Analog & Digital Communications

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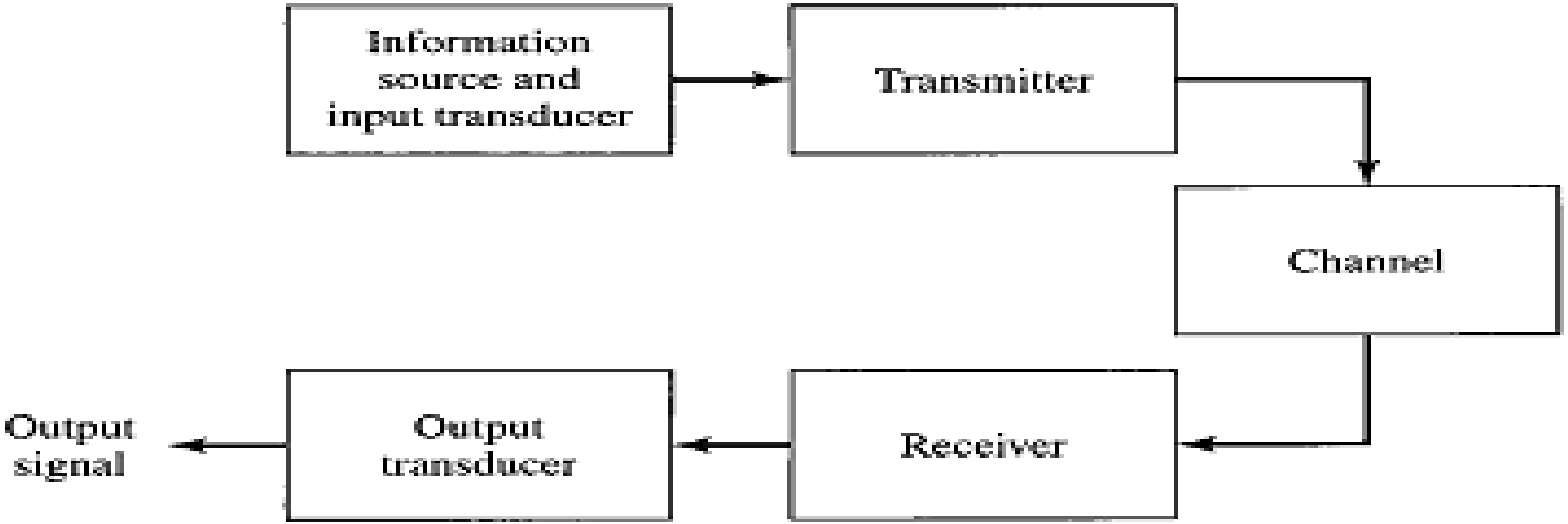
UNIT- III

Transmitters & Receivers

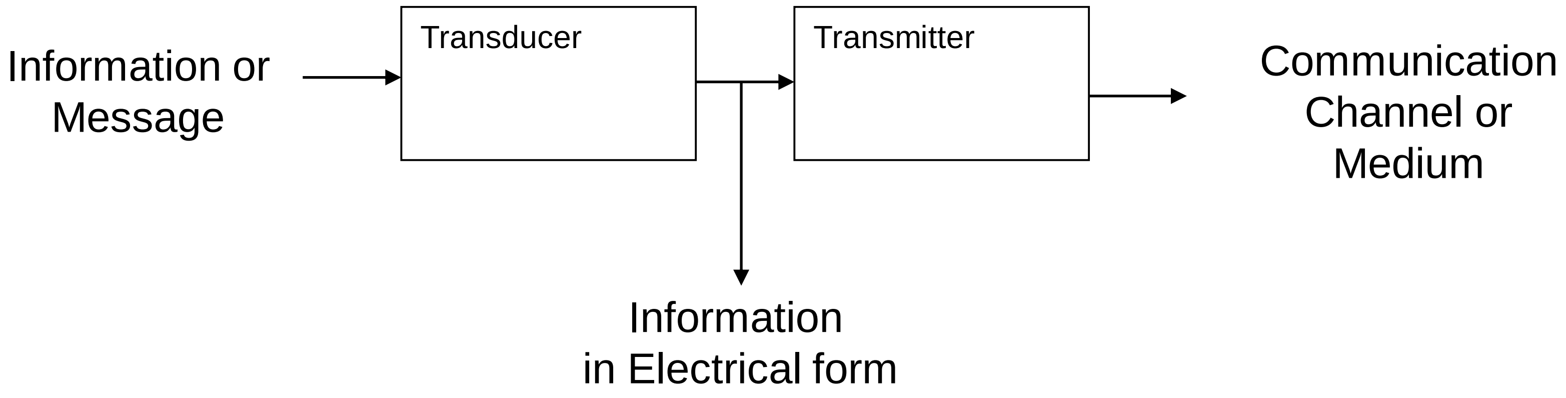
Contents

- **Transmitters:** Classification of Transmitters, AM Transmitters, FM Transmitters.
- **Receivers:** Radio Receiver - Receiver Types - Tuned radio frequency receiver, Superheterodyne receiver, RF section and Characteristics - Frequency changing and tracking, Intermediate frequency, Image frequency, AGC, Amplitude limiting, FM Receiver, Comparison of AM and FM Receivers.

Block diagram of communication system

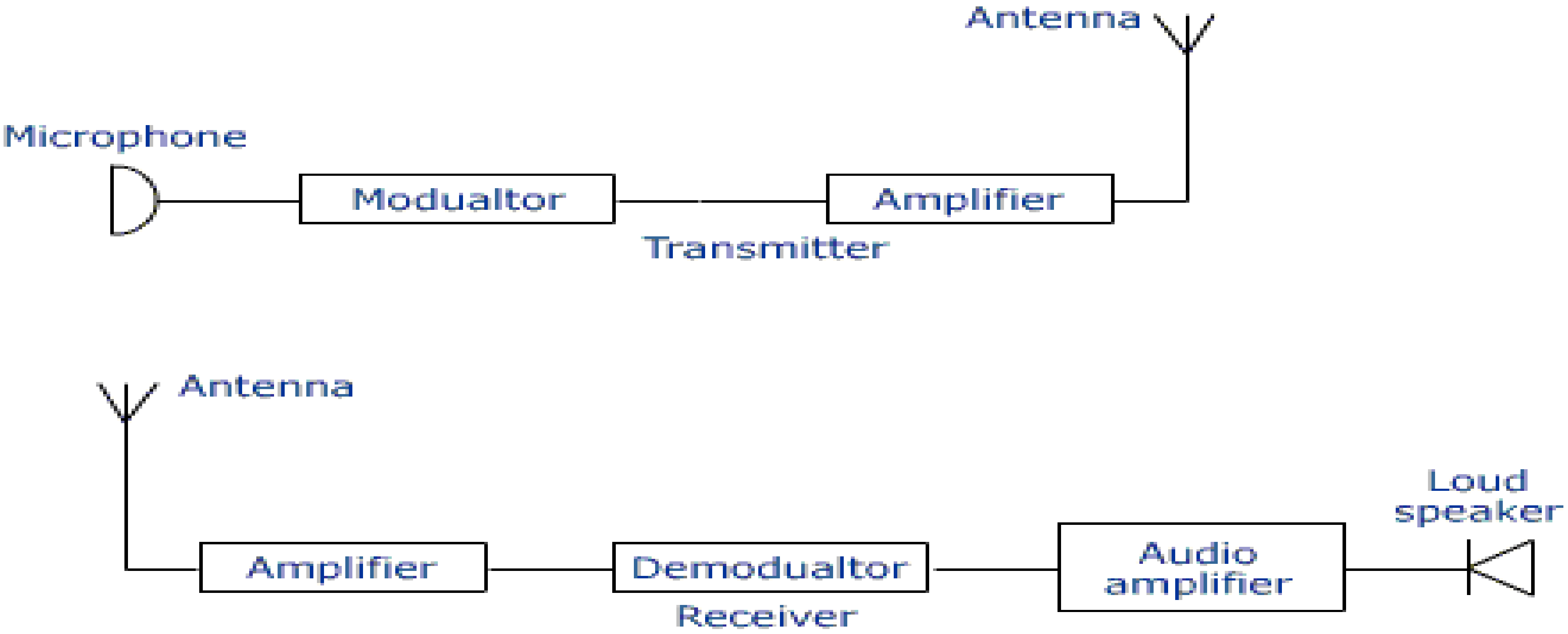


TRANSMITTER



- It takes the information to be communicated in electrical form and convert it into an electronic signal compatible with the communication medium .

- In this block diagram of communication system, the upper section is called the transmitting section and Lower section is Receiver.



TRANSMITTER

- The main parts of transmitter are

Microphone : It converts sounds into electrical signals in wires. It is the opposite of a loudspeaker.

Modulator : The audio signal is modulated into the radio frequency carrier in this modulator stage.

Frequency generator : The frequency generation stage will decide the frequency on which the transmitter will operate.

RF power amplifier : The power amplification of the radio signal is carried out in the final stage. It makes the signal stronger so that it can be transmitted through the channel over long distances.

An **antenna** is a transducer which converts electrical signals into electromagnetic waves.

BASIC FUNCTIONS OF TRANSMITTER

- Modulation
- Carrier generation
- Amplification (Power)

Every transmitter has three basic functions as follows:

The transmitter must generate a signal of correct frequency at a desired point in the spectrum.

Secondly it must provide some form of modulation to modulate the carrier.

Third it must provide sufficient power amplification in order to carry the modulated signal to a long distance.

CLASSIFICATION OF RADIO TRANSMITTERS

1. According to the type of modulation used.
2. According to service involved.
3. According to the frequency range involved.
4. According to the power used.

CLASSIFICATION BASED ON TRANSMITTED FREQUENCY

- Low frequency (LF) transmitters (30 KHZ- 300KHZ)
- Medium frequency (MF) transmitters (300 KHZ-3 MHZ)
- High frequency (HF) transmitters (3 MHZ- 30MHZ)
- Very high frequency (VHF) transmitters (30MHZ-300 MHZ)
- Ultra high frequency (UHF) transmitters (300 MHZ- 3GHZ)
- Microwave transmitters (>3GHZ)

CLASSIFICATION BASED ON TYPE OF SERVICE INVOLVED

- Radio broadcast transmitters.
- Radio telephony transmitters.
- Radio telegraph transmitters.
- Television transmitters.
- Radar transmitters.
- Navigational transmitters.

CLASSIFICATION BASED ON TYPES OF MODULATION

- CW Transmitters
- AM Transmitters
- FM Transmitters
- SSB Transmitters

CONTINIOUS WAVE (CW) TRANSMITTERS

- The CW Transmitter is the simplest type of transmitter.
- It is a simple crystal oscillator circuit.
- This oscillator generates a carrier signal of the desired frequency.
- Information to be transmitted is expressed in a special form of code using dots and dashes to represent letters of the alphabet and numbers.
- The information transmitted in this way is called as continuous wave (CW) transmission.

CONTINIOUS WAVE (CW) TRANSMITTERS

- The key is a simple hand operated switch connected in emitter of the transistor. By closing the key, we can turn on the crystal oscillator on and by opening the key the oscillator is turned off.
- When the key is closed, the oscillator produces a sinusoidal signal at a frequency equal to the crystal frequency, whereas with the key open, the output of oscillator is zero.
- The key is opened and closed in order to produce zero output and dots or dashes. Dots correspond to the short duration output whereas a dash corresponds to a long duration output.
- The required messages can be transmitted using different combinations of dots and dashes for different alphabets and letters.

ADVANTAGES OF CW TRANSMITTER

- Simple to construct
- Compact and portable
- Can be operated on batteries

Disadvantages

- A skilled operator is required to convert the message to be sent into a coded form of dots and dashes.
- Long distance communication is not possible.
- Voice or picture can not be sent.

AM TRANSMITTER

- Amplitude modulation technique is used in AM transmitters, here the amplitude of carrier is varied in proportion with the amplitude of the modulating signal, keeping its frequency and phase constant.

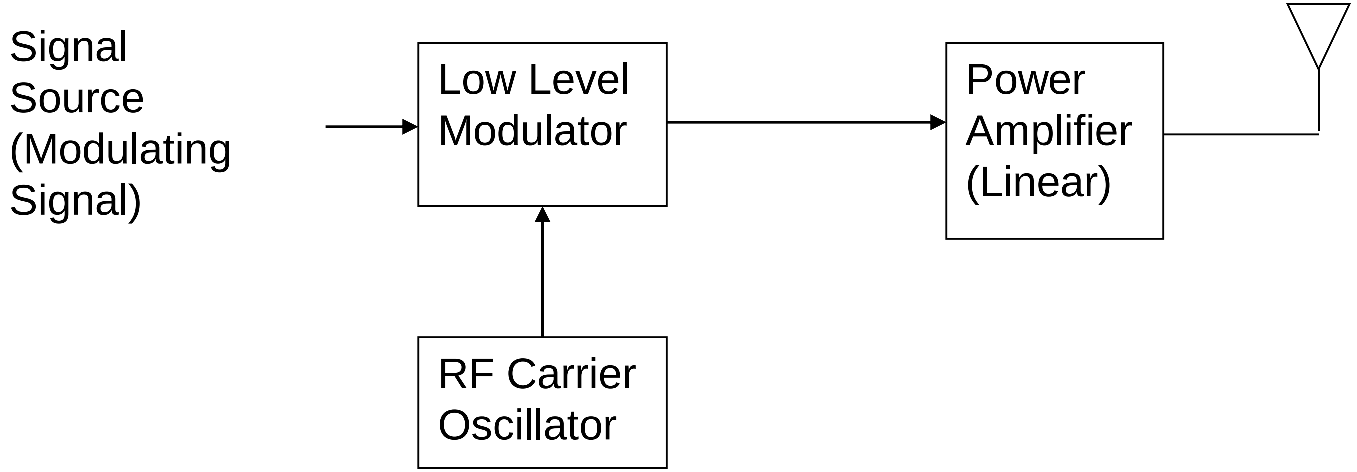
In AM Transmitter, AM signal is transmitted by a transmitter. The information is contained in its amplitude variation.

- Used in radio & TV broadcasting.

TYPES OF AM TRANSMITTERS

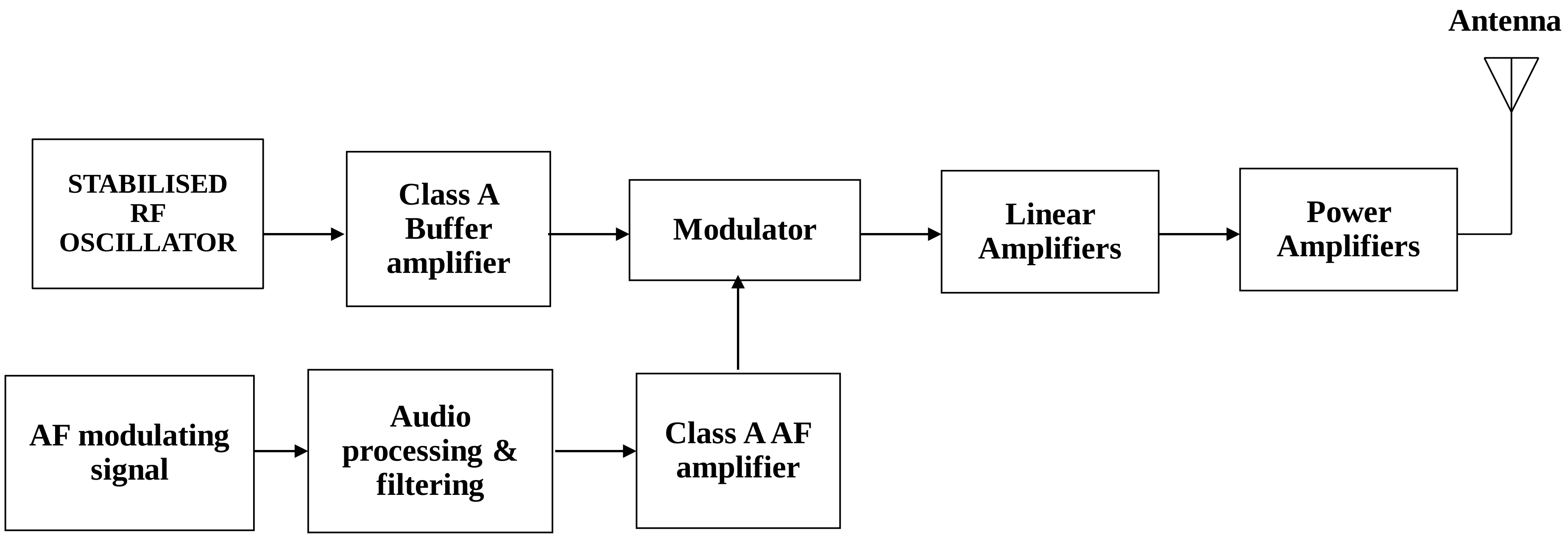
- Low Level modulation transmitters.
- High Level modulation transmitters.

LOW LEVEL MODULATION TRANSMITTERS



- The generation of AM wave takes place at a low power level.
- The generated AM signal is then amplified using a chain of linear amplifier (A , AB or B).

LOW LEVEL MODULATION TRANSMITTERS



LOW LEVEL MODULATION TRANSMITTERS

- The RF oscillator produces the carrier signal. The RF oscillator is stabilized in order to maintain the frequency deviation within the prescribed limit. The carrier frequency is equal to the transmitter frequency.
- Usually, the transmitter operates on assigned frequencies or channels. Crystal Oscillator provides the best way to obtain the described frequency with good stability.

LOW LEVEL MODULATION TRANSMITTERS

- We cannot use the LC oscillator because they have low frequency stability.
- The carrier signal from the crystal oscillator is applied to the modulator with a modulating signal. At the output of the modulator, we get the AM wave.
- The modulating signal is obtained from a source such as a microphone and applied to a buffer processing unit.
- The buffer is a class A amplifier which isolates the AF source from the rest of high-power circuit and amplifies it to an adequate level.

- The amplified modulating signal is applied to the modulator along with the carrier. At the output of the modulator, we get the AM wave.
- The AM signal is then amplified using a chain of linear amplifier to raise the power level.
- The linear amplifier can be class A, AB or B type amplifiers. The linear amplifier are used in order to avoid the wave form distortion in AM wave.
- The amplitude modulated signal is then transmitted using transmitted antenna.

- The transistorized modulator circuits can be used for low level modulator due to the low power which is to be handled.

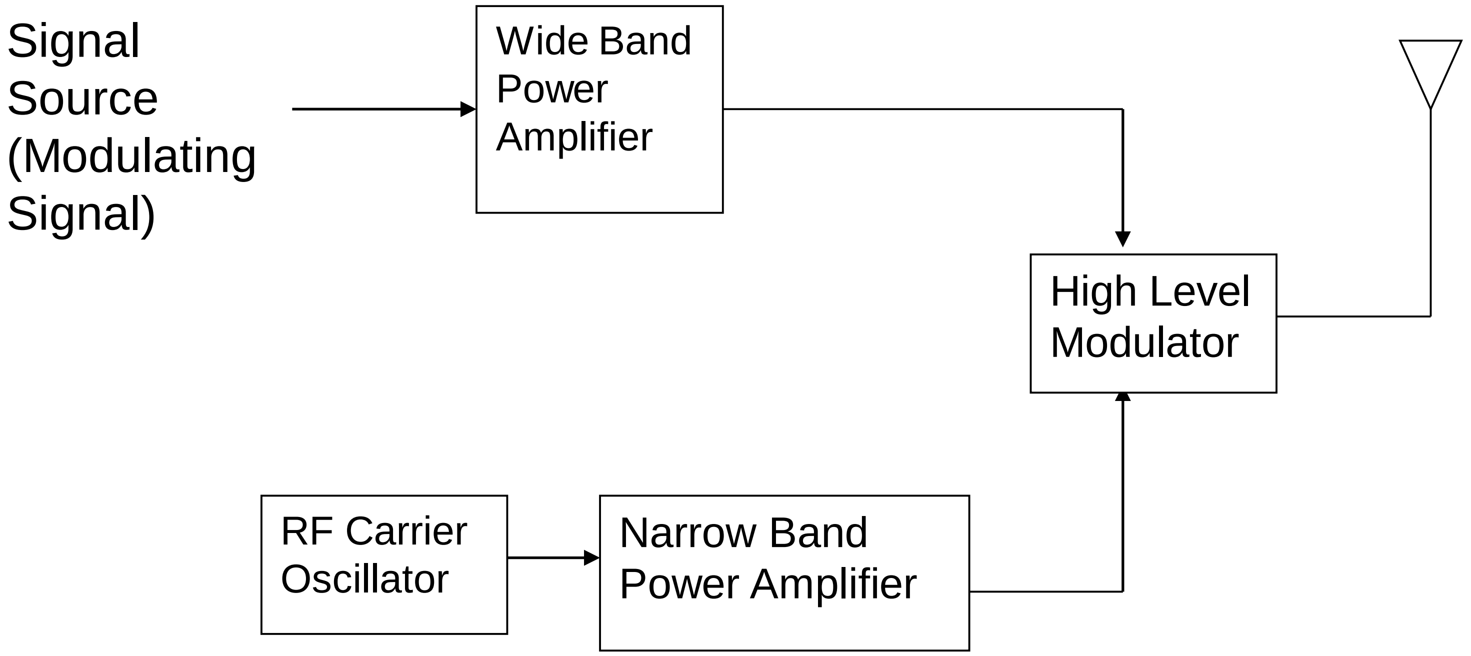
- The low-level transmitter does not require a large AF modulator power, so its design is simplified.

- Overall efficiency is much lower compared to high level modulation . This reduce to the use of less efficient linear amplifiers.

