ANALOG COMMUNICATION

Course Code :20EC07

Radio Transmitters and Receivers

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AM Spectrum: 535-1700KHz,
Band width of AM:10KHz
FM Spectrum: 88-108MHz,
Band width of AM:200KHz, it is 20 times of BW of AM

Radio Transmitters

Radio frequency range: **3 KHz up to 300 gigahertz**

Transmitter: It is an electronic device which convert a message (modulating) signal into a signal (modulated sign or RF) which is suitable form to the channel and it transmit to long distance with the help of antenna .

in general, the transmitter performs the matching of the message signal to the channel by the process called modulation,

ex: AM,FM

The basic components of a radio transmitter include an oscillator, a modulator, an amplifier, and an antenna.

Classification of Radio Transmitters:

Classification on the basis of type of modulation used

1. Amplitude Modulation Transmitters: Here the modulating signal modulates the carrier with respect to amplitude. AM transmitters are used for radio broadcast, radio telephony, radio telegraphy and TV pict broadcast.
2. Frequency Modulation Transmitters: In FM transmitters, the frequency of the carrier is varied in accordar with the modulating signal. These are used for radio broadcast, TV sound broadcast in VHF & UHF range a radio telephone communication.
3. Pulse Modulation Transmitters: The signal changes any of the characteristics like pulse width, positi amplitude of the pulse carrier.

Radio Transmitters

Classification on the basis of the service involved

1. Radio Broadcast transmitters: These transmitters are particularly designed for broadcasting speech signals, music, inform etc. These systems may be amplitude or frequency modulated.
2. Radio Telephone Transmitters: These transmitters are mainly used for transmitting telephone signals over long distanc radio waves. The transmitter uses volume compressors, peak limiters etc.
3. Radio Telegraph Transmitters: It transmits telegraph signals from one radio station to another radio station. The transm uses either amplitude modulation or frequency modulation.
4. Television Transmitters: TV broadcast requires transmitters for transmission of picture and sound separately. Both operate and UHF frequency range.
5. RADAR Transmitters: RADAR stands for Radio Detection And Ranging. These transmitters are of two types: Pulse Rada Continuous Wave Radar. 6. Navigation Transmitters: Special types of radio transmitters and receivers are used these day sea and air navigation, blind landing of aircrafts etc.

Classification on the basis of Frequency range used

1. Long Wave Transmitters: These transmitters operate on frequencies below 300 kHz. Such long wave radio transmitters are for broadcasting, where atmospheric disturbances on long waves are not severe.
2. Medium Wave Transmitters: The frequency range of MW transmitters is from 550 to 1650 kHz. The carrier power varies f kW to 1000kW.
3. Short Wave Transmitters: The SW transmitters work on frequencies in the short wave range i.e. from 3 to 30MHz. For exa ionospheric propagation.
4. VHF & UHF Transmitters: These transmitters operates either VHF or UHF frequency ranges. These are used for FM casting , Television broad casting, FM radio telephony etc.
5. Microwave Transmitters: These transmitters operates at microwave ranges i.e above 1Ghz frequency. These are used RA Microwave link between two countries or between mainland or adjoining Islands etc.

Radio Transmitters

Classification on the basis of power

1. High level modulation Transmitter: In high level AM modulator, the modulation is carried out at high power l of the carrier and baseband signal. Its advantage is that linear amplifiers are not required for the amplification stages after AM modulation. The efficiency of high level modulation is very high due to the us class C power amplifiers.
2. Low level modulation Transmitter: In low level AM modulator, the modulation is done at low power level of input signals, typically in the RF generation stages. It has the advantage of lesser distortion in output. disadvantage of this method is that linear amplification is needed for the RF stages.

Carrier frequency requirements of Radio Transmitters:

1. Generated carrier frequency must be exactly a specified value

- Every radio transmitting station is allocated one or more frequencies at which it must operate
- Carrier frequency is determined by the master oscillator frequency
- The frequency generated by master oscillator may be adjusted to any desired value by suitable selection of frequency determining components in the tank circuit of master oscillator
- Of course, the master oscillator generates only sub harmonics of the final carrier frequency and frequency bro to the final value by harmonic generators

2. Carrier frequency must be readily adjustable : Most of the radio transmitters use crystal controlled master oscillator in which the carrier frequency cannot be readily changed

If conventional 'LC ' tuned circuits are used in master oscillator, then the frequency of oscillations may be readily changed by varying either the capacitor 'C' or the inductor 'L' in tuned circuits.

Radio Transmitters

3. Frequency drift and frequency scintillation should be extremely small
Frequency drift means slow variations in frequency with time

In any oscillator, the frequency of oscillations is close to the resonant frequency of the tank circuit, but the value of frequency of oscillations is influenced by the following factors

i) Resistance and Reactance coupled into the tank circuit by the load
ii) Effective 'Q' of the tank circuits
iii) Effect of electrode voltages on frequency
iv) Effect of harmonics on frequency stability

The maximum frequency drift permitted in radio transmitters is ±20Hz for medium wave transmitters and ±0.0 for short waves and UHF transmitters

The frequency scintillation is caused by abrupt changes in the load on the master oscillator

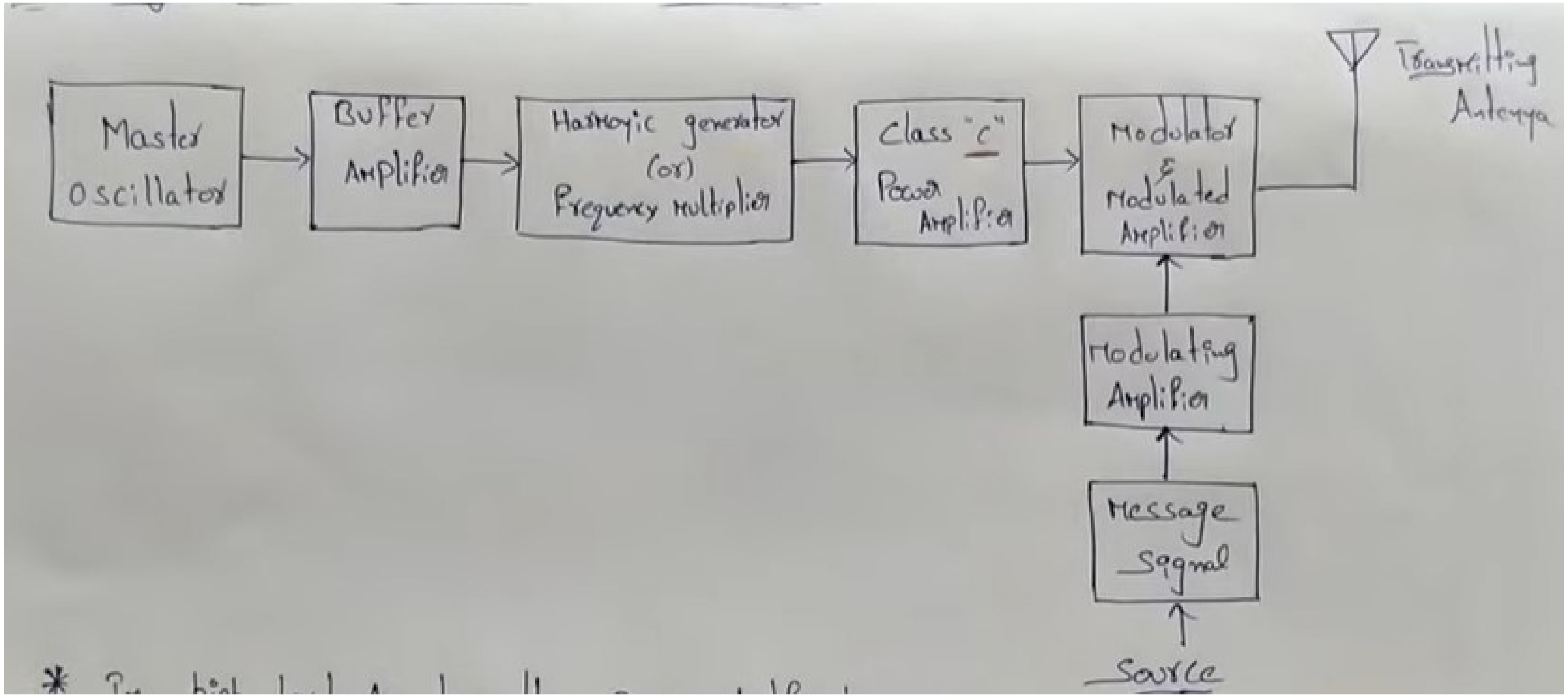
Any abrupt change in the load causes change in the resistance and reactance coupled into the tank circuit o oscillator and cause corresponding change in frequency of oscillations.

Radio Transmitters

AM transmitter using High Level and Low Level Modulation:

AM range: 530KHz-1700KHz

High level modulation Transmitter*: In high level AM modulator, the modulation* is carried out at high pov level of the carrier and baseband signal. Its advantage is that linear amplifiers are not required for the amplification stages after AM modulation. The efficiency of high level modulation is very high due to the use class C power amplifiers. In this Power amplification done before modulator.



Radio Transmitters

Low level modulation Transmitter: In low level AM modulator, the modulation is done at low power level of input signals, typically in the RF generation stages. It has the advantage of lesser distortion in output. disadvantage of this method is that linear amplification is needed for the RF stages.

AM transmitter using modulation at low carrier power levels called Low level Modulation.

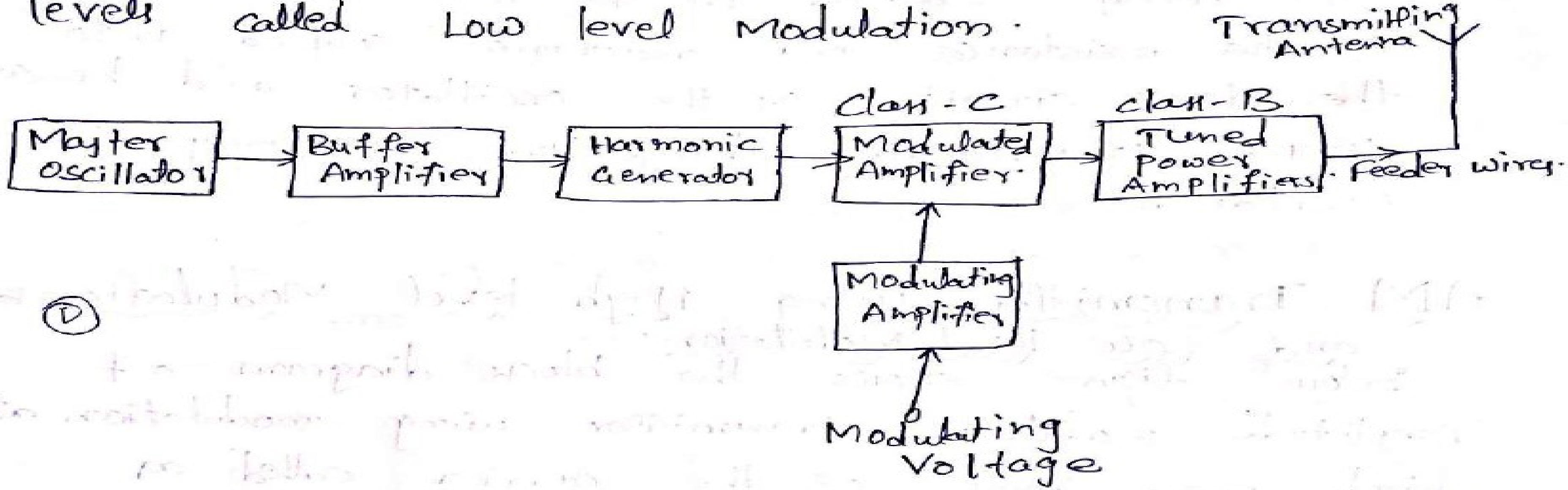


fig. Block diagram of AM transmitter using low level Modulation.

Radio Transmitters

Block diagram of AM transmitters

The transmitters which transmit AM signals are known as AM transmitters. These transmitters are used in med wave and short wave frequency bands for AM broadcast. The MW band has frequencies between 550 KHz 1650 KHz, and the SW band has frequencies ranging from 3 MHz to 30 MHz.

The basic difference between high level and low level modulation is, In high level modulation, the modu process is done at high power levels i.e. Amplification done before modulation.

In low level modulation, the modulation process is done at low power levels i.e. Amplification is done modulation.

Apart from this difference, all the blocks are same for AM transmitters.

Master oscillator: The oscillator generates the carrier signal (oscillations)of desired frequency (RF)range with frequency stability. The generated frequency is required to remain constant in spite of variations in the su voltage, ambient temperature, temperature of components of load. Further frequency variations with time an of components are to be avoided.

An ordinary LC oscillator may be used as master oscillator. If extreme frequency stability is required, th oscillator is replaced by crystal controlled oscillator.

Radio Transmitters

Buffer Amplifier or Isolating Amplifier:

The purpose of the buffer amplifier is to match the output impedance of the master oscillator with the i
impedance of the harmonic generator. So, it isolates the oscillator and harmonic generator.

If the master oscillator directly drives the harmonic generator, loading effect may occurs on master oscillator w
cause variations of effective resistance of tank circuit of the oscillator hence causing frequency variations.

Buffer amplifier Isolates the oscillator and harmonic generator.

This buffer amplifier does not draw any input current and hence no loading of oscillator.

Hence variations in frequency are to be avoided.

Harmonic Generator:

Usually master oscillator generates voltage at a frequency which is a sub multiple of carrier frequency.

Basically harmonic generators generates higher harmonics. Harmonic generators are Class C tuned amplifie
which the output of RF voltage is first distorted through class C operation and then tuned circuit in the ou
circuit of amplifier selects the desired harmonic frequency.

Power Amplifier: RF signal generated by oscillator has usually small power in order to few watts. The powe
the carrier signal is then amplified using the power amplifier stage. A class C power amplifier is used to give h
power current pulses of the carrier signal at its output.

Radio Transmitters

Modulated Class C Amplifier: This is class C tuned amplifier usually push pull type**.** The amplified modulating a
signal and the carrier signal are applied to this modulating stage to carry out AM modulation. This signal is fi
passed to the antenna, which radiates the signal into space.
The efficiency series type modulation is most popularly used in high power radio broadcast and radio telep
transmitters.

Modulating Amplifier:
This is usually a class B push Pull amplifier and feeds audio power into the modulation a amplifier
Class B operation is generally used, but also some times class A modulating amplifiers are also used in low pov
transmitters.

Feeder and Antenna:
The transmitting power is fed to a transmitting antenna for effective radiation.
The antenna is normally located at a distance from the transmitter and hence the power from the transmitter
fed to the antenna through a properly design transmission line is called Feeder.
The impedance of the feeder must be match with transmitter impedance at one end and with antenna impeda
at other end.

