DAYANANDA SAGAR COLLEGE OF ENGINEERING

An Autonomous Institute Affiliated to Visvesvaraya Technological University, Belagavi, Approved by AICTE & ISO 9001 -2008 Certified

Shavige Malleshwara Hills, Kumaraswamy Layout, Bengaluru-560078

Accredited by National Assessment and Accreditation Council (NAAC) with 'A' Grade

DEPARTMENT OF TELECOMMUNICATION ENGINEERING

Accredited by National Board of Accreditation (NBA)

NOTES : MODULE 1

TELECOMMUNICATION SYSTEMS

COURSE CODE: 17TE6IETCS

CONTENTS:

Unit-1

Introduction to Telecommunication.

* The Significance of Human Communication.
* Communication System Model.
* Types of Electronic communication.
* A survey of communication Application

Fundamentals of communication

* Characteristic of Electromagnetic Spectrum.
* Wavelength & Frequency.
* Simplex, Half-duplex, Full-Duplex.
* Bandwidth, Sampling, Gain, Noise Attenuation.
* Bit error rate, channel capacity.
* Decibels & Quality of Services.

1.1 The significance of Human Communications:—

*. "Communication" is the process of exchanging information.

→ people communicate to convey their thoughts, ideas & feelings to others. The process of communication is inherent to all human life & includes Verbal, non-verbal, print & electronic processes.

*. Two main barriers to human commn are language & distance.

⇒. Language barriers arise b/w persons of different cultures or different nationalities.

⇒. Communicating over long distances is another problem. different ways of communicating between human beings as follows.

*.) Face to face encounters.

*) Long-distance commn by sending simple signals such as drumbeats, horn blasts & smoke signal.

*) Waving signal flags (semaphores).

*) Sending of written messages by horseback, human runner, ship & trains.

*) Advancement in communication happened in late 19th century. when "Electricity" was discovered.

*) The Telegraph - 1844, Telephone - 1876

Radio - 1887 & demonstrated in 1895. comm..

*. Later electronic communication, such as the telephone, radio, TV & the internet, have increased ability to share information

1.2. Communication Systems :—

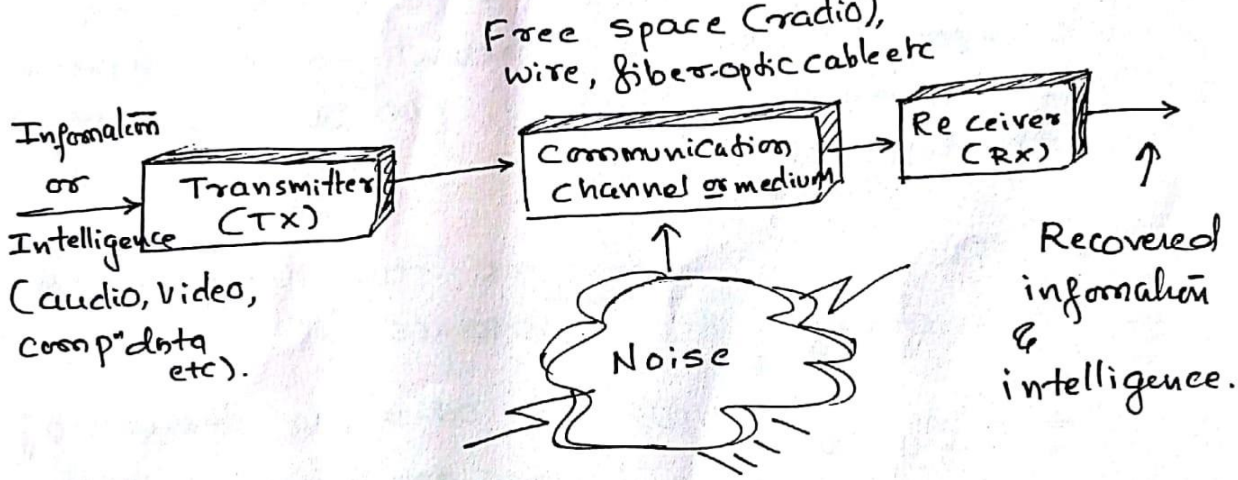


Fig (1): A general model of all communication systems.

#. All electronic communication systems have a transmitter, a communication channel or medium & a receiver. These are shown in fig(1). A general model of commn system.

#. The process of communications begins when a human being generates some kind of message, data or other intelligence that must be received by others. A message can be generated by a computer or electronic current.

#. In "Electronic communication systems", the message is referred to as "information", or an intelligence signal.

#. This message, in the form of an electronic Signal, is fed to the transmitter, which then transmits the message over the communication channel.

#. The message is picked up by the receiver & relayed to another human.
Along the way, noise is added in the commn channel & in the receiver.

#. "Noise" is the general term applied to any phenomenon that degrades or interferes with the transmitted information.

✡ Transmitter :—

⇒. The first step in sending a message is to convert it into electronic form suitable for transmission.
Ex: For voice messages, a microphone is used to translate the sound into an electronic audio signal. & Transducers convert physical characteristics into electrical signal etc.

⇒. The "transmitter" is a collection of electronic components & circuits designed to convert the electrical signal to a signal suitable for transmission over a given commn medium.

⇒. Transmitters are made up of oscillators, amplifiers, tuned circuits & filters, modulators, frequency mixers & other circuits.

* Communication channel :—

*. The " communication channel" is the medium by which the electronic signal is sent from one place to another.

Many different types of media are used in commun systems, including wire conductors, fiber-optic medium/ cable & free space.

1. Electrical conductors :—

The medium may simply be a pair of wires that carry a voice signal from a microphone to a headset.

Ex :- Co-axial Cable → TV
Twisted-pair cable → LAN.

2. Optical media :—

The commn medium may also be a fiber-optic cable or " light pipe" that carries the message on a light wave.

Ex :- Long-distance calls & Internet commn.

→ The information is converted to digital form that can be used to turn a laser diode off & on at high speeds.

3. Free space :—

when free space is a medium, the resulting system is known as "Radio". Also known as as "Wireless".

Radio is broad general term applied to any form of wireless commn from one point to another. It makes use of the electromagnetic spectrum.

→ Signals are converted to electric and magnetic fields that propogate instantaneously through space over long distances. commn by visible or infrared light also occurs in free space.

4). Other types of Media :—

Few special commn systems uses other than the media mentioned above.

→. "Sonar" – Water is used as the medium. Passive & active sonars.

→ "Alternate - current (ac)" power lines – to operate all electrical & electronic devices.

✡. Receivers :—

*. A receiver is a collection of electronic components & circuits that accepts the transmitted message from the channel & converts it back to a form understandable by humans.

*. Receivers contain amplifiers, oscillators, mixers, filters & demodulators.

Scanned by CamScanner

Transceivers :-

* Most electronic communication is two-way, & so both parties must have both a transmitter & a receiver. As a result, most common equipment incorporates circuits that both send & receive. These units are commonly referred to as "Transceivers."

