PHY 359 2.0 / ASP 487 2.0
Telecommunication

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AM and FM Radio Receivers

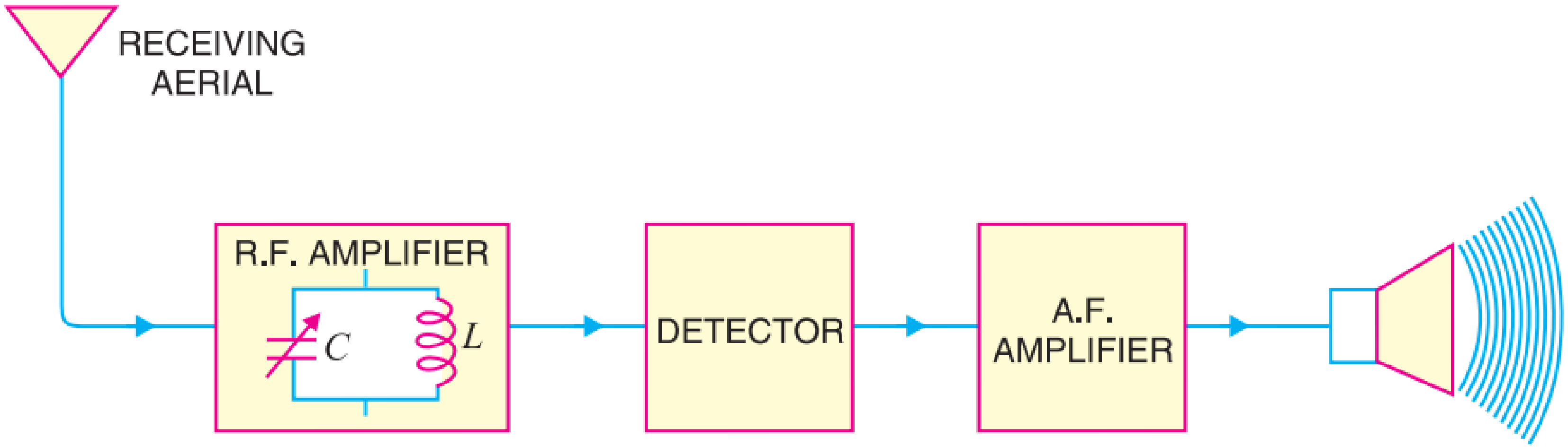
A.M. Radio Receivers

To reproduce the A.M. wave into sound waves, every radio receiver must perform the following functions:

(i) The receiving aerial must intercept a portion of the passing radio waves.
(ii) The radio receiver must select the desired radio wave from several radio waves intercepted by the receiving aerial. For this purpose, tuned parallel LC circuits must be used. These circuits will select only the radio frequency resonating with them.
(iii) The tuned frequency amplifiers must amplify the selected radio wave.
(iv) The audio signal must be recovered from the amplified radio wave.
(v) The audio signal must be amplified by a suitable number of audio amplifiers.
(vi) The amplified audio signal should be fed to the speaker for sound reproduction.

Types of A.M. Radio Receivers

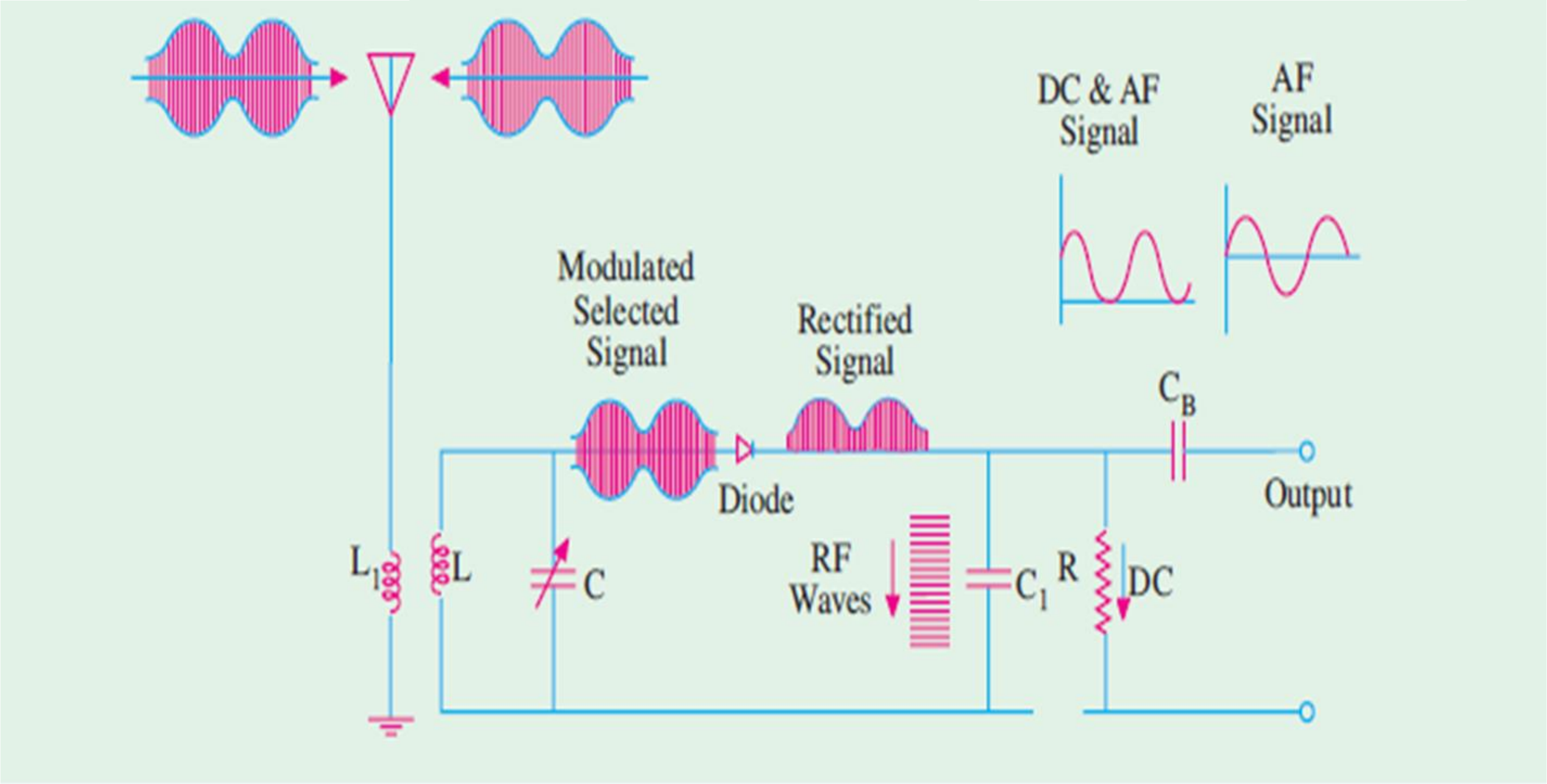
1. Straight radio receiver.



