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CO4: AM Transmitters and Receivers

AM Transmitters

1. Carrier frequency requirements in Radio Transmitters.

There are three major requirements of a radio transmitter for choosing the carrier frequency.

(a) The 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 to avoid sidebands of station completely or partially overlapping in frequency spectrum, the sidebands of any other radio station. The carrier frequency is determined by the master oscillator frequency. The frequency generated by master oscillator may adjusted to any desired value by suitable selection of frequency determining components in the tank circuit of master oscillator.

(b) Carrier frequency should be readily adjustable: Most of the radio transmitters are crystal controlled master oscillator in which case the carrier frequency cannot be readily changed. 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.

(c) 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 ± 20 Hz for medium wave transmitters and ± 0.002% for short wave and UHF transmitters. By frequency scintillation means abrupt changes in frequency caused mostly by abrupt variations in load.

2. **AM Transmitters:** Transmitters that transmit AM signals are known as AM transmitters. These transmitters are used in medium wave (MW) and short wave (SW) frequency bands for AM broadcast. The MW band has frequencies between 550 KHz and 1650 KHz, and the SW band has frequencies ranging from 3 MHz to 30 MHz. The two types of AM transmitters that are used based on their transmitting powers are:

- High Level
- Low Level

High level transmitters use high-level modulation, and low-level transmitters use low level modulation. The choice between the two modulation schemes depends on the transmitting power of the AM transmitter.

- In broadcast transmitters, where the transmitting power may be of the order of kilowatts, high level modulation is employed.
- In low power transmitters, where only a few watts of transmitting power are required, low level modulation is used.

2.1 Low-Level Transmitters: Fig.1 shows a block diagram for a low-level AM transmitter. The function of each block is illustrated below.

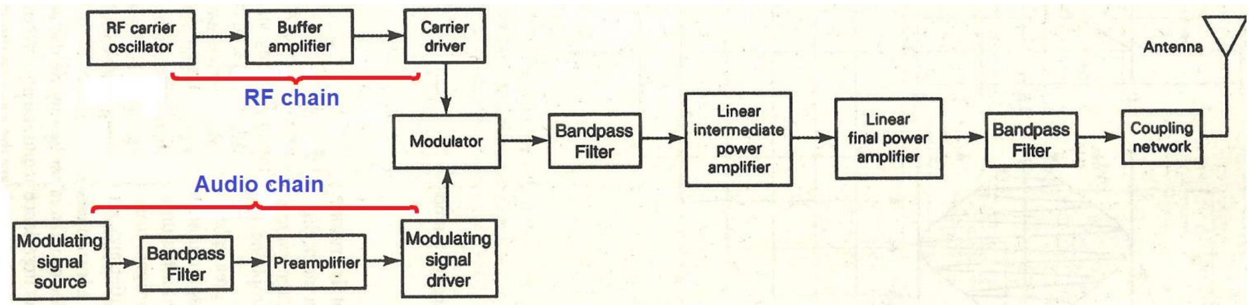


Fig1. Low level AM transmitter.

Audio Chain: For voice or music transmission, the source of the modulating signal is generally an acoustical transducer, such as a micro-phone, a magnetic tape, a CD, or a phonograph record.

(a) Pre-amplifier: The preamplifier is typically a sensitive, class-A linear voltage amplifier with a high input impedance.

(b) Driver amplifier: The driver amplifier for modulating signal is also a linear amplifier that simply amplifies the information signal to an adequate level to sufficiently drive the modulator. More than one driver amplifier may be required.

RF Chain: The Radio Frequency chain consists of carrier oscillator, isolated buffer amplifier and carrier driver.

(a) Carrier oscillator: The carrier oscillator generates the carrier signal, which lies in the RF range. The frequency of the carrier is always very high. Because it is very difficult to generate high frequencies with good frequency stability, the carrier oscillator generates a sub multiple with the required carrier frequency. This sub multiple frequency is multiplied by the frequency multiplier stage to get the required carrier frequency. Further, a crystal oscillator can be used in this stage to generate a low frequency carrier with the best frequency stability. The frequency multiplier stage then increases the frequency of the carrier to its required value.

(b) Buffer Amplifier: The purpose of the buffer amplifier is twofold. It first matches the output impedance of the carrier oscillator with the input impedance of the frequency multiplier, the next stage of the carrier oscillator. It then isolates the carrier oscillator and frequency multiplier. This is required so that the multiplier does not draw a large current from the carrier oscillator. If this occurs, the frequency of the carrier oscillator will not remain stable. Emitter followers or integrated-circuit op-amps are often used for the buffer.