Radio Transmitters

Direct Method of FM Generation

- **Direct method** is also known as **parameter variation method**, where the baseband or modulating signal directly modulates the carrier
- The carrier signal is generated with the help of an **oscillator circuit**
- This **oscillator circuit** uses a parallel tuned **L-C circuit**

The **frequency of oscillation** of the carrier generation is given by: $\omega_c = \frac{1}{\sqrt{LC}}$

- The carrier frequency ω_c **vary** in accordance with the baseband or modulating signal x(t) if L or C is varied according to x(t)
- An oscillator circuit whose frequency is controlled by a modulating voltage is known as **voltage controlled oscillator (VCO)**
- The **frequency of VCO is varied** according to the modulating signal just by putting a shunt voltage variable capacitor with its tuned circuit
- This voltage variable capacitor is known as **varactor** or **varicap**

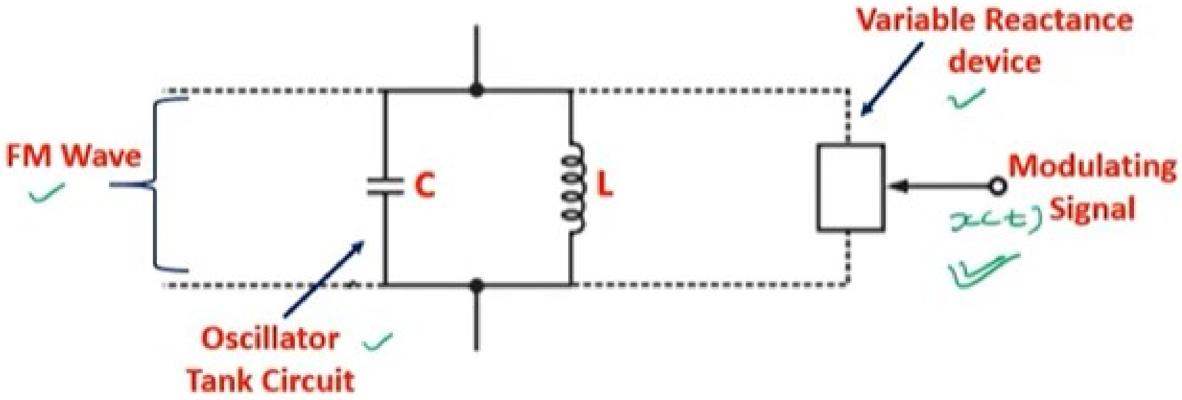
- The **inductance L** of the tuned circuit may also be varied in accordance with the baseband or modulating signal x(t)
- The FM circuit using such inductors is called **saturable reactor modulator**

Radio Transmitters

FM transmitter using Reactance modulator or Direct Method:

Reactance Modulator

- In **direct FM generation**, the instantaneous frequency of the carrier is changed directly in proportion with the message signal
- A **reactance modulator** changes the frequency of tank circuit of oscillator by changing its **reactance**



- The **frequency** of this **oscillator** is **changed** by changing the reactive components involved in the tuned circuit
- If **L or C of a tuned circuit** of an oscillator is **changed** in accordance with the amplitude of modulating signal then FM can be obtained across the tuned circuit

$$X_C = \frac{1}{2\pi f C}$$

$$X_L = 2\pi f L$$

- A **two** or **three** terminal device is placed across the tuned circuit
- The reactance of the device is varied proportional to modulating signal voltage
- It will vary the frequency of the oscillator to produce FM
- **The devices used are FET, transistor or varactor diode**

Radio Transmitters

FM transmitter using Reactance modulator or Direct Method:

Figure shows a simple 96MHz FM transmitter using reactance modulator

The reactance of FET and BJT, varactor diode etc. can be varied by the application of voltage. If it is placed acros tank circuit of the L-C oscillator, then FM will be produced when the reactance of the device is varied accordi the modulating voltage

FM range: 88-108M

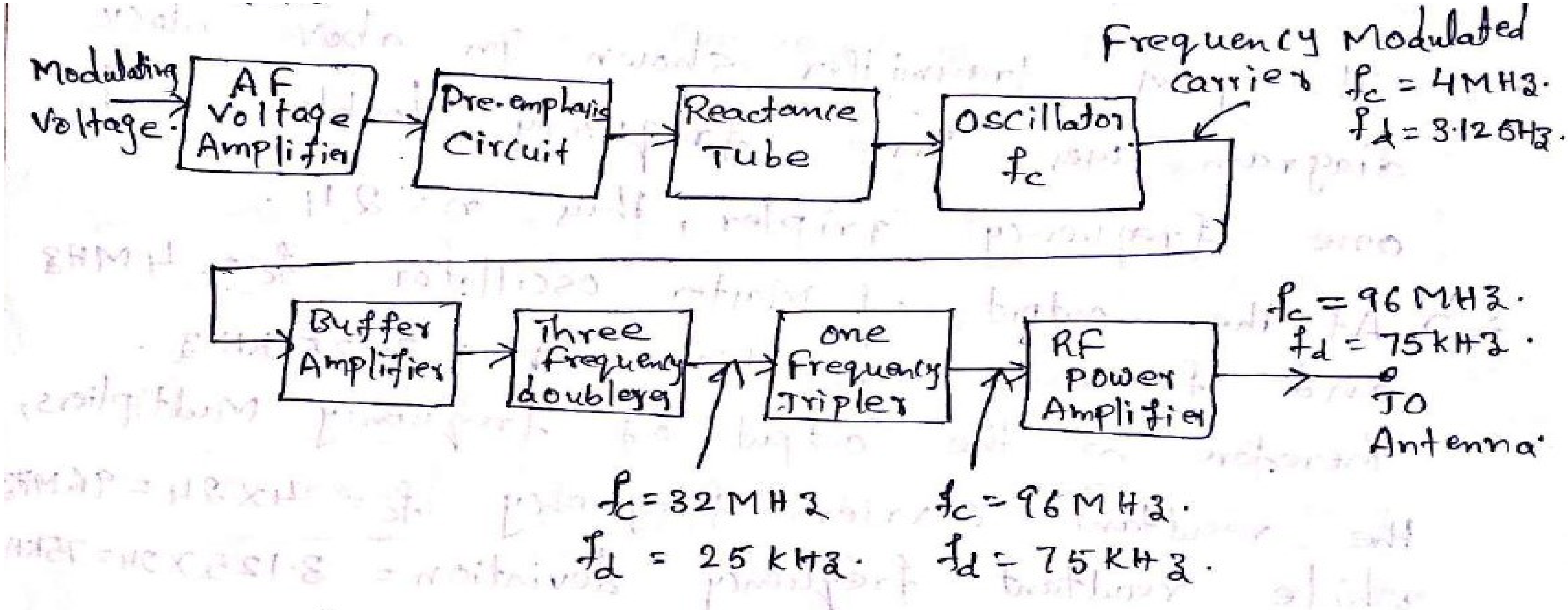


fig:- Simple FM Transmitter using reactance Modulator.

Radio Transmitters

FM transmitter is designed to generate FM signal at 96MHz frequency.

Modulating signal is applied to AF(Audio Frequency) Voltage amplifier, It amplifies modulating signal voltage. The output of AF amplifier is then applied to pre – emphasis circuit.

Pre-emphasis is boosting the relative amplitudes of the modulating voltage for higher audio frequencies from approximately 15 KHz.

The output of the pre emphasis circuit is given to Reactance tube. Based on the modulating voltage obtained pre emphasis, the reactance of the reactance tube will be varied.

The reactance tube frequency modulates the carrier frequency of master oscillator to 4MHz and produce frequency deviation 3.125KHz.

The output of master oscillator is applied buffer amplifiers to reduce or avoid loading effect.

The output of buffer amplifier is applied to frequency multipliers(two) to obtained desired frequency (96MHz)

The frequency multipliers follows masters oscillator output and carrier frequency and frequency devia multiply by the factor 'n'.

Radio Transmitters

In the block diagram uses Three frequency doublers and one frequency triplers to obtain the 96MHz frequency

So three frequency doublers i.e. 2X2X2 = 8 and one frequency Tripler i.e.3

Therefore frequency multiplier output , n= 8X3 = 24

Out put of master oscillator carrier frequency is 4 MHz it is applied to frequency multiplier.

Hence it is multiplied by factor, n=24

Then the output of frequency multiplier is 24x4 = 96Mhz

And it also multiplies the frequency deviation 24X3.125KHz = 75KHz

The output of frequency multiplier is raised to desired power level, it is apply to RF power amplifiers.

The final output is fed to antenna to transmit to channel.

Stabilized FM transmitter using Reactance modulator: The carrier frequency of reactance modulator FM transm may drift due to i) Variation in supply voltage ii) variation due to temperature and humidity. iii)Age of componen By using the following arrangement , frequency drift can be avoid and maintain high frequency stability.

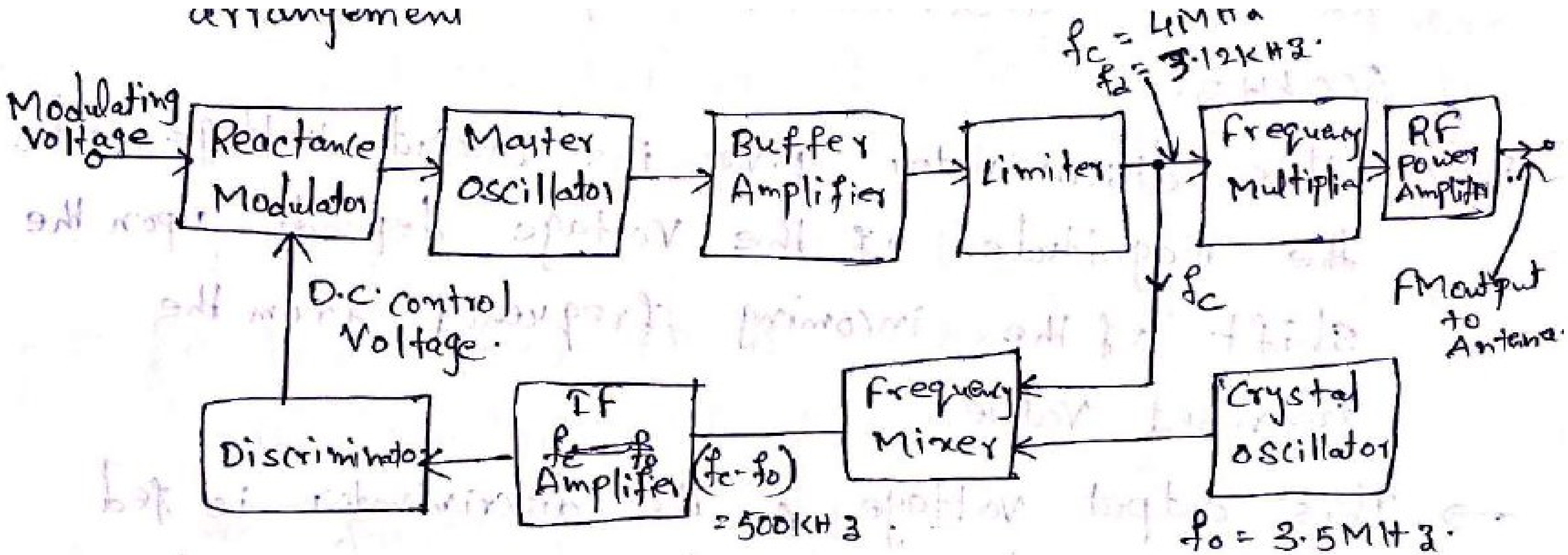


fig:- Reactance Modulalulator FM transmitter using AFC frequency stabilization.

Radio Transmitters

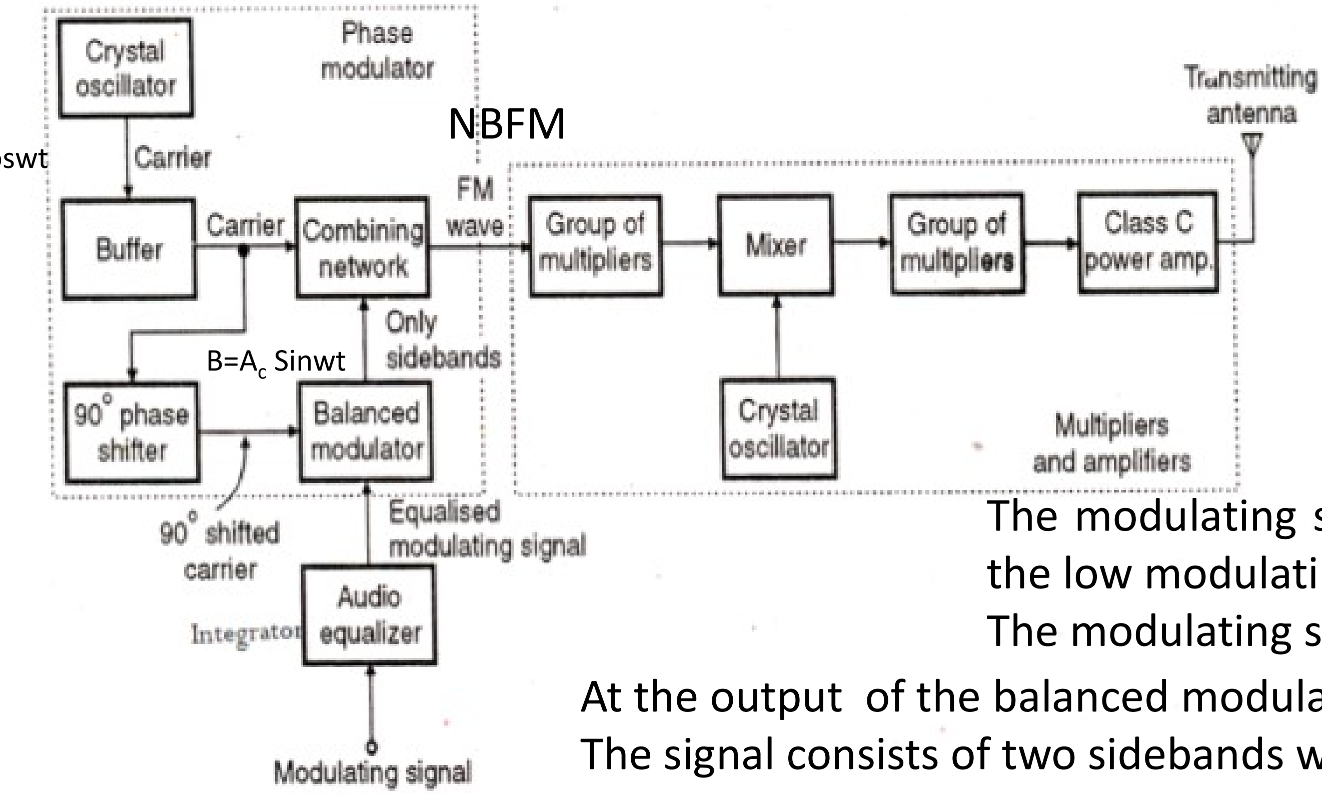
The master oscillator is not a crystal controlled oscillator, whose frequency is varied due variation in reactance
reactance modulator.
The reactance of the reactance modulator varied by modulating signal.
Modulating signal applied to reactance modulator. Due to modulating signal, the reactance of the modulator is v
The output of reactance modulator is applied to master oscillator. Due variation of the reactance causing to va
frequency of the master oscillator in accordance with modulating signal.
The signal obtained from master oscillator is applied to buffer amplifier followed by limiter to avoid loading
and control the power level.
The output of limiter i.e master oscillator output and crystal oscillator output are applied to frequency mixer.
The crystal controlled oscillator frequency differs the carrier frequency of the master oscillator.

Frequency mixer produce the frequency deviation between oscillators. i.e f_c-f_o.
The difference in frequency signal obtained from mixer is applied to IF amplifier then fed to discriminator des
to operate one fixed frequency.
The discriminator gives output voltage which is depends on frequency deviation(f_c-f_o).
The output of discriminator is fed to reactance modulator that cause to vary the reactance, it cause to var
frequency of master oscillator. It may tends to frequency of master oscillator is equal to frequency of C
oscillator. Then frequency deviation is zero.
Any deviation(drift) in frequency can be reduced by using this system. Hence frequency stability is improv
using this system.