Ex:- Telephones, handheld radios, cellular telephones, & computer modems etc.

Attenuation :-

→ Signal "Attenuation" or degradation, is inevitable no matter what the medium of transmission.

→ Attenuation is proportional to the square of the distance b/w the transmitter & receiver. & distorting digital pulses, reducing signal amplitude over long distances.

→ To avoid this, considerable signal amplification in both the transmitter & the receiver, is required for successful transmission.

*. Noise :—

→ Noise is the bane of all electronic communications.

→ It's effect is experienced in the receiver part of any communications System.

⇒. The measure of noise is usually expressed in terms of the "Signal-to-noise (S/N) ratio (SNR), which is the signal power divided by the noise power & expressed numerically or in terms of decibels (dB).

"A very high SNR is preferred for best performance".

—o—

1.3. Types of Electronic Communication :—

*. Electronic communications are classified according to whether they are.

(1). one-way (Simplex) or two-way (full duplex or half duplex). transmissions.

(2). Analog or digital signals.

#. Simplex :—

The Simplest way in which electronic communication is conducted is one-way communications, normally reffered to as "Simplex communication".

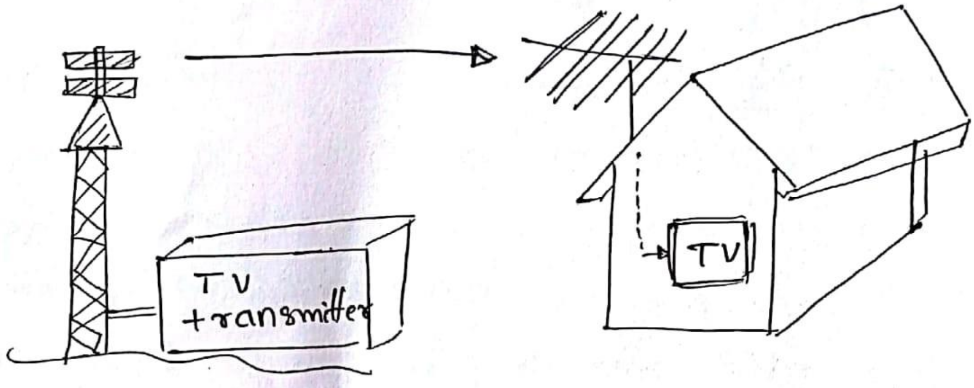


Fig (2): TV broadcasting.

#. The most common forms of simplex commn are radio and TV broadcasting.

#. Another example is remote controlled toy cars or an unmanned aerial vehicle (UAV or drone).

#. Full Duplex :—

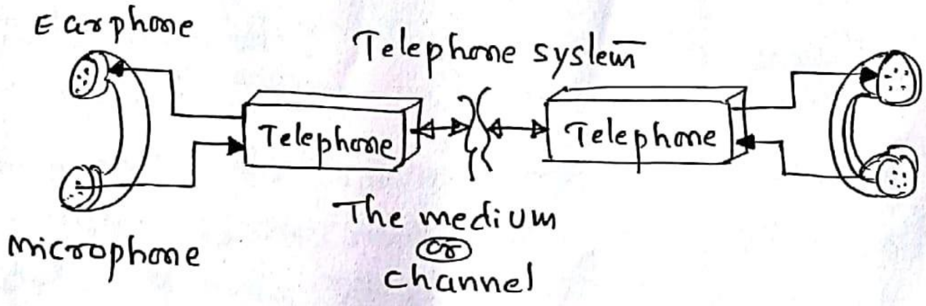


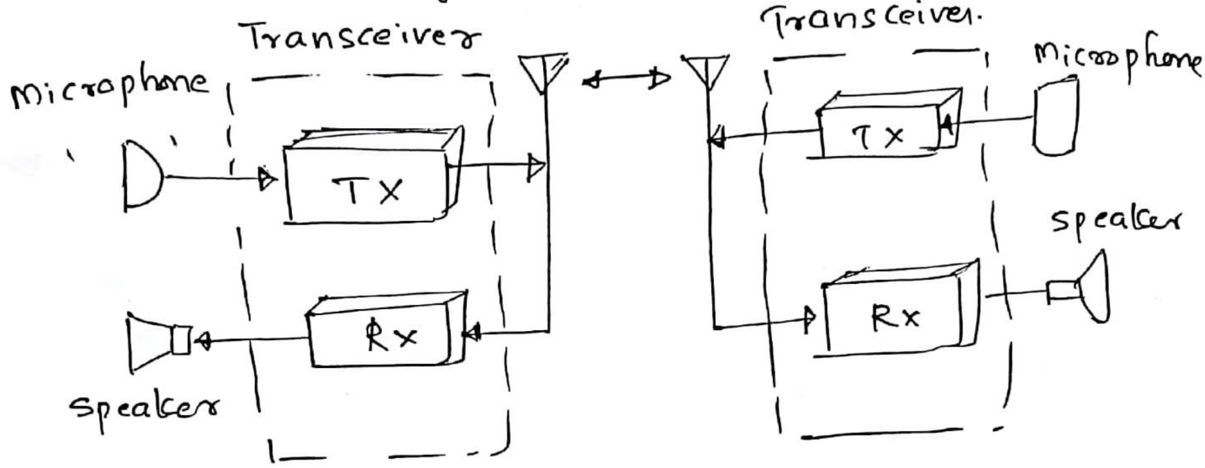
Fig (3): Full duplex. (two-way).

#. The bulk of electronic communication is two-way or duplex communication.

→. Typical duplex application shown in fig (3). People communicating with one another over the telephone can talk & listen simultaneously

Half duplex :-

→ The form of two-way communication in which only one party transmits at a time is known as "Half duplex Commn".
as shown in fig (4).



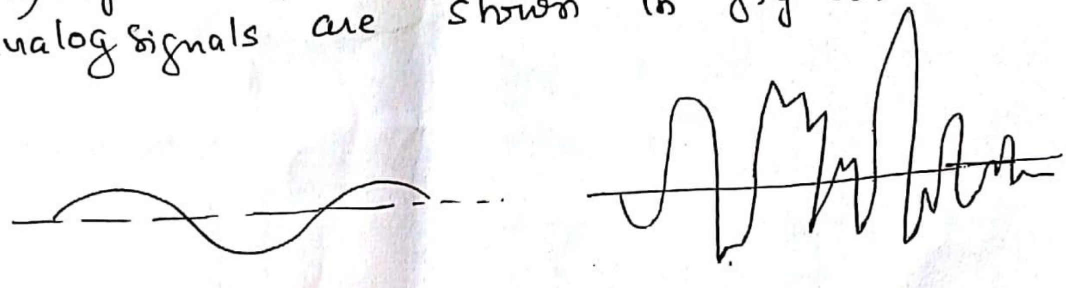
Fig(4) Half duplex (one way at a time).