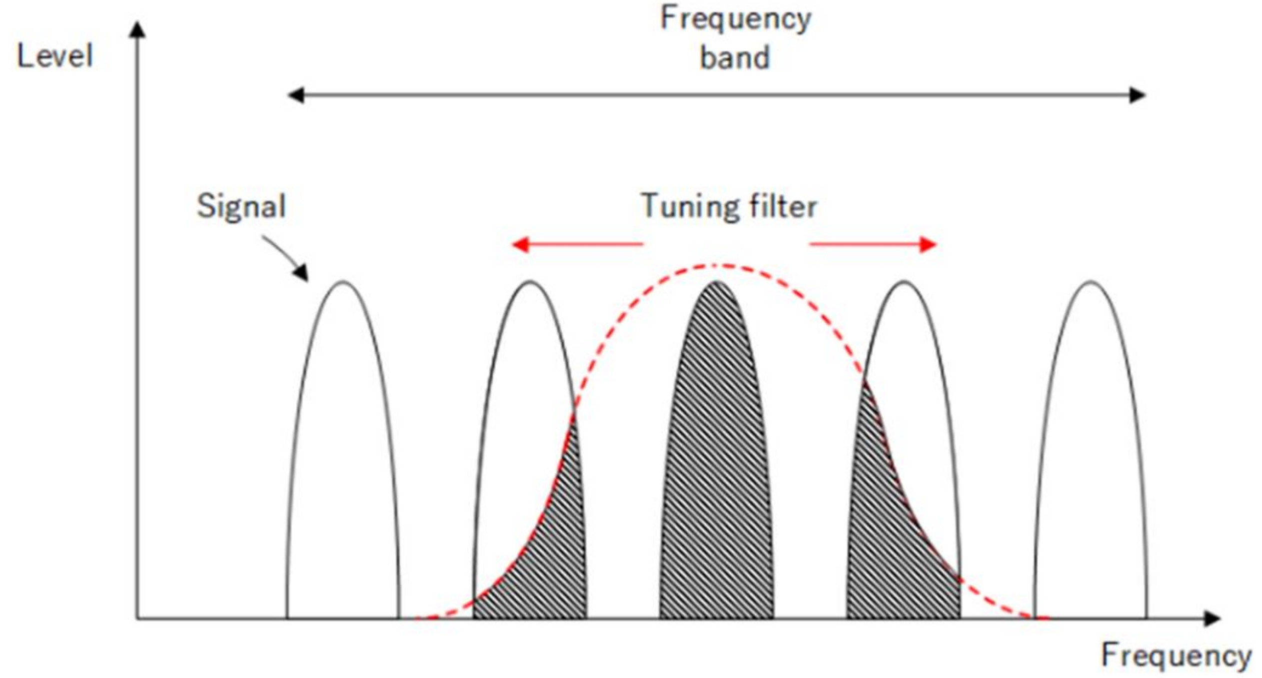
Types of A.M. Radio Receivers

AM broadcast
535 kHz to 1605 kHz

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$



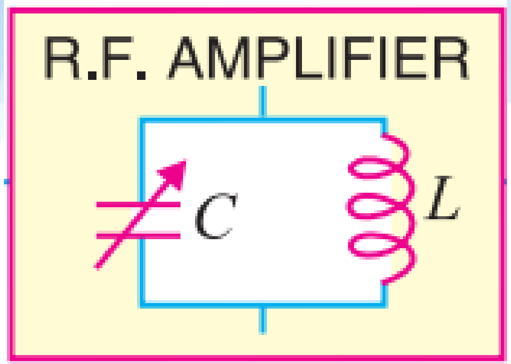
Types of A.M. Radio Receivers



Example: Consider the variable capacitor range of the receiver varying from 15pf to 65pf and the inductance value of the RF tune circuit inductor is 10mH. The RF filter capacitor and resistance values are 100 pf and 120 kΩ respectively.