Radio Transmitters

FM transmitter using Indirect Method or Armstrong Method:

Armstrong method of FM generation is the indirect method because the modulating signal directly varies the phase of the carrier, which indirectly changes the frequency.
The direct method of FM have the disadvantage of using LC oscillator, It is not suitable for communication and broadcasting. Hence Indirect or Armstrong method is used for communication.



In this method FM is obtained through P
and Crystal oscillator can be used
improve the very high frequency stabilit

The crystal oscillator generates the carrier at frequency at 1MHz.
This is applied to the combining network and phase shifter.

The modulating signal is passed through an audio equalizer to the low modulating frequencies.
The modulating signal is then applied to a balanced modulator.

At the output of the balanced modulator, we get DSBSC signal i.e AM signal without c
The signal consists of two sidebands with 90^0 phase shifted.

Radio Transmitters

The un modulated carrier and 90^0 phase shifted sidebands are added in the combining network.

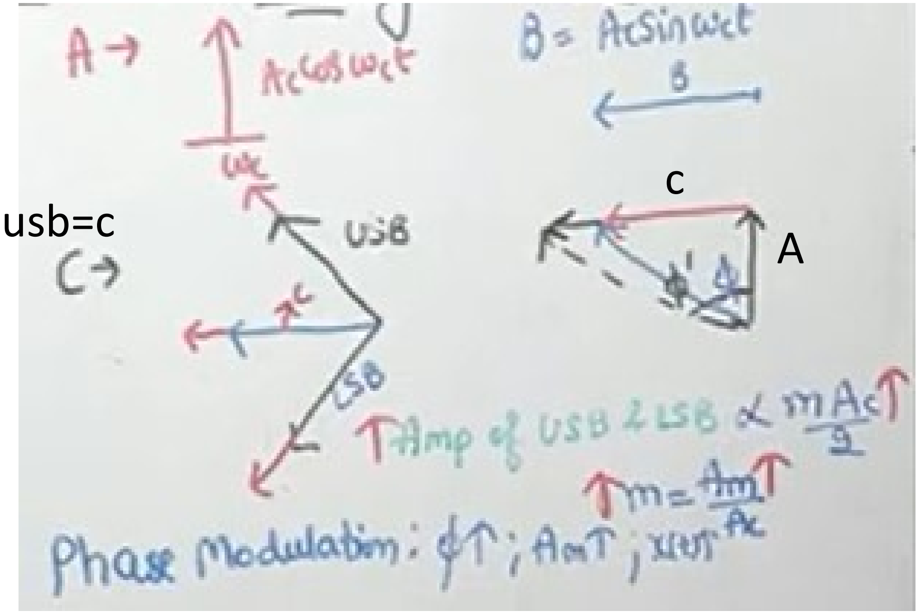
At the output of combining network we get FM wave. This wave has a low carrier frequency 'f_c 'and low val modulation index.

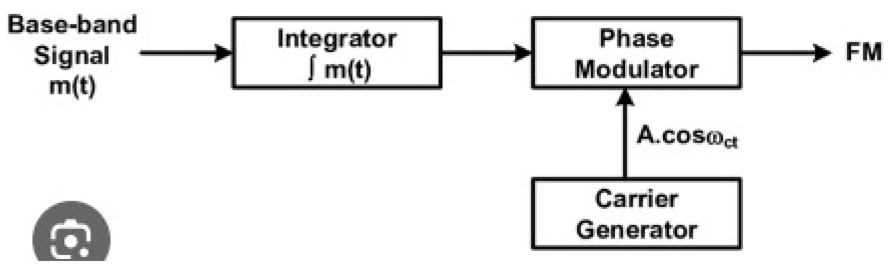
The carrier frequency and modulation Index are then raised by passing FM wave through first group of multipl Mixers and second group of multipliers to obtain required value of carrier frequency.

The FM signal with high carrier frequency is passed through a class C power amplifier to raise the power leve FM signal .

Final FM signal is fed to the transmitting antenna.

Resultant of lsb &usb=c





Radio Receivers

Radio Receivers:

A radio transmitters transmits or radiates a modulated carrier signal. This radiated signal (modulated signal) is received by the receiving antenna of the Radio receiver.

A radio receiver is an electronic equipment which receives the desired modulated signal and amplifie demodulates the received signal to get original modulating signal and reject unwanted signals.

The following are the main functions of the radio receivers

1. Intercept the incoming modulated signal (i.e. electromagnetic waves) by the receiving antenna to produce desi modulated signal
2. Select the desired signal and reject the unwanted signals.
3. Amplify this selected R.F. signal.
4. Detect the modulated signal to get back the original modulating or baseband signal.
5. Amplify the modulating frequency signal.

> *This means that a radio receiver is electromagnetic equipment that picks u the desired signal, rejects the unwanted signals, amplifies the desired signal, and demodulates the modulated signal to get back the original modulating frequency signal.*

Radio Receivers

Classification of Radio Receivers: We can classify the radio receivers in two ways:

(A) Depending upon the applications, the radio receivers may be classified as follows:

Amplitude modulation (A.M.) Broadcast Receivers: These receivers are used to receive the broadcast of speec music transmitted from amplitude modulation broadcast transmitters which operate on longwave, mediumwave short wavebands.

Frequency Modulation (F.M.) Broadcast Receivers: These receivers are used to receive the broadcast progran F.M. broadcast transmitters which operate in VHF or UHF bands.

Communication Receivers: Communication receivers are used for the reception of telegraphs and short-v telephone signals. This means that communication receivers are used for various purposes other than broac services.

Television Receivers: Television receivers are used to receive television broadcasts in VHF or in UHF bands.

Radar Receivers: Radar receivers are used to receive Radar signals.

(B) Depending upon the fundamental aspects, the radio receivers may also be classified as under:

1.Tuned Radio Frequency (TRF) receiver 2. Super heterodyne receiver.

In fact, various forms of receivers have been proposed from time to time. However, only two of them beca popular for commercial applications. These are the Tuned Radio Frequency (TRF) receiver and the su heterodyne receiver. Presently, the super heterodyne receiver is the most popular and most widely used. The receiver was used earlier in the 1940s. The TRF receiver had some inherent drawbacks which were remove the superheterodyne receiver.

Radio Receivers

Characteristics or features of Radio Receiver:

➢**Simplicity of Operation** : The receivers to be handled by the technician with little technical knowledge and simplicity of operation is essential.

Simplest broadcast receivers has three controls

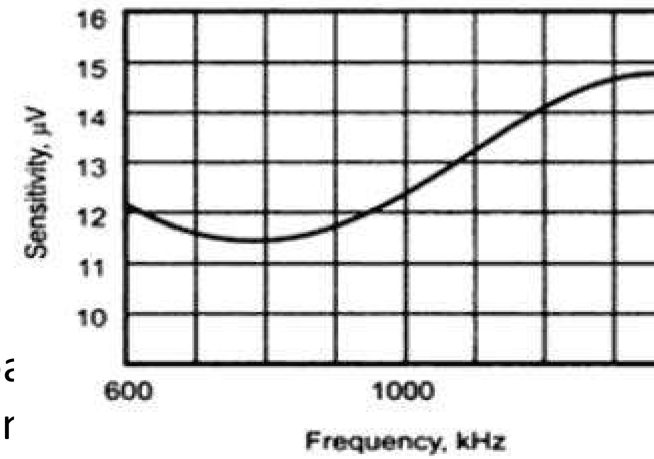
1. Band selection switch for selection of desired band of frequencies
2. Tuning control for tuning to the desired stations. 3. Volume control for adjusting the volume.

➢**Sensitivity**: ***The sensitivity of a radio receiver may be defined as its ability to receive weak signals and ampl***

It is generally defined in terms of the voltage which must be applied at receiver input terminals to provic standard output power measured at the output terminals.

sensitivity is expressed in microvolts or in decibels below 1 volt and is measured at three points along with tuning range when a production receiver is lined up.

Receivers has high sensitivity, So that good response to desired signals with medium and low strengths. But receiver should not have very high sensitivity. Because of very high sensitivity it also gives the response to unwanted (noise) signal.



Sensitivity can be represented as a curve shown in Fig 2 above, which shows the variation of sensitivity over the tuning band.

The figure shows the sensitivity curve over the tuning band at 1MHz, this pa 12.7 microvolts or -98dB. Sometimes the sensitivity definition is extended, ar may quote it to be, not merely 12,7 microvolts, but 12.7 microvolts for an SNR of 20dB in the output of receiver.

Radio Receivers

However, for professional receivers, the sensitivity is generally quoted in terms of signal power required to produce a minimum acceptable output signal with a minimum acceptable output noise level.
A few factors determining the sensitivity of a receiver are as under:

- The gain of the IF amplifier.
- The gain of the RF amplifier.
- The noise figure of the receiver.

Selectivity: The selectivity of a receiver is defined as its ability to accept or select the desired band of frequency and reject all other unwanted frequencies which can interfere with the original signals.
Hence, the adjacent channel rejection of the receiver can be obtained from its selectivity parameter. Selectivity depends upon the response of IF section, mixer and RF section. The signal bandwidth must be narrow for better selectivity.
Selectivity can be represented by a curve shown in Fig1. , which shows the attenuation offered to the unwanted signals around the tuned frequency.

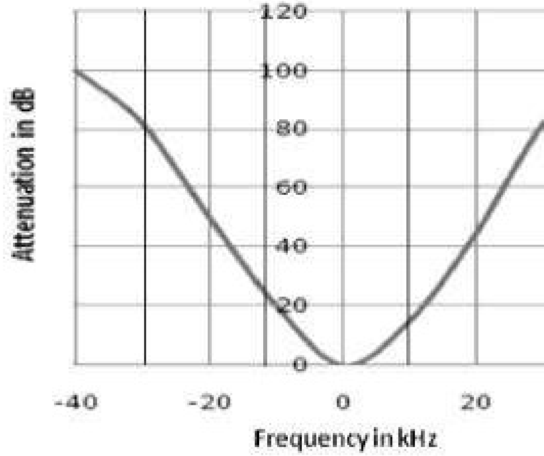


Fig1. Selectivity curve

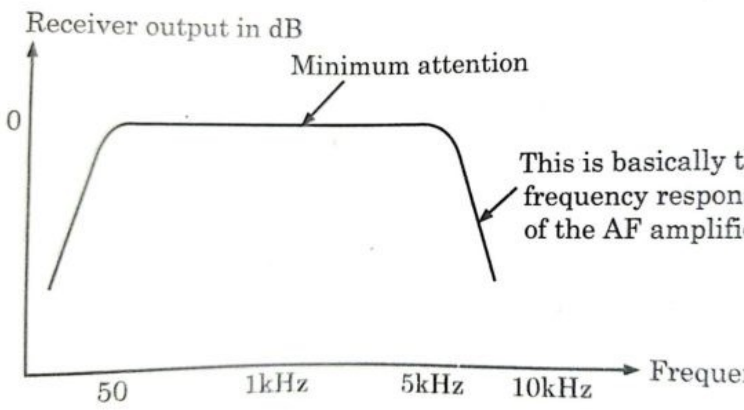
The selectivity of the receiver depends upon the following factors:
1.Selectivity varies with receiving frequency and becomes somewhat worse when the receiving frequency is raised
2.In general, it is mainly determined by the response of the IF section, with the mixer and RF amplifier input circui playing a small but significant part.
3.Selectivity is the main factor that **determines the adjacent channel rejection** of a receiver.

Radio Receivers

➢**Fidelity:** ***Fidelity is the ability of a receiver to reproduce all the modulating frequencies equally.***

➢Fidelity of a receiver may be defined as its ability to reproduce the exact replica of the transmitted signals at the receiver output. The amplifier must pass high bandwidth signals to amplify the frequencies of the outermost sidebands for achieving better fidelity, while for better selectivity the signal should have narrow bandwidth. Thus, a trade off between selectivity and fidelity is necessary.

➢For high fidelity, it is essential to have a flat frequency response over wide range of frequencies. Ideally fidelity curve is flat over entire frequency.



The Figure shows the fidelity curve of a receiver is basically the frequency response of the AF amplifier stage in the receiver.

Ideally, the curve should be flat over the entire audio frequency range, but practically, it decreases on the lower and higher frequency side

Radio Receivers

➢**Signal to Noise Ratio (SNR):**

It is defined as the ratio of signal power to noise power at the same point in the circuit. It is used to measure rad receiver sensitivity. The lower the noise generated in the receiver, the better will be the SNR.

SNR=Signal Power / noise power

➢**Double Spotting**:.

When a receiver picks up the same short wave station at two nearby points o the receiver dial, the double spotting phenomenon takes place.

➢The main cause for double spotting is poor front-end electricity, i.e., inadequate image frequency rejection. The end of the receiver does not select different adjacent signals very well.

➢The adverse effect of double spotting is that a weak station may be marked by the reception of a nearby s strong station at the spurious point of the dial.

➢On the other hand, double spotting may be used to calculate the IF of an unknown receiver.

➢If image frequency rejection is improved, then certainly there will be a corresponding decrease in the d spotting occurrence.

➢**Tracking:**

In a super heterodyne receiver, the local oscillator frequency is made to track with the tuned circuits which are to the incoming signal frequency in order to make a constant frequency difference at the output of the mixer.

For a general, AM broadcast system, the intermediate frequency (I.F.) is 455kHz.

This indicates that the local oscillator should always be set at a frequency that is 455kHz above the incoming frequency.

Radio Receivers

AM receivers:

1.Tuned Radio Frequency (TRF) receiver
2. Super heterodyne receiver.

AM Spectrum: 535-1700KHz, Band width of AM:10K
FM Spectrum: 88-108MHz, Band width of AM:200KH
FM Band width is 20 times of Band Width of AM,
To transmit one signal required Band Width is 200KH

Tuned Radio Frequency (TRF) receiver :A tuned radio frequency (TRF) receiver is the simplest radio receiver

The very first block of this receiver is an RF stage. This stage generally contains two or three RF amplifiers. Actually, these RF (radio frequency) amplifiers are tuned RF amplifiers i.e. they have variable tuned circuits at the input and output sides.

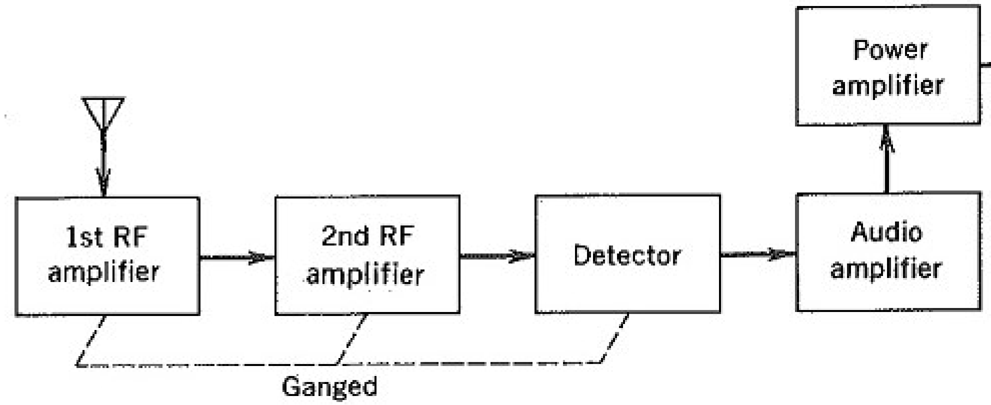


FIGURE 6-1 The TRF receiver.

