who have been exposed to strong field exposure have complained of sweating and headaches, among other things. These phenomena are being researched. Electromagnetic fields can cause errors in electronic equipment.

Semiconductors are particularly sensitive to force fields. It is possible that sensitive instruments, heart stimulators (pacemakers) etc. can be affected by high-frequency electromagnetic fields from radio transmitters. When using a transmitter, mobile phone, etc. and someone has heart or breathing difficulties,Ωou must immediately turn offΩour device completely!

Over time, more interference-insensitive electronics are developed, butΩou can never be safe from interference. See further in chapter 11.

12.1.6 Standards for field strengths

There are several different standards and recommendations for electromagnetic field strengths. Some of these standards, for example, have the aim that different types of devices should be able to coexist and therefore function without being affected by electromagnetic fields or radiating electromagnetic fields exceeding given limit values (EMC). Other standards and advice have the purpose ofprotecting workers or individuals from the public from acute biological effects when they are exposed to electromagnetic fields. Through the publication of SSMFS 2008:18, the Radiation Safety Authority has published general advice on limiting the public's exposure to electromagnetic fields. These advices are based on recommendations from the Council of the European Union. See further in chapter 11.

12.2 The general electricity grid HAREC a.10.2

Electrical energy is delivered to consumers via transformer stations where high voltage is first transformed to low voltage. From the substations, the low-voltage network branches out to service cabinets out in neighborhoods and villages. In Sweden, the secondary windings of the distribution transformer are usually connected to aΩ (so-calledΩ or star connection) where the center point is grounded.

The most common 3-phase low-voltage networks in Sweden have a main voltage of 400 V and a phase voltage of 230 V. The voltage between the phase conductors is called the main voltage and the voltage between the respective phase conductor and the neutral conductor is called the phase voltage.

Figure 12.1: CE mark

The appliances in the house are usually connected 1-phase, that is between one of the phase conductors and the neutral conductor. Reasonably equal load between the phases is desirable. More power-demanding devices such as electric boilers and stoves are therefore connected to all three phases (3-phase).

Amateur radio equipment is usually connected 1-phase.

New construction, alteration or repair of high-current installation, permanent connection of electrical equipment to a high-current installation or disconnection of permanently connected electrical equipment from a high-current installation is classified as electrical installation work and may only be performed by a person authorized as an electrical installer or by professionals subject to the self-control of an electrical installation company.

IfΩou have the required knowledge of electrical safety,Ωou may

• replace an electrical switch (switch) for a maximum of 16 A 400 V
• replace a connection device (wall socket, lamp socket, plug, joint socket or similar) for a maximum of 16 A 400 V
• replace a light fixture in a dry, non-flammable space in homes
• carry out, change or repair a high-current installation that is part of a protective low-voltage circuit with a nominal voltage of no more than 50 V with an output of no more than 200 VA and a current limited by a fuse of no more than 10 A
• change a fuse
• change a light source (lamp, fluorescent tube or similar)
• repair appliances
• repair and manufacture appliance cable and splice cords. "

Remember that an authorized installer must be hired for work in fixed installations.

12.2.1 Radio amateurs and home-built electronics

According to the Radio Equipment Act SFS 2016:392 [8], radio equipment that is released or provided on the market within the EU must be designed and manufactured so that it meets the prescribed requirements, has an EU declaration of conformity andis CE-marked. When the CE mark is placed on a product or a radio equipment, it means that the manufacturer

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or the importer certifies that all the prescribed requirements are met however, when checking CE-marked equipment, there have been deficiencies in electrical safety and electromagnetic compatibility (EMC) the conditions for CE marking have not been met. Learn more about EMC in section 10.1.1 intentionally emits or receives radio waves for radio communication o radio determination, or an electrical or electronic product that must be supplemented with an accessory, such as an antenna, to intentionally emit or receive radio waves for radio communication or radio determination. The laws scope of application and definitions state that the law does not cover radio equipment used by radio amateurs for amateur radio traffic, provided that the equipment is not provided on the market.

Radio equipment used by radio amateurs for radio amateur traffic shall not be considered supplied if it is:

• radio kits intended to be assembled and used by radio amateurs
• radio equipment modified by radio amateurs for use by radio amateurs
• equipment constructed by individuals radio amateurs for experimental and scientific purposes in connection with amateur radio.

This means that as a radio amateur, in addition to ordinary electronics,Ωou can build and use radio equipment.Ωou are then responsible for ensuring that the equipmentΩou have built is safe to use and does not cause disturbances. However, this does not mean thatΩou may do the following:

•Build a transmitter for use outside the amateur radio bands.
• Modify an amateur radio transmitter for use outside the amateur radio bands
• Modify a CE-marked transmitter outside the amateur radio bands.
• Restoring a CE-marked transmitter to its original state after modification to amateur radio transmitters on the amateur radio bands.
•Mount interference filters inside a CE-marked device.

The radio equipment may be intended to be connected to a high current installation if the equipment does not cause any type of damage to personal property or pets when used. Also remember that 12 V from a car battery counts as a high current installation. When an electrical or electronic device is designed or built, there are a number of points that must be taken into account in order for the device to be safe to use regardless of how it is intended to be powered. As support for how an appliance could be built to meet the requirements, the then SEMKO issued Practical advice for the self-builder. The points below are based on this practical advice:
• The housing must be adapted to the device and cannot be opened without tools.
• The housing must be equipped with the necessary ventilation holes to avoid overheating. Observe that live parts must not be reachable through the ventilation holes.
• The housing must not get so hot that damage can occur to people or property.

• If the housing or chassis of a mains-connected device is made of conductive material and the device does not have reinforced insulation, then exposed parts that risk becoming energized in the event of a fault must be connected to protective earth.
• The cable for mains connection must be equipped with a strain relief suitable for the purpose, which also protects the cable against abrasion when it passes through the casing.
• Components in the device must be dimensioned and approved for the effect they develop and for the voltage and amperage they are connected to. Note: A tip is to have a good margin in terms of heat resistance as it gives increased lifespan and greater safety margins.
• The device must be equipped with a correctly dimensioned fuse to protect against short circuit and overload.
• Appliance connected to the mains must be equipped with a 2-pole mains switch.
• Live parts in the device must be equipped with contact protection that protects against accidental contact.
• Components in the device must be mounted securely and placed at appropriate distances from each other so that the risk of interference, flashover, short circuit or overheating is minimized.
• Cables and wiresfor high current must be protected against hot components, abrasion and sharp edges and laid separately from wires for low voltage and signals. "

Endeavor to always connectΩour equipment via wall sockets protected by earth-fault circuit breakers.

12.2.2 Power switch

The power supply of the radio station'sequipment should take place via a common main switch, which can be easily reached. An indicator light should preferably mark that

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Figure 12.2: Double insulation,

Fi mark that the switch is switched on and that the station is under voltage. InformΩour family and others aroundΩou about how that switch works. It's A safety measure in case something happens.

The mains switch of the devices must be designed for the current working voltage and have an approved design. In the case of 1-phase systems, the mains switch in the devices must be 2-pole and break the phase and N conductors, but never the PE conductor.

In the case of a 3-phase system, the mains switch must be 3-pole and break the phase conductors, but never N conductors and PE conductors. "

Remember that an authorized installer must be hired for work in fixed installations.

12.2.3 A little terminology for electrical installations

Group central

The fuse central that follows the electricity meter, for example in villas and apartments.Group lines Lines after a group center, i.e. cables for lighting, electric stoves, sockets and more.

Phase conductor

A conductor that carries phase voltage.

Neutral conductor (N-conductor)

A conductor which is connected to the so-called zero point (neutral rail) of the electricity network and which should not normally carry voltage to earth.

Protective conductor (PE conductor)

The conductors in cables and cords, which are specially intended for protective earthing.

Utility object

A basically movable electrically connected object, for example hand tools and radios.

Reinforced insulation

Some utility items are manufactured with such good insulation that they do not need protective earthing. Thus insulated, the connection cable may be fitted with a special plug, which fits into wall sockets, both with and without earthing. Such utility items are marked with the Fi mark image 12.2 and must not be modified so that they can be protectively earthed.

Figure 12.2 shows the Fi mark, the symbol found on all electrical equipment that has double insulation.

12.2.4 Color codes for phase, neutral and protective conductors

The insulating material around the group conductors in fixed electrical installations has colors that fulfill an important function. Unfortunately, the use of these colors has changed several times over theΩears, creating risks of confusion.

The colors and function of the conductors must never be confused as this can lead to serious injury through fire, electric shock or arcing.

The phase conductor is now brown when newly installed, but was previously both black, grey, white or red.

The N conductor (neutral) is now blue when newly installed, but was previously both black and white.

The protective conductor (PE conductor) withΩellow/green longitudinal striped color marking is always a protective earth conductor and may only be used for that purpose. In older installations, however, the insulation of the protective conductor may be, for example,red.

It is to the phase and N conductors in the wall sockets thatΩou connect the devices to get power. Ideally, the sockets should be in protective earthed design, that is, with an earthing plate. This tin is connected to theΩellow/green conductor for protective earth.

12.2.5 Sockets and plugs with earthing device

The earthing device provides a connection to the electrical systems protective earth (PE). It was previously the design of the room that determined whether the wall and lamp sockets would have sockets with earthing devices.

Kitchens and laundry rooms with conductive sheet metal benches, water taps and so on are considered risky rooms and must have sockets with earthing devices. The same applies to basements and similar other rooms with conductive floors, walls and furnishings.

Living rooms were classified as not particularly risky and have therefore previously not been provided with lamps and wall sockets with earthing devices. In new construction, however, all sockets are now of protective earthed design! It is recommended to install protective earthed wall sockets for the radio station. Please note that all sockets in that room must be protectively earthed!

12.2.6 Protective grounding

Grounding is the common term for connecting an object to protective ground. But the expression is also used a little carelessly in other cases without referring to protective grounding for electrical safety reasons. Metal casings on electrical equipment can become live for various reasons and are then an electrical safety risk. To reduce the risk of dangerous voltage build-up of the metal casing,the casing is connected to protective earth.

" If there is an insulation failure between a live part and the housing, the fuse will pop. The PE conductor must therefore never be broken! There are special regulations for protective earthing. Therefore, contact an authorized electrical installer.

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12.2.7 Earth-fault circuit breaker

Earth-fault circuit breaker is an automatic circuit breaker that quickly breaks the current when the current to and from an appliance is different. This can occur in the event of an earth fault or in case of over-conduction in a protective earthing device or in other cases when the incoming current and outgoing current through the earth-fault circuit breaker are not equal. The earth fault circuit breaker can protectΩou:

• in case of insulation and earth faults

• if the chassis of an appliance becomes live
• ifΩou access live parts and earth at the same time • if the wall sockets lack protective earth
• ifΩou use an appliance incorrectly in wet areas
• ifΩou installed an appliance in the wrong way
• if the appliance'scable is damaged
• against and minimize the risk of fire.

The earth fault circuit breaker does not protect against currents passing through phase conductor and neutral conductor or through phase to phase conductor (3-phase). Earth-fault circuit breakers may not replace protective earthing, but can under special conditions supplement protective earthing as an extra safety measure. When new housing is installed, it is now a requirement that at least one earth-fault circuit breaker be installed. Feel free to order the installation of earth-fault circuit breakers in older facilities!

12.2.8 Separate grounding

Separate grounding is an expression for grounding devices to a separate grounding point, it is done via a separate grounding cable to a grounding tag, i.e. ground plate or ground spike. Special grounding must be done in the right way because the intended protection can otherwise become adanger. IfΩou have plans for special grounding, ask an authorized installer.

12.2.9 Grounding of the antenna system

In the absence of another grounding point, it is tempting to connect the antenna grounding conductor to the connection plate of the PE conductor in the wall socket or to a heating element in the hope of getting a better HF ground plane for the antenna in this way. However, this is a bad example of special grounding, which can both involve safety risks and lead to interference problems.

12.2.10 Fast and slow fuses

There are fast and slow fuses. Fast fuses are what are normally used. Slow-blow fuses for the same amperage may be needed for devices that have a particularly high starting current, for example large mains transformers with a toroid core. The fuses must be able to break sufficiently high voltage, otherwise there will be a residual arc in them when the fuse breaks. Use fuses with the correct current values and choose a fuse with a small margin to the load current so that the fuse does not blow during normal operation. It is forbidden to repair fuses as this could cause a fire.

12.3 Dangers

12.3.1 Overheating

Electricity can easily cause both personal injury and material damage. It is important to know how to avoid injuries. Electrical equipment must be touch-protected with adequate enclosure. At the same time, the heat inside the enclosure must not become so high that there is a risk of fire. After all, spontaneous errors can occur.

Insulation failure poses a risk when touched and a fire can develop quickly. When live equipment is left unattended, it must be done with special care. How electrical devices and installations may be carried out is regulated by laws and regulations. Electrical devices must meet certain requirements in order to be marketed and used. Execution and origin must be documented in the prescribed manner. Self-built devices must also meet the requirements for electrical safety - that is, safety against electric shock and fire - and the builderbears sole responsibility for ensuring that the design and handling of the devices is satisfactory. Anyone who builds and uses an electrical device should therefore have the necessary knowledge of electrical safety.

12.3.2 High voltages HAREC a.10.3

Interference with live electrical devices involves personal danger. Never open an appliance if the voltage is switched on. When working on, for example, transmitters, receivers and power supply units, it is easy to exposeΩourself to high DC voltages. In transmitters with electron tubes, there are voltages in the order of magnitude - hundreds to thousands of volts. This is also the case in monitors. Please note that even devices such as powered by batteries or accumulators may contain circuits that convert the low voltage into directly life-threatening high voltage.

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12.3.3 High currents

High currents cause severe muscle cramps and burns. It is known that there is a difference between damage from direct and alternating current.

Low-frequency alternating current causes muscle cramps, which can make it impossible to let go of the live object.

High frequency alternating current in the MHz range heats the body tissues, rather than causing muscle reactions.

Direct current affects the body differently than alternating current. Through the electrical resistance in the body's tissues and fluids, heat is developed.

This can lead to burns both on the skin and inside the body. If the direct current pulses, muscle reactions occur in a similar way to alternating current.

High voltages are always dangerous. On the other hand, it is not so well known that even low voltages can be. Accumulators and connected devices can give off high currents even if the voltage is low.

Accidental current paths, for example a short circuit through a watch or finger ring, can cause serious burns.

12.3.4 Antennas

Preferably place the antennas out of reach of unauthorized persons. Namely, high HF voltages can occur on transmitter antennas even at low transmitter power. HF burns when touched and a reflex movement makes it easy to lose balance and fall. Feel free to put up signs on or near the antennas, with a warning about high-frequency voltage and information about the owner's name, address and telephone number. An unbalanced antenna can result in high voltage even on the connected antenna cable. Touching the antenna cable can therefore involve the same risks as touching the antenna itself. The T-antenna is an antenna that is designed to exploit this imbalance as the antenna cable itself is part of the radiating parts of the antenna. For most other antennas, the antenna cable should not radiate and therefore touching should not be dangerous, but be careful.

Imbalance should be remedied, not only for personal safety but also to obtain an efficient antenna. Antennas must not cross or be placed near high-voltage, low-voltage or telephone lines.

There is a risk of accident if antennas and power or telecommunication lines collide for some reason. There is also an accident risk if antennas fall over these wires. Only with permission from the relevant authority and/or line owner may cables of any kind be drawn over roads or public places, including antennas. High DC voltages from the transmitter must not enter the antenna. Make sure that the antennas feed lines are connected to a good direct current ground via HF chokes or equipped with surge arresters. As an extra safety measure, the transmitter should be connected to the antenna line via a large capacitor.Avoid touching antennas without grounding them, especially when on roofs or in trees. During thunderstorms, snowfall, rain or fog when charged particles are in motion, the antennas can be charged up to high static voltages. IfΩou then work with the antenna,Ωou can be surprised by an electric shock. It is then easy to loseΩour grip and fall down.

12.3.5 Residual charge in capacitors

Capacitors can retain a significant residual charge for many hours after the power has been cut.

• Connect discharge resistors (bleeders) across filter capacitors, so that they are discharged when the supply is switched off. For safety reasons, the discharge resistors must withstand four times as much power as they themselves consume during operation.

• Warning: When discharging a capacitor, do not short it! Use a discharge resistor that can withstand the effect that develops during discharge!

12.3.6 Safety measures

Transformer with enhanced safety: " IfΩou are unsure about the electrical safety performance of a device,

for example an old transmitter, then use an isolating transformer (full transformer) - preferably of class II (extra-insulated). During repair, the equipment must be de-energized security). If trimming or troubleshooting must be done while live, the following must be observed:
• Do not work with the system whenΩou are tired or unmotivated. ThenΩou are the least vigilant against accidents.
• Make SureΩou don't get current throughΩour body, preferably work with only one hand and keep the other away from the equipmentΩou are working with. Feel free to putΩour free hand inΩour pocket!
• Do not wear headphones onΩour head. Use speakers ifΩou are tuning by ear.
• Ideally, someone should be nearby whenΩou are working on live equipment. Show where the mains switch is located. Please make sure that he/she knows how to help in the event of an electrical accident.

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When working with storage batteries:
• Although the voltage is low, storage batteries can release very high currents in the event of a short circuit. Therefore, remove finger rings, wristwatches, etc.Use insulated tools when working with battery terminals.
• Beware of the electrolyte in the storage batteries – it is highly corrosive.
• Warning for the risk of explosion from explosive gas and acid splashing in the eyes.
• Modern lithium-polymer (LiPo) batteries are incredibly energy-rich. These can start to burn at high temperatures,and should be treated carefully and placed in suitable protective bags. Different variants have different sensitivities, so it is recommended to read about the options available and how best to handle them. Bewareof overcharging!

12.4 Lightning HAREC a.10.4

12.4.1 Dangers

During lightning, a very strong electromagnetic field develops, which spreads out and produces very short voltage surges in all metal objects, for example in antennas. The shocks travel through the cables into the devices. If the surge current is high, things in the current path will be destroyed in some way.Burning and melting down is common. But if the lightning discharge takes place from a distance, the shock current can be so low thatΩou can reasonably avoid damage to devices and houses. If, on the other hand,the lightning discharge occurs very close to the antenna or as a direct impact, then major damage will definitely occur.

12.4.2 Protection and grounding

Antennas and antenna cables can never be protected against lightning strikes. By nature, they are a kind of lightning rod. WhatΩou can try to do is to direct a possible lightning discharge in an antenna system away from houses and people.Please note thatΩou must not "hook on" the house's regular lightning rod. In that case, home insurance does not apply. The antenna cable, which functions as a (too thinly dimensioned) lightning conductor, should of course not be pulled unnecessarily into the house, but the shortest route outside the house to a branch. From the branch, the cable continues to the devices through a surge protector and an earth line the shortest way down to the earth roof over a spark gap. The best way to protect devices against lightning is still to completely disconnect them from the antenna cable and wall outlet. IfΩou live in an apartment building, it is unfortunately usually difficult to take measures like those above. ThenΩou have to contentΩourself with disconnecting the antenna cables from the devices and putting them well aside - preferably outside the house wall.