Modulators: Various kind of modulation techniques are implemented in this block. The modulator can use either emitter or collector modulation.

Power Amplifiers: The intermediate and final power amplifiers are either linear class-A or class-B push-pull modulators. This is required with low-level transmitters to maintain symmetry in the AM envelope.

Coupling Network: The output stage of the modulated power amplifier feeds the signal to the transmitting antenna. To transfer maximum power from the output stage to the antenna it is necessary that the impedance of the two sections match. For this, a matching network is required. The matching between the two should be perfect at all transmitting frequencies.

2.2 High-Level and Low-Level Transmitters: Fig.2 shows the block diagram for a high-level AM transmitter.

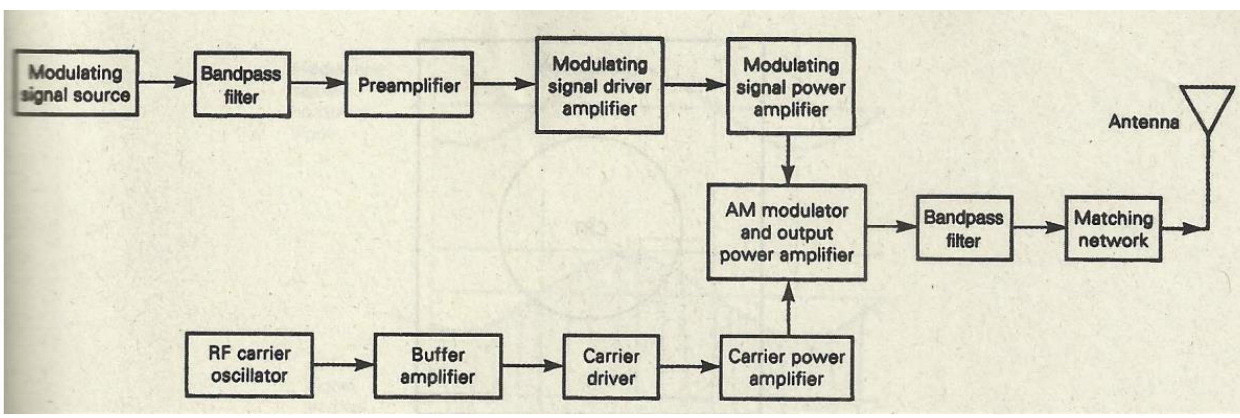


Fig2. High-Level AM Transmitters

The modulating signal is processed in the same manner as in the low-level transmitter except for the addition of a power amplifier. With high level transmitters, the power of modulating signal must be considerably higher than is necessary with low level transmitters. This is because the carrier is at full power at the point in the transmitter where modulation occurs and, consequently, requires a high amplitude modulating signal to produce 100% modulation.

The carrier oscillator, its associated buffer, and the carrier driver are also essentially the same circuits used in low level transmitters. However, with high-level transmitters, the RF carrier and audio signals undergo additional power amplification prior to the modulator stage. Consequently, the modulator is generally a drain-, plate-, or collector-modulated class-C amplifier.

With high level transmitters, the modulator circuit has three primary functions. It provides the circuitry necessary for modulation occurs, it is the final power amplifier (class-C for efficiency), and it is a frequency translator (translates the low-frequency intelligence signals to radio frequency (RF)) that can be effectively radiated from an antenna and propagated through free space.

Differences between Low-level and High level AM Transmission

Parameter	Low-level AM Transmission	High level AM Transmission
Power level	Modulation takes place at high power level	Modulation takes place at low power level
Types of amplifier	Highly efficient class c amplifiers are used.	Linear amplifiers are used after modulation
Efficiency	Very high	Lower than high level modulators
Devices used	Vacuum tubes or transistor for medium power applications	Transistors, JFET, OP-AMPs
Design of AF power amplifier	Complex due to very high power involved	Easy as it is to be done at low power
Applications	High power broadcast transmitters	Sometimes used in TV transmitters (IF modulation).