1. Calculate the minimum and maximum frequency that the tuned circuit of this radio can respond to.
2. Calculate the cutoff frequency of the RF filter.
3. Comment on the suitable cutoff frequency for this radio receiver.

RF tune circuit



Minimum and Maximum Frequency of the Tuned Circuit:
The tuned circuit is an LC circuit with variable capacitance ranging from 15 pF to 65 pF and an inductance of 10 mH.

The resonant frequency of an LC circuit is given by:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

With maximum capacitance (65 pF):

$$f_{\text{min}} = \frac{1}{2\pi\sqrt{10 \times 10^{-3} \times 65 \times 10^{-12}}} \approx 197.4\,\text{kHz}$$

With minimum capacitance (15 pF):

$$f_{\text{max}} = \frac{1}{2\pi\sqrt{10 \times 10^{-3} \times 15 \times 10^{-12}}} \approx 410.9\,\text{kHz}$$

- The tuned circuit can respond to frequencies approximately ranging from 197.4 kHz to 410.9 kHz.

Cutoff Frequency of the RF Filter Circuit

$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi \times 120 \times 10^3 \times 100 \times 10^{-12}} \approx 13.3\,\text{kHz}$$

Types of A.M. Radio Receivers

1. Straight radio receiver.

- The aerial receives radio waves from different broadcasting stations. The desired radio wave is selected by the R.F. amplifier which employs a tuned parallel circuit.
- The tuned R.F. amplifiers amplify the selected radio wave.
- The amplified radio wave is fed to the detector circuit. This circuit extracts the audio signal from the radio wave.
- The output of the detector is the audio signal which is amplified by one or more stages of audio-amplification.
- The amplified audio signal is fed to the speaker for sound reproduction.

Limitations.

(i) The tuned circuits adjust by changing variable capacitors to tune to different stations. This adjustment causes a big change in the Q factor of the capacitors, affecting the radio's sensitivity and selectivity.

(ii) There is too much interference from adjacent stations.