As permanent, but insufficient protection, the various connection points can be provided with suitable surge protectors. More information on how to protectΩour amateur radio station against lightning can be found on the website of Uppsala University, Department of Electrical Engineering. The document To protectΩour amateur radio station against lightning

<http:// www.hvi.uu.se/meny/m5.html>.

13 Traffic regulations

13.1 Phonetic alphabets HAREC b.1.1 – b.1.26

SometimesΩou need to make clarifications by spelling. The international is found in the ITU radio regulations (RR) [21, Appendix 14] and is required in CEPT for HAREC [15, Annex 6]. Swedish radio amateurs must know two phonetic alphabets, partly the international and partly the Swedish. It may be worth knowing that there is slang in other words when spelling. There is also lettering in several languages. While these should not be used in international traffic, it may be good to know.

13.2 The Q-codeHAREC b.2.1 - b.2.28

13.2.1 Background

When sending with Morse telegraphy, international "traffic abbreviations" according to the Q-code have been used since 1912, both to reduce the risk for reception errors due to language difficulties, interference etc. and to reduce transmission time. A traffic abbreviation in the form of a Q-code has a clear meaning, but can be adapted somewhat to the current situation. Each Q code consists of three letters in the letter series QAA–QZZ[21, M.1172]. The regulations test for amateur radio certificates includes questions about Q abbreviations. In CEPT recommendation T/R 61-02 [15 , Annex 6] it is mentioned the following general Q abbreviations as touch amateur radio. However, radio amateurs in practice use more Q abbreviations, some of which are listed at the end of the table. A set of Q codes deals with signal quality and signal strength, these are QRK, QRM, QRN, QRO and QRP. One set of Q codes deals with interaction with the other station, these are QRT, QRZ, QRV and QSB. A set of Q-codes deals with contact exchange, these are QSL, QSO, QSY, QRX and QTH. Use of Q-codes for maritime use according to ITU-R M.

	Kodord	Uttal	Svenskt kodord
A	Alfa	all fa	Adam
B	Bravo	bra vo	Bertil
C	Charlie	tjar li	Cesar
D	Delta	dell ta	David
E	Echo	eck å	Erik
F	Foxtrot	fåcks trått	Filip
G	Golf	gålf	Gustav
H	Hotel	hå tell	Helge
I	India	in dia	Ivar
J	Juliett	djo li ett	Johan
K	Kilo	ki lå	Kalle
L	Lima	li ma	Ludvig
M	Mike	majk	Martin
N	November	no vem bö(rr)	Niklas
O	Oscar	åssk a(rr)	Olof
P	Papa	pa pa	Petter
Q	Quebec	ke beck	Qvintus
R	Romeo	rå mio	Rudolf
S	Sierra	si err ra	Sigurd
T	Tango	täng gå	Tore
U	Uniform	jo ni form	Urban
V	Victor	vick tö(rr)	Viktor
W	Whiskey	oiss ki	Wilhelm
X	X-ray	ecks rej	Xerxes
Y	Yankee	jäng ki	Yngve
Z	Zulu	zo lo	Zäta
Å	Alfa Alfa	all fa all fa	Åke
Ä	Alfa Echo	all fa eck å	Ärlig
Ö	Oscar Echo	åssk a eck å	Östen
0	Zero	ze ro	Nolla
1	One	o ann	Ett (ej etta)
2	Two	to	Tvåa
3	Three	tri	Trea
4	Four	får	Fyra
5	Five	fajv	Femma
6	Six	sicks	Sexa
7	Seven	se ven	Sju (ej sjua)
8	Eight	ejt	Åtta
9	Nine	naj nö(rr)	Nia
,	Decimal	de si mal	Komma
.	Stop	stopp	Punkt

Table 13.1: The international and Swedish phonetic alphabet

261Q code Question Answer or message

Q-kod	Fråga	Svar eller meddelande
QRK	Vilken uppfattbarhet har mina (eller . . . :s)*signaler?	Uppfattbarheten hos dina (eller . . . :s)* signaler är 1. dålig 2. bristfällig 3. ganska god 4. god 5. utmärkt.
QRM	Är min sändning störd?	Störningarna på din sändning är 1. obefintliga 2. svaga 3. måttliga 4. starka 5. mycket starka.
QRN	Besväras du av atmosfäriska störningar?	Atmosfäriska störningar är 1. obefintliga 2. svaga 3. måttliga 4. starka 5. mycket starka.
QRO	Ska jag öka sändningseffekten?	Öka sändningseffekten.
QRP	Ska jag minska sändningseffekten?	Minska sändningseffekten.
QRT	Ska jag avbryta sändningen?	Avbryt sändningen.
QRV	Är du redo?	Jag är redo.
QRX	När anropar du mig igen?	Jag anropar dig igen kl . . . på . . . kHz/MHz.
QRZ	Vem anropar mig?	Du anropas av . . . *(på . . . kHz/MHz).
QSB	Varierar min signalstyrka?	Din signalstyrka varierar.
QSL	Kan du ge mig kvittens?	Jag kvitterar.
QSO	Kan få förbindelse med . . . *direkt?	Jag kan få förbindelse med . . . *direkt.
QSY	Ska jag gå över till annan frekvens?	Gå över till annan frekvens.
QTH	Vilket är ditt geografiska läge?	Mitt geografiska läge är . . .
(QRS)	Ska jag minska sändningshastigheten?	Minska sändningshastigheten (sänd . . . ord i minuten).
(QRU)	Har ni något till mig?	Jag har inget till dig.
(QSA)	Vilken styrka har mina (eller: . . . :s)*signaler?	Dina (eller: . . . :s)*signaler är 1. knappast uppfattbara 2. svaga 3. ganska starka 4. starka 5. mycket starka.
(QTC)	Hur många telegram har du att sända?	Jag har telegram till Dig.
(QTR)	Kan du ge mig rätt tid?	Rätt tid är . . .

* *namn och/eller anropssignal*

QRK What is the comprehensibility of my (or . . . :s)*signals? The comprehensibility ofΩour (or . . . :s)*signals is 1. bad2. deficient3. pretty good4. good5. excellent.QRM Is my transmission jammed? The interference onΩour transmission is 1. non-existent2. weak3. moderate4. strong5. very strong.QRN AreΩou bothered by atmospheric disturbances? Atmospheric disturbances are1. non-existent2. weak3. moderate4. strong5. very strong.QRO Should I increase the transmission power? Increase transmit power.QRP Should I decrease transmit power? Reduce transmission power.QRT Should I cancel transmission? Cancel transmission.QRV AreΩou ready? I'm ready.QRX When areΩou calling me again? I will callΩou again at . . . on. . . kHz/MHz.QRZ Who's calling me?Ωou are called by . . . *(on . . . kHz/MHz).QSB Does my signal strength vary?Ωour signal strength varies.QSL CanΩou give me an acknowledgment? I acknowledge.QSO Can connect with . . . *Immediately? I can connect with . . . *direct.QSY Should I switch to another frequency? Switch to another frequency.QTH What isΩour geographic location? My geographic location is . . .(QRS) Should I reduce the transmission rate? Reduce sending speed (send . . . words per minute).(QRU) Got something for me? I have nothing forΩou.(QSA) What is the strength of my (or: . . . :s)*signals?Your (or: . . . :s)*signals are1. hardly perceptible2. weak3. quite strong4. strong5. very strong.(QTC) How many telegrams doΩou have to send? I have a telegram forΩou. (QTR) CanΩou give me the correct time? The right time is . . .* name and/or callsign

Table

13.2: The Q-codes

2621. Some Q-codes can be given an affirmative meaning by sending the letter C (pronounced as CHARLIE during telephony) immediately after the abbreviation or given a negative meaning by the English word NO immediately after the abbreviation. 2. Q-codes can be supplemented with other suitable abbreviations, call signs, frequencies, time information, personal and place names, numbers, numbers, etc. In the descriptive text for certain Q-codes, additional information is provided in parentheses. These data must then be sent in the order specified in the text.3. The Q-codes take the form of a question, as in radiotelegraphy they are accompanied by a question mark, just as in radiotelephony they are accompanied by the letters RQ (ROMEO QUEBEC). When supplementary information follows a stated question, a question mark must be raisedpective RQ follow after tasks-na.4. Q codes with numbered alternative meanings are accompanied by the corresponding number. The number must be sent immediately after the abbreviation. 5. In international radio traffic, when not accepted, times must be specified in Coordinated Universal Time (UTC), formerly GMT.

13.3 Traffic abbreviations HAREC b.3.1 – b.3.12

In addition to the Q code and plain text, other traffic abbreviations are also used in Morse telegraphy. Since the international radio language is English, abbreviations of English words are most common. However, abbreviations should not be used unnecessarily. An above operator at the opposite station may then find it difficult to understand the message.

13.3.1 Selection for radio amateurs

In CEPT recommendation T/R 61-02, in addition to the Q code, the following other traffic abbreviations are mentioned, which concern radio amateurs. Radio amateurs in practice use many more traffic abbreviations than these. The regulations test for amateur radio certificates includes questions about traffic abbreviations, see table 13.3. In addition to the above traffic abbreviations, the iCEPT recommendation also covers the following letter combinations, which are used in teleprinter traffic instead of the corresponding Morse code, struck without character spaces. (The dash above the letters means that there is no space). AR end sign +VA or SK end sign @ An example of a section from an amateur radio broadcast, where traffic abbreviations are used particularly extensively:

Förkort-ning	Engelskt uttryck	Svensk betydelse
BK	break	avbryt(-a) (sändningen)
CQ	”seek you”	allmänt anrop, till alla
CW	continuous waves	telegrafi (A1A)
DE	franska ”de”	från ..... (anropssignal)
K	come	”kom”
MSG	message	meddelande, telegram
PSE	please	var god (att . . .)
R	received	allt uppfattat, mottaget
RST	readability, signal-strength, tone-report	läsbarhet signalstryka ton
RX	receiver	mottagare
TX	transmitter	sändare
UR	your	din, ditt, dina, er

Abbreviation English expression Swedish meaningBK break cancel (- a) (the broadcast) CQ "seekΩou" general call, to all CW continuous waves telegraphy (A1A) DE French "de" from ..... (call sign) K come "kom" MSG message message, telegram PSE please please (that . report u are cmg inhr ufb my tx is .... and rx .... ant 3 el beam . condxhr god mni dx stns hrd . wl nw nil so tks es 73"In plain text, the example looks like this: "good mor-ning and thankΩou very much Old Man forΩour report.Ωou are coming in here ultra fine business. My transmitter is ..... and receiver .. ... antenna isa 3 element beam. Conditions here are good many stations heard. Well now nothing forΩou so thanksand kindest regards”

13.4 International emergency trafficHAREC b.4.1 – b.4.41

3.4.1 Distress Signals

In CEPT recommendation T/R 61-02 [15], radio amateurs are required to know the international distress signals SOS and MAYDAY. Morse telegraphy consists of the character parts sent in a sequence, where the length of the long character parts is emphasized so that they clearly differ from the short ones. The signal is written as the letters SOS with a dash above it. The emergency signal on radio telephony consists of the word MAY-DAY pronounced as the French expression "m'aider". In Sweden,Ωou can also call out "EMERGENCY CALL".

13.4.2 International emergency frequencies

Emergency signals on telephone are primarily sent on the frequencies:

• 121.5 MHz AM (Aviation radio).
• 156.8 MHz FM (Marine VHF channel 16).An older emergency frequency is 2182 kHz, but it is no longer a primary frequency for emergency and safety traffic. There is no longer a requirement for ships to have radio matching on the frequency, which is evident from the Swedish Transport Agency's regulations and general advice on radio equipment on ships TSFS 2009:95 [28 , §22]. (Read more about emergency frequency in section 13.4.3) Coastal radio in Sweden ceased its radio monitoring, guarding, of the frequency at the beginning of 2005 and the US Coast Guard stopped radio monitoring in August 2013." In the event of an emergency, with an immediate need for assistance, it is therefore inappropriate to primarily seek help on the frequency 2182 kHz. The frequency 2182 kHz is still reserved in the ITU Radio Regulations (RR) [21] for "Distress and safety communications" and radio-obligatory vessels that traffic water in and outside coastal areas must have radio equipment for the frequency.

13.4.3 Emergency traffic

In CEPT recommendation T/R 61-02 [15], requirements are that radio amateurs must know regulations about emergency traffic and the use of amateur radio stations in the event of natural disasters. ITU Radio Regulations (RR) [21] since WRC-07 no longer has information on "Distress and safety communications" for other than GMDSS (Global Maritime Distress and Safety System) With "emergency frequency" refers to a frequency that is radio-matched by, for example, air or sea rescue centers 24/7 (24/7). Although the term "emergency frequency" sometimes appears in Swedish band plans for amateur radio, there are no actual such frequencies within the amateur radio bands. In 1998, an international conference was held in Tampere, Finland (ICET-98). The conference led to the Tampere convention "The Tampere Convention on the Provision of Telecommunication Resources for Disaster Mitigation and Relief Operations" [24]. The convention entered into force on January 8, 2005. In accordance with the convention, the IARU has introduced recommendations on regional and global frequencies for the Emergency Center of Activity. It wantssay center frequencies for radio communication that can be used in the event of natural disasters.!IARU's recommendations and the amendment of the ITU RR all mean that there is no special emergency signal for the amateur radio bands and no emergency frequencies within the amateur radio bands. For further reading, IARU Emer-gency Telecommunications is recommended Guide [1].

13.4.4 IfΩou hear an emergency signal on the radio

Immediately cancelΩour own transmission whenΩou hear an emergency signal. Listen to the emergency message and nervously write what is said. Note the position, frequency, time, etc. Report whatΩou heard in the following way.

13.4.4.1 Distress signal from a radio amateur abroad.

tell them thatΩou have heard an emergency signal from abroad via radio. For the cases that it is further away in Europe, it might be time to be a little more restrictive. Regardless,Ωou should first wait a while to monitor if the call seems to be answered by someone else and write down the information in the message box beforeΩou answer itΩourself. It is never wrong when perceiving emergency traffic to contact 112 and state what has been perceived. They can then decide how the case should be handled.

13.4.5 Emergency signal from Swedish land

Call 112 to call the emergency services, ambulance , police, sea rescue, air rescue, etc.Ωour telephone number is automatically shown in the alarm operator's display. In order to avoid misunderstandings and misdirection of the rescue efforts,Ωou must inform the operator that the emergency call came via radio. The accident site itself may be in a completely different area code than the one from whichΩour telephone call originates.

13.4.6 Distress signal from a ship or aircraft

If the distress signal is not answered by any coast or land station, call 112 and request sea rescue or air rescue and reportΩour observations.! Forward the emergency message without changing it!

13.4.7ΩouΩourself send an emergency signal over the radio

In the first place,Ωou should choose other signal paths than amateur radio, such as landline and mobile telephony, boat or airplane radio or emergency transmitters intended for this if possible. Please choose a frequency with a lot of traffic ifΩou do not uses an emergency frequency, so there is a chance it is monitored so someone can hearΩour emergency call. Using a repeater to be heard better is a good strategy. Be calm and composed when calling for help over the radio. Think first, then send. Try to include as much as possible of what is listed under "actions" below.

13.4.8 Actions

The keyword forΩour actions is ALARM:Location Enter the location of the accident site.Ωou can enter street or road names or landmarks such as the crossroads, the border, the bridge, the railway, etc. Analyze Make an overview of the accident scene and talk about what happened. Any injured? Any trapped? Is it on fire? Are dangerous substances being released?Shout Shout for help. Feel free to use a repeater on the 2-meter band so thatΩou reach many, but other frequencies can also be used. Call with EMERGENCY CALL FROM SMXxxx. Ask for someone by phone. Don't give up ifΩou don't get an answer right away. Notify Notify whenΩou have contact with someone by phone, send EMERGENCY TRAFFIC IN PROGRESS to calm the frequency and the EMERGENCY MESSAGE-IT with the most important information. Ask for the information to be repeated and promise to forward it on. Request to know when this has happened.Remind otherwise!Wait Wait at the scene until help has arrived. The passenger radio soΩou can answer questions.Ωour help is no longer needed, then end with EMERGENCY TRAFFIC CALL FROM SMXxxx. . .CLEAR END.

13.5 Callsigns

13.5.1 The purpose of the callsigns

All radio transmitters must be identifiable, so that the mancan know who is transmitting [21 , §19.1]. Identification is done using a call sign, which is a combination of letters (A–Z) and numbers (0–9). [21 , §19.45]. A character is either a letter or number. National letters such as Å, Ä and Ö and other special characters are not used. Call signals are internationally coordinated and unique, which is necessary when the signals can be heard all over the world. The system is common for commercial traffic and amateur radio, but we will only touch on call signals that are relevant for amateur radio.• All broadcasts with false or misleading identification are prohibited [21, §19.2]!• All amateur radio broadcasts must be identified [21, §19.4, §19.5]. Identification normally takes place in speech or Morse code, but other forms can also occur that are adapted to the modulation method used. There are several ways in which the person behind a call signal can be identified. For Swedish call signs, SSA provides a Callbook <www.ssa.se>. Another popular variant is QRZ <www.qrz.com> whereΩou can register. The call sign is also used for online logging of contacts, such as the Logbook of the World (LoTW) <lotw.arrl.org>.

13.5.2 Composition of the call signs

Each country disposes of one or more series of unique call signs for all its radio traffic. These are designed according to ITU Radio Regulations (RR) [21 , §19] in a way that depends on the purpose of each particular radio station. In RR there are definitions for different types of stations, for example stations for fixed radio, land mobile stations, stations in ships, in maritime rescue vessels, in aircraft, amateur radio stations and so on.

13.5.3 Identification of amateur radio stationsHAREC b.5.1, b.5.3

A radio station must be identified with the call sign assigned by the telecommunications administration (authority) of its own country. In Sweden, it is the Post and Telecommunications Board (PTS) that is responsible and has, by decision, delegated the handling of amateur radio signals to the Association of Swedish Broadcasting Amateurs (SSA). The callsign is announced in the amateur radio certificate that is held after passing the competency test. Callsigns for amateur radio are made up of a prefix, a number and a suffix in the following way [21 , §19.68, §19.69]:• The prefix usually consists of two characters, e.g. SM (Sweden), 9A (Croatia) or S5 (Slovenia).• The prefix can sometimes consist of a single letter, which in that case must be one of B, F, G, I, K, M, N, R or W. Sweden is assigned a prefix in the series SA–SM, 7S and 8S [21, Appendix 42], see table 13.4. The prefix is followed by a number and a suffix. The suffix consists of a minimum of one and a maximum of four characters, where the last character must not be a number. Call signals for special purposes, for example to celebrate an anniversary, can have a suffix that consists of more than four characters [21 , §19.68A]. Such callsigns, or others that do not follow the format template, need in that case to be approved by PTS before they can be assigned by SSA. Example: DL65DARC is an event signal for the German (DL) amateur radio association DARC's 65th anniversary. PTS rules for assigning Swedish callsigns may differ from the basic rules in RR as stated above, but generally follow these.