#. The communication is two-way, but the direction alternates: the communicating parties take turns transmitting & receiving.

Ex :- Radio transmissions in Military, fire police, aircraft, marine etc.
& Citizen Band, Family radio & Ameteur radio are also example.

#. Analog Signals :—

→ An analog signal is a smoothly & continuously varying voltage or current. Some typical analog signals are shown in fig (5).



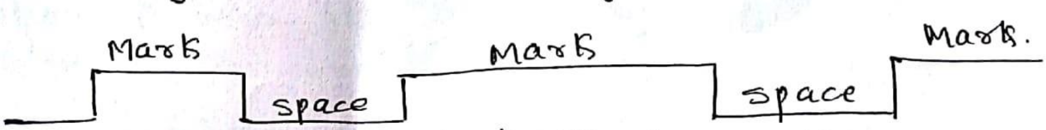
(a) (b).

fig (5) : (a) Sine wave "tone".
(b) Voice Signal.

#. A Sine wave is a single-frequency analog signal. Voice and Video are analog signals that vary in accordance with the Sound or light variations. (Information).

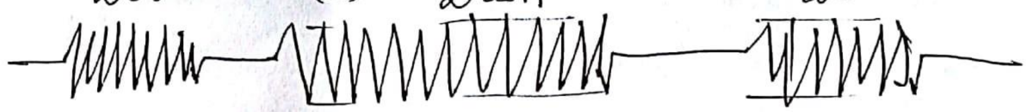
#. Digital Signals :—

→ Digital signals do not vary continuously, but change in step or in discrete increments. Most signals use binary or two-state codes.



Mark = on, Space = off.

(a)



(b).

fig (6) : Digital signals (a) Telegraph (Morse code).
(b) Cont. wave (CW).

→. From fig (6). The telegraph used morse code, with its system of short & long signals to designate letters & numbers. (fig (6)(a).

Fig (6)(b), radio telegraphy also known as continuous-wave (CW) transmission, a Sine-wave signal is turned off & on for short or long durations to represent the dots & dashes.

#. Analog signals can also be transmitted digitally. It is very common to take voice or video analog signals & digitize them with an analog-to-digital (A/D) converter.

—o—

1.4 A Survey of Communication Applications :-

1) Simplex (One-way).

#. AM and FM radio broadcasting:

→ stations broadcast music, news, weather reports, & programs for entertainment etc.

→ Includes "short wave".

#. digital radio :

→ There is both satellite & terrestrial.

→ Digital format.

#. TV broadcasting :

→ Stations broadcast entertainment, info & educational programs. by radio.

digital television (dTV) :

→ Transmission of TV programming is performed by digital methods, both satellite & terres

→ HDTV & Internet protocol TV (IPTV).

Wireless remote control :

→ A device that controls any remote item by radio or infrared.

Ex: Missiles, satellites, robots, toys etc.

Internet of Things (IOT):

→ The monitoring or control of remote devices, appliances & other items in a home, office or other facility is usually accomplished by a combination of wireless & internet.

Few more applications as follows.

*). Telemetry.
*). Radio Astronomy.
*). Surveillance.
*). Music services.
*). Internet radio. etc.

P.T.O.

Duplex (Two-way).

#. Telephones: one-on-one verbal communication is transmitted over the vast world-wide telephone networks employing wire, fiber optics, radio & satellites.

a). Cordless telephone : short distance wireless commn.

b). Cell phones : world wide wireless commn via handsets & base stations & wired telephone system. email, Internet, message, video & games etc.

c). Internet telephones . voice over the internet protocal (VoIP) phones. uses high speed broadband services (cable, DSL, fiber).

d). Satellite phones : uses low-earth orbit satellites to give worldwide voice service from any remote location on earth.

#. Two way radio :

commercial, Industrial & Govt organisations communicati is transmitted b/w vehicles, handheld units, Basestation
Ex:- police, fire, aircraft, marine etc.

#. Radar : This special form of communication makes use of reflected microwave signals for the purpose of detecting ships, planes & missiles.

#. Sonar : For under water communication, water is used a transmission medium.
Ex: To detect enemy submarines.

#. Internet: worldwide interconnections via fiber-optic networks, telecommunications companies, cable TV companies, others provide 'world wide web' (www) access to millions of websites & e-Mail.

#. Few other applications :

- Amateur radio.
- Citizens radio.
- Family radio Units/Services.
- wide-Area networks (WANs).
- Local-Area Networks (LANs) etc.

—o—

1.5 The electromagnetic Spectrum

*. The electromagnetic waves are signals that oscillate. i.e. the amplitudes of electric & magnetic fields vary at a specific rate. Vary "Sinusoidally."

*. Their "frequency" is measured in "cycles per Second" (CPS) or "hertz" (HZ).

#. These oscillations may occur at a very low frequency or at an extremely high frequency. The range of electromagnetic signals encompassing all frequencies is referred to as the → "Electromagnetic Spectrum".

