Transmitters and Recievers

AM Transmitter

AM transmitter are classified as
* Low power level AM transmitter
* High power level AM tansmitter.

Low-power level AM transmitter

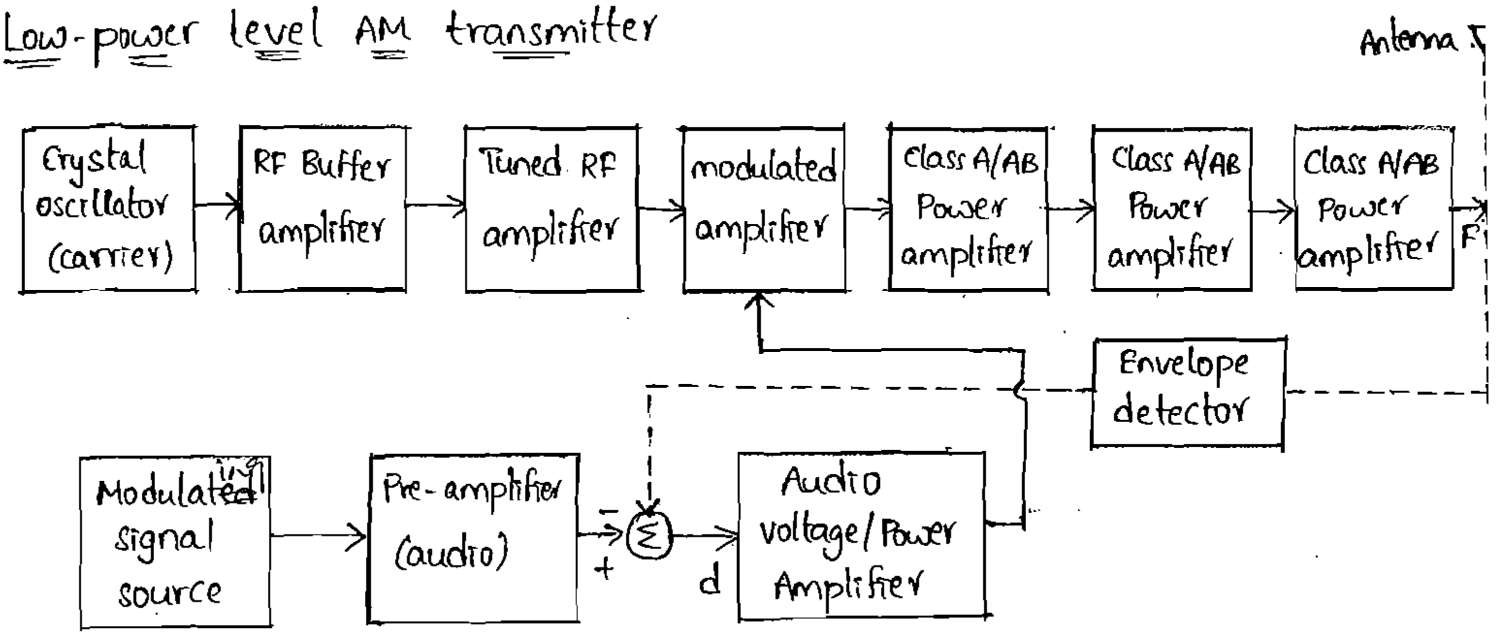


Fig : AM Transmitter with low-level

In the low level transmitters, the modulation process is done at a lower power level and then the modulating signal is passed through a high level power amplifier.

The modulating signal is obtained from a microphone. The pre amplifier is a typically sensitive class A linear voltage amplifier. This amplifier must have a high input impedence. The purpose of the pre amplifier is to bring the source signal to such a level so that the input to the driver amplifier is noise and distortion free. The driver of the modulating signal is also a linear amplifier which amplifies the modulating signal to an adequate level to sufficiently drive the modulator.

The RF Carrier signal is from an oscillator. This can be used to generate the carrier whose frequency stability is quite high. The buffer amplifier is a low-gain, high input impedence linear amplifier that isolates the oscillator from the high power amplifiers. The emitter followers or of late operational amplifiers are used as buffers. Modulators can be either emitter or collector modulation type. The intermediate and Final power amplifie are generally class A or B push-pull type. This helps to maintain symmetry in the AM envelope. The output impedence of the final power amplifier is matched to antenna by using a antenna matching network.

High power level AM transmitter

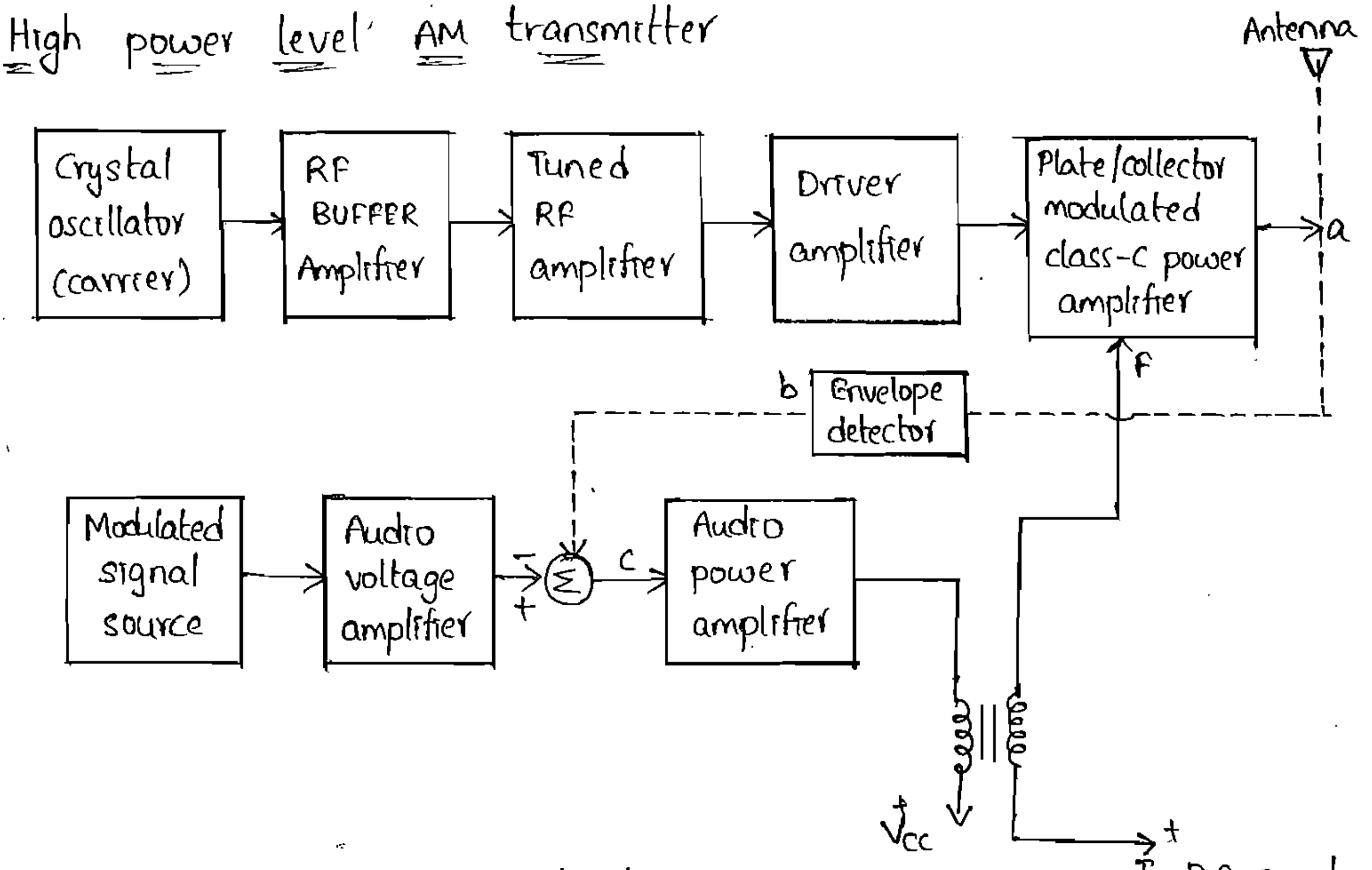


fig : High level modulator

In a high level transmitter, modulation and power amplification are done at a higher level. This requires the modulating signal and carrier signal to be brought to a certain power level before modulation is effected.

The modulating signal goes through the same stage as in the case of low power transmitter except for the addition of a power amplifier. This is due to the fact that for high-level transmitters, the modulating signal should be brought to a higher level before modulating. The carrier will also be at its full power and hence power of the modulating signal be quite high enough to achieve 100% modulation.

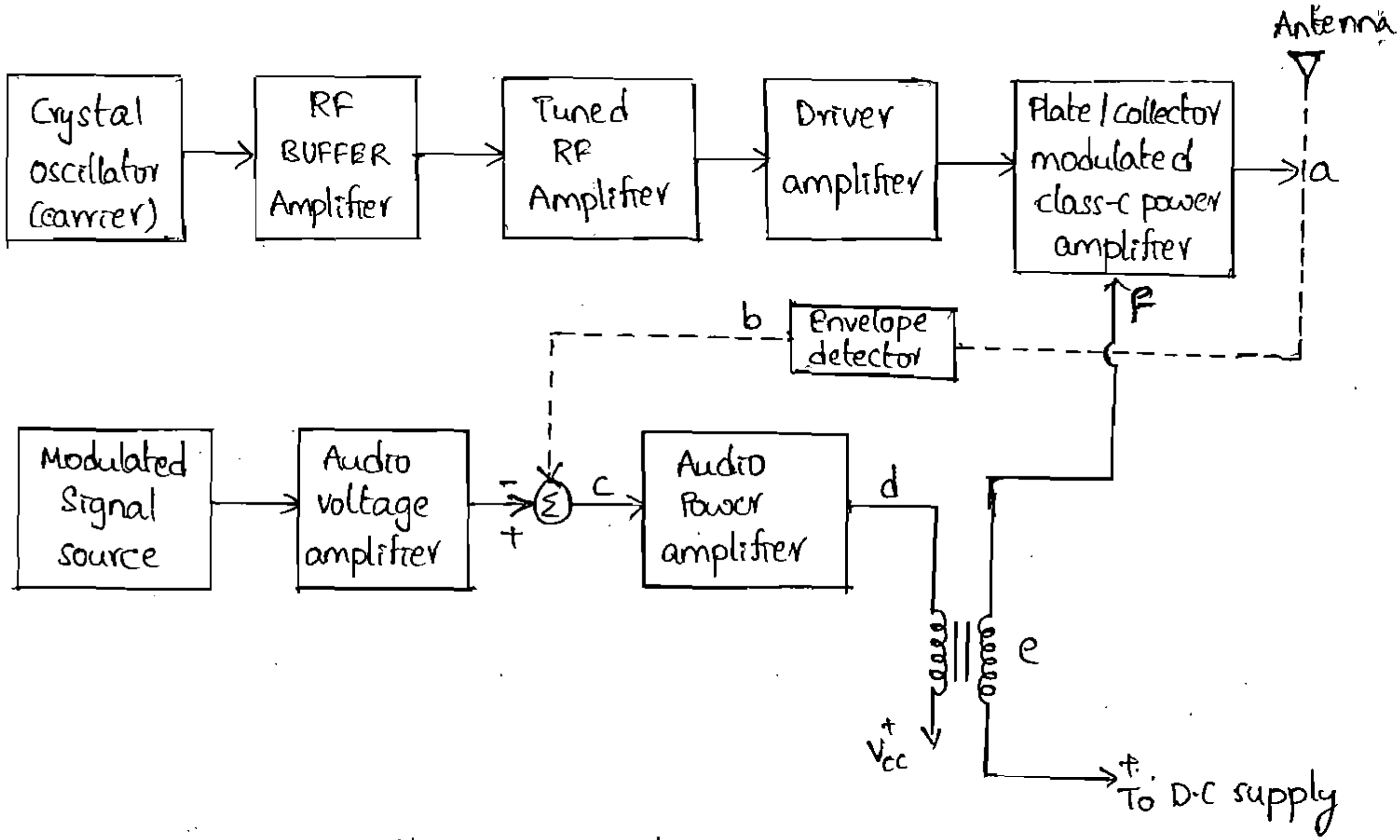
An RF oscillator and its circuit are similar to that of a low-level transmitter. The carrier signal also requires an additional power amplifier before it is given to the modulator. The final power amplifier is the actual modulator. Collector modulator class C type has a very good efficiency.

Advantage

The advantage of high-level modulator transmitter is that all the RF power amplifier can be class C power amplifier, which can be designed to have very high power efficiency of the order of 80 to 90%.

Effect of Feedback on performance of AM transmitters

Generally Negative feedback is provided in AM transmitters with a to improve their performance. The AM signal fed to the antenna should have, its envelope, as the message signal available at the output of the audio voltage amplifier.



This will be the case only if there is no distortion produced in the audio power amplifiers.

The AM signal to be radiated is picked up at the point 'a' its envelope is extracted. This is then subtracted from the voltage amplifier output. The loop a-b-c-d-e-f thus acts as the feedback loop.

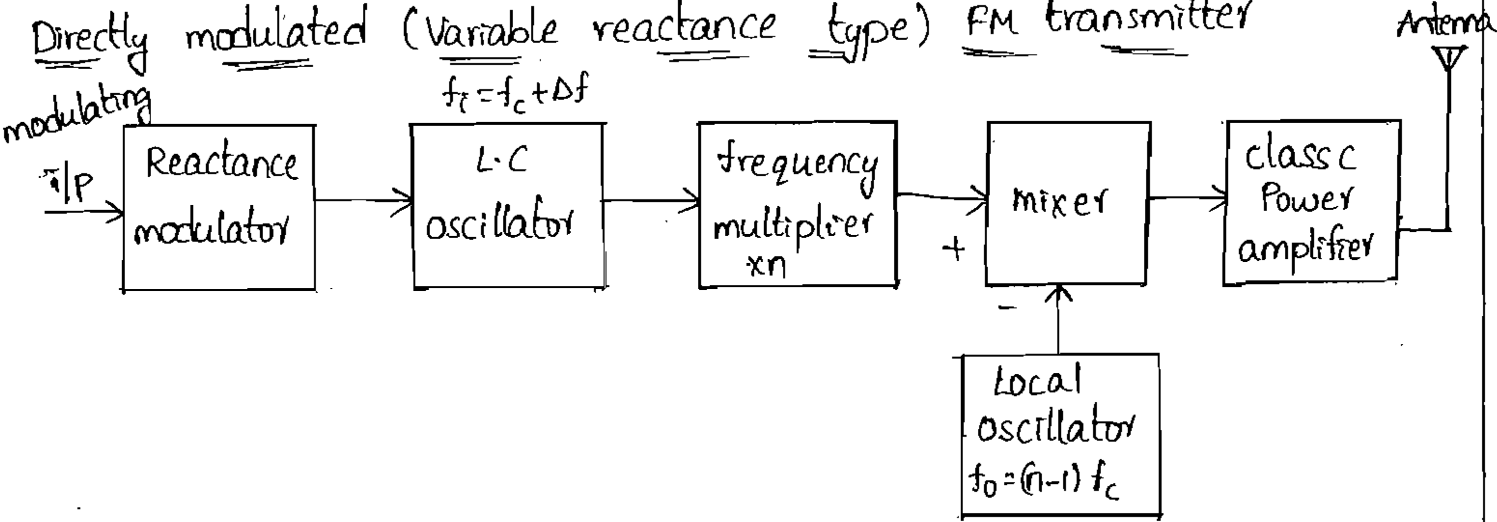
This negative feedback improves the performance of the transmitter as it reduces the distortion of the envelope of the radiated signal by making it closely resemble the message signal. It reduces the noise and power frequency also

→ FM transmitters

FM signals can be generated either directly, by varying the frequency of the carrier oscillator, or indirectly by converting phase modulation to frequency modulation. According to modulation method employed there are two types of FM transmitters.

* Directly modulated / variable reactance type FM transmitter.
* Indirectly / Phase modulated FM transmitter.

Directly modulated (Variable reactance type) FM transmitter



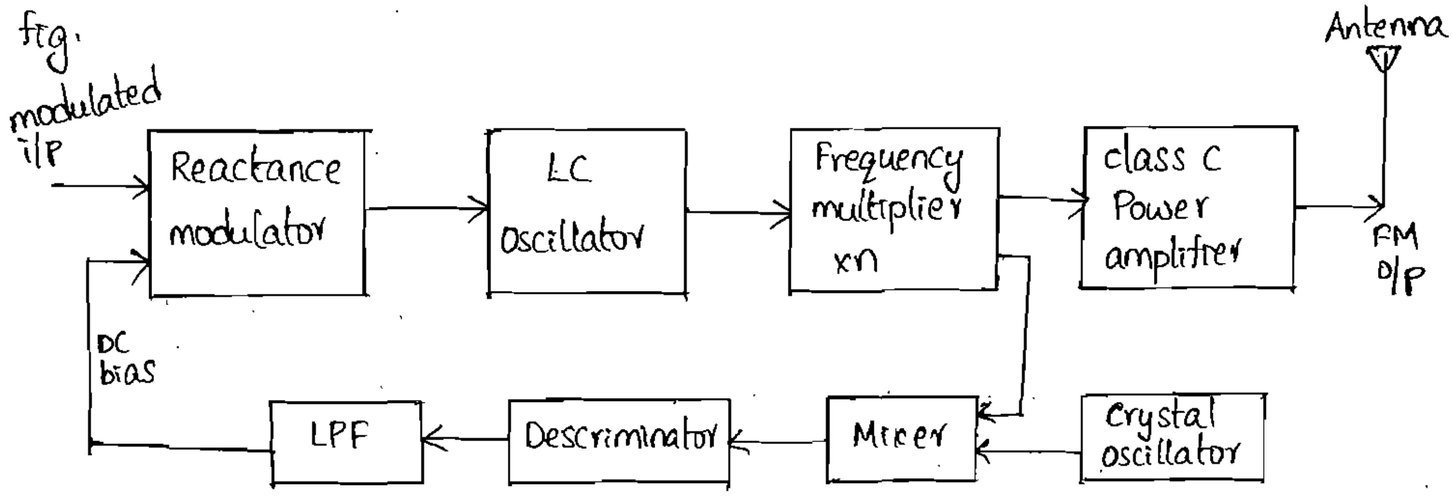
In directly modulated FM transmitters, the frequency modulation is carried out at a lower frequency and with a smaller frequency deviation. Then passing this frequency modulated wave through frequency multiplier circuit, the desired carrier frequency and desired frequency deviation is achieved.

With frequency multiplication, the instantaneous frequency is multiplied. For example, if the instantaneous frequency of an FM oscillator is $f_i = f_c + \Delta f_c$, when passed through a frequency multiplier this becomes $nf_i = nf_c + n\Delta f$, where n is the multiplying factor. The frequency multiplication can be achieved by passing the signal through a class C amplifier and tuning the output to the desired harmonic.

With frequency mixing, the deviation will not change. For example, if a signal with frequency $nf_c + n\Delta f$ is passed through a mixer, which is also fed by a local oscillator f_0, the output can be tuned to difference frequency $nf_c + n\Delta f - f_0$

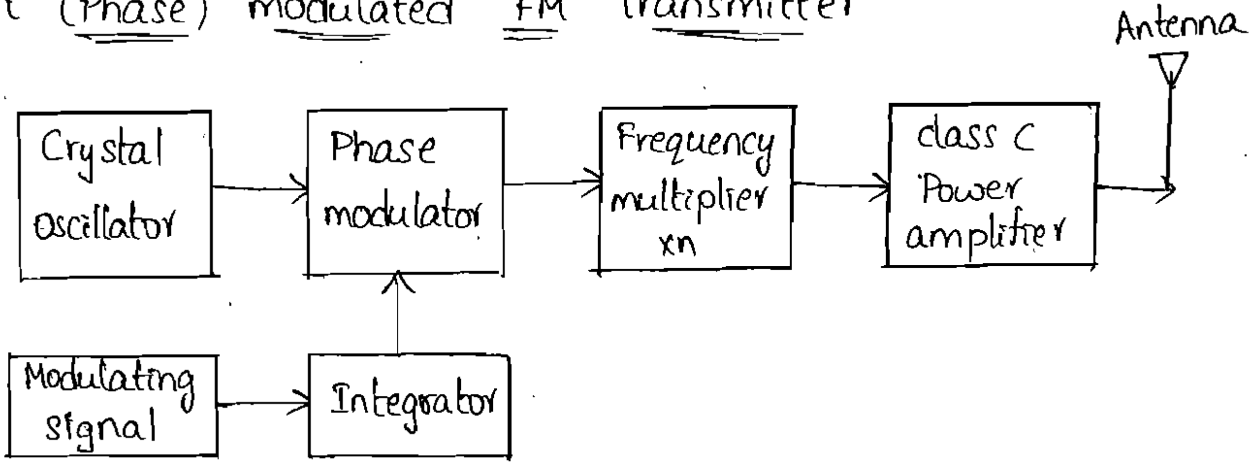
Frequency stability using AFC

It is difficult to maintain stability of unmodulated carrier frequency when LC oscillator is directly frequency modulated to produce relatively large deviation. The unmodulated carrier frequency can be kept stable using an automatic frequency control (AFC) ckt. The block diagram of a typical AFC circuit is shown in below fig.



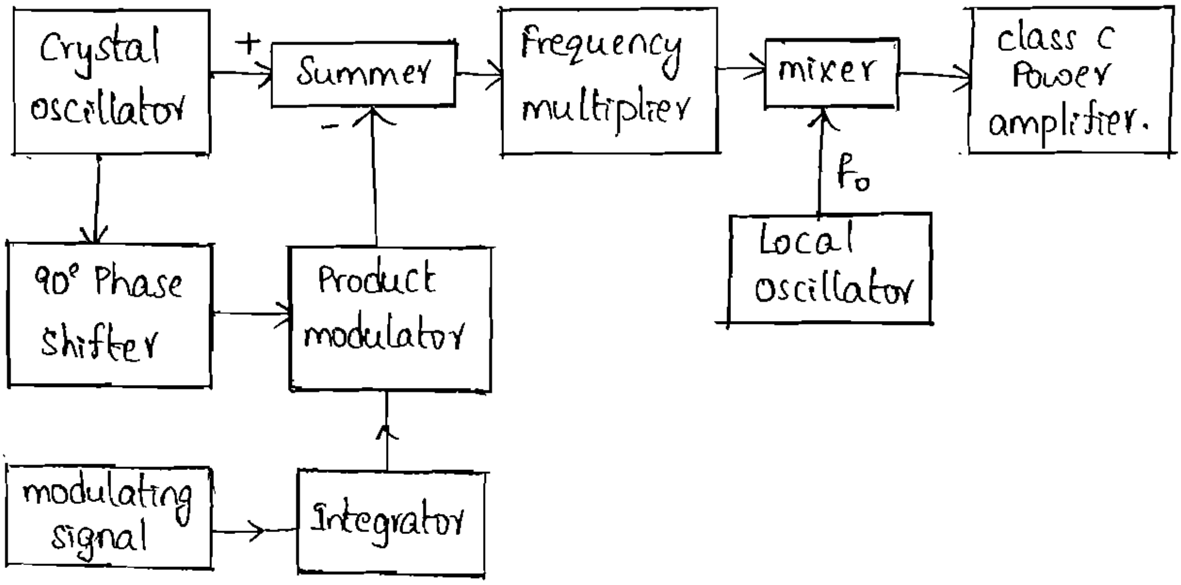
Suppose frequency of carrier increases. This higher frequency is fed to the mixer for which the other i/p frequency is from the stable crystal oscillator. A some what higher frequency will be fed to the descriminator. The descriminator will develop a positive dc voltage. The low pass filter (LPF) removes the signal component and leaves only dc voltage. The output of LPF i.e., the positive dc voltage is applied to the reactance modulator whose transconductance is increased by the positive dc voltage. This increase the equivalent capacitance of the reactance modulator there by decreasing the oscillator frequency. The frequency increase in the carrier frequency is thus lowered and brought to the correct value. Exactly, opposite action takes place when carrier frequency decreases.

Indirect (Phase) modulated FM transmitter



In this technique the phase angle is made to vary while holding the frequency constant. By this technique, a phase modulated signal is generated. With some minor processing this Phase modulated signal can be passed off as an FM as shown in fig.

A very popular indirect method of achieving FM is known as the "Armstrong method"



FM transmitter: Armstrong method.

In this method, the initial modulation takes place as an amplitude modulated DSBSC signal so that a crystal oscillator can be used in desired.

Here the crystal oscillator generates the sub carrier, which can be low, say on the order of 100KHz. One o/p from the oscillator is phase shifted by 90° to produce the sine term, which is then DSBSC modulated in the balanced modulator by $V_m(t)$ This is combined with the direct o/p from the oscillator in the summing amplifier, the result then being the phase modulated signal. The modulating signal is passed through an integrator to the modulator to get the frequency modulated signal. At this stage, the equivalent frequency deviation will be low, so the arrangement shown in fig. is used to increase the peak deviation.

RECEIVERS

Introduction

The primary requirement of any communication reciever is that it should have the ability to select the desired signal from among thousands of others present and to provide sufficient amplification to recover the modulating signal. To provide this primary requirement receiver has to carry out different functions. as given below.

1. Collect the electromagnetic waves transmitted by the transmitter.
2. Select the desired signal and reject all others.
3. Amplify the selected modulated carrier signal.
4. Detect the modulating signal from the modulated RF signal.
5. Amplify the modulating signal to operate the loud speaker.

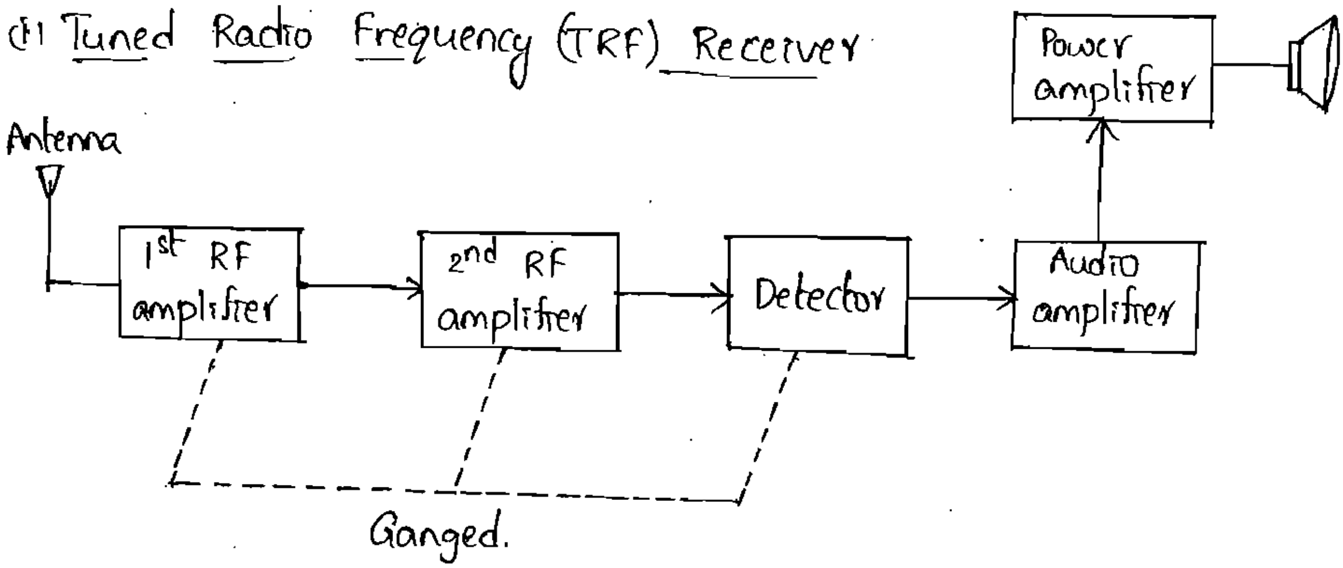
Receiver types

1. AM Receiver 2. FM Receiver

1. AM Receiver

(i) The Tuned Radio frequency Receiver and
(ii) Superheterodyne Receiver.