3. Differentiate between AM and FM broadcasting.

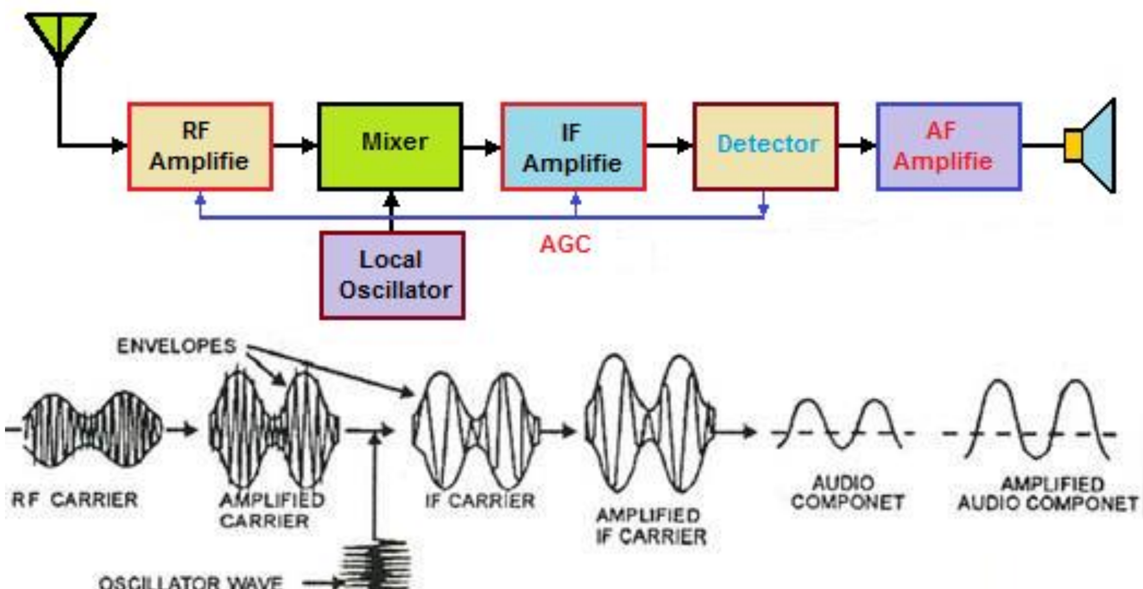
S. No.	AM Broadcasting	FM Broadcasting
1.	It requires smaller transmission bandwidth	It requires larger bandwidth.
2.	It can be operated in low, medium and high frequency bands.	It needs to be operted in very high and high frequency bands.
3.	It has wider coverage.	Its range is restricted to 50 km.
4.	The demodulation is simple.	The process of demodulation is complex.
5.	The stereophonic transmission is not possible.	In this, stereophonic transmission is possible.
6.	The system has poor noise performance.	It has an improved noise performance.
7.	The AM signal reception does not have any threshold in the useful range of signal noise ratio (SNR).	The FM signal recepition exhibits a three the useful range of signal noise ratio.

AM Receivers:

AM Superheterodyne Receivers:

1.0 Introduction: The superheterodyne receiver is one of the most popular forms of receiver in use today in a variety of applications from broadcast receivers to two way radio communications links as well as many mobile radio communications systems.

1.1 Basic superheterodyne block diagram and functionality: The basic block diagram of a basic superheterodyne receiver is shown below. This details the most basic form of the receiver and serves to illustrate the basic blocks and their function.



Block diagram of a basic superheterodyne radio receiver

The Function of each block is illustrated briefly as below

(a) RF Section (*Front end amplifier and tuning block*): The RF signal received through antenna and fed to the RF section. This circuit block performs two main functions:

(i) <u>Tuning:</u> Broadband tuning is applied to the RF stage. The purpose of this stage is to reject the signals on the image frequency and accept those on the wanted frequency. It must also be able to track the local oscillator so that as the receiver is tuned, so the RF tuning remains on the required frequency. Typically, the selectivity provided at this stage is not high. Its main purpose is to reject signals on the image frequency which is at a frequency equal to twice that of the IF away from the wanted frequency. As the tuning within this block provides all the rejection for the image response, it must be at a sufficiently sharp to reduce the image to an acceptable level. However the RF tuning may also help in preventing strong off-channel signals from entering the receiver and overloading elements of the receiver, in particular the mixer or possibly even the RF amplifier.

(ii) <u>Amplification:</u> In terms of amplification, the level is carefully chosen so that it does not overload the mixer when strong signals are present, but enables the signals to be amplified sufficiently to ensure a good signal to noise ratio is achieved. The amplifier must also be a low noise design. Any noise introduced in this block will be amplified later in the receiver.