AUDIO PROCESSING

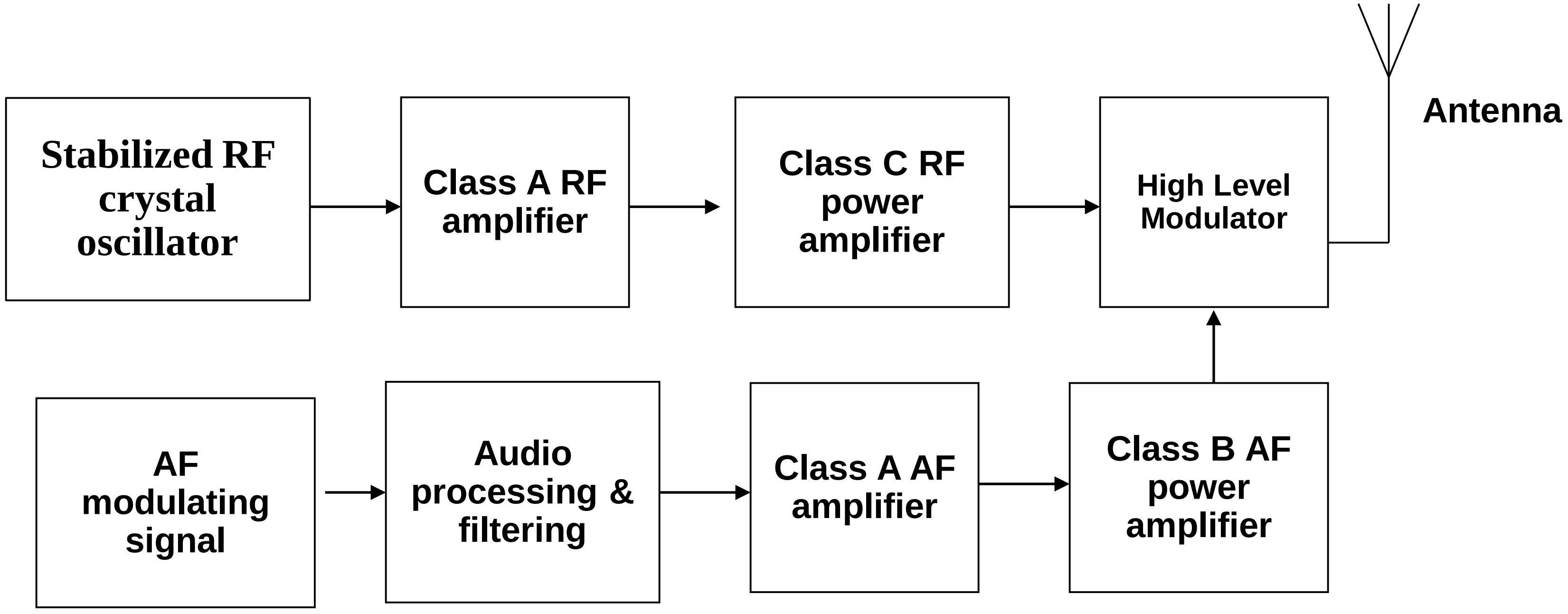
- The AF modulating signal is passed through an audio processing unit before applying it to the modulator.
- This block carries out some form of “speech processing” in the form of filtering and amplitude control.
- The weak signals amplified automatically with a higher gain and strong signals are amplified with smaller gain. This will bring all the signals to a sufficient level.

HIGH LEVEL MODULATION TRANSMITTERS



- The generation of AM wave takes place at high power levels.
- Highly efficient class C amplifier are used in high level modulation.
- Efficiency is more than low level modulation.

HIGH LEVEL MODULATION TRANSMITTERS



HIGH LEVEL MODULATION TRANSMITTERS

- Many of the AM transmitters use the high-level modulation technique.
- The crystal oscillator produces the required carrier signal. The class A amplifier following the oscillator acts as a buffer which isolates the oscillator from the high-power circuit.
- The output of this class A amplifier is applied to a class C power amplifier. It raises the power level of the carrier to an intermediately high value.
- The AF modulating signal is applied to the audio processing unit which processes this signal as discussed in the previous section.

COMPARISION BETWEEN LOW-LEVEL AND HIGH-LEVEL MODULATION

S. No	#	Low–Level Mod.	High-Level Mod.
1	Power level	Modulation is carried out at low power level	Modulation is carried out at high power level.
2	Amplifier stages	Need lesser amplifier stages.	Need more amplifier stages.
3	Power efficiency	After modulation linear amplifiers can only be used. This gives lower power efficiency.	Nonlinear amplifiers can also be used. This leads to higher power efficiency.
4	Power losses	Power losses in amplifiers is higher, the cooling problem is severe.	Power losses is less, the cooling problem is not severe.
5	Applications	Used as higher power broadcast transmitters.	Used in TV transmitters.

FM TRANSMITTER

In FM, frequency of the carrier is varied in proportion with the amplitude of the modulating signal keeping its amplitude constant.

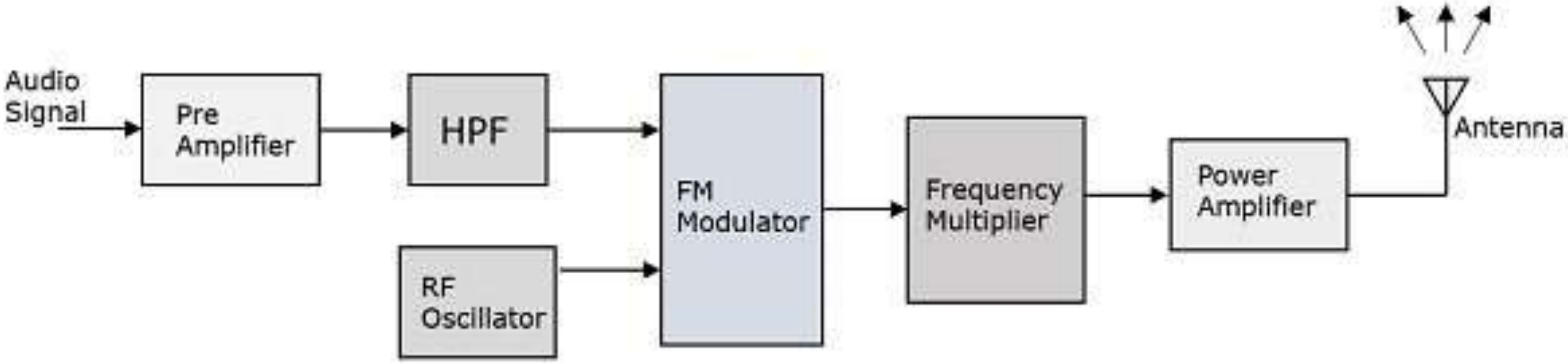
Used in radio, TV sound broadcasting & police wireless transmission.

In FM transmitter the FM signal is transmitted by a transmitter. The information is contained in its frequency variation.

The FCC has assigned a band of 20 MHz to the commercial FM broad cast service.

- FM band extends from 88 MHz to 108 MHz
- FM BW 20 MHz band is divided in 100 channels, each having a bandwidth of 200 KHz.
- For providing high quality reliable music the maximum frequency deviation allowed is 75 KHz, with a maximum modulating signal frequency of 15 KHz.

BD of FM TRANSMITTER



The working of FM transmitter can be explained as follows.

- The audio signal from the output of the microphone is sent to the pre-amplifier, which boosts the level of the modulating signal.

- This signal is then passed to high pass filter, which acts as a pre-emphasis network to filter out the noise and improve the signal to noise ratio.

- This signal is further passed to the FM modulator circuit.

- The oscillator circuit generates a high frequency carrier, which is sent to the modulator along with the modulating signal.

- Several stages of frequency multiplier are used to increase the operating frequency. Even then, the power of the signal is not enough to transmit.

- Hence, a RF power amplifier is used at the end to increase the power of the modulated signal. This FM modulated output is finally passed to the antenna to be transmitted.

COMPARISION OF AM AND FM BROADCASTING

S.No	AM Broadcast	FM Broadcast
1	It requires smaller transmission bandwidth.	It requires larger bandwidth.
2	It can be operated in low, medium and high freq. bands	It needs to be operated in very high and frequency bands.
3	It has wider coverage.	Its range is restricted to 50 km.
4	The demodulation is simple.	The process of demodulation is complex.
5	The stereophonic transmission is not possible.	In this, stereophonic transmission is possible.
6	The system has poor noise performance.	It has an improved noise performance.

AM Radio Receivers

- AM radio receiver is a device which receives the desired AM signal, amplifies it followed by demodulation to get back the original modulating signal.

Radio receivers are broadly of TWO types

1. Depending on the application: AM, FM, COMM.,TV, RADAR

2. Depending on the fundamental aspect/ principle

- Based on principle of operation, the TWO popular radio receivers are there, they are

  i. Tuned Radio Frequency **(TRF)** Receiver

  ii. Superheterodyne Receiver **(SHR)**

Tuned Radio Frequency (TRF) Receiver

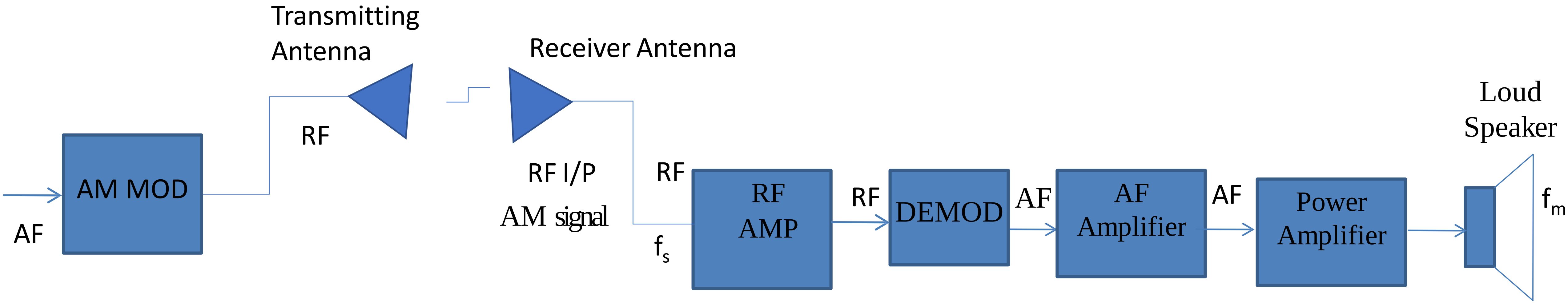


Figure: Functional Block diagram of **Tuned Radio Frequency (TRF) Receiver**

Tuned Radio Frequency(TRF) Receiver

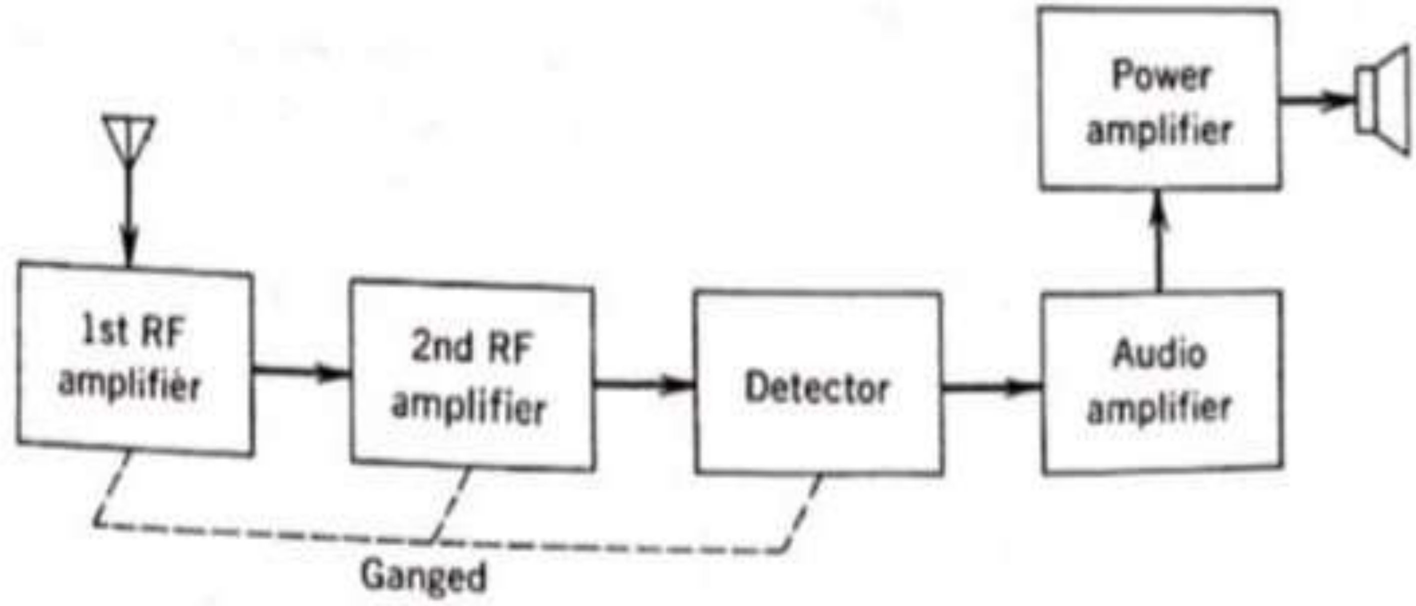
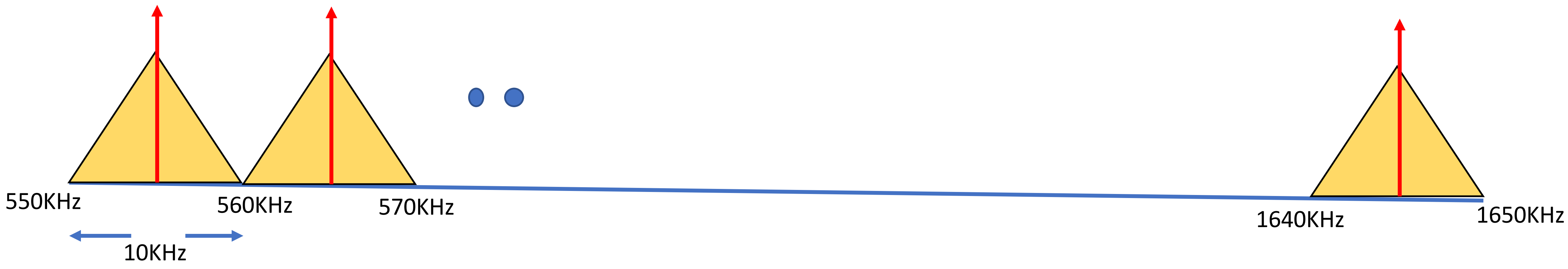


Figure: Block diagram with cascade of Tunned circuits in TRF receiver

- The Frequencies Allotted are 550KHz to 1650KHZ.
- The above range of frequencies are called Medium Wave (mW) band of Frequencies. In this radio stations are multiplexed using FDM.
- The Band Allotted to each station is 10KHz.
- For FM, Frequencies Allotted are 88MHz to 108MHZ.
- Practically, BW given means it includes Guard Band (GB)in FDM & Guard time in (TDM).
- No. of Stations = (1650KHz-550KHz)/10KHz = 110 (Radio Stations)



Tuned Radio Frequency(TRF) Receiver

- The TRF receiver is a simple “logical” receiver.
- Two or three RF amplifiers are used, all are tunned together, to select and amplify the incoming frequency and simultaneously to reject all others frequencies.

$$f_r = \frac{1}{2\Pi\sqrt{LC}}$$

- When Tunning Knob of the Capacitors changes the resonant frequencies changes and required channel also can be selected.

- **Note:** After Receiving signal from the Antenna, RF Amplifier is used to increase the signal strength. This is also tunned Amplifier which is used to select the required signal by adjusting the resonant frequency. So Tunned circuit is used as BPF.
- After the signal was amplified to a suitable level, it is then demodulated (detected) to convert RF to AF, AF Amplifier and Power Amplifier are used to increase the signal to the required level of loud speaker.

Drawbacks

- It is difficult to achieve sufficient selectivity at high frequencies.
- The bandwidth variation over the tuning range
- INSTABLE --Tendency to oscillate at HF

Characteristics of Radio Receivers

The characteristics of a Radio Receiver are as follows:

- Sensitivity
- Selectivity
- Fidelity
- Image Frequency
- Image Frequency Rejection Ratio
- Adjacent Channel Selectivity (Double Spotting)

1) Sensitivity:

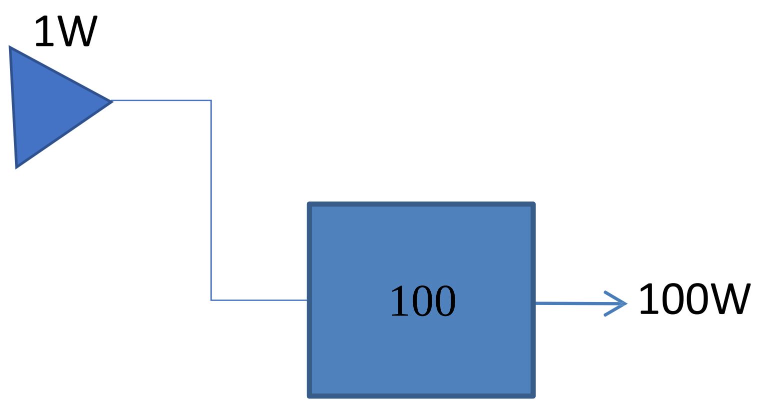
It is defined as the minimum signal strength required for the input of a receiver to get a standard output. Sensitivity depends on the Overall gain of the Receiver.

(Or)

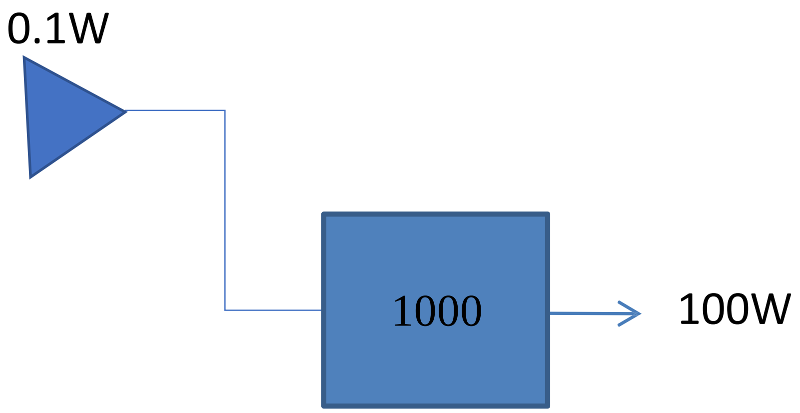
The minimum RF signal level that can be detected at the input of the receiver and produce a usable demodulated information signal with a minimum acceptable signal-to-noise ratio

Typical sensitivity for commercial broadcast-band AM receiver is 50 μV.

A)



B)



NOTE: B is More Sensitive than A

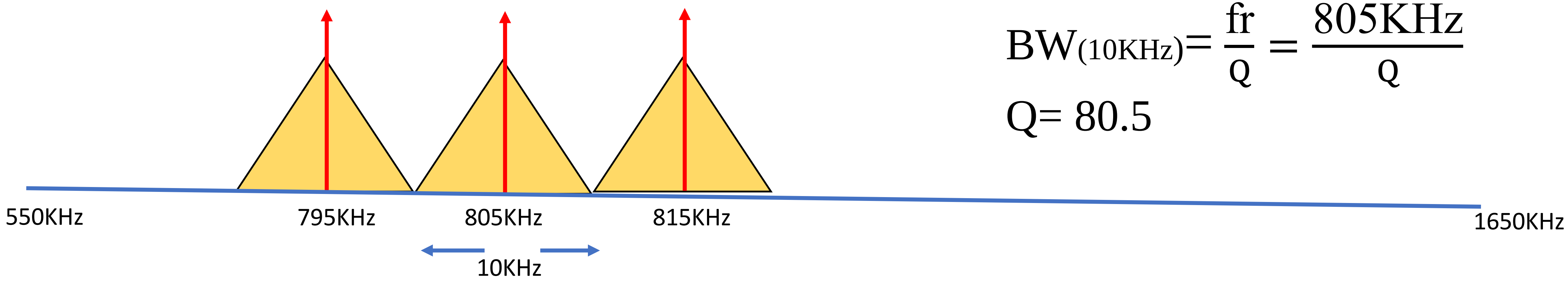
2) Selectivity:

It is defined as the ability of the Receiver to select the required frequencies only. Adjacent channel Interference occurs when tunning circuit range is greater than 10KHz.

(Or)

Used to measure the ability of the receiver to accept a given band of frequencies and reject all other unwanted signal frequencies.

Note: Assume that the receiver is tunned to 805KHz, Tunned circuit should select the frequencies from 800KHz to 810KHz. This is possible if the resonant frequency is adjusted to exactly 805KHz and the Quality Factor should be 80.5



$$BW_{(10KHz)} = \frac{fr}{Q} = \frac{805KHz}{Q}$$

$$Q = 80.5$$

**Simultaneous Variations of Resonant Frequency and Q is not Possible in a tunned Circuit.

3) Fidelity:

It is defined as the ability of the receiver to reproduce all audio frequencies at the output of the receiver. Fidelity indicates the Quality of the Audio signal.

(Or)

The receiver's ability to reproduce all the modulating frequencies of the original information.

In AM Audio frequency always limited to 5KHz.

IN AM Radio, Audio signal is bandlimited to 5KHz because the BW allotted to each Radio station is 10 KHz. The highest frequency reproduced at receiver if 5KHz. So the signal fidelity is very low in AM Radio.