(i) Tuned Radio Frequency (TRF) Receiver



The TRF R_x consists of two or three stages of RF amplifiers, detector, audio amplifier and power amplifier. The RF amplifier stages placed between the antenna and detector are used to increase the strength of the receiver signal before it is applied to the detector. These RF amplifiers are tuned to fix frequency, amplify the desired band of frequencies. Therefore, they provide amplification for selected band of frequencies and rejection for all others. As selection and amplification process is carried out in two or three stages and each stage must amplify the same band of frequencies, the ganged tuning is provided.

The amplified signal is then demodulated using detector to recover the modulating signal. The recovered signal is amplified furthur by the audio amplifier followed by power amplifier which provides sufficient gain to operate a loud speaker. The TRF receivers suffered from number of annoying problems. These are listed in the next section.

Problems in TRF Receivers

1. Tracking of Tuned circuit

In TRF receiver tuned circuits are made variable so that they can be set to the frequency of the desired signal. In most of the receivers, the capacitors in the tuned circuits are made variable. These capacitors are 'ganged' b/w the stages so that they are can be changed simultaneously when the tuning knob is rotated. To have perfect tuning the capacitor values b/w the stages must be exactly same but this is not the case. The difference in the capacitors cause the resonant frequency of each tuned circuit to be slightly different, thereby increasing the pass band.

2. Instability

As high gain is achieved at one frequency by a multistage amplifier, there are more chances of positive feedback through some stray path, resulting in oscillations. These oscillations are unavoidable at high frequencies.

3. Variable Bandwidth

TRF receivers suffer from a variation in bandwidth over the tuning range. Consider a medium wave receiver required to tune over 535KHz to 1640KHz and it provides the necessary bandwidth of 10KHz at 535KHz Let us calculate Q of this ckt.

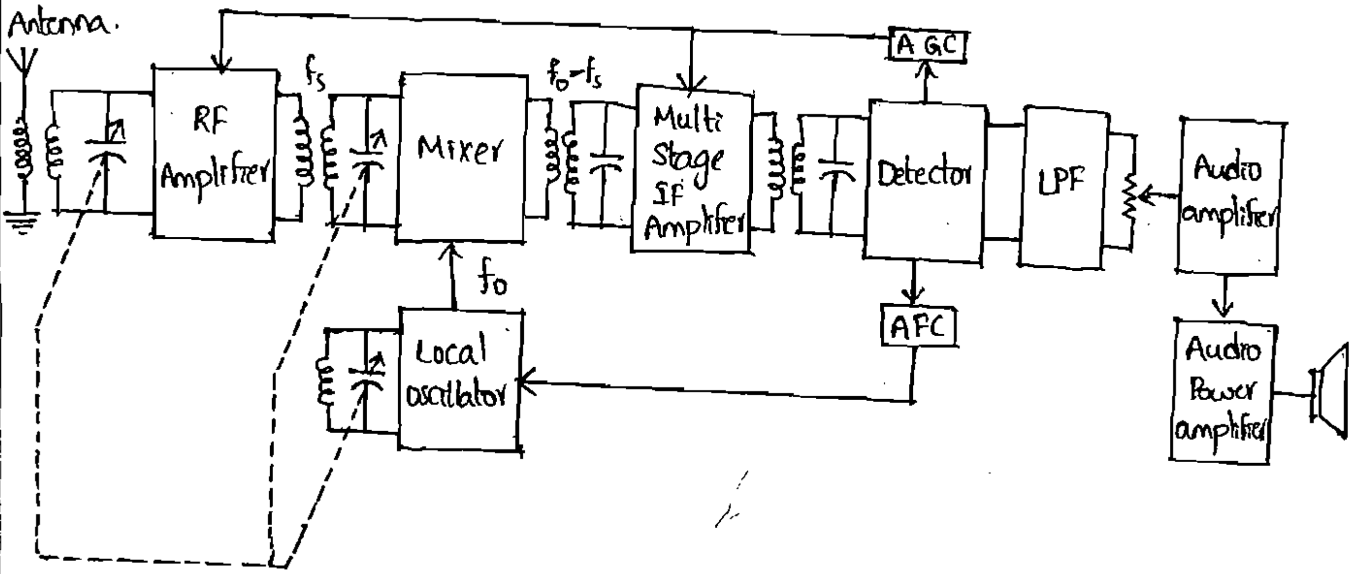
$\Rightarrow Q = \frac{f}{BW} = \frac{535k}{10k} = 53.5$

At 1640KHz Q of the coil should be 164 (1640k/10k)
However, in practice due to various losses depending on freq. we will not get so large increase in Q. let us assume that at 1640KHz frequency Q is increased to value. 100 instead of 164. With this Q of the Kevel tuned circuit bandwidth can be calculated as follows $\Rightarrow BW = \frac{f}{Q} = \frac{1640k}{100} = 16.4KHz$

We know necessary BW is 10KHz we can say that in TRF R_x the BW of the tuned circuit varies over the frequency range, resulting in poor selectivity of the receiver.

Because of the problems of tracking, instability and bandwidth variation, the TRF receivers have almost been replaced by super heterodyne R_x.

Superheterodyne Receivers



In Super heterodyne R_x, first all the incoming RF frequencies are converted to a fix lower frequency called Intermediate frequency (IF). Then this fix intermediate frequency is amplified and detected to reproduce the original information since the characteristics of the IF amplifier are independent of the frequency to which the receiver is tuned, the selectivity and sensitivity of super heterodyne receivers are fairly uniform through out its tuning range.

Mixer circuit is used to produce the frequency translation of the incoming signal down to IF. The incoming signals are mixed with the local oscillator frequency signal in such a way that a constant frequency difference is maintained b/w the local oscillator and the incoming signals. This is achieved by using ganged tuning capacitors.

As shown in the figure, antenna picks up the weak radio signal and feeds it to the RF amplifier

The RF amplifier provides some initial gain and selectivity. The o/p of the RF amplifier is applied to the i/p of the mixer. The mixer also receives an i/p from local oscillator.

The o/p of the mixer circuit is difference frequency (f_o f_s) commanly known as IF. The signal at this intermediate frequency contains the same modulation as the original carrier. This signal is amplified by one or more IF amplifier stages and most of the receiver gain is obtained in these IF stages. The highly amplified IF signal is applied to detector circuits to recover the original modulating information. Finally the o/p of detector ckt is fed to audio and power amplifier which provides a sufficient gain to operate a speaker. Another important ckt in the Superheterodyne receiver are AGC and AFC circuit. AGC is used to maintain a constant o/p voltage level over a widerange of RF i/p signal levels.

AFC circuit generates AFC signal which is used to adjust and stabilize the freq of local oscillator.

Receiver characteristics

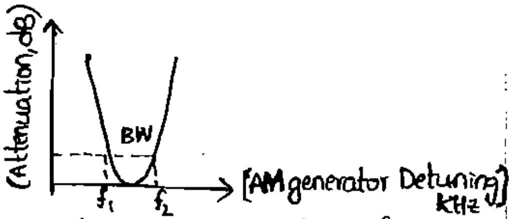
The performance of the radio receiver can be measured in terms of following receiver characteristics.

1. Selectivity
2. Sensitivity
3. Fedility
4. Image frequency and its rejection
5. Double spotting

1. Selectivity

Selectivity refers to the ability of a receiver to select a signal of a desired frequency while reject all others. Selectivity in a receiver is obtained by using tuned circuits. These are LC circuits tuned to resonate at a desired signal frequency. The Q of these tuned circuits determines the selectivity. A good receiver isolates the desired signal in the RF spectrum and eliminate all other signals. we know that bandwidth of the tuned ckt is given by, $BW = \frac{f_r}{Q}$

where f_r is the resonant frequency



Narrower the bandwidth better the selectivity. The below figure shows the selectivity curve for the typical tuned ckt. As shown in the figure below, bandwidth is the difference b/w the upper f_2 and lower f_1 cutoff frequencies which are located at the 3dB or 0.707 points on the sensitivity curve.

2. Sensitivity

The sensitivity of a communication receiver refers to the receivers ability to pickup weak signals, and amplify it. The more gain that a receiver has, the smaller the i/p signal necessary to produce desired o/p power. Therefore, sensitivity is a primary function of the overall receiver gain. It is often expressed in microvolts or in decibells. The sensitivity of receiver mostly depends on the gain of the IF amplifiers. Good communication receiver has sensitivity of 0.2 to 1μV

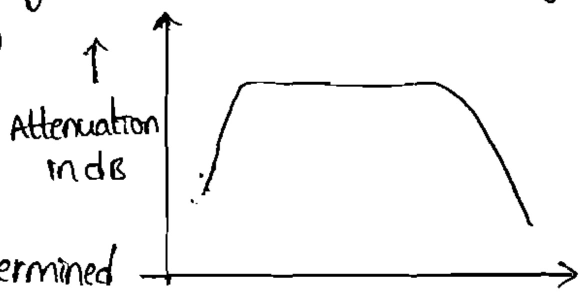
Fig. Sensitivity curve for typical receiver.

3. Fedility

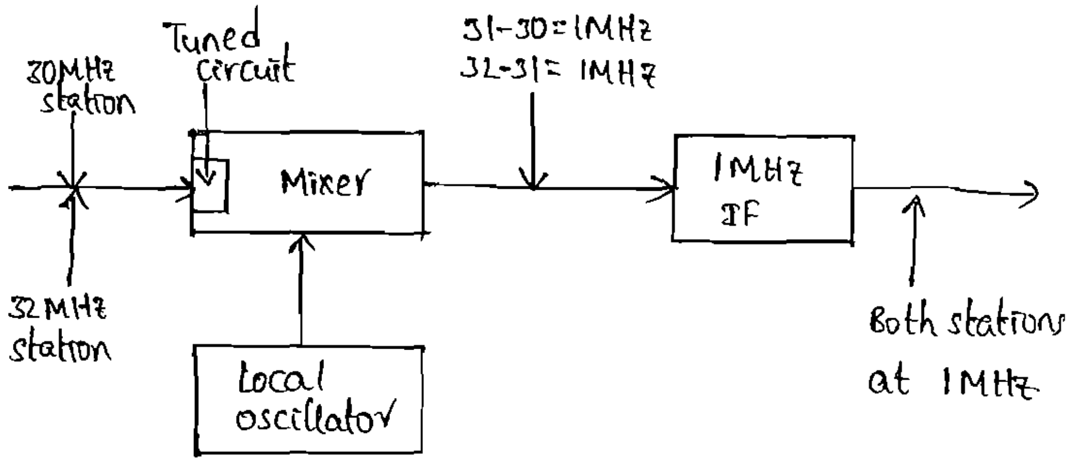
Fedility refers to the ability of the receiver to reproduce all the modulating frequencies equally. The below figure shows the typical fedility curve for radio receiver.

The fedility at the lower modulating frequencies is determined by the low frequency response of the IF amplifier and the fedility at the higher modulating frequencies is determined by the high frequency response of the IF amplifier. Fedility is difficult to obtain in AM receiver because good fedility requires more bandwidth of IF amplifier resulting in poor selectivity.

Fig: Typical Fedility curve



4. Image frequency and its Rejection



Consider a superheterodyne receiver having an intermediate frequency of 1MHz tuned to receive a 30MHz station. The local oscillator frequency necessary for the tuning is equal to 31MHz. so that it may produce an intermediate frequency of 1MHz.

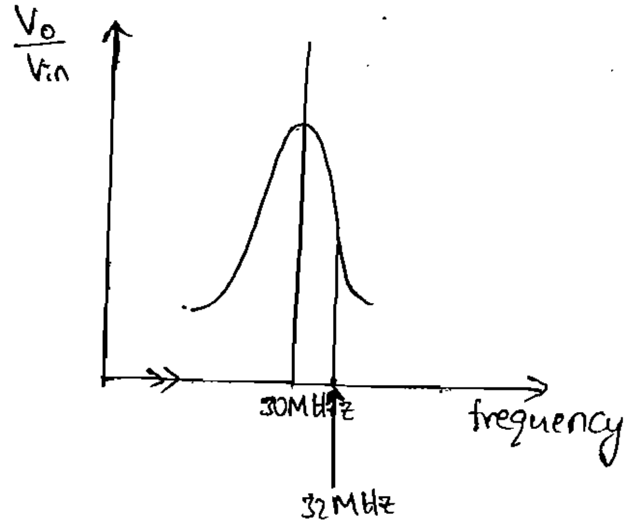


Fig: Response of the tuned.

If another station operating at 32MHz is also present in the air, it is possible for it to get into the mixer. As soon as this signal at 32MHz (undesired station) is present at the mixer input, it will produce a difference frequency with the L.O. frequency This difference frequency 1MHz (32MHz – 31MHz) which is the same IF Thus we now have the undesired 32MHz station in addition to the desired 30MHz station. In the IF section both the desired and undesired signal will be amplified. The desired frequency of 32MHz in this case is called the image frequency.

A superheterodyne receiver must therefore, be designed to have a very high image frequency rejection capability to get rid of this Spurious frequency.

5. Double spotting

The phenomenon of double spotting occurs at higher frequencies due to poor front end selectivity of the receivers. In this, receiver picks up same short wave station at two nearby points on the receiver dial.

When the receiver is tuned across the band, a strong signal appears to be at two different frequencies, once at the desired frequency and again when the receiver is tuned to 2 times IF below the desired frequency. In this second case, the signal becomes the image, reduced in strength by the image rejection, thus making it appear that the signal is located at two frequencies in the band.

Receiver sections

RF Amplifier

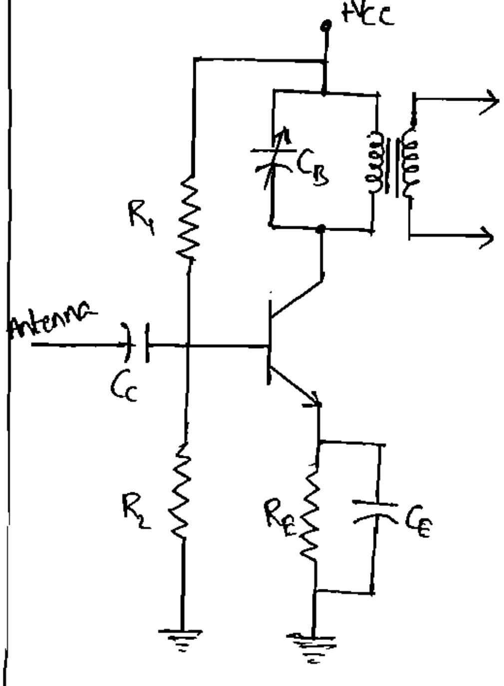


fig a.

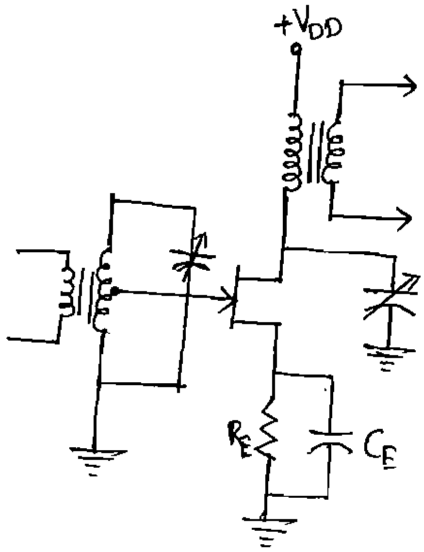


fig b.

The RF amplifier is a tunable circuit. It is there to select the wanted frequency and reject some of the unwanted frequencies and thus to improve signal to noise ratio. It provides initial gain and selectivity. It is a tuned circuit followed by an amplifier is usually a simple class A circuit.

The values of resistors R_1 and R_2 in the bipolar circuit are adjusted such that the amplifier works as class A amplifier. The antenna is connected through coupling capacitor to the base of the transistor. This makes the circuit very broad band as the transistor will amplify virtually any signal picked up by the antenna. However the collector is tuned with a parallel resonant circuit to provide the initial selectivity for the mixer input.

The FET circuit shown in figure is more effective than the transistor circuit. Their high input impedence minimizes the loading on tuned circuits, thereby permitting the Q of the circuit to be higher and selectivity to be sharper.

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 ~~unwanted signals~~ receiver to the antenna.

Mixer or frequency changer/ converter

Types
- Seperately Excited Mixer
- Self Excited Mixer.

(i) Seperately excited mixer

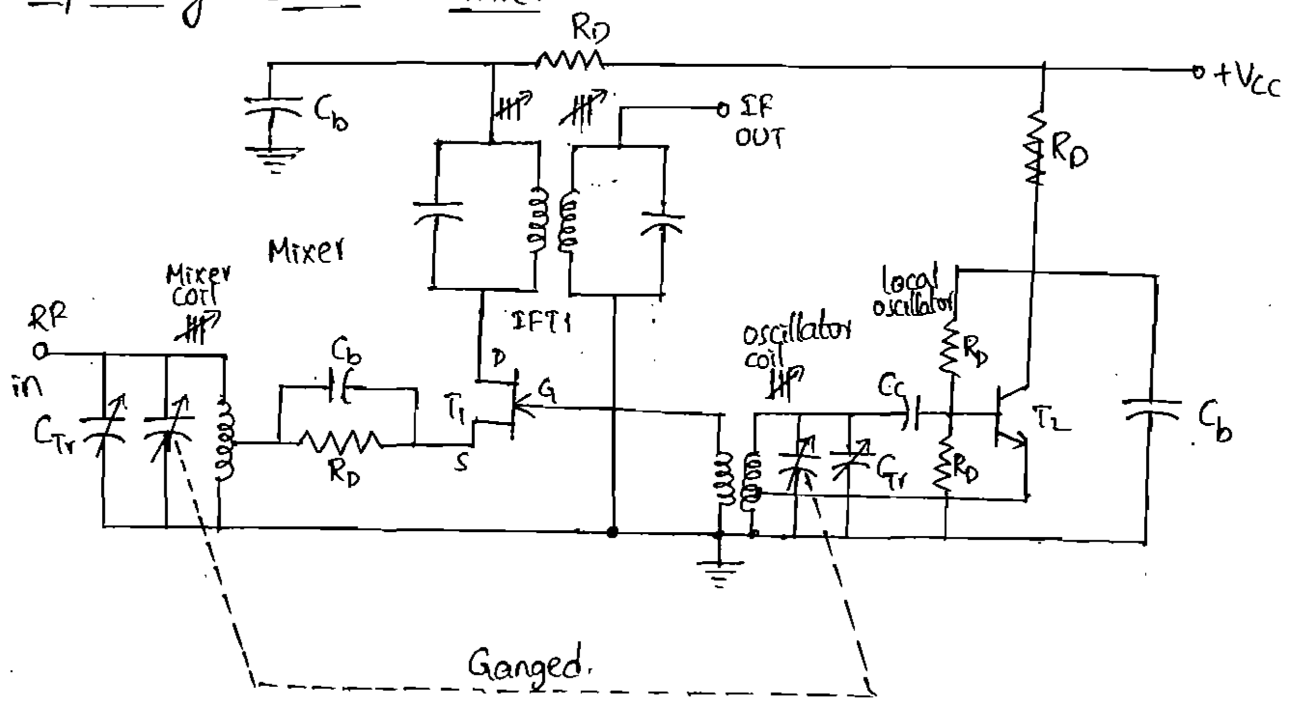


Fig: Seperately excited FET mixer.

In fig one device acts as a mixer while the other supplies the necessary oscillations. The bipolar transistor T_2, forms the Hartley oscillator circuit. It oscillates with local frequency (f_o) FET T_1, is a mixer, whose gate is fed with the output of local oscillator and its bias is adjusted such that it operates in a non linear portion of its characteristic. The local oscillator varies the gate bias of the FET to to vary its trans conductance in a nonlinear manner. resulting inter-mediate frequency at the output. The output is taken through double tuned transformer in the drain of the mixer and fed to the IF amplifier. The ganged tuning capacitor allows simultaneous tuning of mixer and local oscillator.

The C_{Tr}, a small trimmer capacitors across each of the tuning capacitors are used for fine adjustments.

(ii) Self excited Mixer

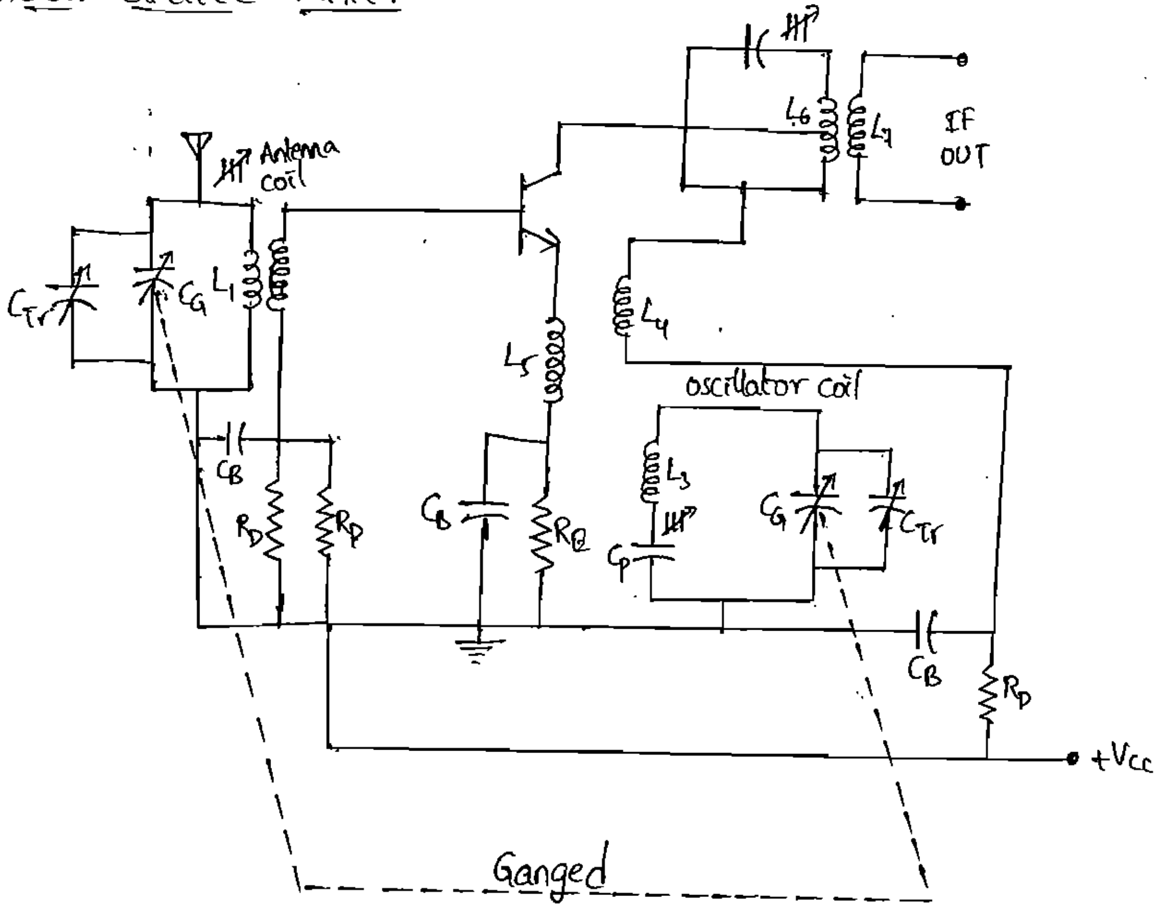


Fig: Self excited Mixer.

It is possible to combine the function of the mixer and local oscillator in one circuit. The circuit is commanly known as self excited mixer. The circuit oscillates and the transconductance of the transistor is varied in a nonlinear manner at the local oscillator rate. This variable transconductance (g_m) is used by the transistor to amplify the incoming RF signal.

Tracking

The process of tuning circuits to get the desired output is called Tracking. Any error that exists in the frequency being fed to the IF amplifier such errors are known as 'Tracking errors' and these must be avoided. To avoid tracking errors standard capacitors are not used, and ganged capacitors with identical sections are used. A different value of inductance and special extra capacitors called trimmers and padders are used to adjust the capacitance of the oscillator to the proper range. There are three common methods used for tracking. These are:

1) Padder tracking
2) Trimmer tracking
3) Three-point tracking.

1) Padder tracking

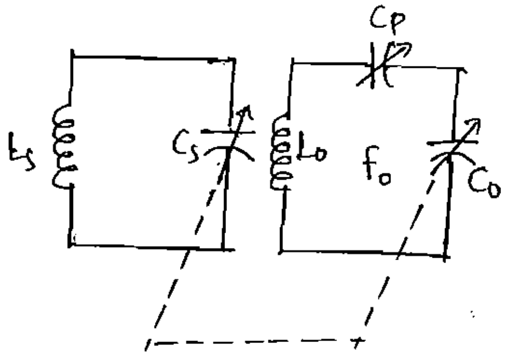


Fig: Padder tracking

In padder tracking the oscillator tunes below the frequency it should be in midband. So the IF created is higher than it is created.

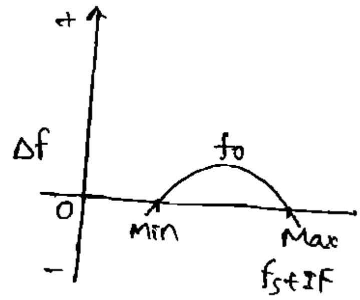


Fig: Tracking error in padder tracking.

2) Trimmer tracking

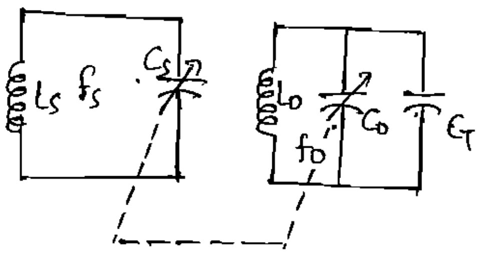


Fig: Trimmer tracking.

In trimmer tracking, the oscillator tunes higher the freq it should be in midband, So the IF created is less than it should be, and a -ve error is created.

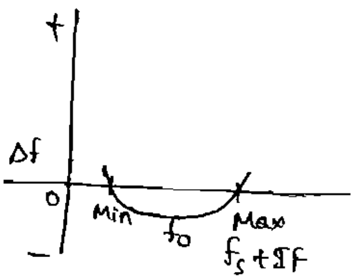


Fig: Tracking error in trimmer tracking.

3) Three-point tracking

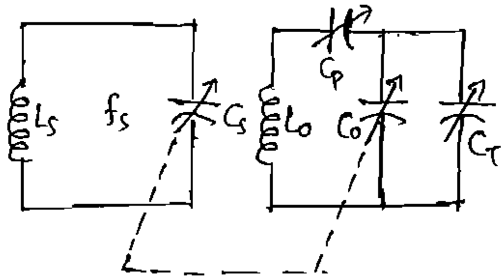


Fig: Three-point tracking.

The combination circuit called three point tracking can be adjusted to give zero error at three points across the band, at each end, and at the middle.

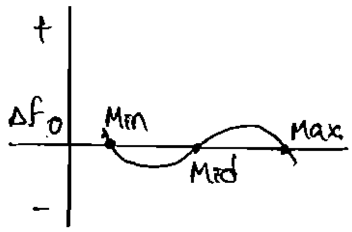


Fig. Tracking error in three point tracking.