At the input of the receiver, there is a receiving antenna, convert EM waves into Electrical signals. At this ante signals from different sources (i.e. stations) are present. However, with the help of the input variable tuned ci of RF amplifiers the desired signal (i.e. station) is selected. But this selected signal is usually very weak in the o of µV. This selected weak signal is amplified by the RF amplifier (i.e. R.F stage).

After this, the amplified incoming modulated signal is applied to the demodulator. The demodulator or dete demodulates the modulated signal and thus at the output of the demodulator, we get modulating or baseband s (i.e. audio signal). This audio signal is amplified by an audio amplifier.

Radio Receivers

In most of the receivers, the capacitors used in the tuned circuits are made variable. These capacitors are gan
between stages so that all the capacitors can be changed simultaneously when the tuning knob is rotated.
At the receiving antenna, signals from different stations are present. However with the help of input variable tu
RF amplifier the desired signal is selected.
After that, this audio signal is further amplified by a power amplifier up to desired power level to drive
loudspeaker. The last stage of this receiver is the loudspeaker. A loudspeaker is a transducer that changes
electrical signals into sound signals.

Drawbacks of TRF Receiver

1. **Instability of the receiver:** The TRF receiver suffers from a tendency to oscillate at higher frequencies from th multistage RF amplifiers with high gain and operating at the same frequency. If such an amplifier has a gain 20,000 then if a small portion of the output leaked back to the input of the RF stage, then positive feedback an oscillation will result. This type of leakage could result from power supply coupling, stray capacitance couplin radiation coupling, or coupling through any other element common to the input and output stages, Definitely, th type of condition is undesirable for a good receiver. This problem is also termed instability of the receiver.

2. **Poor selectivity:** The selectivity of a receiver is its ability to distinguish between the desired signal and undesired signal. The selectivity of the TRF receivers is poor. In fact, it is difficult to achieve sufficient selectivity high frequencies due to the enforced use of single-tuned circuits.

3. Another problem associated with the TRF receiver is the bandwidth variation over the tuning range. F example, in AM broadcast system, let us consider that a tuned circuit is required to have a bandwidth of 10 kHz at frequency of 540 kHz.

Radio Receivers

Variable Bandwidth:

- According to the definition, the Quality factor Q of this tuned circuit must be

$$Q = \frac{resonance\ frequency}{bandwidth} = \frac{540}{10} = 54$$

- Now, at the other end of this AM broadcast band (i.e. 1640 kHz), the Quality factor of the coil. according to the above equation, must increase by a factor of 1640/535 (i.e. 3) to a value of 164. However, in practice, several losses dependent upon frequency would prevent such a large increase. Thus, practically, the Quality factor Q of this tuned circuit is unlikely to exceed 120 and hence: providing a bandwidth of the tuned circuit equal to

$$\Delta = \frac{f_r}{Q} = \frac{1640}{120} = 13.8kHz$$

- Therefore, due to this increased bandwidth of 13.8 kHz in place of a fixed bandwidth of 20 kHz, the receiver would pick up or select adjacent frequencies (i.e. stations) with the desired frequency or station. This means that the bandwidth of the TRF receiver varies with the incoming frequency.

Radio Receivers

Super heterodyne radio receiver:

Definition: Superheterodyne receiver works on the principle of heterodyning which simply means **mixing.** It is type of receiver which mixes the received signal frequency with the frequency of the signal generated by a loc oscillator.
The output of mixer provides a lower fixed frequency also known as **intermediate frequency**.

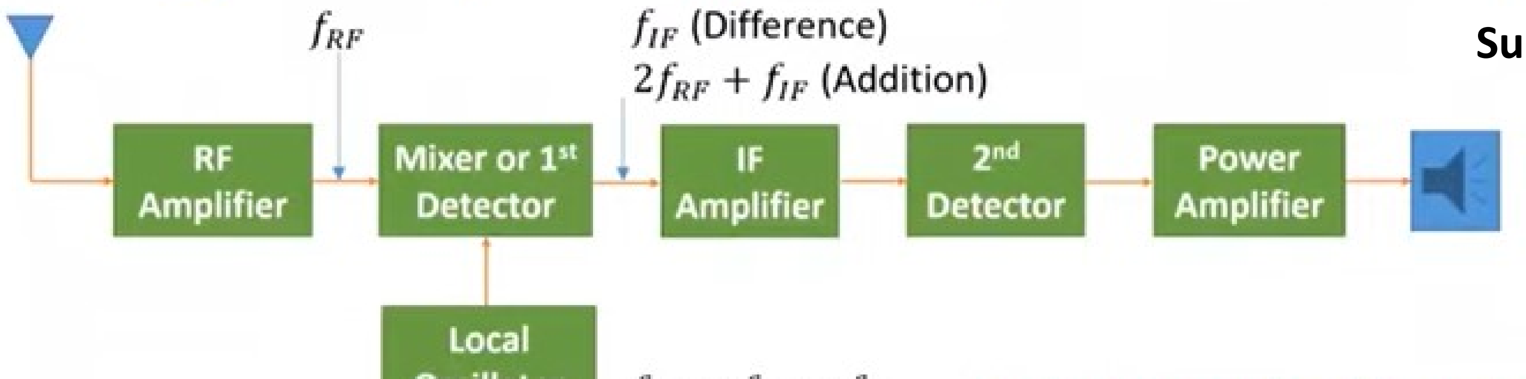
These receivers are called Superheterodyne receivers as the frequency of the signal generated by the local oscillator is more than the frequency of the received signal.

Basics of Super Heterodyne Receiver

- At high frequency, processing cost of circuit is high, so we should do signal processing at low frequency.
- At low frequency, transmission cost of signal is high with low bandwidth, so signal transmission should be done at high frequency.
- So, in super heterodyne receiver, we take care of above points
  - Signal transmission at high frequency
  - Signal processing at lower frequency

To process high frequency (RF) signals, the cost is very high, to minimize the cost high frequency signal is convert to intermediate frequency by mixer.

Super heterodyne radio receiver



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

So, Even we receive different signal at receiver, we have extracted Same signal f_{IF} at the output of mixer. That recived signal is image Signal $f_{image} = f_{RF} + 2f_{IF}$

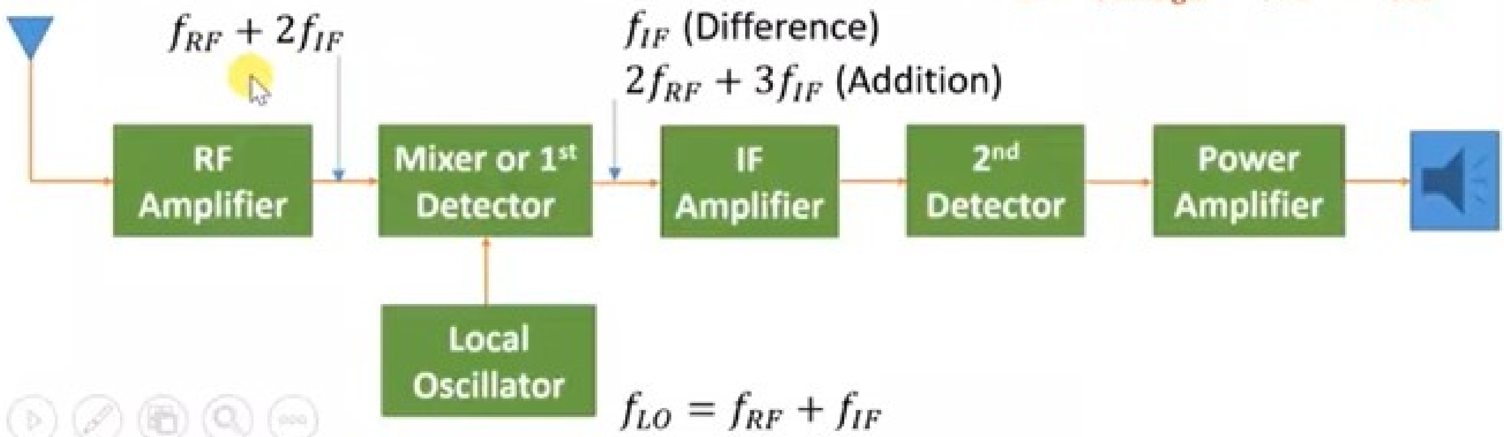
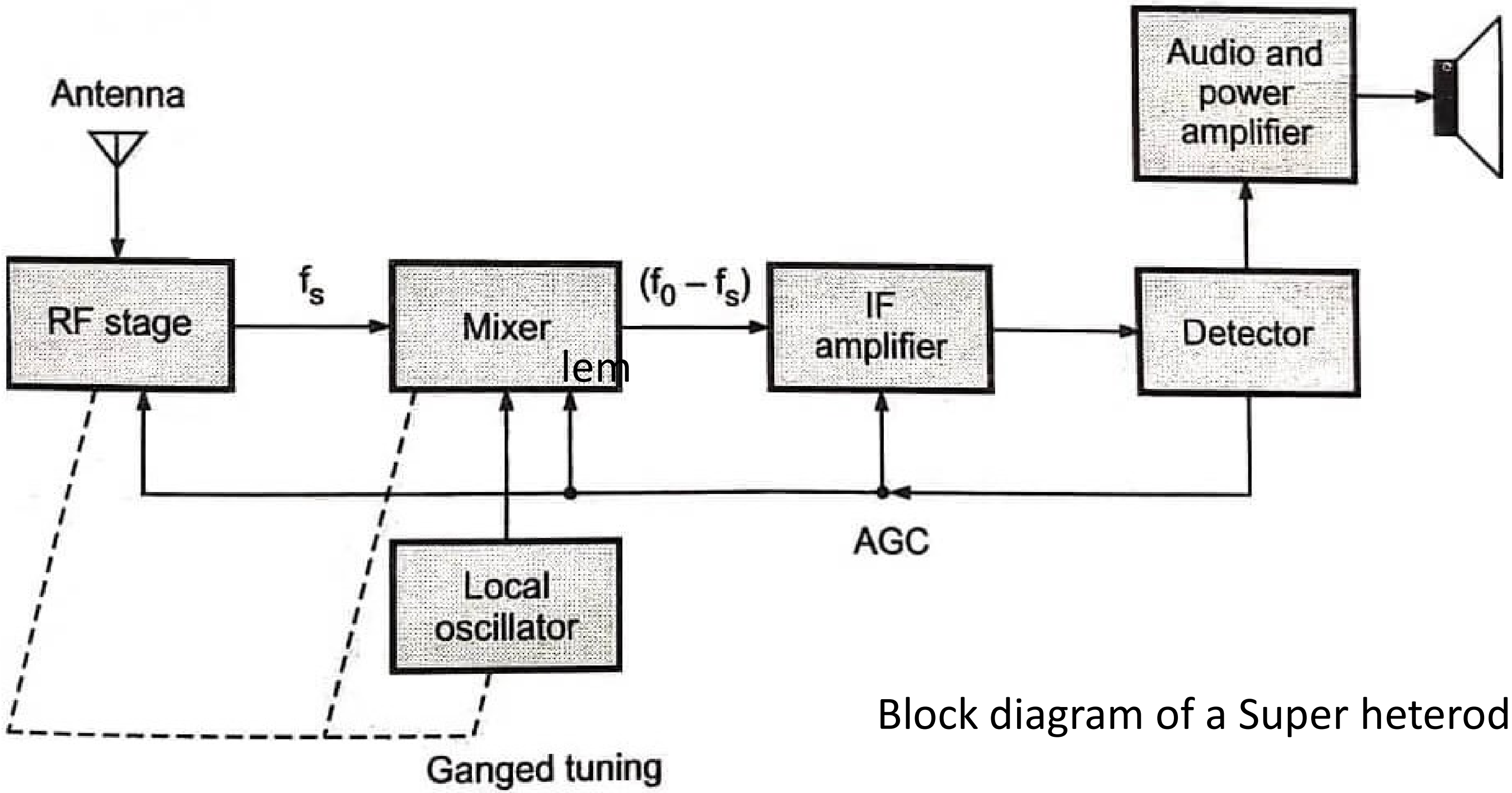


Image Frequency in Super Heterodyne Receiver

Radio Receivers

Super heterodyne radio receiver: To process high frequency (RF) signals, the cost is very high, to minimize cost high frequency signal is converted to intermediate frequency by mi



Block diagram of a Super heterodyne receiv

The problems of [TRF receiver]() are overcome in this receiver. The **super heterodyne receiver** convert incomming RF frequencies to a fixed lower frequency, called Intermediate Frequency (IF). This IF is t amplified and detected to get the original signal.

Radio Receivers

The antenna receives all the frequency signals and gives it to RF amplifier. The RF stage amplifies the signals in required range of frequencies. Thus it provides initial gain and selectivity. The output of the RF amplifier is give the mixer stage. The local oscillator output is also applied to the mixer.

Let us assume that local oscillator frequency is $\mathbf{f_0}$ and signal frequency is $\mathbf{f_s}$. The signal frequency $\mathbf{f_s}$ and l oscillator frequency $\mathbf{f_0}$ are mixed in the mixer in such a way that frequency difference ($\mathbf{f_0 - f_s}$) is produced at output of mixer.

This difference $\mathbf{f_0 - f_s}$ is called Intermediate Frequency (IF). The signal at this IF contains the same modulation as incoming signal. The IF is amplified by one or more IF amplifier stages and given to the detector.

Most of the gain and selectivity is provided by these IF amplifiers. Normally IF is fixed for the AM receivers. To se a particular station, the local oscillator frequency $\mathbf{f_0}$ is changed in such a way that the frequency '$\mathbf{f_s}$' of that sta and '$\mathbf{f_0}$' has the difference equal to IF. Thus whatever is the station being tuned, the IF is fixed. Thus the IF ampli and detector operate at the single frequency IF. Hence the bandwidth of the IF amplifiers is relatively narrow.

A part of output is taken from the detector and it is applied to RF amplifier, mixer and IF amplifiers for gain con This is called Automatic Gain Control or AGC. This AGC maintains the constant output voltage level over a w range of RF input signal levels. The detector obtains the modulating signal from the modulated IF. The outpu detector is amplified and given to speaker.

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Advantages of super heterodyne receiver
Super heterodyne receiver is most suitable for radio receiver application like **AM,FM communications, televisio receivers and even radar receivers with slight modification in principle.**

This means that it can be considered today's standard form of a radio receiver.
1.No variation in bandwidth. The BW remains constant over the entire operating range.
2.High sensitivity and selectivity.
3.High adjacent channel rejection.

IF Requirement
Since IF is used in super heterodyne receiver, the IF amplifiers have to work only at one frequency. Hence the design is relatively simple. Adjacent channel selectivity, image frequency rejection, fidelity, selectivity e performance parameters depend upon IF amplifiers. Since IF amplifiers work only at IF, their performance improved. IF is selected based on following factors.

Considering these points, IF is selected within the range of 438 to 465 kHz. Normally 465 kHz is most commonly used IF.

Radio Receivers

Characteristics or features of Super heterodyne receiver :

➢**Simplicity of Operation** : The receivers to be handled by the technician with little technical knowledge and simplicity of operation is essential.