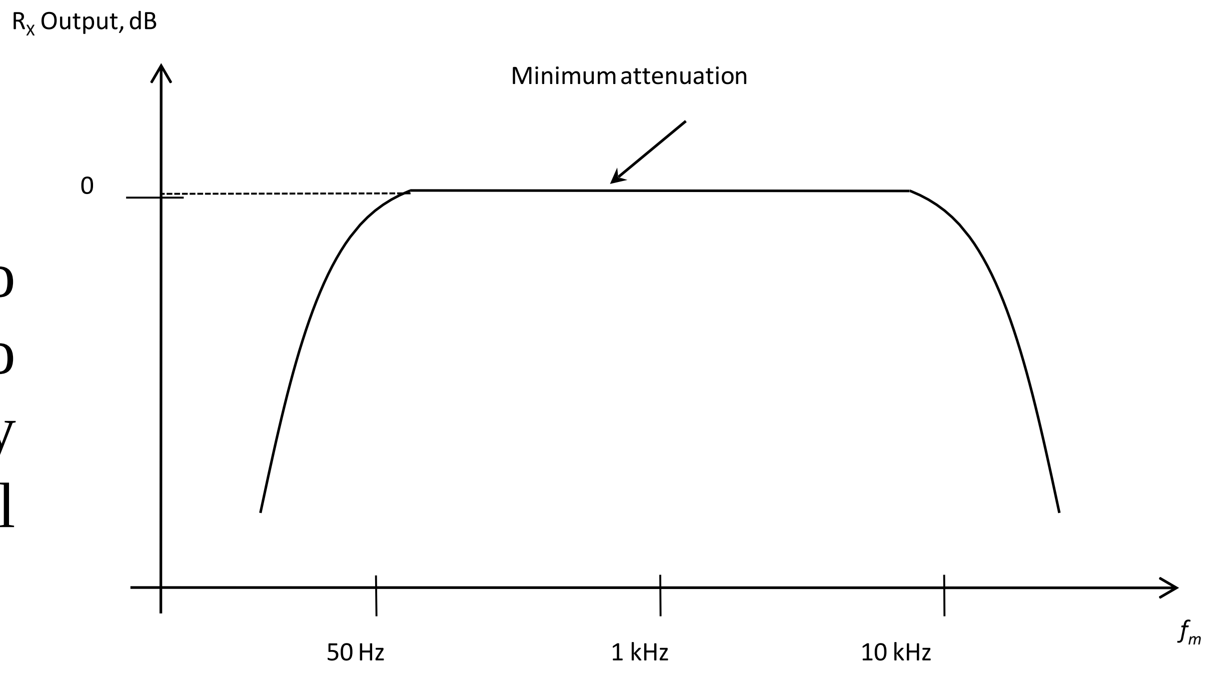
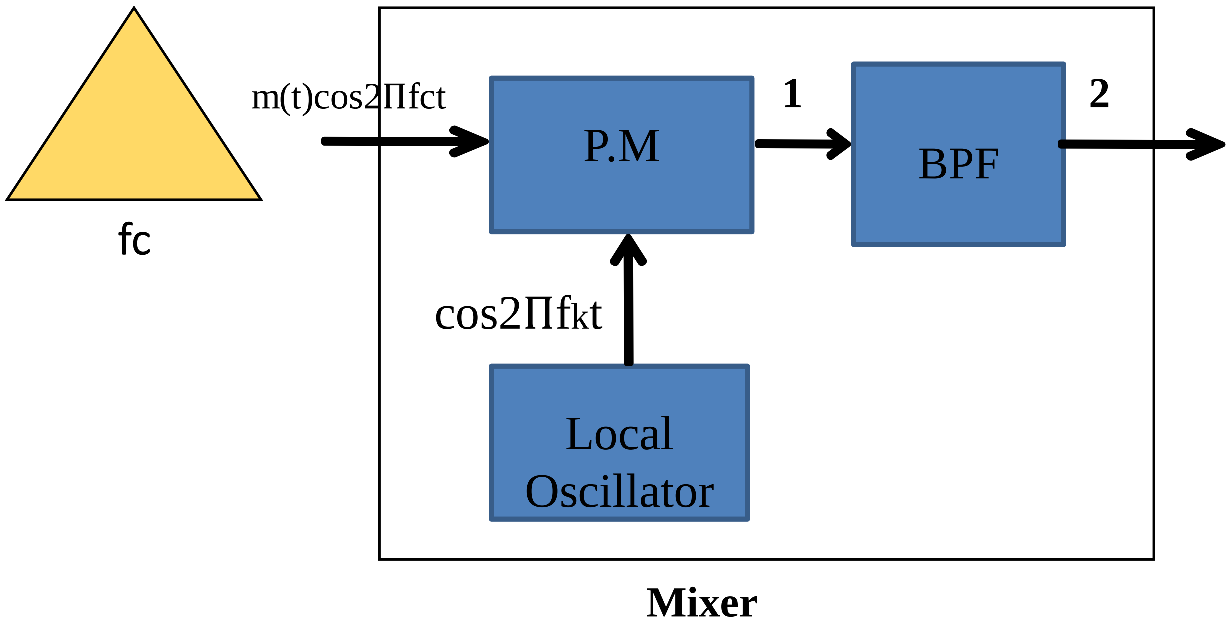


Figure: Fidelity curve of AM Receiver

MIXER

- Mixer is used to change the carrier frequency of a modulated signal.
- f_c is up converted (UC)
- f_c is down converted (DC)



<u>1 Output,</u>

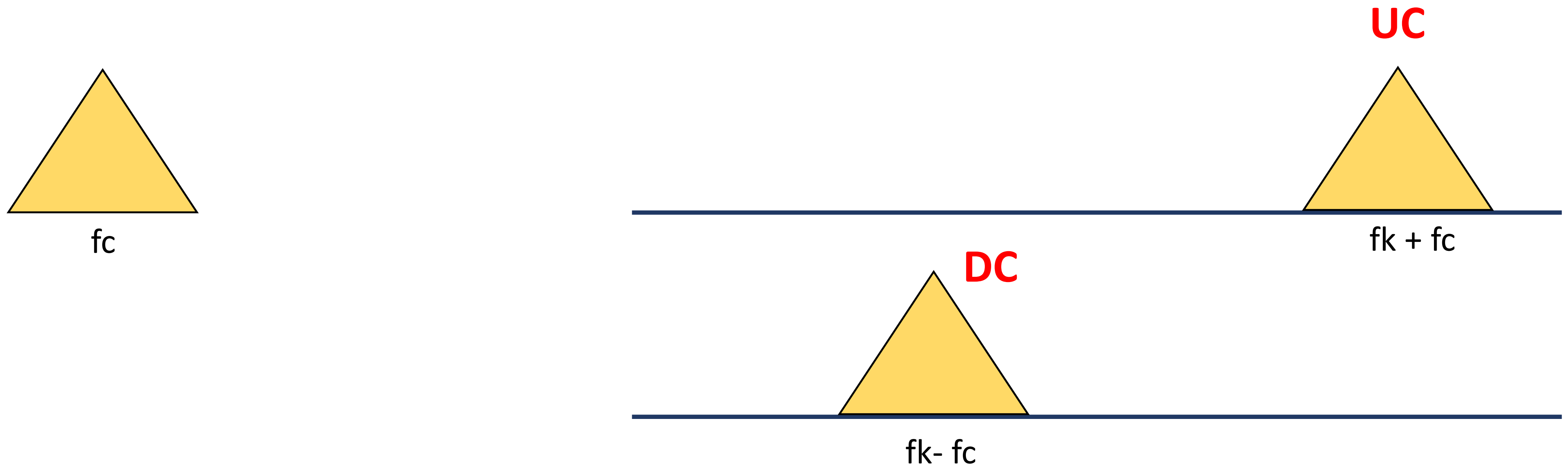
$[m(t)\cos 2\Pi f_c t]\cos 2\Pi f_k t$

$= \frac{m(t)}{2}[\cos 2\Pi(f_k - f_c)t + \cos 2\Pi(f_k + f_c)t]$

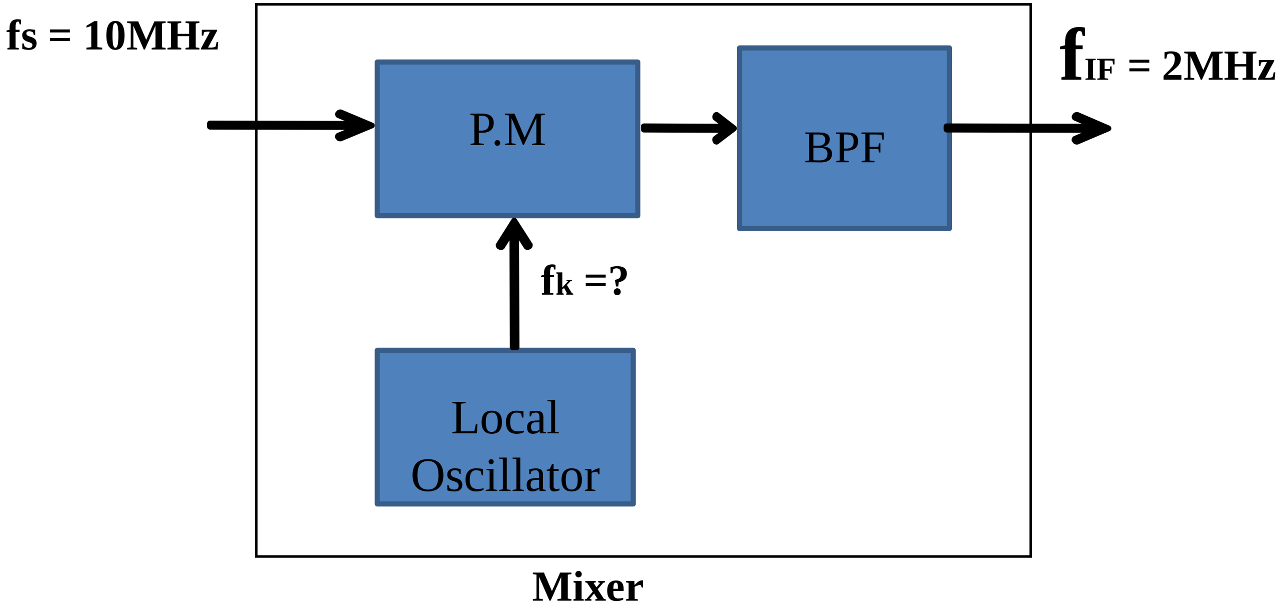
<u>2 Output,</u>

$\frac{m(t)}{2}[\cos 2\Pi(f_k - f_c)t]$ **DC will get**

$\frac{m(t)}{2}[\cos 2\Pi(f_k + f_c)t]$ **UC will not get**



- The output of the multiplier consist of sum & difference frequencies called Upconverted and Down converted signals.
- The process of generating sum & difference frequencies are called as mixing (or) Heterodyning
- BPF is used to select any one of these two signals
- In receivers Down conversion is used



Practically,

1) f_k should be Greater than f_s

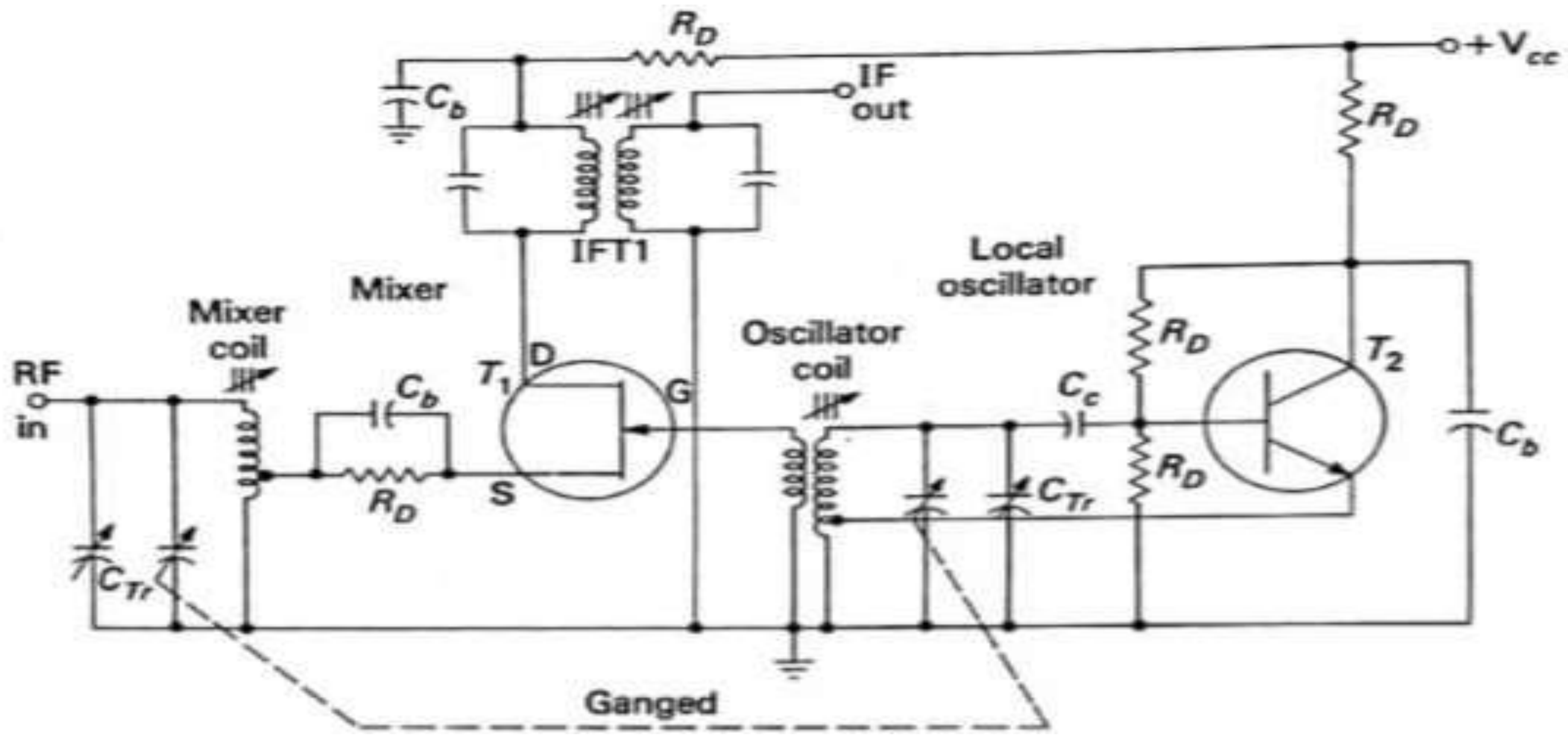
2) Mixer is required in SHR & FM Receivers.

2. Frequency Changing and Tracking:

- The mixer is a non-linear device having two sets of input terminals and one set of output terminals.
- The signal from the antenna or from the preceding RF amplifier is fed to one set of input terminals, and the output of the local oscillator is fed to the other set . Such a non-linear circuit will have several frequencies present in its output, including the difference between the two input frequencies in AM this was called the lower sideband.
- The most common types of mixers are the bipolar transistor, FET, Dual-gate MOSFET and integrated circuit.

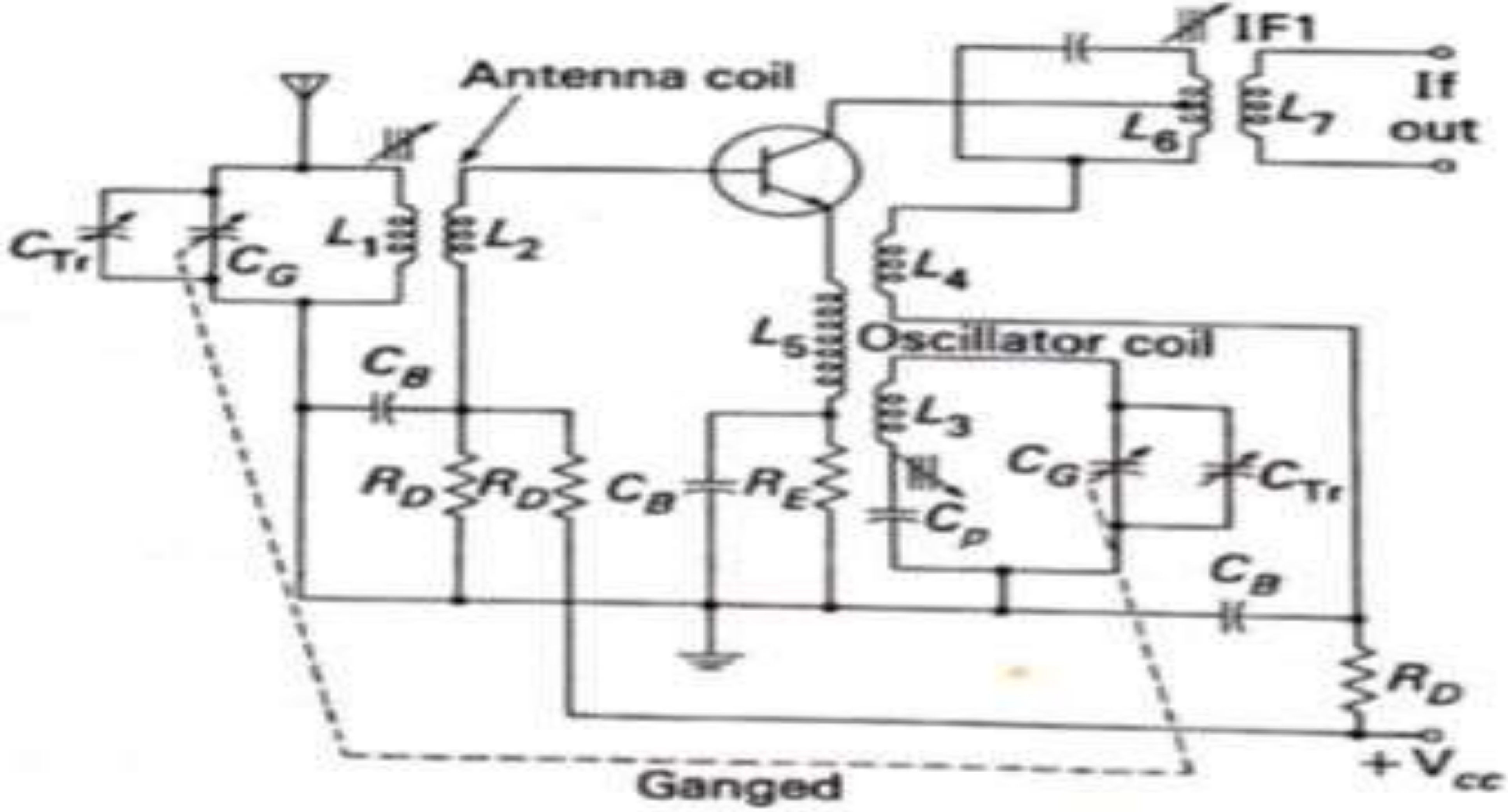
- **Separately Excited Mixer:**

  In this circuit, one device acts as a mixer while the other supplies the necessary oscillations.



- In this circuit, T1 the FET, is the mixer, to whose gate is fed to the output of T2, the bipolar transistor Hartley oscillator .
- If T1 were a Dual-gate MOSFET, the RF input would be applied to one of the gates, rather than to the source as shown in figure, with the local oscillator output going to the other gate, just as it goes to the single gate here.
- The ganging together of the tuning capacitors across the mixer and oscillator coils, and that each in practice has a trimmer across it for fine adjustment by the manufacturer.
- The output is taken through a double tuned transformer in the drain of the mixer and fed to the IF amplifier.
- In domestic receivers, a self-excited mixer is more likely to be encountered.

- **Self-Excited Mixer:**



- At the signal frequency the collector and emitter tuned circuits may be considered as being effectively short circuited so that we have an amplifier with an input tuned circuit and an output that is indeterminate.
- At the IF, we have an amplifier those input comes from an indeterminate source, and whose output is tuned to the IF. Both these amplifiers are CE amplifiers.