Procedure to get values of capacitor required in above ckts

1) Find the min and max frequencies and the required oscillator capacitance ratio.

$$f_{omin} = f_{smin} + IF$$

$$f_{omax} = f_{smax} + IF$$

oscillator capacitance ratio can be given as

$$\frac{C_{omax}}{C_{omin}} = \left(\frac{f_{omax}}{f_{omin}}\right)^2$$

2. Calculate the capacitance ratio and max value of the signal circuit tuning capacitance.

$$\frac{C_{smax}}{C_{smin}} = \left(\frac{f_{smax}}{f_{smin}}\right)^2$$

$$C_{smax} = \left(\frac{f_{smax}}{f_{smin}}\right)^2 \times C_{smin}$$

3. Calculate the oscillator tuning capacitance. It is given by $C_o = C_s$ in series with C_p

$$C_o = \frac{C_s C_p}{C_s + C_p}$$

4. Calculate value of padder capacitor C_p using ratios.

$$\frac{C_{omax}}{C_{omin}} = \frac{C_{smax} \text{ in series with } C_p}{C_{smin} \text{ in series with } C_p} = \frac{(C_{smax} \cdot C_p)/(C_{smax} + C_p)}{(C_{smin} \cdot C_p)/(C_{smin} + C_p)}$$

$$\frac{C_{omax}}{C_{omin}} = \frac{C_{smax} (C_{smin} + C_p)}{C_{smin} (C_{smax} + C_p)}$$

5. Obtain the oscillator coil value. It is given as

$$L_o = \frac{1}{(2\pi f_{omin})^2 C_{omax}}$$

$$= \frac{1}{(2\pi f_{omax})^2 C_{omin}}$$

Intermediate frequency amplifier

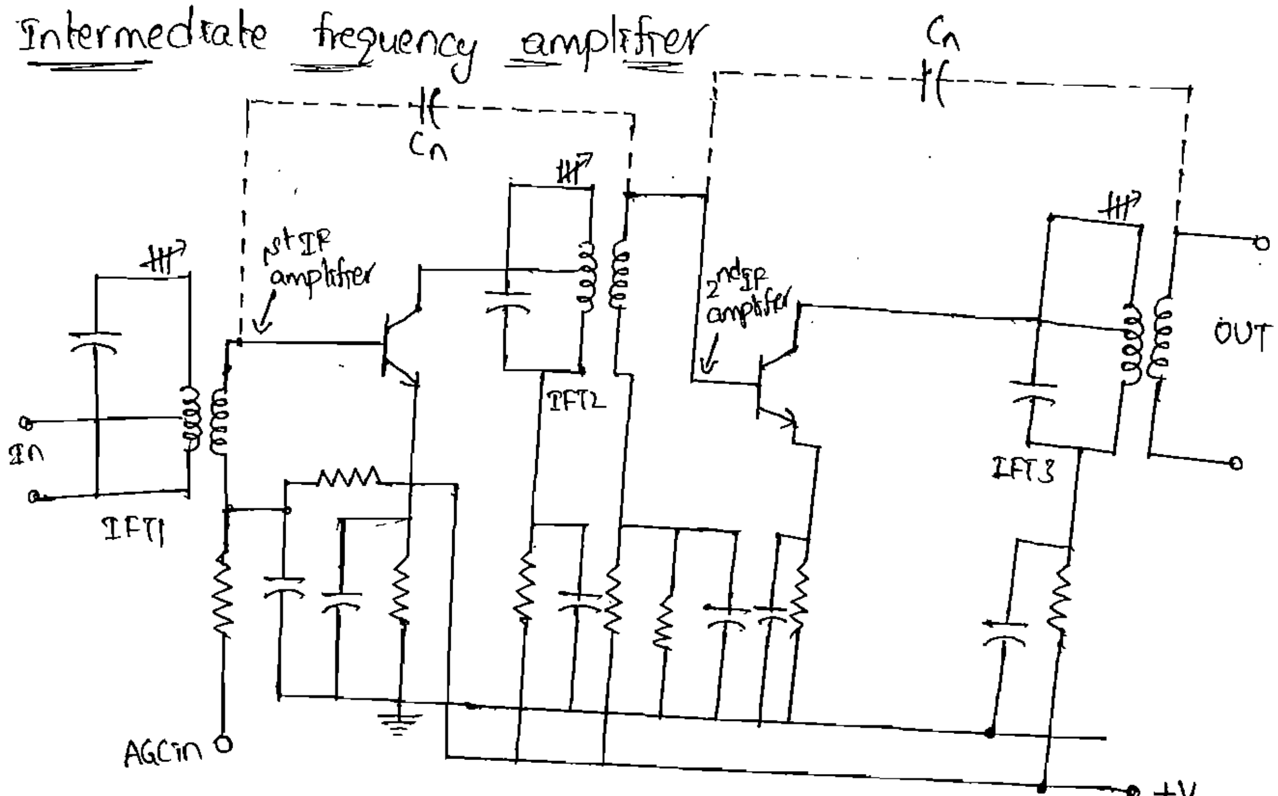


Fig: Two-stage IF amplifier.

IF amplifiers are tuned voltage amplifiers tuned for the fixed frequency. Its important function is to amplify only tuned frequency signal and reject all others. As we know most of the receiver gain, usually two or more stages of IF amplifiers are required.

The ~~above~~ figure shows the two stage IF amplifier. Two stages are transformer coupled and all IF transformers are single tuned, i.e., tuned for single frequency.

Choice of Intermediate frequency

Selection of the intermediate frequency depends on various factors while choosing the intermediate frequency it is necessary to consider following factors.

1. Very high intermediate frequency will result in poor selectivity and poor adjacent channel rejection
2. A high value of IF increases tracking difficulties,
3. At low values of intermediate frequency, image frequency rejection is poor.
4. At very low values of IF, selectivity is too sharp cutting off the sidebands.

With the above considerations the standard broadcast AM receivers [tuning to 540 to 1650 KHz] use an IF within the 438 KHz to 465 KHz range. The 465 KHz IF is most commanly used.

Automatic Gain Control (AGC)

Automatic gain control is a system by means of which the overall gain of a radio receiver is varied automatically with the variations in the strength of the receiver signal, to maintain the output constant.

There are twotypes of AGC circuits in use

→ Simple AGC

→ Delayed AGC

Simple AGC

In simple AGC receivers the AGC bias starts to increase as soon as the received signal level exceeds the background noiselevel. As a result receiver gain starts falling down, reducing the sensitivity of the receiver.

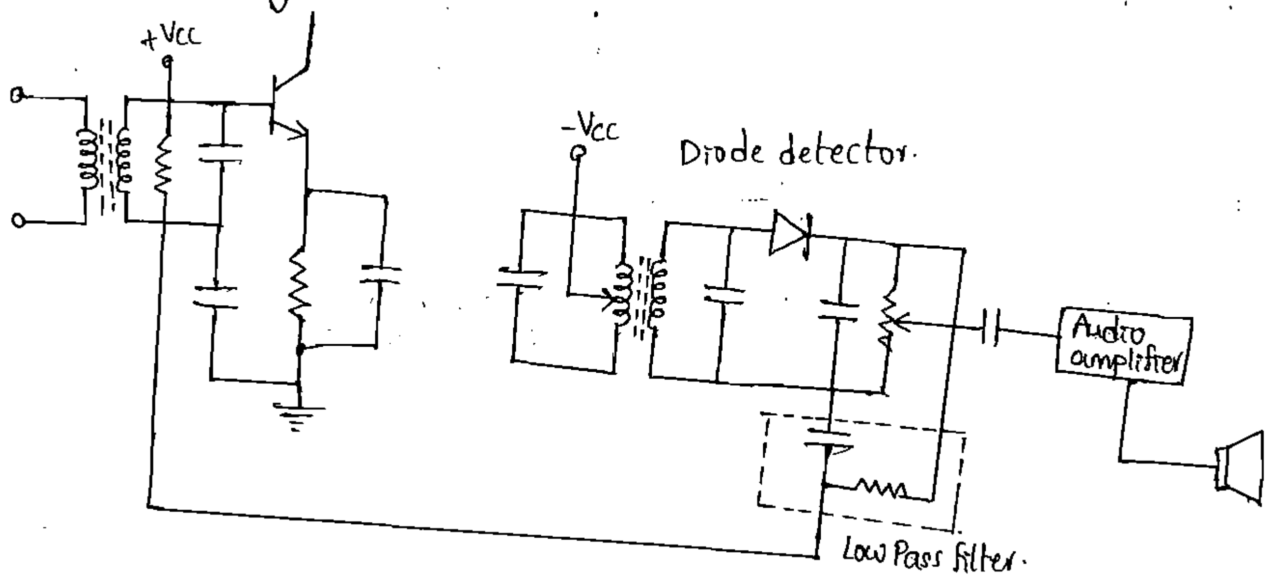


Fig: Simple automatic gain control circuit.

In this circuit, dc bias produced by halfwave rectifier as a AM detector is used to control the gain of RF or IF amplifier. Before application of this voltage to the base of the RF and local oscillator in IF stage amplifier the audio signal is removed by the low-pass filter. The time constant of the filter is kept at least 10 times longer than the period of the lowest modulation frequency received. If the time constant is kept longer: it will give better filtering, but it will cause on annoying delay in the application of the AGC control when tuning from one signal to another. The recovered signal is then passed through C_c to remove the dc. The resulting ac signal is further amplified and applied to the loudspeaker.

Delayed AGC

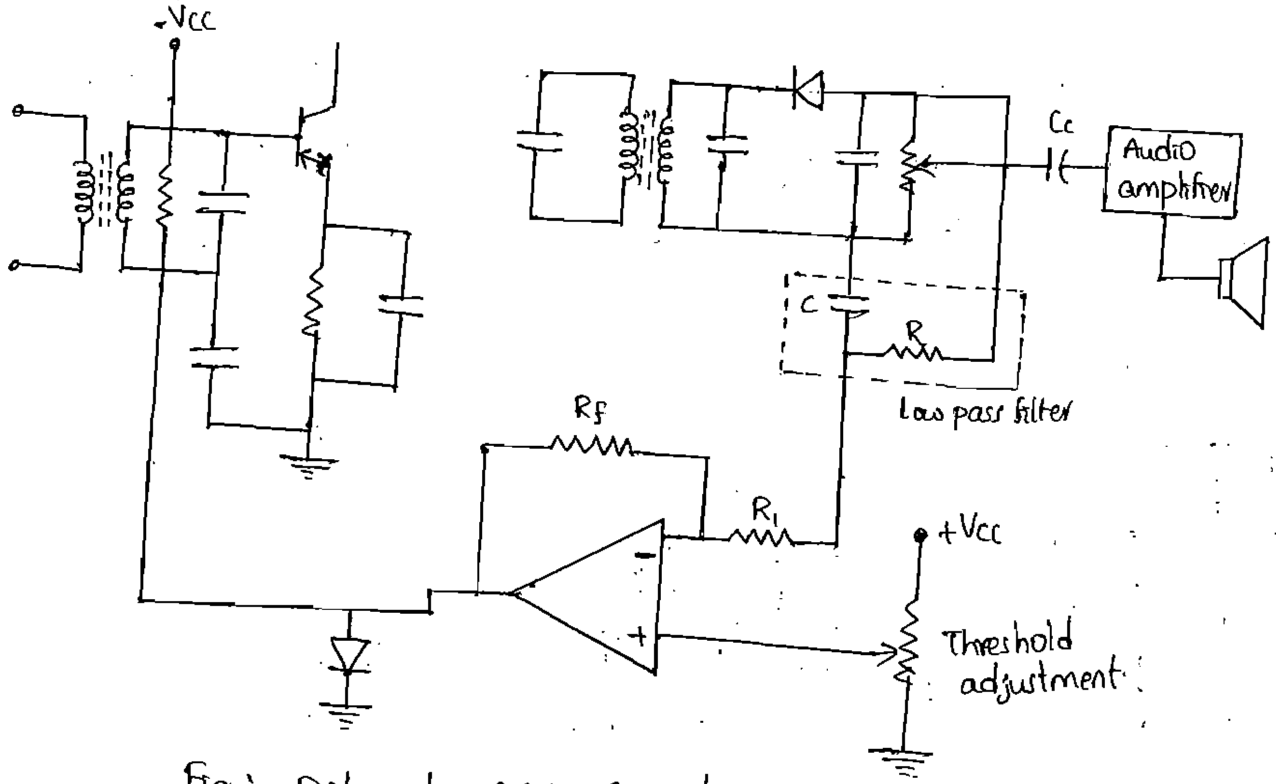
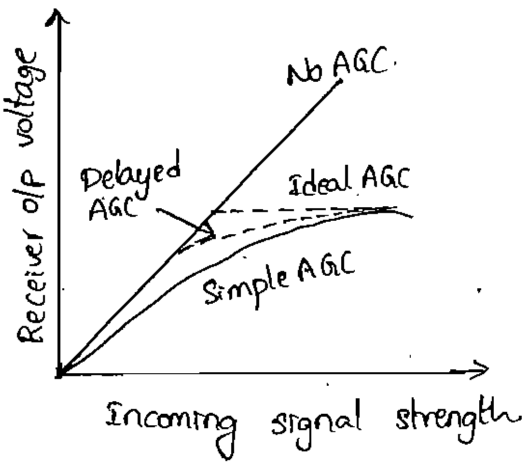


Fig: Delayed AGC Circuit.

Simple AGC is clearly an improvement over no AGC at all. Unfortunately, in simple AGC circuit, the unwanted weak signals are amplifier with high gain. To avoid this, in delayed AGC circuits AGC bias is not applied to amplifiers until signal strength has reached a predetermined level, after which AGC bias is applied as with simple AGC, but more strongly.

Here, AGC o/p is applied to the difference amplifier by diode detector is above certain dc threshold voltage. This threshold voltage can be adjusted by adjusting the voltage at the positive input of the operational amplifier.

The below figure shows the response of a receiver with either simple or delayed AGC compared to one without AGC.



FM Receiver

The FM Receiver is basically a superheterodyne receiver, similar to AM receiver. However it differs from AM receiver with respect to following points.

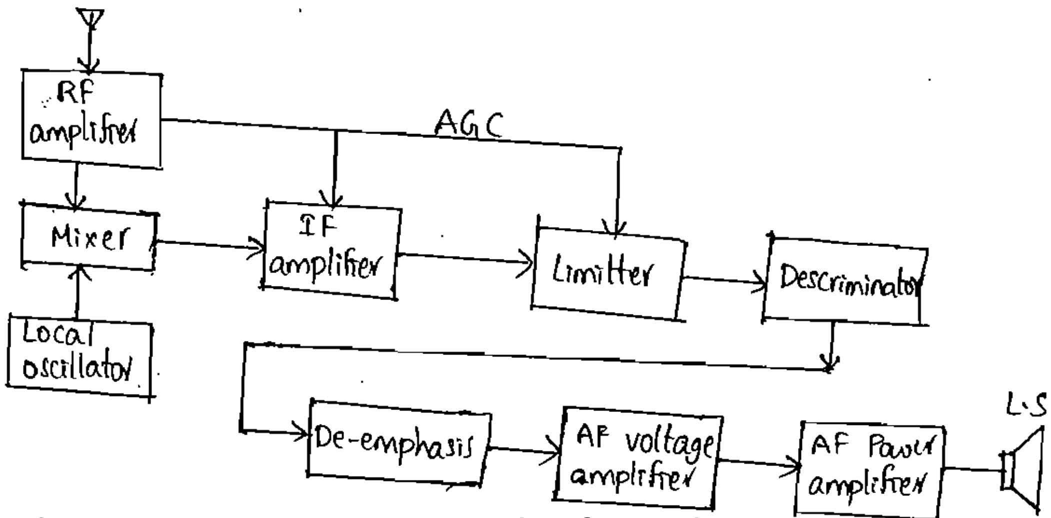
→ AM receiver operates in MW and SW bands, while FM receiver operates at much higher frequencies viz. 88MHz to 108MHz.

→ Limiter and deemphasis circuits are required only in FM receiver

→ The technique of demodulating FM signal is different from detection of AM signal.

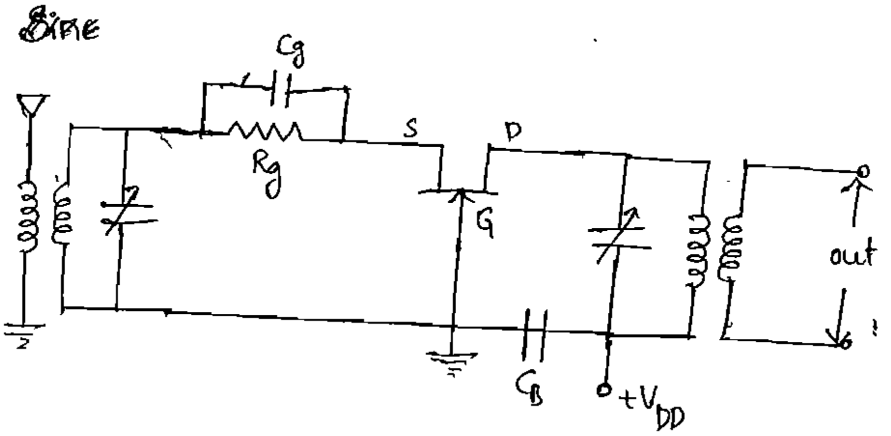
→ FM receiver uses different methods of obtaining AGC.

Block diagram of FM Receiver



Different Stages in F.M Receivers.

R.F Amplifier Stage



Since F.M Signal has a larger bandwidth it is likely to encounter more noise. Hence to reduce the noise figure of the receiver. An RF amplifier Stage is used. This circuits have low input impedance, Suitable for matching with antenna impedance

A typical circuit is shown in the above figure. Since the gate terminal is grounded, the i/p and o/p Sides are isolated for RF Purposes. There is no possibility of feedback and there by instability in operation. Therefore the circuit doesnot require neutralization. The low input impedance of the FET amplifier can be easily matched to antenna through a single Secondary tuned RF transformer. Both the i/p and o/p tank circuits are tuned to Carrier frequency.

Mixer Stage

With the help of local oscillator, this Stage down converts the incoming carrier frequency to I.F, which is 10.7MHZ for FM Receiver. The localoscillator is usually the clapp oscillator, Suitable for VHF frequency and local oscillator frequency is not a

Problem in FM Receiver unlike in an AM Receiver. Compared to AM Receiver, tuning range of incoming carrier frequencies for FM Receiver is small, from 88MHZ to 108MHZ i.e; about 1.25:1. Thus the tracking is comparatively easy in FM Receiver.

Since FETs are less noisy than BJTs, RF amplifier stage and mixer stage uses FETs. With local oscillator constructed with BJT.

The mixer stage uses of tuned circuit as its load. The circuit is tuned to Intermediate frequency of 10.7 MHz and hence selects the difference between incoming carrier frequency and locally generated oscillator frequency.

I.F. Amplifier Stage

In the I.F Amplifier stages, the most of the gain of receiver is developed. The intermediate frequency and bandwidth requirements are normally much larger than in AM Receiver. The typical values for an F.M Receiver operating in FM band from 88MHz to 108MHZ are 10.7MHZ for I.F and 200kHZ for bandwidth. Generally two I.F amplifier stages are employed.

The I.F Amplifier stage uses a tuned circuit as its load. The circuit is tuned to intermediate frequency.

Amplitude Limiting

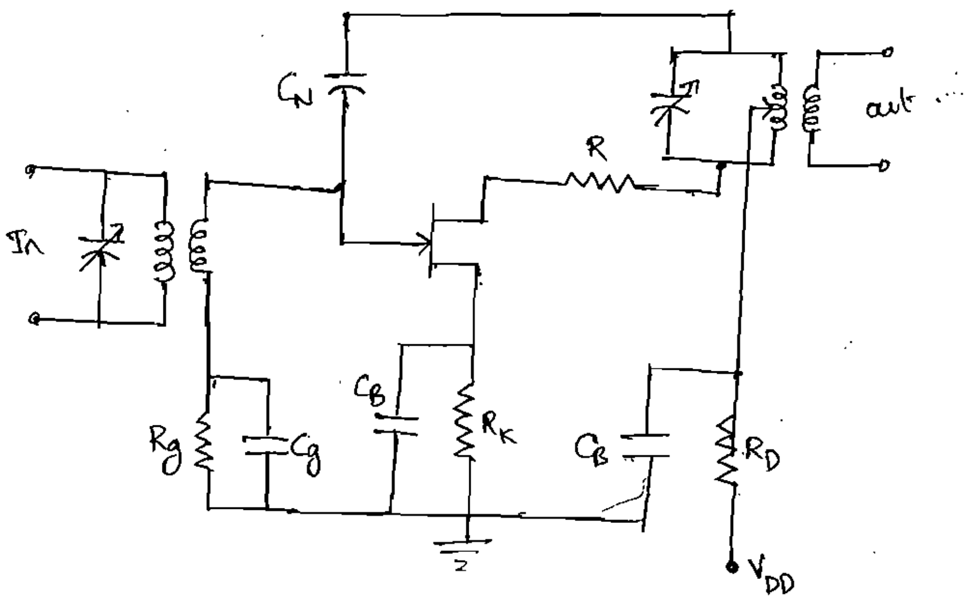


Fig: Amplitude Limitter.

To Remove the amplitude variations of the Signal is main function of the amplitude limiter.

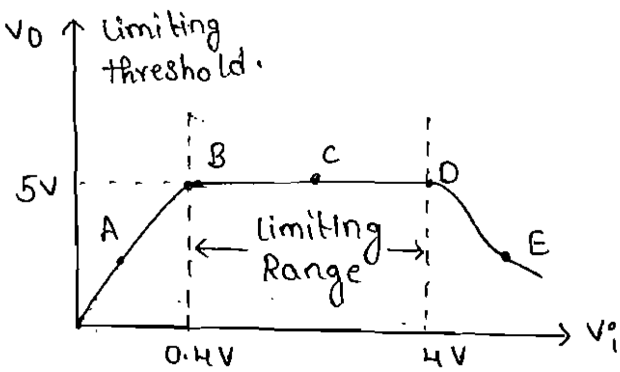


fig : Typical Limiter Response Characteristics.

The Response characteristic of the amplitude limiter. It indicates clearly that limiting takes place only for a Certain range of i/p voltage, outside which output varies with input.

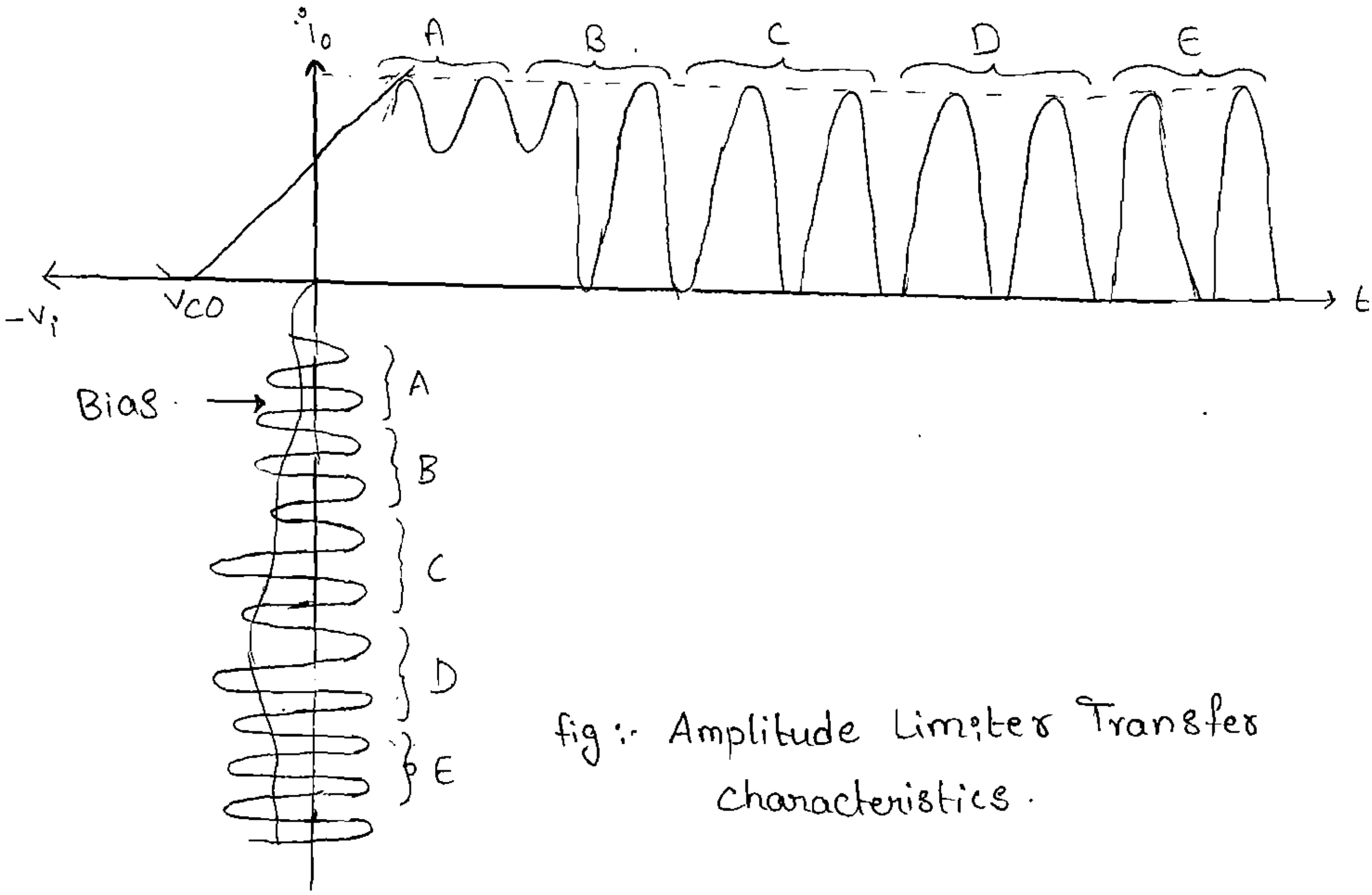


fig :- Amplitude Limiter Transfer Characteristics.

Referring to the above fig. we see that as i/p increases from value A to B ~~input~~ output current also increases. Thus no limiting has yet taken place. However, Comparision of B and c shows that they both yield the same o/p current and voltage. Thus limiting has now begun. value B is the point at which limiting starts and is called the threshold of limiting. As input increases from c to D, there is no rise in o/p, all that happens is that the o/p current flows for a some what shorter portion of the i/p cycle.

UNIT-IV TRANSMITTERS

CLASSIFICATION OF RADIO TRANSMITTERS:

Radio transmitters may be classified according to the following methods:

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

1. CLASSIFICATION ACCORDING TO THE TYPE OF MODULATION USED

According to the method of modulation, radio transmitters may be classified as

(i)Amplitude Modulation Transmitters. In such a transmitter, the modulating signal amplitude modulates the carrier. Such transmitters are used for radio broadcast on long, medium and short waves, radio telephony on short waves, radio telegraphy on short waves, television picture broadcast on very short waves or ultra short waves.

(ii) Frequency Modulation Transmitters. In an F.M. transmitter, the signal voltage frequency modulates the carrier. Such transmitters are used for radio broadcast in V.H.F. and U.H.F. range, television sound broadcast in V.H.F and U.H.F ranges, radio telephone communication in V.H.F. and U.H.F. range over short distances.

(iii) Pulse modulation transmitters. In a pulse modulation transmitter, the signal voltage alters some characteristic of the pulses. These characteristics of the pulses altered on modulation may be pulse width, pulse position, pulse amplitude, pulse frequency or pulse code. Accordingly the various methods of the pulse modulation are: Pulse width modulation, Pulse position modulation, Pulse amplitude modulation, Pulse frequency modulation and the pulse code modulation.

2. CLASSIFICATION ACCORDING TO THE TYPE OF SERVICE INVOLVED:

According to the type of service involved, radio transmitters may be classified as

(i) Radio Broadcast Transmitters: These transmitters are designed for transmitting speeches, talks, music, dramas etc. for the information and recreation of people. The electromagnetic energy is so radiated from the transmitting antenna that largest number of persons may be able to receive the broadcast with the help of their radio receivers. These broadcast transmitters may be either amplitude modulated or frequency modulated. The A.M. transmitters operate on long waves, medium waves and short waves and radiate carrier power as low as about 1 kilowatt and as high as 100 kW or more. The F.M. broadcast transmitters operate on very short waves or on ultra short waves and radiate carrier power of the order of 100 kW or so.

(ii)Radio Telephone Transmitters: These transmitters are designed for transmitting telephone signals over long distance by radio means. A radio telephone transmitter uses certain special devices as volume compressors, privacy devices, peak limiters etc. The transmitting antenna is designed for beaming the electromagnetic energy into a narrow beam directed toward the distant receiving antenna. Smaller amount of power is thus required. Radio telephone transmitters may be either of amplitude modulation type or of frequency modulation type. The A.M. telephone transmitters usually work on short wave, have output carrier power of typically a few kilowatts and are used for point-to-point communication over long distances. The F.M. radio telephone transmitters usually work on ultra high frequencies, carry small power usually less than 1 kW and are used for communication over short distances not exceeding about 30 kilometers or so.

(iii)Radio Telegraph Transmitters: A radio telegraph transmitter transmits telegraph signals from one radio station to another radio station. It may use either amplitude modulation or frequency modulation. When point-to-point radio communication is involved, the transmitting antennas are highly directive so that the electromagnetic energy is beamed into a narrow beam directed towards the receiving antenna at the receiving radio station.