Simplest broadcast receivers has three controls

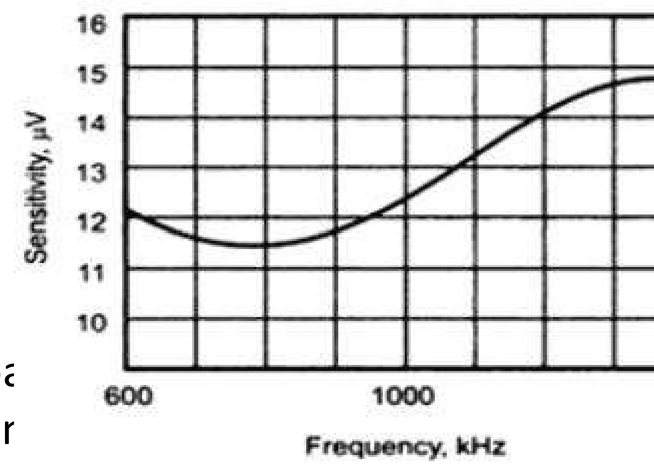
1. Band selection switch for selection of desired band of frequencies
2. Tuning control for tuning to the desired stations. 3. Volume control for adjusting the volume.

➢**Sensitivity**: ***The sensitivity of a radio receiver may be defined as its ability to amplify weak signals.***

It is generally defined in terms of the voltage which must be applied at receiver input terminals to provic standard output power measured at the output terminals.

sensitivity is expressed in microvolts or in decibels below 1 volt and is measured at three points along with tuning range when a production receiver is lined up.

Receivers has high sensitivity, So that good response to desired signals with medium and low strengths. But receiver should not have very high sensitivity. Because of very high sensitivity it also gives the response to unwanted (noise) signal.



Sensitivity can be represented as a curve shown in Fig 2 above, which shows the variation of sensitivity over the tuning band.

The figure shows the sensitivity curve over the tuning band at 1MHz, this pa 12.7 microvolts or -98dB. Sometimes the sensitivity definition is extended, ar may quote it to be, not merely 12,7 microvolts, but 12.7 microvolts for an SNR of 20dB in the output of receiver.

Sensitivity: ***The sensitivity of a radio receiver may be defined as its ability to amplify weak signals.***

- Gain will decide sensitivity, Higher the gain, higher the sensitivity.
- But at higher gain, there is a possibility of instability.
- So, we use moderate gain at stable frequency.
- In TRF receiver, gain was not fixed, so it has a issues regarding stability

Radio Receivers

However, for professional receivers, the sensitivity is generally quoted in terms of signal power required to produce a minimum acceptable output signal with a minimum acceptable output noise level.

A few factors determining the sensitivity of a receiver are as under:

- The gain of the IF amplifier.
- The gain of the RF amplifier.
- The noise figure of the receiver.

Selectivity: The selectivity of a receiver is defined as its ability to accept or select the desired band of frequency and reject all other unwanted frequencies which can interfere with the original signals.

Hence, the adjacent channel rejection of the receiver can be obtained from its selectivity parameter. Selectivity depends upon the response of IF section, mixer and RF section. The signal bandwidth must be narrow for better selectivity.

Selectivity can be represented by a curve shown in Fig1. , which shows the attenuation offered to the unwanted signals around the tuned frequency.

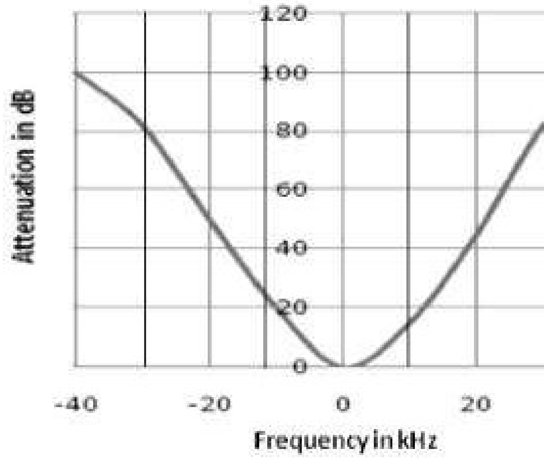


Fig1. Selectivity curve

The selectivity of the receiver depends upon the following factors:

1.Selectivity varies with receiving frequency and becomes somewhat worse when the receiving frequency is raised

2.In general, it is mainly determined by the response of the IF section, with the mixer and RF amplifier input circui playing a small but significant part.

3.Selectivity is the main factor that **determines the adjacent channel rejection** of a receiver.

Selectivity: The selectivity of a receiver is defined as its ability to accept or select the desired band of frequency and reject all other unwanted frequencies which can interfere with the original signals.

- It depends on Quality factor of receiver.
- Better the Q factor, better the selectivity.
- That can be achieved by fixed intermediate frequency f_{IF}.
- We can have fixed intermediate frequency f_{IF} by ganged tuning capacitor in between RF amplifier and Local oscillator.

$$Q = \frac{f_c}{BW}$$

❖ For TRF receiver, signal ranges from 550kHz to 1650kHz with BW = 10kHz.

At Lower end

$$\therefore Q = \frac{f_{c1}}{BW}$$

$$\therefore Q = \frac{550}{10}$$

$$\therefore Q = 55$$

At Higher end

$$\therefore Q = \frac{f_{c2}}{BW}$$

$$\therefore Q = \frac{1650}{10}$$

$$\therefore Q = 165$$

❖ For Super heterodyne receiver, intermediate frequency is fixed at 455kHz with bandwidth of 10kHz

$$\therefore Q = \frac{f_c}{BW}$$

$$\therefore Q = \frac{455}{10}$$

$$\therefore Q = 45.5$$

- So here, with super heterodyne receiver, we have quality factor ranging in between 40 to 50.
- While with TRF receiver, quality factor ranges from 55 to 165.
- So circuit cost is lower with super heterodyne receiver compared to TRF receiver with better selectivity.

amplifier having

❖ We use class C amplifier.

❖ It should reject image frequency.

❖ If we have good SNR then it improves sensitivity.

❖ It rejects unwanted signals (Image, Noise).

o minimize the cost of receiver: by reduce the cost of ganged tuning capacitor is obtained by below process and naintain local oscillator frequency must greater than received signal frequency

- We are using ganged tuning capacitor in between RF amplifier and Local oscillator.
- Cost of ganged tuning capacitor depends in range of capacitor from C_{Min} to C_{Max}.

- For TRF receiver, signal ranges from 550kHz to 1650kHz.

$$\therefore \frac{C_{max}}{C_{min}} = \left(\frac{f_{max}}{f_{min}}\right)^2$$

$$\therefore \frac{C_{max}}{C_{min}} = \left(\frac{1650}{550}\right)^2$$

$$\therefore \frac{C_{max}}{C_{min}} = 9 : 1$$

- For Super heterodyne receiver, intermediate frequency is fixed at 455kHz. ($f_{LO} > f_{RF}$)

$$\therefore \frac{C_{max}}{C_{min}} = \left(\frac{f_{max} + f_{IF}}{f_{min} + f_{IF}}\right)^2$$

$$\therefore \frac{C_{max}}{C_{min}} = \left(\frac{1650 + 455}{550 + 455}\right)^2$$

$$\therefore \frac{C_{max}}{C_{min}} = 4.4 : 1$$

- For Super heterodyne receiver, intermediate frequency is fixed at 455kHz. ($f_{LO} < f_{RF}$)

$$\therefore \frac{C_{max}}{C_{min}} = \left(\frac{f_{max} - f_{IF}}{f_{min} - f_{IF}}\right)^2$$

$$\therefore \frac{C_{max}}{C_{min}} = \left(\frac{1650 - 455}{550 - 455}\right)^2$$

$$\therefore \frac{C_{max}}{C_{min}} = 158 : 1$$

- ❑ So for the case of super heterodyne receiver with $f_{LO} > f_{RF}$, we have minimum range of ganged tuning capacitor.
- ❑ So we have good quality factor with minimum cost with $f_{LO} > f_{RF}$ for super heterodyne receiver.

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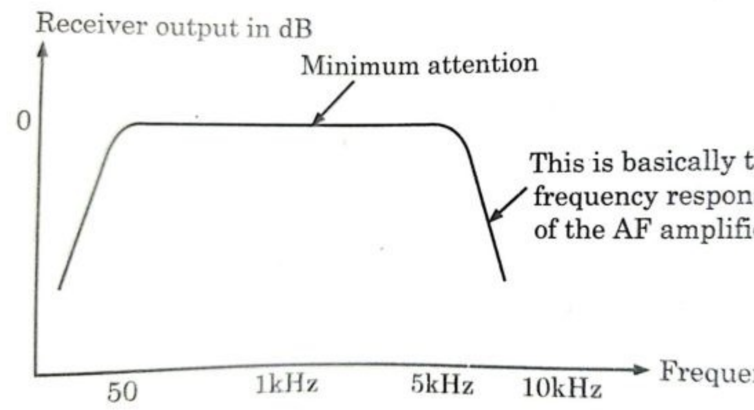
➢**Fidelity:** ***Fidelity is the ability of a receiver to reproduce all the modulating frequencies equally.***

➢Fidelity of a receiver may be defined as its ability to reproduce the exact replica of the transmitted signals at the receiver output. The amplifier must pass high bandwidth signals to amplify the frequencies of the outermost sidebands for achieving better fidelity, while for better selectivity the signal should have narrow bandwidth. Thus, a trade off between selectivity and fidelity is necessary.

➢For high fidelity, it is essential to have a flat frequency response over wide range of frequencies. Ideally fidelity curve is flat over entire frequency.



The Figure shows the fidelity curve of a receiver is basically the frequency response of the AF amplifier stage in the receiver.

Ideally, the curve should be flat over the entire audio frequency range, but practically, it decreases on the lower and higher frequency side

Radio Receivers

➢**Signal to Noise Ratio (SNR):**

It is defined as the ratio of signal power to noise power at the same point in the circuit. It is used to measure rad receiver sensitivity. The lower the noise generated in the receiver, the better will be the SNR.

SNR=Signal Power / noise power

➢**Double Spotting**:.

When a receiver picks up the same short wave station at two nearby points o the receiver dial, the double spotting phenomenon takes place.

➢The main cause for double spotting is poor front-end electricity, i.e., inadequate image frequency rejection. The end of the receiver does not select different adjacent signals very well.

➢The adverse effect of double spotting is that a weak station may be marked by the reception of a nearby s strong station at the spurious point of the dial.

➢On the other hand, double spotting may be used to calculate the IF of an unknown receiver.

➢If image frequency rejection is improved, then certainly there will be a corresponding decrease in the d spotting occurrence.

➢**Tracking:**

In a super heterodyne receiver, the local oscillator frequency is made to track with the tuned circuits which are to the incoming signal frequency in order to make a constant frequency difference at the output of the mixer.

For a general, AM broadcast system, the intermediate frequency (I.F.) is 455kHz.

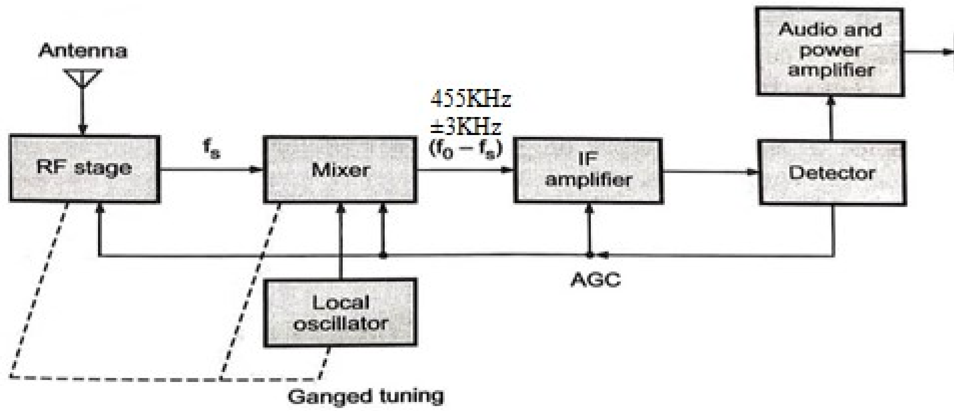
This indicates that the local oscillator should always be set at a frequency that is 455kHz above the incoming frequency.

Radio Receivers

Tracking or tuning of super heterodyne receiver:

In a super heterodyne receiver, the local oscillator frequency is made to track with the tuned circuits which are t
to the incoming signal frequency in order to make a constant frequency difference at the output of the mixer.
For a general, AM broadcast system, the intermediate frequency (I.F.) is 455kHz.
For this purpose the local oscillator should always be set at a frequency that is 455kHz above the incoming si
frequency.
To achieve this, the front end of the receiver tuned circuit are made to track together simply by mechanically linke
ganged capacitors.

In addition to this, small variable capacitances known as trimmers are connected in parallel with each operation.
These capacitances can be adjusted for proper operation at highest frequency.
However for lowest frequency adjustment, other variable capacitors known as padders are connected with inductors of the tank circuits.



If any error that may exist in the frequency difference at the output of the mixer due to tracking is called the tra
errors. These error must naturally be avoided.
It is quite possible to keep the maximum tracking error is below ± 3KHz
**Tacking is a process of, the local oscillator frequency follows or track the signal frequency to have a co
frequency difference**

Radio Receivers

Image frequency and its rejection:

A super heterodyne receiver suffers from a major drawback known as Image frequency problem

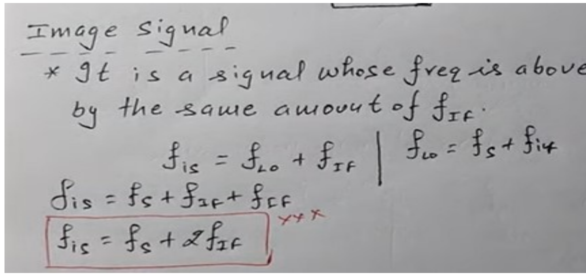
Image frequency is signal frequency plus two times image frequency $f_{is} = f_s + 2f_{if}$

The frequency conversion process carried out by the local oscillator and mixer often allow an undesired frequen addition to the desired incoming frequency.

In a standard broadcast receiver, the local oscillator frequency is always made higher than the incoming signal frequency

We know that the output of mixer will produces intermediate frequency component i.e

$$\mathbf{f_i = f_0 - f_s} \text{ ---------(1)}$$



f_i is intermediate frequency

f_0 is local oscillator frequency

f_s is the incoming signal frequency

Hence IF is the difference between the local oscillator frequency and signal frequency.

Now, if a frequency fsi manages to reach the mixer, such that if $f_{si} - f_0 = f_i$ -----(2)

i.e difference of image signal frequency (fsi) and local oscillator frequency produces an intermediate frequency

Which is amplified by the IF amplifier stage and thus causes **interference.**

This has the effect of two sources or stations being received simultaneously. This station is obviously undesirabl

Radio Receivers

The term f_{si} is the image signal frequency . Which is higher the local oscillator frequency.
From equation (2) we have

$$f_{si} = f_i + f_0 \text{ ----------(3) and}$$

$$f_0 = f_i + f_s \text{ ----------(4)}$$

From (3) & (4) $\quad f_{si} = f_i + f_i + f_s = 2f_i + f_s$ ----------(5)

Therefore Image frequency is defined as signal frequency plus twice the intermediate frequency

Image frequency rejection ratio is given by $\alpha = \sqrt{1 + Q^2\rho^2}$ $\quad$ $where\ \rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}}$

and Q is quality factor of the tuned circuit, ρ consta

The Image frequency rejection of receiver depends upon front end selectivity of the receiver.
The rejection of the image frequency must be achieved before the IF stage. Once, an undesired or spurious freque
enters the first IF amplifier, it would become impossible to remove it from the desired signal.