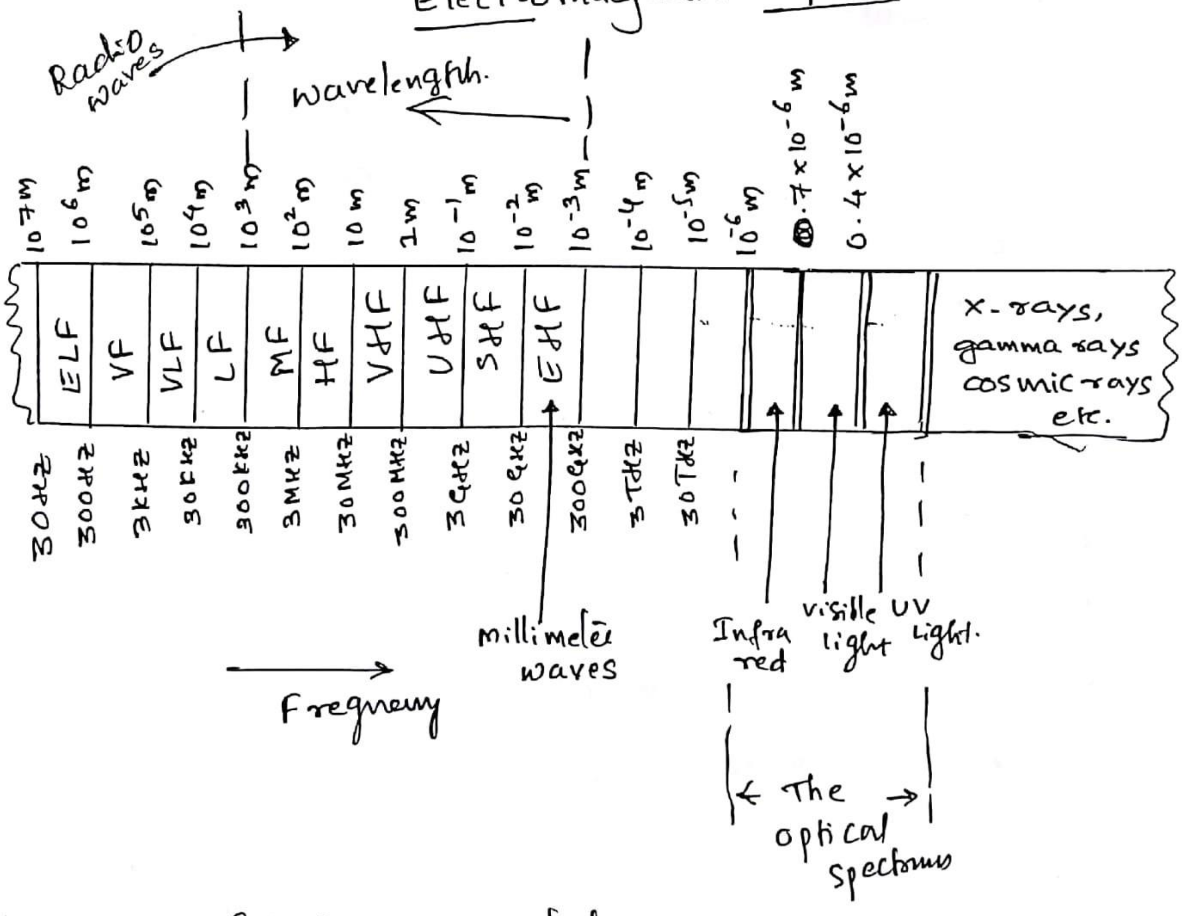


Fig (7) : The electromagnetic spectrum.

#. Fig (7) shows the entire electromagnetic spectrum, giving both frequency & wavelength.

#. Within the middle ranges are located the most commonly used 'radio' frequencies for two-way communication.

Ex: TV, cellphones, radar etc appln.

#. At the upper end of spectrum are infrared & visible light.

Figure(8): The electromagnetic spectrum used in electronic comm.

Name	Frequency	Wavelength.
Extremely low frequencies	30-300Hz	$10^7 - 10^6$ m
Voice frequencies	300- 3KHz	$10^6 - 10^5$ m
Very low frequencies	3 - 3KHz	$10^5 - 10^4$ m.
Low frequencies	30-30KHz	10^4 10^3 m.
Medium frequencies	300KHz - 3MHz	$10^3 - 10^2$ m
High frequencies	3-30MHz	$10^2 - 10^1$ m
Very high frequencies	30-300MHz	$10^1 - 1$ m.
Ultra high frequencies	300MHz - 3GHz	$1 - 10^{-1}$ m
Super high frequencies	3-30GHz	$10^{-1} - 10^{-2}$ m
Extremely high frequences	30-300GHz	10^{-2} 10^{-3} m.
Infrared	—	0.7-10 μm
The visible light	—	0.4-0.8 μm.

#. Frequency & Wavelength :—

1) Frequency :—

→. Frequency is the number of times a particular phenomenon occurs in a given period of time.

→. In electronics, It is the number of cycles of a repetitive wave that occurs in a given time period.

→. A cycle consists of two voltage/current polarity reversals or electromagnetic field oscillations.

→. It is measured in "cycles per second (cps)." In electronics, the 'Unit of frequency' is "hertz". named for German physicist "Heinrich Hertz".

→. One cycles per second = 1 hertz.

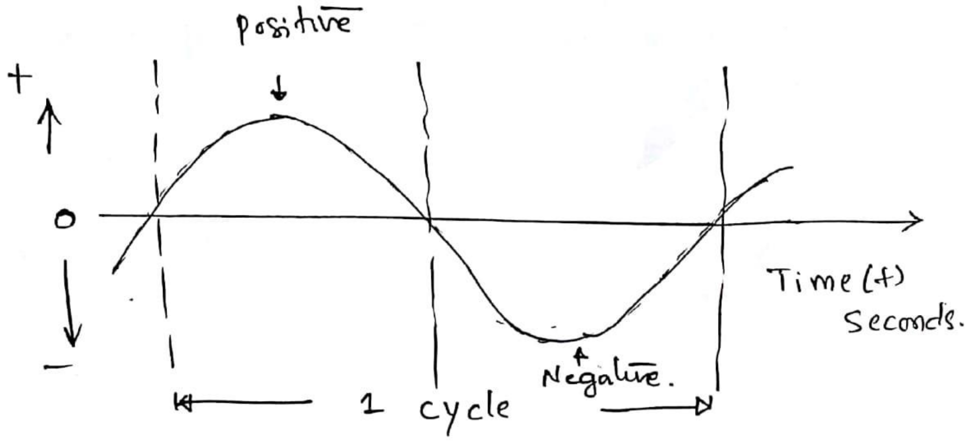


Fig (9) : Frequency (one - cycle). of a Sine wave.

#. Fig (9) shows a sine wave variations of Voltage, one positive & one negative alternation form a cycle.

Ex: If 2500 cycles occur in 1s, the frequency is 2500Hz.

#. Prefixes representing powers of 10 are often used to express frequencies.

$K = kilo = 10^3$
$M = mega = 10^6$
$G = giga = 10^9$
$T = tera = 10^{12}$

Ex: $1000\,Hz = 1\,kHz$, $9,000,000\,Hz = 9\,MHz$ etc.

2>. **Wavelength :—**

"wavelength" is the distance occupied by one cycle of a wave, & its expressed in "meters".

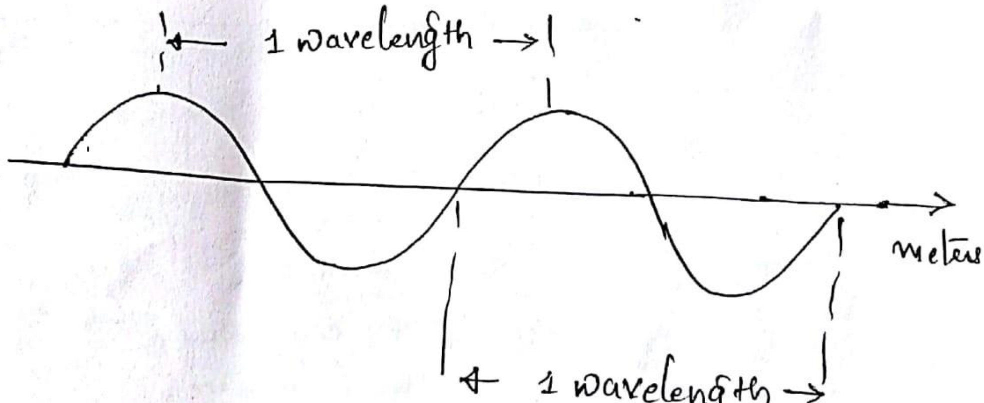


Fig (10): One wavelength.