Superheterodyne Receiver

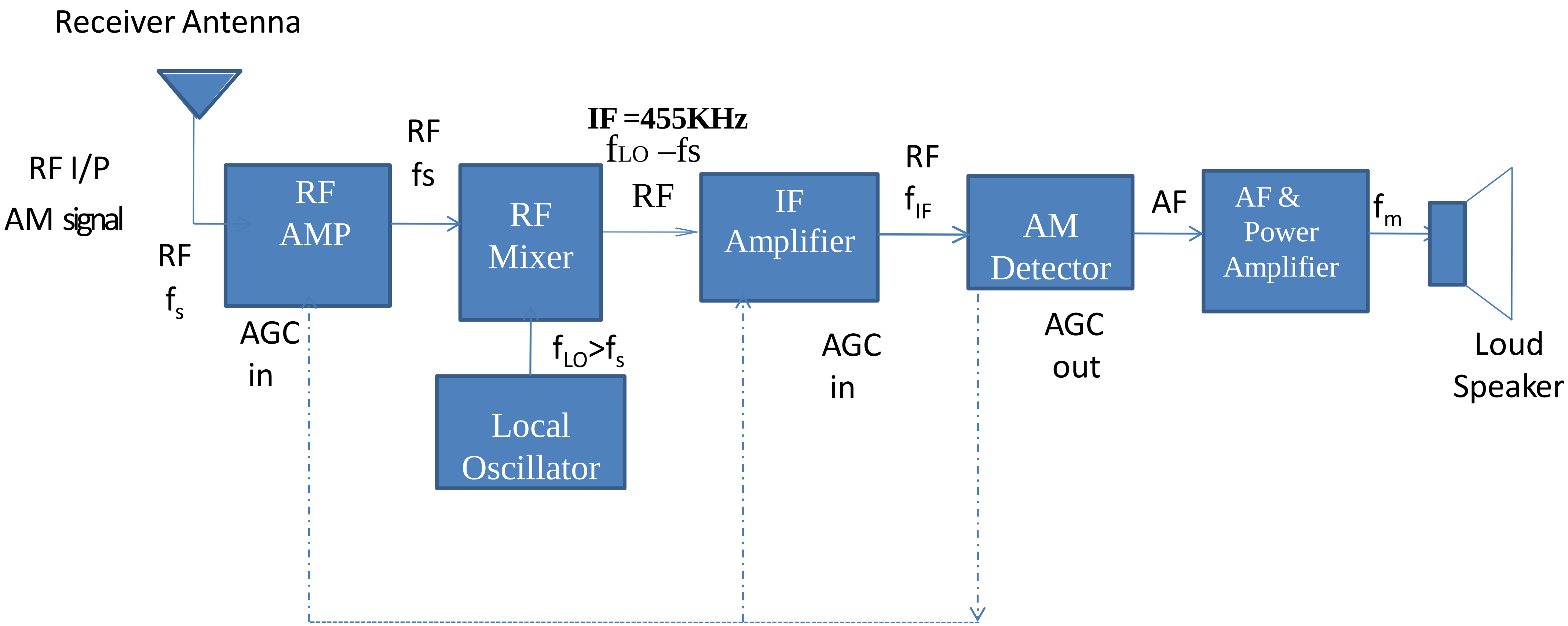
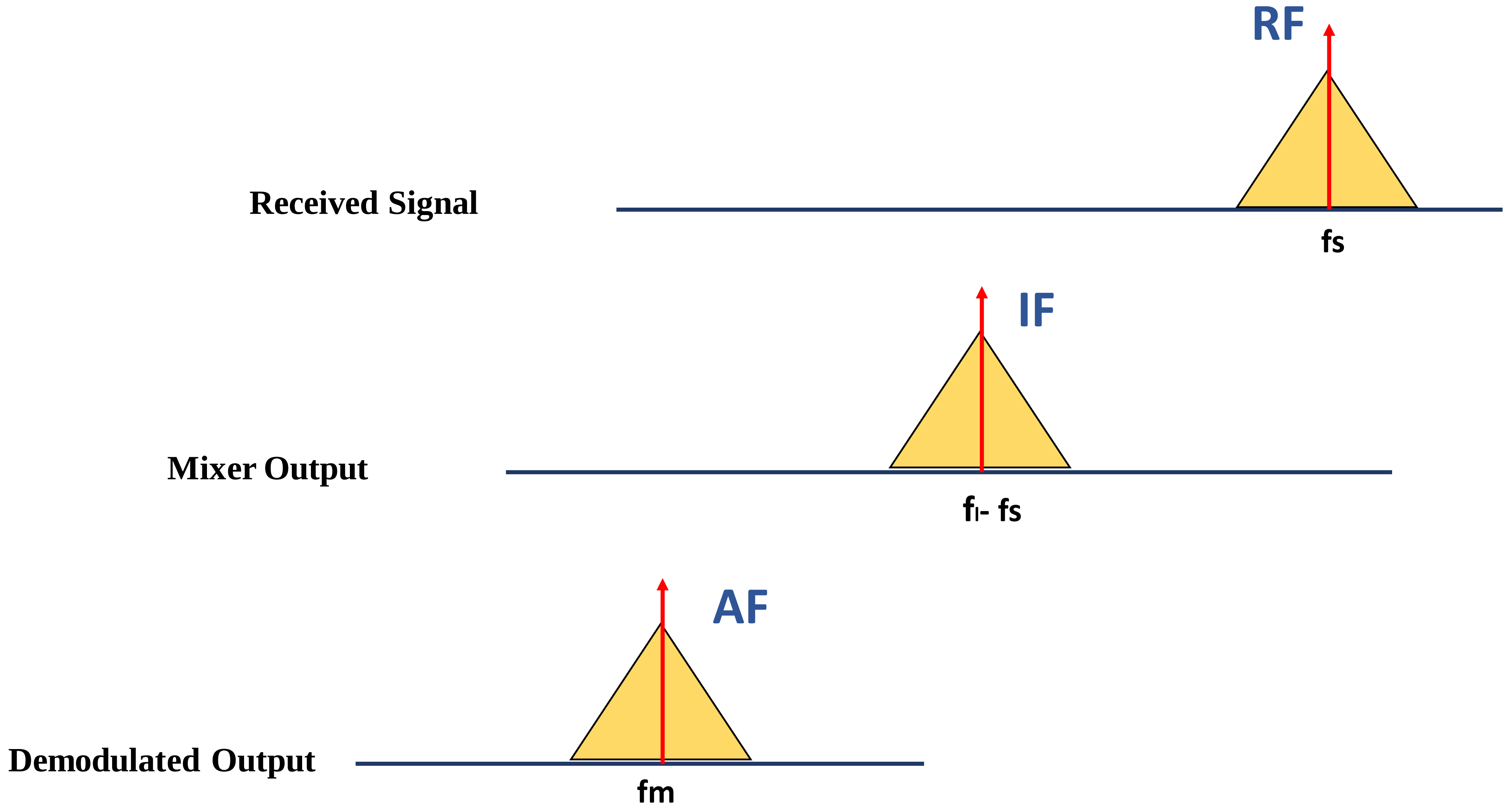


Figure: Functional Block diagram of Superheterodyne Receiver


RF
Received Signal
fs
IF
Mixer Output
fl- fs
AF
Demodulated Output
fm

Superheterodyne Receiver

- After received the signal from antenna ,RF Amplifier is used to increase the signal strength.
- Mixer is used to Down convert the RF signal to IF.
- IN AM Radio IF value is constant i.e. IF= 455KHz and varies from Application to Application

Let the local oscillator frequency is a tunned amplifier which is always tunned to 455KHzand the Quality factor is set at 45.5 for BW of Modulated signal 10KHz. This Process is called as tunning.

$$Q\ BW_{(10KHz)} = \frac{f_r}{BW} = \frac{455KHz}{BW_{10KHz}}$$

Therefore, Q= 45.5

- Hence no need of changing f_r & Q for different incoming signals.

$$f_r = \frac{1}{2\Pi\sqrt{(L1+L2)C}}$$

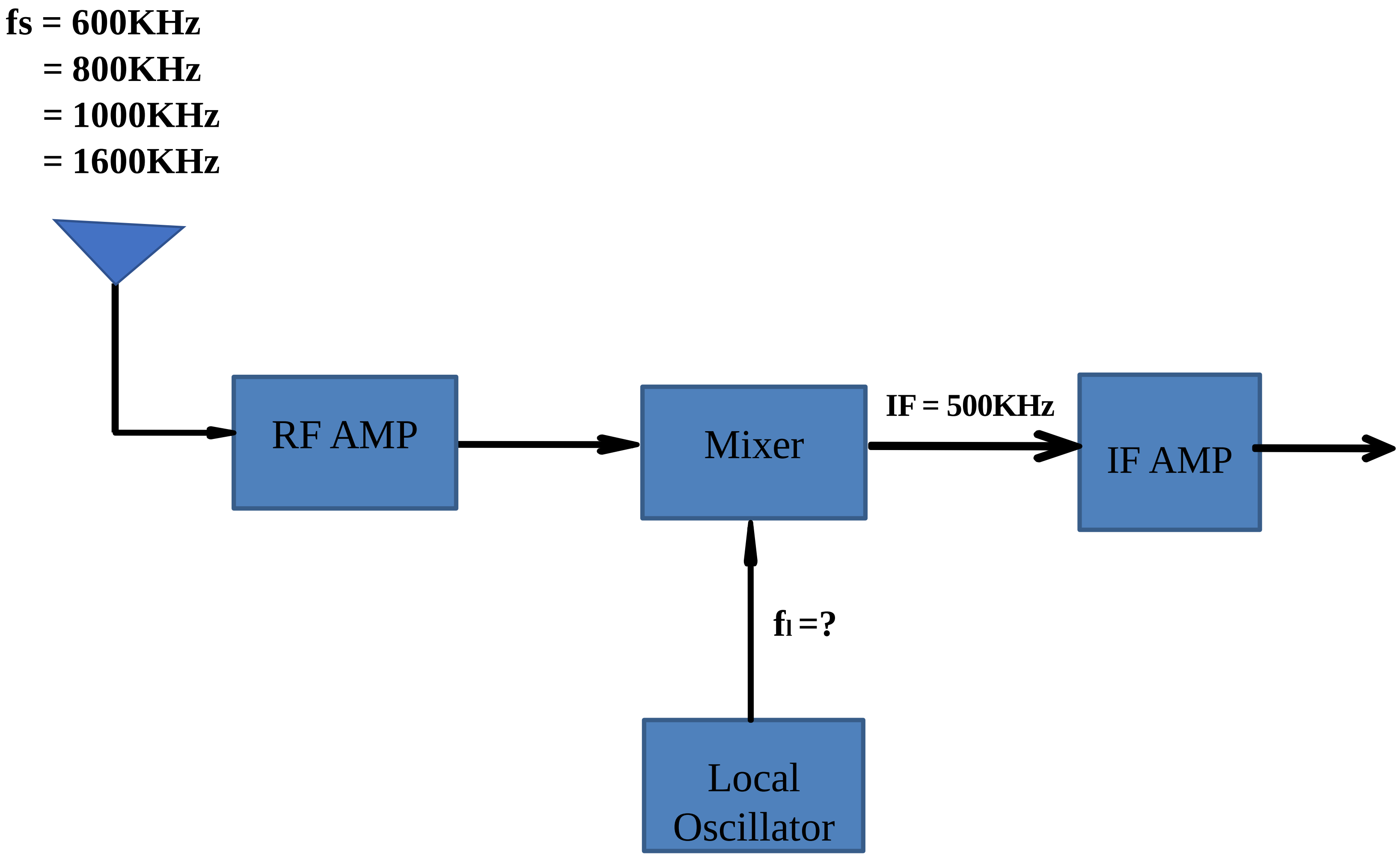
- The superheterodyne Receiver also has the same essential components as in TRF receiver, except mixer, local oscillator and intermediate-frequency (IF) amplifier .
- A constant frequency difference is maintained between the local oscillator and the RF circuit normally through capacitance tuning, in which all the capacitors are ganged together and operated in union by one control knob.
- The IF amplifier generally uses two or three transformers, each consisting of a pair of mutually coupled tuned circuits. With this large number of double tuned circuits operating at a constant, specially chosen frequency, the IF amplifier provides most of the gain and bandwidth requirements to the receiver.

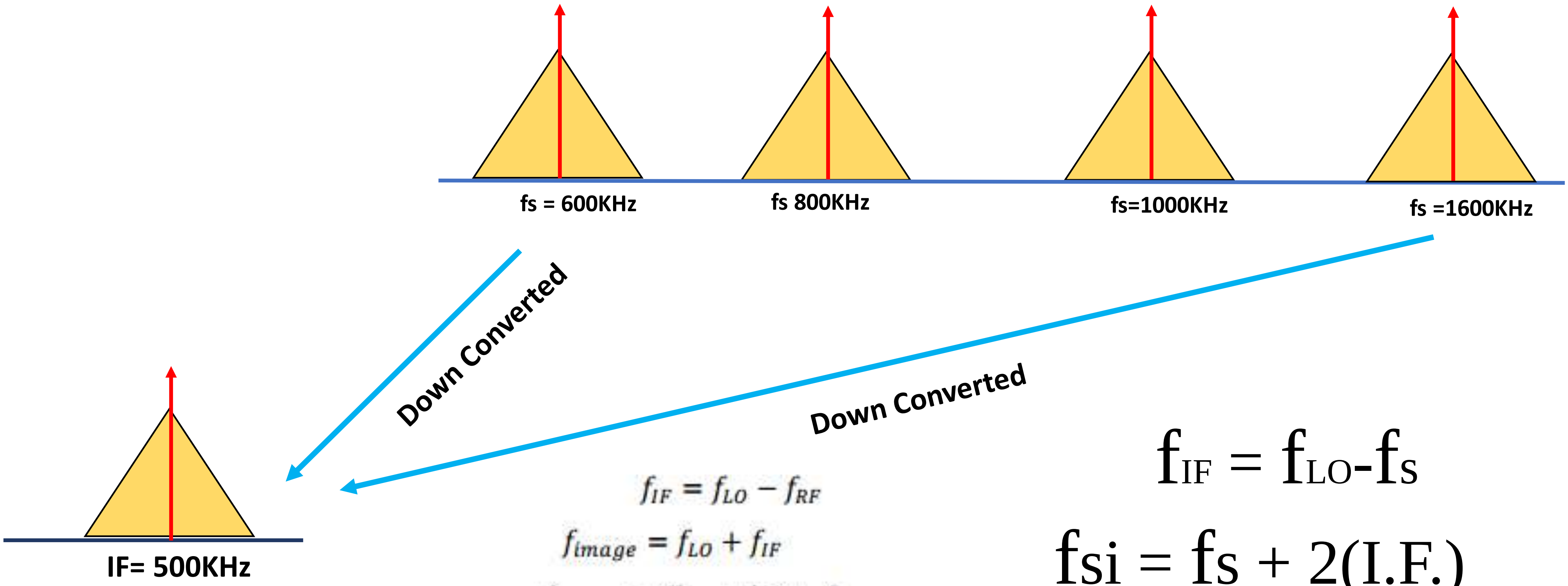
- The characteristics of the IF amplifier are independent of frequency to which the receiver is tuned , the selectivity and sensitivity of the superhet are usually fairly uniform throughout its tuning range and not subject to the variations that effect the TRF receiver.
- The RF circuits are used mainly to select the wanted frequency, to reject interference such as the image frequency and (especially at high frequencies) to reduce the noise figure of the receiver.
- The IF signal output is amplified and given to demodulated (detected) to convert RF to AF, AF Amplifier and Power Amplifier are used to increase the signal to the required level of loud speaker.

Advantages:

- No variation in bandwidth. The BW remains constant over the entire operating range
- High sensitivity and selectivity.
- High adjacent channel rejection

4) Image Frequency





$$f_{IF} = f_{LO} - f_{RF}$$

$$f_{image} = f_{LO} + f_{IF}$$

$$f_{image} = (f_{RF} + f_{IF}) + f_{IF}$$

$$f_{image}\,(\text{or } f_{si}) = f_{RF} + 2f_{IF}.$$

$$f_{IF} = f_{LO} - f_S$$

$$f_{si} = f_s + 2(\text{I.F.})$$

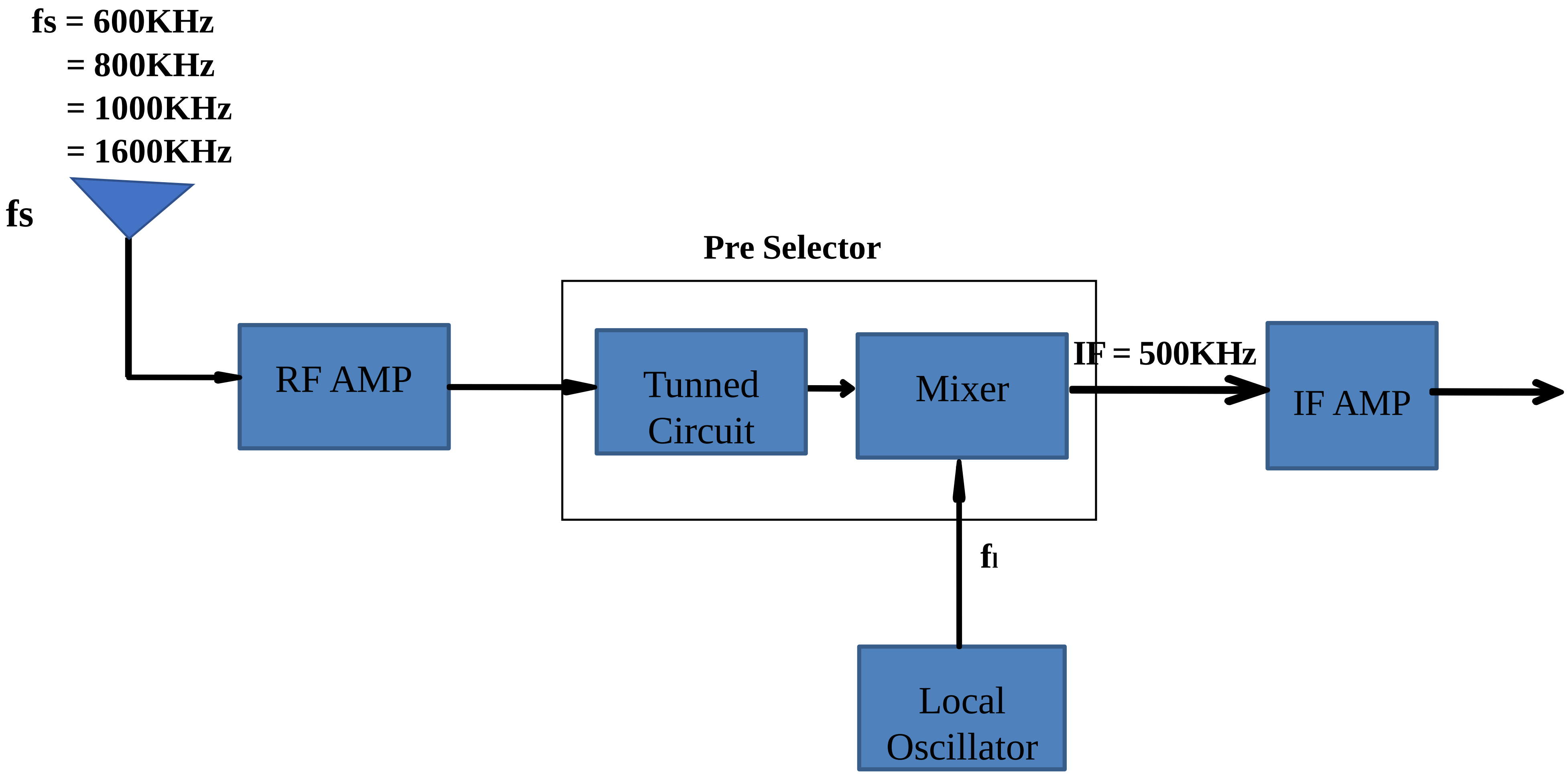
Note:

1) Any unwanted signal causing interference to the wanted signal is called Noise.

2) Reducing f_{si} is not possible after the mixer because both f_s & f_{si} occupied the same frequency range.

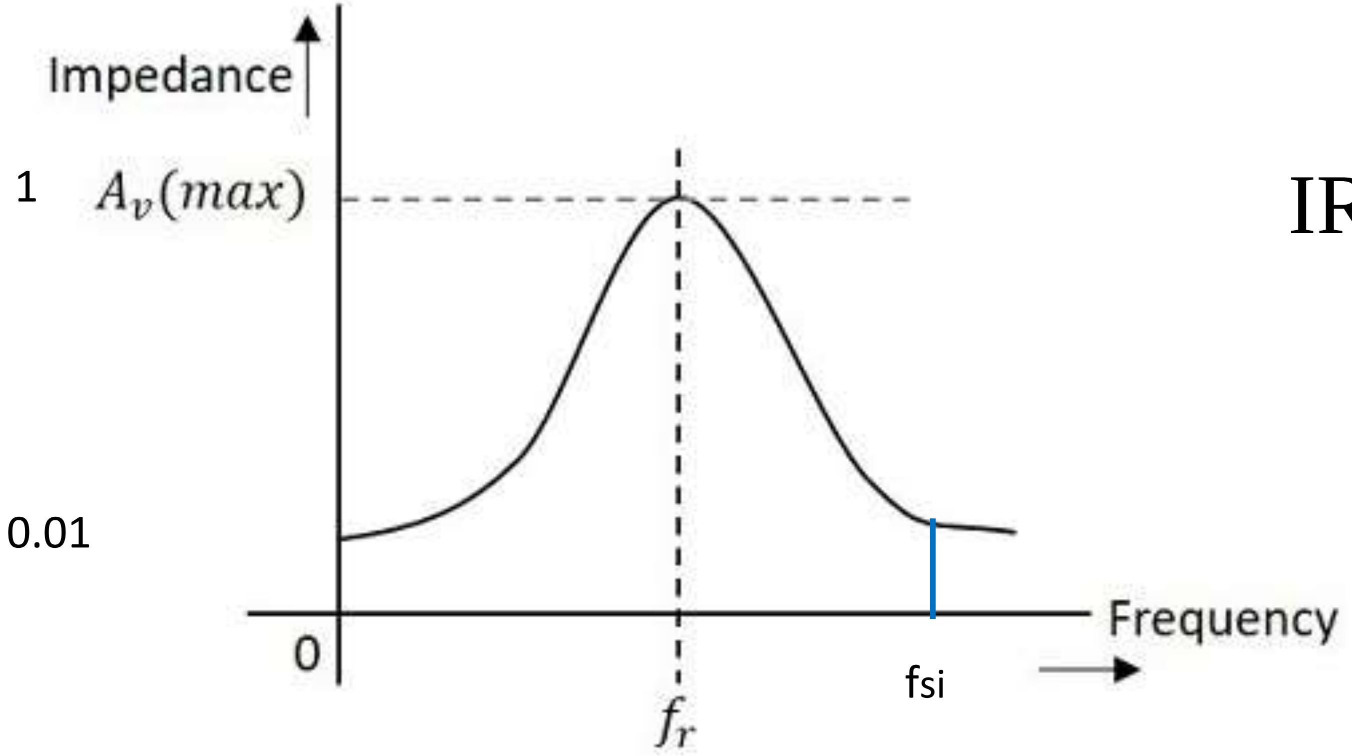
Pre Selector

- The Mixer along with Tunned circuit is called as Pre-Selector



5) Image Rejection Ratio(α)

- The Frequency Response of the Tunned Circuit is as shown in the figure.
- The Gain of the Tunned Circuit at f_{si} should be as LOW as possible



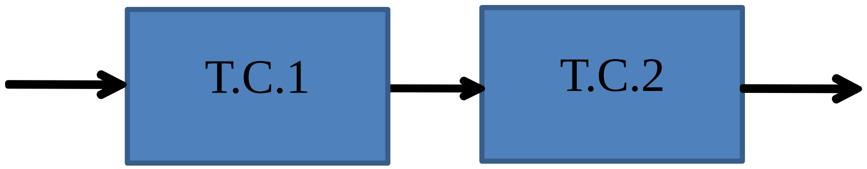
$$IRR = \alpha = \frac{Gfs}{Gfsi} = \frac{1}{0.01} = 100$$

f_{si} is Reduced by 100

IRR = α Image Rejection Ratio should be as High as Possible
(Ideally it should be Infinity)

$$\text{IRR} = \alpha = \frac{\text{Gfs}}{\text{Gfsi}} = \sqrt{1 + Q^2\rho^2} \qquad where, \qquad \rho = \frac{fsi}{fs} - \frac{fs}{fsi}$$

To improve IRR, Tunned Circuits can be connected in cascade $= \sqrt{1 + Q^2\rho^2}$



α1 α2

$$\alpha = \alpha 1 * \alpha 2 = \sqrt{1 + Q1^2\rho^2} * \sqrt{1 + Q2^2\rho^2}$$

A Tunned circuit can also be used at the RF Amplifier to improve the IRR

Image Frequency rejection ratio:

IRR=$\frac{gain\ offererd\ by\ tuned\ amplifier\ to f_s}{gain\ offeredby\ tuned\ amplifier\ to f_{si}}$

IRR= α=$\frac{G_{fs}}{G_{fsi}}$

If tuned amplifiers are connected in cascade then effective image rejection ratio

Effective IRR=$\alpha_1\alpha_2\alpha_3\alpha_4$..............$\alpha_N$

If G_s *and* G_{fsi} *are not known* then image rejection ratio

$$\alpha = \sqrt{\rho^2 Q_1^2 + 1} * \sqrt{\rho^2 Q_2^2 + 1} * \ldots\ldots\ldots\ldots \sqrt{\rho^2 Q_N^2 + 1}$$

Where Q=quality factor of tuned circuit

$\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}}$ and $Bandwidth = \frac{f_r}{Q}$

Where f_r=resonant frequency of the tuned circuit=$\frac{1}{2\pi\sqrt{LC}}$

$$Q=\frac{1}{2\pi}\sqrt{\frac{L}{C}}$$

- A Receiver having NO RF Amplifier is tunned to 1000KHz the I.F. is 455KHz & Q is 100 Calculate
  - fsi & IRR
  - Repeat the above Calculations if receiver is tunned to 25MHz.