Callsigns for Swedish amateur radio stations are structured in the following way, whereby district means amateur radio district.

individual radio amateurs SA + district number + three-digit suffix (basic signal)

individual radio amateurs SM + district number + two- or three-digit suffix (basic signal)

amateur radio clubs SA + district number + two-digit suffix

amateur radio clubs SK + district number + two-digit suffix

military units and FRO SL + district number + two- or three-digit suffix

enskilda radioamatörer	**SA**	+ distriktssiffra + treställigt suffix (grundsignal)
enskilda radioamatörer	**SM**	+ distriktssiffra + två- eller treställigt suffix (grundsignal)
amatörradioklubbar	**SA**	+ distriktssiffra + tvåställigt suffix
amatörradioklubbar	**SK**	+ distriktssiffra + tvåställigt suffix
militära förband och FRO	**SL**	+ distriktssiffra + två- eller treställigt suffix

Table 13.4: Swedish callsign prefix assigned by SSA from 2004. Older iSM series callsigns are assigned with two-digit suffixes, whilenewer SM and SA signals have three-digit suffixes. In addition to the basic signal, there are also extra callsigns assigned in the other available series.

Example: SM0XXX is a radio amateur assigned a signal by PTS. Example: SA0XXX is a radio amateur assigned a signal by the SSA.

Example: SK2XX is an amateur club. Example: SM7X is a radio amateur with a short call signal. Sweden is divided into amateur radio districts with the following numbering and extent: District Extent0 Stockholm (AB) county1 Gotland (I) county2 Västerbotten (AC) and Norrbotten (BD) county3 Gävleborg (X), Jämtland (Z) and Västernorrland (Y) county4 Örebro (T), Värmland (S) and Dalarna (W) county5 Östergötland (E), Södermanland (D), Västmanland (U) and Uppsala (C) counties6 Halland (N) and Västra Götaland (O) counties7 Skåne (M), Blekinge (K), Kronobergs(G), Jönköpings (F) and Kalmar (H) counties. The district number in the call sign is determined by the county that home address is located within When broadcasting outside the home address, it should be clear from the addition to the callsign.

Distrikt	*Utsträckning*
0	Stockholms (AB) län
1	Gotlands (I) län
2	Västerbottens (AC) och Norrbottens (BD) län
3	Gävleborgs (X), Jämtlands (Z) och Västernorrlands (Y) län
4	Örebro (T), Värmlands (S) och Dalarnas (W) län
5	Östergötlands (E), Södermanlands (D), Västmanlands (U) och Uppsala (C) län
6	Hallands (N) och Västra Götalands (O) län
7	Skåne (M), Blekinge (K), Kronobergs (G), Jönköpings (F) och Kalmar (H) län.

Example: SA0XXX is a radio amateur from Stockholm County. Example: SM7YYY is a radio amateur from Jönköping County.

Example: SK7AX is an amateur club from Jönköping County. which must be used, when sending from a place other than the home address. Based on practice, however, SSA recommends that the following rules be applied:

• In the case of traffic from a regularly used holiday home, the district number that shows where the holiday home is located can be used in the call sign.

• In the case of traffic from another temporary location, the call sign should be accompanied by slashes and the number of the district from which the transmission is made. For example SM0XYZ in district 6 becomes SM0XYZ/6 which sounds like "S M zero XΩ Z dash six."

• In the case of traffic from a mobile station, the ordinary call sign should also be accompanied by /M. For example, SM0XYZ mobile in district 6 becomes SM0XYZ/6/M which sounds like "S M zero XΩ Z dash six mobile."

• However, in the case of traffic from a mobile station within the home area, the extra district digit can be omitted. For example SM9XYZ mobile at home at becomes SM0XYZ/M which sounds like “ S M zero XΩZ mobile.”

• In the case of traffic from sea craft, the ordinary call sign should be appended by /MM which sounds like “maritime mobile.”

• In the case of traffic from aircraft, the ordinary call sign should be accompanied by /AM which sounds like “aeromobile.”

• In traffic from Swedish vessel on international territory, the district number 8 can be used.
• When sending from another country's territory, that country's regulations apply. In case of uncertainty – turn to SSA!

• Foreign radio amateurs visiting Sweden must use their call sign from their own country, preceded by SM/. For example SM/LA9XX which sounds like “S M streak L A nia X X” [14].

13.5.4 National prefixes HAREC b.5.4

Prefix	*Land*	*Prefix*	*Land*	*Prefix*	*Land*
DL	Tyskland	K	USA	PY	Brasilien
EA	Spanien	LA	Norge	S5	Slovenien
EA8	Kanarieöarna	LU	Argentina	SP	Polen
ES	Estland	LY	Litauen	SV	Grekland
F	Frankrike	OH	Finland	UA	Ryssland
G	Storbritannien	OH0	Åland	VE	Kanada
HB	Schweiz	OK	Tjeckien	VK	Australien
HS	Thailand	ON	Belgien	YL	Lettland
I	Italien	OZ	Danmark	ZL	Nya Zeeland
JA	Japan	PA	Holland	ZS	Sydafrika

Tabell 13.5: Landsprefix

Table 13.5 shows some important national prefixes available.266 Prefix CountryDL GermanyEA SpainEA8 Canary IslandsES EstoniaF FranceG Great BritainHB SwitzerlandHS ThailandI ItalyJA JapanPrefix CountryK USALA NorwayLU ArgentinaLY LithuaniaOH FinlandOH0 ÅlandOK Czech Republic ON BelgiumOZ DenmarkPA HollandPrefix CountryPY BrazilS5 SloveniaSP PolandSV GreeceUA RussiaVE CanadaVK AustraliaYL LatviaZL New ZealandZS South AfricaTable 13.5: Country prefix

13.6 Use of callsignHAREC b.5.2, b.7.2.2

Both the opposite station's and own callsigns must be used at the beginning and end of each transmission .During the transmission, the call signal must be repeated "with short intervals", without further specification of the interval. Even ifΩou are not in contact with an opposite station,Ωour own call sign must be entered with each transmission. See further in PTS regulations.

13.7 Example of contact HAREC b.7.2.1

There are many ways to carry out a radio contact, but there are some basic rules for how to behave and exchange calls. A pleasant and friendly appearance is a matter of honor in amateur radio. It doesn't have to be rigid because of that! General calling is a way to call someone - anyone - to communicate with. On telegraph it sounds like this:– CQ CQ CQ de SM0XYZ SM0XYZ KThat means the call first and then the own call signal. On telephony it sounds like this:- General call, general call, general call from SM0XYZ Come Don't forget Come at the end. Directed calls are made whenΩou want to talk to a particular station. ThenΩou first send the call signal of the stationΩou want to talk to and thenΩour own call signal. On telegraphy it sounds like this:– SM0ZYX SM0ZYX de SM0XYZ SM0XYZ KOn telephony it sounds like this:– SM0ZYX SM0ZYX from SM0XYZ SM0XYZKom The opposite station hopefully answers the call, so – SM0XYZ from SM0ZYX Kom

13.7.1 Connection established

When a station answers a call, it first leaves its signal report according to the RST code and introduces itself with its first name and tells where it is. The opposite station probably acknowledges with its corresponding information. WhenΩou hand over the word to the opposite station man the meaning of Come and listen. IfΩou have a telegraph connection and just want that stationΩou haver connection with shall answer, one can send KN (eng. come named station). If the connection lasts a long time, it is advisable to repeat the call signals approximately every ten minutes when handing over.– SM0ZYX from SM0XYZ Kom

13.7.2 Terminate connection

WhenΩou eventually end the connection, thankΩourself on and exchange farewell greetings. It might sound like this: - ThankΩou for a pleasant connection and seeΩou soon. SM0ZYX from

SM0XYZ. Clear End. Train withΩour instructor to cope with different traffic situations!

13.7.3 Second operator

Anyone who independently uses an amateur radio transmitter must have an amateur radio certificate. There is an exception to the requirement for an amateur radio certificate when a person temporarily uses an amateur radio transmitter under the supervision of someone who holds an amateur radio certificate. This is called second operator and means that a person who does not have an amateur radio certificate can act as operator together with a person who has one. In Sweden, it is regulated in the exception regulation PTSFS 2022:19 which is covered in section 14.3.2. This allows one to demonstrate the hobby and also practice under controlled conditions. In order for this to work, it is required that the person with the amateur radio certificate instructs how to behave on the air, how the handling takes place and can monitor that this is followed. Of course, the call sign is used for the holder of the amateur radio certificate. It is good that it is clear that it is a second operator who is active. Either the amateur calls out and then tells that he is handing over to second operator Simon. Alternatively, a second operator can make the calls himself267 and then call out, for example, "SM5XYZ second operatorAnna". The possibility of using a second operator must be used wisely, and if used correctly can create a good understanding of the hobby and be a carrot to get bothΩoung people and adults interested in amateur radio .

13.7.4 CQ

DX and split It happens thatΩou hear someone call "CQ DX", which means that the station is looking for long-distance contacts, generally outside its own continent. - "CQ DX, CQ DX, CQ DX, SM0XYZ callingCQ DX and standing by"In this case it is SM0XYZ who is looking for someone outside Europe. IfΩou are not a DXΩourself, i.e. ifΩou are in the same part of the world, thenΩou should avoid answering. Sometimes so-called DX expeditions are carried out because the person goes to a place that is rarely activated. People use to talk about rare DX (eng. rare DX), when an unusual land area is activated, which many want to have in the log. A station that shouts CQ can get answers from many stations at the same time. Then a mass of signals occurs which is called a pile-up. When the station grazes a pile-up, the station master can ask "QRZ?", i.e. "who there"? A nice DX can suffer from huge pile-ups, and it can be difficult for the opposite stations to hear the DX station among all the others calling at the same time. It can also be difficult for the DX station to distinguish which counter stations are responding, if they all respond on the same frequency. A strategy to make this work more efficiently is to run split [20], that is, the DX station transmits and listens on different frequencies (but still within the same frequency band). Most often, the DX station chooses to listen to a frequency that is a few kilohertz higher than the own transmission frequency, and indicates this by transmitting, for example, "listening up" or "listening five up". By using split, the DX station avoids being disturbed by its own pile-up. The DX station can also choose to spread out its pile-up, by not listening to only one frequency, but by sweeping over a slightly larger area."Listening five to ten up" then means that the DX station is listening in an area between 5 and 10 kHz above their own transmission frequency, and the opposite stations must try to guess where in this frequency range the DX station is listening at the moment. telephony, since the telegraph signals occupy less bandwidth. Modern transceivers almost always have the option of setting the split by using "VFOA/B", "RIT/XIT" or "clarifier". More advanced transceivers may have the ability to separate the two frequencies in the left and right channels of the headphones, respectively. When a station calls CQ and pauses for calling stations, stateΩour own signal briefly and clearly once in each pass. Instead ofΩelling several times each shift,Ωelling or otherwise taking up space, be patient and wait for the right opportunity. Do not shout during the time the DX station is transmitting its CQ. Then he won't hearΩou anyway. It can be useful to listen to the opera singer's style. Be aware that the DX station may hear completely different stations stronger than whatΩou hear, because the conditions may be completely different for the DX station. In case of large pile-ups, the operator may choose to only listen for certain stations, and therefore ask for "only number five stations" please” or after “onlyEuropean stations please”. This aims to break up a large pile-up for a chance of easier perceptionwho are calling. When breaking down by number, the operator will intercept a few stations with a certain number in the callsign, then move on to the next and so on, until 0 to 9 are gone through. The option of going by region or country prefix may be preferred if the operator feels that the conditions there will soon disappear and therefore the goats want an extra head start before they completely lose the chance. Learn the "DX rules of procedure":

• I will listen, and listen, and then listen some more.
• I will call only if I can read DX sta- tion properly.
•I shall not rely on cluster information, but be fully aware of the DX station's call sign before calling.
• I shall not disturb the DX station, or anyone calling it, and I shall never tune into the DX's own frequency, or in the segment where he is listening.
• I shall wait until the DX has completed the previous contact before calling myself.
• I shall always enter my full call sign.
• I shall call and listen at appropriate intervals.
• I shall not call continuously.
• I shall not call when the DX is answering someone other than me.
• I shall not call when the DX is asking for a callsign that does not resemble my own.
• I shall not call when the DX is searching for a geographical area other than mine own.268
• When the DX answers me, I shall not repeat my call sign, unless I believe that he has not understood it correctly.
• I shall be grateful if and when I receive contact.
• I shall respect my fellow amateurs and behave as such I deserve their respect. Do not try to act as the police and correct other stations that you believe are breaking the rules!

13.8 Content in connections HAREC b.7.2.3

In the past, it has been regulated in Sweden what content may be in connections, or rather what they may not contain. That regulation has now been removed. One should be aware that the same rules and conditions do not apply in all countries and for their radio amateurs. Therefore,Ωou are asked to use common sense, keep a good tone and respect all amateurs. See also IARU ethics and traffic methods.

13.8.1 Duty of silence

The content of a radio connection is protected by the Electronic Communications Act (LEK) [12]. In LEK, the duty of confidentiality for radio transmitted messages is regulated in chapter 6. Anyone who, in other cases than referred to in section 31 first paragraph and section 32 in radio receivers, has intercepted or otherwise obtained access to a radio transmitted message through the use of such a receiver in an electronic communication network that is not intended for him or her personally or for the public may not pass it on without authorization. Law (2022:482).[12 , ch.9, §33] The duty of silence applies to all radio messages that have been intercepted, regardless of origin. This means that ifΩouΩourself were a party to the radio message or if the radio message was a news bulletin intended for many people,Ωou may pass it on. However, a large part of the amateur radio hobby is based on radio communication with others and that others can hearΩou whenΩou broadcast. A radio amateur cannot therefore be considered unaware that someone else is listening to what is being broadcast. Therefore, much is accepted in amateur radio that would otherwise be prohibited. Tips about rare DX, tips about someone shouting CQ, QSL from listening amateurs, telling thatΩou heard someone communicating with someone else is therefore not normally considered a breach of confidentiality. Connecting a radio receiver to the web so that someone can listen to radio traffic in real time is permitted. Also note the text in the second point of ch. 6. Section 20 regarding the person who, in connection with the provision of an electronic communication service, has received part of or access to the content of an electronic message may not unauthorizedly pass on or use the information he has received or access to. This may be relevant when someone who provides an electronic communication service from point A to point B gains access to the content of an electronic message after it has left point A and before it reaches point B.

13.8.2 Recording of radio messages

Radio conversations in whichΩouΩourself participate may be recorded without informing other participants in the conversation to record the conversation. The basic rule is that the recording of radio messages is permitted unless the recording is prohibited in order to protect people's personal integrity. Playback of the recorded messages must not violate the provisions on confidentiality. This means that the message must not be forwarded without authorization. All radio messages may not be recorded. The legislation also differentiates between analogue and digital recordings. The Data Protection Ordinance [9] and ch. 4 Section 9a of the Criminal Code [3] is an example of laws that limit the recording of intercepted radio messages. It follows from the above that it is not permitted to store recorded radio traffic for later listening via web-based media as it can be considered to violate personal integrity.

13.8.3 Encryption of radio messages

Within Sweden's borders is encryption of radio messages on amateur radio frequencies permitted under the condition that a call signal is regularly broadcast, calledThe signal must then be able to be read using known techniques. Despite this, the use of encryption is not recommended for amateur radio traffic. The technology for encrypting radio messages has become more readily available in connection with the introduction of digital radio systems such as DMR (Digital Mobile Radio) on the amateur bands. However, a number of these radio systems are connected via international networks and can therefore be heard in several countries where encryption is not permitted. The use of encryption technology on amateur radio frequencies therefore risks entailing limitations in the rights we have according to PTSFS 2022:19.269

13.9 The radio amateur's honor codeHAREC b. 7.1.1

The radio amateur is CONSIDERATE He never deliberately acts in a way that reduces the enjoyment of others. LOYAL He offers loyalty, encouragement and support to other amateurs, local clubs, the IARU organization in his country through which amateur radio in his country is represented nationally and internationally. PROGRESSIVE He keeps his station at a high technical level. It is well built and efficient. His operating technique is impeccable. FRIENDLY He communicates slowly and patiently when requested; offers peer support and good advice to the newbie; friendly assistance, cooperation and concern for the interests of others. This is the hallmark of the amateur spirit. BALANCED Radio is a hobby and must never conflict with obligations to family, work, school or community. PATRIOTIC His station and his skills are always available to assist country and community. – adapted from the original Amateur's Code, written by Paul M. Segal, W9EEA, 1928.

13.10 Radio amateurs rules of order HAREC b.7.1.2

13.10.1 Basic Principles

Basic principles that should govern our behavior on the amateur bands are: Togetherness, brotherhood and camaraderie: many, many of us are active on the air (our game plan).We are never alone. All other amateurs are our colleagues, our brothers and sisters, our friends. Act accordingly. Always be considerate. Tolerance: not all amateurs necessarily share the same opinion asΩou, andΩour opinion may not be the best. Understand that there are others with a different opinion on a certain topic. Be tolerant.Ωou don't have this world toΩourself.Decency: profanity and obscenities must never be uttered on the tapes. Such behavior says nothing about the person for whom they are intended, but a lot about the person who utters them. KeepΩour cool in all situations.Understanding: Please understand that not everyone is as smart, as professional or as much an expert asΩou. IfΩou want to do something about this, act positively (how can I help, how can I improve, how can I teach) instead of negatively (with profanity, insults, etc.).

13.10.2 The risk of conflicts

Only one playing field, the airwaves: all radio amateurs want to play their game or practice their sport but it must be done on a single playing field: our amateur bands. Hundreds of thousands of players on a single playing field sometimes lead to conflicts. An example: SuddenlyΩou hear someone shouting CQ onΩour frequency (the frequencyΩou have been running for a while). How is this possible?Ωou have been running here for more than half an hour on a completely clean frequency! Well, if possible; that other station may also thinkΩou are jamming him on

HIS frequency. Maybe the skipper or the conditions have changed?

13.10.3 How to avoid conflicts?

• By explaining to all players which rules apply and by motivating them to apply these rules. Most conflicts are caused by ignorance: many players do not know the rules well enough.• Furthermore, many conflicts are handled poorly again and again due to ignorance.• The IARU Ethics Manual translated on the SSA website aims to address this lack of knowledge in mainly by teaching how to avoid conflicts of all kinds.

13.10.4 Moral Aspects

• In most countries the authorities do not care in detail how the amateurs behave on the band, provided they stick to the rules laid down by the authority.• The radio amateurs considered to be self-governing, it means that self-discipline must form the basis of our actions. However, this does not mean that radio amateurs have their own police function!