#. Wavelength is measured b/w identical points on succeeding cycles of a wave. as in fig (10).

Scanned by CamScanner

#. If the signal is an electromagnetic wave, one wavelength is distance that one cycle occupies in free space.

#. It is the distance b/w adjacent peaks or valleys of the electric & magnetic field making up the wave.

#. Wavelength is also distance travelled by an electromagnetic wave during the time of one cycle.

#. Electromagnetic waves travel at the speed of light 2,99792,800 m/s ≃ 300,000,000 m/s (3×10^8 m/s).

#. The wavelength of a signal, is represented by 'λ' (lamda).

$$\lambda = \frac{300,000,000}{f\ (Hz)} \quad — ①.$$

#. If the frequency is expressed in megahertz, the formula can be simplified to

$$\lambda\ (m) = \frac{300}{f\ (MHz)} \quad — ②.$$

#. Very high frequency wavelengths are sometimes expressed in centimeters (cm).

Ex 1.

Find the wavelengths of

(a) 150 MHz (b) 430 MHz (c) 8 MHz

(d) 750 KHz.

soln:

(a) $\lambda = \frac{3\times10^8}{150\times10^6} = 2m.$

$\because \lambda = \frac{c}{f}.$

$c = 3\times10^8$ m/s

(b) $\lambda = \cancel{\frac{430\times10^6}{150\times10}}$ $\frac{3\times10^8}{430\times10^6} = 0.697m.$

(c) $\lambda = \frac{3\times10^8}{8\times10^6} = 37.5\,m$

(d) $\lambda = \frac{3\times10^8}{750\times10^3} = 400m.$

Ex 2:

A signal with a wavelength of 1.5m has frequency of.

Given: $\lambda = 1.5m$, $c = 3\times10^8$ m/s $f = ?$

w.r.t.

$\lambda = \frac{c}{f}. \Rightarrow f = \frac{c}{\lambda} = \frac{3\times10^8}{1.5m}$

$f = 200MHz.$

Ex 3:

A signal travels a distance of 75 ft in the time it takes to complete 1 cycle. What is its frequency?

soln: $\boxed{1\,m = 3.28\,ft.}$

$$\frac{75\,ft}{3.28\,ft} = 22.86\,m.$$

Now $f = \frac{3 \times 10^8}{22.86.} = \underline{13.123\ MHz.}$

Ex. 4:

The maximum peaks of an electromagnetic wave are separated by a distance of 8 in. What is the frequency in megahertz? in gigahertz?

soln: $\boxed{1\,m = 39.37\,inch}$

$$\frac{8}{39.37} \Rightarrow 0.203\,m.$$

Now,

$$f = \frac{3 \times 10^8\ m/s}{0.203\ m} = \underline{1.477\ GHz}$$

$$f = 1477.8 \times 10^6\ Hz$$
$$= 1477.8\ MHz.$$

Frequency Ranges from 30Hz to 300GHz & its applications :

1). Extremely Low Frequencies : 30 - 300Hz.

*. AC power line frequencies (50-60Hz).

2). Voice frequencies : 300 - 3000Hz.

*. Normal range of human speech.

3). Very low Frequencies : 9KHz - 30KHz.

*. Radio transmission used by the Navy to communicate with Submarines.

*. Few musical instruments sounds in this range.

4). Low Frequencies : 30 - 300 KHz.

*. Aeronautical & marine commn.

5). Medium Frequencies : 300 - 3000 KHZ (0.3 to 3MHz).

*. AM radio broadcasting (535KHz - 1605KHz
*. Amateur radio communication.

6). High Frequencies : 3MHz - 30 MHz.

*. Simplex, Half duplex two-way radio commn
*. Govt uses in diplomatic commn b/w embassie

7). Very High Frequencies : 30 MHz - 300 MHz.

*. Mobile radio, marine & aeronautical commn.
*. FM radio broadcasting (88 - 108 MHz).

8). Ultra high Frequencies : 300 MHz - 3000 MHz.

*. Land mobile communication & services i.e cellular telephones.

*. Some radar & navigation services occupy this portion of spectrum.

9). Microwaves & SHF's : 1000 MHz - 30 GHz.

*. Microwave Ovens = 2.45 GHz

*. SHF's for satellite communication & radar.
*. wireless local-area networks & cellular phones.

10). Extremely High frequencies (30 GHz - 300 GHz)

*. Satellite commn, telephony, special radars.

11). Frequencies b/w 300 GHz & Optical spectrum :

1). Infrared : 0.1 mm to 700 nm

*. Astronomy to detect stars.
*. Guiding missiles to targets.
*. TV remote.

↳. Visible spectrum (or ordinary light).

0.4 μm – 0.8 μm.

*. Are expressed in angstroms (Å).

$1 \text{Å} = 10^{-10}$ m.

*. Light is used for various kinds of communication
→. fiber transmission.
→. Free space transmission.
→. Lasers – modulating voice, video, data info.

12). Ultraviolet (UV). ⇒ 4 nm – 400 nm.

*. Not used for communication.
primary use is Medical.

*. x-ray, gamma rays etc.

—o—

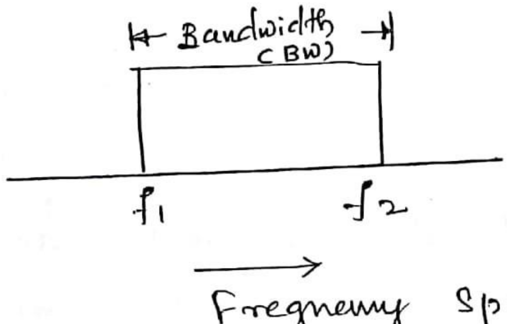
Scanned by CamScanner

#. 3 BANDWIDTH :

*. Bandwidth (BW) is that portion of the electro-magnetic spectrum occupied by a signal.

*. It is also the frequency range over which a receiver or other electronic circuit operates.

*. Bandwidth is the difference between the upper & lower frequency limits of the signal or the equipment operation range.



*. The upper frequency is 'f_2' & lower frequency is 'f_1'

The bandwidth is.

$$\boxed{BW = f_2 - f_1} \quad \rightarrow *.$$

Ex 1: A commonly used frequency range is 902 to 928 MHz, What is the width of this band?

$f_1 = 902\,MHz$, $\quad f_2 = 928\,MHz$.

$BW = f_2 - f_1 \quad = 928 - 902 = \underline{\underline{26\,MHz}}$

Ex 2:

A television signal occupies a 6MHz bandwidth. If low-frequency limit of channel 2 is 54MHz. what is the upper-frequency limit ?

soln:

$BW = 54MHz$, $f_1 = 6MHz$

$BW = f_1 - f_2$

$f_2 = BW + f_1$

$= 6 + 54 = 60MHz$.