(iv)Television Transmitters: Television broadcast requires two transmitters one for transmission of picture and the other for transmission of sound. Both operate in very high frequency or in ultra high frequency range. The picture transmitter is amplitude modulated by the picture signal occupying a band of about 5.5 MHz. Vestigial sideband transmission is used i.e. one full sideband and only a vestige or a part (about 0.75MHz) of the other sideband together with the carrier are radiated from the transmitting aerial. The total bandwidth occupied by one television channel is about 7 MHz. The sound carrier is frequency modulated.

(v)Radar Transmitter: Radar may be of two types i) Pulse Radar and ii) Continuous Wave Radar. Pulse radar transmitter uses pulse modulation of carrier. It uses high output power typically 100 kW peak and operates at microwave frequencies typically 300 MHz or 10,000MHz. The C.W. radar transmitter may use frequency modulation of the carrier voltage or may utilize Doppler Effect.

(vi)Navigation Transmitters: A number of navigational aids using special types of radio transmitters and receivers are used these days for sea and air navigation. Also radio aids are used for blind landing of aircrafts. Typical radio aids to landing are I.L.S. (Instrument Landing System) and G.C.A. (Ground Controlled Approach). In addition to these, several other radio means are provided at air port for surveillance.

3. CLASSIFICATION ACCORDING TO THE CARRIER FREQUENCY

According to this method of classification, transmitters may be classified as

(i)Long Wave Transmitters: These transmitters operate on long waves i.e. on frequencies below 300 kHz. Such long wave radio transmitters are used for broadcast in temperate countries, where atmospheric disturbances on long waves are not severe. Since long wave radio signals travel along the surface of earth and are rapidly attenuated, for reasonably high signal strength at the distant receiving aerial, the carrier power radiated from the transmitting aerial must be very large typically 100 kW or more.

(ii)Medium wave Transmitters: These transmitters operate on frequencies in the range of 550 to 1650 kHz and are usually used for broadcast. Hence the band of frequency extending from 550 to 1650 kHz is commonly referred to as the Broadcast Band. The carrier power may vary from as low as 5 kW to as high as 500 to 1000 kW.

(iii) Short Wave Transmitters: These transmitters operate on frequencies in the short wave range of 3 to 30 MHz. In practice, frequencies beyond 24 MHz are not used. Ionospheric propagation of electromagnetic waves takes place at such short waves. The attenuation of radio waves travelling from the transmitting aerial to the distant receiving aerial though the ionosphere is small. Hence carrier required to be radiated from the transmitting aerial is small. For national broadcast, the carrier power used may vary from about 1 to 10 kW. For overseas broadcast, certain amount of beaming of power is required to be done. But in spite of such a beaming of energy, because of the large distance involved, the carrier power generally used is 10 to 100 kW. For radio telephone working over long distances on short waves, highly directive transmitting and receiving antenna are used so that carrier power required may be relatively small, of the order of 5 kW or so.

(iv)V.H.F. and U.H.F. transmitters. These transmitters operate either in V.H.F. range or in the beyond about 1000 MHz and are used in radar, television relay, microwave link between two adjoin countries or between mainland and adjoining island etc.

COLLECTOR MODULATOR: Figure 6.1a shows the circuit diagram of a collector modulation method. Here, the transistor T_1 makes a radio frequency (RF) class C amplifier. At the base of T1, the carrier signal is applied. Vcc makes the collector supply used for biasing purpose. The transistor T2 makes a class B amplifier which is used to amplify the audio signal. The baseband signal appears across the modulation transformer after amplification. This amplified baseband signal appears in series with the collector supply V_{CC}.

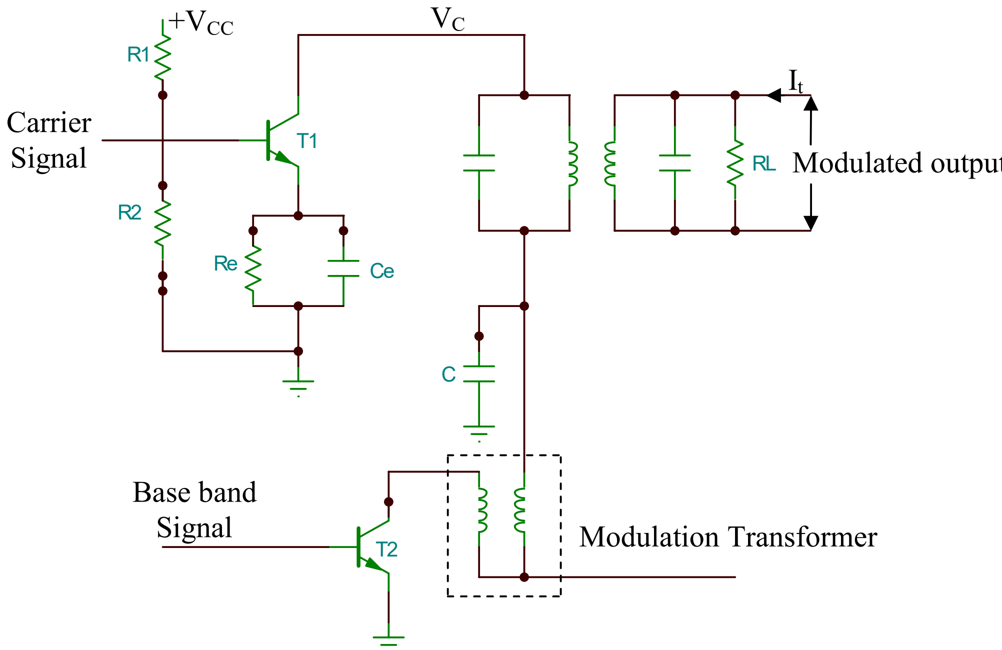


Fig 6.1a: Collector Modulator

In a class C amplifier, the magnitude of the output voltage is a definite fraction of or at the most equal to the supply voltage Vcc. In addition to this a linear relationship exists between the output tank current I_t and the variable supply voltage Vc (i.e. varying value of V_{CC} is denoted by Vc). In class C amplifier, the output voltage will be an exact replica of the input voltage waveform and the magnitude of the output voltage will be approximately equal to the carrier supply voltage Vcc. if R is the resistance of the output tank circuit at resonance, then the magnitude of the output voltage is given as $RI_t = Vcc$

Therefore, the un-modulated carrier is amplified by class C modulated amplifier using transistor T_1 and its magnitude will remain constant at Vcc since there appears no voltage across the modulating transformer in the absence of baseband voltage. But now if a baseband voltage $v_m = V_m \cos \omega_m t$ appears across the modulating transformer, this signal will be added to the carrier supply voltage Vcc. This results in a quite slow variation in carrier supply voltage Vcc. This type of slow variation in carrier supply voltage changes the magnitude of the carrier signal voltage at the output of the modulated class C amplifier as shown in figure 6.1b. It may be observed that the envelope of the output voltage is identical with the baseband voltage and hence an AM signal is generated.

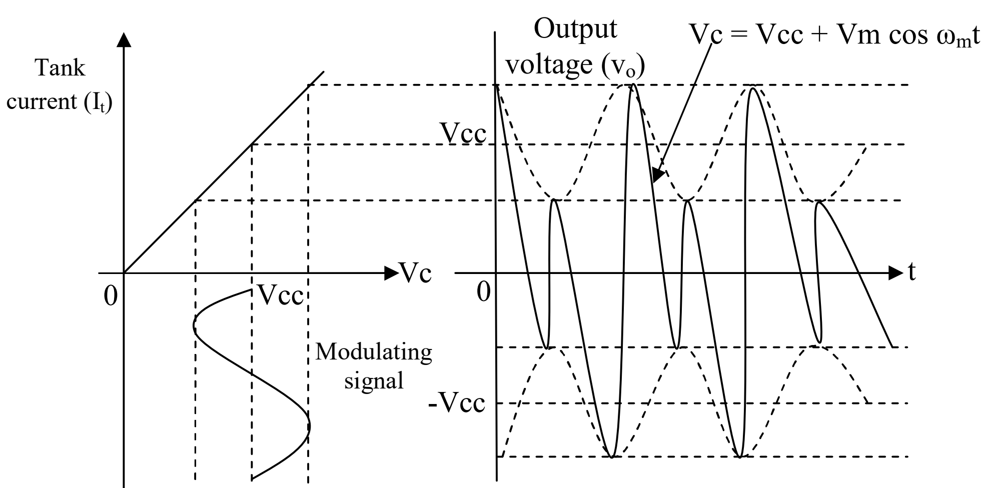


Fig 6.1b: Waveforms of collector modulator

HIGH LEVEL AMPLITUDE MODULATION RADIO TRANSMITTERS:

The block diagram of amplitude modulation radio transmitter using high power level modulation is shown in figure 6.2a. It consists of Master Oscillator, Buffer Amplifier, Harmonic Generators, Class C amplifiers, Modulated Amplifier, Modulating amplifier and transmitting antenna.

Master Oscillator: It generates oscillations of desired frequency with high consistency of frequency. The generated frequency is required to remain constant within close limits in spite of variations in the supply voltage, ambient temperature, and temperature of components of load. Further frequency variations with time and with age of the tube or transistor are to be avoided.

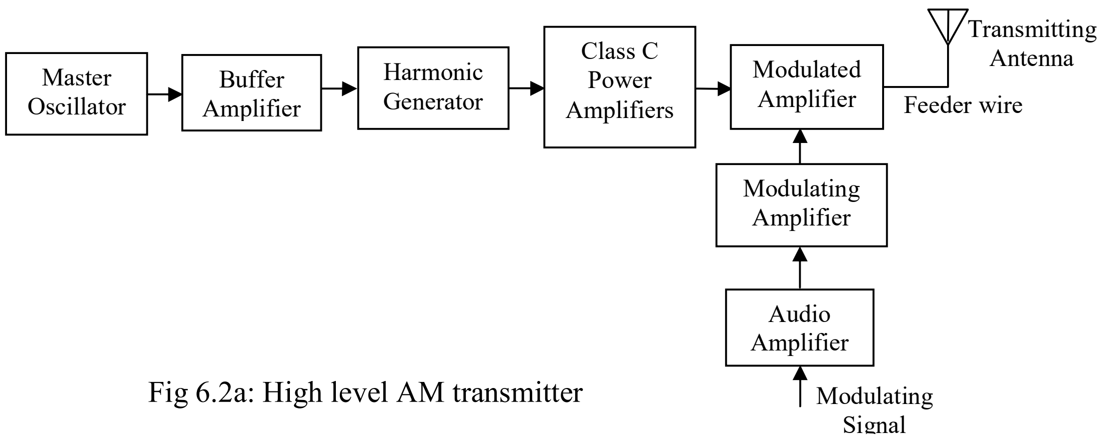


Fig 6.2a: High level AM transmitter

Buffer Amplifier. If the master oscillator directly drives a harmonic generator or class C power amplifier, which may draw input current, then power is drawn from the master oscillator. This results in loading of master oscillator which in turn causes variation of effective resistance of the tank circuit of the oscillator and hence results in frequency variation. Accordingly a buffer amplifier or isolating amplifier is placed between the master oscillator and the harmonic generators. This buffer amplifier does not draw any input current and hence causes no loading of the master oscillator. Changes in carrier frequency due to variations in loading are thus avoided.

Harmonic Generators. Usually master oscillator generates voltage at a frequency which is a sub multiple of the carrier frequency. Basically these harmonic generators are class C tuned amplifiers in which the output R.F. voltage is first distorted through class C operation and then the tuned circuit in the output circuit of the amplifier selects a the desired harmonic frequency.

Class C amplifiers. R.F. voltage generated by the master oscillator has usually very small power, of the order of a few watts. The power level is required to be raised to the final high value in a chain of class C amplifier having high output circuit efficiency of the order of 70%. First few stages of class C amplifier act as harmonic generators.

Modulated Amplifier. This is a class C tuned amplifier usually of push pull type and is modulated by audio modulating voltage from modulating amplifier. High efficiency series plate modulation is most popularly used in high power radio broadcast and radio telephone transmitters. Grid bias modulation and suppressor grid modulation are sometimes used particularly for modulation at low power levels. In small transistorized radio transmitter, collector modulation or base modulation or both may be used.

Modulating amplifier. This is usually a class B push pull amplifier and feeds audio power into the modulation amplifier in the plate circuit, control grid circuit or suppressor grid circuit depending upon the method of modulation used. Class B operation is generally used because of high plate circuit efficiency. Class A modulating amplifiers are also sometimes used particularly in low power transmitters.

Audio amplifier: Modulating signal is fed to the input of audio amplifier. This modulating signal is very weak even it is not sufficient to drive the modulating amplifier. So the audio

amplifier amplifies the signal to the desired voltage level and is fed to the modulating amplifier.
Transmitting antenna: The output of modulated amplifier is fed to the antenna through feeder wire. This antenna converts the electrical signal into electromagnetic waves and radiates into space.

LOW LEVEL AMPLITUDE MODULATION RADIO TRANSMITTERS: The block diagram of amplitude modulation radio transmitter using low power level modulation is shown in figure 6.2b. It consists of Master Oscillator, Buffer Amplifier, Harmonic Generators, Power amplifiers, Modulated Amplifier, Modulating amplifier and transmitting antenna.

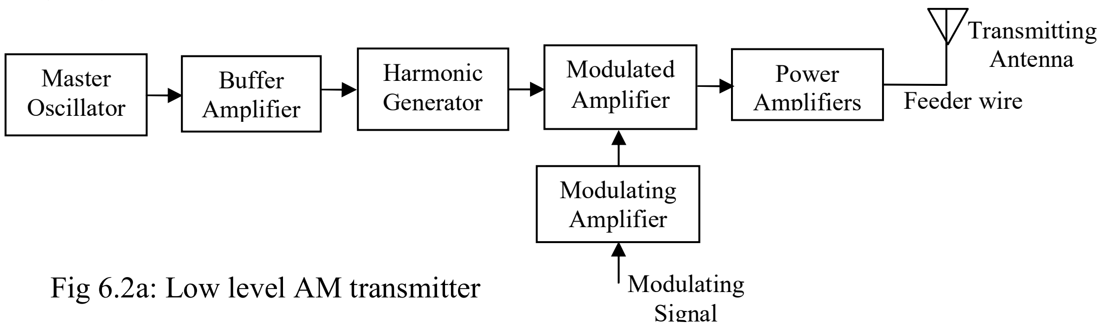


Fig 6.2a: Low level AM transmitter

Master Oscillator: It generates oscillations of desired frequency with high consistency of frequency. The generated frequency is required to remain constant within close limits in spite of variations in the supply voltage, ambient temperature, and temperature of components of load. Further frequency variations with time and with age of the tube or transistor are to be avoided.
Buffer Amplifier. If the master oscillator directly drives a harmonic generator or class C power amplifier, which may draw input current, then power is drawn from the master oscillator. This results in loading of master oscillator which in turn causes variation of effective resistance of the tank circuit of the oscillator and hence results in frequency variation. Accordingly a buffer amplifier or isolating amplifier is placed between the master oscillator and the harmonic generators. This buffer amplifier does not draw any input current and hence causes no loading of the master oscillator. Changes in carrier frequency due to variations in loading are thus avoided.
Harmonic Generators. Usually master oscillator generates voltage at a frequency which is a sub multiple of the carrier frequency. Basically these harmonic generators are class C tuned amplifiers in which the output R.F. voltage is first distorted through class C operation and then the tuned circuit in the output circuit of the amplifier selects a the desired harmonic frequency.
Modulated Amplifier. This is a class C amplifier usually of push pull type and is modulated by audio modulating voltage from modulating amplifier. High efficiency series plate modulation is most popularly used in high power radio broadcast and radio telephone transmitters. Grid bias modulation and suppressor grid modulation are sometimes used particularly for modulation at low power levels. In small transistorized radio transmitter, collector modulation or base modulation or both may be used.
Power amplifier. R.F. voltage generated by the Modulated Amplifier has usually very small power, of the order of a few watts. The power level is required to be raised to the final high value in a chain of class B amplifier.
Modulating amplifier. This is usually a class B push pull amplifier and feeds audio power into the modulation amplifier in the plate circuit, control grid circuit or suppressor grid circuit depending upon the method of modulation used. Class B operation is generally used because of high plate circuit efficiency. Class A modulating amplifiers are also sometimes used particularly in low power transmitters.

Transmitting antenna: The output of modulated amplifier is fed to the antenna through feeder wire. This antenna converts the electrical signal into electromagnetic waves and radiates into space.

COMPARISON BTWEEN LOW LEVEL AND HIGH LEVEL MODULATION

S.No	LOW LEVEL MDOULATION	HIGH LEVEL MODULATION
1	Modulation takes place in the initial stages of amplification	Modulation takes place in the final stage of amplification
2	Modulation circuitry has to handle low power	Modulation circuitry has to handle high power
3	Modulation circuitry is simple as it has to handle low power.	Modulation circuitry is quite complex as it has to handle high power.
4	Simplicity is the prime requirement	High efficiency and low distortion is the prime requirement
5	Low audio power is required to produce modulation	High power is required to produce modulation
6	Each amplifier stage following modulation must handle sideband power as well as the carrier. All these subsequent amplifiers must have sufficient bandwidth for the sideband frequencies	This is not the case with high level modulation because in this modulation takes place in the output stage
7	Linear amplifier such as class A amplifier is used because all stages must be capable of handling amplitude variations caused by the modulation	High efficient class C amplifiers are used
8	Transistor amplifiers and op-amps are used	Vacuum tubes and power transistors are used
9	Efficiency is lower than high level modulators	Efficiency is Very high
10	These are some times used in TV transmitters	These are used in High power broadcast AM transmitters

CARRIER FREQUENCY REQUIREMENTS OF RADIO TRANSMITTER: There are three main requirements of radio transmitters regarding the carrier frequency. They are generated carrier frequency must be exactly at the specified value, carrier frequency should be readily adjustable and frequency drift and frequency scintillation should be extremely small.

Generated carrier frequency must be exactly at the specified value. Every radio transmitting station is allocated one or more frequencies at which it must operate. This has become necessary in order to avoid sidebands of one station completely or partially overlapping in frequency spectrum of the sidebands of any other radio station. The 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. This requirement is usually not difficult to meet. Of course, the master oscillator generates only sub harmonic of the final carrier frequency and the frequency is brought to the final value by harmonic generators.

Carrier frequency should be readily adjustable. Most of the radio transmitters use crystal controlled master oscillator in which case the carrier frequency cannot be readily changes. It is necessary in such radio transmitters to change the crystal in the master oscillator and tune all the tuned circuits in the subsequent tuned amplifiers and harmonic generators accordingly.

However, if conventional L-C tuned circuits are used in master oscillator, then the frequency of oscillation may be readily changed over reasonable limits by varying either the capacitor C or the inductor L in the tuned circuit.

Frequency drift and frequency scintillation should be extremely small. By frequency drift is meant slow variation in frequency with time. The maximum frequency drift permitted in radio transmitters is $\pm$20 Hz for medium wave transmitters and $\pm$0.002% for short wave and UHF transmitters. By frequency scintillation is meant abrupt changes in frequency caused mostly by abrupt variations in load.

(i)Frequency scintillation:

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 of the oscillator and hence causes corresponding change in frequency of oscillation.

To avoid scintillation, the master oscillator should be made to drive buffer amplifier adjusted to draw little power from the master oscillator thereby producing little loading of the master oscillator. Thus although the load on the transmitter may change, the loading of the master oscillator does not change No abrupt change in master oscillator frequency takes place. Such an assembly consisting of Master oscillator and Power amplifier (buffer amplifier) is called Master Oscillator Power Amplifier, abbreviated as MOPA.

(ii)Frequency drift:

In any oscillator, the frequency of oscillation is close to the resonant frequency of the tank circuit but the exact value of frequency of oscillation is influenced by the following factors; i) Resistance and reactance coupled into the tank circuit by the load ii) effective Q of the tank circuit iii) voltage acting on the electrodes of the oscillator tube or transistor and iv) harmonics generated.

These factors produce small phase shift between the exciting voltage and the output voltage of the oscillator transistor (or tube) . In order to cancel this phase shift, the oscillator has to operate slightly off the resonant frequency of the tank circuit.

EFFECT OF FEEDBACK ON PERFORMANCE OF AM TRANSMITTER:

Negative feed back is generally provided in AM transmitter. Negative feed back reduces the distortion in a class C modulator system. It also linearizes the output of the class C modulator. Figure 6.3 shows the negative feed back circuit.

Negative feed back circuitry samples the RF signal sent to the antenna. This sampled signal is demodulated by linear demodulator to produce feed back signals.

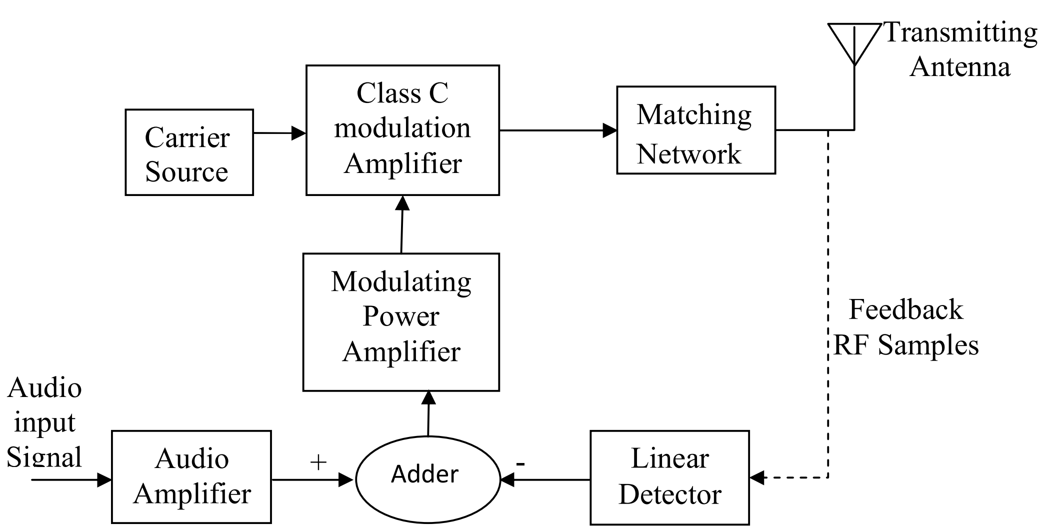


Fig 6.3: Negative feedback effect

AM BROADCAST TRANSMITTER: Figure6.4 shows a typical AM broadcast transmitter.

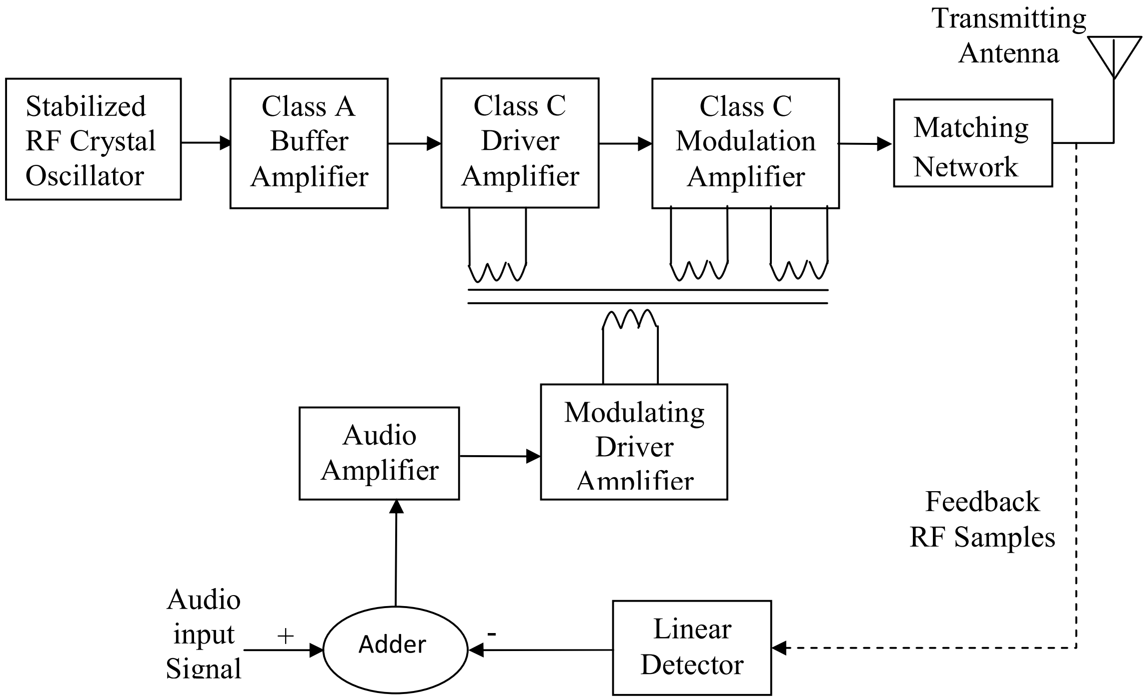


Fig 6.4: AM Broad cast transmitter

Crystal oscillator is used to generate stabilized RF signal. It is amplified through class A buffer amplifiers. The modulated system used here is known as triple equilibrium system, in which the main part of the modulation is performed by plate modulation in the final class C power amplifier. Secondary modulation of both the final grid and the plate of the driver stage are also provided to compensate for bias shift in the final amplifier that results from the nonlinear characteristics of the amplifier.

The output power amplifier is push pull amplifier with each side of the push pull stage composed of several vacuum tubes connected in parallel, to obtain the required power. Due to parallel connection, in case of failure of one tube, remaining tubes provide partial output until repairs are made. The output of the final amplifier is fed to antenna through matching network.

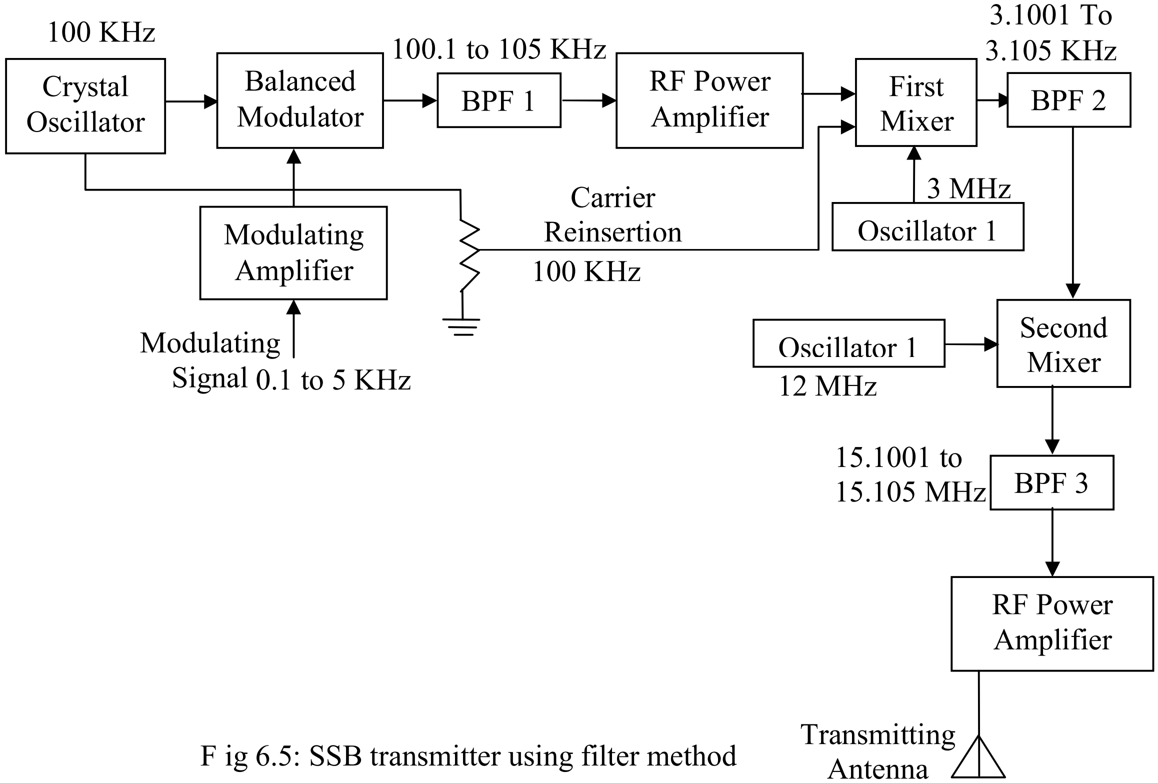
The feedback circuitry is provided to linearize the class C amplifier and to reduce distortion in it. It includes linear detector and the difference amplifier. Linear detector samples transmitter output and demodulates it to generate feedback signal.