Image rejection is the measure of a receiver's ability to reject signals at its image frequency. It is normall
expressed as the ratio, in dB, of the receiver's sensitivity at the desired frequency versus the sensitivity at the
image frequency.

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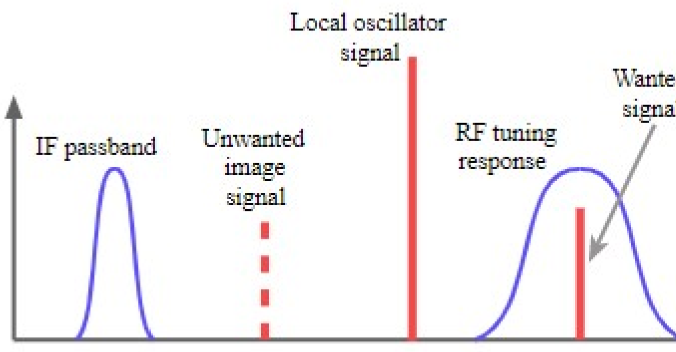
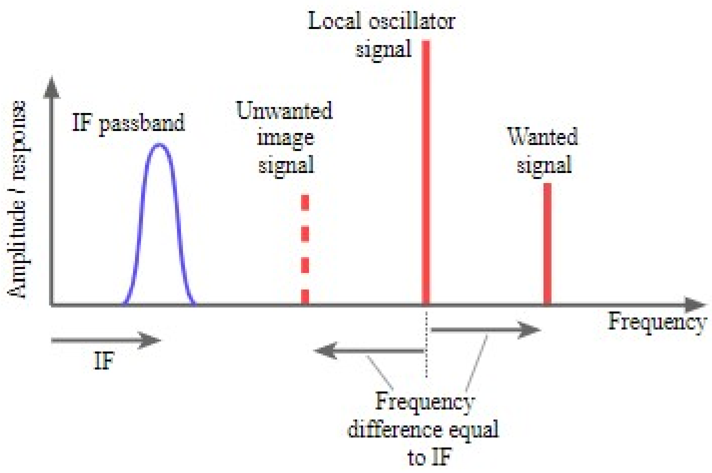
The basic concept of the superhet radio means that it is possible for two signals to enter the intermediate frequency, IF, amplifier. For example with the local oscillator set to 5 MHz and with an IF of 1 MHz it can be seen that a signal at 6 MHz mixes with the local oscillator to produce a signal at 1 MHz that will pass through the IF filter. However if a signal at 4 MHz is also able to produce an output at 1 MHz. It is clearly unacceptable to receive signals on two frequencies at the same time and it is possible to remove the unwanted one by the addition of a tuned circuit prior to the mixer.



RF tuned circuit removes image in a superheterodyne recei



Superheterodyne receiver image is twice the IF away from the wanted signal

Fortunately this tuned circuit does not need to be excessively sharp. It does not need to reject signals on adjacent channels, but instead it needs to reject signals on the image frequency. These will be separated from the wanted channel by a frequency equal to twice the IF. In other words with an IF at 1 MHz, the image will be 2 MHz away from the wanted frequency.

Unit-IV

1.In a broadcast super heterodyne receiver having no RF amplifier, the loaded Q of the antenna coupling circuit is 125. If the IF frequency is 455 kHz DetermineThe image frequency and its rejection ratio for tuning at 250 kHz

given IF = 455K, Q = 125, f_s = 250K

$f_{si} = f_s + 2IF = 250K + 2(455K) = 1160$ KHz

$\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}} = \frac{1160}{250} - \frac{250}{1160} = 4.424$

$\alpha = \sqrt{1 + Q^2 \rho^2} = \sqrt{1 + (125)^2 (4.42)^2} = 553.00$

IF → intermidiate freq.

for AM = 455KHz

FM = 10.7MHz

f_s → signal freq

f_{si} → image freq.

Q → loaded Q

α → rejection ration

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

$\alpha = \sqrt{1 + Q^2 \rho^2}$

Radio Transmitters

2.In a broadcast AM receiver having no RF stage the loaded Q of the coupling circuit is 125.If the intermediate frequency is 455KHz, calculate image frequency and its rejection ratio at 1 MHz and 30 MHz.

given $Q = 125$, $IF = 455KHz$,

i, $f_s = 1MHz$

$f_{si} = f_s + 2IF = 1000K + 2(455K) = 1910K$

$\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}} = \frac{1910K}{1000k} - \frac{1000K}{1910K} = 1.386$; $\alpha = \sqrt{1 + Q^2\rho^2} = \sqrt{1 + (125)^2(1.386)^2}$

$= 173.25$

ii, $f_s = 30MHz$

$f_{si} = f_s + 2IF = 30000K + 2(455K) = 30910KHz$

$\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}} = \frac{30910K}{30000k} - \frac{30000K}{30910K} = 0.059$

$\alpha = \sqrt{1 + Q^2\rho^2} = \sqrt{1 + (125)^2(0.059)^2} = 7.442$

Radio Receivers

3.In a broadcast super heterodyne receiver having no RF amplifier, the IF frequency is 455 kHz .Determine loaded Q if
The image frequency rejection ratio is 75 at 30MHz.

given IF = 455 KHz, $\alpha = 75$, $f_s = 30MHz$, Q = ?

$f_{si} = f_s + 2IF = 30M + 2(455k)$

$= 30910k$

$f_{si} = f_s + 2IF$

$\alpha = \sqrt{1 + Q^2 \rho^2}$

$\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}} = \frac{30910}{30000} - \frac{30000}{30910} = 0.059$

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

$Q = \sqrt{\frac{\alpha^2 - 1}{\rho^2}} = \sqrt{\frac{(75)^2 - 1}{(0.059)^2}} = 1271.07.$

4.Find the tuning range of ganged capacitor in AM receiver designed to tune 550KHz to 1650KHz. Also obtain the image frequency rejection ratio if the loaded Q is 7.2 and the incoming signal frequency is 900 KHz.

given Q = 7.2, f_s = 900K, AM receiver ⊃ IF = 455 KHz, α = ?

$f_{si} = f_s + 2IF = 900k + 2(455k) = 1810k$

$\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}} = \frac{1810k}{900k} - \frac{900k}{1810k} = 1.51$

$\alpha = \sqrt{1 + Q^2 \rho^2} = \sqrt{1 + (7.2)^2 (1.51)^2} = 10.1$

tuning range, $f_{LO1} = 550k + 455k = 1005 KHz$; $f_{LO2} = 1650k + 455k = 210$

... RF amplifier. If the IF

Radio Receivers

5.In a broadcast super heterodyne receiver having no RF amplifier. If the IF frequency is 455 kHz and input signal frequency is 1200KHz , determine The image frequency and its rejection ratio for aloaded Q of 40

given $Q = 40$, $f_s = 1200K$, $IF = 455K$, $f_{si} = ?$, $\alpha = ?$

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

$$\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}} = \frac{2110K}{1200K} - \frac{1200K}{2110K} = 1.189$$

$$\alpha = \sqrt{1 + Q^2\rho^2} = \sqrt{1 + (40)^2(1.189)^2} = 47.57$$

5.Obtain the loaded Q of an FM receiver if incoming signal frequen 90MHz andimage frequency rejection ratio is 12.

given $\alpha = 1.2$, $f_s = 90MHz$, $Q = ?$

$$\alpha = \sqrt{1 + Q^2\rho^2} \Rightarrow Q = \sqrt{\frac{\alpha^2 - 1}{\rho^2}}$$

$f_{si} = f_s + 2IF$; for F.M receiver, $I.F = 10.7MHz$

$$= 90M + 2(10.7M)$$

$$f_{si} = 111.4MHz$$

$$\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}} = \frac{111.4}{90} - \frac{90}{111.4} = 0.42$$

$$Q = \sqrt{\frac{\alpha^2 - 1}{\rho^2}} = \sqrt{\frac{(12)^2 - 1}{(0.42)^2}} = 28.47$$

Question

For a superheterodyne 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, then the image frequency (in MHz) is ________. **[Set - 03]**

If $f_{LO} > f_{RF}$ then
Image frequency $f_{SI} = f_{RF} + 2f_{IF}$

If $f_{LO} < f_{RF}$ then
Image frequency $f_{SI} = f_{RF} - 2f_{IF}$

→ $f_{IF} = 15$ MHz
$f_{LO} = 3500$ MHz

→ $f_{RF} > f_{LO}$

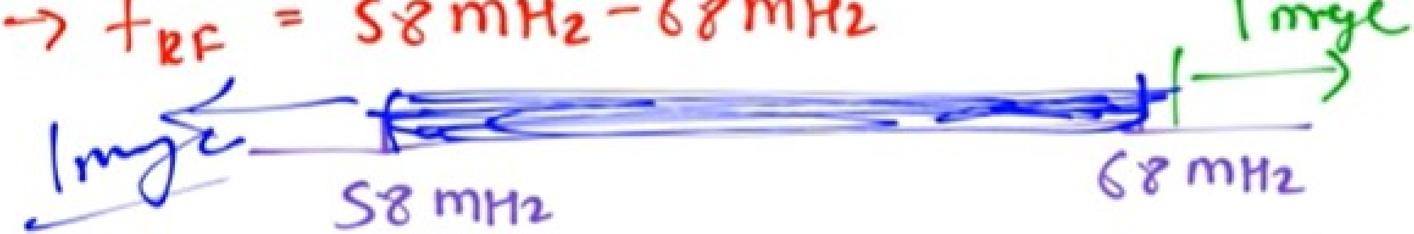
→ Imag freq $f_{img} = f_{RF} - 2f_{IF} = 3515 - 2(15)$
$= 3485$ MHz

⇒ $f_{LO} = f_{RF} - f_{IF}$

→ $f_{RF} = f_{LO} + f_{IF}$
$= 3500 + 15$
$= 3515$ MHz

A superheterodyne receiver operates in the frequency range of 58 MHz-68 MHz. The intermediate frequency f_{IF} and local oscillator frequency f_{LO} are chosen such that $f_{IF} \le f_{LO}$. It is required that the image frequencies fall outside the 58 MHz-68 MHz band. The minimum required f_{IF} (in MHz) is ______. **[Set - 01]**

→ $f_{RF} = 58\ \text{MHz} - 68\ \text{MHz}$



→ $f_{IF} \le f_{LO}$

→ $f_{image} = f_{RF} + 2f_{IF} > 68$

⇒ $58 + 2f_{IF} > 68$

⇒ $2f_{IF} > 10$

⇒ $\boxed{f_{IF} > 5\ \text{MHz}}$

→ $f_{LO} < f_{IF}$

→ $f_{img} = f_{RF} - 2f_{IF} < 58$

⇒ $68 - 2f_{IF} < 58$

⇒ $10 < 2f_{IF}$

⇒ $\boxed{f_{IF} > 5\ \text{MHz}}$

A superheterodyne receiver is to operate in the frequency range 550 – 1650 kHz, with the intermediate frequency of 450 kHz. Let $R = \frac{C_{max}}{C_{min}}$ denote the required capacitance ratio of local oscillator and I denote the image frequency (in kHz) of the incoming signal. If the receiver is tuned to 700 kHz, then

(A) $R = 4.41, I = 1600$ (B) $R = 4.41, I = 1150$

(C) $R = 3.0, I = 1600$ (D) $R = 3.0, I = 1150$

$\rightarrow f_{RF} = 550 - 1650$ kHz

$f_{IF} = 450$ kHz

$\rightarrow f_{RF} = 700$ kHz

$\rightarrow f_{LO} > f_{RF}$

$\rightarrow I_{mg} = f_{RF} + 2f_{IF}$
$= 700 + 2(450)$
$= 1600$ kHz

$\rightarrow f_{LO} = \frac{1}{2\pi\sqrt{LC}} \propto \frac{1}{\sqrt{C}}$

$\Rightarrow \frac{(f_{LO})_{max}}{(f_{LO})_{min}} = \frac{1/\sqrt{C_{min}}}{1/\sqrt{C_{max}}} = \sqrt{\frac{C_{max}}{C_{min}}}$

$\Rightarrow \frac{C_{max}}{C_{min}} = R = \left(\frac{(f_{LO})_{max}}{(f_{LO})_{min}}\right)^2$

$\Rightarrow R = \left(\frac{1650 + 450}{550 + 450}\right)^2 = \left(\frac{2100}{1000}\right)^2$
$= 2.1^2 = 4.41$

Radio Receivers

RF amplifiers:

RF amplifier is a small signal tuned amplifier with a tuned circuit both on the input side and the output side.

Both this input and output tuned circuits are tuned to the desired incoming carrier frequency.

Accordingly, the tuned circuits select the desired carrier frequency and reject all undesired frequencies includin the image frequency. Hence the RF amplifier provides image frequency rejection.

Also, the gain provided by the RF amplifier will result in an improved signal-to-noise ratio in the output of th receiver. This is due to the fact that the incoming weak signal is fed directly to the frequency mixer, the signal-to noise ratio at the output of the mixer stage is quite poor. Thus the one important function of the RF amplifier i to improve the Signal to Noise Ratio.

There are some receivers where an RF amplifier is not used. The best example of this kind of receiver is domestic receiver used in a high signal strength area like a metropolitan city like Delhi.
However, a receiver having an RF amplifier is obviously superior in performance to a receiver without an R amplifier.

Radio Transmitters

The receiver having an RF amplifier stage has following advantages :

1. It provides greater gain, i.e. better sensitivity.
2. It improves image-frequency rejection.
3. It improves signal to noise ratio.
4. It improves rejection of adjacent unwanted signals, providing better selectivity.
5. It provides better coupling of the receiver to the antenna.
6. It prevents spurious frequencies from entering the mixer and heterodyning there to produce an interfering frequency equal to the IF from the desired signal.
7. It also prevents reradiation of the local oscillator through the antenna of the receiver.

Radio Transmitters

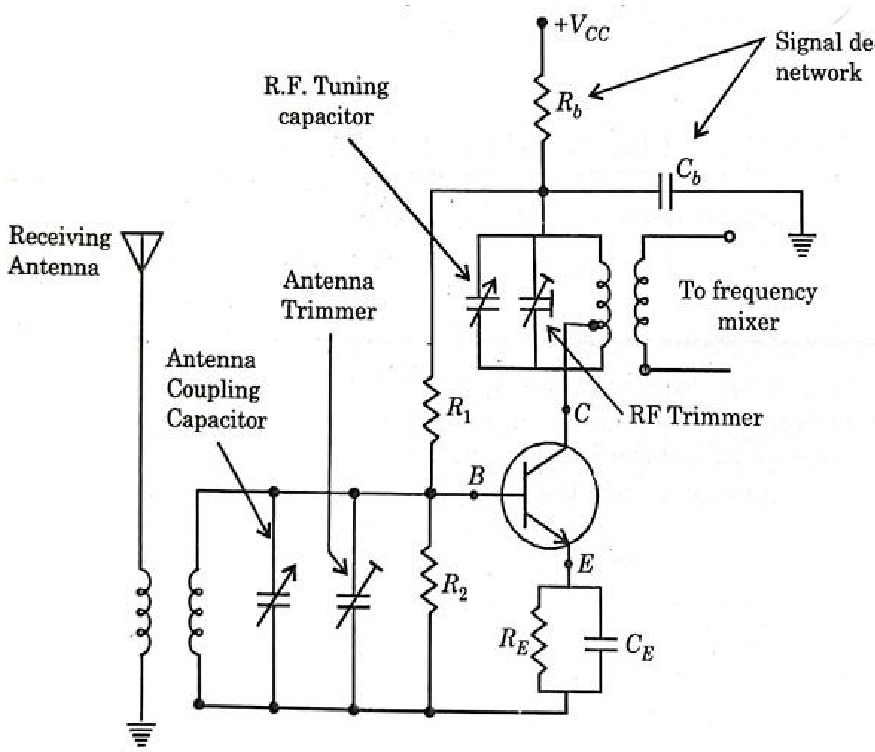
The below figure shows the circuit diagram of one stage RF amplifier using an NPN transistor.