—o—

#. Channel Bandwidth :-

*. when information is modulated onto a carrier somewhere in the electromagnetic spectrum, the resulting signal occupies a small portion of the spectrum surrounding the carrier frequency. These are called as "side bands".

Ex:- In AM broadcasting, audio signal up to 5KHz can be transmitted. If the carrier frequency is 1MHz (1000kHz). & modulating frequency is 5KHz.

Then side bands will be at

$1000 - 5 = 995 kHz$

&

$1000 + 5 = 1005 kHz$

P.T.O

⇒. The term "channel Bandwidth" refers to the range of frequencies required to transmit the desired information.

so, BW of AM signal described above is

$$BW = 1005 - 995 = 10 \text{ kHz.}$$ —*.

therefore, signal takes up a 10kHz piece of the spectrum.

Spectrum Management :-

*. The Federal Communications commission (FCC), is a regulatory body whose function is to allocation of spectrum space, issue licenses, set standards & police the airwaves. Controls all telephone & radio communication in United states.

*. The International Telecommunications Union (ITU) an agency of the United nations, including 189 member countries.

The ITU brings together the various countries to discuss how the frequency spectrum is to be divided up & shared.

Standards :

→. standards are specifications & guidelines that companies & individuals follow to ensure compatibility b/w transmitting & receiving equipment in communication system.

→. There must be "interoperability" b/w the equipment from one manufacturer to work with that of another.

→. standards are detailed outlines of principles of operation, blueprint of construction, & methods of measurement that define common equipment.

→. List of organizations that maintain standards for comm Systems.

1→. American National Standards Institute (ANSI).
2→. Electronic Industries Alliance (EIA).
3→. European Telecommunication standards Institute (ETSI).
4→. Institute of Electrical & Electronics Engineers. (IEEE).
5→. Internet engineering task force (IETF).
6→. Optical Internetworking Forum (IF).

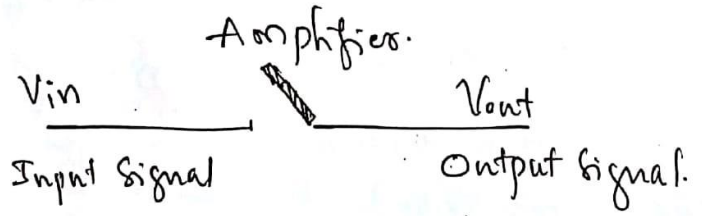
—o—

1.6. Gain, Attenuation, & Decibels

*. Most electronic circuits in communication are used to process signals. i.e to manipulate signals to produce a desired result. All signal processing circuits involve either gain or attenuation.

1. GAIN :-

*. 'Gain' means amplification. If a signal is applied to a circuit such as the amplifier shown in below fig (11).



$$A = gain = \frac{V_{out}}{V_{in}}$$

Fig (11): An amplifier has gain.

*. The output of the circuit has a greater amplitude than the input signal, the circuit has gain.

* Gain is simply the ratio of the output to the input.

P.T.O.

#. Voltage gain A_v is expressed as follows

$$A_v = \frac{\text{output}}{\text{input}} = \frac{V_{out}}{V_{in}} \quad -(1).$$

Ex: If the input is $150\mu V$, the output is $75mV$.

$$A_V = \frac{75 \times 10^{-3}}{150 \times 10^{-6}} = 500.$$

#. $V_{out} = A_v \times V_{in} \quad -(2).$

$$V_{in} = \frac{V_{out}}{A_v} \quad -(3).$$

Ex: If the output is $0.6V$ & the gain is 240, the input is $V_{in} = \frac{0.6}{240} = 2.5mV$.

1. what is the voltage gain of an amplifier that produces an output of 750mV for a $30\mu V$ input?

soln: $V_o = 750mV$, $V_{in} = 30\mu V$, $A_V = ?$

$$A_V = \frac{V_{out}}{V_{in}} = \frac{750 \times 10^{-3} V}{30 \times 10^{-6} V} = 25{,}000.$$

Q> The power output of an amplifier is 6 watts (W). The power gain is 80. What is the input power?

Sol^n: $P_{out} = 6W$. $P_{in} = ?$ A_p = power gain $= 80$.

$$A_p = \frac{P_{out}}{P_{in}}, \quad P_{in} = \frac{P_{out}}{A_p}$$

$$P_{in} = \frac{6W}{80} = 0.075W \approx \underline{75}mW.$$

—o—

Total gain of cascaded circuits :-

When two or more stages of amplification or other forms of signal processing are cascaded, the overall gain of the combination is the
the overall gain of the individual circuit gains.
product of the

$V_{in} = 1mV$ → $5mV$ → $15mV$ → $V_{out} = 60mV$

$A_1 = 5$ $A_2 = 3$ $A_3 = 4$

$$A_T = A_1 \times A_2 \times A_3 = 5 \times 3 \times 4 = 60.$$

1. Three cascaded amplifiers have power gains of 5, 2, & 17. The input power is 40 mW what is the output power?

Soln: $A_p = A_1 \times A_2 \times A_3$

$= 5 \times 2 \times 17$

$= 170.$

$\Rightarrow A_p = \frac{P_{out}}{P_{in}}$, $P_{out} = A_p P_{in}$

$\Rightarrow P_{out} = 170 \times (40 mV)$

$= \underline{\underline{6.8 W}}.$

2. A two stage amplifier has an input power of 25 μW & an output power of 1.5 mW. One stage has a gain of 3. What is the gain of the second stage?

Soln: $\Rightarrow A_p = \frac{P_{out}}{P_{in}} = \frac{1.5 mW}{25 \mu W} = 60.$

$\Rightarrow A_p = A_1 \times A_2$

$60 = 3 \times A_2$

$\underline{\underline{A_2 = 20}}.$

∵ Two stage & one stage = 3.

Attenuation:-

*. Attenuation refers to a loss introduced by a circuit or component.

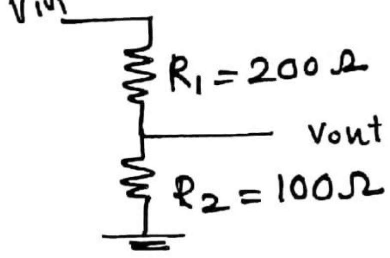
*. Many electronic circuits, sometimes called stages, reduce the amplitude of a signal rather than increase it. If the output is lower than the input, the circuit has loss or attenuation.

*. Attenuation is the ratio of the output to the input. the letter A is used to represent attenuation as well as gain:

$$\text{Attenuation } A = \frac{\text{output}}{\text{input}} = \frac{V_{out}}{V_{in}} \quad - (*).$$

*. Circuits that introduce attenuation have a gain that is less than 1.

EX:-



$$V_{out} = V_{in}\left(\frac{R_2}{R_1+R_2}\right).$$

"Voltage divider"

Example shows the voltage divider introduces attenuation.