The main requirements of AM broadcast transmitters are listed below:

i) It must produce output within the limits of the 5 kHz audio bandwidth.
ii) It should have highest possible fidelity.
iii) The modulator circuits in the transmitter must produce a linear modulation function.
iv) Tuned class C amplifier must provide sufficient power gain to drive the final power amplifier.
v) Antenna systems for AM transmitters must be located at some point remote from the studio operations.

SSB TRANSMITTER USING FILTER METHOD:

Figure 6.5 shows the block diagram of SSB transmitter using filter method. A crystal controlled master oscillator produces a stable carrier frequency of say 100 kHz. This carrier voltage is amplitude modulated by the AF voltage lying in the frequency range of 0.1 to 5 kHz in a suppressed carrier balanced modulator. The band pass filter separate out one sideband say the upper sideband (extending from 100.1 to 105 kHz) from the lower sideband.



F ig 6.5: SSB transmitter using filter method

This upper sideband is amplified and heterodyned in first frequency mixer with 3 MHz voltage from crystal oscillator 1 to produce sum and difference frequencies. The upper sideband of 3.1001 and 3.105 MHz is selected by another band pass filter. The output of this second band pass filter is applied to the second frequency mixer to which is added the output of second crystal oscillator generating a frequency of say 12 MHz. The sum frequency band of 15.1001-15.105 MHz is picked up by the band pass filter. The output is amplified in a chain of RF power amplifiers to raise the power level to the desired value and is then radiated from the transmitting antenna.

SSB TRANSMITTER USING PHASE SHIFT METHOD: Figure 6.6 shows the block diagram of SSB transmitter using phase shift method.

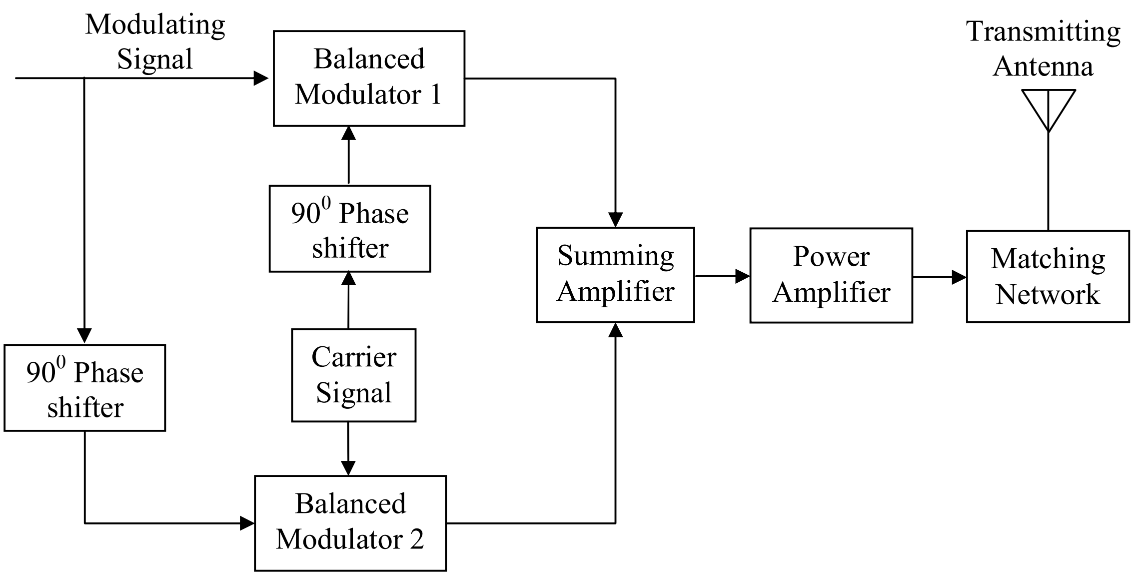


Fig 6.6: SSB transmitter using phase shift method

image frequency the signal is reduced in strength by the image rejection thus making it appear that the signal is located at two frequencies in the band.

RF AMPLIFIER: The RF amplifier is a tuned circuit. It is used to select the wanted frequency and reject all other frequencies. It improves the signal to noise ratio. It provides initial gain and selectivity. Figure 7.3 shows the RF amplifier circuits. It is a tuned circuit followed by an amplifier. The RF amplifier is usually a simple class A amplifier. The typical bipolar transistor circuit is shown in figure 7.3a and a typical FET circuit is shown in figure7.3b.

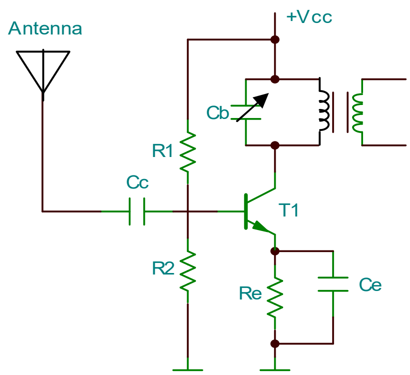


Fig 7.3a: Circuit diagram of RF Amplifier using Transistor

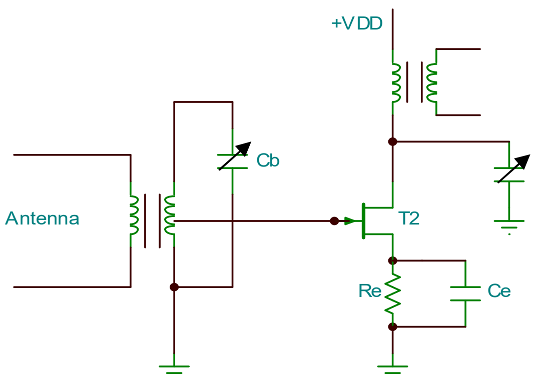


Fig 7.3b: Circuit diagram of RF Amplifier using FET

The values of resistors R1 and R2 in the bipolar circuit are adjusted such that the amplifier works as class A amplifier. The antenna is connected through coupling capacitor to the base of the transistor. This makes the circuit very broad band as the transistor will amplify virtually any signal picked up by the antenna. The collector is tuned with a parallel resonant circuit to provide the initial selectivity for the mixer input.

The FET circuit shown in figure 7.3b is more effective than the transistor circuit. Its high input impedance minimizes the loading on tuned circuits, thereby permitting the Q of the circuit to be higher and selectivity to be sharper.

Advantages of the receivr having RF amplifier.

1. It provides greater gain and better sensitivity.
2. It improves image frequency rejection.
3. It improves signal to noise ratio.
4. It provides better selectivity.
5. It provides better coupling of the receiver to the antenna.
6. It prevents re-radiation of the local oscillator through the antenna of the receiver.

MIXER: It is a non linear device having two sets of input terminals and one set of output terminals . The two inputs to the mixer are the input signal along with any modulation and the input from the local oscillator. The output contains several frequencies including the difference between the input frequencies. The difference frequency is called intermediate frquency (IF) and the output circuit of mixer is tuned for the IF. There are two types of mixers. They are separately exicited mixer and self excited mixer.

SEPARATELY EXICITED MIXER: The figure 7.4 shows the separately exicited mixer using FET. Here one device acts as a mixer while other suppllies the necessary oscillations. The bipolar transistor T_2 forms hartley oscillator circuit. It oscillates with local frequency f_0. FET T_1, is a mixer whose gate is fed with the output of local oscillator and its bias is adjusted such that it operates in non linear portion of its characteristics. The local oscillator varies the gate bias of the FET to vary its transconductance in a non linear manner resulting intermediate frequency at the output. The outut is taken through double tuned transformer in the drain of the FET and fed to the RF amplifier. The gang tuning capacitor allows simulataneous tuning of mixer and local oscillator.

The C_{Tr}, a small trimmer capacitors across each of tuning capacitors are used for fine adjustments.

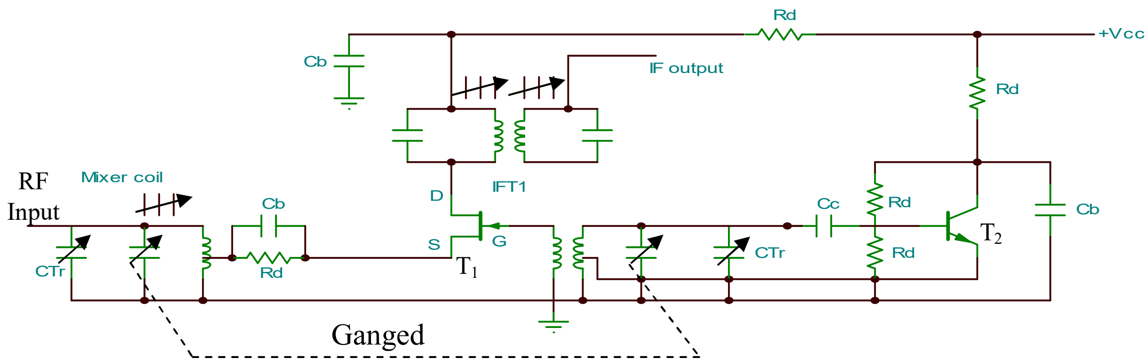


Fig 7.4: Separately excited FET Mixer

SELF EXICITED MIXER: If the function of the mixer and local oscaillator is combined in one circuit then the mixer is called as selt exicited mixer. Figure 7.5 shows the self exicited bipolar transistor mixer.

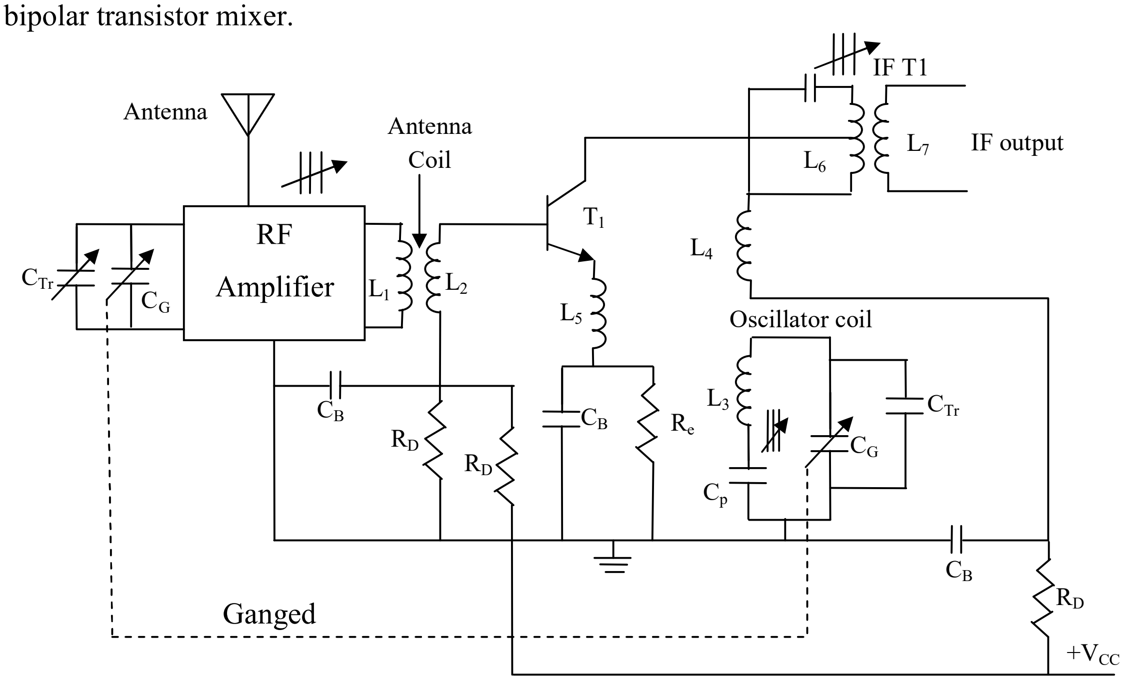


Fig 7.5: Self excited Transistor mixer

The Oscillator coil acts as a local oscillator. The transistor T_1 acts as a mixer. The Oscillator coil output is fed to the one of the input to the mixer as shown in figure 7.5.The circuit oscillates and the transconductance of the transistor is vary in a non linear manner at the local oscillator frequency. This variable transconductance is used by the transistor to amplify the incoming RF signal.

TRACKING: Process of tuning circuit to get the desired output is called tracking. Any error that exists in the frequency difference will result in an incorrect frequency being fed to the IF amplifier. Such errors are known as tracking errors. To avoid the tracking errors, ganged capacitors with identical sections are used. A different value of inductance and special extra capacitors called trimmers and padders are used to adjust the capacitance of the oscillator to the proper range. There are three common methods used for tracking. They are padder tracking , trimmer tracing and three point tracking.

PADDER TRACKING: Figure 7.6a shows the connection of tuned circuit for padder tracking. In this the oscillator tunes below the desired frquency. It should be in midband, so the IF created is higher than it should be, and positive error is created as shown figure 7.6b.

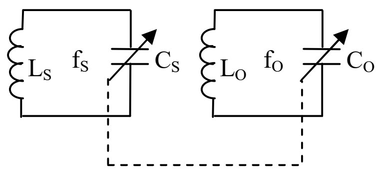


Fig 7.6a: Padder tracking

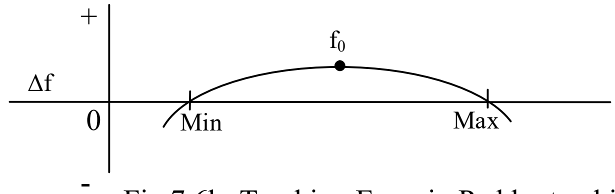


Fig 7.6b: Tracking Error in Padder tracking

TRIMMER TRACKING: Figure 7.7a shows the connection of tuned circxuit for trimmer tracking. In this, the oscillator tunes above the desired frquencies. It should be in midband, so the IF created is less than it should be and a negative error is created as shown in figure 7.7b.

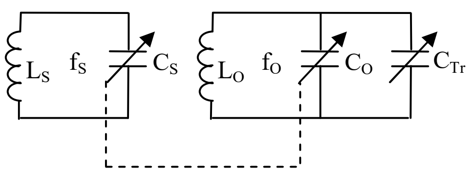


Fig 7.7a: Trimmer tracking

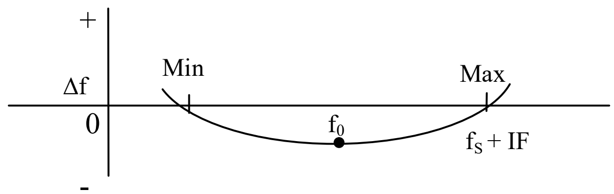


Fig 7.7b: Tracking Error in Trimmer tracking

THREE POOINT TRACKING: The cobination of padder tracking and trimmer tracking is called three point tracking. It can be adjusted to give zero error at three points across the band at the middle. Figure 7.8 shows the connection of three point tracking and its error.

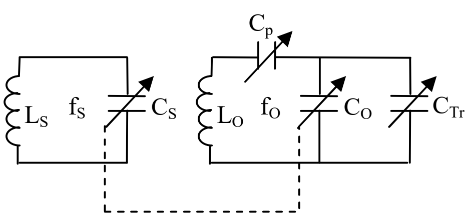


Fig 7.8a: Three point tracking

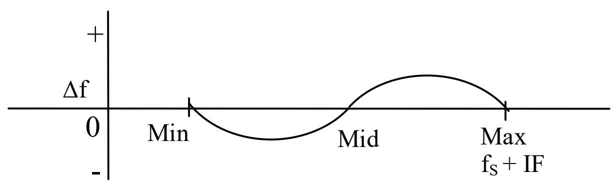


Figure 7.8b: Tracking Error in three point tracking

Procedure to get values of capacitors required in the tracking circuits.

1. Find the minimum and mazmum frequencies and the required oscillator capacitance ratio.
   $f_{o\,min} = f_{o\,min} + IF$
   $f_{o\,max} = f_{o\,max} + IF$

Oscillator capacitance ratio can be given as

We know that the resonant frequency of an LC oscillator is $f_o = \frac{1}{2\pi\sqrt{LoCo}}$

From the above equation

$f_{o\,max} = \frac{1}{2\pi\sqrt{LoCo\,min}} \rightarrow C_{o\,max} = \frac{1}{2\pi\sqrt{Lofomin}}$

$f_{o\,min} = \frac{1}{2\pi\sqrt{LoCo\,max}} \rightarrow C_{o\,min} = \frac{1}{2\pi\sqrt{Lofomax}}$

$\frac{C_{o\,max}}{C_{o\,min}} = (\frac{f_{o\,max}}{f_{o\,min}})^2$

2. Calculate the capacitance ratio and maimum value of the signal circuit tuning capacitance.

$\frac{C_{s\,max}}{C_{s\,min}} = (\frac{f_{s\,max}}{f_{s\,min}})^2$

$C_{s\,max} = (\frac{f_{s\,max}}{f_{s\,min}})^2 C_{s\,min}$

3. Calculate the oscillator tuning capacitance. It is given by
   $C_O = C_S$ in series with C_P
   $= \frac{C_S C_P}{C_S + C_P}$
4. Calculate the value of padder capacitor C_P using ratios
   From the above equation $C_{O\,max} = \frac{C_{S\,max} C_P}{C_{S\,max} + C_P}$
   $C_{O\,min} = \frac{C_{S\,min} C_P}{C_{S\,min} + C_P}$
   $\frac{C_{O\,max}}{C_{O\,min}} = \frac{C_{s\,max}(C_{s\,min} + C_P)}{C_{s\,min}(C_{s\,max} + C_P)}$
5. Obtain the oscillator coil value. It is given as,
   $L_O = \frac{1}{(2\,\pi\, f_{O\,min})^2\, C_{O\,max}}$
   Or
   $L_O = \frac{1}{(2\,\pi\, f_{O\,max})^2\, C_{O\,min}}$
6. To calculate the value of trimmer capacitance required in trimmer tracking we can use same procedure except step3. In step 3, value of C_0 is given as
   $C_0 = C_S$ in parallel with $C_P = C_S + C_P$

IF AMPLIFIER: this stage of a superheterodyne receiver usually consists of two or more stages of tuned small signal amplifier using CE transistors. the out put of the frequency mixer developed across the tuned circuit is coupled to the input of this amplifier, while the I.F. amplifier output developed across the load circuit of last stage drives the second detector.. Such a tuned circuit tuned to the intermediate frequency and inductively coupled to the next stage is usually referred to as IF transformer (IFT). In most of the commercial broadcast receivers two IF amplifier stages are used. The Q of the tuned circuit is kept high since the band of frequencies accommodated is small being only 10 kHz in amplitude modulation broadcast receiver. Figure 7.9 shows the basic circuit of two stage IF amplifier using PNP transistors.

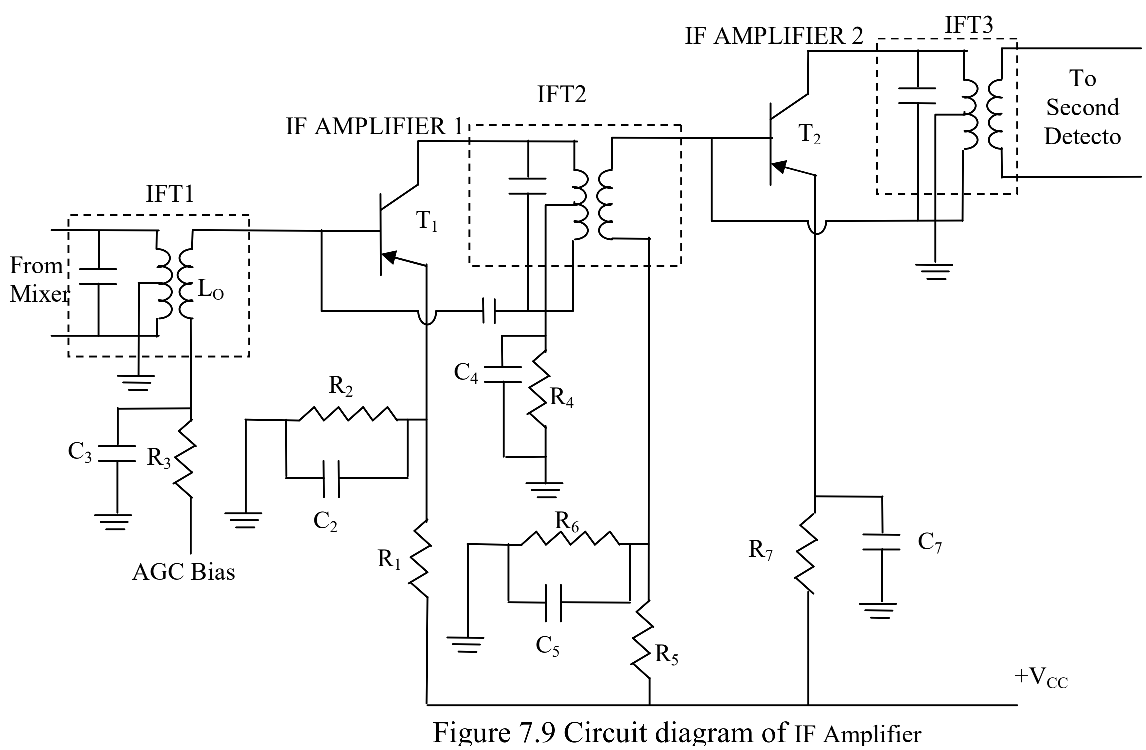


Figure 7.9 Circuit diagram of IF Amplifier

The two stages are more or less similar. The IF voltage from the first IF transformer is fed to the base of the transistor T_1. To the lower end of the first IF transformer secondary the AGC bias is applied. In the first I.F. amplifier stage, the collector is grounded through resistor R_4 while the emitter is given a positive bias from the d.c. supply through a potential divider constituted by resistors R_1 and R_2. Further since base is grounded through the AGC bias, there results the desired negative bias at the base with respect to the emitter. R_3C3 combination constitutes the AGC decouplint network. The collector to base bias is (R_4.Ic),where IC is the collector d.c. current. In the second stage, the collector is at d.c. ground potential while the full + d.c. supply is applied at the emitter. The base is connected thorugh the IF transformer secondary to a part of the positive d.c. supply thorugh the potential divider consisting of resistors R_5 and R_6. Thus there results the desired negative collector-to-base bias and positive emitter to base bias. The output of the second I.F. amplifier stage is fed to the detector. The R_7C_7 combination provides the emitter self bias. The R_4C_4 combination provides the collector self bias in the first stage.

Impedance match of the high collector impedance of one stage to the low input impedance of the following stage is obtained by using a step down transformer.

Choice of intermediate frequency: While choosing the intermediate frequencyc it is necessary to consider the following factors.

1. Very high intermediate frquency will result in poor selectivity and poor adjacent channel rejection.
2. A high value of intermediate frequency increases tracking difficulties.
3. At low values of intermediate frequency, image frequency rejection is poor.
4. At very low values of intermediate frequency, selectivity is too sharp. Cutting off the sidebands.
5. At very low IF, the frequency stability of the local oscillator must be correspondingly high because any frquency drift is now a larger proportion of the low IF than of a high IF.
6. The IF must not fall in the tuning range of the receiver, otherwise instability will occur and heterodyne whistles will be heard, making it impossible to tune to the frquency band immediately adjacent to the intermediate frequency.

AUTOMATIC GAIN CONTROL (AGC): Automatic gain control is a system by means of which the overall gain of a radio receiver is varied automatically with the variations in the strength of the receiver signal, to maintain the output substantially constant. AGC circuitry derives the dc bias voltage from the output of the detector. It applies this derived dc bias voltage to a selected numbdr of RF,IF and mixer stages to control their gains. When the average signal level increases, the size of the AGC bias increases, and the gain of the controlled stages decrease. When there is no signal, there is a minimum AGC bias, and the amplifiers produce maximum gain. There are two types of AGC circuits in use like Simple AGC and Delayed AGC.

SIMPLE AGC: In simple AGC receivers the AGC bias starts to increase as soon as the received signal level exceeds the background noise level. As a result receiver gain starts falling down, reducing the sensitivity of the receiver. Figure 7.10 shows the simple AGC circuit.

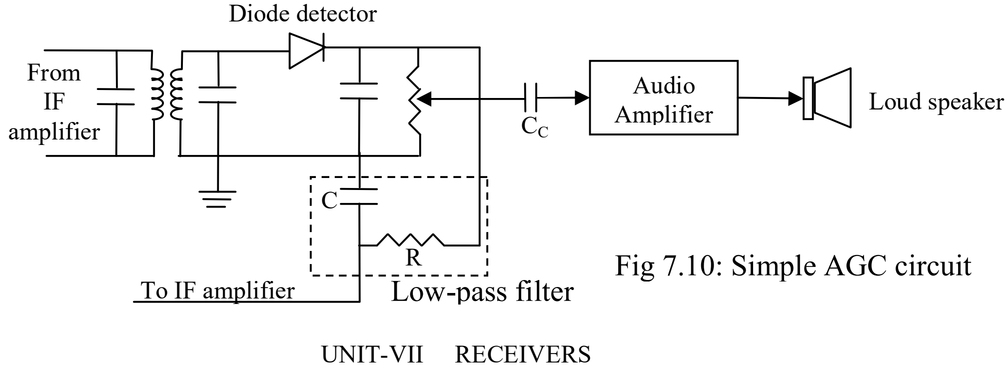


Fig 7.10: Simple AGC circuit

In this circuit, dc bias produced by half wave rectifier as a AM detector, is used to control the gain of RF or IF amplifier. Before application of this voltage to the base of the RF and/or IF stage amplifier the audio signal is removed by the low pass filter. The time constant of the filter is kept at leaast 10 times longer than the period of the lowest modulation frequency received. If the time constant is kept longer, it will give filtering, but it will cause an annoying delay in the application of the AGC control when tuning from one signal to another. The recovered signal is then passed through C_C to remove the d.c. The resulting ac signal is further amplified and applied to the loudspeaker.

DELAYED AGC:

In simple AGC circuit, the unwantd weak signals(noise signals) are amplified with high gain. To avoid this, in delayed AGC circuits, AGC bias is not applied to amplifiers until signal strength has rached a predetermined level,after which AGC bias is applied as with simple AGC, but more strongly. Figure 7.11 shows the simple delayed AGC circuit.

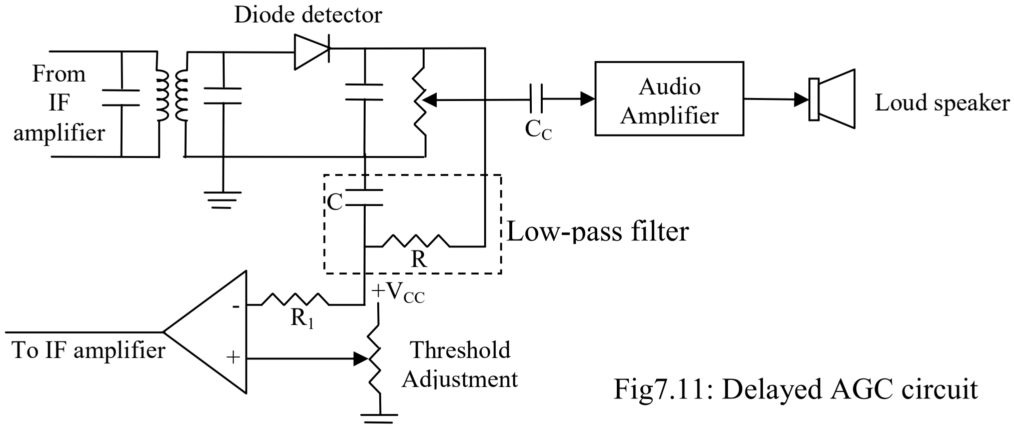


Fig7.11: Delayed AGC circuit

Here, AGC output is applied to the difference amplifier. It gives negative dc AGC only when AGC output generated by diode ddetector is above certain dc threshold voltage. This threshold voltage can be adjusted by adjusting the voltage at the positive input of the operational amplifier.

