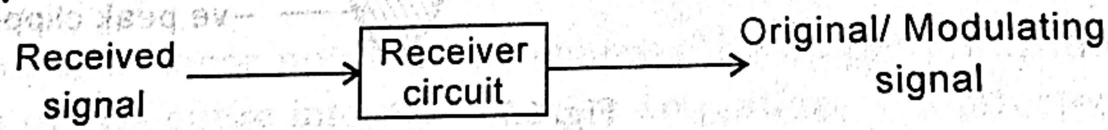
4.1 Radio Receiver Characteristics

The main function of the receiver is to regenerate the original signal from the received signal.



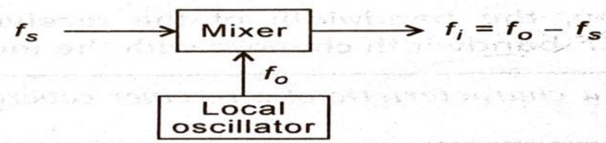
Frequency range

- A radio receiver may be designed to tune to a fixed frequency,
- MF AM broadcast band, 535 kHz - 1605 kHz
- General coverage MF/HF communications receiver 100 kHz - 30 MHz
- VHF FM broadcast band, 88 - 108 MHz
- UHF TV broadcast band (analogue or digital) 470 - 860 MHz
- Scanning receiver 0.5 MHz - 1300 MHz
- GSM 900, GSM1800 or 3G mobile phone bands
- Wireless LAN band 2400 - 2483.5 MHz

Super heterodyne Radio Receiver

In superheterodyne radio receivers, the incoming radio signals arc intercepted by the antenna arid converted into the corresponding currents and voltages. In the receiver, the incoming signal frequency is mixed with a locally generated frequency. The output of the mixer consists of the sum and difference of the two frequencies. The mixing of the two frequencies is termed *heterodyning*. Out of the two resultant components of the mixer, the sum component is rejected and the difference component is selected. The value of the difference frequency component varies with the incoming frequencies, if the frequency of the local oscillator is kept constant. It is possible to keep the frequency of the difference components constant by varying the frequency of the local oscillator according to the incoming signal frequency. In this case, the process is called Superheterodyne and the receiver is known as a superheterodyne radio receiver.

Super heterodyne Radio Receiver



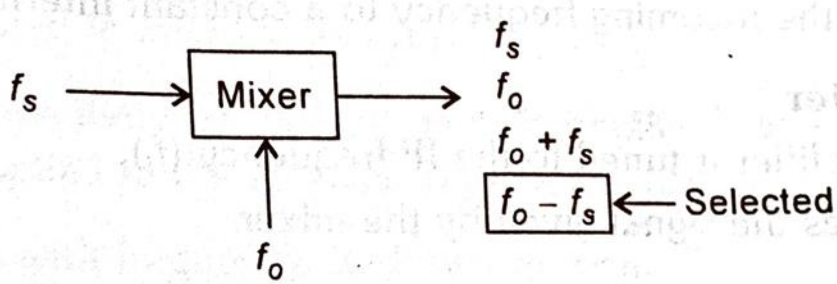
f_s = Incoming frequency
f_o = Oscillator frequency
f_i = Intermediate frequency

- Our main aim is to keep the output i.e. f_i at a constant value.

Working

- As f_s changes, if f_o is also changed then, the difference will be constant.
- Hence, f_o is always changed with f_s using ganged tuning.

Note : *The mixer circuit in practice gives many frequencies at its output but only the difference frequency is selected for the next stages.*



Receiver Parameters/Characteristics

- Sensitivity
- Selectivity
- Fidelity
- Tracking

  Two Point Tracking

  Three point Tracking
- Image Frequency and its rejection

  Double Spotting

  Blocking

1. Sensitivity

(i) **Sensitivity**

- Sensitivity of a receiver is defined as its ability to amplify weak signal.
- Sensitivity is measured in micro volts (μv).
- If a receiver has sensitivity of 150 μv, then it implies that minimum 150 μv signal should be applied to the receiver to get a desired output.
- Sensitivity changes with frequency as shown in *figure 7.3*.