Solution:

$$\rho = \frac{fsi}{fs} - \frac{fs}{fsi}$$

a) fs= 1000KHz ; I.F= 455KHz & Q= 100

fsi= 1910KHz ; $\rho = 1.386$

α= $\sqrt{1 + Q^2\rho^2}$ =138.6

b) fs= 25MHz ; I.F= 455KHz & Q= 100

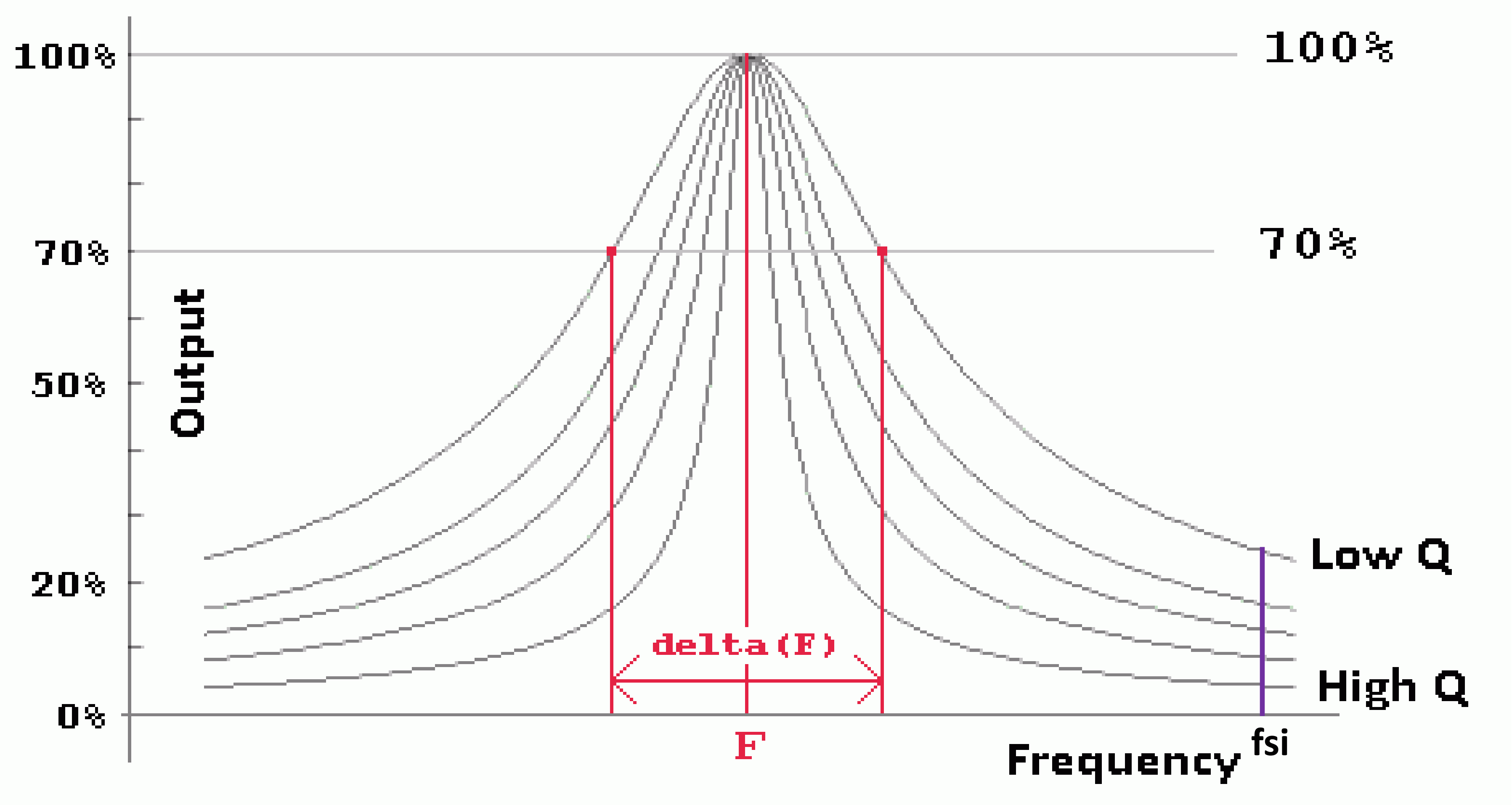
fsi= 25.910MHz ; $\rho = 0.071$

α= $\sqrt{1 + Q^2\rho^2}$ =7.2

- ***To Improve IRR either Q or IF should be increased.

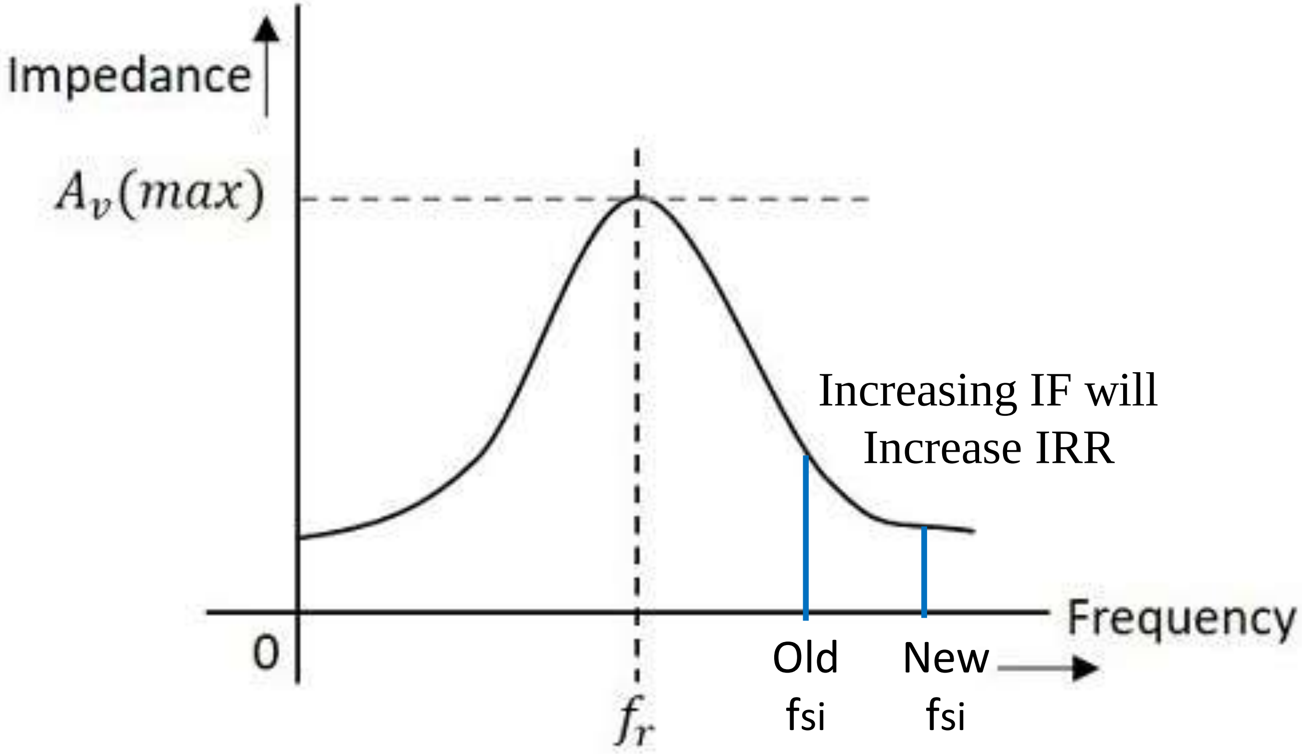
Case1: When Q is Increased

- When Q is increased the BW of the Tunned circuit decreases, The gain at the f_{si} increases .Hence IRR Increases (But Practically not possible which will effect the Selectivity)



Case2: When I.F. is Increased

- When IF is increased the separation between fs & f_{si} also increases (which reduces gain) which is Good. So the gain at f_{si} decreases and IRR improves.



- In the Above Problem determine the value of I.F required . So that the IRR at 25MHz is also equal to 138.6

Solution: The IRR will be equal to 138.6 only when ρ is 1.386

$$1.386 = \frac{fs + 2(I.F)}{fs} - \frac{fs}{fs + 2(I.F)}$$

we Know

$$fsi = fs + 2(I.F)$$

I.F. = 11.4MHz

Note1:

S. No	fs	I.F.
1	KHz	KHz
2	MHz	MHz

(Otherwise IRR Decreases)

Note 2: for FM I.F is 10.7MHz

A super heterodyne radio receiver with an intermediate frequency of 455 KHz is tuned to a station operating at 1200 KHz. The associated image frequency is ______KHz

[GATE 1993: 2 Marks]

Solution: In most receivers the local oscillator frequency is higher than incoming signal i.e.

$$f_0(frequency\ of\ local\ oscillator) = f_s + f_i$$

Where f_s------- signal frequency
f_i or f_{si}-------- Image frequency

$$f_{si} = f_s + 2IF = f_s + 2f_i$$
$$f_{si} = 1200 + 2(455)$$
$$f_{si} = 2110\ KHz$$

so, answer is 2110 KHz

The image channel selectivity of superheterodyne receiver depends upon

(a) IF amplifiers only

(b) RF and IF amplifiers only

(c) Pre selector, RF and IF amplifiers

(d) Pre selector and RF amplifiers

[GATE 1998: 1 Marks]

Image rejection depends on front end selectivity of receiver and must be achieved before If stage. So image channel selectivity depends upon pre selector & RF amplifier. If it enters IF stage it becomes impossible to remove it from wanted signal.

Option (d)

A receiver is tuned to 600 Khz and intermediate frequency IF=450 kHz find f_l, f_{si}

Given

Incoming signal frequency is tuned to $f_s = 600k$

intermediate frequency IF =450K

We need to remember that

Always local Oscillator frequency should be greater than the incoming signal frequency

Depending upon that up conversion and down conversion needs to be done

$f_l - f_s = I.F$ (down conversion)

$f_l + f_s = I.F\ (up\ conversion)$

$f_l = I.F + f_s$=600+450=1050 k

$f_{si} = f_s + 2\ I.F$=600+2*450=1500k

A receiver is tuned to 500 k ,local oscillator frequency is given as 1050k. Find I.F and f_{si} Image rejection ratio, if quality factor Q=50

Sol:

Given data

f_l=local oscillator frequency=1050 K

f_s= incoming signal frequency=500K

$f_l - f_s = intermediate\ frequency = 1050 - 500 = 550K$

$f_{si} = f_s + 2\ I.F$=500+2*550=1600 K

$$\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}}$$

$$= \frac{1600}{500} - \frac{500}{1600} = 2.8$$

Image rejection ratio:

$\alpha = \sqrt{\rho^2 Q_1^2 + 1} = \sqrt{(1 + 2.8^2 * 100)}$ =144.3

An receiver is tuned to 750K,corresponding image frequency is given by 1750 k

find f_l and image frequency , Image rejection ratio if two tuned amplifiers of having Q=50 and 70 are

connected in cascade

Given

Incoming signal frequency is tuned to $f_s = 750k$

Image frequency $\quad f_{si} = f_s + 2\, I.F = 1750$ k

Therefore intermediate frequency

$$I.F = \frac{1750-750}{2} = 500K$$

$f_l - f_s = I.F$

$f_l = I.F + f_s = 500+750 = 1250K$

$\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}}$

$$= \frac{1750}{750} - \frac{750}{1750} = 1.9$$

$\alpha = \sqrt{\rho^2 Q_1^2 + 1} * \sqrt{\rho^2 Q_2^2 + 1} = \sqrt{1.9^2 * 2500 + 1} * \sqrt{1.9^2 * 4900 + 1}$

$= 12636.05$

For a super heterodyne receiver, the intermediate frequency is 15 MHz and the local oscillator frequency is 3.5 GHz .if the frequency of the received signal is greater than the local oscillator frequency ,than the image frequency is

Given data:

I.F=15 MHz

f_l=3500 MHz

Given that frequency of the received signal is greater than the local oscillator frequency

$$f_s - f_l = I.F$$

$f_s = I.F + f_l$=(15+3500) MHz=3515 MHz

if the frequency of the received signal is greater than the local oscillator frequency ,than the image frequency is

$$f_{si} = f_s - 2\,I.F$$

=(3515-2*15)MHz=3485 MHz

A super Heterodyne receiver operates in the frequency range of 58 MHz - 68 Mhz. The intermediate frequency (I.F) and the local oscillator f_l are chosen such that I.F$\leq f_l$.It is required that the image frequencies fall outside the 58 MHz -68 MHz band. The minimum intermediate frequency (in MHz) is

The frequency range of the receiver

58Mhz -68 MHz

Image frequency $f_{si} = f_s + 2\, I.F$

From the question f_{si} *should be outside the range*

$$f_{si} \gg 68MHz$$

$$f_s + 2\, I.F \gg 68MHz$$

To calculate minimum required intermediate frequency the signal frequency should be minimum

$$f_{s(min)} = 58 \text{ MHz}$$

$$58 \text{ MHz} + 2\, I.F \gg 68MHz$$

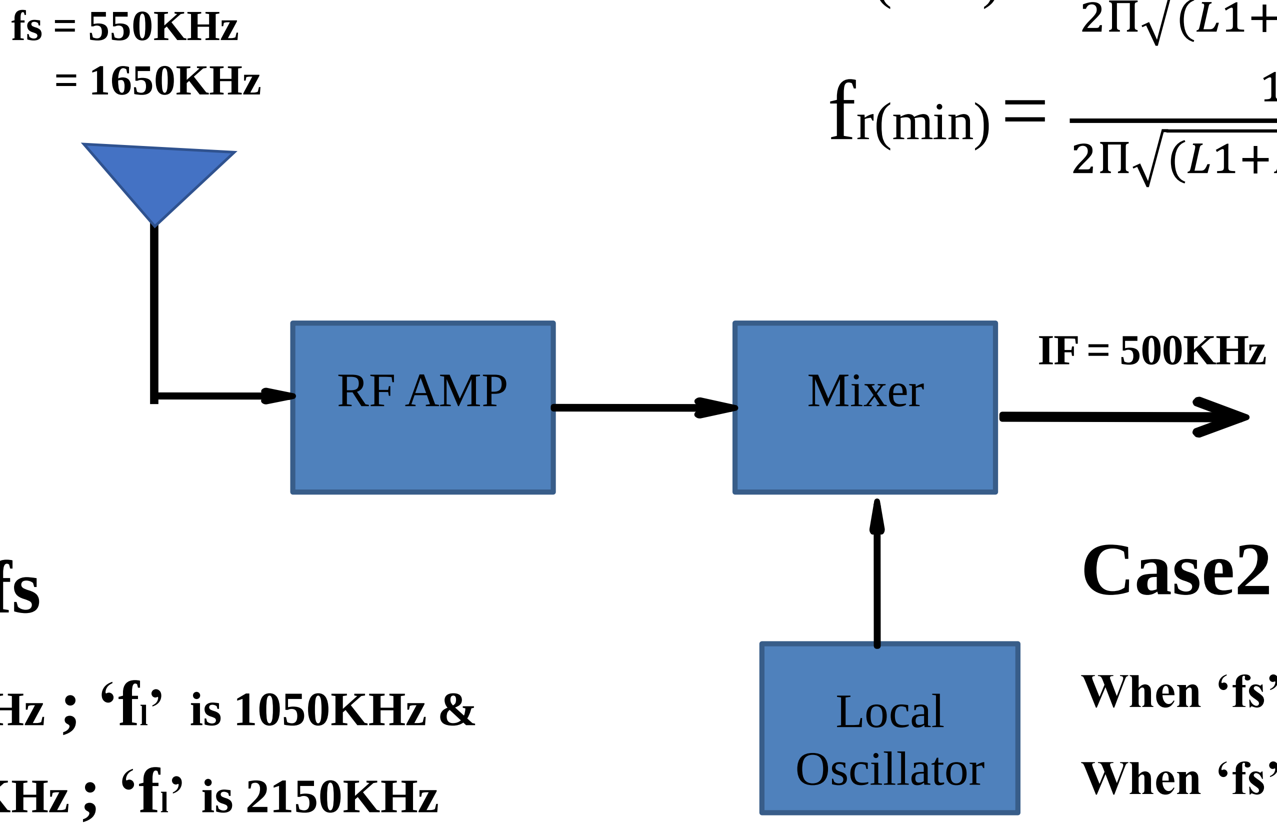
$$\text{I.F} \gg 5MHz$$

(Answer is 5)

Local Oscillator

$$f_{r(max)} = \frac{1}{2\Pi\sqrt{(L1+L2)Cmin}}$$ for Hartley Oscillator

$$f_{r(min)} = \frac{1}{2\Pi\sqrt{(L1+L2)Cmax}}$$ for Hartley Oscillator



Case1: $f_l > fs$

When 'fs' is 550KHz ; 'f_l' is 1050KHz &

When 'fs' is 1650KHz ; 'f_l' is 2150KHz

Case2: $f_l < fs$

When 'fs' is 550KHz ; 'f_l' is 50KHz &

When 'fs' is 1650KHz ; 'f_l' is 1150KHz

Local Oscillator

Note:

1) $\frac{Cmax}{Cmin}$ = 10 (It is possible only with $f_l > fs$

2) If f_l < fs the ratio of capacitance is not possible so we have to follow fl > fs

Case-1: I.F. = f_l - fs

fsi = fs+2(I.F)

Case-2: I.F. = f_s - f_l

fsi = fs - 2(I.F)

Assume that the tuned amplifier is an Hartley oscillator and the incoming signal is tuned to an AM range (550K to 1650) K .
assume that ($f_l > f_s$) for case 1 and ($f_l < f_s$) for case 2 , intermediate frequency is 500K . Find the ratio of $\frac{C_{max}}{C_{min}}$ *in Hartley oscillator*

Solution:
Case 1:
Given data AM range:550K -1650k
Intermediate frequency I.F =500 k
We know that for Hartley oscillator the resonant frequency is

$$f_r = \frac{1}{2\pi\sqrt{(L_1 + L_2)C}}$$

If the incoming signal is tuned to f_s(min)=550K
$f_l - f_s = I.F$
$f_{l\,(\mathrm{min})} = I.F + f_{s(min)}$=500+550=1050K

If the incoming signal is tuned to f_s=550K then the local oscillator frequency is tuned to $f_{l(min)} = f_{r(min)}$=1050K

$$f_{r(min)} = \frac{1}{2\pi\sqrt{(L_1+L_2)C_{max}}} = 1050\text{K}$$

(1)

If the incoming signal is tuned to f_s(max)= 1650K

$$f_l - f_s = I.F$$

$$f_{l\,(\text{max})} = I.F + f_{s(max)} = 500+1650 = 2150\text{K}$$

If the incoming signal is tuned to f_s=1650K then the local oscillator frequency is tuned to $f_{l(max)} = f_{r(max)}$=2150K

$$f_{r(max)} = \frac{1}{2\pi\sqrt{(L_1+L_2)C_{min}}} = 2150\text{K}$$

(2)

Solving with equation 2 by equation1.... $\frac{C_{max}}{C_{min}} = (\frac{2150}{1050})^2 \cong 4$

case 2: ($f_l < f_s$)

$f_s - f_l = I.F$

$f_{l\,(\min)} = f_{s(min)}$-I.F=550-500=50K

If the incoming signal is tuned to f_s=550K then the local oscillator frequency is tuned to $f_{l(min)} = f_{r(min)}$=50K

$$f_{r(min)} = \frac{1}{2\pi\sqrt{(L_1+L_2)C_{max}}}=50\text{K} \tag{1}$$

If the incoming signal is tuned to f_s(max)=1650K

$f_s - f_l = I.F$

$f_{l\,(max)} = f_{s(max)}$-I.F=1650-500=1150K

If the incoming signal is tuned to f_s=1650K then the local oscillator frequency is tuned to $f_{l(max)} = f_{r(max)}$=1150K

$$f_{r(max)} = \frac{1}{2\pi\sqrt{(L_1+L_2)C_{min}}}=1150\text{K} \tag{2}$$

Solving equation 2 by equation1

$$\frac{C_{max}}{C_{min}} = \left(\frac{1150}{50}\right)^2 \cong 500$$

Note:

Tuning of capacitor will be easy when ($f_l > f_s$) .so it is always preferred

Image Frequency and its Rejection Ratio

$f_l - f_s = I.F$ (down conversion)

$f_l + f_s = I.F\ (up\ conversion)$

Where f_l=local oscillator frequency

f_s= incoming signal frequency

I.F =intermediate Frequency

Image frequency

$f_{si} = f_s + 2\,I.F$

Where f_s= incoming signal frequency

I.F =intermediate Frequency

- If the frequency of the received signal is greater than the local oscillator frequency ,than the image frequency is

$$f_{si} = f_s - 2\,I.F$$

3. Intermediate Frequencies and IF amplifiers:

The following are the major factors influencing the choice of the intermediate frequency in any particular system

a. If the IF is too high, poor selectivity and poor adjacent channel rejection result unless sharp cutoff filters are used in the IF stages.

b. A high value of IF increases tracking difficulties

c. As the IF is lowered, image frequency rejection becomes poorer.

d. A very low IF can make the selectivity too sharp, cutting off the sidebands. This problem arises because the Q must be low when the IF is low and therefore the gain per stage is low.

e. If IF is very low, the frequency stability of the local oscillator must be made correspondingly higher because any frequency drift is now a larger properties of the low IF than of a high IF.