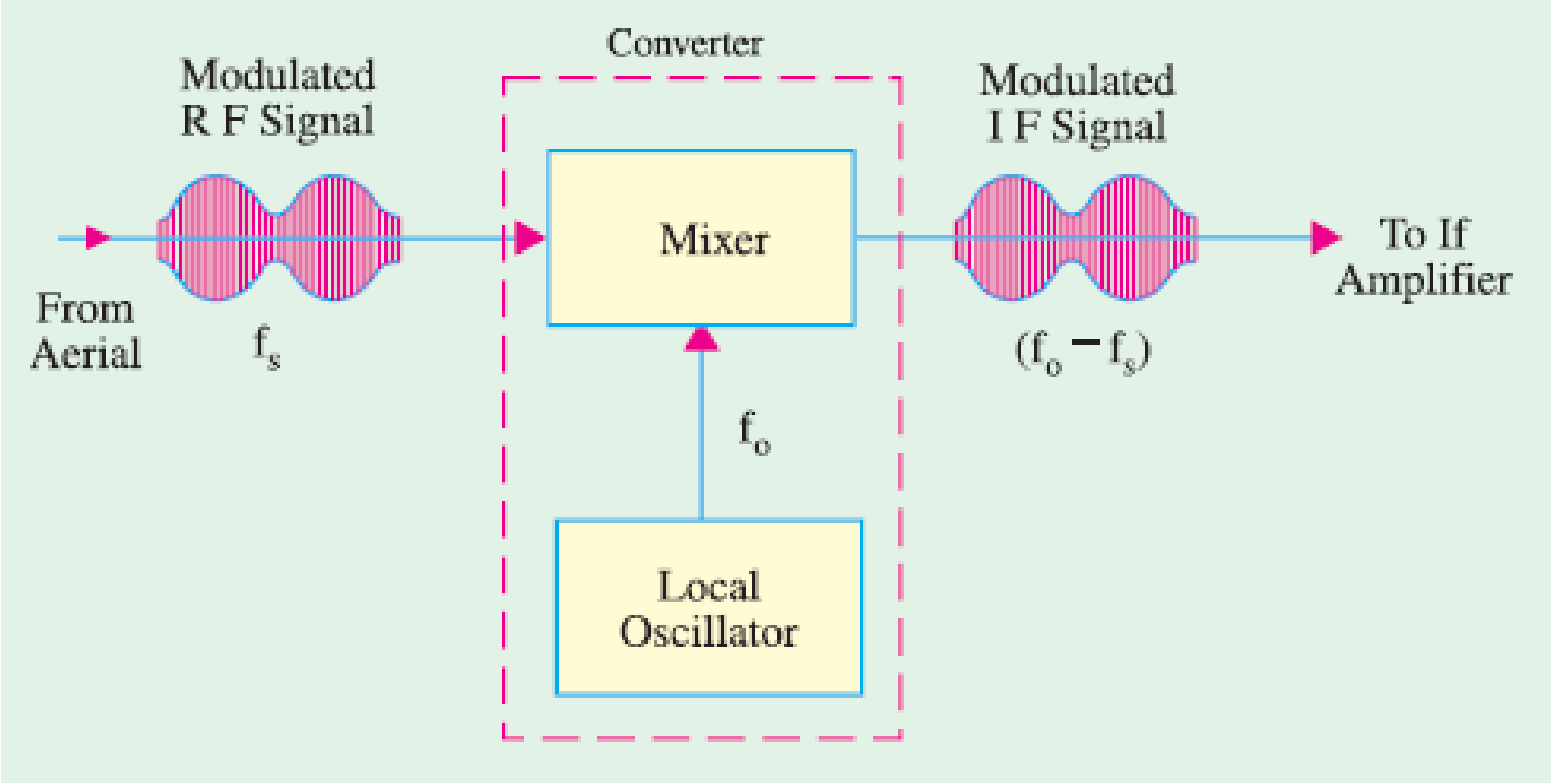
Types of A.M. Radio Receivers

2. Superhetrodyne receiver.

- The selected radio frequency is converted to a fixed lower value, called intermediate frequency (IF).
- This is achieved by a special electronic circuit called a mixer circuit. There is a local oscillator in the radio receiver itself. This oscillator produces high-frequency waves. The selected radio frequency is mixed with the high frequency wave by the mixer circuit.
- In this process, beats are produced, and the mixer produces a frequency equal to the difference between the local oscillator and radio wave frequency.
- The circuit is so designed that the oscillator always produces a frequency 455 kHz above the selected radio frequency. Therefore, the mixer will always produce an intermediate frequency of 455 kHz regardless of the station to which the receiver is tuned.

Types of A.M. Radio Receivers

2. Superhetrodyne receiver.



Types of A.M. Radio Receivers

2. Superhetrodyne receiver.

- If the 600 kHz station is tuned, then the local oscillator will produce a frequency of 1055 kHz. Consequently, the output from the mixer will have a frequency of 455 kHz.
- The selected radio frequency f_s is mixed with a frequency f_0 from a local oscillator. The output from the mixer is a difference (i.e. $f_0 - f_s$) and is always 455 kHz regardless of the station to which the receiver is tuned.
- The production of fixed intermediate frequency (455 kHz) is the salient feature of superhetrodyne circuit.
- At this fixed intermediate frequency, the amplifier circuits operate with maximum stability, selectivity, and sensitivity.
- As the conversion of incoming radio frequency to the intermediate frequency is achieved by heterodyning or beating the local oscillator against radio frequency, therefore, this circuit is called **superhetrodyne** circuit.

Types of A.M. Radio Receivers

Stages of Superhetrodyne Radio Receiver

R.F. amplifier stage

The R.F. amplifier stage uses a tuned parallel circuit L_1C_1 with a variable capacitor C_1. The radio waves from various broadcasting stations are intercepted by the receiving aerial and are coupled to this stage. This stage selects the desired radio wave and raises the strength of the wave to the desired level.