(b) Mixer / frequency translator block: The tuned and amplified signal then enters one port of the mixer. The local oscillator signal enters the other port. The performance of the mixer is crucial to many elements of the overall receiver performance. It should eb as linear as possible. If not, then spurious signals will be generated and these may appear as 'phantom' received signals.

(c) Local oscillator: The local oscillator may consist of a variable frequency oscillator that can be tuned by altering the setting on a variable capacitor. Alternatively it may be a frequency synthesizer that will enable greater levels of stability and setting accuracy.

(d) Intermediate frequency amplifier, IF block : Once the signals leave the mixer they enter the IF stages. These stages contain most of the amplification in the receiver as well as the filtering that enables signals on one frequency to be separated from those on the next. Filters may consist simply of LC tuned transformers providing inter-stage coupling, or they may be much higher performance ceramic or even crystal filters, dependent upon what is required.

(e) Detector / demodulator stage: Once the signals have passed through the IF stages of the superheterodyne receiver, they need to be demodulated. Different demodulators are required for different types of transmission, and as a result some receivers may have a variety of demodulators that can be switched in to accommodate the different types of transmission that are to be encountered. Different demodulators used may include:

(f) <u>AM diode (envelope) detector:</u> This is the most basic form of detector and this circuit block would simple consist of a diode and possibly a small capacitor to remove any remaining RF. The detector is cheap and its performance is adequate, requiring a sufficient voltage to overcome the diode forward drop. It is also not particularly linear, and finally it is subject to the effects of selective fading that can be apparent, especially on the HF bands.

(g) <u>Synchronous AM detector:</u> This form of AM detector block is used in where improved performance is needed. It mixes the incoming AM signal with another on the same frequency as the carrier. This second signal can be developed by passing the whole signal through a squaring amplifier. The advantages of the synchronous AM detector are that it provides a far more linear demodulation performance and it is far less subject to the problems of selective fading.

(h) <u>SSB product detector:</u> The SSB product detector block consists of a mixer and a local oscillator, often termed a beat frequency oscillator, BFO or carrier insertion oscillator, CIO. This form of detector is used for Morse code transmissions where the BFO is used to create an audible tone in line with the on-off keying of the transmitted carrier. Without this the carrier without modulation is difficult to detect. For SSB, the CIO re-inserts the carrier to make the modulation comprehensible.

<u>(i) AGC:</u> An important part of superheterodyne receiver is Automatic gain control (AGC) which is given to the RF, IF and mixer stages in order to generate constant output irrespective of the varying input signal.

<u>(j) Audio amplifier:</u> The output from the demodulator is the recovered audio. This is passed into the audio stages where they are amplified and presented to the headphones or loudspeaker Further developments for superheterodyne block diagram

The diagram above shows a very basic version of the superheterodyne receiver. Many sets these days are far more complicated. Some superheterodyne radios have more than one frequency conversion, and other areas of additional circuitry to provide the required levels of performance. However the basic superheterodyne concept remains the same, using the idea of mixing the incoming signal with a locally generated oscillation to convert the signals to a new frequency.

AGC: Automatic gain control (AGC) is a mechanism wherein the overall gain of the radio receiver is automatically varied according to the changing strength of the received signal. AGC is used to maintain the output at a constant level.

If the gain is not varied as per the input signal, consider a stronger input signal, then the signal might probably be distorted with some of the amplifiers reaching saturation level.

AGC is applied to the RF, IF and mixer stages, which also helps in improving the dynamic range of the receiver antenna to 60-100 dB by adjusting the gain of the various stages in the radio receiver as shown below:

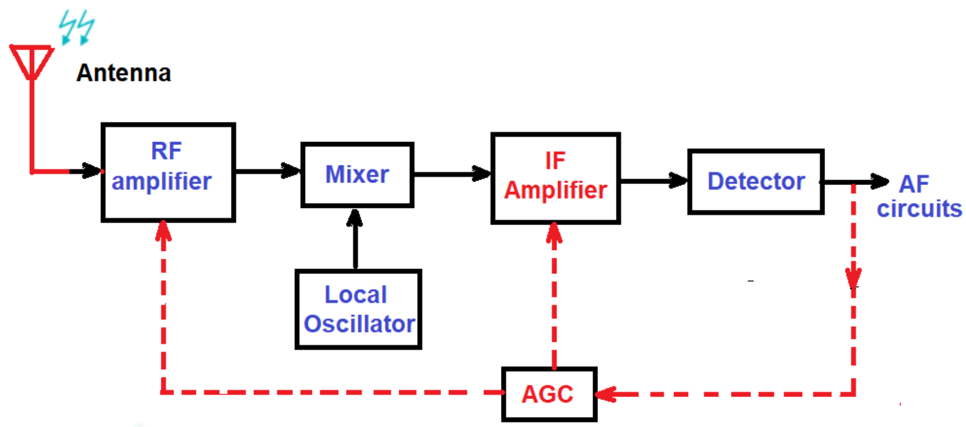


Fig. The block diagram of AGC process

- The AGC derives dc bias voltage from the part of the detected signal to apply to the RF, IF and mixer stages to control their gains. The transconductance and hence the gain of the devices used in these stages of the receiver depends on the applied bias voltage or current.
- When the overall signal level increases, the value of the applied AGC bias increase leading to the decrease in the gain of the controlled stages.
- When there is no signal or signal with low value, there is minimum AGC bias which results in amplifier generating maximum gain.
- AGC facilitates tuning to varying signal strength stations providing a constant output.
- AGC smoothens the amplitude variations of the input signal and the gain control does not have to be recalibrated every time the receiver is tuned from station to station.
- An AGC which is not designed correctly can lead to considerable distortion to a smooth signal.

Performance metrics for Radio Receiver

(a) Sensitivity of a radio receiver:

The sensitivity of a radio receiver is expressed in terms of voltage or power that must be applied to the receiver expressed in terms of voltage or power that must be applied to the receiver input to give a standard output. In the case of AM the receivers the definition of sensitivity has been standardized as the amplitude of the carrier voltage modulated with 30% at 400 Hz. The signal is applied to the receiver input terminals through a standard artificial antenna will develop an output of 0.5 watts in a resistance load of appropriate value simulated for a loud speaker. The sensitivity of a radio receiver often expressed in microwatt or decibels below one volt, and is measured at three different points along the tuning range.

(b) Selectivity of a radio receiver.

The selectivity of a receiver is its ability to reject unwanted (adjacent) signals. It is expressed as a curve, such as the one of figure which shows the attenuation that the receiver offers to signals at frequencies near to the one to which it is tuned.

Selectivity is measured at the end of a sensitivity test with conditions are same as for sensitivity, except that now the frequency of the generator is varied to either side of this frequency to which the receiver is tuned. The output of the receiver naturally falls, since the input frequency is now 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 which the generator is tuned to the receiver’s frequency is calculated at a number of points and then plotted in decibels to give the curve as shown in figure. Looking at this curve, we see that, for example, at 20 KHz below the receiver tuned frequency, an interfering signal would have to be 60 dB greater than the wanted signal to come out with the same amplitude.

Selectivity is determined by the response of the IF section with the mixer and RF amplifier input circuits playing a small but significant part. It should be noted that it is selectivity that determines the adjacent-channel rejection of a receiver.

(c) Fidelity of a radio receiver:

The important characteristic of a receiver is fidelity. Fidelity gives the information that how faithful a radio receiver can reproduce the original signal. Fidelity is the manner in which the output of a radio receiver depends on the modulation frequency.

The fidelity of a receiver is determined with the help of the arrangement shown in Figure. The carrier frequencies of the signal generator is adjusted to tuned frequency of the receiver. The signal generator carrier level is set at convenient arbitrarily level, and the manual value control is adjusted to give the standard test output. The modulation frequency is then varied over the audio range, while keeping the degree of modulation constant.

Intermediate frequency for a radio receiver.

Choosing a suitable intermediate frequency is a matter of compromise. The lower the IF used, the easier it is to achieve a narrow bandwidth to obtain good selectivity in the receiver and the greater the IF stage gain. On the other hand, the higher the IF, the further removed is the image frequency from the signal frequency and hence the better the image rejection. The choice of IF is also affected by the selectivity of the RF end of the receiver. If the receiver has a number of RF stages, it is better able to reject an image signal close to the signal frequency and hence a lower IF channel can be tolerated.

Another factor to be considered is the maximum operating frequency the receiver. Assuming Q to be reasonably constant, bandwidth of a tuned circuit is directly proportional to its resonant frequency and hence, the receiver has its widest RF bandwidth and poorest image rejection at the highest frequency end of its tuning range.