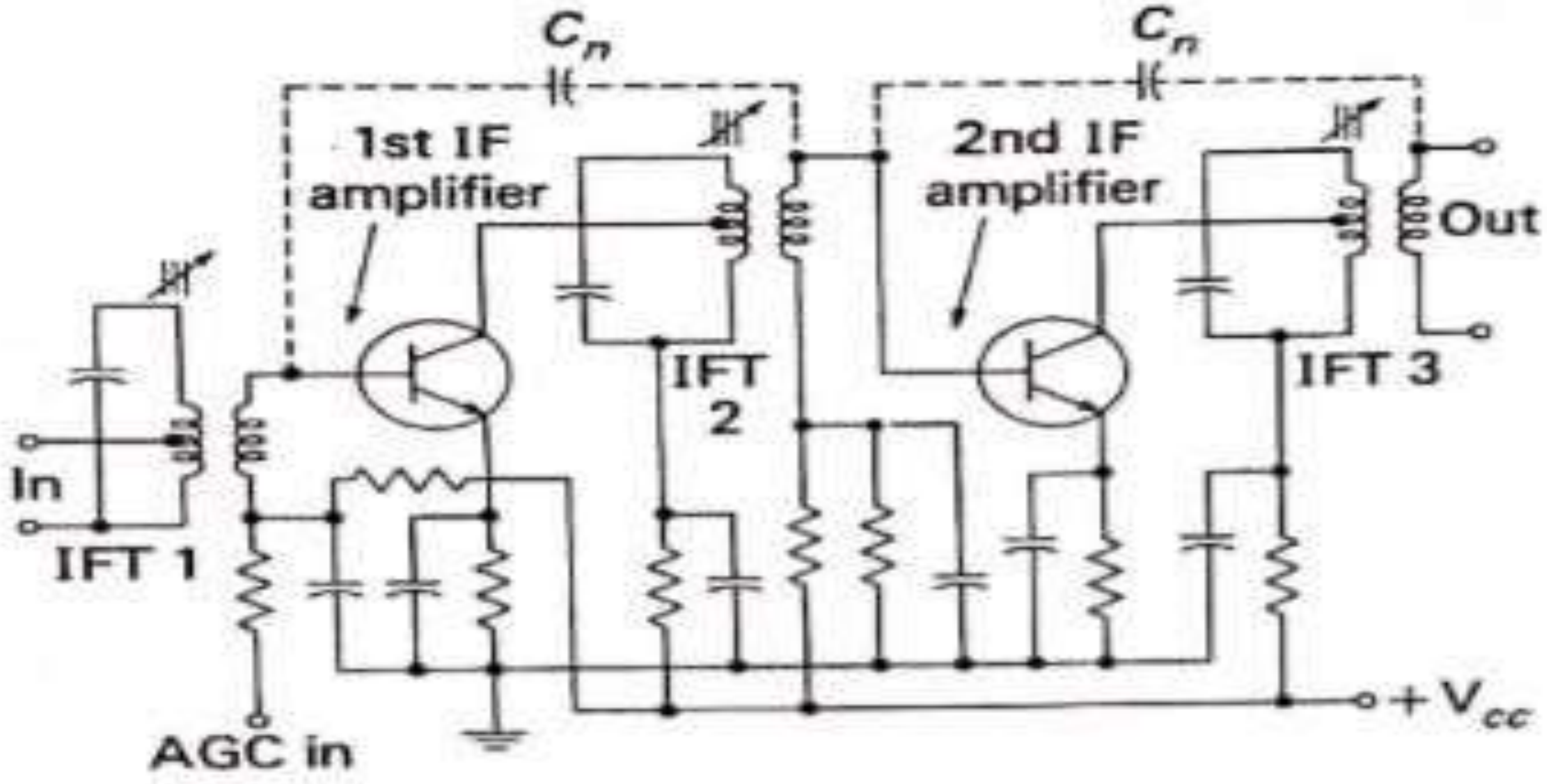
f. The IF must not fall within the tuning range of the receiver, or else instability will occur and heterodyne whistles will be heard, making it impossible to tune to the frequency band immediately adjacent to the IF.

Frequencies Used:

- Standard broadcast AM receivers use an IF within the 438-465 KHz range, with 455 KHz by far the most popular frequency.

- AM, SSB and other receivers employed for shortwave or VHF reception have a first IF often in the range from about 1.6 to 2.3MHz, or else above 30 MHz.
- FM receivers using the standard 88-108 MHz band have an IF which is almost always 10.7 MHz
- Television receivers in the VHF band and in the UHF band uses an IF between 26 and 46 MHz, with approximately 36 and 46 MHz the two most popular values.
- Microwave and Radar receivers, operating on frequencies in the 1-10 GHz range, use intermediate frequencies depending on the application, with 30, 60 and 70 MHz among the most popular.

- **IF Amplifiers:**



IF Amplifiers Contd.,

- The IF amplifier is a fixed-frequency amplifier with the very important function of rejecting adjacent unwanted frequencies. It should have a frequency response with steep skirts.
- FET and integrated circuit IF amplifiers generally are double tuned at the input and at the output, bipolar transistor amplifiers often are single tuned.
- The above circuit is two stage amplifier, with all IF transformers single tuned. This departure from a single stage, double tuned amplifier is for the sake of extra gain and receiver sensitivity.
- If a double tuned transformers were used, both sides of it might have to be tapped, rather than just one side as with a single tuned transformer. Thus a reduction in a gain.

6) Adjacent Channel Selectivity (Double Spotting):

- This is well known phenomenon, which manifests itself by the picking up of the same short wave station at two near by points on the receiver dial. It is caused by poor front-end selectivity.
- The front-end of the receiver does not select different adjacent signals very well, but the IF stage eliminating almost all of them.
- Double spotting may be used to calculate the intermediate frequency of an unknown receiver, since the spurious point on the dial is precisely 2fi below the correct frequency.

Various Blocks of AM Superheterodyne Receiver

1. RF section and Characteristics

2. Frequency Changing and Tracking

3. Intermediate Frequencies and IF amplifiers

4. Detection and Automatic Gain Control

Various Blocks of AM Superheterodyne Receiver

1. RF Section and Characteristics:

A radio receiver always has an RF section, which is a tunable circuit connected to the antenna terminals. It is there to select the wanted frequency and reject some of the unwanted frequencies.

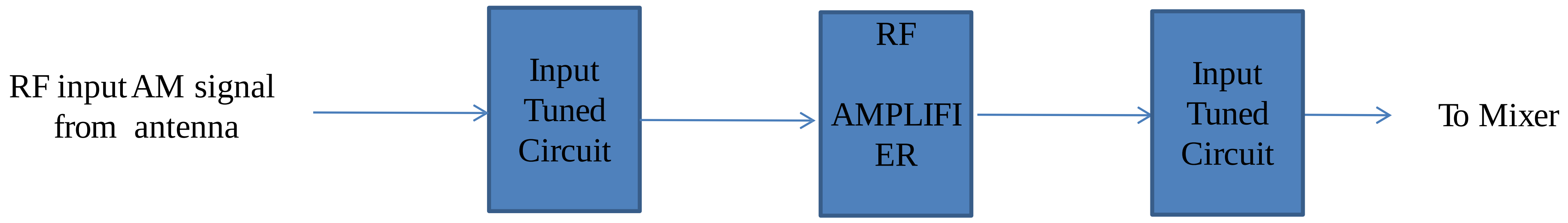


Figure: A Simplified Block Diagram of RF Front-end

Various Blocks of AM Superheterodyne Receiver

Reasons for use and functions of RF amplifier:

- Greater gain i.e better sensitivity
- Improved image-frequency rejection
- Improved signal-to-noise ratio
- Improved rejection of adjacent unwanted signals, i.e better selectivity
- Better coupling of the receiver to the antenna
- Prevention of spurious frequencies from entering the mixer and heterodyning there to produce an interfering frequency equal to the IF from the desired signal.
- Prevention of re-radiation of the local oscillator through the antenna of the receiver.

- The single tuned transformer coupled amplifier is most commonly employed for RF amplification, as illustrated in below figure.

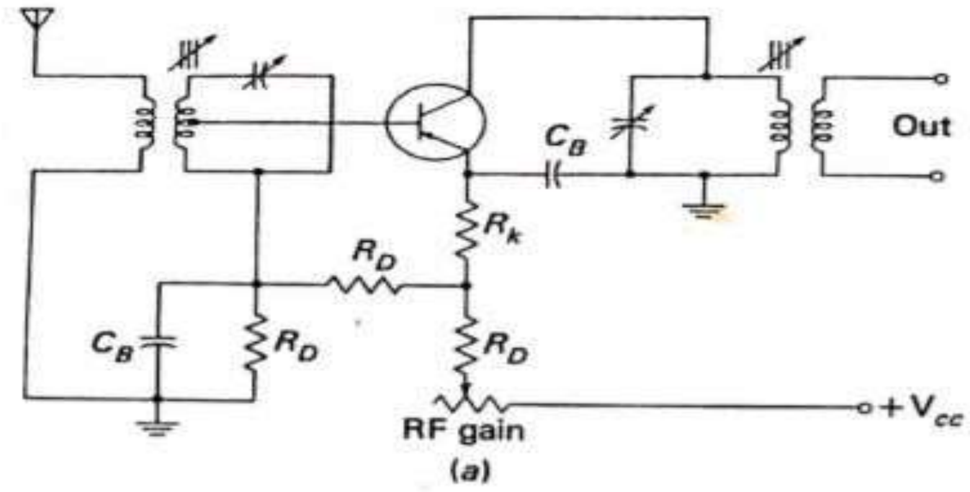


Figure: (a) Transistor RF amplifer (Mid frequency)

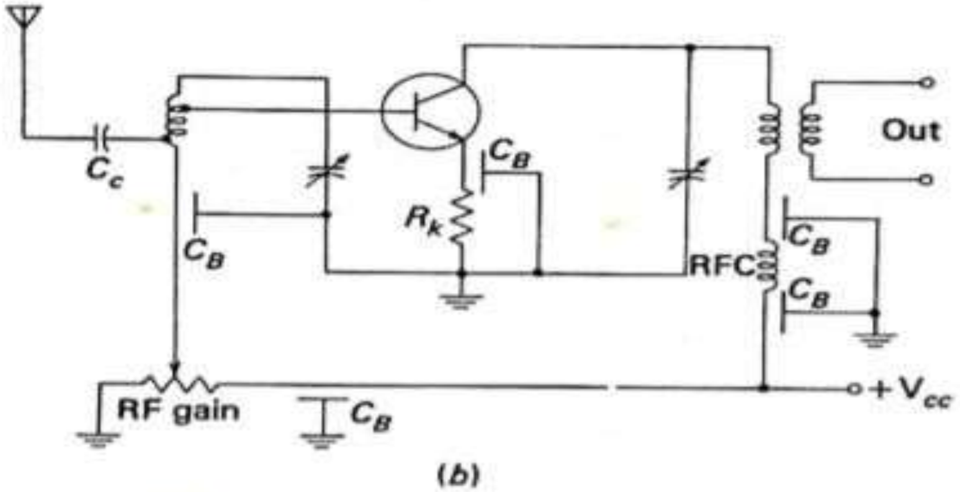


Figure: (b) Transistor RF amplifer (VHF)

- **Superheterodyne Tracking:**

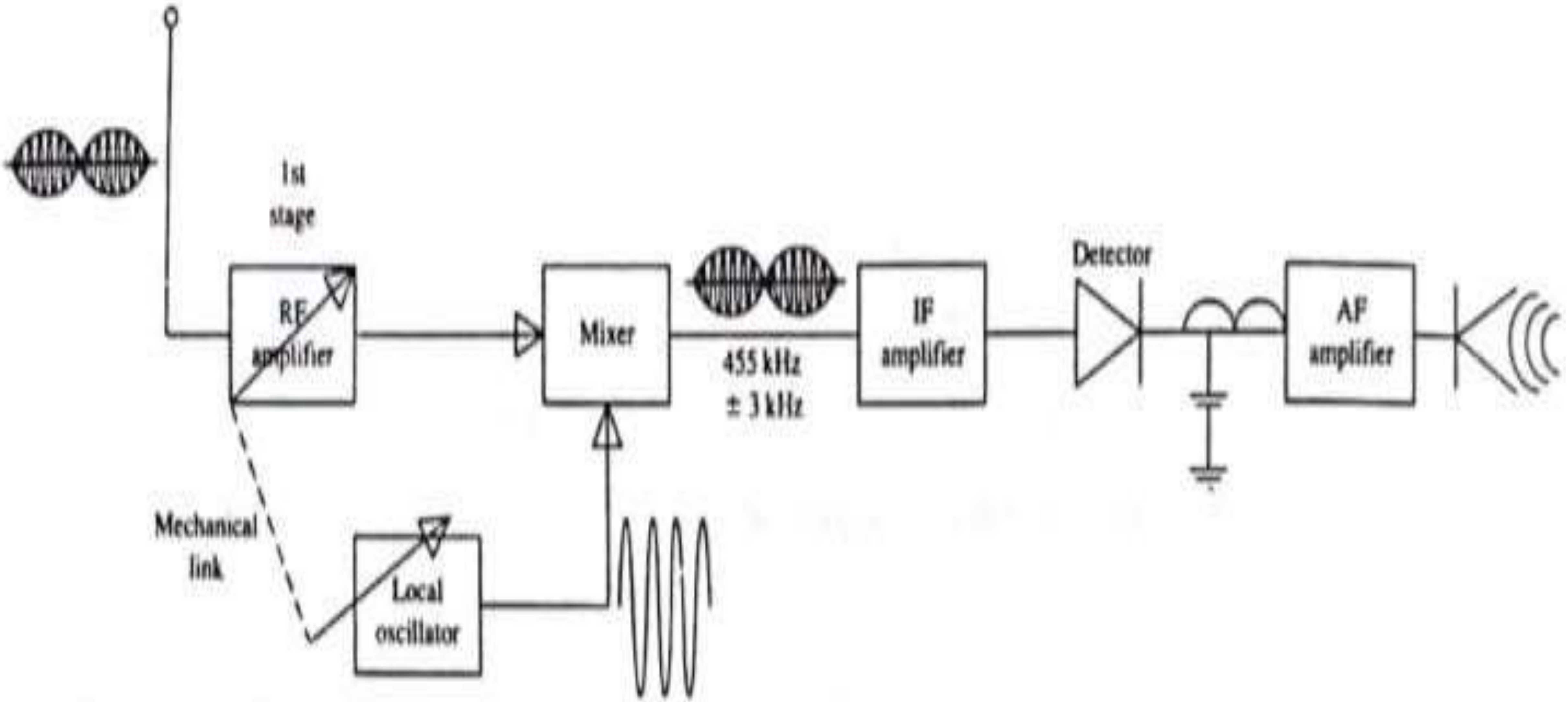


Figure: Superheterodyne Reciever

Tracking

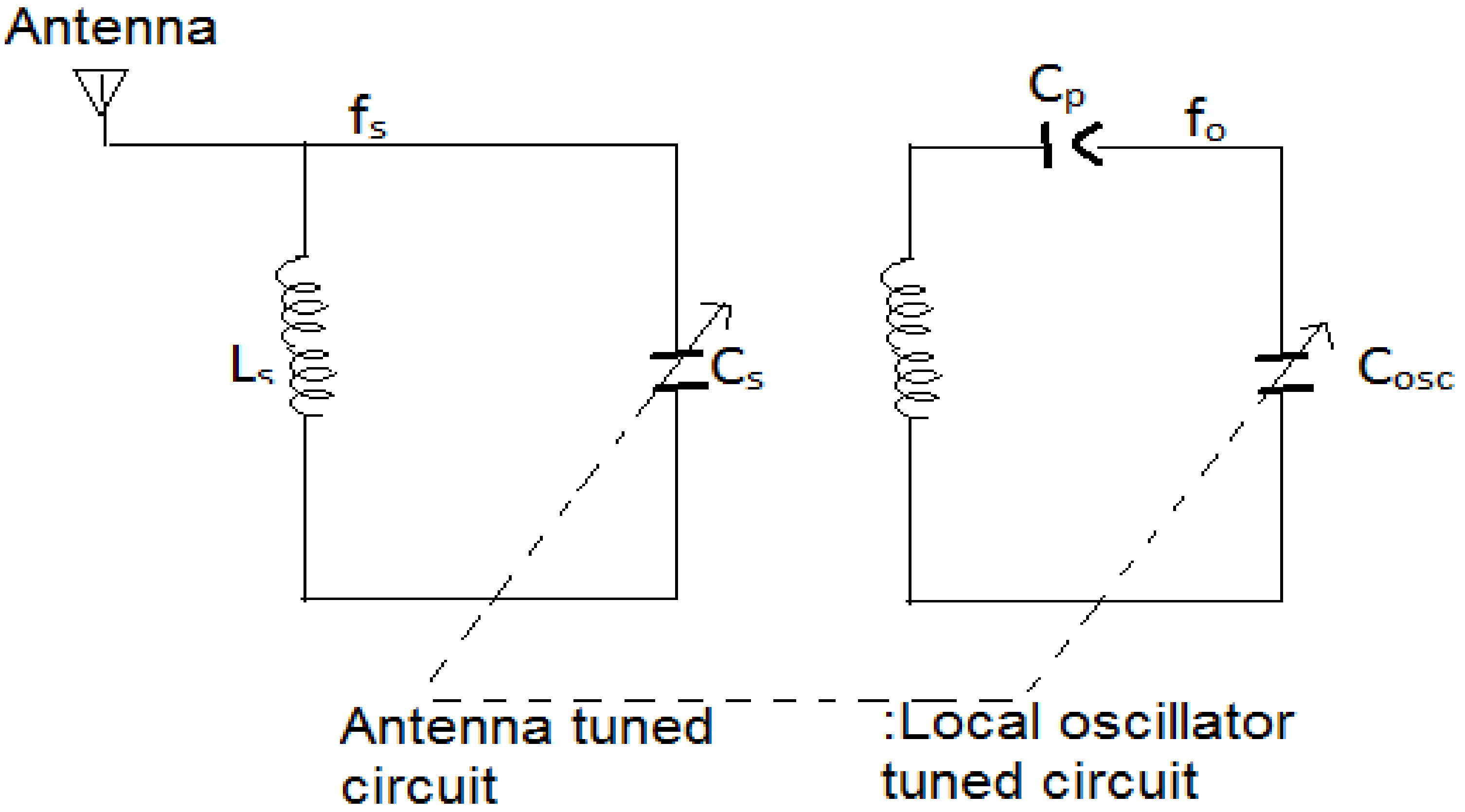
- The receiver has a number of tunable circuits such as the antenna or mixer or a local oscillator tuned circuits.
- All this circuits must be tuned correctly if any station is to be tuned.
- For this reason the capacitors in the various tuned circuits are ganged(mechanically coupled to each other).
- Due to this arrangement it is possible to use only one tuning control to vary the tuning capacitors simultaneously.
- The local oscillator frequency (f_o),must be precisely adjusted to a value which is above the signal frequency(f_s) by IF. i.e. $f_o=f_s+IF$
- If this tuning is not done precisely then the frequency difference i.e.(f_o-f_s) is not correct.

- This type of errors are known as the “tracking errors ”, because tracking is a process in which the local oscillator frequency follows or tracks the signal frequency to have a correct frequency difference.
- Due to the tracking errors the stations will appear away from their correct position on the frequency dial of the receiver.
- There are two types of Tracking.