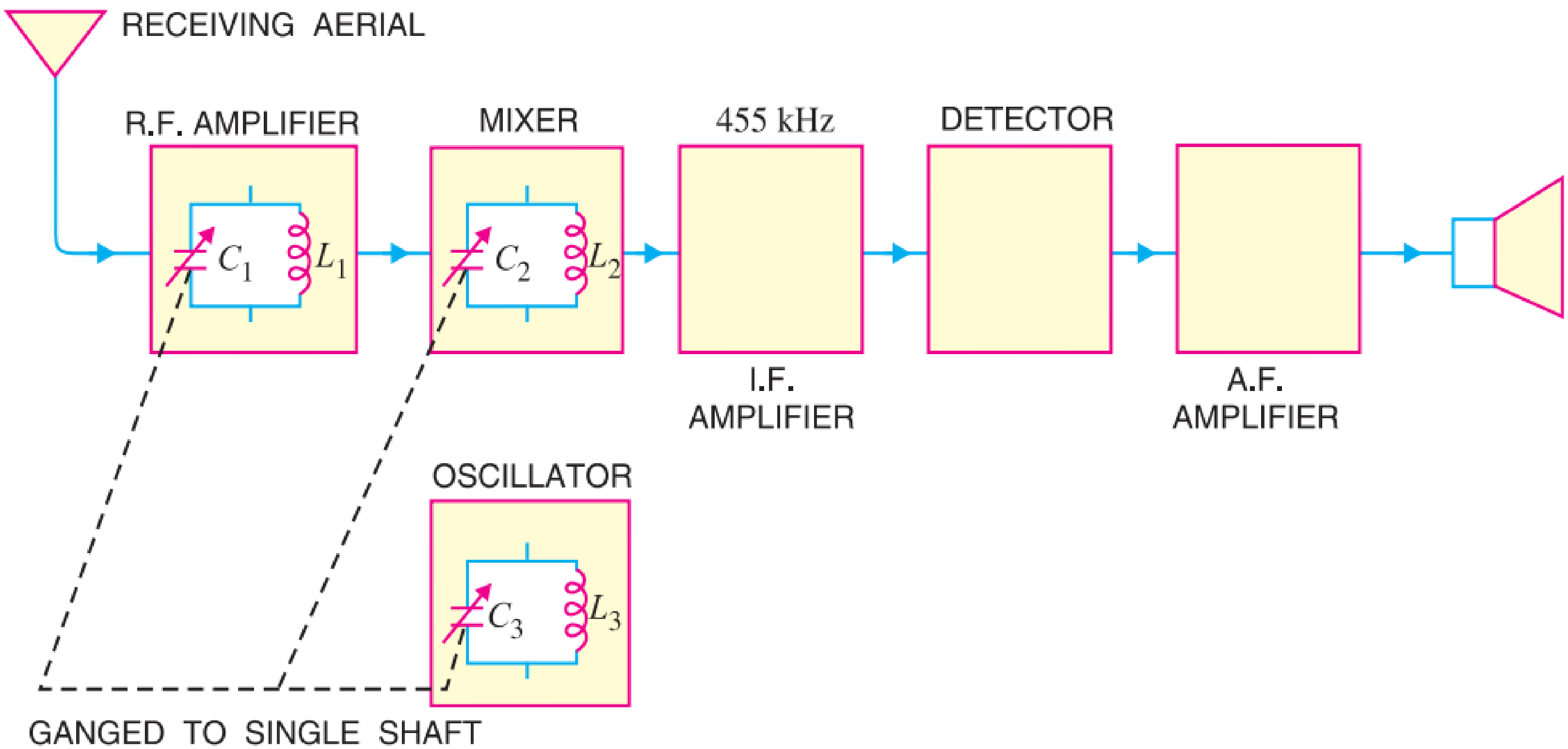
Mixer stage

The amplified output of the R.F. amplifier is fed to the mixer stage where it is combined with the output of a local oscillator. The two frequencies beat together and produce an intermediate frequency (IF). The intermediate frequency is the difference between oscillator frequency and radio frequency.

Intermediate Frequency (I.F.) = Oscillator frequency − Radio frequency

Types of A.M. Radio Receivers

Stages of Superhetrodyne Radio Receiver



Types of A.M. Radio Receivers

Stages of Superhetrodyne Radio Receiver

Mixer stage

- The I.F. is always 455 kHz regardless of the frequency to which the receiver is tuned. The reason why the mixer will always produce 455 kHz frequency above the radio frequency is that the oscillator always produces a frequency 455 kHz above the selected radio frequency.
- This is achieved by making C_3 smaller than C_1 and C_2. By making C_3 smaller, the oscillator will tune to a higher frequency. In practice, the capacitance of C_3 is designed to tune the oscillator to a frequency higher than radio wave frequency by 455 kHz.
- This frequency difference (i.e. 455 kHz) will always be maintained because when C_1 and C_2 are varied, C_3 will also vary proportionally. It may be noted that in mixer stage, the carrier frequency is reduced. The I.F. still contains the audio signal.

I.F. amplifier stage

The output of the mixer is always 455 kHz and is fed to fixed-tuned I.F. amplifiers. These amplifiers are tuned to one frequency (i.e. 455 kHz) and render nice amplification.

Types of A.M. Radio Receivers

Stages of Superhetrodyne Radio Receiver

Detector stage

The output from the last IF amplifier stage is coupled to the input of the detector stage. Here, the audio signal is extracted from the IF output. Usually, diode detector circuit is used because of its low distortion and excellent audio fidelity.

A.F. amplifier stage

The audio signal output of detector stage is fed to a multistage audio amplifier. Here, the signal is amplified until it is sufficiently strong to drive the speaker. The speaker converts the audio signal into sound waves corresponding to the original sound at the broadcasting station..

Types of A.M. Radio Receivers

Advantages

(i) High RF amplification

The superhetrodyne principle makes it possible to produce an intermediate frequency (i.e. 455 kHz) which is much less than the radio frequency. R.F. amplification at low frequencies is more stable since feedback through stray and interelectrode capacitance is reduced.

(ii) Improved selectivity.