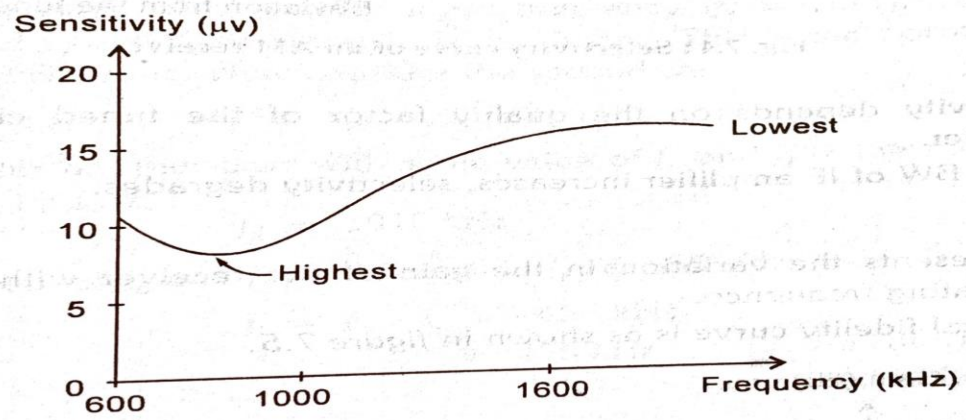


Fig. 7.3 : Sensitivity curve of an AM receiver.

- It depends on the gain of
  - RF Amplifier
  - IF Amplifier.

2. Selectivity

(ii) Selectivity

- It is defined as the ability of a receiver to reject unwanted signal.
- If a receiver is tuned to 900 kHz then, the selectivity is said to be good if the receiver only selects signal of 900 kHz frequency and rejects other frequencies.
- Selectivity is expressed as a curve called the *selectivity curve*.

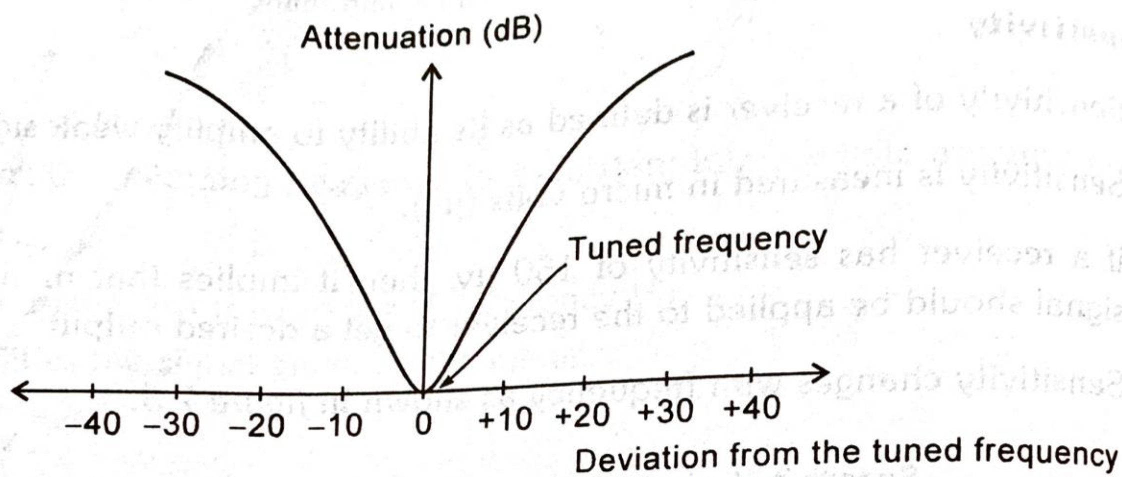


Fig. 7.4 : Selectivity curve of an AM receiver.

- Selectivity depends on the quality factor of the tuned circuit used in IF amplifier.
- Also if BW of IF amplifier increases, selectivity degrades.

3. Fidelity

(iii) Fidelity

- It represents the variation in the gain of the receiver with variation in the modulating frequency.
- A typical fidelity curve is as shown in *figure 7.5.*