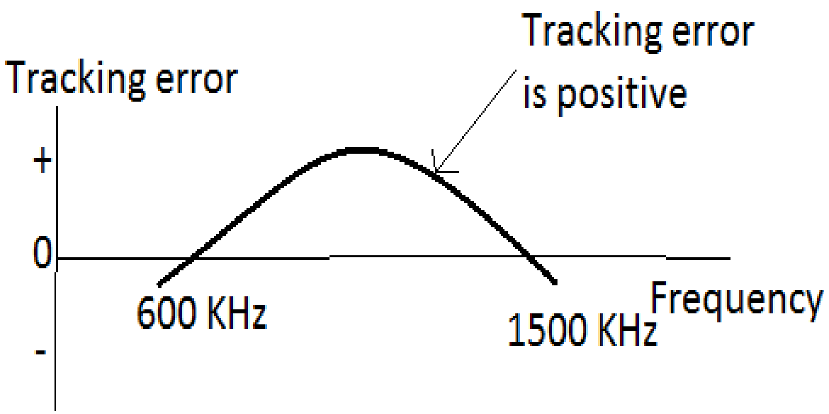
1) Two Point tracking
    - ➢ Padder Tracking
    - ➢ Trimmer Tracking

2) Three point Tracking

Padder Tracking

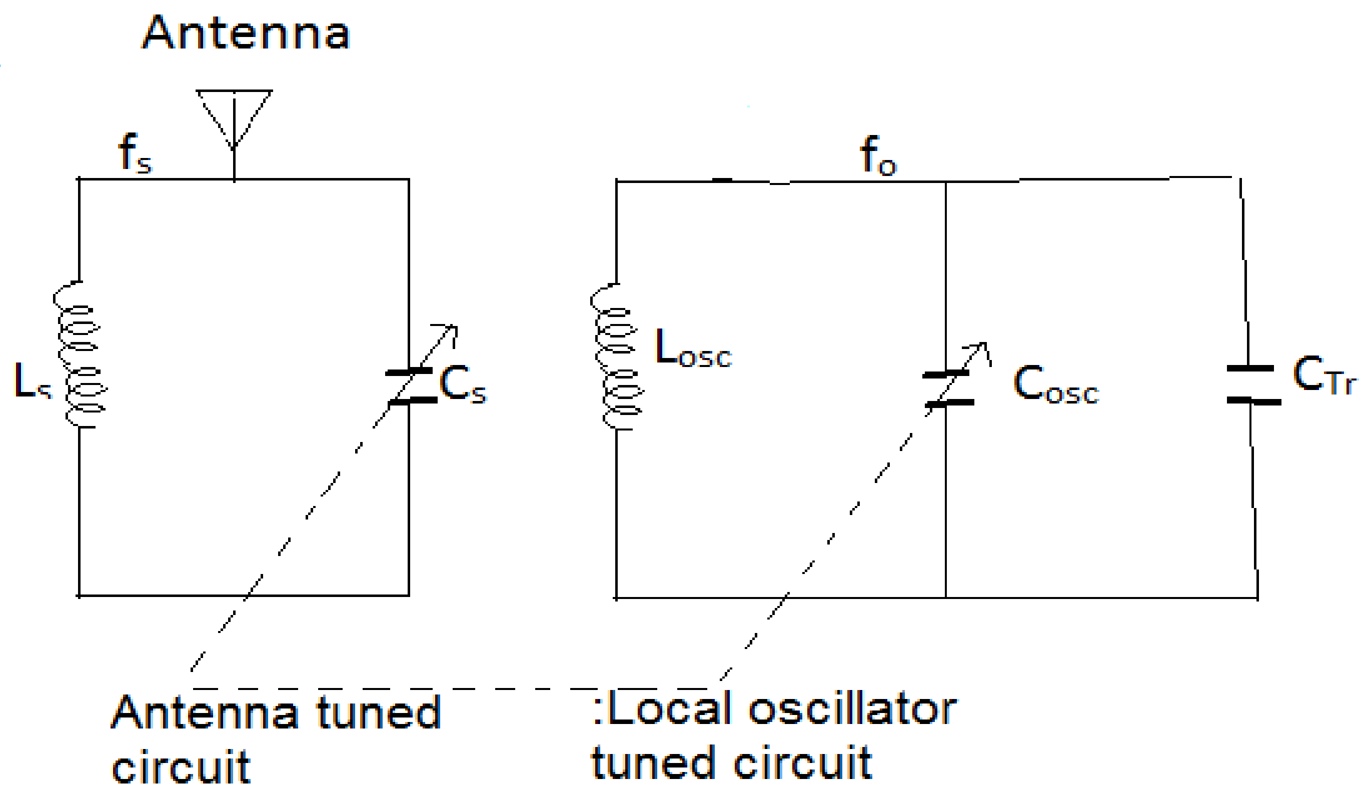


Error in padder tracking

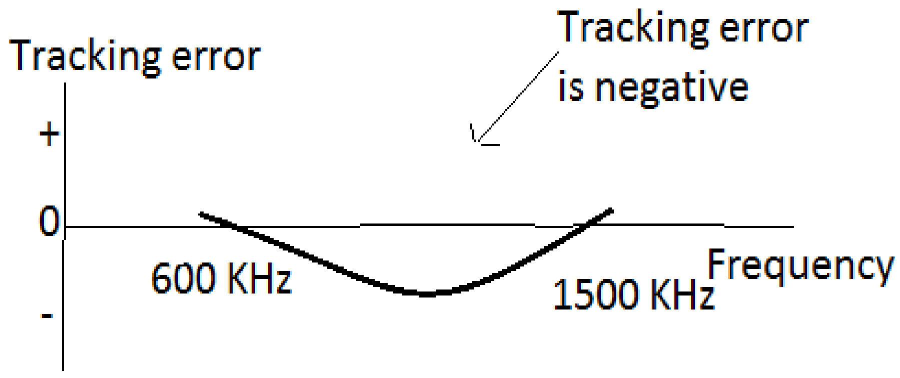


- A Small variable capacitor C_p called as the padder capacitor is connected in series with the oscillator coil.
- Due to the series connection of $C_{p\,and}C_{osc}$ the effective capacitance will be less than C_{osc} alone.
- This will increase the oscillator frequency making the tracking error positive.
- The padder capacitor is adjusted to have zero tracking error on two extrme points on the frequency dial.

Trimmer Tracking

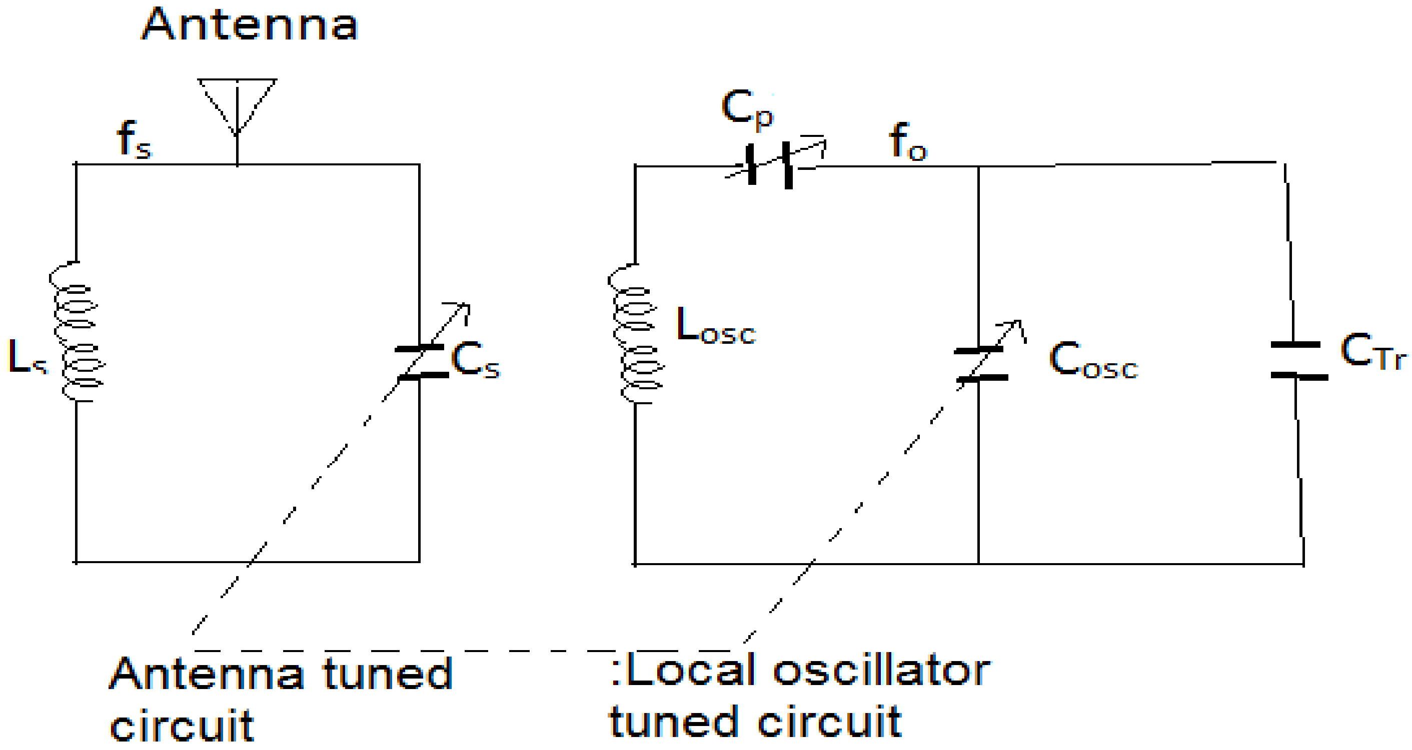


Error in Trimmer Tracking

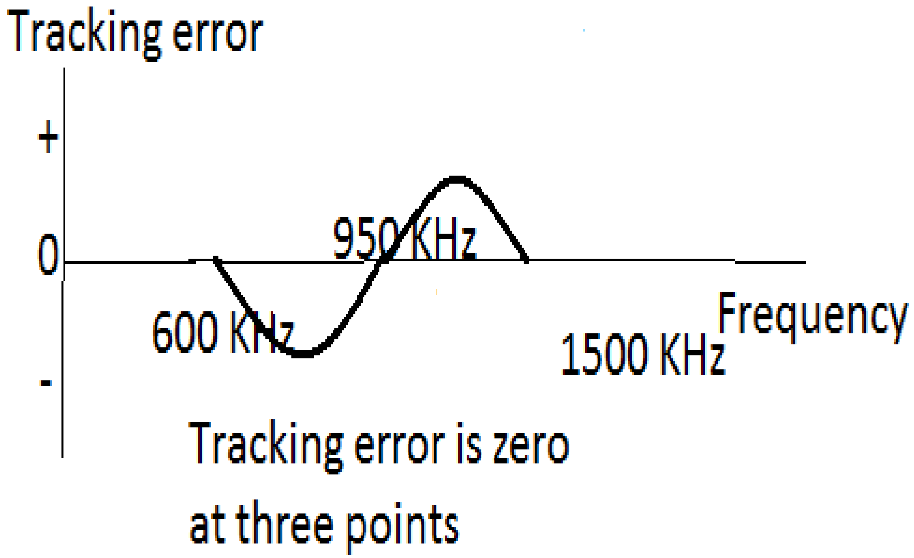


- A small variable capacitor C_{Tr} called as the trimmer capacitor is connected in parallel with the main capacitor $C_{osc.}$
- Due to parallel connection of C_{Tr} and C_{osc} the effective capacitance will be greater than c_{osc} alone.
- This decreases the oscillator frequency making the error negative.
- The Trimmer is adjusted to get zero error at two points on the frequency dial.

Three point Tracking



Associated Tracking Error



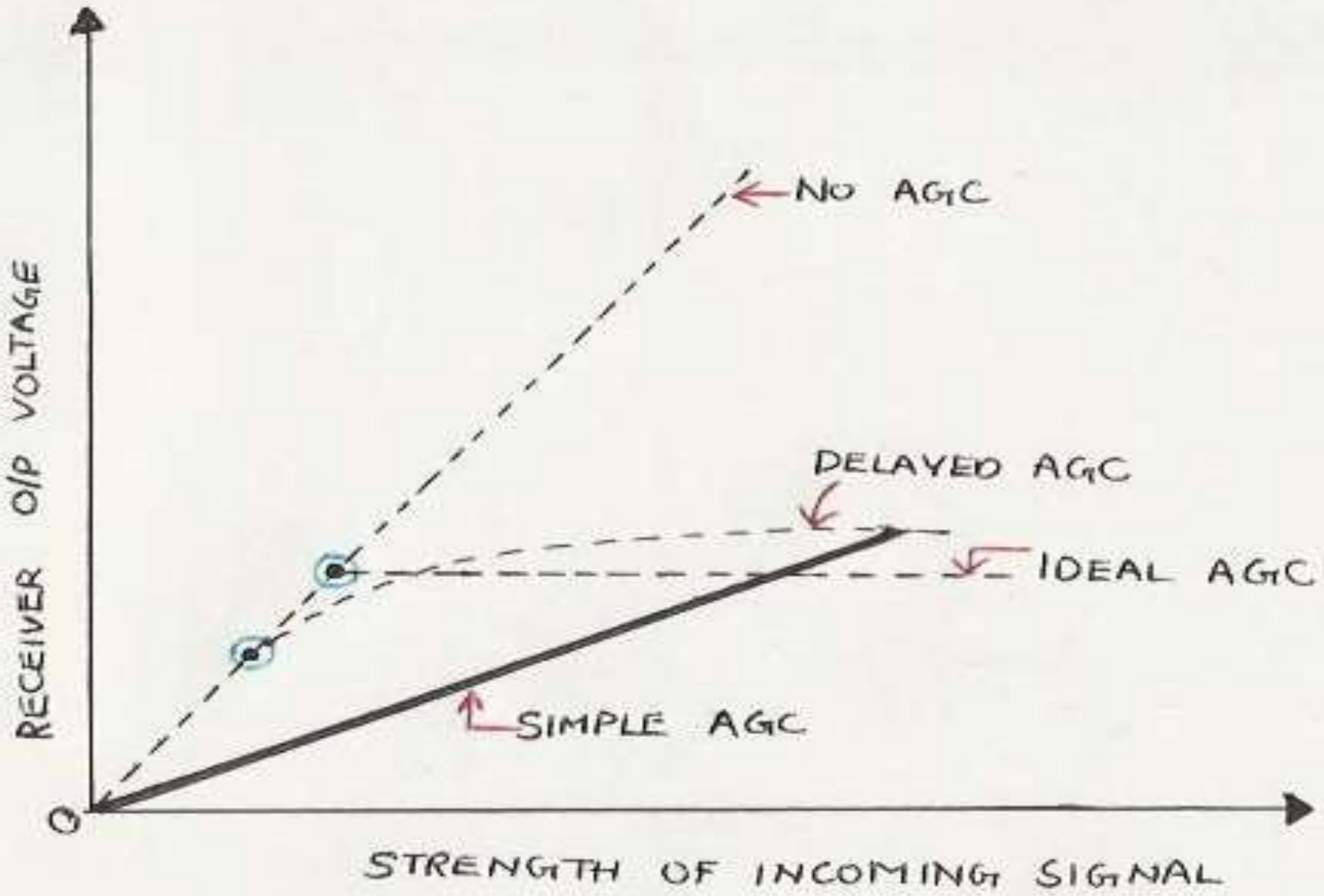
- This combines the padder and trimmer tracking.
- The three frequencies of correct tracking i.e. at which zero tracking error exists are normally 600 KHz,1500 KHz and the geometric mean of the two i.e.950 KHz.
- It is possible to keep the tracking error below 3 KHz.

AUTOMATIC GAIN CONTROL

- Signals receiving at receiver input are not of same strength
- Signals of strong station are strong and from weak stations are weak
- If receiver gain constant, then receiver o/p will fluctuate proportional to i/p signal strength which is not desired
- So AGC adjust receiver gain automatically to have constant o/p irrespective of i/p strength

Types of AGC

- No AGC
- Simple AGC
- Ideal AGC
- Delayed AGC



NO AGC
DELAYED AGC
IDEAL AGC
SIMPLE AGC
RECEIVER O/P VOLTAGE
O
STRENGTH OF INCOMING SIGNAL

SIMPLE AGC

- It will change overall gain of a receiver automatically
- Thus, keep receiver o/p constant even when i/p signal strength changes
- Receiver gain is automatically reduced as i/p signal becomes stronger

- Advantages
    - Simplicity
    - Low cost
- Disadvantages
    - Weak signals are also attenuated
- Applications
    - Low-cost domestic radio receivers

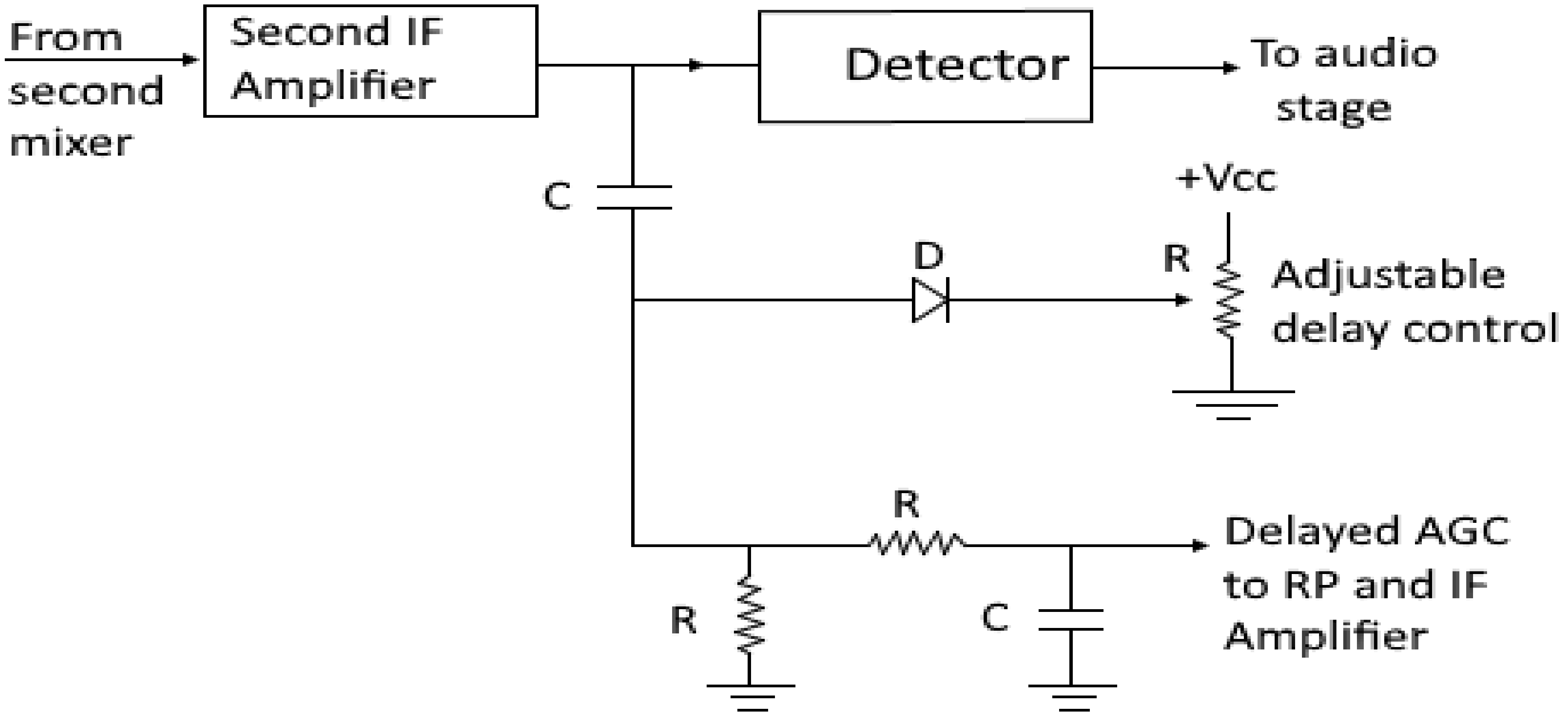
IDEAL AGC

- For the portion ‘OA’ i.e for weak signal no AGC is applied
- After point ‘A’ AGC is applied, keeping receiver o/p constant
- Thus, there is no gain reduction for weak signals

DELAYED AGC

- In this case AGC bias is not applied until i/p signal strength reaches a predetermined level point B
- After this point is reached AGC bias is applied like simple AGC but more strongly
- Thus, reducing receiver gain for weak signals is avoided

Delayed AGC


From second mixer
Second IF Amplifier
Detector
To audio stage
C
+Vcc
D
R
Adjustable delay control
R
Delayed AGC to RP and IF Amplifier
R
C

- **Delayed AGC:**

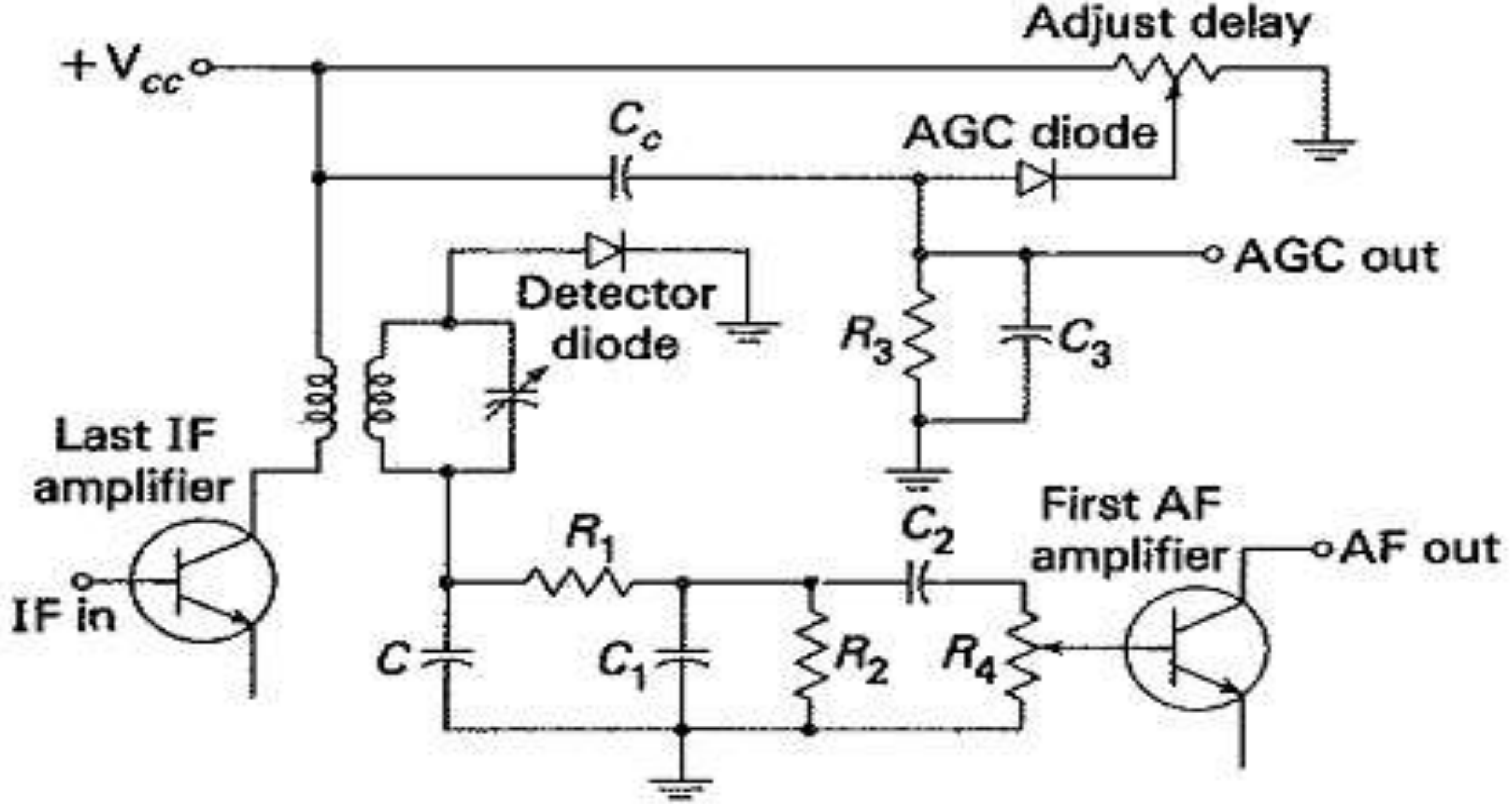


FIGURE 6-20 Delayed AGC circuit.