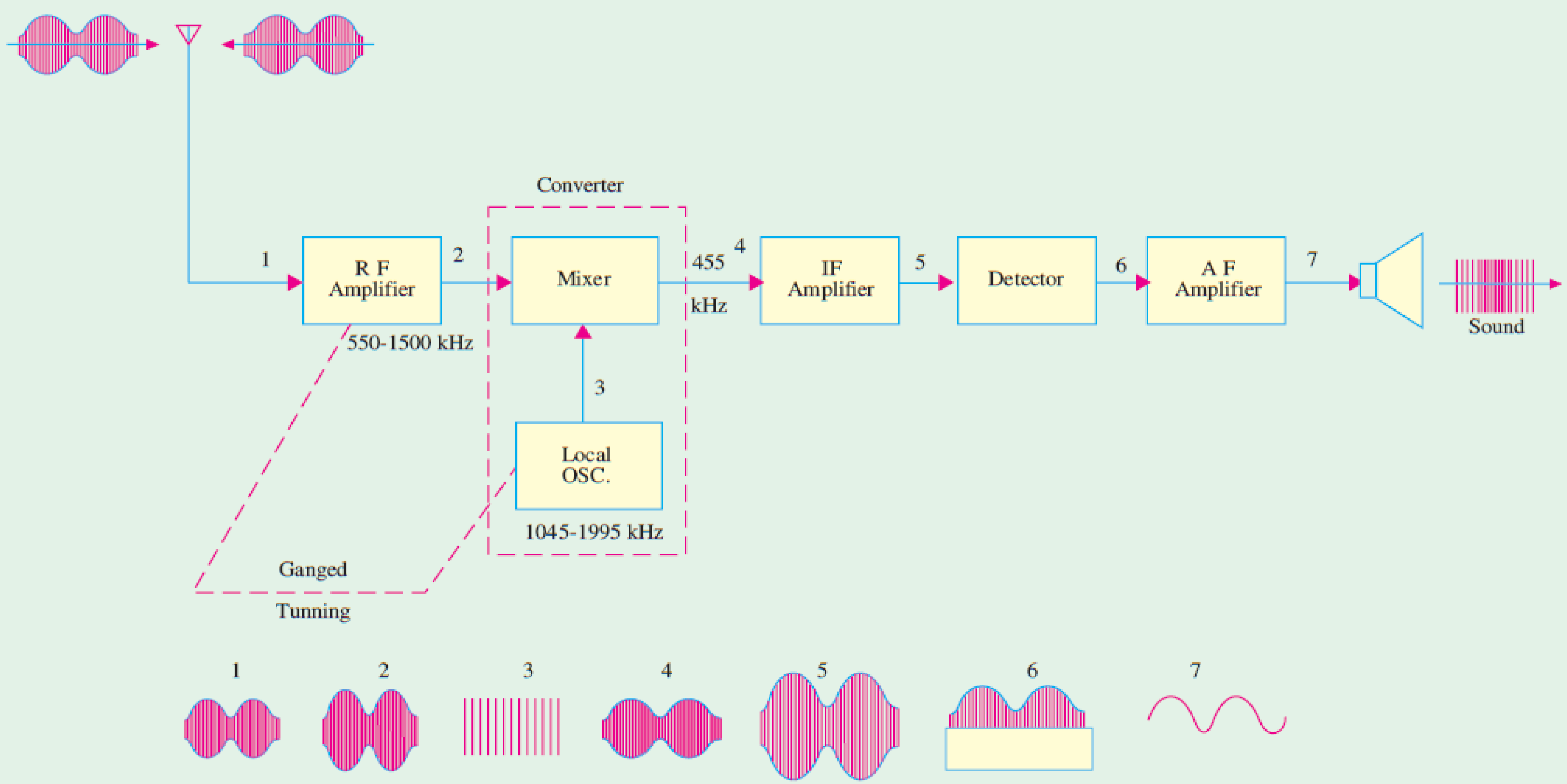
Losses in the tuned circuits are lower at intermediate frequency. Therefore, the quality factor Q of the tuned circuits is increased. This makes the amplifier circuits to operate with maximum selectivity.

(iii) Lower cost

In a superhetrodyne circuit, a fixed intermediate frequency is obtained regardless of the radio wave selected. This permits the use of fixed R.F. amplifiers. The superhetrodyne receiver is thus cheaper than other radio receivers.