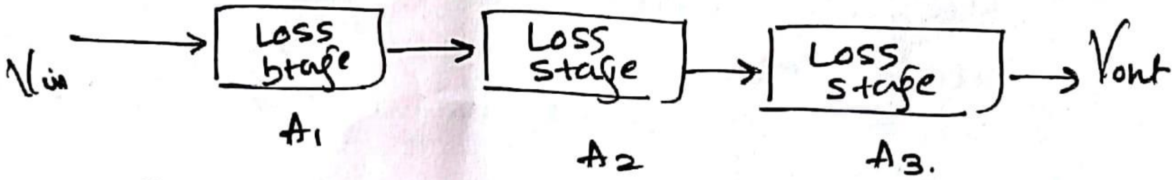
$$A = \frac{R_2}{R_1+R_2} = \frac{100}{100+200} = 0.3333.$$

If 10V applied to the circuit, the output is

$$V_{out} = V_{in} \cdot A = 10 \times 0.333 = \underline{3.33V}.$$

#. When several circuits with attenuation are cascaded, the total attenuation is, again the product of individual attenuation.

Ex:



Suppose $V_{in} = 3V$, $A_1 = 0.2$, $A_2 = 0.9$

$A_3 = 0.06$

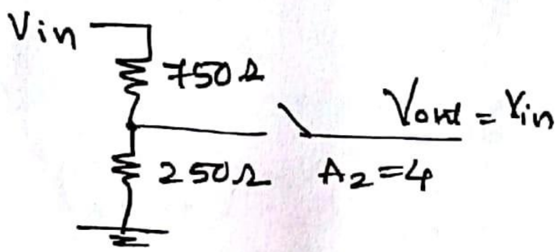
$A_T = A_1 \times A_2 \times A_3 = 0.2 \times 0.9 \times 0.06$

$A_T = 0.0108$.

$V_{out} = A_T V_{in} = 0.0108 \times 3$

$= \underline{0.0324} = 32.4 \, mV$.

Ex:



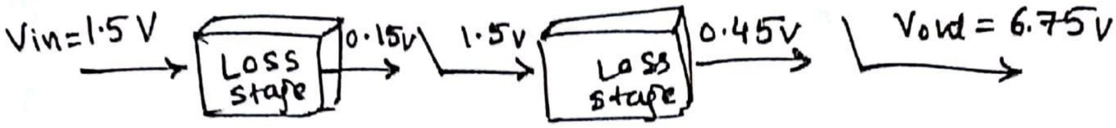
$$A_1 = \frac{250}{750 + 250} = 0.25$$

$A_2 = 4$, $A_T = A_1 \times A_2 = 0.25 \times 4 = \underline{1}$

From above example, Voltage divider introduces an attenuation of 0.25. To offset this, it is followed with an amplifier whose gain is 4. The overall gain or attenuation of the circuit is now $\underline{1}$.

Scanned by CamScanner

Ex 3:



$A_1 = 0.1$ $\quad A_2 = 10$ $\quad A_3 = 0.3$ $\quad A_4 = 15$

Example shows two attenuation circuits & two amplifier circuits. The overall gain is

$$A_T = A_1 \cdot A_2 \cdot A_3 \cdot A_4$$

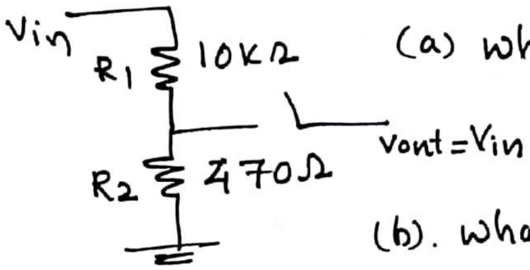
$$= 0.1 \times 10 \times 0.3 \times 15$$

$$A_T = 4.5$$

Now. For an input voltage of 1.5 V, the output voltage is

$V_{in} = 1.5V$, $A_T = 4.5$, $V_o = 1.5 \times 4.5 = \underline{6.75\text{ V}}$.

Ex 4:



(a) what is the attenuation?

(b). what amplifier gain would you need to offset the loss for an overall gain of 1?

soln:

a).

$$A_1 = \frac{R_2}{R_1 + R_2} = \frac{470\Omega}{10K\Omega + 470\Omega} = 0.045$$

b).

$$A_T = A_1 \cdot A_2$$

where A_1 = attenuation, A_2 = gain

$1 = 0.045 \times A_2$, $\quad A_2 = \frac{1}{0.045} = 22.3$

Ex 5:

An amplifier has a gain of 45,000, with an input voltage of 20μV. What attenuation factor is needed to keep the output voltage from exceeding 100 mV?

Let A_1 = Amplifier gain, A_2 = attenuation factor

A_T = total gain.

Soln:

$$A_T = \frac{V_{out}}{V_{in}} = \frac{100 \times 10^{-3}}{20 \times 10^{-6}} = 5,000$$

$$A_T = A_1 \times A_2$$

therefore $A_2 = \frac{A_T}{A_1} = \frac{5,000}{45,000} = 0.1111$

—o—

Decibels :—

→ The gain or loss of a circuit is usually expressed in "decibels" (dB).

→ A decibel is one-tenth of a bel.

→ when gain & attenuation are both converted to decibels, the overall gain or attenuation of an electronic circuit can be computed by simply adding gains or attenuations, expressed in decibels.

Decibel calculation :—

The formulas for computing the decibels gain or loss of a circuit are.

$$dB = 20 \log \frac{V_{out}}{V_{in}} \quad —(1).$$

$$dB = 20 \log \frac{I_{out}}{I_{in}} \quad —(2).$$

$$dB = 10 \log \frac{P_{out}}{P_{in}} \quad —(3).$$

*. Formula (1) is used for expressing the Voltage gain or attennation of a circuit. formula (2) for current gain or attennation. Formula (3) is used to compute power gain or attenuation.

P.T.O.

Ex 1:

An amplifier has an input of 3mV & an output of 5V. what is the gain in decibels?

soln: $V_{in} = 3mV$. $V_{out} = 5V$.

$$dB = 20 \log \frac{V_{out}}{V_{in}} = 20 \log \frac{5V}{3mV}$$

$$dB = \underline{64.43 dB}.$$

Ex 2:

A filter has a power input of 50mW & an output of 2mW. what is the gain or attenuation?

soln: $P_{in} = 50mW$. $P_{out} = 2mW$.

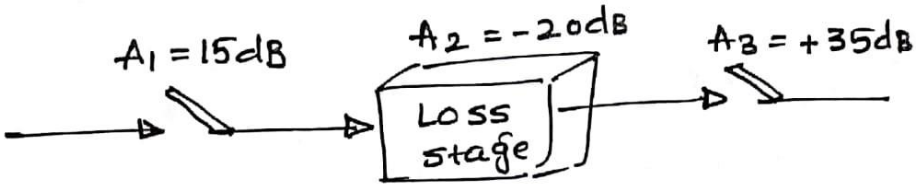
$$dB = 10 \log \frac{2mW}{50mW} = \underline{-13.98 dB}$$

#. Note that when the circuit has gain, the decibels figure is positive.