13.10.5 Rules of conduct

What do we mean by rules of conduct (code of conduct)? They are a set of rules based on ethical principles as well as traffic considerations. Ethics Ethics determine our attitude and our general behavior as radio amateurs. Ethics has to do with morality. Ethics constitute the principles of morality. Example: ethics tells us never to knowingly interfere with the radio traffic of other stationsIn Sweden, amateur radio use is primarily regulated by the Post and Telecommunications Authority's (PTS) regulations PTSFS 2022:19 [11] and by the Electronic Communications Act LEK SFS 2022:482 [12]. In connection with the frequency allocation, the permitted power and amateur radio status are specified in each band. Within this framework, it is up to the radio amateurs themselves to make the best use of their opportunities. Band plans function as radio amateurs' recommendations to each other. Only to the smallest extent does PTS contribute to regulation within these plans. The IARU Region 1 band plans can be found in Appendix F and the Swedish frequency plan can be found in Appendix G. The Association of Swedish Broadcasting Amateurs SSA - represents the Swedish radio amateurs in IARU Region 1.Ωou can find more information about the current band plans for HF, VHF and UHF in appendix Nmen always check against an official source before using them for broadcasting.272

14 Regulations

Technically speaking, the radio amateurs around the world, with the help of their radio stations, can quite easily establish contact with each other. In doing so, it is required that the rules in the sub-countries affected by the contact be respected. A whole series of both international and national rules govern radio communications in a nation. Every radio amateur must know and follow these rules as far as they have a connection to amateur radio. Some countries - for example the CEPT countries - have to some extent harmonized their regulations among themselves. National deviations still occur and the rules of the country from which radio broadcasts are made must always be followed.

14.1 ITU Radio Regulations (RR)

The International Telecommunication Union (ITU) is international cooperation bodies where different countries' authorities (administrations) for telecommunications cooperate and coordinate, among other things through joint regulations and standards. It is important to coordinate the use of spectrum and the signals. It is the common framework that is used, and each country starts from it to then write the national regulations and allocations. However, the responsible authority does not have to strictly follow the ITU RR and there are several cases where the ITU RR looks permissible but the national regulations does not allow the same. One should therefore not interpret the ITU RR as valid instead of the national regulations, but rather a starting point. There may have been changes in the ITU RR but where existing frequency allocations nationally prevent the possibility of following the ITU RR. Conversely, it is often difficult for the national regulations to go outside ITURR because it can require difficult negotiations, and therefore they often try to change ITURR instead. cation and spectrum It is their regulations that regulate all radio including the amateur service. Where ITURR mentions the concept of "administration", it refers to Sweden's part of PTS. As part of the ITU RR, "Amateur services" are defined[21, Article 25]. The Amateur and Amateur satellite services are radio communication services with the aim of providing necessary communication in the event of natural disasters, training operators and technicians in radio and telecommunication technology at no cost to the state and society, contributing to the promotion of timely radio communication and improving international understanding and goodwill.

14.1.1 Article 1 (RR) Terms and definitionsHAREC c.1.1, c.1.21.56

(RR) Amateur service [21, 1.56]A radio communication service intended for self-education, mutual communication and technical research conducted by amateurs, that is by authorized persons interested in radio technology, only for personal interest and without financial purpose.1.57 (RR) Amateur Satellite Service [21, 1.57]A radio communication service using space stations on Earth satellites for the same purpose as the Amateur Radio Service.1.96 (RR) Amateur Radio Station [21, 1.96]Radio station within amateur radio service.

14.1.2 Article 25 (RR) Amateur servicesHAREC c.1.3, c.1.4

14.1.2.1 Section I.

Amateur service25.1 §1 Radio communication between amateur stations in different countries shall be permitted, unless the administration in one of the the nations concerned have announced their opposition to such radio communications. [21, 25.1]25.2 §2 1) Transmission between amateur stations and different countries shall be limited to spontaneous communication with the aim of using the amateur service, as defined in 1.56, and of a personal nature. [21, 25.2]25.2A §2 1A) Transmission between amateur stations and different countries must not be coded with the aim of hiding its meaning, other than for control signals exchanged between earth station and satellite station in amateur radio service. [21, 25.2A]25.3 §2 2) Amateur radio stations may be used for international radio communication on behalf of third parties only in case of emergency or crisis management. [21 , 25.3]25.5 §3 1) The administrations decide whether a personapplicants for a license to operate an amateur station must prove their ability to transmit and receive text morning signals. [21, 25.5]25.6 §3 2) The administrations must check the operational and technical qualifications of every person who wishes to use an amateur radio station. A guide to the competence required can be found in the latest edition of ITU-R recommendation M.1544. [21, 25.6]27325.7 §4 The maximum power from an amateur station shall be determined by the administrations concerned. [21 ,25.7]25.8 §5 1) All general rules in the agreement and those in this article must be applied to amateur radio stations. [21, 25.8]25.9 §5 2) During the course of the transmissions, radio amateur stations transmit their call signals with short intervals. [21, 25.9]25.9A §5A Administrations are encouraged to take necessary steps to permit amateur stations to prepare for and meet communication needs in disaster situations. [21, 25.9A]25.9B §5B An administration can decide whether a person who has permission to use an amateur station with another administration can be allowed to use an amateur station while this person is on a temporary visit to the country, and what conditions and restrictions they choose to specify . [21, 25.9B]

14.1.3 Section II. Amateur satellite service 25.10 §6

The provisions in Section 1 of this article shall apply to all applicable extent also to amateur satellite service. [21, 25.10]25.10 §7 Administrations that approve space stations in amateur satellite service must ensure that satisfactory ground control stations are established before launch to ensure that any reported harmful interference can be canceled immediately by the authorizing administration. See 22.1. [21 ,25.11]*

14.1.4 Article 5 Frequency allocation

14.1.4.1 Introduction

5.1 In all documents of the Union where the terms allocation, allotment and assignment are used, they shall have the meaning given in 1.16 to 1.18, whereby the terms in the three working languages shall be as follows (French, English and Spanish): [21 , 5.1] Frequency distribution to: Services Allocation (allocation) Areas Allotment (distribution) Stations Assignment (instruction) .... etc. (For the sake of simplicity, only the meanings in the English language are reproduced here).

14.1.4.2 Section I. Regions and areasHAREC c.1.55.2

For the allocation of frequencies the world is divided into three Regions as shown on the following map and as described in 5.3 to 5.9 ... etc. [21, 5.2]This means that allocation, distribution and assignment of frequencies may well differ between the ITU regions. The differences are explained, for example, by regionally different needs structure, population, etc.∗22 deals with "Space Services" There are also similarities. On the map below, a tropical zone has been marked, which explains the different wave propagation there. For example, special consideration needs to be taken when assigning frequencies (allocation) to the broadcasting service in the zone.

14.2 CEPT14.2.1

The concept of CEPT In addition to legally binding agreements such as the International Telecommunication Convention (ITC) - international cooperation has led to agreements that are not binding. Such agreements are made, among other things, within CEPT. CEPT stands for Conférence Européenne des ad-ministrations des postes et télécommunications, that is, the European Conference for postal and telecommunications administrations. "Conference" is to be understood as a continuously working cooperation body. The work within CEPT is mainly characterized by mutual program declarations between countries. Despite the fact that these declarations of intent or recommendations are not binding, they have proven valuable for the development of international cooperation.

14.2.2 CEPT recommendations

Countries affiliated to CEPT now simplifies the handling of license matters regarding amateur radio by mutually confirming and within their country applying recommendations that the countries formulated in consultation. This means that Swedish amateur radio regulations can be harmonized with those of other countries. Pre-competence requirements for the examination of radio amateurs can be found in the CEPT recommendation T/R 61-02 [15].

14.2.2.1 CEPT recommendation T/R 61-01HAREC c.2.1, c.2.2, c.2.3

Recommendation T/R 61-01 [14] enables radio amateurs from the CEPT countries to practice amateur radio during short visits to other CEPT countries, without needing a temporary permit from the visited CEPT country. Experience with this system is good.

14.2.2.2 CEPT recommendation T/R 61-02

The recommendation T/R 61-02 [15] means that the administrations in CEPT countries issue mutually recognized amateur radio certificates (Harmonized Amateur Radio Examination Certificate - HAREC) to those who in the case of national tests, the recommendation's knowledge requirements are met. Radio amateurs with a CEPT certificate (HAREC) may practice amateur radio in another country that accepts T/R 61-01 and may be granted a permit by that country without having to undergo additional knowledge tests. 274 Figure 14.1: ITU Region map (from RRB-2) The Swedish amateur radio certificate corresponds to the requirements for HAREC and Sweden applies T/R 61-01 and T/R 61-0

2.14.3 Swedish law and regulation

rift Laws, regulations and instructions apply for amateur radio use. Note that changes may occur. Therefore, use current versions!

14.3.1 Act on electronic communicationHAREC c.3.1

Act (2022:482) on electronic communication [12] regulates all radio communication in Sweden. A license is required for all radio broadcasting that is not exempt from the license requirement. The law is often abbreviated LEK. The Swedish Post and Telecommunications Board (PTS) is, according to regulation (2022:511) on electronic communications, the Swedish authority that handles matters concerning telecommunications. PTS must, among other things, be responsible for ensuring that the possibilities for radio communications are used effectively and in doing so must take into account the international regulation in the area. The regulation of amateur radio use is now limited to the minimum scope that follows from international agreements and European recommendations, CEPT recommendations.

14.3.2 The Swedish Post and Telecommunications Board's regulations on exemptions from the license requirement for the use of certain radio transmitters HAREC c.3.2

The Swedish Post and Telecommunications Board stipulates in PTSFS 2022:19[11] with the support of Section 5 of the Ordinance (2022:511) [13] on electronic communication that the use of amateur radio transmitters is exempt from the permit requirement. Note that PTS regularly updates the circular acceptance regulations, and thereforeΩou should check on the PTS website what is the latest version and use it when it comes into force. In the exemption regulation [11] there are the following definitions that are relevant to the amateur radio service: amateur radio certificate certificate of knowledge issued or approved by the Swedish Post and Telecommunications Agency, which shows that an approved knowledge test has been taken. amateur radio transmitter radio transmitter that is intended to be used by persons holding amateur radio certificates, for transmission on frequencies intended for amateur radio traffic. amateur radio traffic non-professional radio traffic practice, communication and technical research, conducted in personal radio technical interest and without profit. antenna gain gain in relation to a reference antenna which is either isotropic or endipole and which is measured in dBi or dBd. The antenna gain indicates how good the directivity of an antenna is. 275 EIRP equivalent isotropically radiated power (equivalent isotropically radiated power). ERP effective radiated power (effective radiated power relative to a half-wave dipole). § 26 exemption regulation [11]: The technical characteristics of the amateur radio transmitter must be adapted so that they do not interfere with the use of other radio facilities. Anyone who uses amateur radio transmitters must have an amateur radio certificate. In order to obtain an amateur radio certificate, knowledge is required in accordance with Annex 6 of CEPT Recommendation T/R 61-02 [15]. Exceptions from the requirement for an amateur radio certificate apply to those who, during a limited period, train to obtain such certificate and for those who temporarily use amateur radio transmitters during a demonstration, provided that the use of the radio transmitter takes place under the supervision of a holder of an amateur radio certificate. (Read more about use in section 13.7.3) Those who hold an amateur radio certificate must have their own call signal. This can be seen from the certificate, or previously from the amateur radio licence. The receiving and transmitting station call signs shall be transmitted at the beginning and at the end of each radio connection. The call signals must also be repeated at short intervals during the radio connection. During the training and demonstration sessions specified in the paragraph above, the call signal must be used that belongs to the holder of the amateur radio certificate who supervises the use of the radio transmitter. On these occasions, the callsign belonging to the amateur radio association or institution that organizes the training or demonstration event may also be used if representatives of the association or institution have supervision over the overuse of the radio transmitter. Automatic amateur radio transmitters, for example a radio beacon, repeater or transmitter for positioning can be identified by a callsign regularly sent by Morse code, voice message or other means. The call sign must indicate who is responsible for the automatic transmitter. Whoever starts or uses automatic amateur radio transmitters must have their own amateur radio certificate and must use their own call sign. Such start-up and use may also be carried out by the person who does not have an amateur radio certificate, if it is done under the supervision of the holder of the amateur radio certificate and his call signal is used.

14.3.3 Literature reference on laws and regulations•

CEPT recommendation T/R 61-01 [14]• CEPT recommendation T/R 61-02 [15]• Act (2022:482) on electronic communication[12]• Ordinance (2022:511) on electronic communication [13]• The Swedish Post and Telecommunications Board's regulations on exemptions from licensing requirements for the use of certain radio transmitters PTSFS 2022:19 [11]276

15 Writing a log book

15.1 PurposeHAREC c.3.3.2

Ωour radio connections and other events with the radio station should be recorded in a stationdiary also known as logbook. In the past there was an authority requirement to keep a logbook, but there is no longer. The amateur radio business is based on trust and then it is important to be able to documentΩour own activities, for example in interference situations and more. The log is also used to be able to show whenΩou have been active. Completely inΩour own interest, it is also nice to have a log book. Just think how good it is to have all the documents for competitions and diplomas with more documentation.

15.2 Be able to show how to keep a log bookHAREC c.3.3.1

Table 15.1 shows an example of how a simplified log page can look like with a couple of radio connections (QSO) entered. Consider the following:1. At half past three in the afternoon on the tenth of October, Arne (SM6XYZ) makes a general call on the local repeater on the 2 meter band. Eva(SM6ZYX), who is on her way home from school, answers. Arne tells us that he has just finished building his new 25 W output stage and asks Eva if there is any difference when he disconnects it. After some small talk about everything possible, they say 73 to each other and then seven minutes have passed since they started. Fill in the logbook for Arne! 2. Make a mock QSO with a classmate. Letter-spelΩour "call signs". Enter in the log.

15.3 Enter data HAREC c.3.3.3

What is written in the log is• the time at the beginning and at the end of the connection (forgot the date)• the opposite station's call sign•Ωour power (input power, PEP or radiated power)• frequency band, possible frequency • type of transmission (FM, SSB, CW, packet radio, etc.) • information about whereΩou sent from (own QTH) • signal reports (report codes). General information about the opposite station, for example signal report, name, QTH, the other party's equipment, QSL address and so on furthermore, it's usually also good to bring along.Ωou should also write down whenΩou have made a general call, sent out a carrier wave for tests, experiments and other things that may be of interest. If any other radio amateur usesΩour station,Ωou should also write down their name and call signal.

15.4 Report codes

Ωou are often asked by the opposite station to leave a so-called signal report on its transmission. Conversely, it is good to get a signal report onΩour own broadcast. For reporting between radio amateurs, the RST code is used. For listener reports, for example to broadcast radio stations, there is a code system called SINPO or SINPFEMO. See appendix I. band / time-UTC call- RST QSLdate frequency start end signal sent received name and QTH s m remark20171021 80 06:55 07:13 SK0HQ 59 59 Anders HQ-nänet20171021 80 07:15 07:38 SM0ZXY 579 559 Eva SollentunaTable 15.1: Example of log sheet 27727816 Morse signaling

16 Morse signaling

16.1 Introduction

Many types of signals have been used throughout the ages to send messages. At first, acoustic and optical signals were used, such as shouts, horn blasts, puffs of smoke, flashing lights, signal flags and so on. In the early 19th century, messages were sent using electrical impulses through wires. In 1837, the American Samuel F. B. Morse presented the electromagnetic typewriter telegraph. Already at the beginning of the 1840s, he had improved the device and developed a system, which has largely been retained to this day. Over time, several other people have further developed the character code that Morse first formulated and supplemented it with punctuation marks and further other characters. The code is still called the MORSE code. The method of communication is called telegraphy and means remote writing (from the Greek kanstele = far and graphein = writing). The basic principle of telegraphy is still the same today, but now mostly mechanical aids are used, both for sending and receiving. Alongside the Morse code, which was designed for manual signalling, signal codes have been developed which are specially intended for signaling with, for example, teleprinters, fax machines and computers. But despite the rapid technological development, messages are still transmitted manually using Morse code. The method holds up particularly well under difficult atmospheric and traffic conditions, while the technical equipment can be relatively simple. That is why the 180-year-old Morse signaling lives on.

16.2 Morse signaling in amateur radio

With amateur radio, people of many nationalities and with many different professions and backgrounds have very good contact opportunities. A fun way to have contacts over the radio is then to signal in the morning. It is a living way of expressing oneself. Radio amateurs like to have a chat or participate in competitions that way. However, this does not prevent many other types of transmission also being used.

16.3 Morse code

Figure 16.1 shows the structure of Morse code. The Morse characters consist of short and long character parts and spaces. The starting point is the short part of the character whose length is set to one unit. A long character part must Figure 16.1: The structure of Morse code be three units long, that is, three times the length of the short character part. Between character parts within the character, the space must be one unit long. Between entire characters within a word or character group, the space must be three units long and between entire words or character groups seven onecalled long. The Mor set signs are standardized in ITU-R M.1677-1[23].

16.4 Planned practice

Attending an organized course in the local radio club, FRO department etc. is good, asΩou can then get a tutor and access to exercise material. Not least important is the support of fellow students. It is also possible to learn to signal onΩour own, the team is alone and therefore perhaps a little more difficult. To learn Morse signalingΩou have to be motivated. It requires patience and regular training. Ideally, exercise should be included in the personal daily routine, even if it is only for a few minutes. It is possible to skip 1–2 days a week, but it should then be included in the exercise plan. Skipping even more easily becomes unaccustomed. Practicing a little now and then does not give good results.

16.5 Order for character learning

The learning order according to picture 16.1 is recommended.Ωou start with characters that sound as different as possible. This is to avoid confusion later on, when the characters become more and the speed higher. The sub-learning mixes new characters with the ones already learned. Follow the order of the course and don't skip anything! Practice without interruption so that the brain is properly "programmed". It is advisable to learn 2 to 4 new characters every week.

16.6 Learning time

The learning time required is very individual. For 40 characters/minute, which corresponded to a C certificate once upon a time, one should count on at least 100 effective hours for reception and 25 hours for transmission.Lesson New signs1 L N E O = + (separation and end)2 I X3 V T4 / ? √ (wait)5 - x (repetition)6 A Z7 .8 H Ö9 7 4 9 510 8 111 3 612 R D13 2 014 FΩ15 Ä B16 P S17 U Q18 W K19 Å M20 C G J21 ~ (listening)22 @ (conclusion)23 f (understood)24 .... (mistyping) Table 16.1: Learning order for the Morse code To cope with an increase in rate to 60 characters/minute and higher demands on security in both reception and transmission, one should count on additional 25 hours or more.

16.7 Learning methodology

Morse telegraphy should be learned using proven methodology. The best way is to also write down the signs whenΩou hear them. The method is so-called "nerve pathing" with the goal that the hand reflexively writes a certain sign when a certain rhythm is heard. Practicing just by hearing the signs is almost ineffective. Only whenΩou have thoroughly learned all Morse signs through reception is it time for sending training.