- So AGC o/p is zero
- When i/p signal is strong then AGC diode is forward biased
- AGC o/p will be constant (Vb + Vd)
- Thus delayed AGC reduces gain for strong signal and not for weak signals
- We can say characteristics of delayed AGC is like ideal AGC
- But here we can adjust point B ,by adjusting delay adjust potentiometer

- Advantages
  - Weak signals are not attenuated
- Disadvantages
  - Complex than simple AGC
- Applications
  - High quality communication receivers

4. Detection and Automatic Gain Control:

- This simple diode detector has the disadvantages that Vo, inaddition to Vin proportional to the modulating voltage, also has a DC component, which represents the average envelope amplitude (carrier strength), and small RF ripple. The unwanted components are removed in a practical detector, leaving only the intelligence and some second harmonic of the modulating signal.

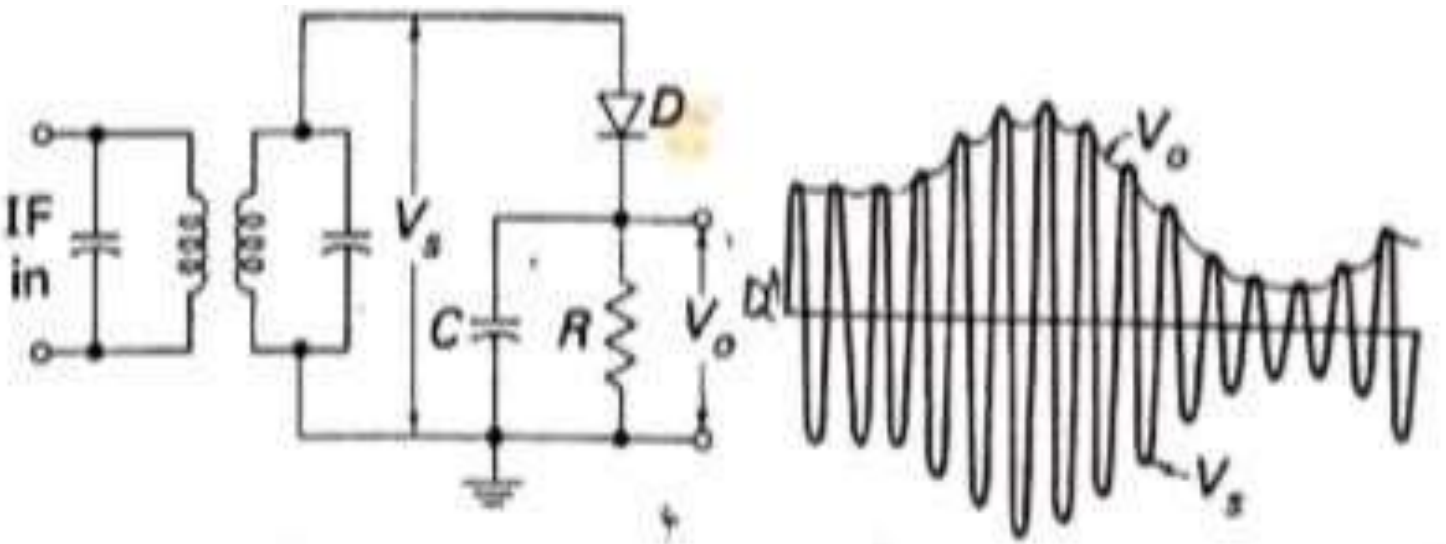


Figure: Simple Diode Detector

- **Practical Diode Detector:**

It can be seen from the figure that the DC diode load is equal to R1+R2, where as the audio load impedance Zm is equal to R1 in series with the parallel combination of R2, R3 and R4, assuming that the capacitors have reactance's which may be ignore. This will be true at medium frequencies, but at high and low audio frequencies Zm may have a reactive components, causing a phase shift and distortion as well as an uneven frequency response.

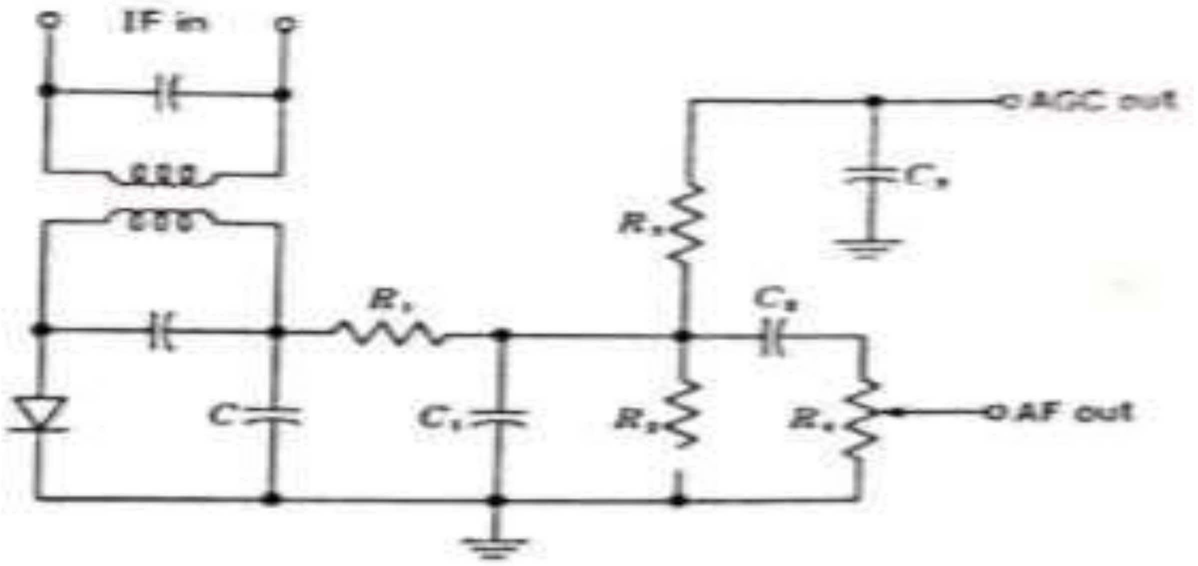


Figure: Practical Diode Detector

FM Receiver

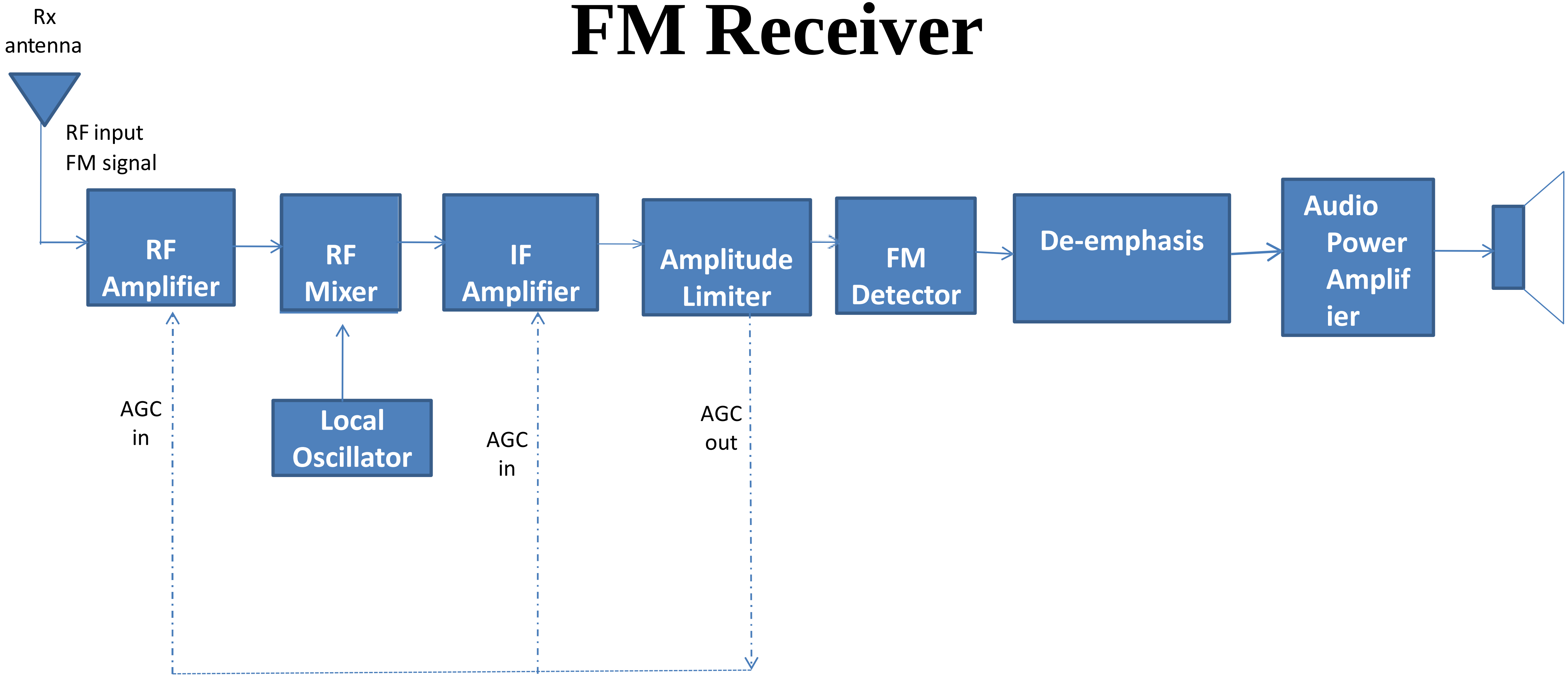


Figure: Block Diagram of FM Superheterodyne Receiver

- **<u>Amplitude limiter stage</u>** :-
  - Transmitted FM wave has constant amplitude, but unwanted noise and signal added to it change its amplitude.
  - This has to be removed before demodulation process otherwise distortion appears in demodulated signal.
  - As demodulators react to amplitude changes as well as frequency changes.
  - Limiter removes all unwanted amplitude variations

Amplitude Limiter

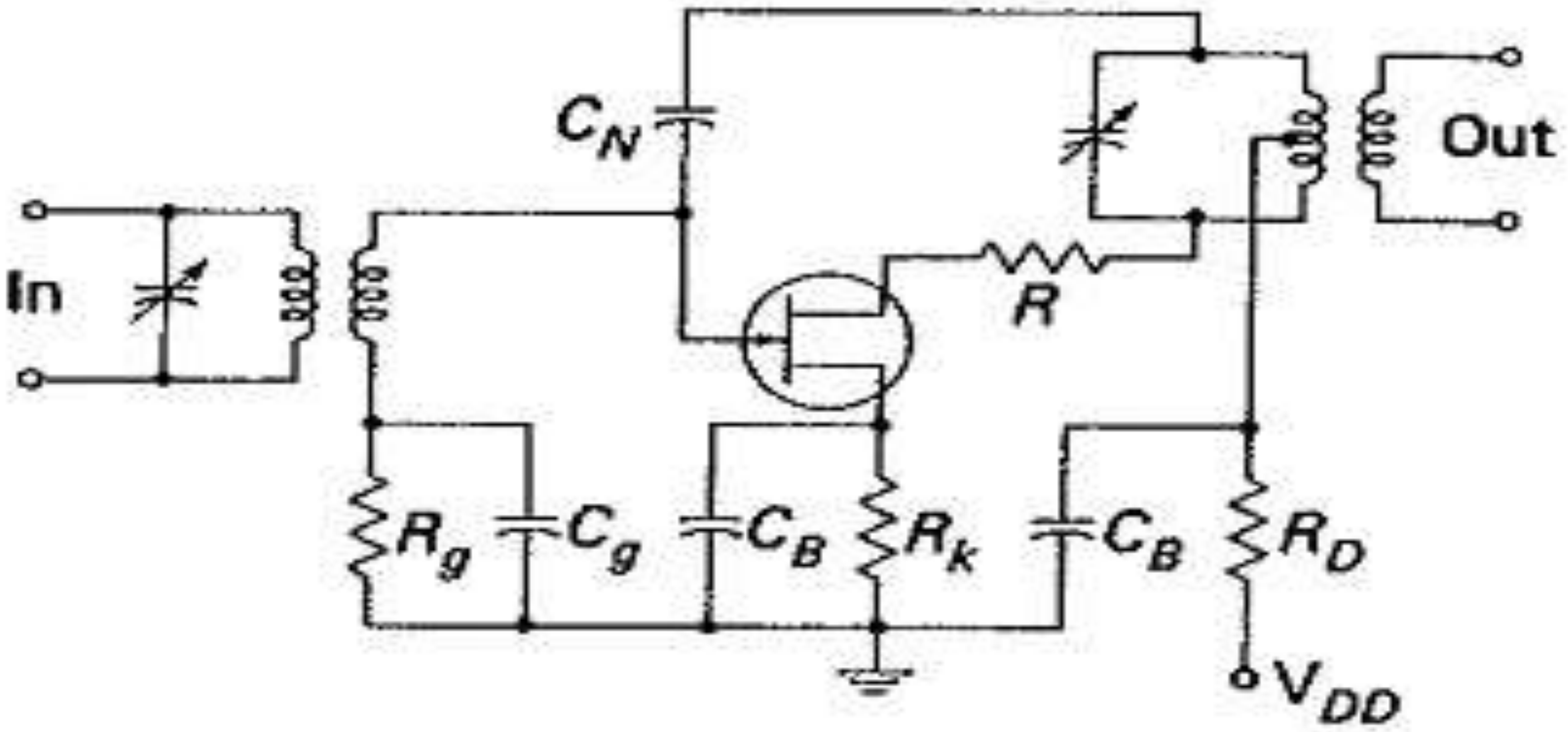


FIGURE 6-30 Amplitude limiter.

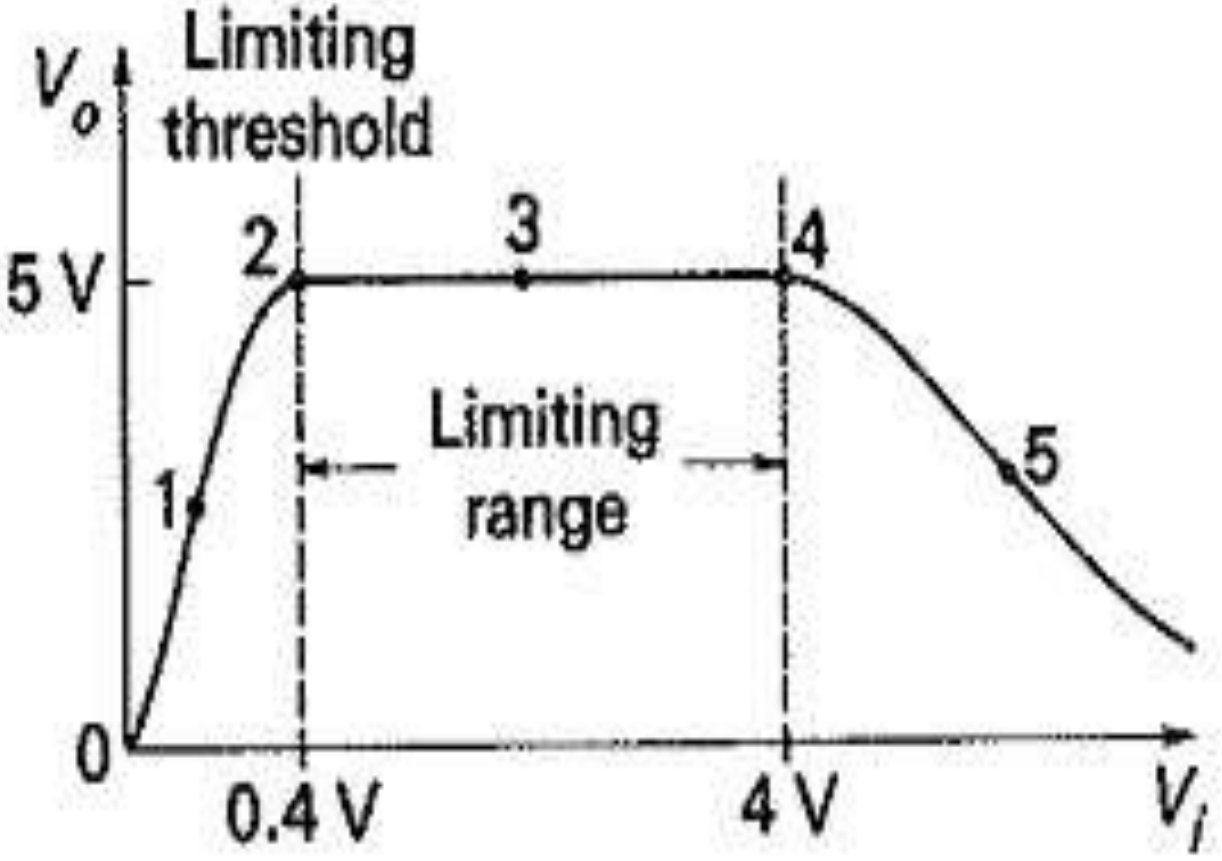


FIGURE 6-32 Typical limiter response characteristic.

AM RECEIVERS Vs FM RECEIVERS

AM Receiver	FM Receiver
AM: 540 kHz – 1600 kHz	FM: 88 MHz – 108 MHz
AM detector basically envelope detector	FM demodulator basically a frequency to amplitude converter
No limiter and de-emphasis stage	limiter and de-emphasis stage needed
IF 455 kHz	IF 10.7MHz
For AM radio, each station occupies a maximum bandwidth of 10 kHz	For FM radio, each station occupies a maximum bandwidth of 200 kHz
AM: Bt = 2W	FM: Bt = 2(D + 1)W (Carson's Rule)
Input signal is AM wave	Input Signal is FM wave

Extra Information

AM is an non linear modulation:

Proof:

General equation of AM is given by

$S_{AM}(t) = A_c(1+\mu m(t))\cos(2\pi f_c t)$

$m_1(t) \Rightarrow S_{AM1}\ (t) = A_c(1+\mu m_1\ (t))\cos(2\pi f_c t)$ --- (1)

$m_2(t) \Rightarrow S_{AM2}\ (t) = A_c(1+\mu m_2\ (t))\cos(2\pi f_c t)$ --- (2)

$$m_3(t) = m_1(t) + m_2(t) \Rightarrow S_{AM1}\ (t) + S_{AM2}(t)$$
$$= A_c(1+\mu(m_1\ (t) + m_2(t)))\cos(2\pi f_c t) \quad \text{--} \quad (3)$$

Add equation(1)+equation(2) we will get

$A_c(2+\mu(m_1\ (t) + m_2(t))\cos(2\pi f_c t)$ -- (4)

Equation(3) $\neq$ $equation$ (4)

Therefore AM is not a linear modulation method

DSB SC is a linear modulation:

$$m_1(t) \rightarrow x_{c_1}(t) = m_1(t)\cos \omega_c t$$

$$m_2(t) \rightarrow x_{c_2}(t) = m_2(t)\cos \omega_c t$$

$$\begin{aligned} m_1(t) + m_2(t) \rightarrow x_{c_1}(t) &= [m_1(t) + m_2(t)]\cos \omega_c t \\ &= m_1(t)\cos \omega_c t + m_2(t)\cos \omega_c t \\ &= x_{c_1}(t) + x_{c_2}(t) \end{aligned}$$

FM is not an linear modulation

Proof:

General equation of FM

$$S_{FM}(t) = A_c \cos[2\pi f_c t + 2\pi k_f \int_{-\infty}^{\infty} m(t)\ \mathrm{dt}]$$

$$m_1(t) = S_{FM1}(t) = A_c \cos[2\pi f_c t + 2\pi k_f \int_{-\infty}^{\infty} m_1(t)\ \mathrm{dt}] \qquad (1)$$
$$m_2(t) = S_{FM2}(t) = A_c \cos[2\pi f_c t + 2\pi k_f \int_{-\infty}^{\infty} m_2(t)\ \mathrm{dt}] \qquad (2)$$

$$\begin{aligned} m_3(t) &= m_1(t) + m_2(t) = S_{FM1}(t) + S_{FM2}(t) \\ &= A_c \cos[2\pi f_c t + 2\pi k_f \int_{-\infty}^{\infty} (m_1(t) + m_2(t))\ \mathrm{dt}] \qquad (3) \end{aligned}$$

Add equation(1)+equation(2) we will get

$A_c \cos[4\pi f_c t + 2\pi k_f \int_{-\infty}^{\infty} (m_1(t) + m_2(t))\ \mathrm{dt}]$ ---(4)

Equation(3)$\neq$ $equation(4)$

Therefore FM is not a linear modulation

PM is not an linear modulation

Proof:

$$m_1(t) \to x_{c_1}(t) = A\cos\left[\omega_c t + k_p m_1(t)\right]$$

$$m_2(t) \to x_{c_2}(t) = A\cos\left[\omega_c t + k_p m_2(t)\right]$$

$$m_1(t) + m_2(t) \to x_c(t) = A\cos\left\{\omega_c t + k_p[m_1(t) + m_2(t)]\right\}$$

$$\neq x_{c_1}(t) + x_{c_2}(t)$$

Hence, PM is a nonlinear modulation.

Base band signal m(t):

Is the original transmission signal that has not been modulated, or has been demodulated to its original frequency.

Most telecommunication protocols require baseband signals to be converted ,or modulated ,to a higher frequency so that they can be transmitted over long distances.

Therefore the base band or low pass signals are converted during the transmission

Ethernet is an example of protocol that does not require signal modulation, since it transmits data in base band

|m(t|

Assume that bass band signal is of the form

x=3+5i= |x|=$\sqrt{(3^2+5^2)}$

Similarly if the signal is of the form

X(t)=$A_c \cos(2\pi f_c t)$ whose magnitude/modulus include |x(t)|= A_c

X(t)=$A_c \sin(2\pi f_c t)$ whose magnitude/modulus include |x(t)|= A_c

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Thank You