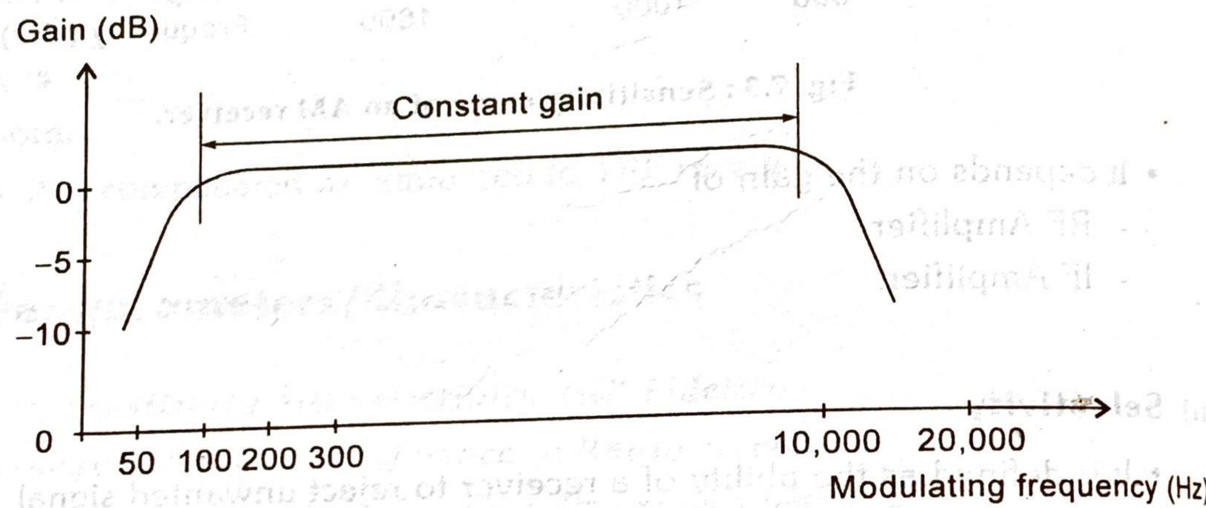


Fig. 7.5 : Typical fidelity curve of a receiver.

- The fidelity of any receiver depends on the audio amplifiers.

4. Image Frequency

In Super heterodyne receiver, mixer will process not only the desired input signal at fRF, but also all signals present at its inputs. There will be many mixer products (heterodynes). Most other signals produced by the mixer (such as due to stations at nearby frequencies) can be filtered out in the IF (Intermediate frequency) tuned amplifier; that gives the superheterodyne receiver its superior performance. However, if fLO is set to fRF + fIF, then an incoming radio signal at fLO + fIF will also produce a heterodyne at fIF; the frequency fLO + fIF is called the image frequency and must be rejected by the tuned circuits in the RF stage.

(iv) Image Frequency and its Rejection

Image Frequency

To understand image frequency, consider a receiver which is tuned to receive 1000 kHz frequency. Now, consider the following cases :

4. Image Frequency

Case (i)

- The receiver is tuned to a frequency of 1000 kHz.

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

- As the IF frequency is set to 455 kHz, the local oscillator frequency is

$$f_o = f_s + f_i$$

$$\boxed{f_o = 1455 \text{ kHz}}$$

- Now, the receiver will work for input frequency (f_s = 1000 kHz), since the difference of f_s and f_o is equal to IF frequency. This is the normal operation and nothing is wrong. Now consider the second case.

Case (ii)

- Now consider another case with same value of f_o and f_i in the above case but f_s is now 1910 kHz.

$$\therefore \quad f_s = 1910 \text{ kHz}$$

- The difference of f_o and f_s is still equal to f_i i.e. 455 kHz

$$f_i = f_o - f_s = -455 \text{ kHz}$$

$$= 455 \text{ kHz} \qquad \left(\because \text{ We cannot have -ve frequency}\right)$$

- Since, the receiver will always work if the difference of f_s and f_o is f_i, the receiver will detect this signal also.
- The frequency of 1910 kHz in this case is called *image frequency* and it is given by

$$\boxed{f_{si} = f_s + 2f_i}$$

f_{si} = Image frequency

f_i = Intermediate frequency, normally f_i = 455 kHz

f_s = Signal frequency.

4. Image Frequency Rejection

Image Frequency Rejection Ratio

- It is denoted by α
- It is the ratio of the gain of the receiver at signal frequency to the gain at image frequency.
- It is given by

$$\alpha = \frac{\text{Gain at signal frequency}}{\text{Gain at image frequency}}$$

- It depends on the quality factor Q in the following manner

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

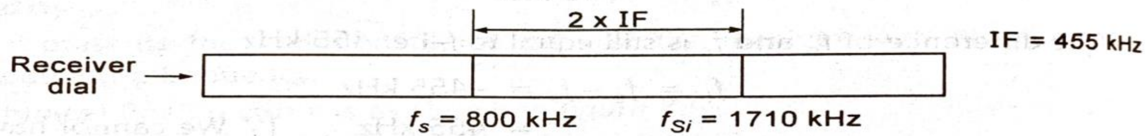
where $$\boxed{\rho = \frac{f_{Si}}{f_s} - \frac{f_s}{f_{Si}}}$$

Double Spotting

Double Spotting

> **Note :** *Double spotting is not a receiver characteristic, it is just a problem faced in some receivers due to poor characteristics.*

- Double spotting means the same station gets picked up at two different points on the receiver dial.
- It can occur if a signal is stronger than the signal at its image frequency.