A number of other factors that influence the choice of the intermediate frequency:

1. The frequency should be free from radio interference. Standard intermediate frequencies have been established and these are kept near signal channel allocation. If possible, one of these standard frequencies should be used.
2. An intermediate frequency which is close to some part of the tuning range of the receiver is avoided as this leads to instability when the receiver is tuned near the frequency of the IF channel.
3. Ideally, low order harmonics of the intermediate frequency (particularly second and third order) should not fall within the tuning range of the receiver. This requirement cannot always be achieved resulting in possible heterodyne whistles at certain spots within the tuning range.
4. Sometimes, quite a high intermediate frequency is chosen because the channel must pass very wide band signals such as those modulated by 5 MHz video used in television. In this case the wide bandwidth circuits are difficult to achieve unless quite high frequencies are used.

5. For the reasons outlined above, the intermediate frequency is normally lower than the RF or signal frequency. However, there we some applications, such as in tuning the Low Frequency (LF) band, where this situation could be reversed. In this case, there are difficulties in making the local oscillator track with the signal circuits.

Superheterodyne FM Radio Receiver:

The block diagram of an FM receiver is illustrated in Figure . The RF amplifier amplifies the received signal intercepted by the antenna. The amplified signal is then applied to the mixer stage. The second input of the mixer comes from the local oscillator. The two input frequencies of the mixer generate an IF signal of 10.7 MHz. This signal is then amplified by the IF amplifier.

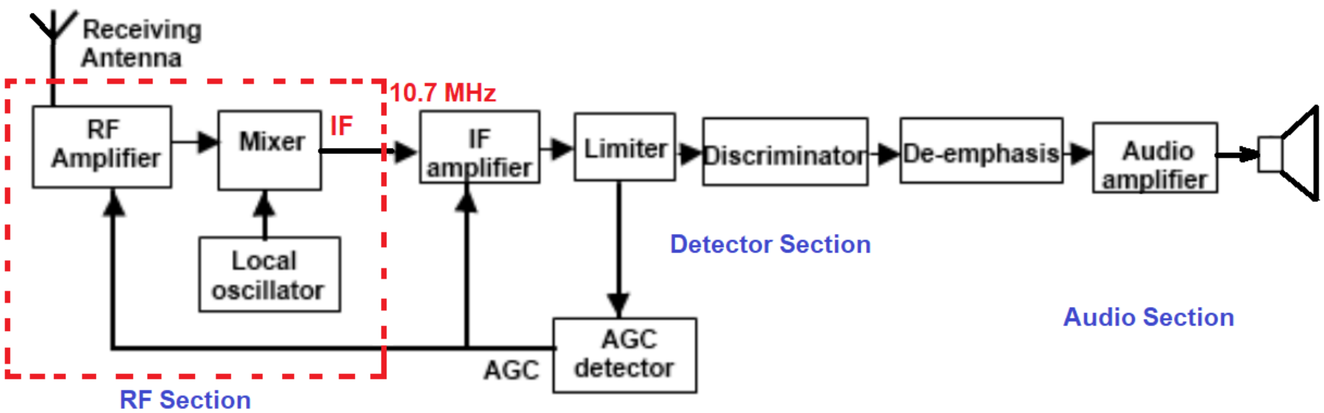


Fig. Block diagram of superheterodyne FM Receiver

The output of the IF amplifier is applied to the limiter circuit. The limiter removes the noise in the received signal and gives a constant amplitude signal. This circuit is required when a phase discriminator is used to demodulate an FM signal.

The output of the limiter is now applied to the FM discriminator, which recovers the modulating signal. However, this signal is still not the original modulating signal. Before applying it to the audio amplifier stages, it is de-emphasized. De-emphasizing attenuates the higher frequencies to bring them back to their original amplitudes as these are boosted or emphasized before transmission. The output of the de-emphasized stage is the audio signal, which is then applied to the audio stages and finally to the speaker.

It should be noted that a limiter circuit is required with the FM discriminators. If the demodulator stage uses a ratio detector instead of the discriminator, then a limiter is not required. This is because the ratio detector limits the amplitude of the received signal. In Figure (a) a dotted block that covers the limiter and the discriminator is marked as the ratio detector.

In FM receivers, generally, AGC is not required because the amplitude of the carrier is kept constant by the limiter circuit. Therefore, the input to the audio stages controls amplitudes and there are no erratic changes the volume level. However, AGC may be provided using an AGC detector. This generates a dc voltage to control the gains of the RF and IF amplifier.