It is a small signal amplifier using parallel tuned circuits as the load impedance. This parallel output tuned circuit is tuned to the incoming desired signal frequency.

The output from the receiving antenna is a transformer coupled to the base of the transistor.

The secondary coil of the input tuned circuit is tuned to the incoming desired signal frequency with the help of ganged tuning capacitor.

In fact, the tuning capacitor i.e. variable air capacitors in the input side and the output side of the RF amplifier are ganged together.



Circuit diagram of RF amplifier.

In addition to this, small trimmer capacitors are connected in shunt with these tuning capacitors for the purpose of RF alignment.

A self-bias is provided with the help of resistors R_1 and R_2 and R_E-C_E assembly

The amplified R.F. signal developed across the collector tuned circuit is coupled through a step-down transform the input of the frequency mirror.

Radio Receivers

Concept of Intermediate Frequency:

An intermediate frequency (IF) is a frequency to which a carrier is shifted as an intermediate step in reception in transmission.

The intermediate frequency is created by mixing the carrier with a local oscillator signal in a process call heterodyning, resulting a signal at the difference or beat frequency.

Intermediate frequencies are used in super heterodyne radio receivers, in which an incoming signal is shifted an IF for amplification before final detection is done.

IF frequencies are used for three general reasons:

1. At very high frequencies, signal processing circuitary performs poorly and cost is also vey high. Active devic such as transistors cannot perform much amplification without becoming unstable. Ordinary circuits usi capacitors and inductors must be replaced with high frequency techniques such as stripling and waveguid So, a high frequency signal is converted to a low frequency Intermediate Frequency (IF) for processing.
2. A second reason to use an IF, in receivers that can be tuned to different stations is to convert various differe frequencies of the station to a common frequency for processing.

- it is difficult to build amplifiers, filters and detectors that can be tuned to different frequencies. But it is ea to built tunable oscillators, by adjusting the frequency of local oscillator on the input side.
- Without using an IF, the complicated filters and detectors in radio or television receivers would have to tuned at same time the station was changed.

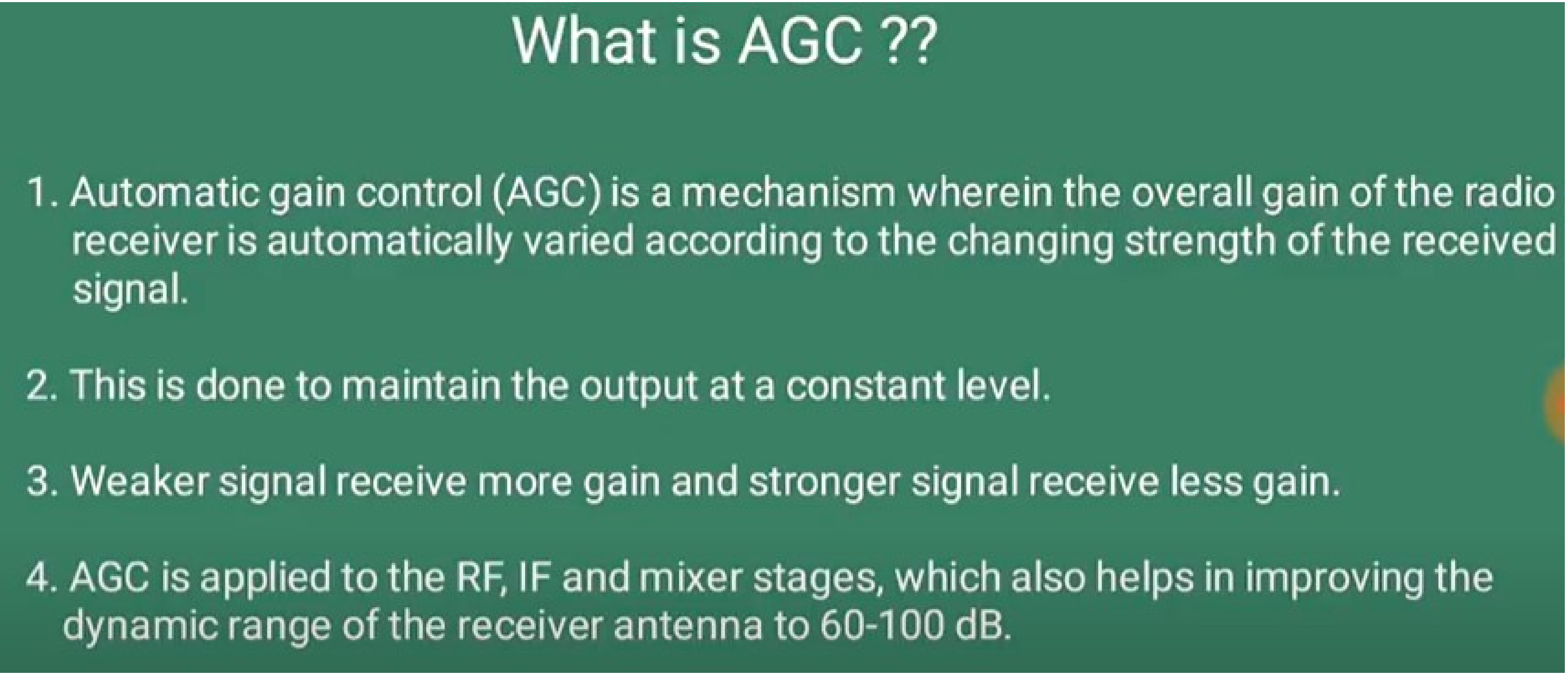
Radio Receivers

3. The main reason for using an Intermediate Frequency is to improve frequency selectivity.

- In communication circuits, a very common tank is to separate signals or signal components that are c together in frequency. This is called Filtering.
- The bandwidth of filters increases as the frequency increases. So, a narrower bandwidth and more selectivity be achieved by converting the signal to a lower IF and performing the filtering at that frequency.
- The effectiveness of the super heterodyne design is such that even today 99.99% of all radios used this desi

Intermediate Frequencies used

1. Standard broadcast AM receivers which are tuned to 540 to 1650 kHz, use an IF within the 438- to 465 range, with 455 kHz by far the most popular
2. AM, SSB and other receivers employed for shortwave or VHF reception have a first IF often in the range about 1.6 to 2.3 MHz, or else above 30 MHz. (Such receivers have two or more different Interme Frequencies)
3. FM receivers using the standard 88- to 108-MHz band have an IF which is almost always 10.7 MHz.
4. Television receivers in the VHF band (54 to 223 MHz) and in the UHF band (470 to 940 MHz) use an IF c and 46 MHz which are the two most popular values.
5. Microwave and radar receivers, operating on frequencies in the 1- to 10-GHz range, use interme frequencies depending on the application, with 30, 60 and 70 MHz among the most popular.



Automatic gain control (AGC) is a closed-loop feedback circuit present in radio receivers which helps to maintain a constant output, irrespective of the input variations. In communication systems, the inclusion of AGC regulates the system output to a constant value, even if the input voltage decreases or increases.

Radio Transmitters

Automatic Gain Control (AGC):

The automatic gain control, AGC, was introduced to stop variations in signals causing large variations in received signal.
AGC was implemented first in Radios for the reason of avoiding **fading** effect (i.e slow variations in the amplit of received signal).
Such circuits required continuous adjustments in the receivers gain in order to maintain a constant output sigr
AGC circuits are designed in such a way to maintain constant output signal level regardless of the signal varia at the input of the system.

Principle of Automatic Gain Control :

The principle of operation of AGC contains following steps

1. A d.c. Voltage proportional to the carrier amplitude is derived by rectifications of carrier voltage in a linea diode detector.
2. To apply this d.c. Voltage as a reverse biased voltage at the input of RF amplifier, frequency mixer and IF amplifier.

   Now if the carrier signal amplitude increases, AGC bias increases and is applied in reverse to the precedir stages resulting in decrease in carrier amplitude , thus bringing it back to its original normal value.
   If the carrier amplitude decreases due to same reason, then the reverse action takes place.
   Hence, AGC smoothens out the variations in the carrier amplitude to a very large extent.

Radio Transmitters

Simple Automatic Gain Control :

Figure shows the circuit of a linear diode detector with simple AGC.

In this circuit, the half wave rectified voltage is developed across load resistor 'R'.

The capacitor 'C' filters the RF components due to which, only d.c. and the modulating frequency (low frequency) voltage are obtained across the load resistor 'R'.

The d.c. Component is removed from the output by the use of coupling capacitor 'C_c'.

The voltage from the diode end consists of modulating frequency components and d.c. Voltage required for AGC bias.

Diode detector

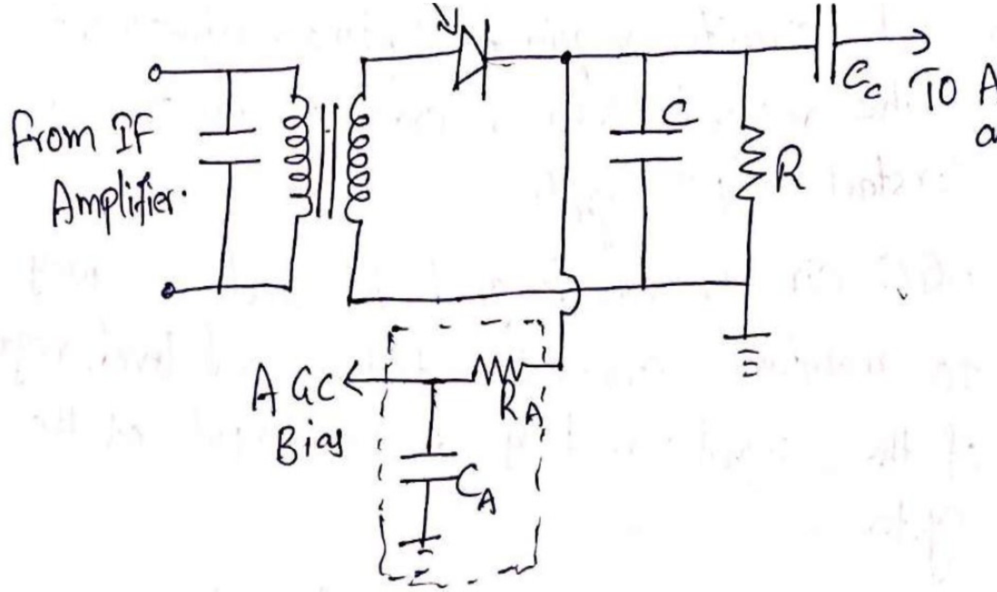


fig:- Linear diode detector with capacitor

An AGC filter consists of a series resistor 'R_A' and shunt capacitor 'C_A' which is used to remove modulating frequen components thus leaving a positive d.c. Voltage required for AGC bias.

This positive AGC bias is applied at the base of PNP transistors of preceding tuned stages of RF amplifier. This posi AGC bias then reduce the net forward bias thereby reducing the gain of the amplifier.

However, in the case of NPN transistors, a negative AGC bias is applied at the base of the transistors of prece tuned stages of RF amplifier. In the case, the detector circuit is similar to above fig. Except that the polarity of dio reversed.

Advantages of Simple AGC:

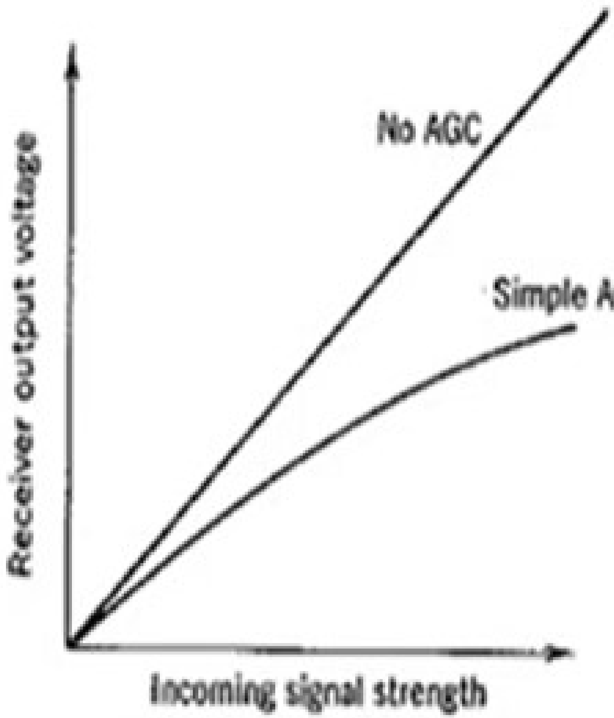
1. Simple.
2. Low cost.
3. Improvement over No AGC.

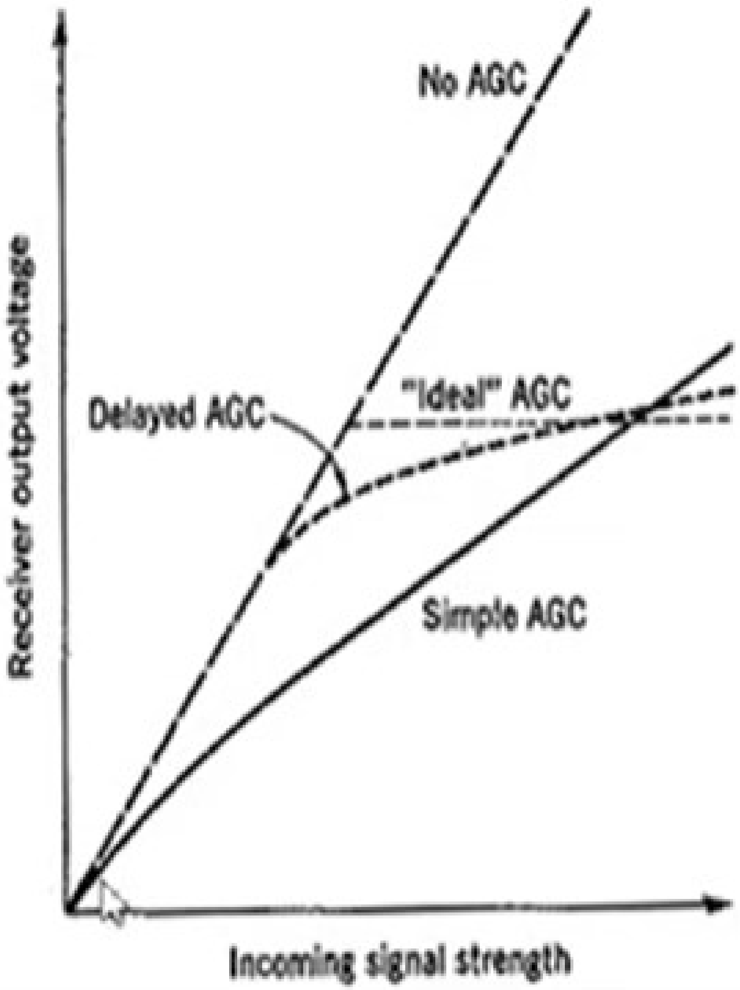
Disadvantages:

- Reduction in gain of the receiver will take place even for the weak signals.