DIFFERENCES BETWEEN SIMPLE AGC AND DELAYED AGC:

S.NO	SIMPLE AGC	DELAYED AGC
1	The AGC which is responsible for increasing in the bias,when the received signal level exceeds the thermal noise of the receiver is known as simple AGC	The aGC which prevents the AGC feedback voltage from reaching RF or IF amplifiers until the RF level exceeds the predetermined magnitude known as delayed AGC.
2	This AGC circuit is useful in most inexpensive broad cast radio receivers	This AGC circuit is useful in expensive broad cast radio receivers
3	The gain has immediate effect in the receiver using this AGC	The gain is effected in the receiver using this AGC only when the threshold value is exceeded

FM RECEIVER: Figure 7.11 shows the block diagram of a superhetrodyne FM receiver. It consists of Receiving antenna, RF amplifier, Frequency mixer, LocalOscillator, IF amplifier, Limiter, Discriminator, De-emphasis, Audio Amplifier, Power Amplifier and loud speaker.

Receiving antenna: It intercepts the electromagnetic waves. Voltages induced in the antenna are communicated to the receiver input circuit by means of a feeder wire. A parallel tuned circuit at the input of the receiver responds only to voltage at the desired carier frequency and rejects voltages at all other frequencies. The voltage so picked up is fed to the input of the RF amplifier stage.

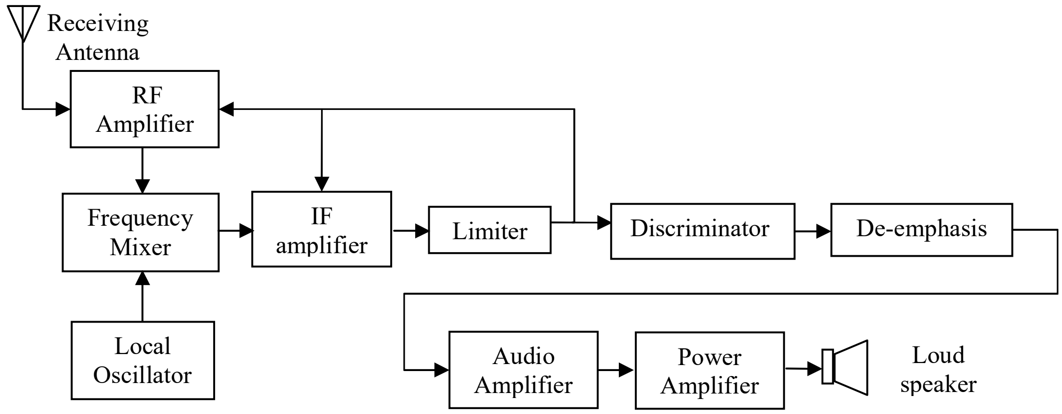


Fig 7.11: block diagram of FM rceiver

RF amplifier: It serves to raise the signal level appreciable before the signal is fed to the mixer and to discriminate against the image signal. But in F.M. broadcast, the signal bandwidth is large being 200 kHz as against 10 kHz in A.M. broadcast. Hence the RF amplifier must be designed to handle this large bandwidth.

Frequency mixer: It performs the usual function of mixing or heterodyning the signal frquency voltage and the local oscillator voltage to produce the difference frequency voltage which is the intermediate frquency voltage. Since F.M. broadcast takes place either in the VHF band or UHF band, single transistor frquency convertor is not used. A separate local oscillator is always used and another transistor serves as the frequency mixer. The intermediate frequency used in F.M. receivers is higher than that in A.M.receivers operating at short waves. Typical value ofintermediate frequency is 10.7 MHz. This high intermediate frquency helps in image rejection.

LocalOscillator: A separate local oscillator is always used. At ultra high frequencies, it is preferred to keep the local oscillator frequency smaller than the signal frquency by an amount equal to the intermediate frequency.

IF amplifier: A multistage IF amplifier is used to provide large gain. Further this IF amplifier should be designed to have high overall bandwidth of the order of 200 kHz. Since the overall bandwidth decreases as the number of stages in cascade increases, it is necessary to design individual stages to have correspondingly higher bandwidth than the overall bandwidth desired. Double tuned circuits may used but it is preferred, particularly at higher frequencies in the UHF range, to use stagger tuned signle tuned circuit which are found to produce more gain bandwidth product than the conventional double tuned circuits.

Limiter:The IF amplifier is followed by a limiter which limits the IF voltage to a predetermined level and thus removes all amplitude variations which may be incidentally caused due to changes in the transmission path or by man made static or natural static.

Discriminator: This extracts the original audio modulation frequency voltage from the frequency modulated carrier voltage. A discriminator is used as the FM detector.

De-emphasis: It is used to reduce the amplitude of the modulating signal that is artificially boosted in the transmitter by pre-emphasis to its original value.

Audio amplifier: The output of the F.M. detector is fed to an audio frquency small signal amplifier and one or more audio frquency large signal amplifiers. The output audio voltage is then fed to the loudspeaker. In FM broadcast, the maximum modulating frquency permitted is 15 kHz and hence the audio frequency must be designed to accommodate such large bandwidth. Similarly the loudspeaker must be capable of reproducing all high frquencytones upto 15 kHz. Often two or more loudspeakers are used, each reproducing a limited range of frquencies.

COMPARISON BETWEEN AM AND FM RECEIVERS:

SIMILARITIES BETWEEN THE FM AND AM RECEIVERS:

1) Both the systems can use the same antenna for receiption of the incoming RF signal.
2) The primary stages in reception path like Duplexer, antenna couplers, RF amplifiers, mixers etc., can be used in AM and FM receiver.
3) At the last stage of the receiver, like audio processing circuits, 2-wire to- 4 wire conversion at the hybrid transformer can be used by both the systems.
4) Same modulating frquency can be extracted from FM and AM receivers.

DIFFERENCES BETWEEN FM AND AM RECEIVERS

1) Amplitude modulation receivers are of broad cast receivers ranging from 550 to 1650 kHz, medium wave 3-30 MHz.
   For frequency modulation receivers operating frequencies are in the range of 88 to 108 MHz
2) In TV receivers, the picture reception is in AM system and the sound reception in FM systems.
3) The bandwidth requirement is more in FM compared to the AM.
4) Special circuits like Limiters, Automatic gain control, Beat frequency oscillators are required in FM, which are not found in AM.
5) In AM, the intermediate frequency is in the range of 450 kHz to 465kHz. For FM it employes an IF of about 10.7 MHz.

UNIT VII RECEIVERS

A radio receiver is electronic equipment which picks up any desired radio frequency signal, i.e. modulated carrier wave and recovers from it the original modulating signal.

FUNCTIONS OF RECEIVER:

1) Receiver collects the electromagnetic waves transmitted by the transmitter.
2) It selects the desired signal and rejects all others.
3) Amplify the selected modulated carrier signal.
4) Detect the modulating signal from the modulated RF signal.
5) Amplify the modulating signal to operate the loud speaker.

CLASSIFICATION OF RADIO RECEIVERS:

Radio receivers are generally classified according to the type of applications as

1. **AM Broadcast receivers**. These are meant for listening to broadcast of speech or music radiated from amplitude modulation broadcast transmitter operating on long wave, medium wave or short wave bands.
2. **FM Broad Receivers**. These are used for receiving broadcast programs from F.M. broadcast transmitters operating in VHF or in UHF bands.
3. **T.V Receivers.** These receivers are used for receiving television broadcast in VHF or in UHF bands.
4. **Communication receivers**: These are super heterodyne receivers used for reception of telegraph and shortwave telephone signals. These are used for various purposes other than broad cast services.
5. **Code Receivers**. These are simple super heterodyne receivers with the addition of I.F. beating oscillator to produce audio beat note with IF signal. Other code receivers are meant for receiving code signals, i.e. radio telegraph signals only and consist of an oscillating detector with amplifier stages.
6. **Radar Receivers.** These receivers are used for receiving RADAR (Radio Detection and Ranging) signals.

Depending up on the fundamental aspects receivers are classified as
1. Tuned Radio Frequency (TRF) receivers.
2. Super heterodyne receiver.

Super heterodyne receiver is the most popular and most widely used receiver, TRF receiver was used earlier in the 1940s.

TRF RECEIVER: It is the simplest radio receiver. The block diagram of TRF rceiver is shown in figure 7.1.

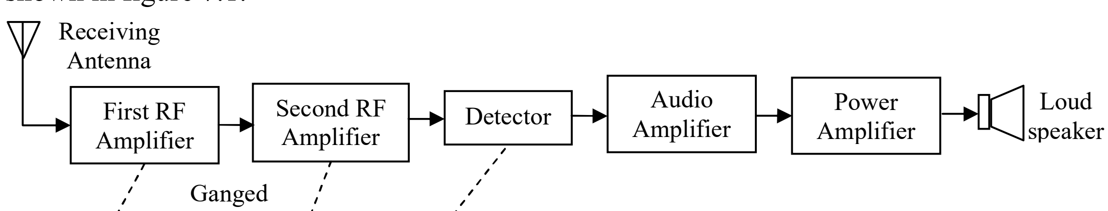


Fig 7.1: block diagram of TRF rceiver

It consists of two or three stages of RF amplifiers, detector, audiio amplifier and power amplifier. The RF amplifier stages placed between the antenna and detector are used to increase the strength of the received signal beofre it is applied to the detector. These RF amplifiers are tuned to fixed frequency, amplify the desired band of frequencies. Therefore, they provide amplification for selected band of frquencies and rejec all other frequencies. As selection and amplification process is carried out in two or three stages and each stage must amplify the same band of frquencies and the ganged tuning is provided.

The amplified signal is then demodulated using detector to recover the modulating signall. The recovered signal is amplified further by the audio amplifier followed by power amplifier which provides sufficient gain to operate a loudspeaker.

ADVANTAGES OF TRF RECEIVER: The following are the advantages of TRF receivers
1. TRF receiver is simple and cheaper.
2. It is easy to constuct.
3. The amplifiers in this circuit strengthens the weak input signal.

DISADVANTAGES OF TRF RECEIVER: The followin are the disadvantages of TRF receivers.
1. Tracking of tuned circuits.
2. Instability.
3. Variable bandwidth.

Tracking of tuned circuits. Tuned circuits are made variable so that this can be set to the frequency of the desired signal. The capacitors in the tuned circuits are m ade variale . These capacitors ar ganged between the stages so that they all can be changed simultaneously when the tuning knob is rotated. To have perfect tuning the capacitor values between the stages must b exactlly the same. But this is not the case. The difference in the capacitors cause the resonant frquency of each tun ed circuit to be slightly different, there by increasing the pass band.

Instability: As the high gain is achieved at one frequency by a multistage amplifier, there are more chances of positive feed back through some stray path resulting in oscillations. These oscillations are unavoidable at high frequencies.

Variable Bandwidth: Consider a medium wave receiver required to tune 550 to 1650 kHz and it provides the necessary bandwidth of 10 kHz.

We know that the quality factor Q = frequency / Bandwidth= 550/10=55

The quality factor at 1650kHz is Q = 1650/10 =165

In practice due to various losses depending on frequency , we will not set so large increase in Q .

Let us assume that at 1650 kHz frequency, Q is increased to value 100 instead of 165. Then the bandwidth =1650/100 = 16.5 Khz.

We know that the necessary bandwidth is 10 kHz.

This increasde in bandwidth of tuned circuit , pick up the adjacent stations along with the stations it is tuned for., providing insufficient adjacent frquency rejection . Thismeans that TRF has poor selectivity.

PRINCIPLE OF SUPERHETERODYNE RECEIVER:

Heterodyne means mixing. Heterodyne reception stands for the radio reception after converting the modulated carrier voltage into similarly modulated voltage at a different carrier frequency. Thus the the heterodyne process involves a simple change of carrier frquency. This change in carrier frequency is achieved by mixing the modulated carrier voltage with a locally generated high frequency voltage in a nonlinear device to obtain the modulated carrier voltage at different carrier frequency .

Superheterodyne reception is a form of heterdoyne reception in which frequency convrsion takes place one or more times before the modulated carrier voltage is fed to the detector to recover the original modulating signal.

Thus in a simple superheterodyne receiver, the modulated carrier voltage of carrier frequency f_S is fed to a device called frequency mixer to which is also fed the voltage of frequency f_O generated in a local oscillator and at the output is selected a voltage of frequency f_i which is the difference of local oscillator frequency and the signal frequency. This difference frequency is termed the Intermediate frequency (IF). The IF voltage obtained at the output of frequency mixer is exactly similar to the modulated carrier voltage except for the change in carrier frequency. Intermediate frequency is fixed for a receiver.

SUPERHETERODYNE RECEIVER: Figure 7.2 shows the block diagram of superheterodyne receiver. It consists of antenna, RF amplifier, Mixer, Multi stage IF amplifier, Second Detector, Audio Amplifier, Local Oscillator, Power Amplifier and Loud Speaker.

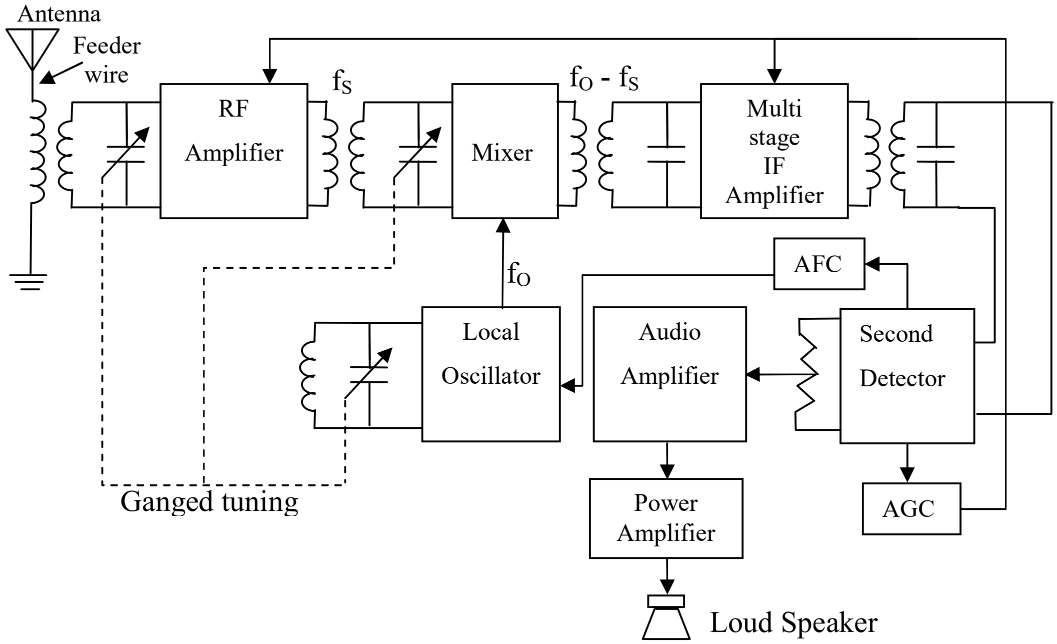


Fig 7.2: Block diagram of super heterodyne Receiver

Antenna: It intercepts the electromagnetic waves. Voltages induced in the antenna are communicated to the receiver input circuit by means of a feeder wire. A parallel tuned circuit at the input of the receiver responds only to voltage at the desired carier frequency and rejects voltages at all other frequencies. The voltage so picked up is fed to the input of the RF amplifier stage.

R.F. Amplifier: This stage is generally a tuned voltage amplifier tuned to the desired carrier frequency. It amplifies the input signal voltage to a suitable high level before feeding it to the frequency mixer which contributes large noise. Thus signal/noise ratio is improved. It provides selectivity against image frequency signal and intermediate frequency signal.

Frequency converter stage: This consists of a local oscillator and frequency mixer. To the frequency mixer are fed both the local oscillator voltage as well as signal voltage. The mixer produces at its output the various intermodulation terms.The difference frequency voltage is picked up by the tuned circuit in the output circuit of the mixer. This difference frequency is called the intermediate frequency, the vallue of which is constant for a receiver. For all wave receivers, typical value of intermediate frequency is 465 kHz or 456 kHz. Sometimes two separate transistors are used as local oscillator and frequency mixer but more often only one transistor functions both as lcoal oscillator and frequency mixer. Such a transistor is then refered to as a frequency converter transistor . Thus with the help of frequency converter stage, RF signal of any carrier frequency are converted into similarly modulated fixed frequency IF signal.

IF Amplifier Stage: It aconsists of two or more stages of fixed frequency tuned voltage amplifier having a 3 dB bandwidth of 10 kHz for AM broadcast. This IF amplifier provides most of the receiver a mplification and selectivity.

Second Detector: Output of the last IF amplifier stage is fed to this second detector wich is generally a linear diode detector. Output of this detector is the original modulation frequency voltage. For satisfactory operation of this detector,i.e. for linear detection, it is necessary that the carier voltage fed to it be atleast 1 volt. Hence the preceding amplifier stages must be designed to provide enough gain so as to feed a carrier of atleast one volt to the detector for the weakest signal desired to be received by the receiver.

Audio Frequency Amplifier: Audio frequency output from second detector is fed to the A.F. amplifier which provides additional amplififcation. Usually one stage of audio voltage amplifier is used followed by one or more stages of audio power amplifier.

Loud speaker: Ampliifed audio output voltage of audio power amplifier is fed to loudspeaker through impedance matching transformer. The loudspeaker reproduces the original programme.

ADVANTAGES OF SUPERHETERODYNE RECEIVER: The following are the advantages of superheterodyne receiver.

1. The bandwidth ramains constant over the entire operating range.
2. It provides high sensitivity.
3. It provides high selectivity.
4. It provide high adjacent channel rejection.

RECEIVER CHARACTERISTICS: The following are the characteristics of a receiver.

1. Selectivity 2. Sensitivity 3. Fidelity 4. Image frequency and its rejection. 5. Double spotting.

Selectivity: It is defined as the ability of the receiver to select the signal of a desired frequency while rejecting all other frequencies. It is obtained by using a tuned circuit.These are LC circuit tuned to resonante at a desired frequency. The Q of the tuned circuit determines the selectivity. This shows the attenuation that the receiver offers to signal at frequencies near to the one to which it is tuned. A good receiver isolates the desired signal in the RF spectrum and elimintes all other frequencies.

The bandwidth of a tuned circuit is measure of the selectivity, narrower the bandwidth better the selectivity.

Sensitivity: It is defined as the ability of a receiver to pick up weak signals and amplify it. It is often defined in terms of the voltage that must be applied to the receiver input terminals to give a standard output power measured at the output terminals. The more gain that a receiver has, the smaller the input signal necessory to produce desired output power. Therefore, sensitivity is a primary function of the over all receiver gain. It is often expressed in microvolts or decibles.

Fidility: It is defined as the ability of the receiver to reproduce the all modulating signal frequency components equally. The fidility at the lower modulating frequencies is determined by the lower frequency response of the IF amplifier and the fidility at the higher modulating frequencies is determined by the high frequency response of the IF amplifier.

Image Frequency and its Rejection: If a frequency $f_{si} = f_s + 2f_i$, appears at the input of mixer then it will produce the sum and difference frequency regardless of inputs. Therefore the mixer output will be the difference frequency at the IF value. The term f_{si} is called the image frequency and is defined as the signal frequency plus twice the intermediate frequency. Unfortunalely this image frequency signal is also amplifed by the IF amplifiers resulting in interference. This has the effect of two stations being received simultaneously and is naturally undesirable .

The rejection of an image frquency by a single tuned circuit is the ratio of the gain at the signal frequency to the gain at the image frequency. Image frequency rejection ratio is denoted by α and is given by $\alpha = \sqrt{1 + Q^2 \rho^2}$

where $\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}}$ and Q = loaded Q of the tund circuit.

The image rejection depends on the selectivity of the RF amplifier and tuned circuit.

Double Spotting: The phenomenon of double spotting occurs at higher frequencies due to poor front and selectivity of the receiver. Receiver picks up same short wave station at two near by points on the receiver dial.

When the receiver is tuned across the band, a strong signal appears to be at two different frequencies , once at the desired frequency and again at the image frquency. At the

Radio Receivers

9

9.1 INTRODUCTION: FUNCTIONS OF A RECEIVER

We know that in a communication system, a radio transmitter radiates or transmits a modulated carrier signal. This modulated carrier signal travels down the channel *i.e.* transmission medium and reaches at the input of radio receiver. This means that the modulated carrier signal is picked up by the antenna of the radio receiver. This modulated signal so received is generally very weak. Therefore, inside the receiver this weak signal is first amplified in an R.F. (Radio frequency) amplifier stage of the radio receiver. Also, since the received modulated signal contains a lot of noise or unwanted signals at adjacent frequencies, it must be selected and the noise must be rejected. Finally, in receiver, the R.F. carrier or modulated signal must be demodulated to get back the original modulating or baseband signal. Further, since the demodulated or detected signal (*i.e.* audio signal in case of broadcast receiver) is generally weak, it has to be amplified in one or more stages of audio amplifier.

From the above discussion, we can summarize the main function of a radio receiver as:

(*i*) Intercept the incoming modulated signal (*i.e.* electromagnetic waves) by the receiving antenna.

(*ii*) Select the desired signal and reject the unwanted signals.

(*iii*) Amplify this selected R.F. signal.

(*iv*) Detect the modulated signal to get back the original modulating or baseband signal.

(*v*) Amplify the modulating frequency signal.

This means that a radio receiver is an electronic equipment which picks up the desired signal, rejects the unwanted signals, amplifies the desired signal, demodulates the modulated signal to get back the original modulating frequency signal.

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9.2 CLASSIFICATION OF RADIO RECEIVERS

We can classify the radio receiver in two ways as under :

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

(i) *Amplitude Modulation (A.M.) Broadcast Receivers :* These receivers are used to receive the broadcast of speech or music transmitted from amplitude modulation broadcast transmitters which operate on long wave, medium wave or short wave bands.

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

(iii) *Communication Receivers :* Communication receivers are used for reception of telegraph and short wave telephone signals. This means that communication receivers are used for various purposes other than broadcast services.

(iv) *Television Receivers:* Television receivers are used to receive television broadcast in VHF or in UHF bands.

(v) *Radar Receivers* : Radar receivers are used to receive Radar (*i.e.* Radio detection and ranging) signals.

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

(i) Tuned Radio Frequency (TRF) Receivers.

(ii) Superheterodyne Receiver.

In fact, various forms of receivers have been proposed from time to time. However, only two of them became popular for commercial applications. These are Tuned Radio frequency (TRF) receiver and superheterodyne receiver. Presently, the superheterodyne receiver is the most popular and most widely used. The TRF receiver was used earlier in the 1940s. The TRF receiver had some inherent drawbacks which were removed in superheterodyne receiver. Therefore, we shall start our discussion with TRF receiver and then come to the superheterodyne receiver.

9.3 TUNED RADIO FREQUENCY (TRF) RECEIVER

Tuned radio frequency (TRF) receiver is the simplest radio receiver. Figure 9.1 shows the block diagram of a tuned radio frequency 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 circuit at the input and output sides. At the input of the receiver, there is a receiving antenna as shown in block diagram in figure 9.1. At this antenna signals from different sources (*i.e.* stations) are present. However, with the help of input variable tuned circuit of RF amplifiers the desired signal (*i.e.* station) is selected. But this selected signal is usually very weak of the order of μV. This selected weak signal is amplified by the RF amplifier (*i.e.* R.F stage).

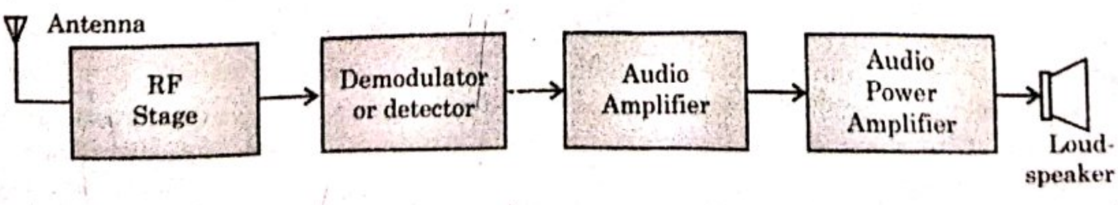

Fig. 9.1 *Block diagram of a TRF receiver*

Thus the function of RF stage is to select the desired signal and amplify it.

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After this, the amplified incoming modulated signal is applied to the demodulator. The demodulator or detector demodulates the modulated signal and thus at the output of the demodulator, we get modulating or baseband signal (*i.e.* audio signal). This audio signal is amplified by audio amplifier. After that, this audio signal is further amplified by a power amplifier upto desired power level to drive the loudspeaker. The last stage of this receiver is the loudspeaker. A loudspeaker is a transducer which changes electrical signal into sound signal.

9.3.1 Drawbacks of TRF Receiver

As discussed above, although TRF receiver is cheaper and the simplest one, it has certain drawbacks as under:

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

This problem is also termed as instability of the receiver.

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

(*iii*) Another problem associated with the TRF receiver is the bandwidth variation over the tuning range. For example, in AM broadcast system, let us consider that a tuned circuit is required to have a bandwidth of 10 KHz at a frequency of 540 KHz.

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

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

Now, at the other end of this AM broadcast band (*i.e.* 1640 KHz), the Quality factor Q of the coil, according to above equation, must increase by a factor of 1640/535 (*i.e.* 3) to a value of 164. However, in practice due to 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

$$\Delta f = \frac{f_r}{Q} = \frac{1640}{120} = 13.8 \text{ KHz}$$

Therefore, due to this increased bandwidth of 13.8 KHz in place of a fixed bandwidth of 10 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.

9.4 SUPERHETERODYNE RECEIVER : BASIC ELEMENTS*

(RGTU Bhopal, Sem. Exam., June 2005)(05 marks)

Figure 9.2 shows the block diagram of a superheterodyne receiver. All the drawbacks in TRF receiver have been removed in a superheterodyne receiver. The basic superheterodyne receiver is most widely used. This means that the superheterodyne principle is used in all types of receiver like television receiver, radar receiver etc.

In a superheterodyne receiver, the incoming RF signal frequency is combined with the local

* Explain the principle working of super heterodyne receiver.

oscillator signal frequency through a mixer and is converted into a signal of lower fixed frequency. This lower fixed frequency is known as **intermediate frequency**. However, the intermediate frequency signal contains the same modulation as the original signal. This intermediate frequency signal is now amplified and demodulated to reproduce the original signal.

The word heterodyne stands for mixing. Here we have mixed the incoming signal frequency with the local oscillator frequency. Therefore this receiver is called superheterodyne receiver.

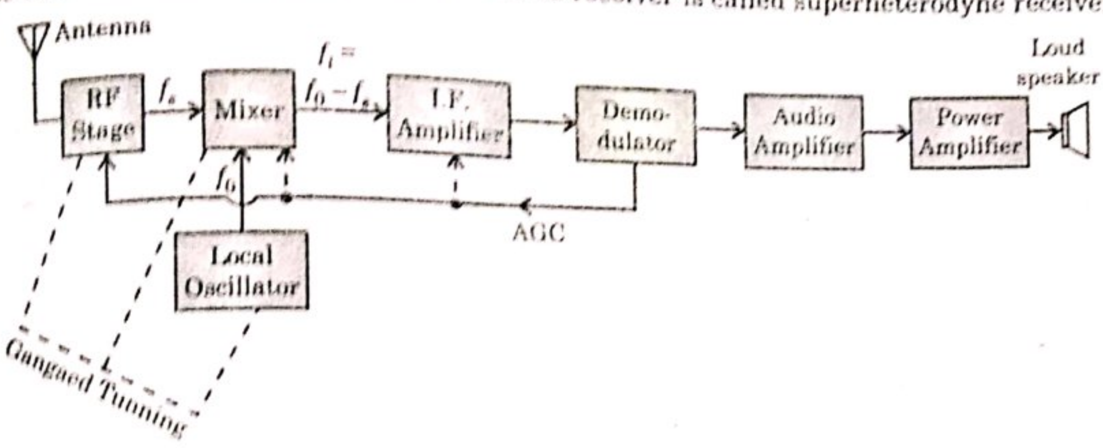

Fig. 9.2 *Block diagram of a Superheterodyne Receiver.*

Thus, in a superheterodyne receiver, a constant frequency difference is maintained between the local oscillator signal frequency and incoming RF signals frequency through capacitance tunning in which the capacitances are ganged together and operated by a common control knob. The intermediate frequency (IF) amplifier generally contains a number of transformers each consisting of a pair of mutually coupled tuned circuits. Thus, with this large number of double-tuned circuits, operating at a specially chosen frequency, the IF amplifier provides most of the gain (*i.e.* sensitivity) and band width requirements (i.e. selectivity) of the receiver. This means that the IF amplifier determines the sensitivity and selectivity of the superheterodyne receiver.