16.8 Reception exercises

Morse signs are long and short parts of characters in the form of sound, light, etc. They can also be illustrated as long and short strokes. In order for the characters to be perceived as a melody or sequence of sounds and for one not to be tempted to count short or long parts of characters, it is advisable that Morse code be learned at high speed, but with extended intervals, so-called blocked style. It is the sound image itself that is to be learned. In the beginning, it can be difficult not to count sign parts, but after allΩou perceive the signs as sound images. WhenΩou have to write a lot for a long time, the sitting position is important. In order not to get tired, one should try to adopt a relaxed sitting position and let the entire forearm rest against the table. Use paper with large squares and a good ballpoint pen. Feel free to write on every other line so that there is room to correct the text. To save time,Ωou should use small hand movements and not lift the pen more than necessary. Study the writing instructions at the end of this chapter. For the sake of clarity, use subtitled style, but clear writing style is fine also good. Listen to the entire sign before writing it down. Write calmly. Skip signsΩou miss! Don't try to remember charactersΩou just missed. ThenΩou will probably miss subsequent characters as well. Instead, concentrate on the characters that are coming. Some morse characters are so short that it is difficult to have time to write them down. To save time, certain characters must be written in one stroke, for example the letters M, N and more. The letter E, which is the shortest character, is written as a backwards three "3". The letter U should be shaped square and the letter V pointed, otherwise they are easily confused. A zero is written as Ø, with a strike through, and a one as 1. A zero without a dash can easily be confused with the letter O, and a one without a foot with the letter I. Be careful withΩour handwriting from the beginning and spend time improving it. An unsuitable learned handwriting is very difficult to work away and thenΩou get problems at higher speeds.Ωou must be able to decipherΩour text afterwards, but the most important thing is that the examiner must also be able to read it. Learning texts are often divided into groups of 5 or 4 characters. These should simulate words. Make sure thatΩou get clear word spaces on the paper as well.

16.9 Lagging when receiving

The time for each Morse code varies greatly. To get a more relaxed writing down,Ωou should try to keep a few characters inΩour memory and lag behind with the writing down. This is necessary at higher speeds and especially with certain character combinations. Do not read! It is tempting to try to form words from the lettersΩou have just written down. The reading takes attention away from the reception and it is easy to make wrong guesses.Ωou easily lose track of the textΩou just received. So don't read and guess the words. Cover the writing withΩour free hand! 16.10 Sending exercises To telegraph is to expressΩourself. The hand gestures must be clear, in the same way that speech and normal handwriting must be. It is therefore very important that the giving of signs is learned in the right way. Especially the first broadcasting exercises should take place together with a knowledgeable instructor. If an instructor is missing - then follow the instructions carefully and be self-critical! 28016.11 Aids for broadcasting practice For the broadcasting exercises, a computer with sound files or training programs is needed.Ωou also need a buzzer connected to a telegraph key and a stereo earphone. Optionally,Ωou can have a second buzzer that is keyed by the computer and whose sound is fed into one of the headphones. Learn to transmit with a manual telegraph key and not with a so-called bug. When taking samples,Ωou often get nervous and then it is easy to send errors with a bug. With an electrical bug, there is a high risk of new errors "just becauseΩou happened to touch the wrong paddle", therefore an error rarely occurs alone. Image 16.2: Correct sitting position seen from the front and from the side

16.12 Working position during transmission

It is important to have the correct working position right from the start . At a high transmission rate and long transmission sessions,Ωou otherwise get tired easily and get poor signal transmission. Above 60-speed, the right working position begins to take on great importance. Image16.3: Correct wrist movements In the event of fatigue during broadcasting, one often raises the shoulder and the elbow goes out. It then becomes laborious andΩou have to "scratch" through the end of the text's poor signage. Figure 16.2 shows the correct sitting position. The seat height should be such that both feet can rest on the floor or on a footstool. The telegraph key should be positioned so that the forearm is horizontal when the hand rests on the key knob. The upper arm can then hang relaxed straight down and the upper and lower arm can form a right angle. The key should be attached. Unfortunately, it is common for the key to be placed loosely on an inappropriately high table. This results in an inappropriate and tiring working position.

16.13 Key grip and hand movements

Figure 16.3 shows keying with wrist movements. Loosely around the key knob with the thumb and middle finger. The underside of the index finger should rest lightly on top of the knob. Always use this three-finger grip. Hold the key knob quite far intoΩour fingers. WhenΩou want to increase the tempo,Ωou can move the handle out towards the fingertips. Morse code is created with rhythmic wrist swings up/down. Don't hold the knob tightly - but don't let go either - and don't tenseΩour wrist. The wrist should swing between a slightly raised and a horizontal position. In the horizontal position, the key reaches its so-called contact position. In order for the next character to be caught in time, the wrist must not swing deeper than the horizontal position.

16.14 Controlled transmission

The transmission exercises begin with controlled transmission, but only after the Morse code has been thoroughly learned by listening. In controlled transmission, stereo headphones are used so that the computer or tape recorder's transmission 281 Figure 16.4: Telegraph key is heard in one earpiece and the own transmission in the other. The keyed tone is taken from a generator that emits a constant tone. A text printout is used as a template for the own transmission. It is necessary to listen to the Morse code from the computer or the tape, at the same time read the same characters from the printout and send theseΩourself with the key. The sound image from one's own transmission must then coincide with the one from the model. In this way, the hand and arm muscles, vision and hearing are exercised together for giving correct signals. In courses on audio tapes and data there are rhythmic rhymes for practicing controlled transmission. Start by practicing the rhymes in numerical order. WhenΩou become more confident,Ωou don't always need to practice all rhymes.Ωou knowΩourself which rhymesΩou need to practice. Controlled transmission is practiced without blocking. The character speed and the traffic speed must then be equal. The traffic speed should be at least 35 to 45 characters/minute for the character rhythm to be good. Practice a lot on numbers in the controlled broadcast. It gives skill at the transitions between short and long character parts of the characters. Even the transitions between certain morse characters can be difficult.

16.15 Free transmission

First, controlled transmission of rhymes and signs must be completed without problems. Only then start with free broadcasting without sound model. Normally, transmission should be done without blocking. Try to remember the character rhythm from the controlled transmission. Numbers and punctuation are the most difficult to send. Therefore, practice these signs extra. Then the letters will be easier to transmit! Do not transmit faster than the wrist still works smoothly at the contact position, but still distinct. The transmission isΩour business card and therefore it needs to have quality.

16.16 Control of the sign presentation

The legibility of the transmission style, which is demonstrated in the certificate test, is assessed. An otherwise approved test may therefore be failed due to poor marking. Therefore, recall a questionably designed morse character and resend it, but then be aware that the sample text increases with the number of charactersΩou resend. This means a loss of time. In the past, one-character printers with a paper strip were used to check the signing during the broadcast test, and to record it. However, such a printer is now a hard-to-reach aid. The aid that is available instead is an audio tape recorder, but unfortunately it has such an integrated display. A person skilled in telegraphy should therefore be hired to assess the sign assignment.

16.17 Calculation of the number of character values

When calculating the number of character values in a telegram text, letters (except Å) must be counted as one (1) character value. Numbers, punctuation marks, error transmission characters and the letter Å must be counted as two (2) character values. In the above example of sample text 16.2, the distribution of the character values is as follows: Letters 1 · 211 = 211 Numbers 2 · 12 = 24 Punctuation marks 2 · 13 = 26 Total character values = 261 Please note that the flashing, end and closing characters as well as erroneously sent sections with the respective erroneous transmission characters must also be included in the sum of character values. The rate then calculated is the so-called telegram or traffic speed. 282 Sample text letters numbers punctuation marks ~ ASCUNCION IS THE CAPITAL OF PARAGUAY , 29 4LOCATED IN SOUTH AMERICA. ON SHORT WAVE 31 2 USES FREQUENCY IN KILOHERTZ. 29 2ACCORDING TO THE BAND PLAN IS 3560 KHZ 21 8CENTER FOR CW QRP. 15 2QRV? MEANS AREΩOU READY? 19 4THE RECEIVER CONTROL SETTINGS SHOULD 32BE ADJUSTED AS INDICATED ON PAGE 3-4. = words/min (WPM) Example Error-free transmission of the above example on test text 16.2 with total character value 261 takes exactly 4 minutes and 20 seconds (260 seconds). The rate then becomes:261 · 60260 = 60.2 characters/min283A 1B 2C 3D 4E 5F 6G 7H 8I 9 sometimes abbreviated to J 0 sometimes abbreviated to KL . PeriodM, CommaN? Question markO - Hyphen or minusP / Fraction lineQ = Separation, also written BTR ~ Lyring, also written KAS √ Wait, also written AST f UnderstoodU HH MistransmissionV + Plus or end, also written ARW @ Termination, also written SKX (Left parenthesisY) Right parenthesisZ " IntroductionÅ ' ApostropheÄ _ UnderscoreÖ × RepetitionSOSÉ ! Exclamation markÜ : Colon or divisionÑ ; V. In the final stage of an amateur radio transmitter, the anode voltage can be higher than 2000 V and the output power up to 1000 W. In the spectrum of electromagnetic waves there are very high frequencies such as 10 000 000 000 Hz. pre, before and fixer, to add).The prefix indicates which multiplication or division factor (number factor) is used. See table A.1. If necessary, prefixes can be used for all units. In the table below, prefixes are used together with the units Hz, W, V, F, etc. as examples. In the examples above, the signal voltage is written 1 µV, the anode voltage 2 kV, the output power 1 kW and the frequency 10 GHz, which in many cases can be easier to read and more difficult to misinterpret. Exponents, for example the number 6 in the expression 106, are explained in appendix B.5.

A.1 Floating-point numbers

A decimal number is often expressed with a so-called technical floating-point number. The decimal sign is then placed so that the displayed ten-exponent in the number becomes a multiple of 3, as shown in A.1. The decimal sign can also be placed so that the ten-exponent is something other than a multiple of 3. The numerical value is then expressed with a called general floating point number. In calculators, among other things, the exponent is often shown as the letter

E, accompanied by a value. Sometimes the letter itself is omitted while the exponent value remains.1000 becomes 1 · 103 or 1 E+03125 becomes 1.25 · 102 or 1.25 E+0210 becomes 1 · 101 or 1 E+011 becomes 1 · 100 or 1 E+ 000.1 becomes 1 · 10−1 or 1 E-010.01 becomes 1 · 10−2 or 1 E-020.012 becomes 12 · 10−3 or 12 E-03 of the numbers above are rounded to varying degrees, in the next paragraph we explain the concepts of accuracy. A.2 Approximate values and Accuracy When we write a number, it is usually not the exact correct value, we write down an approximate value or an approximation. It may be because we do not know exactly what the number is, that we have only been able to measure it with a certain accuracy, or that we simply do not need more than a certain accuracy. The number of digits, value digits or significant digits, we use shows how accurately the approximate value is. The number of value digits is equal to the number of digits in the number, excluding leading zeros. If trailing zeroes are significant or do not depend on how the approximate value is rounded, see the table below for examples.1 000 000 000 000 Hz = 1 · 1012 Hz = 1 THz (T is pronounced tera)1 000 000 000 W = 1 · 109 W = 1 GW (G is pronounced giga)1 000 000 W = 1 · 106 W = 1 MW (M is pronounced mega)1000 W = 1 · 103 W = 1 kW (k is pronounced kilo)100 = 1 · 102 (h is pronounced hekto)10 = 1 · 101 (da is pronounced deka)1 V = 1 · 100 V 1 V (1 = 100 is the base unit)0.1 m = 1 · 10−1 1 dm (d is pronounced deci)0.01 m = 1 · 10−2 1 cm (c is pronounced centi)0.001 V = 1 · 10−3 V = 1 mV (m is pronounced milli)0.000 001 V = 1 · 10−6 V = 1 μV (μ is pronounced micro)0.000 000 001 F = 1 · 10 −9 F = 1 nF (n is pronounced nano)0.000 000 000 001 F = 1 · 10−12 F = 1 pF (p is pronounced pico) Table A.1: Prefixes with some typical units of measurement as examples.285 Number Number of value digits 0.04711 44711 44711,000 74 711 000 4 to 7 depending on rounding The last row of the table shows the problem that the magnitude and accuracy cannot be separated ifΩou write a number in the usual way. There is no way to know which of the trailing zeros are value digits and how the number is rounded. In order not to confuse magnitude and accuracy of a number, scientific notation is used, preferably with a prefix as described above. Scientific notation only prints the value digits, with a decimal point after the first value digit, multiplied by a power of ten that determines the magnitude. For example, the speed of light rounded to 2 significant figures is 3.0 · 108 m/s. If |∆a| ≤ 0.5 · 10−t, where ∆a is the difference between the correct value and the approximate value, the approximate value ¯a is said to have t correct decimal places. In an approximate value with > 0 correctdecimals, all digits in positions with a unit greater than or equal to 10 are said to be significant digits, except leading zeros, which only indicate the position of the decimal point. IfΩou perform calculations with numbers with different numbers of value digits, a good rule of thumb is thatΩou end up with an answer with as many significant figures as the least accurate number. A more detailed analysis of how calculations affect accuracy is studied within numerical analysis. It is practically important thatΩou do not use more value figures thanΩou need. Most measurementsΩou can make deliver quite a few values. To put accuracy into perspective, NASA allegedly uses 15 numbers to send spacecraft around the solar system and approximately 39-40 numerical values are needed to describe the circumference of the universe to the size of an atom. A.3 The Greek alphabet Letters from, among other things, the Greek alphabet are used as symbols for technical concepts. Note that the same symbols are used in different areas of technology. Below are shown uppercase and lowercase letters, pronunciation, and also some common uses in electronics.Pronunciation ExampleA α AlphaB β BetaΓ γ Gamma Conductivity∆ Delta Part of .. magnitudeδ Delta Loss angle etc. E ε Epsilon Dielectric constant etc .Z ζ ZetaH η Æta EfficiencyΘ ϑ Theta AnglesI ı IotaK κ Kappa Coupling CoefficientΛ λ Lambda WavelengthM μ My PermeabilityN ν New FrequencyΞ ξ XiO o OmikronΠ π Pi 3.14159. . .P ρ Rho ResistivityΣ σ Sigma SumT τ Tau Time constantY υΩpsilonΦ Fi Magnetic fluxφ Fi Phase angleX χ ChiΨ ψ PsiΩ Omega Resistanceω Omega Angular frequency286B Mathematics This section includes some mathematical concepts, equations and formulas that can be helpful when studying for the amateur radio certificate. The degree of difficulty spans elementary and high school levels. The review of exponential numbers and logarithms is the basis for the explanation of the concepts decibel and s-unit, which often appear in radio engineering contexts.

B.1 ExpressionHAREC I.c.1, I.c.2, I.c.6

Equation is another word for equality. In mathematical calculations, the quantities are set up in one or more equations. In a so-called true equation, the result of the set up quantities has the same value on both sides of the equal sign. Example: 3 · 5 = 15 (3 multiplied by 5 is 15)4 + 7 − 1 = 10 (4 plus 7 minus 1 is 10)155 = 3 (15 divided by 5 is 3) to be correct, given rules must always be followed when treating the quantities in the setups. In multiplication and addition, the quantities can be handled in any order, but not in division and subtraction. The result is 15, either we write 3 · 5 or 5 · 3. Similarly, the result is 8, either we write 3 + 5 or 5 + 3. In contrast, the result is different whenΩou write 315 instead of 153. Similarly, the result is different whenΩou write 15 − 5 instead of 5 − 15. By division, the numbers can be set up as so-called fractions. They can be written in one of the ways 15 : 3 or 15/3 or 153. The number before the colon, before the slash and the superscript are called the numerator. The number after the colon, the backslash and below the fractional line is called the denominator. An inverse is whenΩou can rewrite 15 as 0.2, then 0.2 is the inverse of 5 and conversely, 5 is also the inverse of 0.2. With an inverse, one can therefore rewrite 155 to 15 · 15 , which can be written as 15 · 0.2.

B.2 FormulasHAREC I.I.d

In order to more clearly describe universal relationships between the quantities in an equation, quantities can be expressed with letters instead of numbers. Such an equation is called a formula. Searched or unknown quantities are usually denoted by letters from the end of the alphabet, for example x,y or z. Given or known quantities are usually denoted by letters from the beginning of the alphabet, for example, b or c. Assume two numbers a and b, whose product is c. Formula then:a · b = cSet c = 15, then a · b = 15. Then a · b can be 3 · 5or 5 · 3 or 7.5 · 2 or any other numbers whose product is 15. According to the mathematical rules, the equation xy = ab can be written in one of the following ways: xy = ab b x = aΩΩx = baxa =Ωbx = aΩbΩ = b xa a = b · xy b = a ·Ωx That all these ways are variants of one and the same equation can be proved, by multiplying the original equality b · x = a ·Ω with b ·Ω on both sides of the equality sign,b ·Ω · xy = ab · b ·Ω i.e. b · x = a ·ΩThis shows the so-called diagonal rule, which involves cross-multiplying the denominators and the numerators. During the multiplication, the same result is obtained for each of the variants, which shows that they are equivalent.