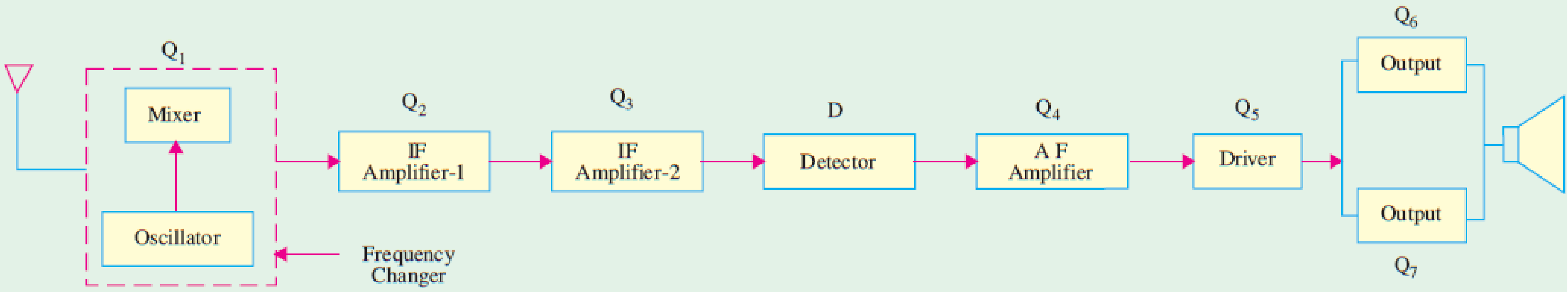
Types of A.M. Radio Receivers

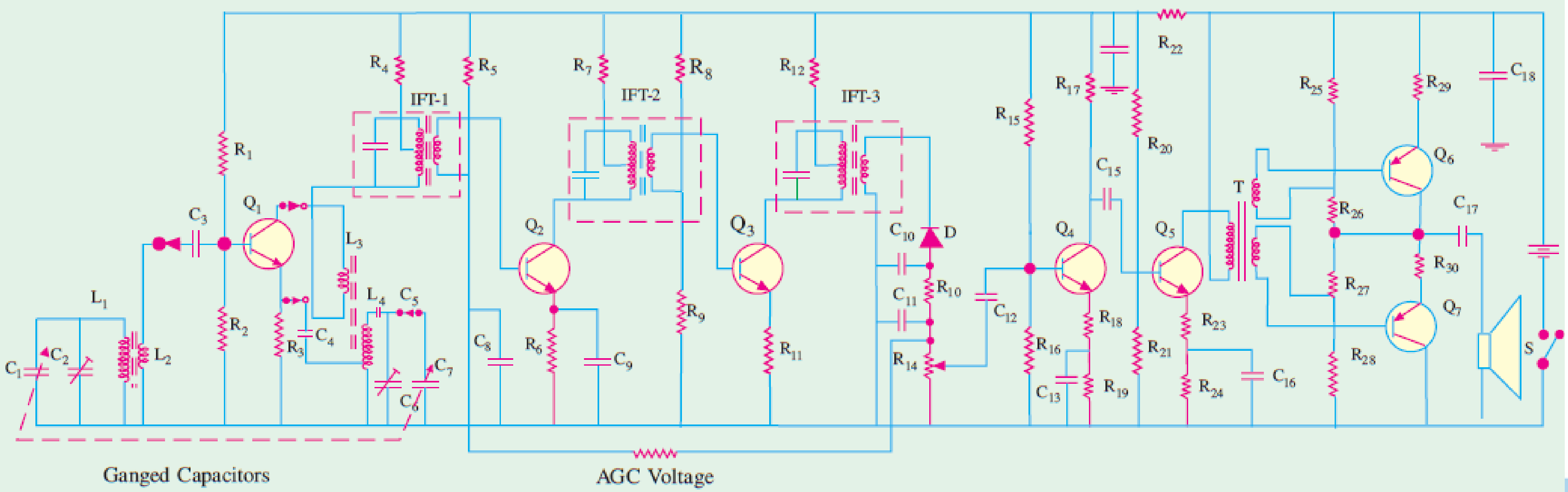
Stages of Superhetrodyne Radio Receiver



Types of A.M. Radio Receivers

Standerd Superhetrodyne Radio Receiver

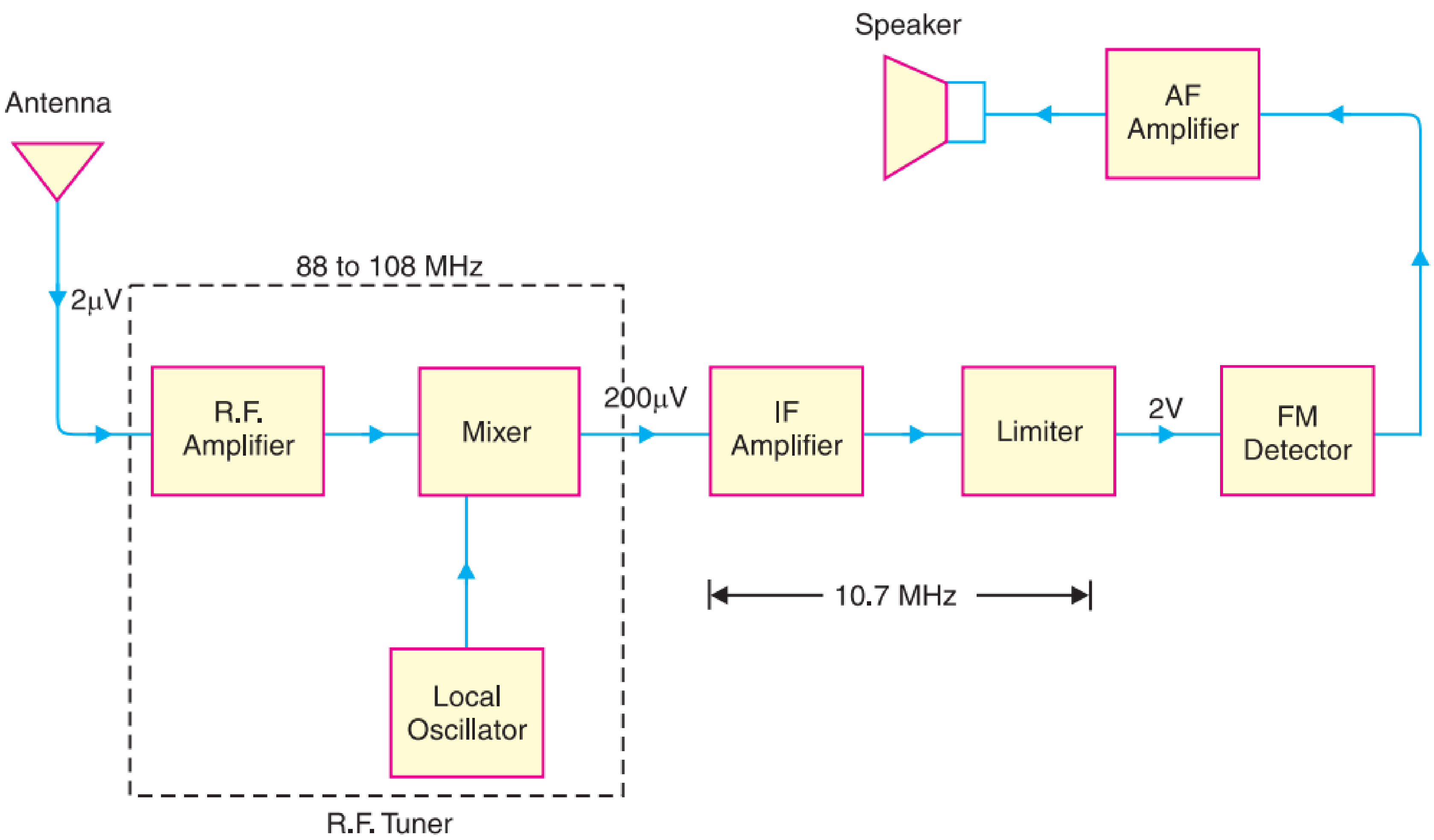




FM Receiver

- It is more complicated and, therefore, more expensive than the normal AM receiver.
- FM receiver also uses superheterodyne principle. The FM broadcast signals lie in the frequency range between 88 MHz and 108 MHz.
- The IF (intermediate frequency) of an FM receiver is 10.7 MHz—much higher than the IF value of 455 kHz in AM receivers.

FM Receiver



Speaker
AF Amplifier
Antenna
88 to 108 MHz
2μV
R.F. Amplifier
Mixer
200μV
IF Amplifier
Limiter
2V
FM Detector
10.7 MHz
Local Oscillator
R.F. Tuner

FM Receiver

R.F. Tuner

The FM signals are in the frequency range of 88 to 108 MHz. The weak FM signal (say 2 μV) is picked up by the antenna and is fed to the R.F. tuner. The R.F. tuner consists of **R.F. amplifier, Mixer** and **local oscillator.**

- The R.F. amplifier amplifies the selected FM signal (to 200 μV in the present case). The output from the RF amplifier is fed to the mixer stage where it is combined with the output signal from a local oscillator.
- The two frequencies beat together and produce an intermediate frequency (IF). The intermediate frequency (IF) is equal to the difference between the oscillator frequency and the RF frequency.
- The IF is always 10.7 MHz (Recall IF in AM receiver is 455 kHz) regardless of the frequency to which the FM receiver is tuned.

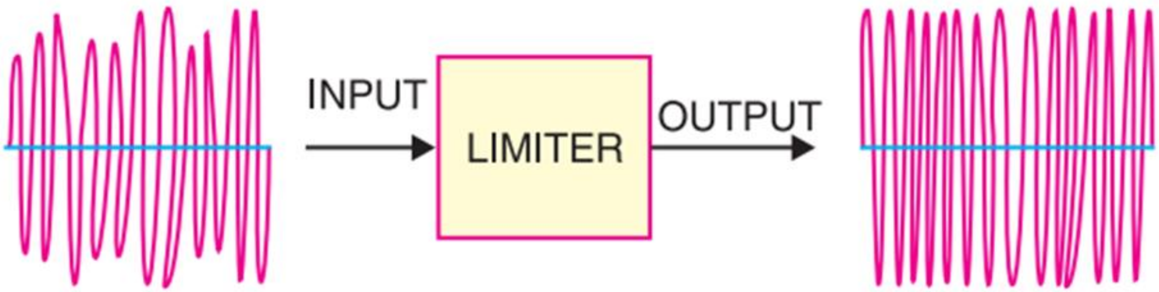
FM Receiver

IF Amplifier Stage