Also, since the characteristics of the IF amplifier are independent of the incoming frequency to which the receiver is tuned, the selectivity and sensitivity of the superheterodyne receiver are quite uniform throughout its tunning range and not subject to the variations like a TRF receiver. Further since the I.F. amplifier works at a fixed I.F. frequency, the design of this system is quite easy to provide high gain and constant bandwidth.

Because of its narrow bandwidth, the I.F. amplifier rejects all other frequencies except intermediate frequency (I.F.). Actually, this rejection process reduces the risk of interference from other stations or sources. In fact, this selection process is the key to the superheterodyne receiver's exceptional performance.

After the I.F. amplifier, the signal is applied at the input of demodulator which extracts the original modulating signal (*i.e.* audio signal). This audio signal is amplified by an audio amplifier to get a particular voltage level. This amplified audio signal is further amplified by a power amplifier to get a specified power level so that it may activate the loudspeaker. The loudspeaker is a transducer which converts this audio electrical signal into audio sound signal and thus the original signal is reproduced *i.e.* the original transmission is received.

The advantages of the superheterodyne receiver make it the most suitable for the majority of radio receiver applications like AM, FM, communications, single-sideband, television and even radar receiver; all use superheterodyne principle. This means that it can be considered as today's standard form of radio receiver.

9.4.1 Advantages of Superheterodyning

(*i*) No variation in bandwidth. The BW remains constant over the entire operating range.

(*ii*) High sensitivity and selectivity.

(*iii*) High adjacent channel rejection.

9.4.2 Frequency Parameters of AM Receiver

The AM receiver has the following frequency parameters :

(*i*) Two frequency bands: Medium wave (MW) band and short wave (SW) band.

(*ii*) RF carrier range (MW band) : 535 kHz to 1650 kHz (SW band) : 5 to 15 MHz

(*iii*) Intermediate frequency IF: 455 kHz

(*iv*) IF bandwidth B : 10 kHz.

9.5 RECEIVER CHARACTERISTICS (*JNTU, Hyderabad, Sem. Exam., June 2006*)

Because the type of receiver is almost the same for various forms of modulation or system, therefore, it is generally most convenient to explain the various principles of a superheterodyne receiver while dealing with AM receivers. Thus, with the discussion of AM receiver, a basis is formed for the more complex versions of superheterodyne receiver. In this section, let us discuss various superheterodyne receiver characteristics. They are as under:

(*i*) Sensitivity,

(*ii*) Selectivity

(*iii*) Fidelity.

(*iv*) Double spotting.

(*v*) Tracking.

9.5.1 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 provide a standard output power measured at the output terminals. For AM broadcast receivers, several relevant quantities have been standardized. A signal modulated by a 400 Hz sine wave and modulation index of 30% is applied through standard coupling network known as a **dummy antenna.**

In addition to this, the loud-speaker is replaced by an equivalent load resistance. After this the output is measured across this resistance and it must be equal to the standard value of 50 mW.

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

Figure 9.3 shows the sensitivity curve over the tuning band. At 1 MHz, this particular receiver has a sensitivity of 12.7 μ volt or –98 dB volt. Sometimes, the sensitivity defintion is extended, and the manufacture of this receiver may quote it to be, nor merely 12.7 μV, but "12.7 μV for an SNR of 20 dB in the output of the receiver".

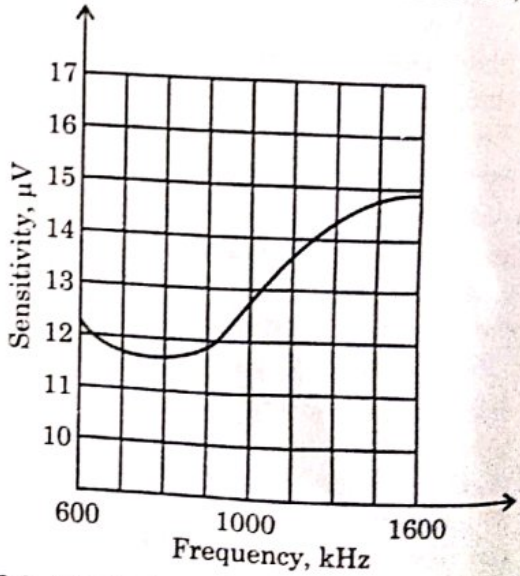

Fig. 9.3 A typical sensitivity curve for a good domestic receiver.

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. Few factors determining the sensitivity of a superheterodyne receiver are as under :

(a) The gain of the If amplifiers.

(b) The gain of the RF amplifiers.

(c) The noise figure of the receiver.

It may be noted that the typical values of sensitivity are 150 μ volt for small broadcast band receivers, and 1 μ volt or below for high quality communication receiver in the HF band.

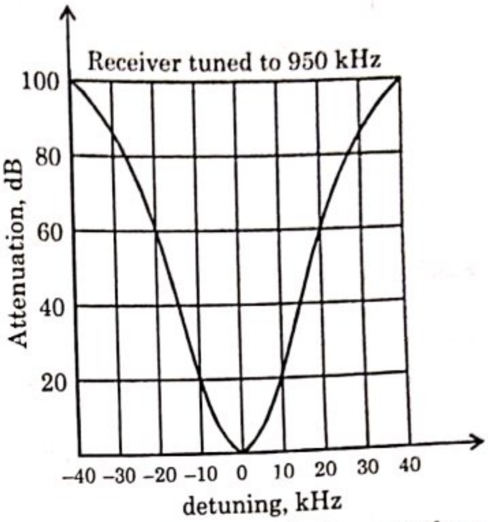

Fig. 9.4 *A typical sensitivity curve for a good domestic receiver.*

9.5.2 Selectivity

The selectivity of a receiver may be defined as the ability to reject unwanted signals. It also expresses the attenuation that the receiver offers to signal at frequencies adjacent to the one to which it is tuned. It is generally, expressed as a curve as shown in figure 9.4. In selectivity measurement, the frequency of the generators is varied to either side of the frequency to which the receiver is tuned. Naturally, the output of the receiver falls since the input frequency is not incorrect. Thus the input voltage must be increased until the output is the same as it was originally.The ratio of the voltage required of resonance to the voltage required. When the generator is tuned to the receiver's frequency it is calculated at a number of points and then plotted in decibels to give a curve as shown in figure 9.4. It may be noted that selectivity depends upon the following factors :

(i) Selectivity varies with receiving frequency and becomes somewhat worse when the receiving frequency is raised.

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

(iii) Selectivity is the main factor which determines the adjacent channel rejection of a receiver.

9.5.3 Fidelity

As a matter of fact, the fidelity is the ability of a receiver to reproduce all the modulating frequencies equally. The fidelity basically depends on the frequency response of the AF amplifier. Figure 9.5 shows the typical fidelity curve.

High fidelity is essential in order to reproduce a good quality music faithfully *i.e.* without introducing any distortion. For this, it is essential to have a flat frequency response over a wide range of audio frequencies. The fidelity curve for a receiver shown in figure 9.5 is basically the frequency response of the AF amplifier stage in the receiver. Ideally, the curve fidelity curve should be flat over the entire audio frequency range. But, practically, it decreases on the lower and higher frequency sides.

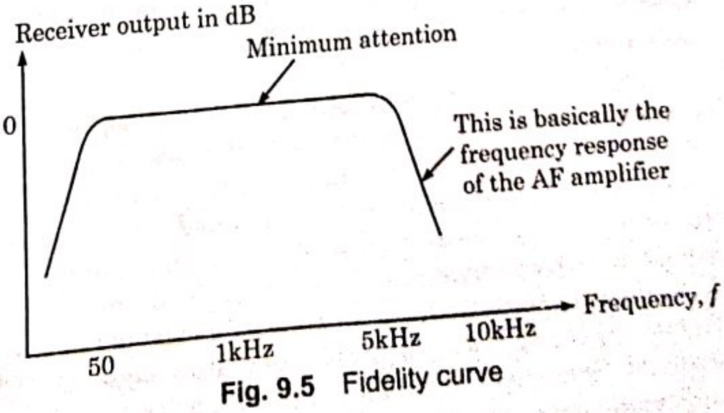

Fig. 9.5 Fidelity curve

9.5.4 Double Spotting

When a receiver picks up the same short wave station at two nearby points on the receiver dial, the double spotting phenomenon takes place. The main cause for double spotting is poor front-end

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selectivity, *i.e.*, inadequate image-frequency rejection. The front-end of the receiver does not select different adjacent signal very well.

The adverse effect of double spotting is that a weak station may be marked by the reception of a nearby strong station at the spurious point on the dial. On the other hand, double spotting may be used to calculate the *IF* of an unknown receiver. The spurious point on the dial is precisely $2f_i$ below the correct frequency. If image-frequency rejection is improved, then certainly there will be a corresponding decrease in the double spotting occurrence.

9.5.5 Tracking or Tunning of a Superheterodyne Receiver

In a superheterodyne receiver, the local oscillator frequency is made to track with the tuned circuits which are tuned to the incoming signal frequency in order to make a constant frequency difference at the output of mixer. For general AM broadcast system, the intermediate frequency (I.F.) is 455 kHz. This indicates that the local oscillator should always be set at a frequency which is 455 kHz above the incoming signal frequency. For purpose the front end of the receiver tuned

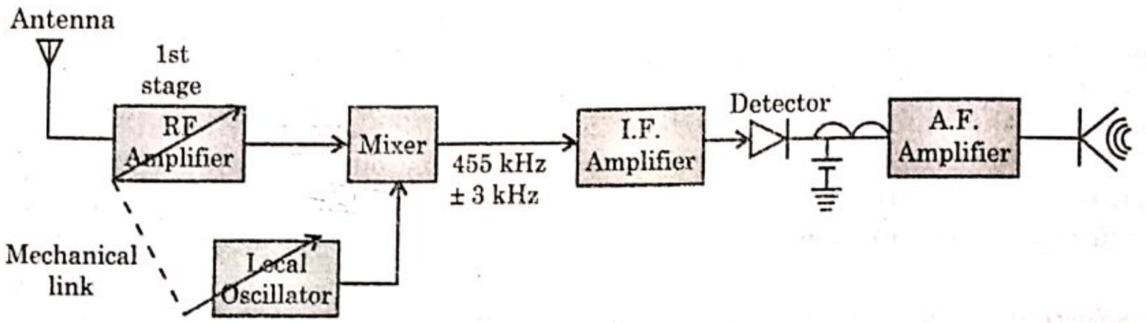


Fig. 9.6 *Tunning of a superheterodyne receiver.*

circuits are made to track together simply by mechanically linked or ganged capacitors. A ganged capacitor has three capacitor sections, one each for the RF amplifier, mixer and the local oscillator. In addition to this, small variable capacitances known as trimmers are connected in parallel with each section. These capacitances can be adjusted for proper operation at highest frequency. However for lowest frequency adjustment, small variable capacitors known as padders are connected in series with the inductor of the tank circuit.

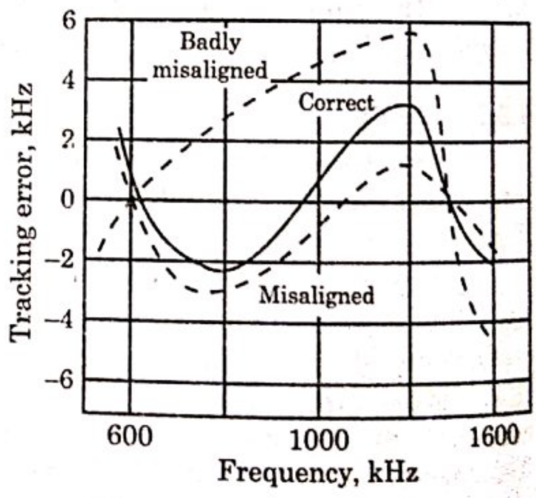


Fig. 9.7 *Tracking curves.*

The various tuned circuits are mechanically coupled so that only one tunning control and dial are required. This means that no matter what is the incoming signal frequency, the RF and mixer input tuned circuits must be tuned to it. The local oscillator must simultaneously be tuned to a frequency which is precisely higher than the signal frequency by the intermediate frequency. However, any error that may exist in the frequency difference would result in an incorrect frequency being fed to the intermediate frequency (I.F.) amplifier. This error must naturally be avoided. Such type of errors are known as tracking errors. These tracking errors result in stations appearing away from their correct position on the dial.

It is quite possible to keep the maximum tracking error below 3 kHz. A value as low as this is quite acceptable.

9.5.6 Image Frequency and its Rejection*

(Anna University, Chennai, Sem. Exam., June 2006)

We know that a superheterodyne receiver is a better receiver than a Tuned Radio Frequency (TRF) receiver. However a superheterodyne receiver suffers from a major drawback known as Image Frequency problem. This problem of image frequency is inherent to a superheterodyne receiver and arises because of the use of heterodyne principle. In fact, the frequency conversion process carried out by the local oscillator and the mixer often allow an undesired frequency in addition to the desired incoming frequency.

In a standard broadcast receiver, the local oscillator frequency is always made higher than the incoming signal frequency. It is kept equal to the signal frequency plus the intermediate frequency (I.F.).

Mathematically, $f_o = f_s + f_i$ ...(9.1)

where f_o = local oscillator frequency

f_s = desired incoming frequency

f_i = intermediate frequency

From equation (9.1), we have

$$f_i = f_o - f_s$$

Hence, the intermediate frequency is the difference between the local oscillator frequency and the signal frequency.

Now, if a frequency f_{si} manages to reach the mixer, such that

$$f_{si} = f_o + f_i \quad ...(9.2)$$

then this frequency f_{si} would also produce f_i when it is mixed with f_o. This undesired or spurious intermediate frequency signal will also be amplified by the I.F. stage and thus would cause interference. This has the effect of two sources or stations being received simultaneously. This situation is obviously undesirable.

The term f_{si} is known as the image frequency and is defined as the signal frequency plus twice the intermediate frequency.

Putting the value of f_o in equation (9.2) from equation (9.1), we get

$$f_{si} = f_o + f_i$$

$$f_{si} = f_s + f_i + f_i$$

or

$$f_{si} = f_s + 2f_i \quad ...(9.3)$$

Thus this spurious frequency signal cannot be distinguished by the I.F. stage and hence would be treated in the same manner as the desired frequency signal.

The rejection of an image frequency signal by a single tuned circuit may be defined as the ratio of the gain at the signal frequency to the gain at the image frequency. This is given as

$$\alpha = \sqrt{1 + Q^2\rho^2} \quad ...(9.4)$$

Here

$$\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}} \quad ...(9.5)$$

and Q = Quality factor of the tuned circuit in a loaded condition.

If the receiver has an RF stage, then there is only a single tuned circuit and the rejection will be calculated using equation (9.4). However if the receiver has an RF stage then there are two tuned circuits both tuned to f_s. The image frequency rejection of each stage will be calculated by using equation (9.4). The total or overall rejection will be the product of the two.

* What is image signal? Why is the local oscillator frequency always kept higher than the signal frequency in superheterodyne receivers? *(RTU, Kota, Sem. Exam., June 2009)(10 marks)*

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

It may be observed that if $\frac{f_{si}}{f_s}$ is large as is the case for AM broadcast band the use of an RF stage is not necessary for good image frequency rejection. However, it would become essential above about 3MHz.

EXAMPLE 9.1. For a broadcast superheterodyne AM receiver having no RF amplifier, the loaded Quality factor Q of the antenna coupling circuit is 100. Now if the intermediate frequency is 455 kHz, then determine the following :

(*i*) the image frequency and its rejection ratio at an incoming frequency of 1000 kHz.

(*ii*) the image frequency and its rejection ratio at an incoming frequency of 25 MHz.

Solution : Given that

$$Q = 100$$

and

$$f_i = 455 \text{ kHz.}$$

$$f_s = 1000 \text{ kHz}$$

The image-frequency is given as

$$f_{si} = f_s + 2f_i = 1000 + 2 \times 455 = 1000 + 910 = 1910 \text{ kHz}$$

Further,

$$\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}} = \frac{1910}{1000} - \frac{1000}{1910} = 1.910 - 0.524 = 1.386$$

Since the given receiver has no RF amplifier, therefore there is only single tuned circuit. The rejection ratio is given as

$$\alpha = \sqrt{1+Q^2\rho^2} = \sqrt{1+(100)^2 \times (1.386)^2}$$

or

$$\alpha = \sqrt{1+(138.6)^2} = 138.6 \qquad \textbf{Ans.}$$

(*ii*) For second case, it is given that

$$Q = 100$$

$$f_i = 455 \text{ kHz} = 0.455 \text{ MHz}$$

and

$$f_s = 1000 \text{ kHz}$$

The image frequency is given as

$$f_{si} = f_s + 2f_i = 25 + 2 \times 0.455 = 25.91 \text{ MHz}$$

$$\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}} = \frac{25.91}{25} - \frac{25}{25.91} = 1.0364 - 0.9649 = 0.0715$$

The rejection ratio α is given as

$$\alpha = \sqrt{1+Q^2\rho^2} = \sqrt{1+(100)^2 \times (0.0715)^2}$$

$$\alpha = \sqrt{1+(7.15)^2} = 5.22 \qquad \textbf{Ans.}$$

EXAMPLE 9.2. In a superheterodyne receiver having no RF amplifier, the loaded Q of the antenna coupling circuit (at the input of the mixer) is 90. If the intermediate frequency is 455 kHz, calculate the following :

therefore, $$1.411 = \frac{f_{si}}{30\text{ MHz}} - \frac{30\text{ MHz}}{f_{si}} \quad ...(v)$$

But from equation (*ii*), we have,

$$1.411 = \frac{1930}{1000} - \frac{1000}{1930}$$

Hence, equating this expression with equation (*v*), we obtain

$$\frac{1930}{1000} = \frac{f_{si}}{30\ MHz}$$

or $$1.9 \times 30\text{ MHz} = f_{si}$$

$$\text{New } f_{si} = 57\text{ MHz} \quad ....(vi)$$

But $$f_{si} = f_{si} + 2\text{IF}$$

Hence, $$\text{IF} = \frac{f_{si} - f_s}{2} = \frac{57-30}{2}$$

or $$\text{IF} = 13.5\text{ MHz}$$ **Ans.**

9.6 AM SUPERHETERODYNE RECEIVER: (DESCRIPTION OF VARIOUS BLOCKS)

In this section, let us discuss the principle and working of different blocks used in a superheterodyne AM receiver.

9.7 R.F. AMPLIFIER

R.F. amplifier is a small signal tuned amplifier with tuned circuits both in the input side and the output side. Both these 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 including the image frequency. Hence the R.F. amplifier provides image frequency rejection. Also the gain provided by the R.F. amplifier will result in improved signal/ noise ratio in the output of the receiver. This is due to the fact that the incoming weak signal is raised to a higher level with the help of RF amplifier before it is fed at the input of the mixer stage which contributes most of the noise generated in the receiver. However, if the incoming weak signal is fed directly to the frequency mixer, the signal/noise ratio at the output of the mixer stage is quite poor and hence any amount of subsequent amplification cannot improve S/N ratio. Thus the one important function of the RF amplifier is to improve S/N ratio.

There are some cases also where an RF amplifier is not used in the receiver rather its use is uneconomical there. The best example of this kind of receiver is a domestic receiver used in a high-signal-strength area like a metropolitan city. Since in a metropolitan city like Delhi, several stations are situated and in such places strength is obviously very high and thus there is no need for the use of R.F. amplifier. In such cases the tuned circuit connected to the antenna is the actual input circuit of the mixer.

However, a receiver having an RF amplifier is obviously superior in performance to a receiver without RF amplifier.

We may summarize the advantages of RF amplifier as under :

(*i*) Greater gain *i.e.* better sensitivity

(*ii*) Improved rejection of adjacent undesired signals *i.e.* better selectivity

(*iii*) Improved signal/noise ratio

(*iv*) Improved image frequency rejection

(*v*) Improved coupling of the receiver to the antenna

(*vi*) Prevention of re-radiation of the local oscillator voltage through the antenna

(viii) Prevention of spurious frequencies from entering the mixer and heterodyne to produce interfering frequency equal to I.F.

Circuit of R.F. Amplifier

Figure 9.10 shows the circuit diagram of one stage RF amplifier using an NPN transistor. It is a small signal amplifier using parallel tuned circuit as the load impedance. This parallel output tuned circuit is tuned to the incoming desired signal frequency. The output from the receiving antenna is 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 capacitors *i.e.* variable air capacitors in the input side and the output side of the RF amplifier are ganged together. 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. A de-coupling network consisting of resistor R_b and capacitor C_b is placed in the collector supply lead.

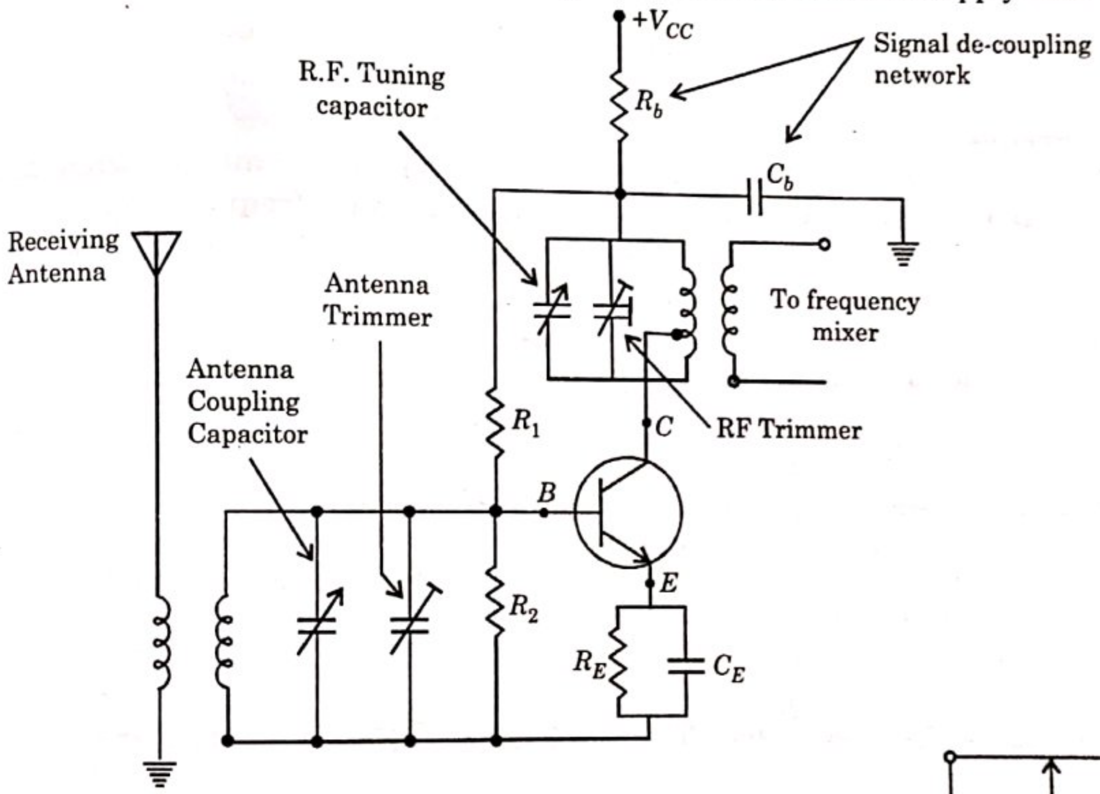


Fig. 9.10 *Circuit diagram of RF amplifier.*

The amplified R.F. signal developed across the collector tuned circuit is coupled through a step down transformer to the input of the frequency mixer. This step down transformer provides the impedance matching between the high impedance of the R.F. amplifier collector circuit and the low impedance of the base to emitter circuit of the following stage. Also the collector is connected to a suitable point on the primary of the output transformer so that load impedance to the collector is optimum.

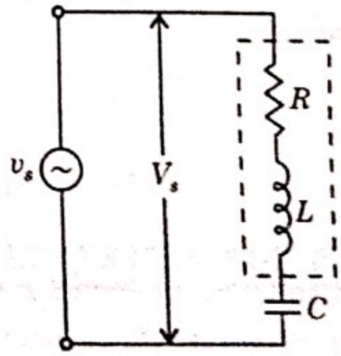


Fig. 9.11 *A series resonance circuit*

9.8 A SERIES RESONANCE CIRCUIT

As discussed in last article, in a series resonance circuit an inductor (L) and a capacitor (C) are connected in series across an ac source as shown in figure 9.11. The frequency of the supply source can be varied. At any given frequency f, the inductive reactance is given by case, the local oscillator should be capable of varying frequency in the range of 85 kHz to 1195 kHz. This gives a ratio of maximum to minimum frequency equal to 14:1. However, this ratio cannot be achieved by normal tunable capacitance. The capacitance of normal tunable capacitors may be varied in the ratio of maximum capacitance to minimum capacitance equal to 10 :1 which gives a maximum frequency ratio of 3.2 :1. This means that if the local oscillator frequency is kept lower than the signal frequency by an amount of 455 kHz, the normal tunable capacitors cannot be used.

On the other hand, if the local oscillator frequency is made larger than the incoming signal frequency by an amount of 455 kHz then the variation of the capacitance over the complete AM band would be from 995 kHz to 2105 kHz which gives a ratio of 2.2 : 1. This ratio can be easily achieved by using normal tunable capacitor. Thus, due to this reason, the superheterodyne receivers used for commercial broadcasting use local oscillator frequency which is higher than the incoming signal frequency which is higher than the incoming signal frequency by an amount equal to the intermediate frequency.

9.20 FREQUENCY MIXERS

A frequency mixer is a nonlinear device which produces a number of frequencies when two different frequencies are applied at the input of a mixer. In the frequency mixer shown schematically in figure 9.31, an incoming RF signal voltage of frequency f_s and a local oscillator voltage of frequency f_o are applied at its input. The frequency mixer uses a device which has non-linear dynamic characteristics. Due to this, the two input voltages beat together or heterodyne within the mixer to produce an output current which has components of frequency f_s, f_o, $mf_o \pm nf_s$, where m and n are integers. Out of all these terms, one of interest is the component of deference frequency $(f_o - f_s)$. This component is selected in the outside of mixer by a tuned circuit which is tuned to this difference frequency term. This difference frequency term $(f_o - f_s)$ is called **intermediate frequency (I.F.).**

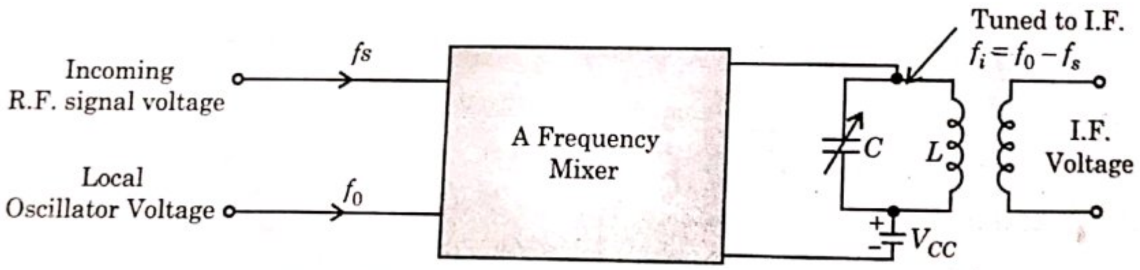


Fig. 9.31 *Schematic diagram of a frequency mixer.*

Thus every incoming RF signal voltage irrespective of its frequency is reduced to this standard intermediate frequency (455 kHz for AM). This means that it is essential that the local oscillator frequency f_o must be made to vary in such a manner so as to maintain the difference frequency $(f_o - f_s)$ which is always equal to the intermediate frequency f_i (455 kHz for AM).

9.20.1 Classification of Mixers

The mixers may be classified based on several factors, such as :

(i) The components being used

(ii) Switching mixers

(iii) According to the circuit arrangement

(iv) Frequency mixers

Classification according to the component used

According to the circuit arrangement, the mixers are classified into two categories as self excited mixers and separately excited mixer. In the self excited mixer, the same device acts as an oscillator as well as mixer whereas in the separately existed mixer, two devices are used, one each for the mixer and oscillator.