B.3 Equation with an unknown HAREC I. d

The following examples show some of the methodsΩou can use to solve an equation with an unknown. If one-third of a number is 8 units greater than one-fifth of the same number, then what is the number? The sought, unknown number is called, for example, x. Thirdthe quotient of x is x3 . and the fifth is x5 . When 8 is added to the fifth, two equal numbers are apparently obtained, and an equation (equality) can be written x3 = 8 + x5287 We can multiply, divide, add or subtract arbitrarily on one side of the equals sign if we also do the same operations on the other side. The condition of equality must never be compromised. In order to be able to read out which number corresponds to x, it is necessary to get x alone - "free" on one side next to the equals sign. We multiply all terms on both sides by 3 in the above formula.3 x3 = 3 8 + 3 x5 which can be shortened to x = 24 + 3 x5 Then the terms on both sides are multiplied by 5.5 x = 5 24 + 3 x 55ie .5 · x = 120 + 3 · xBoth sides of the equal sign are then reduced by 3 · x, thus5 · x − 3 · x = 120 + 3 · x − 3 · xThe multiplication sign is usually not printed, neither between numbers and letters nor between groups of letters. :5x − 3x = 120 + 3x − 3x5x − 3x = 2x and3x − 3x = 0What then becomes 2x = 120, where x is the same as 1 · xor 1x. The last obtained equation is divided by 2 on both sides of the equals sign2x2 = 1202, which gives x = 60. The searched number is therefore 60. Check: 603 = 8 + 60520 = 8 + 1220 = 20 Which would be proved. In the first example, we used the diagonal rule. The two examples show that it is possible to make transfers when solving an equation. A number with a positive or negative sign, and which is on one side of the equals sign, can for example be "moved" over to the other side of the equals sign, if the sign changes to the opposite.5x = 120 + 3x can also be written +5x = +120 + 3x5x − 3x = 1205x − 3x − 120 = 0Antilogarithm Dignity Logarithm of numbers with for log10 x10 base and the exponent (rounding dex i.e. (10x) number)1.00 1.00 · 100 0.001.25 1.25 · 100 0.097 ≈ 0.101.6 1.6 · 100 0.204 ≈ 0.202.0 2.0 · 100 0.301 ≈ 0.302.5 2.5 · 100 0.398 ≈ 0.403.2 3.2 · 100 0.505 ≈ 0.504 4 · 100 0.602 ≈ 0.605 5 · 100 0.699 ≈ 0.706 6 · 100 0.778 ≈ 0.807 7 · 100 ≈ 0.858 8 · 100 0.903 ≈ 0.909 9 · 100 ≈ 0.9510 1 · 101 1.0020 2 · 101 1.301 ≈ 1.3030 3 · 101 1.477 ≈ 1.5050 5 · 101 1.699 ≈ 1.70100 1 · 102 2.00500 5 · 102 ≈ 2.701 000 1 · 103 3.005 000 5 · 103 ≈ 3.7010 000 1 · 104 4.00100 000 1 · 105 5.001 000 000 1 · 106 6.00Binary numbersHAREC I.c.8 are numbers that are written on number base 2 instead of our normal number base 10. This means that each number on the left has a weight that is twice as large as the previous one. Each digit can only be 0 or 1. An easy way to illustrate it is a short table.binary number 22 21 20 decimal number000 0 0 0 0001 0 0 1 1010 0 2 0 2011 0 2 1 3100 4 0 0 4101 4 0 1 5110 4 2 0 6111 4 2 1 7 Binary values are often grouped into groups of three or four numbers depending on the context. For larger values, binary is unmanageably long. Therefore, it is preferred to convert the groups of values into numbers and letters, where groups of three are written in octal form (number base 8) and groups of four are written in hexadecimal form (number base 16).BIN 23 22 21 20 OCT HEX DEC0000 0 0 0 0 00 0 00001 0 0 0 1 01 1 10010 0 0 2 0 02 2 20011 0 0 2 1 03 3 30100 0 4 0 0 04 4 40101 0 4 0 1 05 5 50110 0 4 2 0 06 6 60111 0 4 2 1 07 7 71000 8 0 0 0 10 8 81001 8 0 0 1 11 9 91010 8 0 2 0 12 A 101011 8 0 2 1 13 B 111100 8 4 0 0 14 C 121101 8 4 0 1 15 D 131110 8 4 2 0 16 E 141111 8 4 2 1 17 F 15291292C Conversion between dB and the ratio of numbers The name Bel comes from the name of the American Alexander Graham Bell, who in 1876 invented the first practically useful telephone based on ideas from the German Philipp Reiß. In telecommunications, the term decibel is used to describe the progress of power, current and voltage. The term also appears in other contexts, for example acoustics where it is instead a question of sound pressure. The measurements in the metric system are commonplace and no one finds it strange that, for example, there are ten decimeters in a meter. However, the concept of decibels is unfamiliar to many. Calculating with decibels is based on the use of logarithms, which is a convenient way to express and process numerical values. This has been briefly explained in section 1.9. A conversion procedure is described here using tables. Decibel is a dimensionless expression for the degree of attenuation or amplification. Attenuation is the result of certain components slowing down electric current. Amplification means that an active component can control a larger electric current and thus a greater effect than it itself is controlled with.C.1 Decibel over 1 mW at 50ohm [dB(m)]As now described, the expression decibel is a logarithmic measure of how two effects relate to each other. When the compared effects occur over equal impedances, the ratio between two voltages or two currents are expressed in decibels. In all cases, it is about the relationship between two quantities – never absolute quantities. Example: A drive stage in a transmitter is operated with 1 watt and emits 10 watts. The power ratio is 10:1 and the power gain is 10 times or 10 dB. The final amplifier in the same transmitter is driven with 10 watts from the driver stage and emits 100 watts to the antenna. Also in this case the power ratio is 10:1 and the power gain is 10 times or 10 dB. The power amplifier handles a power level 10 times as high as the drive stage andΩet the gain is 10 dB in both cases. Decibel is, in other words, dimensionless. But if one of the two compared effects is always the same and well defined, new possibilities are admitted. The effect to be quantified can now be set in relation to the known reference effect. With this prerequisite, the absolute power levels, for example through a transmitter, can be expressed in decibels. This is obtained in the following way. It is very common that the inputs and outputs of iHF equipment are made with an impedance of 50 Ω. For good adaptation, choose then the coaxial cables between the devices with a characteristic impedance of 50 Ω. It has become a practice that the reference value when comparing signal levels in radio systems should be one milliwatt (1 mW) developed in a load with an impedance of 50 Ω. Signal levels above the load 50 Ω can be expressed as dB(m) , where (m) stands for milliwatts, whereby the reference power 1 mW is 0 dB(m) at 50 Ω. The voltage drop that forms across the load 50 Ω at the power level 0 dB(m) is U = √P · R = √1 · 10 −3 · 50 ≈ 0.224 VThe current flowing through the load 50 Ω at the power level 0 dB(m) is I =√ PR =√ 1 · 10−350 = 0.0045 A = 4.5 mAThe current 4.5 mA through the load 50 Ω corresponds to -rar is thus 0 dB(m). Every other power, voltage drop and current that occurs at a load of 50 Ω can be compared with the respective reference values 1 mW, 0.22 V and 4.5 mA. dB(m) is an absolute and logarithmic measure .Power:a[dB(m)] = 10 log P[50 Ω]1[mW50 Ω]P50 = 1[mW] · 10 a10Current:0dB(m) = 4.47mA50a[dB(m)] = 20 log I504.47Voltage:0dB(m) = 0.223V50a[dB(m)] = 20 log U500.223U50 = 0.223 · 10 a20293C .2 The relationship between voltage over 50 ohms and dB(m)dB(m) V dB(m) V−40 0.00224−30 0.00707−20 0.0224−10 0.07070 0.2241 0.251 11 0.7932 0.282 12 0.8903 0.316 13 0.9994 0.354 14 1.1215 0.398 15 1.2576 0.446 16 1.4117 0.501 17 1.5838 0.562 18 1.7769 0.630 19 1 .99310 0.707 20 2.236dB(W) is another absolute measure. Power levels across a load can also be expressed in dB(W), where (W) stands for watts. The reference power is then 1 W, that is, 0 dB(W). As with dB(m), the impedance is specified in the load over which the effect develops. For example, 26 dB(W) corresponds to 398 W (see the table for the relationship between power ratio and dB). 294D S units and dBI communication radio receivers there is almost always a device that measures and displays the strength of received signals. Because the voltage from the antenna into the receiver can vary over a large area, it is practical to express the strength values with a logarithmic measurement unit, so-called S unit. The signal voltage is measured across an impedance of 50 Ω. Since the S unit is logarithmic, for example the signal strength S8 corresponds to half the signal voltage, that is 25 μV or −6 dB compared to S9. The halving is continued, it is obtained that S0 (zero) corresponds to a signal strength of 0.1 μV. In a short-wave receiver, an internal noise with a level of at least 0.1 μV is generated. This noise is mixed with the incoming signal. An input signal with a strength below the noise level (S0) will therefore not be heard. At higher signal strengths than S9, the strength is indicated as S9 + a number of dB. It is then a question of very strong signals. The following table applies to the ideal relationship between S-units and signal strengths over two alternative noise levels. The signal strength is measured at the receiver's antenna, which is why the difference in signal strength in different antennas and reception directions as well as the attenuation in the antenna and downline may need to be assessed .In the shortwave range (below 30 MHz) an atmospheric broadband noise appears together with the noise from the large amount of broadcast radio etc. other strong transmitters. This noise is more dominant than the internal noise of the receiver. In practice, most KV receivers have a higher noise level than 0.1 μV. Above 30 MHz, however, it is mostly the receiver's internal noise that sets the limit for audibility of weak signals. With the same S-scale as for the short-wave range, one begins to perceive signals in the noise without the S-meter giving results. At the 1978 IARU Region 1 conference in Miskolcz, the national associations VERON (Netherlands) and RSGB (Great Britain) proposed another S- scale above 30 MHz. At the 1981 conference in Brighton, the proposal was adopted as a recommendation. In both cases, measurements must be made with a quasi-peak value detector with a rise time of 10 ms ±0.2 ms and a fall time of 500 ms. S-Meter Below 30 MHz Above 30 MHz value dBm (μV at 50 Ω) dBμV dBm (μV at 50 Ω) dBμVS9 +40 dB −33 5000 74 −53 500 54S9 +30 dB −43 1600 64 −63 160 44S9 +20 dB −53 500 54 −73 50 34S9 +10 dB −63 160 44 −83 16 24S9 −73 50 34 −93 5 14S8 −79 25 28 −99 2.5 8S7 −85 12.6 22 −105 1.26 2S6 −91 6.3 16 −111 0.63 −4S5 − 97 3.2 10 −117 0.32 −10S4 −103 1.6 4 −123 0.16 −16S3 −109 0.8 −2 −129 0.08 −22S2 −115 0.4 −8 −135 0, 04 −28S1 −121 0.21 −14 −141 0.02 −34Table D.1: Table of S-values, voltages and effects295296E Description code type of transmission Radio transmissions are described according to ITU-RR [21, Appendix 1] with standardized combinations of numbers and letters that describe the transmission's necessary bandwidth and transmission class. The complete description of a radio transmission begins with four characters that describe the necessary bandwidth. This is followed by three characters describing the transmission class. If necessary, the three characters of the transmission class can be supplemented with two additional characters that more clearly describe the signal. However, this naming system is not without problems. It takes more into account the method of how a signal is generated, rather than what a signal simply looks like when it is transmitted. Direct modulation of the main carrier is named one way, while modulation of a subcarrier in single sideband suppression carrier transmitters is named another. If, for example,Ωou key an RTTY modem with a direct-write teleprinter and then switch to a computer to do the same, the name of the transmission mode changes. E.1 Bandwidth The necessary bandwidth (eng. necessary bandwidth) is described with three numbers and a letter. The letter character is placed in the place of the decimal point and represents the unit of bandwidth. The letters H (Hz), K (kHz), M (MHz) and G (GHz) are used, while neither 0 nor K, M or G can be the first character. Numeric values with more than three significant digits are rounded off. The decimal characters are used as follows: bandwidth 0.001–999 Hz (decimal character H), bandwidth 1.00–999 kHz (decimal character K), bandwidth 1.00–999 MHz (decimal character M),bandwidth 1.00–999 GHz (decimal sign G).Example:0.002 Hz is written H00212.5 kHz is written 12K50.1 Hz is written H1002.4 kHz is written 2K4025.3 Hz is written 25H36 kHz is written 6K00180 kHz is written 180K6.25 MHz is written 6M25 It is especially important to remember the bandwidth when transmitting near the band limits. For example, the sideband (USB) in a telephone signal with carrier frequency 29.699 will clearly exceed the upper band limit of the 10-meter band. The band limits must not be exceeded and this also applies to the transmission's sideband. The baseband is the frequency range that is occupied by signals before they modulate the carrier wave. The signaling baseband is usually much lower in frequency than the carrier wave. At the low end of the baseband, the frequency can approach or be DC (0 Hz). At the high end, the frequency depends on the value at which information is present, as well as whether there are subcarriers or other special signals within the baseband. There is a baseband for all types of signals, whether analog or digital. It should also be understood that the term baseband is related to the modulation referred to on a case-by-case basis. There may be more than one baseband in a complete modulation process. For example, a keyed tone going to the transmitter through the microphone input is its analog baseband while the keying pulses to the tone generator are its digital baseband. Sidebands are always generated when a carrier is modulated. They are mixing products on both sides of the carrier, as a result of baseband signals modulating the carrier in some way. The upper sideband is called USB (eng. upper sideband (USB)) and the lower sideband LSB (eng. lower sideband (LSB)). In amplitude modulation systems, the width of the sidebands is roughly equal to the highest frequency component in the baseband. The sidebands are mirror images of each other and contain exactly the same information. In order to save bandwidth, it is sufficient to transmit one sideband, whereby the other sideband can be suppressed, as well as the carrier wave. In modulation systems other than amplitude modulation, however, the width of the sidebands can far exceed the highest frequency component in the baseband signal. Use bandwidth (eng. occupied bandwidth) the distance between (−23 dB) of the total average effect. For amateurs, it is not always easy to determine the upper and lower part of a spectrum, where the mean effect is lower than 0.5%, the used bandwidth. It can be measured with a spectrum analyzer, but such an instrument is difficult to access for most amateurs. The used bandwidth can also be calculated, but this requires knowledge of mathematics and information theory and is not covered here. Necessary bandwidth is the part of the used bandwidth that is sufficient to secure the information transfer in the required scope and quality. 297 Simplified ways to calculate the necessary bandwidth for specific modulation systems are available in chapter 1.8. Allocated frequency band is the required bandwidth plus two times the absolute frequency tolerance. Frequency tolerance (eng. frequency tolerance) expressed in PPM (part per 106), percent or in Hz is the maximum permitted frequency deviation from the correct frequency .E.2 Transmission class Transmission class is indicated with three characters where • the first character describes the modulation of the main carrier • the second character describes the nature of the modulated signal • the third character describes the type of information. E.2.1 Modulation of the main carrier First character – the modulation of the main carrier. N No modulation Broadcast where the main carrier is amplitude-modulated (even in cases with angle-modulated subcarrier)A Double sidebandH Single sideband, full carrierR Single sideband, reduced carrier or carrier of varying levelJ Single sideband, suppressed carrierB Mutually independent sidebandsC Truncated sideband Transmission where the main carrier is angle-modulatedF Frequency modulationG Phase modulation Transmission whose main carrier is amplitude and angle modulatedD either simultaneously or in a certain predetermined sequence.Emission of the main carrier as a sequence of pulses not.P Unmodulated pulsesK Amplitude modulated pulsesL Width or time modulated pulsesM Phase position modulated pulsesQ Angle modulated carrier during the duration of the pulseV Combination of the above or generated in another wayOther cases where the transmission main carrier wave is modulated, either simultaneously or in a predetermined sequence in two or more of the ways amplitude, angle or pulse modulationX Other cases Note: Broadcast where the main carrier wave is directly modulated by a signal, which is coded in quantized form (e.g. pulse code modulation) shall be attributed to amplitude or angle modulation.E.2.2 Character of the modulating signal The second character – the character of the modulating signal.0 No modulating signalA single channel of quantized or digital information,1 without the use of modulating subcarrierA single channel of quantized or digital information,2 using modulating subcarrier3 A single channel of analog information7 Two or more channels of quantized or digital information8 Two or more channels of analog information Composite systems of one or more channels of quantized or9 digital information and one or more channels of analog informationX OtherIn the case of the nature of the base signal, a distinction is made on the one hand between channels for quantized or digital information, that is, where the signal changes in leaps and bounds between certain given states, and channels for analog information, where the signal can vary continuously within given limits. To determine the nature of the main carrier modulation may require some thought. In many cases, the information to be transmitted may modulate a subcarrier, which in turn is applied to the modulator of the main carrier. E.2.3 The form of the informationThird sign – the form of the information.N No information transmittedA Telegraphy for auditory receptionB Telegraphy for automatic receptionC FacsimileD Data transmission, remote measurement , remote controlE Telephony, also broadcast radioF Television, videoW Combination of the above casesX Other cases Telegraph signals are quantized (on/off, ground/space). Telephony signals have mostly been analog, but are increasingly quantized (digital). Facsimile signals are analog or quantized, depending on whether grayscale is transmitted or not.E.3