Use:

Used in domestic radio receivers.


No AGC
Simple AGC
Receiver output voltage
Incoming signal strength


No AGC
"Ideal" AGC
Delayed AGC
Simple AGC
Receiver output voltage
Incoming signal strength

Simple Automatic Gain Control with π – filter or Practical AGC:

To provide better modulating frequency output a **π – filter** is used in a place of a simple capacitor filter, as shown in figure.

The figure shows the circuit of linear diode detector with **π – filter** and simple AGC. Also, a manual volume control is generally provided by using a variable resistor at the input of the first audio amplifier as shown in fig.

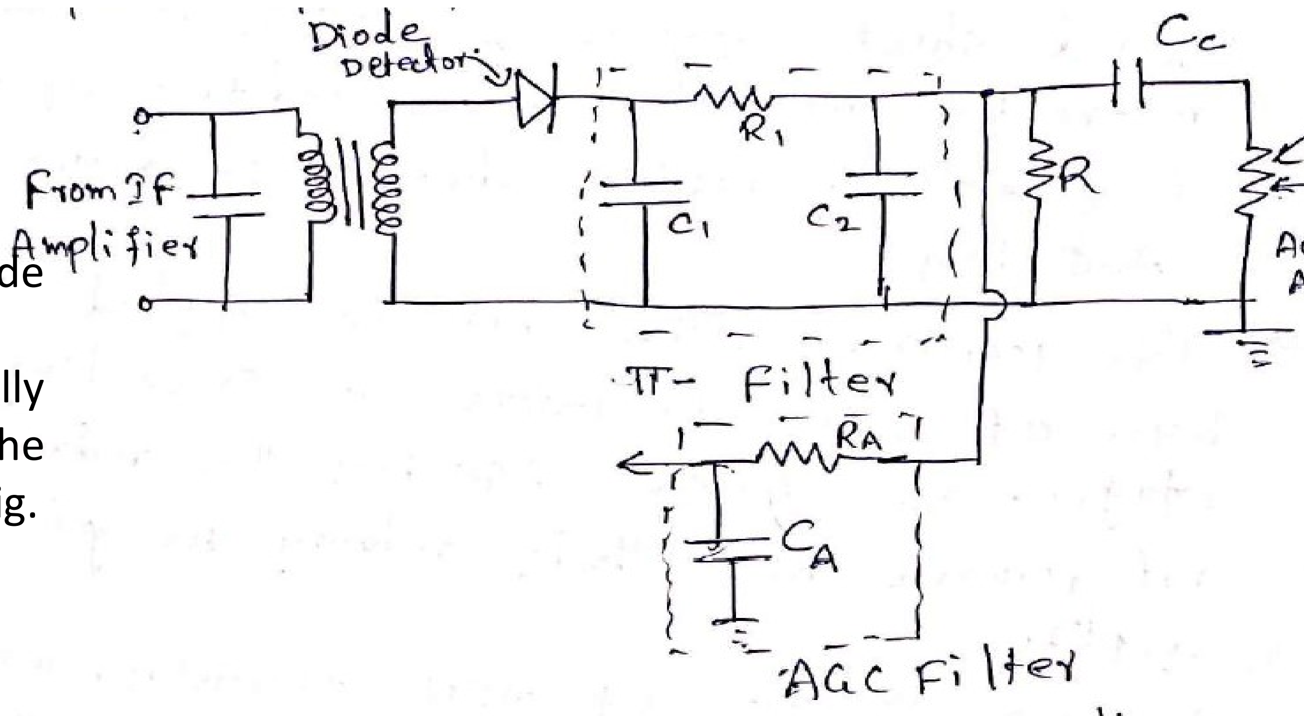


fig:- Simple AGC with π filter.

Delayed Automatic Gain Control :

Simple AGC suffers from a major drawback that the AGC become active even for very weak signals. Due to this receiver gain starts falling. But Ideal AGC remain active, the carrier voltage reach a reasonable threshold voltage(large). Subsequently, the AGC must come into **operation to maintain output level constant** instead of variation in the input level of carrier voltage.

Delayed AGC to provide delay in AGC operation. With Zero and small signal voltages, diode D2 conducts due to which the AGC bias just equals the potential of cathode of the diode. Hence AGC remains fixed at a low positive value.

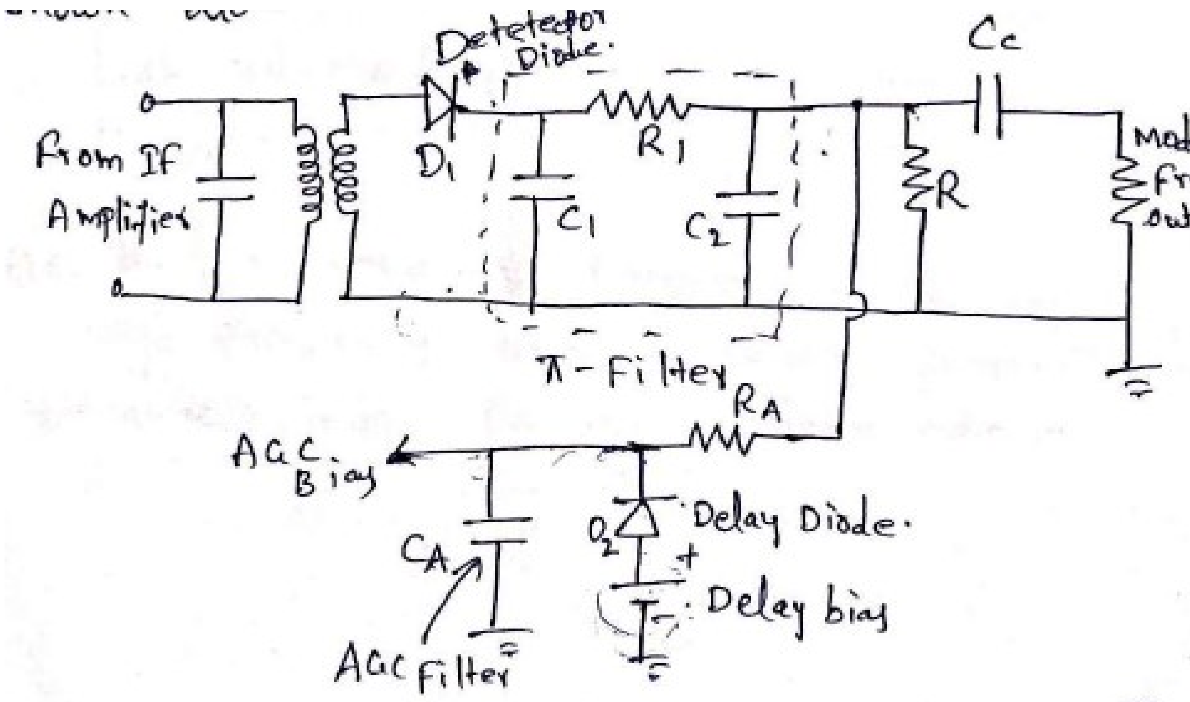


fig:- Delayed AGC.

As the input carrier voltage increases, AGC bias produced due to rectification of carrier voltage in detector d D1 increases. When this rectified bias magnitude exceeds the voltage of Diode D2, then diode D2 stops conduc and AGC system works normally.

Radio Receivers

Choke of Intermediate Frequency:

The Intermediate Frequency(IF) of a receiving system is usually a compromise, since there are reasons why it should be neither low nor high nor in a certain range between the two.

1. The intermediate frequency must not be with in the tuning range of receiver otherwise heterodyne whistle will be heard.
2. If the intermediate frequency too high, poor selectivity and poor adjacent channel rejection results unless sharp cut off filters are used in IF stages.
3. A high value of IF increases tracking difficulties.
4. As, the intermediate frequency is lowered , image frequency rejection becomes poorer. This is because ima frequency rejection ratio is

$$\alpha = \sqrt{1 + Q^2\rho^2} \qquad where\ \rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}}$$

Image signal frequency $f_{si} = f_i + f_i + f_s = 2f_i + f_s$

Radio Transmitters

FM Receiver:

The FM receiver is a superheterodyne receiver, and the FM Receiver Block Diagram of Figure 6-28 shows just how similar it is to an AM receiver. The basic differences are as follows:

1. **Generally much higher operating frequencies in FM**
2. **Need for limiting and de-emphasis in FM**
3. **Totally different methods of demodulation**
4. **Different methods of obtaining AGC**

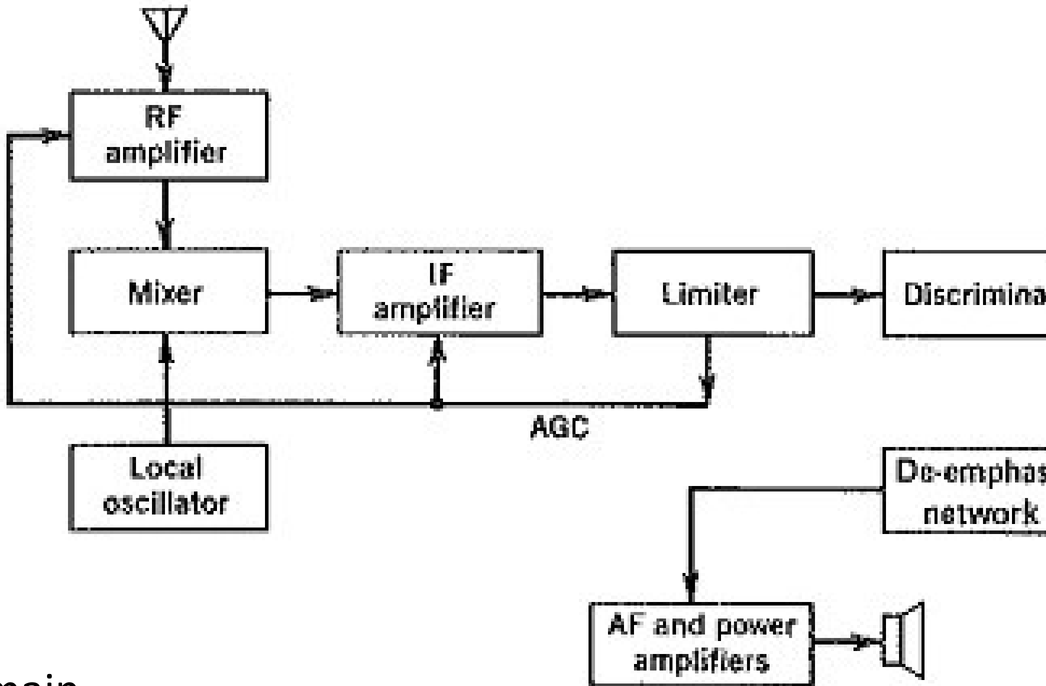


FIGURE 6-28 FM receiver block diagram.

RF amplifier:

An RF amplifier is always used in an FM receiver. Its main purpose is to reduce the noise figure, which could otherwise be a problem because of the large bandwidths needed for FM.

It is also required to match the input impedance of the receiver to that of the antenna.

In FM broadcast the signal bandwidth is large being 200KHz. RF amplifiers must be designed to handled this large bandwidth. input from output.

Radio Receivers

Frequency mixers:

The mixer performs the function of mixing or heterodyning the signal frequency and local oscillator frequenc produce a difference frequency (f0-fs) component of these two.

Since FM broad cast takes place either in VHF or UHF band, single frequency converter is not used. There may need of another frequency converter.

The output of the mixer will be Intermediate Frequency and such frequency for FM receiver is 10.7MHZ.

VHF:30-300MHZ and UHF 300MHz-3Gh

Local oscillator:

When FM receiver is operating at ultra high frequencies, it is preferable that the local oscillator frequency must be smaller than the signal frequency by amount equal to the intermediate frequency i.e.

$$f_i = f_s - f_0$$
$$f_0 = f_s - f_i$$

If f_s= 90MHz and we know f_i = 10.7MHz then f_0 = 79.3MHz

IF amplifier:

The IF amplifier may be a multistage amplifier. This IF amplifier should be designed to have a overall bandwidth of 2

Double tuned IF amplifier circuits are used particularly at higher frequencies in UHF range.

Radio Receivers

Limiter:

If amplifier is followed by a limiter, which limits the IF voltage predetermined level and removes all amplitude variations which may be caused due to change in the transmission path or by man made noise or natural noise

Discriminator:

The discriminator is a frequency discriminator in which input frequency variations are converted into amplitu variations.

From this amplitude variations, extract the original modulating frequency signal form the FM wave.

De- emphasis circuit:

The De-emphasis circuit does the inverse job of the pre-emphasis circuit. The high modulating frequency components boosted by pre-emphasis are bring back to original amplitude level by de-emphasis.

AF Power Amplifier:

This amplifier the audio frequency(AF) modulating signal recovered by FM detector.
This amplifier has wider bandwidth of AM receiver and given to the load speaker.
The loud speaker convert the electrical signal into sound signal.

Radio Receivers

Radio Receivers

Radio Receivers

Radio Receivers

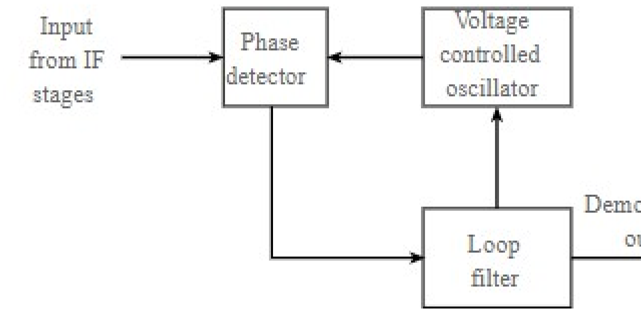
Radio Receivers

Radio Receivers

Radio Receivers

PLL FM Demodulators

The phase locked loop, PLL is a very useful RF building block. The PLL uses the concept of minimising the difference in phase between two signals: a reference signal and a local oscillator to replicate the reference signal frequency. Using this concept it is possible to use PLLs for many applications from frequency synthesizers to FM demodulators, and signal reconstitution.



PLL Phase locked Loop FM demodulator

To look at the operation of the PLL FM demodulator take the condition where no modulation is applied and carrier is in the centre position of the pass-band the voltage on the tune line to the VCO is set to the mid positio However if the carrier deviates in frequency, the loop will try to keep the loop in lock. For this to happen the frequency must follow the incoming signal, and in turn for this to occur the tune line voltage must vary. Monitoring the tune line shows that the variations in voltage correspond to the modulation applied to the signa amplifying the variations in voltage on the tune line it is possible to generate the demodulated signal. Although no basic changes to the phase locked loop are required for it to be able to demodulate FM, a b amplifier is typically provided from the tune line to prevent the tune line being loaded by other sections of receiver. It provides a lower output impedance and as a result, this prevents loading from the audio amplifier f upsetting the loop in any way.