- The output signal from the mixer always has a frequency of 10.7 MHz and is fed to the IF amplifiers. Since IF amplifiers are tuned to IF (= 10.7 MHz), they render nice amplification.
- Note that bandwidth of IF amplifiers is about 200 kHz or 0.2 MHz. The IF gain is very large (assumed 10,000 in this case) so the output is 2V.

Limiter Stage

- The output from IF stage is fed to the limiter.
- This circuit is an IF amplifier tuned to 10.7 MHz but its main function is to remove AM interference from the FM signal.
- The input is an FM signal, but it has different amplitude levels because of AM interference has been added. However, the limiter circuit keeps the output level constant for different input levels.



FM Receiver

FM Detector

- After the removal of amplitude modulation from the FM signal by the limiter, the IF signal drives the input of the FM detector.
- An FM detector is a circuit that converts frequency variations to amplitude variations.
- The FM detector is also called a discriminator because it can distinguish between different frequencies in the input to provide different output voltages.
- The resultant amplitude-modulated signal is then rectified and amplified for feeding to the speaker for sound reproduction.

Difference Between FM and AM Receivers

- An FM receiver has two additional stages viz. limiter and discriminator, which are quite different from an AM receiver.

- FM broadcast signals lie in the frequency range between 88 and 108 MHz whereas AM broadcast signals lie in the frequency range from 540 kHz to 1600 kHz.

- FM receivers are free from interference, and this means that much weaker signals can be successfully handled.

- FM bandwidth is about 200 kHz compared to 10 kHz bandwidth for AM.

- The IF for FM receivers is 10.7 MHz whereas IF for AM receivers is 455 kHz.