Additional characters21360 kHz–Global Emergency Center of Activity24 24890–24915 CW, 24906 kHz–QRP center of activity24915–24925 Narrow band modes–digimodes24925–27929 Narrow band modes–digimodesautomatically controlled data stations (unattended)24929–24931 IBP, exclusively for beacons24931–2494 0 All modes–digimodesautomatically controlled data stations (unattended)24940–24990 All modes, 24950 kHz–SSB QRP Center of Activity24960 kHz–Digital Voice Center of Activity28 28000–28070 CW, 28055 kHz–QRS Center of Activity28060 kHz–QRP Center of Activity28070– 28120 Narrow band modes–digimodes28120–28150 Narrow band modes–digimodesautomatically controlled data stations (unattended)28150–28190 Narrow band modes28190–28199 IBP, regional time shared beacons28199–28201 IBP, worldwide time shared beacons28201–28225 IBP, continuous duty beacons282 25–28300 All modes–beacons28300–28320 All modes–digimodesautomatically controlled data stations (unattended)28320–29000 All modes, 28330 kHz–Digital Voice Center of Activity28360 kHz–SSB QRP Center of Activity28680 kHz–Image Center of Activity29 29000–29100 All modes29100–29200 All modes–FM simplex–10 kHz channels29200–29300 All modes–digimodesautomatically controlled data stations (unattended)29300–29510 Satellite Links29510–29520 Guard channel29520–29590 All modes–FM repeater input (RH1–RH8)29600 All modes–FM calling channel29610 All modes–FM simplex repeater (parrot input and output)29620–29700 All modes–FM repeater outputs (RH1–RH8)F.1.1 NotesF.1.1.1 DefinitionsAll modes CW, SSB and AM as well as the traffic modes specified as Center of activity .Image modes All analog or digital traffic modes for image transmission that fit within the agreed bandwidth. For example SSTV and FAX.Narrow band modes All traffic modes that use a bandwidth up to 500 Hz including CW, RTTY, PSK and more.Digimodes All digital traffic modes that fit within agreed bandwidth. For example RTTY, PSK, MT63 and more. F.1.1.2 Transmitting frequencies Frequencies specified in the band plan are "transmitting frequencies" (not the frequency of the suppressed carrier). F.1.1.3 Digital modes of transport Includes Baudot/RTTY, AMTOR, PACTOR, CLOVER, ASCII, Packet Radio. Note the exceptions for 1.8; 7 and 10 MHz where Packet Radio is not included in Digital Traffic. F.1.1.4 Sideband Up to 10 MHz the lower sideband (LSB) must be used and above 10 MHz the upper sideband (USB). 303F.1.1 .5 Segments for tests When DX traffic is not involved, the test segments shall not include 3500-3510 or 3775-3800 kHz. The frequency bands of 10, 18 and 24 MHz must not be used for tests. F.1.1.6 The 10 MHz band In case of emergency traffic, SSB may also be used on this band. News bulletins shall not be broadcast on the 10 MHz band. 10 120–10 140 kHz may be used during daylight hours by SSB stations in Africa south of the equator. F.1.1.7 Unmanned transmitters IARU member associations are encouraged to limit the use of unmanned transmitters on the shortwave bands. Unmanned stations on shortwave must only be activated under the control of an operator who is responsible for the use not causing interference. This is especially important on 30 m where amateur radio has secondary status. Exceptions apply to lighthouses and special experimental stations. F.1.1.8 Remote controlled radio stations With remote controlled radio stations (eng. remote controlled station) is meant a transmitter that is remotely controlled by a radio amateur via some type of control terminal. The use of a remote controlled radio station must be permitted in the country where the station is located. The call sign used for remote control must be assigned by the authority of the country where the station is located regardless of where in the world the radio amateur using it is located. Note that the agreement in CEPT T/R 61-01 [14] on the use of own call sign with addition of country prefix for visited country only applies if the operator is in the country, not in case of remote control. 304F.2 VHF and higher The left part is the actual band plan, while the right part recommends use/meeting points. (PTS band plan and status for amateur radio in Sweden, shown in Chapter 13.11 as well as appendix G Swedish frequency plan and appendix H frequencies for Swedish amateur radio repeaters.) F.2.1 50 MHz band plan This band plan is based on IARU Region 1 2014 [2].Table F.1: 50 MHz Use: Experimental band, land mobile and, broadcast radio primary Segment Traffic mode Subband Recommended useMHz50,000 CW50,000–50,030 Beacons50,050 CW activity center, international50,090 CW activity center, intercontinental50,10050,100 All narrowband modes(CW, SSB, AM, RTTY,SSTV, ETC)Narrowband = 2.7 kHz50,100–50,130 intercontinental50,110 activity center intercontinental50,130–50,200 international50,150 activity center international50,200–50,300 General use50,285 crossband50,305 activity center PSK50, 310–50.320 activity center MSSmalband 1000 Hz 50.400–50.500 exclusive beacons50.401 ± 500 Hz WSPR beacons50.50050.500 All moder50.510 SSTV (AFSK)50.520–50.540 FM simplex Internet gateways50.550 Image working frequency50.600 RTTY (FSK) 50,620– 50,750 Digital communicationion50,630 DV call51,19051,210 RF81NBFM repeater in frequencies, 20 kHz channel division, 10 kHz channel width51,390 RF9951,410 F41NBFM, simplex 51,510 NBFM call frequency51,590 F5951,810 RF81NBFM repeater out frequencies, 20 kHz channel division, 10 kHz channel width51, 990 RF9952 ,000Notes: transmission stroke Telegraphy is permitted over the entire band, but is exclusive in the range 50.000–50.100 MHz.b Below 50.500 MHz, FM is not used.c 50.110 MHz is intercontinental DX calling frequency and should not be used for traffic within Europe.d For channel traffic, the channel division is 20 kHz, offset 10 kHz.305F.2.2 144 MHz band plan This band plan is based on IARU Region 1 2016 [2]. Table F.2: 144 MHz Use: Amateur radio primary144.000144.000–144.025 satellite downlink exclusive useCW(a) 144.025– 144,110 EME144,050 CW calling frequency144,100 CW MS reference frequency, random144,110–144,160 EME MGM144,138 activity center PSK31144,140–144,150 CW, MGM144,150 SSB 144,150–144,180 CW SSB MGM144,195– 144,205 SSB MS (Meteor Scatter), Random144 ,300 SSB calling frequency144.370 FSK441, Random calling144.399 144.390–144.399 CW SSB MGM144.400CW MGM Exclusive beacons(b)144.4920 ± 500 Hz WSPR beacons144.491144.500 All mother (c) 144.500 Image activity center FAX144, 525 ATV SSB talk back center144.600 activity center data MGM RTTY144.794 144.750 ATV calling frequency144.9625Digital communication (d)144.975 RV46NBFM repeater input frequencies, 12.5 kHz channel separation, 600 kHz shift145.1875 RV63145.200 V16–V45 145.2 00 Manned space traffic, uplink12 .5 kHz NBFM 145.375 DV calling frequency simplex 145.500 (Mobile) calling frequency 145.575 RV46NBFM repeater output frequencies, 12.5 kHz channel separation, 600 kHz shift 145.7875 RV63 145.800 Manned space traffic, downlink 145.794 Satellite service 146.000 Notes General . No transmissions may take place on frequencies below 144.0025 MHz.b. In Europe, no input or output frequencies for NBFM repeaters shall occur within the segment 144.000–144.794 MHz.c. Except for the satellite segment, input or output frequencies in the 2-meter band are not allowed for repeaters in other bands.d. Beacons, regardless of ERP, must be in the beacon band. Special (a) Telegraphy is permitted over the entire band, exclusively in the segment 144.035–144.150 MHz. (b) Beacons with ERP above 10 W are coordinated by the IARU Region 1 Beacon Coordinator. (c) No unmanned stations shall be used in the all-mode segment.(d) Unmanned stations are only permitted in the segment 144.800–144.990 MHz provided they are fully capable of 12.5 kHz channel splitting.306F.2.3 432 MHz band plan This band plan is based on IARU Region 1 2014 [2].Table F .3: 432 MHz Use: Amateur radio and radiolocation shared primary432.000CW (a) 432.000–432.025 EME432.050 CW activity center432.088 PSK31 activity center432.150SSB/CW 432.200 SSB activity center432.350 Microwave “talk-back” center432.370 F SK441, Random callingCW MGM 432,400–432,490 Exclusive beacons(b)432,500 All modes 432,500 APRS432,500 RU361 Note agreement NRAU 2004NBFM repeater input frequencies, 12.5 kHz channel separation, 2 MHz shift432,975 RU399433,000 RU368 Note that repeater with 1, 6 MHz shift shall phase outNBFM repeater frequencies, 12.5 kHz channel separation, 1.6 MHz shift433.3875 RU399433.400 433.400 SSTV FM AFSKFM/DV 12.5 kHz 433.450 DV calling frequency433.500 (Mobile) FM calling channel433.5875 U287433.600 433.60 0 Data Activity Center433, 625–433.775 Digital communication All modes 433.700 FAX (FM/AFSK)434.000 Digital wide band modes center frequency434.450–434.575 Digital communication, not more than434.500 25 kHz channel separation434.5125 RU 361 Note agreement NRAUNBFM repeater output frequencies, 12.5 kHz channel separation434, 9875 RU 399435,000satellite service438,000RemarksGenerala. In Europe, no input or output frequencies for NBFM repeaters shall occur within the segment 432-432.6 MHz.b. Beacons regardless of ERP must be placed in the beacon band.Special(a) Telegraphy is permitted over the entire narrowband segment, exclusively in the segment 432.000–432.100 MHz.(b) Beacons with ERP above 10 W are coordinated by the IARU Region 1 Beacon Coordinator.307F.2.4 1296 MHz Band PlanThis Band Plan based on IARU Region 1 2014 [2]. Table F.4: 1296 MHz Use: Amateur radio secondary1240,000 All modes 1240,000–1241,000 Digital modes1242,025–1242,250 Repeater out RS1–RS101242,275–1242, 700 Repeater out RS11–RS281242.725–1243.250 Digital modes RS29–RS501243.250 Amateur television 1258.150–1259.350 Repeater out, R20–R681260.000 Satellite service 1270.025–1270.700 Repeater in, RS1–RS281270 ,725–1271,250 Packet duplex, RS29–RS501272,000 Amateur television1290,994 FM/DV 1291,000 RM0–RM19NBFM repeater in 25 kHz channel separation, 6 MHz shift1291,4751291,500 All mode 1293,150–1294,350 Repeater in, R 20 –R681296.000CW(a) 1296.000–1296.025 EME1296.138 PSK31 activity center1296.1501296.200 Narrowband activity center1296.400–1296.600 Linear transponder infrequencySSB 1296.500 Image SSTV FAX1296.600 Data narrowband MGM RTTY1296,600–1296 ,800 Linear transponder output frequency1296,700–1296,800 Local beacons max 10W ERP1296,800CW MGM Exclusive beacons1296,9941297,000 RMO (used in Swedene)NBFM repeater output frequencies, 25 kHz channel separation, 6 MHz shift1297.481 RM191297.500 SM20 1297.500 FM activity centerNBFM simplex channels, 25 kHz channel separation,1297.975 SM391298.0001298.025–1298.975 Repeater out, RS1–RS39All modes 1299.000–1299.750 Digital Communications1298.750–1300.000 FM/DVANotesSpecial(a) Telegraphy is permitted throughout the narrowband segment, exclusively in the segment 1296.000–1296.150 MHz.(b) Beacons with ERP above 10 W are coordinated by IARU Region 1 lighthouse coordinator.308F.2.5 2300 MHz band plan This band plan is based on IARU Region 1 2014 [2]. The subband 2300–2400 MHz is no longer an amateur band, which is why only the remaining subband is reported here. Table F.5: 2300 Mhz Use: Amateur radio secondary2400,000Satellite service2450,000F.2.6 5650 MHz band plan This band plan is based on IARU Region 1 2014 [2]. Table F .6: 5650 MHz Use: Amateur radio secondary5650.000Satellite service, uplink5670.0005668.000Narrowband, CW/SSB/FM 5668.200 Activity center5670.000Digital communication5700.000Amateur television5720.000Narrowband, CW/SSB/FM 57 60,200 Activity Center5762,000 All Mothers5790 ,000Satellite service, downlink5850,000F.2.7 10 GHz band plan This band plan is based on IARU Region 1 2014 [2].Table F.7: 10000 MHz Use: Amateur radio secondary10000,000 Digital communication10150,000 All modes: ATV, data, FM simplex/duplex/repeaters10250 ,000Digital communication10350,000All modes10368,000Narrowband CW/SSB/beacons 10368,200 Activity centers10370,000All modes10500,000309F.2.8 24 GHz band plan This band plan is based on IARU Region 1 2014 [2].Table F.8: 24000 MHz Use: Amateur radio secondary24000,000Satellite service24048,000CW/SSB/beacons 24048,200 Activity center, narrowband mother24050,000All mothers 24125,000 Activity center, wideband mother24250,000F.2.9 47 GHz band plan This band plan is based on IARU Region 1 2014 [2].Table F.9: 47000 MHz Use: Amateur radio primary47000.00047088.200 Activity center, narrowband mother47200.000310G Swedish frequency plan Each country's telecommunications administration issues regulations for how amateur radio may be used in the country. These regulations are based on the international agreements in ITU-RR [21, ARTICLE 5] on how the frequencies and radio spectrum should be used to reduce interference between different services and countries. The agreements lead to a frequency plan which, in addition to frequency bands, also reports for which services have primary status and in that case, benefits with a lower status have priority. Note that several services may have shared primary status in a band, such as in the frequency bands 3500–3800 kHz and 432–438 MHz. With the support of SFS 2022:511, the Swedish Post and Telecommunications Board (PTS) Ordinance on electronic communication [13] has published PTSFS 2019:1 General advice on the Swedish frequency plan [10]. Note that PTS updates the exception regulations with some regularity, and thereforeΩou should check on the PTS website what is the latest version and use it when it comes into force. Appendix 1 to the general advice constitutes the Swedish frequency plan which regulates which frequencies are granted in Sweden as well as which services can use the frequencies and which services have primary and secondary status within the frequency bands. The general advice and the Swedish frequency plan also include binding implementation decisions by the European Commission regarding the effective use of radio spectrum and conditions for harmonized frequency bands within the EU. The detailed regulation regarding amateur radio in Sweden, which is based on the above agreements, regulations and regulations, then in PTSFS 2020:5 PTS regulations on exemptions from licensing obligations for the use of certain radio transmitters [11]. The regulation specifies the frequency bands that are allocated for amateur radio in Sweden, and under what conditions the frequency bands may be used for amateur radio. It is this so-called exception regulation that strictly regulates what frequency bands and outputs are permitted for amateur radio in Sweden. This regulation naturally takes precedence over IARU's band plans, which are only recommendations for how allocated frequency bands should be managed. Table G.1, which is based on PTSFS 2019:1 and PTSFS2022:19, shows which frequency bands are allocated for amateur radio in Sweden, maximum output and whether amateur radio has primary or secondary status in the frequency band .With the introduction of PTSFS 2020:5, the maximum output

power on the amateur radio frequency bands was limited to 200 W PEP. At the same time, PTS introduced an opportunity for individual locations to apply for a permit for higher power. More information regarding the application for a permit for higher power can be found on the PTS website under the heading permit for amateur radio. Please note that it is not possible to apply for a permit for higher power on all frequency bands. This has been marked in the table's High power column, where the maximum power on these frequency bands is indicated.Table G.1: Frequency bands for amateur radio in Sweden
Frequency band band Effect High power Amateur radio
135.7–137.8 kHz 2200 m 1 W 1 W ERP secondary
472–479 kHz 600 m 1 W 1 W EIRP secondary
1810–1850 kHz 160 m 200 W PEP primary
1850–1900 kHz 160 m 10 W 10 W PEP secondary
1900–1950 kHz 160 m 100 W 100 W PEP secondary
1950–2000 kHz 160 m 10 W 10 W PEP seconds
3500–3800 kHz 80 m 200 W PEP primary
5351.5–5366.5 kHz 60 m 15 W 15 W EIRP secondary
7000–7200 kHz 40 m 200 W PEP primary
10100–10150 kHz 30 m 150 W 150 W PEP secondary
14000–14350 kHz 20 m 200 W PEP primary
18068–18168 kHz 17 m 200 W PEP primary
21000–21450 kHz 15 m 200 W PEP primary
24890–24990 kHz 12 m 200 W PEP primary
28000–29700 kHz 10 m 200 W PEP primary
50000-52000 kHz 6 m 200 W 200 W PEP secondary
144–146 MHz 2 m 200 W PEP primary
432-438 MHz 70 cm 200 W PEP primary
1240–1300 MHz 23 cm 200 W PEP secondary
2400-2450 MHz 11 cm 100 mW 100 mW PEP secondary
5650–5850 MHz 5 cm 200 W PEP secondary
10.0-10.5 GHz 3 cm 200 W PEP secondary
24.00-24.25 GHz 11 mm 200 W PEP pri/sec
47.0-47.2GHz 6mm 200W PEP primary
75.5-81.0 GHz 4 mm 200 W PEP pri/sec
122.25-123.00 GHz 2 mm 200 W PEP secondary
134-141 GHz 2 mm 200 W PEP pri/sec
241-250 GHz 1 mm 200 W PEP pri/sec
312
H Frequencies for amateur radio repeaters
In the case of direct connections on high frequencies, the range is
limited, especially for moving (mobile) stations with low power and small antennas. Both terrain and technology
limits the range. A repeater with high located antenna often gives a better possibility of connection. One
such repeater can in lucky cases not only enable connections, but sometimes also double the range i and with each station only needing to reach up to the repeater, see picture 8.11. A practical thing to remember
with repeaters, especially ifΩou are transmitting at low power
thatΩou cannot always reach the repeater, even ifΩou can
receive signals from it.
A repeater immediately transmits what it receives, so since the transmitter and receiver work simultaneously,
must the distance between their working frequencies be so
great that no mutual interference occurs. Des-
said working frequencies are called frequency pairs or channel and
the distance between them is called the repeater shift. The frequency pair in a repeater must work in reverse frequency position relative to that in the stations that it serves. The channel spacing between the repeaters in a band
is also uniform and transmissions over the repeaters must
naturally have less bandwidth than the channel spacing.
Within IARU, they have agreed, among other things, on the frequency pairs
for narrowband FM repeaters. See IARU band plans for 10 m repeaters in Appendix F. For VHF repeaters there is
the band plan in appendix F.2. Frequency plans are available for repeaters
within the bands 51–52 MHz (6 m), 145–146 MHz (2 m), 432–
438 MHz (70 cm), 1240–1300 MHz (10 cm) and 28,000–
29,700 kHz (10 m).
H.1 Channel numbering method
When introducing 12.5 kHz channel spacing of 2 meters and
A new numbering system was introduced for the 70 cm bands. MAN
starts with a letter that tells which band it is
and then a number.
Code Base Frequency Channel Spacing Repeatershift
(MHz) (kHz) (kHz)
H 29.5 10 −100
F 51 10 −600
V 145 12.5 −600
U 430 12.5 −2000
M 1240 25 −6000

Note that repeater shift can be positive or negative, depending on whereΩou are in the world. In our neighborhood is
it's negative, but in, for example, Great Britain it is positive on the 70-centimeter band. Always consult local
band plans.
The channel number n starts with 0, 00 is written on each
such band and increases by one (1) for each channel in the band.
For repeater channels, an R is placed before the band letter.
To calculate the repeater's transmission frequency takes
one the base frequency b band and add the channel spacing
k multiplied by the channel number n (f = b + kn) and for
that the repeater's receiver frequency, thenΩou add repeat-
tershift r (f = b + kn + r). The repeater's transmission frequency
isΩour receiver frequency in the tables below.
For example, let's work out the frequencies for channel 371 on the 70-centimeter band. Then the base frequency becomes
since b = 430 · 106, the channel number n = 371, the channel spacing
k = 12.5 · 103, and repeater shift r = −2000 · 103. Note-
ra that the base frequency is in MHz and channel spacing as well
repeater shift in kHz. The repeater's transmission frequency becomes
430 · 106 + 12.5 · 103 · 371 = 434.6375 · 106 = 434.6375 MHz
and its reception frequency becomes 430 · 106 + 12.5 · 103 ·
371 + (−2000 · 103) = 432.6375 · 106 = 432.6375 MHz.

H.2 The 70-centimeter band

ChannelΩour transmitter-Ωour receiver-
New former frequency frequency
[MHz] [MHz]
RU361 432.5125 434.5125 DV
RU362 432.5250 434.5250 DV
RU363 432.5375 434.5375 DV
RU364 432.5500 434.5500 DV
RU365 432.5625 434.5625 DV
RU366 432.5750 434.5750 DV
RU367 432.5875 434.5875 DV
RU368 RU0 432.6000 434.6000
RU369 RU0x 432.6125 434.6125
RU370 RU1 432.6250 434.6250
RU371 RU1x 432.6375 434.6375
RU372 RU2 432.6500 434.6500
RU373 RU2x 432.6625 434.6625
RU374 RU3 432.6750 434.6750
RU375 RU3x 432.6875 434.6875
RU376 RU4 432.7000 434.7000
RU377 RU4x 432.7125 434.7125
RU378 RU5 432.7250 434.7250
RU379 RU5x 432.7375 434.7375
RU3
video broadcast),
Noise
(atmospheric disturbances),
Propagation disturbance
(wave propagation disturbances),
Frequency of fading
(fading frequency),
Emission quality
(modulation quality)
Modulation depth
(modulation degree),
Over all merit
(summary judgment).
The report begins with the code SINPO followed by five
numbers, each of which in turn grades its own
the lockers on a scale of 1–5. For non-assessed properties shall
the letter X replaces the number for the property.
315

Code Grade Assessment S
1 Barely comprehensible
2 Poor
3 Satisfactory
4 Good
5 Excellent

Code Grade Assessment I, N, P

1 Very strong
2 Strong
3 Moderate
4 Weak
5 No Code

Grade Assessment F

1 Very fast
2 Fast
3 Moderate
4 Slow
5 No Code

Grade Assessment E
1 Very poor
2 Poor
3 Satisfactory
4 Good
5 Excellent

Code Grade Assessment M

1 Constant overmodulation
2 Poor or none
3 Satisfactory
4 Good
5 Maximum

Code Grade Assessment O

1 Unusable
2 Poor
3 Satisfactory
4 Good
5 Excellent

316 J Knowledge requirements in CEPT HAREC the edition of KonCEPT is based on CEPT T/R 61-02 Harmonized Amateur RadioExamination Certificate (HAREC) Edition 4 June 2016 [15]

The actual knowledge requirements in HAREC are described in "Annex 6: Examination syllabus and requirements for a HAREC". All the requirements in it are included here, in the original HAREC wording, only reworked with respect to format.

For each requirement, one or more references are then reported in the rest of the text wherethat requirement is considered fulfilled. In the text of the book it says HAREC a.1.4 where magnetic fields are treated to refer to the HAREC requirement 1.4 Magnetic field;. The same place is then referenced from the requirement with subchapters in brackets (1.4). Where applicable, a requirement may be divided into several references so that it is covered in several separate places in the text. In the PDF edition, these references are clickable links for easy navigation.