9.20.2 A Bipolar Junction Transistor (BJT) Mixer

The circuit diagram of a BJT mixer is shown in figure 9.32. The input signal $V_i = V_{m1} \sin\omega_L t$ is at a lower frequency than the other signal $V_{OSC} = V_{m2} \sin \omega_H t$. The low frequency signal is applied to the base and the oscillator signal is applied to the unbypassed emitter of the transistor.

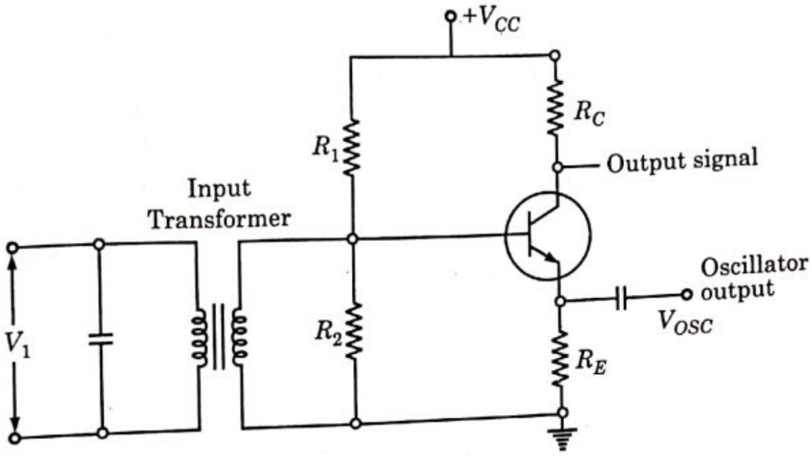


Fig. 9.32. *A transistor mixer*

Let $V_i = V_{m1}$ sing $\omega_L t$

and $V_{OSC} = V_{m2} \sin \omega_H t$

The output of the mixer is given by,

$$V_0 = V_i \times V_{OSC} = V_{m1} \sin \omega_L(t).V_{m2} \sin\omega_H t$$

$$V_0 = V_{m1}\, V_{m2} \times \frac{1}{2}[\cos (\omega_H + \omega_L)]\, t - \cos (\omega_H - \omega_L)]\, t] \qquad ...(9.18)$$

Thus, the output of the mixer consists of two frequency components. One of the components is at the sum frequency $(\omega_H + \omega_L)$ and the other one is the difference frequency $(\omega_H - \omega_L)$. The difference frequency is called as the **intermediate frequency** and it is selected by using a frequency selective network at the output of the mixer.

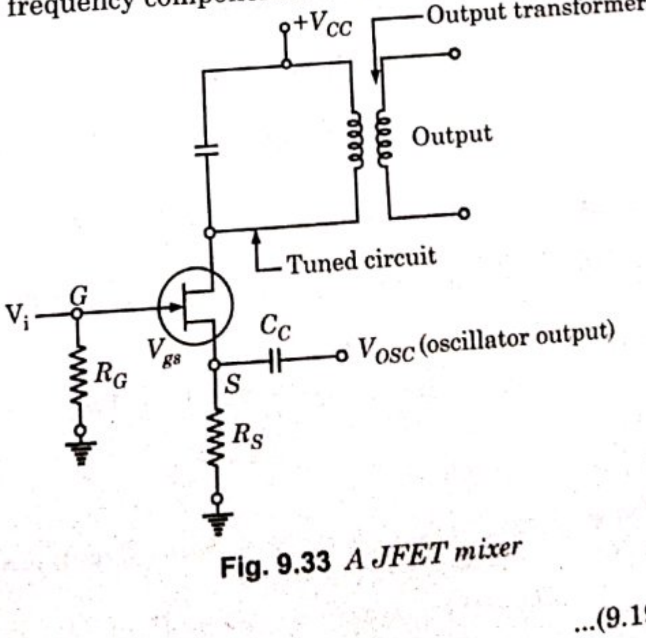


Fig. 9.33 *A JFET mixer*

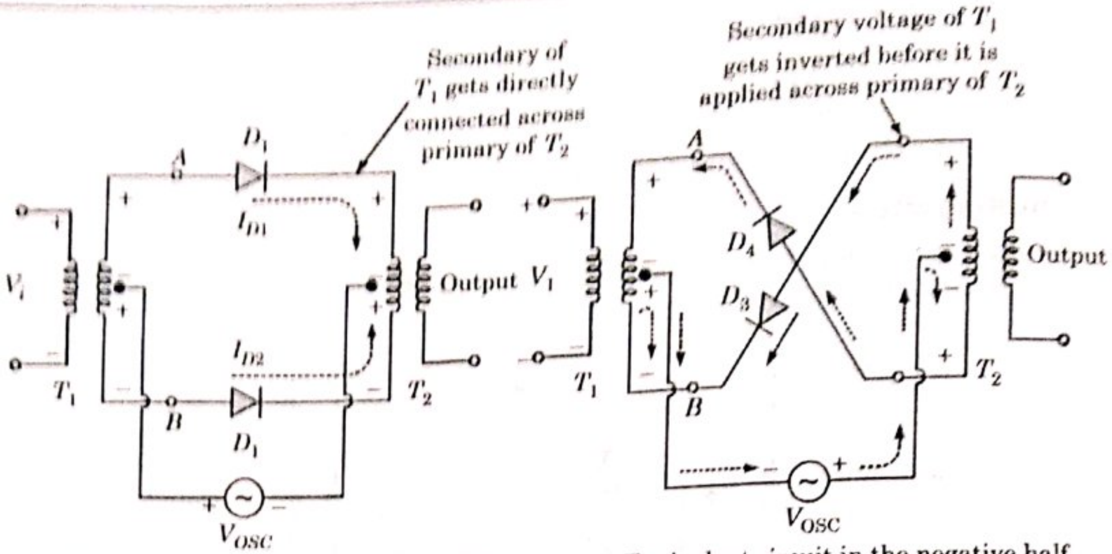
9.20.3 FET Mixer

The active device used for the FET mixer is the *N*-channel JFET. The JFET mixer is as shown in figure 9.33. The low frequency signal V_i is applied at the gate and the oscillator output is applied to the source through a coupling capacitor.

The drain current of the JFET is related to V_{GS} as under :

$$I_D = I_{DSS}\left[1 - \frac{V_{GS}}{V_P}\right]^2 \qquad ...(9.19)$$

where I_{DSS} = Maximum drain current



(a) Equivalent circuit in the positive half cycle of V_{OSC}

(b) Equivalent circuit in the negative half cycle of V_{OSC}

Fig. 9.38 *Equivalent circuits in the two half cycles of the oscillator voltage*

Types of mixer

The mixers can be of two types *i.e.* separately excited mixers or self excited mixers. The diode mixers are separately excited mixers, whereas mixer circuits using transistors, EFT or MOSFET are self excited. In self excited mixer, the same device acts as oscillator as well as mixer.

9.20.7 Conversion Transconductance

It will be recalled that the coefficient of non-linearity of most nonlinear resistance is rather low. Due to this, the IF output of the mixer will be very low. To increase the mixer output at IF, the oscillator voltage is made very large, 1 volt rms or more. It is said that the local oscillator "varies the bias" on the mixer from zero to cut-off, thus varying g_m and an IF output results. Like any other amplifying device a mixer has transconductance. However, since the output frequency is different from the input frequency, we define the **conversion transconductance** as under:

$$\text{Conversion transconductance, } g_c = \frac{\Delta i_p \text{ (output current at IF)}}{\Delta v_g \text{ (at the signal frequency)}}$$

The conversion transconductance of a transistorised mixer is lower than its transconductance g_m when it is being used as an amplifier.

9.20.8 Separately Excited Mixer

The circuit diagram of the separately excited mixer is as shown in figure 9.39. Here, the FET acts as a mixer and the bipolar transistor is connected in the oscillator circuit. The output of the transistorised Hartley oscillator is fed at the gate of the FET. This is at frequency f_0. The other input to the mixer is the receiver input signal at frequency f_s. This signal is applied to the source of the mixer FET. The tuning capacitors connected across the mixer and oscillator coils are ganged. The dotted line shows that their value can be changed by using a common tuning control. The variable capacitors C_{Tr} across each of the tuning capacitors are known as the **trimmer** capacitors. These are small value variable capacitors, which are used for the fine adjustments.

The double tuned transformer in the drain of FET is actually the first IF transformer (IFT). The output is taken across it as shown in the figure 9.39.

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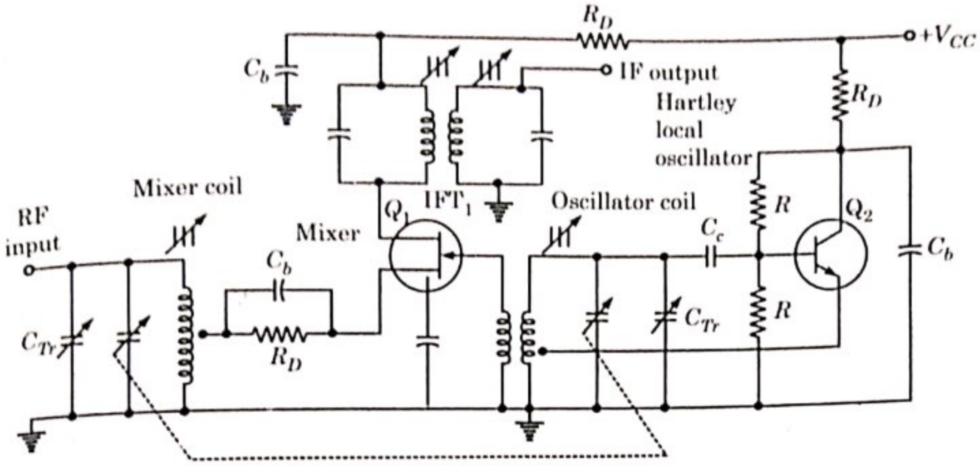

Fig. 9.39 *Separately excited mixer*

9.20.9 Self Excited Mixer

The circuit diagram of the self excited mixer has been shown in figure 9.40. The same circuit works as the mixer as well as the local oscillator. The self excited mixer is preferred over the separately excited mixer. It is extensively used in the domestic receivers. The same circuit oscillates, the transconductance of the transistor is varied nonlinearly at the local oscillator rate. This variable transconductance (g_m) is used by the transistor to amplify the incoming RF signal. Thus, two signals at different frequencies are applied to a nonlinear resistance. Therefore, the desired IF component will be produced at the output of the circuit.

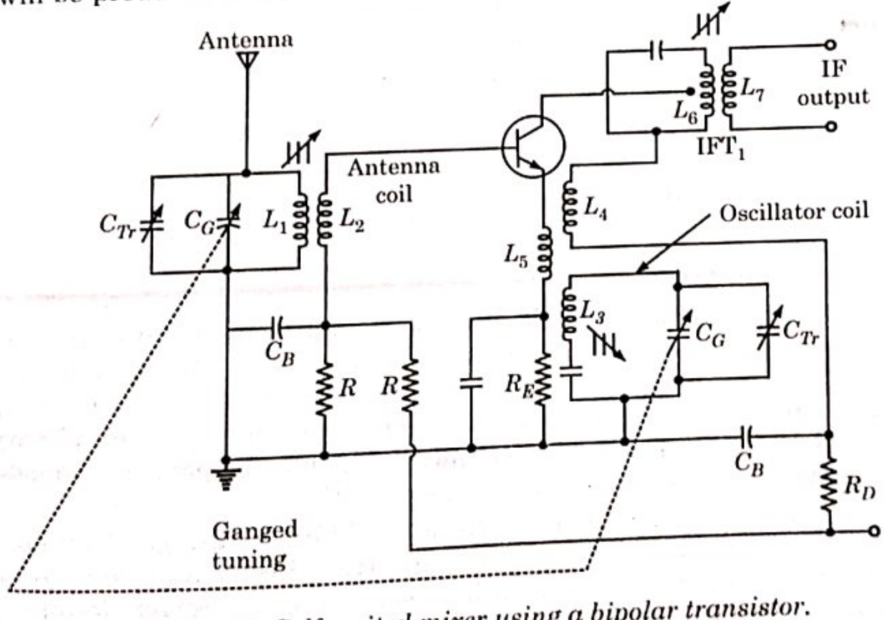

Fig. 9.40 *Self excited mixer using a bipolar transistor.*

EXAMPLE 9.7. A receiver is tuned to 3 – 30 MHz frequency range with IF frequency of 40.525 MHz.

(i) Find the range of local oscillator frequency and image frequency. It is an AM receiver with each channel occupying 10 kHz of bandwidth.

(ii) Draw frequency response of IF and AF amplifiers.

Solution: Given that Input frequency range : 3 to 30 MHz, IF = 40.525 MHz.

9.22 AUTOMATIC GAIN CONTROL (AGC) OR AUTOMATIC VOLUME CONTROL (AVC)

(Expected)

It is generally observed that as a result of fading, the amplitude of the I.F. carrier signal at the detector input may vary as much as 30 or 40 dB. This results in corresponding variations in general level of reproduced programme at the receiver output. At a carrier minimum, the loudspeaker output becomes inaudible and gets mixed in noise. On the other hand, at the carrier maximum, the output of the loudspeaker becomes intolerably large. The simplest and the most effective means adopted to balance the fading is the automatic gain control (AGC) or automatic volume control (AVC). Infact, this is universally used in all broadcast and radio receivers. It has been observed that a properly designed AGC system reduces the amplitude variation due to fading from a high value of 30 to 40 dB to a small value of 3 to 4 dB.

Principle of Automatic Gain Control (AGC)

The principle of operation of AGC contains the following steps :

(*i*) to derive by rectification of carrier voltage in a linear diode detector, a d.c. voltage proportional to the carrier amplitude.

(*ii*) to apply this d.c. voltage as a reverse-biased voltage at the input of the R.F. amplifier, frequency mixer and the I.F. amplifier.

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Thus, now if the carrier signal amplitude increases, the AGC bias increases and the gains of all the tuned stages preceding the detector decrease resulting in decrease in carrier amplitude at the input of the detector bringing it back to its original or normal value. Now, if the carrier amplitude decreases due to some reason, then the reverse action takes place. Hence, the AGC smoothens out the variations in the carrier amplitude to a very large extent.

9.22.1 Linear Diode Detector with Capacitor Filter and Simple AGC

Figure 9.43 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. Capacitor C filters the R.F. components due to which only the d.c. and the modulating 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. AGC is picked up from the diode end of the load resistor R. But, since this voltage consists of modulating frequency component as well, therefore an AGC filter consisting of a series resistor R_A and shunt capacitor C_A is used to remove the modulating or baseband frequency component and thus leaving only a positive d.c. voltage as the required AGC bias.

The time-constant of this AGC filter is suitable selected to remove all modulating frequency components. This time-constant R_AC_A must be large enough to remove even the lowest modulating frequency component from the AGC bias. However, AGC must be on the other hand, small enough to enable the AGC bias to follow the change in carrier amplitude. A typical time-constant of AGC filter is in the range of 0.1 to 0.2 second. Now, this positive AGC bias is applied at the base of PNP transistors of preceding tuned stages. This positive AGC bias then reduces the net forward bias at emitter junction thereby reducing the gain of the amplifier. However, in case of NPN transistors, a negative AGC bias is applied at the bases of the transistors of preceding tuned stages. In this case, the detector circuit is similar to that shown in figure 9.44. except that the polarity of the diode is reversed.

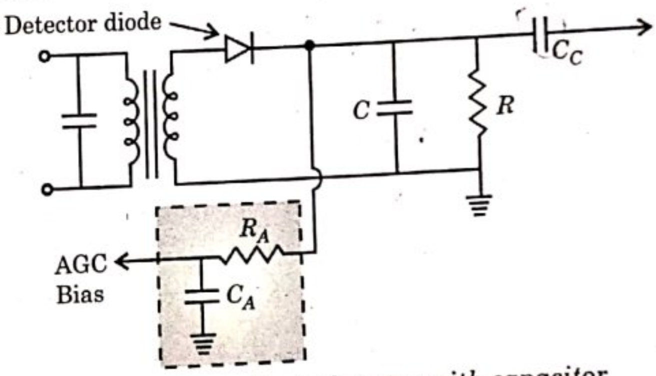

Fig. 9.43 *Linear diode detector with capacitor filter and simple AGC.*

9.23 LINEAR DIODE DETECTOR WITH π-FILTER AND SIMPLE AGC

To provide the better removal of R.F. components from the modulating frequency output, a π-filter is used in place of a simple capacitor filter. Figure 9.45 shows the circuit diagram 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 the figure.

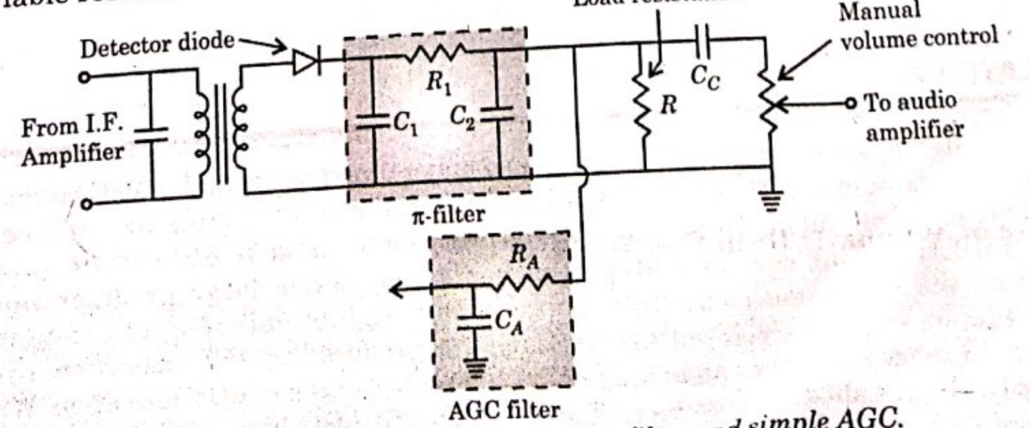

Fig. 9.45 *Linear diode detector with π-filter and simple AGC.*

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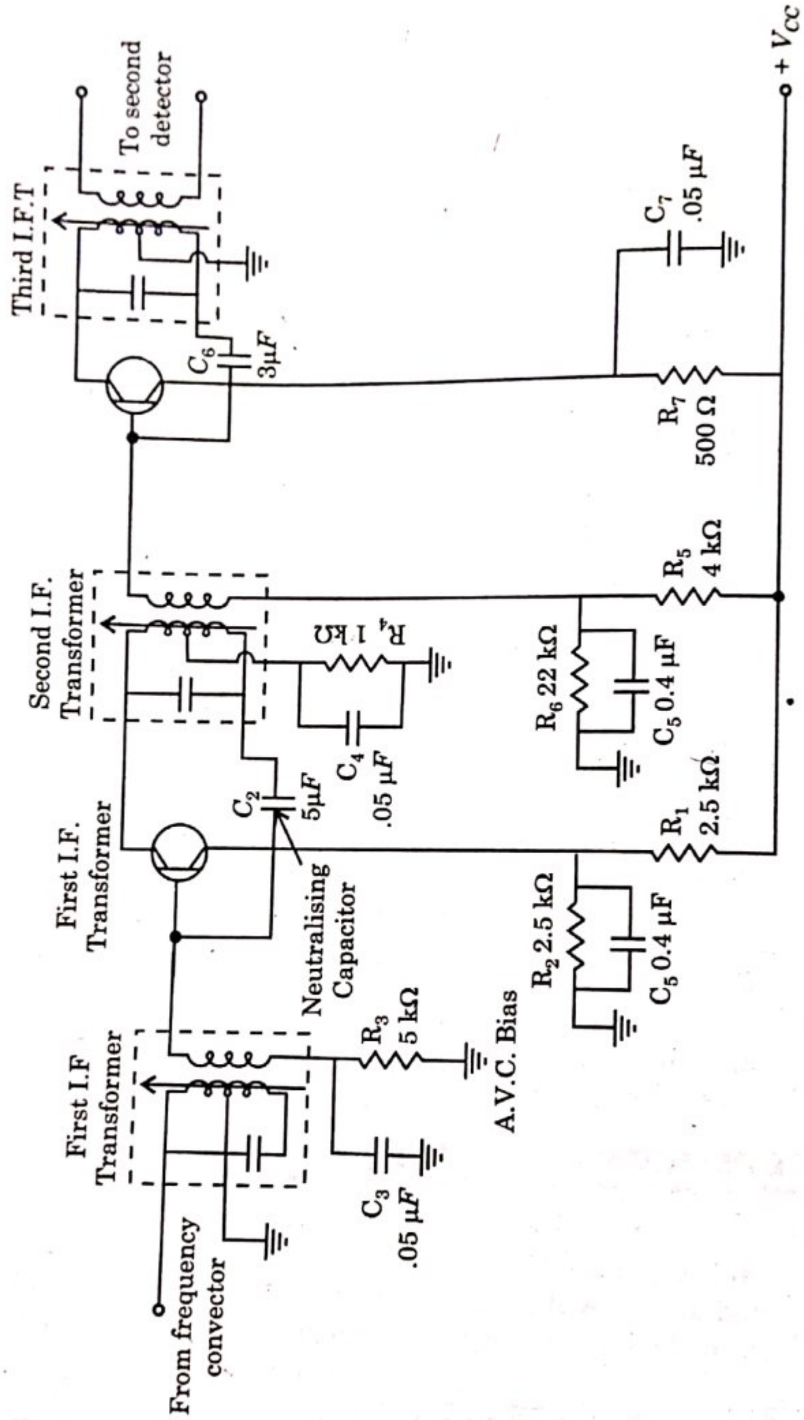

Fig. 9.44 *Two-stage transistorized I.F. amplifier.*

9.24 DELAYED AGC

Simple AGC systems discussed till now suffer from a major drawback that the AGC becomes operative even for very week signals. The result of this is that the receiver gain starts falling as soon as detector diode starts producing the output. On the other hand, an ideal AGC system must remain in operative until the input carrier voltage reaches a reasonable large predetermined voltage. Subsequently, the AGC must come into operation to maintain output level constant instead of variation in input level of carrier voltage. If a delay is produced in AGC operation, then it serves some purpose. Figure 9.46 shows an arrangement to produce delay in AGC operation. With zero and small signal voltages, diode D_2 conducts due to which the AGC bias just equals the potential of

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cathode of this diode. Hence AGC remains fixed at a low positive value. As the input carrier voltage increases, the AGC bias produced due to rectification of carrier voltage in detector diode D_1 increases. Also, when this rectified bias magnitude exceeds the magnitude of the positive cathode voltage of diode D_2, then diode D_2 stops to conduct and the AGC system works normally.

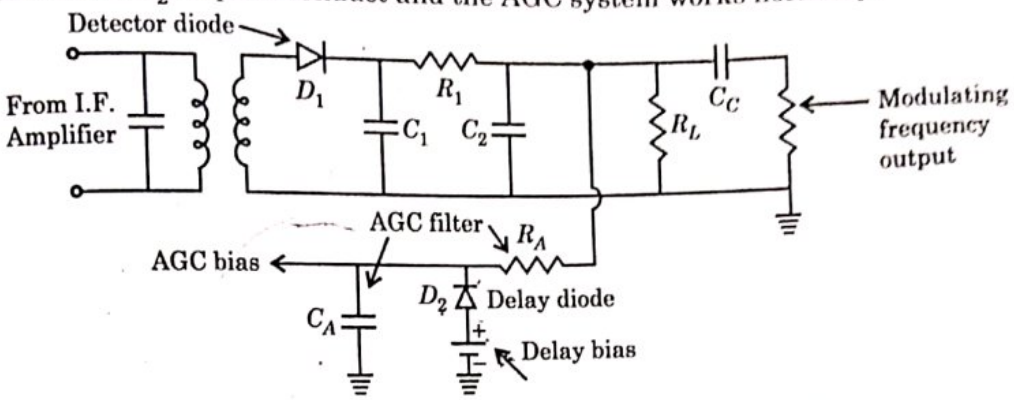

Fig. 9.46 *Linear diode detector with delayed AGC.*

9.25 AMPLIFIED AND DELAYED AGC

Going one step further, if the delayed AGC bias is amplified before application as reverse bias to the tuned amplifiers, the AGC behaviour or characteristics closely approaches the ideal delayed AGC.

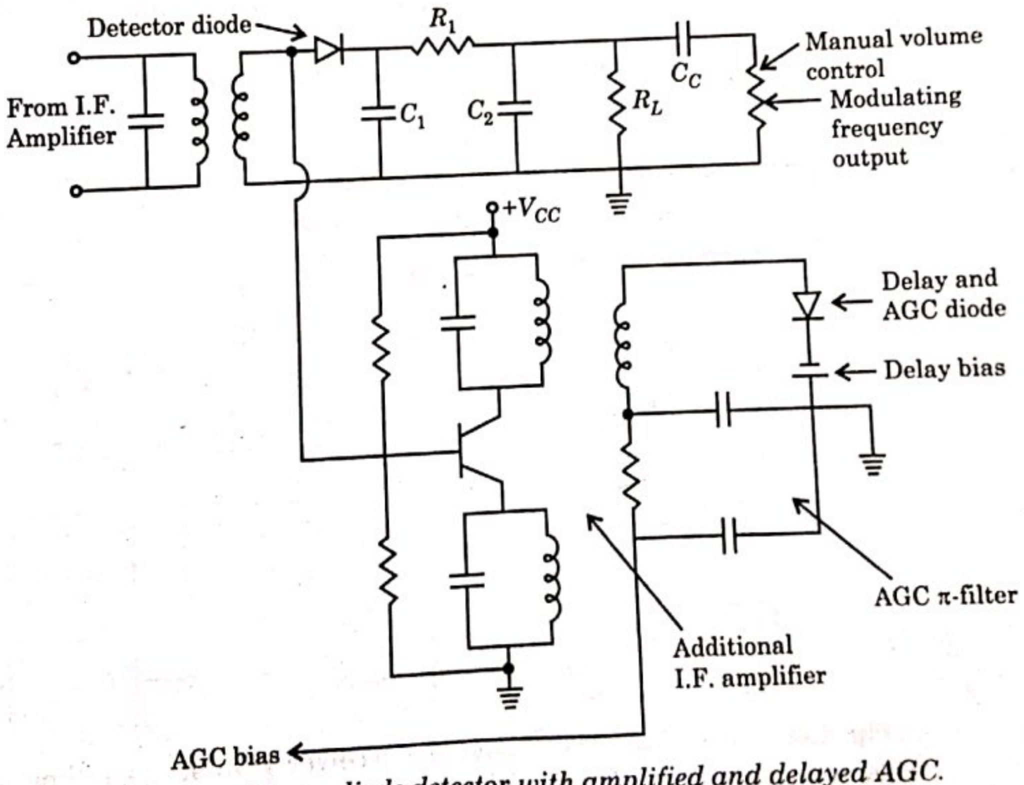

Fig. 9.47. *Linear diode detector with amplified and delayed AGC.*

9.26 AGC CHARACTERISTICS

The AGC characteristic *i.e.* the curve giving audio output of receiver plotted against input carrier voltage is shown in figure 9.48 for different cases.

Simple AGC is given by the curve *S* whereas an ideal AGC is represented by the curve ID.

The curve PD gives the AGC characteristics of delayed AGC and the curve AD gives the amplified and delayed AGC characteristics.

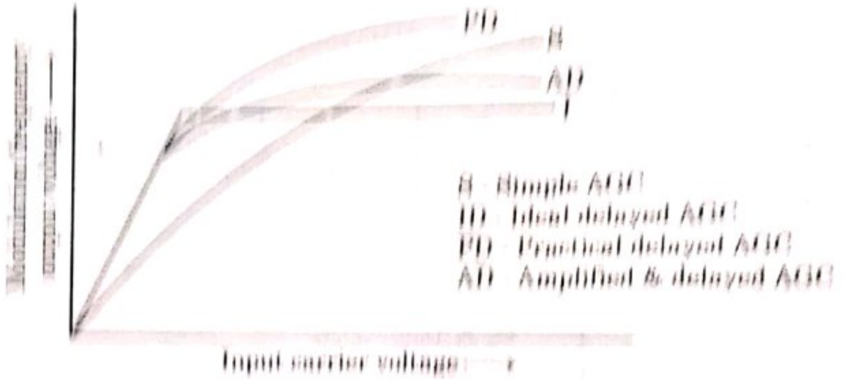

Fig. 9.48. *AGC Characteristics.*

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