If the gain is less than 1, which means that there is an attenuation. the decibel figure is negative.

#. Now, to calculate the overall gain or attenuation of a circuit or system, ~~you~~ simply add the decibel gain & attenuation factors of each circuit. An example is shown in fig shown

P.T.O.



Two gain stages & an attenuation block.

→ the overall gain of the circuit.

$$A_T = A_1 + A_2 + A_3 = 15 - 20 + 35$$

$$A_T = 30dB.$$

#. Decibels are widely used in the ~~the~~ expression of gain & attenuation in communication system./circuits.

#. Antilogs :—

To calculate the input or output voltage or power, given the decibel gain or attenuation & the output or input, the antilog is used.

The antilog is the number obtained when the base is raised to the logarithm. which is the exponent:

$$dB = 10 \log_{10} \frac{P_{out}}{P_{in}} \quad \& \quad \frac{dB}{10} = \log \frac{P_{out}}{P_{in}}$$

$$\frac{P_{out}}{P_{in}} = \text{antilog} \frac{dB}{10} = \log^{-1} \frac{dB}{10}$$

The antilog is simply the base 10 raised to the dB/10 power.

*: $N = 10^y$ & $y = \log N$.

Ex 1:

A power amplifier with a 40dB gain has an output power of 100W. what is the input power.

soln: Gain = 40 dB, Vout = 100W.

$$dB = 10 \log \frac{P_{out}}{P_{in}}$$

$$\frac{dB}{10} = \log \frac{P_{out}}{P_{in}}$$

$$\frac{40}{10} = \log \frac{P_{out}}{P_{in}}$$

$$\frac{P_{out}}{P_{in}} = \log^{-1} 4$$

$$\frac{P_{out}}{P_{in}} = 10,000$$

$$P_{in} = \frac{P_{out}}{10,000} = \frac{100}{10,000} = 0.01W$$

or

10mW

Scanned by CamScanner

Ex 2.

An amplifier has a gain of 60dB. If the input voltage is 50μV. what is the output voltage?

Sol: Since.

$$dB = 20 \log \frac{V_{out}}{V_{in}}$$

$$\frac{dB}{20} = \log \frac{V_{out}}{V_{in}}$$

$$\frac{V_{out}}{V_{in}} = \log^{-1} \frac{dB}{20}$$

$$= \log^{-1} \frac{60}{20} \quad \text{or} \quad 10^{60/20}$$

$$\frac{V_{out}}{V_{in}} = 1000$$

$$V_{out} = 1000 \times 50\mu V = 0.05\,V \approx \underline{50mV}.$$

—o—

dBm:–

When the gain or attenuation of a circuit is expressed in decibels, implicit is a comparison b/w two values, the output & the input.

When an absolute value is needed, can use a "reference value" to compare any other value.

An often used reference level in communication is 1mW. when a decibel value is computed by comparing a power value to 1mW, the value called the "dBm".

It is computed with the standard power decibel formula with 1mW as the denominator of the ratio :

$$dBm = 10 \log \frac{P_{out}(W)}{0.001(W)}.$$

Ex :

The output of a 1-W amplifier expr in dBm is

$$dBm = 10 \log \frac{1}{0.001} \Rightarrow 10 \log 1000$$

$$\Rightarrow 30 dBm$$

Ex: If a microphone has an output of -50dBm, the actual output power can be computed as follows:

$$-50dBm = 10 \log_{10} \frac{P_{out}}{0.001}$$

$$-\frac{50}{10} = \log_{10} \frac{P_{out}}{0.001}$$

$$\frac{P_{out}}{0.001} = 10 \times 10^{-6}$$

$$P_{out} = 10 \times 10^{-6} \times 0.001$$

$$= 10 \times 10^{-9} W \approx \underline{10nW}$$

bel

Ex :

A power amplifier has an input of 90mV across 10kΩ. The output is 7.8V across an 8-Ω speaker. What is the power gain, in decibels?

Soln: $P = \frac{V^2}{R}$

$$P_{in} = \frac{(90 \times 10^{-3})^2}{10k\Omega} = 8.1 \times 10^{-7} W$$

$$P_{out} = \frac{(7.8)^2}{8\Omega} = 7.605 W$$

$$A_p = \frac{P_{out}}{P_{in}} = \frac{7.605}{8.1 \times 10^{-7}} = 9.39 \times 10^6$$

$$A_p(dB) = 10 \log A_p = 10 \log (9.39 \times 10^6).$$

$$= 69.7 dB$$

—o—

dBc :—

This is a decibel gain attenuation figure where the reference is the carrier. The carrier is the base communication signal, a sine wave that is modulated. Often the amplitude's sidebands, spurious or interfering signals, are referenced to the carrier.

P.T.O.

Ex: If the Spurious Signal is 1mW compared to the 10-W carrier, the dBC is

$$dBc = 10 \log \frac{P_{signal}}{P_{carrier}}$$

$$= 10 \log \frac{0.001}{10}$$

$$= 10(-4)$$

$$= -40$$

Ex: An amplifier has a power gain of 28dB. the input power is 36mW. what is the output power?

Soln: $A_p = 28dB$. $P_{in} = 36mW$.

$$\frac{P_{out}}{P_{in}} = 10^{dB/10}$$

$$\frac{P_{out}}{P_{in}} = 10^{28/10} \Rightarrow P_{out} = 630.95 \times p_{in}$$

$$P_{out} = \underline{22.71\ W}$$

Ex: A circuit consists of two amplifiers with gains of 6.8 & 14.3dB & two filters with attenuations of -16.4 & -2.9dB. If the output voltage is 800mV. what is the input voltage?

P.T.O.

Soln:

$$A_T = A_1 + A_2 + A_3 + A_4$$

$$= 6.8 + 14.3 - 16.4 - 2.9$$

$$= \underline{\underline{1.8\,dB}}.$$

$$A_T = \frac{V_{out}}{V_{in}} \Rightarrow 10^{dB/10}$$

$$= 10^{-1.8/10}$$

$$= 10^{0.09}$$

$$\frac{V_{out}}{V_{in}} = 1.23 \quad , \quad V_{in} = \frac{V_{out}}{1.23} = \frac{800m}{1.23} = \underline{\underline{650.4\,mV}}.$$

Ex:

Express $P_{out} = 12.3\,dBm$ in Watts.

$$\frac{P_{out}}{0.001} = 10^{dBm/10}$$

$$= 10^{12.3/10}$$

$$\frac{P_{out}}{0.001} = 16.98$$

$$P_{out} = 16.98 \times 0.001$$

$$= \underline{\underline{16.98\,mW}}.$$

—o—