J.1 Introduction a Where quantities are referred to, candidates should know the units in which these quantities are expressed, as well as the generally used multiples and sub-multiples of these units.
b Candidates must be familiar with the compound of the symbols.

c Candidates must know the following mathematical concepts and operations: c.1 adding, subtracting, multiplying and dividing (B.1) c.2 fractions (B.1) c.3 powers of ten, exponentials, logarithms (B.7) c.4 squaring (B.5) c.5 square roots (B.6) c.6 inverse values (B.1) c.7 interpretation of linear and non-linear graphs c.8 binary number system (B.8)
d Candidates must be familiar with the formulas used in this syllabusand be able to transpose them. (B.2, B.3) Note: These overall requirements are scattered throughout the book and are expected to be met. J.2

Technical Content

1. Electrical, electro-magnetic and radio theory 1.1 Conductivity; (1.1) 1.1.1 Conductor, semiconductor and insulator; (1.1.4) 1.1.2 Current (1.1.7), voltage (1.1.5) and resistance; (1.1.10) 1.1.3 The units ampere (1.1.7), volt (1.1.5) and ohm; (1.1.10) 1.1.4 Ohm'sLaw [E = I ·R]; (1.1.11, 3.1.13) 1.1.5 Kirchhoff'sLaws; (1.1.12) 1.1.6 Electric power [P = E ·I]; (1.1.13) 1.1.7 The unit watt; (1.1.13) 1.1.8Electric energy [W = P ·t]; (1.1.15) 1.1.9 The capacity of a battery [ampere-hour]. (1.1.17) 1.2 Sources of electricity; (1. 1.2.1 Voltage source, source voltage [EMF], short circuit current, internal resistance andterminal voltage; (1.2.1) 1.2.2 Series and parallel connection of voltage sources. (1.2.5) 1.3 Electric field; (1.3) 1.3.1 Electric field strength; (1.3.4) 1.3.2 The unit volt/meter; (1.3.4) 1.3.3 Shielding of electric fields. (1.3.5) 1.4 Magnetic field; (1.4) 1.4.1 Magnetic field surrounding live conductor; (1.4.3) 1.4.2 Shielding of magnetic fields. (1.4.9) 1.5 Electromagnetic field; (1.5)1.5.1 Radio waves as electromagnetic waves; (1.5.1)1 1.5.2 Propagation velocity and its relation with frequency and wavelength [v =Ω ·f]; (1.5.3) 1.5.3 Polarization. (1.5.4) 1.6 Sinusoidal signals; (1.6) 1.6.1 The graphic representation in time; (1.6) 1.6.2 Instantaneous value(1.6.1), amplitude [Emax] (1.6.2), effective [RMS] value (1.6.4) and average value[Uef f = UmaxΩ2](1.6.4) ; 1.6.3 Period (1.6.7) and duration of period (1.6.8); 1.6.4 Frequency; (1.6.9)1.6.5 The unit hertz; (1.6.10) 1.6.6 Phase difference. (1.6.11) 1.7 Non-sinusoidal signals, noise; (1.7)1.7.1 Audio signals; (1.8.7) 1.7.2 Square wave; (1.7.1) 1.7.3 The graphic representation in time;(1.7.1) 1.7.4 DC voltage component (1.7.2), fundamental wave and higher harmonics (1.7.1); 317 1.7.5 Noise [PN = TB] (receiver thermal noise, band noise, noise density, noise power in receiver bandwidth). (1.7.3) 1.8 Modulated signals; (1.8) 1.8.1 CW; (1.8.9) 1.8.2

Amplitude modulation; (1.8.8) 1.8.3 Phase modulation (1.8.11), frequency modulation (1.8.12)4 and single-sideband modulation (1.8.10); 1.8.4 Frequency deviation and modulation index [m =ΩF fmod]; (1.8.12.3) 1.8.5 Carrier, sidebands and bandwidth; (1.8.4, 1.8.5) 1.8.6 Waveforms of CW (1.8.9), AM (1.8.8), SSB (1.8.10) and FM (1.8.12) signals (graphical presentation); 1.8.7 Spectrum of CW (1.8.9), AM (1.8.8) and SSB (1.8.10) signals (graphical presentation); 1.8.8 Digital modulations (1.8.16): FSK (1.8.16.1), 2-PSK (1.8.16.2), 4-PSK (1.8.16.3), QAM(1.8.16.4); 1.8.9 Digital modulation (1.8.17): bit rate (1.8.17.1), symbol rate (Baud rate)(1.8.17.2) and bandwidth (1.8.17.3); 1.8.10 CRC (1.8.18.3) and retransmissions (eg packet radio) (1.8.18.4), forward error correction (eg Amtor FEC) (1.8.18.5). 1.9 Power and energy;(1.9) 1.9.1 The power of sinusoidal signals[P = i2 ·R; P = u2 R ; u = Uef f ; i = Ief f] ; (1.9.1)1.9.2 Power ratios corresponding to the following dB values: 0 dB, 3 dB, 6 dB, 10 dB and 20 dB [both positive and negative]; (1.9.2) 1.9.3 The input/output power ratio in dB of series-connected amplifiers and/or attenuators; (1.12.1) 1.9.4 Matching [maximum power transfer]; (1.12.2) 1.9.5 The relationship between power input and output and efficiency [ÿ = Pout Pin ·100%]; (1.12.3)1.9.6 Peak Envelope Power [PEP]. (3.4.10) 1.10 Digital signal processing (DSP). 1.10.1 sampling and quantization; (1.13.1) 1.10.2 minimum sampling rate (Nyquist frequency); (1.13.2)1.10.3 convolution (time domain / frequency domain, graphical presentation); (1.13.3)1.10.4 anti-aliasing filtering, reconstruction filtering; (1.13.4) 1.10.5 ADC / DAC. (1.13.5) 2.Components 2.1 Resistor; (2.1) 2.1.1 The unit ohm; (2.1.2) 2.1.2 Resistance; (2.1.3) 2.1.3Current/voltage characteristic; (2.1.7) 2.1.4 Power dissipation. (2.1.10) 2.2 Capacitor; (2.2) 2.2.1Capacitance; (2.2.2) 2.2.2 The unit farad; (2.2.4) 2.2.3 The relationship betweencapacitance, dimensions and dielectric. (Qualitative treatment only); (2.2.3) 2.2.4 The reactance[XC = 1 2ÿf ·C];(2.2.7) 2.2.5 Phase relationship between voltage and current. (2.2.8) 2.3Coil; (2.3) 2.3.1 Self-inductance; (2.3.2) 2.3.2 The unit henry; (2.3.5) 2.3.3 The effect ofnumber of turns, diameter, length and core material on inductance. (Qualitative treatment only);(2.3.6) 2.3.4 The reactance [XL = 2ÿf ·L]; (2.3.7) 2.3.5 Phase relationship between current andvoltage; (2.3.8) 2.3.6 Q factor. (2.3.9) 2.4 Transformer application and use; (2.4) 2.4.1 Idealtransformers [Pprim = Psec]; (2.4.4) 2.4.2 The relationship between turn ratio and: 2.4.2.1 voltageratio [usec uprim = nsec nprim] ; (2.4.4) 2.4.2.2 current ratio [isec iprim = nprim nsec] ; (2.4.4) 2.4.2.3 impedanc (Qualitative treatment only); (2.4.6) 2.4.2.4 Transformers. (2.4.5) 2.5 Diode; (2.5) 2.5.1 Use andapplication of diodes: 2.5.1.1 Rectifier diode, zener diode, LED [light-emitting diode], voltage-variable and capacitor [varicap]; (2.5.3) 2.5.1.2 Reverse voltage and leakage current.(2.5.2) 2.6 Transistor; (2.6) 2.6.1 PNP- (2.6.4) and NPN-transistor (2.6.2); 2.6.2 Amplification factor; (2.6.3) 2.6.3 Field effect vs. bipolar transistor (voltage vs. current driven); (2.6.5) 2.6.4 The transistor in the: 2.6.4.1 common emitter [source] circuit; (3.4.3) 2.6.4.2 common base [gate] circuit; (3.4.3) 2.6.4.3 common collector [drain] circuit; (3.4.3) 2.6.4.4 input and output impedances of the above circuits. 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(13.2) 2.8 QRO = Increase transmitter power (13.2) 2.9 QRP? = Shall I decrease transmitter power? (13.2) 2.10 QRP = Decrease transmitter power (13.2) 2.11 QRT? = Shall I stop sending? (13.2) 2.12 QRT = Stop sending (13.2) 2.13 QRZ? = Who is calling me? (13.2) 2.14 QRZ =Ωou are being called by ... (13.2) 2.15 QRV? = AreΩou ready? (13.2) 2.16 QRV = I am ready (13.2) 2.17 QSB? = Are my signals fading? (13.2) 2.18 QSB =Ωour signals are fading (13.2) 2.19 QSL? = CanΩou acknowledge receipt? (13.2) 2.20 QSL = I am acknowledging receipt (13.2) 2.21 QSO? = CanΩou communicate with ... directly? (13.2) 2.22 QSO = I can communicate ... direct (13.2) 2.23 QSY? = Shall I change to transmission on another frequency? (13.2) 2.24 QSY = Change transmission to another frequency (13.2) 2.25 QRX? = When willΩou call again? (13.2) 2.26 QRX = I will callΩou again at ... hours on ... kHz (or MHz) (13.2) 2.27 QTH? = What isΩour position in latitude and longitude (or according to any other indication)? (13.2) 2.28 QTH = My position is ... latitude, ... longitude (or according to any other indication) (13.2) 3. Operational Abbreviations 3.1 BK = Signal used to interrupt a transmission in progress (13.3) 3.2 CQ = General call to all stations (13.3) 3.3 CW = Continuous wave (13.3) 3.4 DE = From, used to separate the call sign of the station called from that of the calling station (13.3) 3.5 K = Invitation to transmit (13.3) 3.6 MSG = Message (13.3) 3.7 PSE = Please (13.3) 3.8 RST = Readability, signal-strength, tone-report (13.3) 3.9 R = Received (13.3) 3.10 RX = Receiver (13.3) 3.11 TX = Transmitter (13.3) 3.12 UR =Ωour (13.3) 4. International distress signs, emergency traffic and natural disaster communication 4.1 radiotelegraph ...—...[SOS] (13.4) 4.2 radiotelephone "MAYDAY" (13.4) 4.3 International use of the amateur station in the event of national disasters; (13.4) 4.4 Frequency bands allocated to the amateur service and amateur satellite service. (13.4) 5. 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Stuff That Shows Up On The Exam That I Couldn't Find In Koncepten:

Transistor Circuits

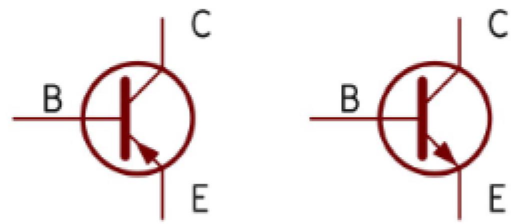


Figure 10-iii: PNP (left) and NPN (right) bipolar junction transistors (BJT) symbols. [EI9ILB]

Transistors are components that are commonly used to control a big current with a very small one, like a switch. Transistors are considered the most important member of the semiconductor family, and the foundation of solid-state electronics.

There are many types of transistors. The most traditional one, and the one that you need to study in some detail is known as a BI-POLAR JUNCTION TRANSISTOR (BJT)

These can be PNP transistors and NPN transistors and the big difference is how the N and P materials are sandwiched together!

It is useful to understand how a BJT works. Without a voltage between the base and the emitter of a transistor, no current can flow between the collector and the emitter terminals. Like a diode, when a small voltage of between 0.6–0.7 V (for a silicon transistor) is applied between the base and the emitter, it has the effect of turning on the transistor. The level of bias voltage determines when the transistor turns on. This is known as BIASING .

It is useful for designing different classes of amplifiers, which will be discussed in section 10.7.3 Biasing. When it turns on, the transistor will allow a larger current to flow between the collector and the emitter terminals. It will have two separate currents flowing through it at the same time. One current, known as the BASE CURRENT *IIdd*, flows An easy way to identify the transistor from its symbol uses a handy mnemonic of not pointing in or never points in, meaning that on an NPN transistor the arrow never points towards the centre. It is common in electrical circuits to have several different currents, often with different voltages, all flowing through a shared connection or a wire at the same time.. The other current, the COLLECTOR CURRENT *IICC* , flows between the collector and the emitter, see Figure 10-iv. The flow of this current is controlled by the flow of the base current.

The emitter is carrying the current *IIPP* that is the sum of the two other currents:

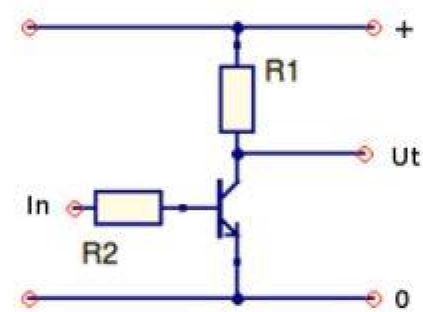
IIPP = *IICC* + *IIdd*

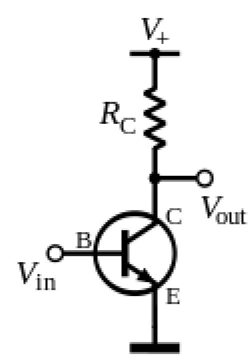
Transistors can be connected in different ways in a circuit. By sharing one of its three terminals with other parts of the circuit it is possible to take ad- vantage of different current flows to cater for different signal processing designs.

A transistor can be used in various circuits: common emitter, common collector and common base

You have to know the different circuits for some reason!

Common Emitter





Basic NPN common-emitter circuit

This is the most common BJT circuit you’ll come across. A small voltage goes into the base and “switches on” the big current that flows between the collector and the emitter.

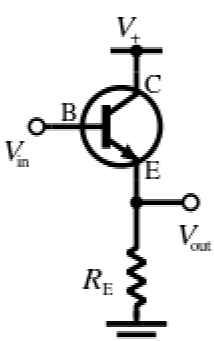
The common emitter configuration provides voltage gain, meaning that the output voltage is larger than the input voltage. The voltage gain is determined by the transistor's characteristics and the biasing conditions.

The common emitter configuration also provides current gain. The collector current is significantly larger than the base current, providing amplification.

Common emitter amplifiers typically introduce a phase shift between the input and output signals. The amount of phase shift depends on various factors such as the transistor's frequency response, biasing conditions, and the external components in the circuit.

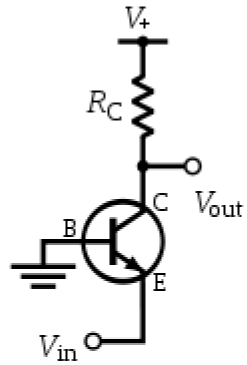
Common-emitter amplifiers are also used in radio frequency circuits, for example to amplify faint signals received by an antenna

Common Collector



Basic NPN common collector circuit
The circuit can be explained by viewing the transistor as being under the control of negative feedback.

Common Base

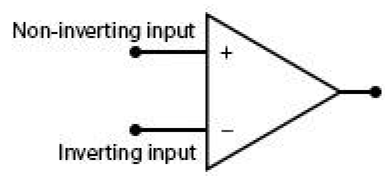


Basic NPN common base circuit

The common base circuit is typically used as a current buffer or voltage amplifier.

Operational Amplifiers

A circuit is said to be **linear**, if there exists a linear relationship between its input and the output. Similarly, a circuit is said to be **non-linear**, if there exists a non-linear relationship between its input and output.



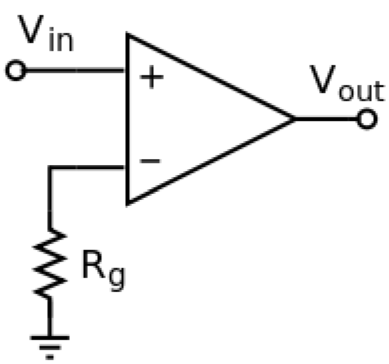
Op-amps can be used in both linear and non-linear applications.

Inverting Amplifier

An inverting amplifier takes the input through its inverting terminal through a resistor R1, and produces its amplified version as the output. This amplifier not only amplifies the input but also inverts it (changes its sign).

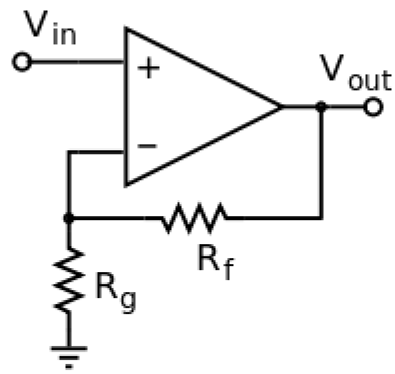
Inverting op amps work following the op amp golden rules:

1. The Current Rule: No current flows into the inputs of the op amp. $(I_+=I_-=0)$
2. The Voltage Rule: The output of the op amp attempts to ensure that the voltage difference between the two inputs is zero $(V_+=V_-)$



Non-Inverting Amplifier

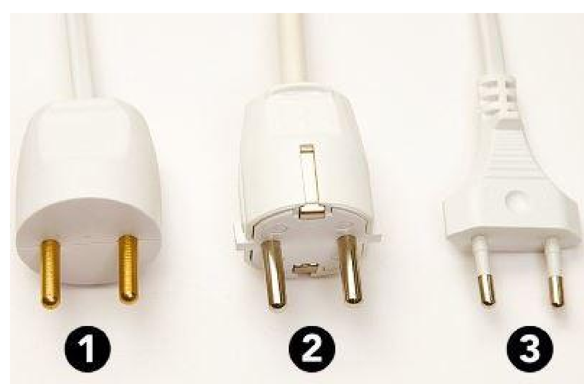
A non-inverting amplifier takes the input through its non-inverting terminal, and produces its amplified version as the output. As the name suggests, this amplifier just amplifies the input, without inverting or changing the sign of the output.



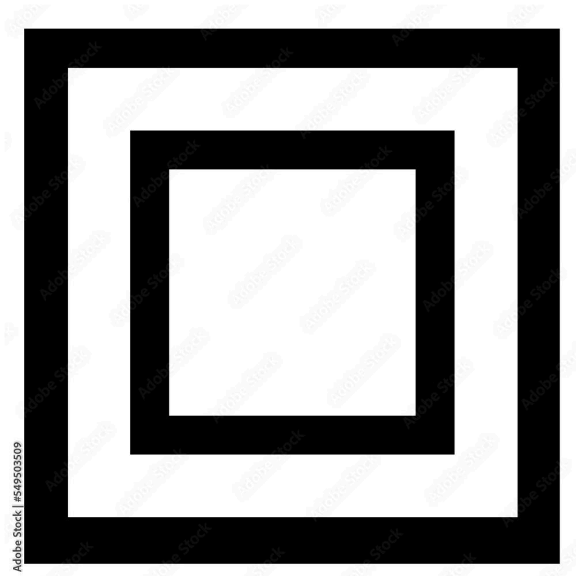
You should probably know the different between the two! For me, I can usually tell the difference between the two by seeing whether there are any components connected to the non-inverting terminal.

Circuits for Measuring Equipment

Plug Sockets



1) Old deprecated ungrounded plug - not allowed anymore
2) Schuko Grounded plug (if its round)
3) Ungrounded, double insulated europlug



Double insulated meaning
Class 2 - does not need grounding and has
2 layers of insulation