- Consider the figure above

$$f_s = 800 \text{ kHz}$$

$$f_{Si} = 2 \times \text{IF} + 800 \text{ kHz} = 1710 \text{ kHz}$$

Assume that the signal with frequency 800 kHz is of very high strength compared to the signal with frequency 1710 kHz.

Consider the following cases

Case (i) : Receiver Dial is Tuned to 800 kHz

- As the strength is very high, the signal is picked up and nothing is wrong. Problem occurs in the next case.

Case (ii) : Receiver Dial is Tuned to 1710 kHz

- As the signal at 1710 kHz is weak and also, as 1710 kHz is the image frequency of 800 kHz, the receiver can detect both the signals.
- Now, as the strength of original signal is less than the image signal, the image signal is selected.
- Thus, the same signal is selected at two points. This is called *double spotting*.

Blocking

Blocking

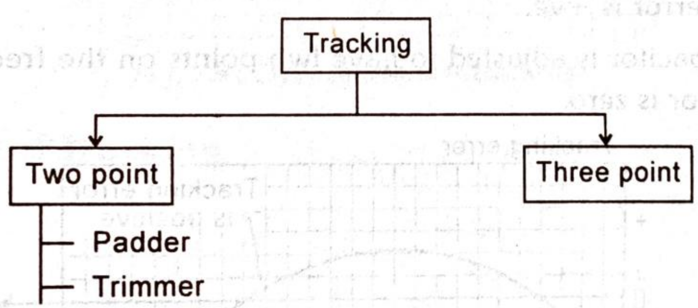
- If a radio receiver is tuned to a weak signal, then the corresponding Automatic Gain Control (AGC) will be very low, and the gains of the RF and IF stages will be high. If a strong signal which is close in frequency to the weak signal is present then the AGC voltage may reduce due to its presence. This may suppress the wanted signal completely. Also if the strong signal is fluctuating then the AGC voltage will fluctuate.
- A receiver which has a very little reaction to the nearby unwanted signals is said to have good blocking. To have excellent blocking, high adjacent channel rejection should be there. For this the selectivity of the IF amplifier should be high.

5. Tracking

7.5 Tracking

Q. Explain local oscillator tracking and tracking error in radio receiver.

- Tracking is a process in which the local oscillator frequency follows or tracks the incoming signal frequency to have a constant frequency difference (i.e. f_i).
- To keep the frequency difference constant, the capacitors of tuned circuit and local oscillator are ganged i.e. mechanically coupled or tuned simultaneously.
- Then too, in practice the frequency difference is never constant resulting in error. This is called *tracking error*.
- Tracking error can not be eliminated, it can just be suppressed by using two point and three point tracking.



5. Two Point Tracking

Two Point Tracking

- Since tracking error cannot be eliminated, here we try to minimize the tracking error to zero at two different frequencies by connecting capacitors in series or parallel with capacitor of oscillator.
- Hence the name two point tracking.

- It is of two types
  - Padder tracking
  - Trimmer tracking

7.5.1 Padder Tracking

C_O = Overall capacitance

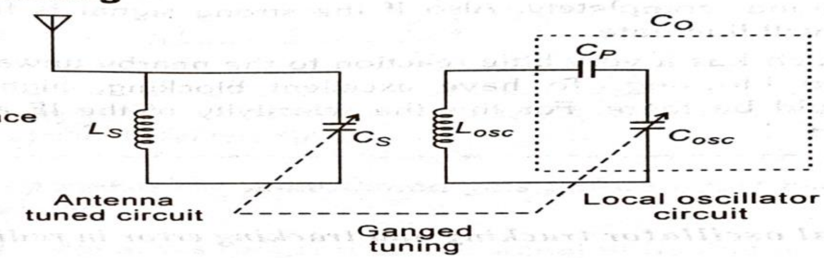


Fig. 7.6 : Padder tracking.

Note : *If overall capacitance C_O is less than C_{osc} then, tracking error is +ve else –ve.*

- A padder capacitor C_P is connected in series with C_{osc}.
- Thus the overall capacitance is

$$C_O = \frac{C_P\, C_{osc}}{C_P + C_{osc}}$$ and is less than C_{osc}

- Thus, tracking error is +ve.
- The padder capacitor is adjusted to have two points on the frequency dial where the tracking error is zero.

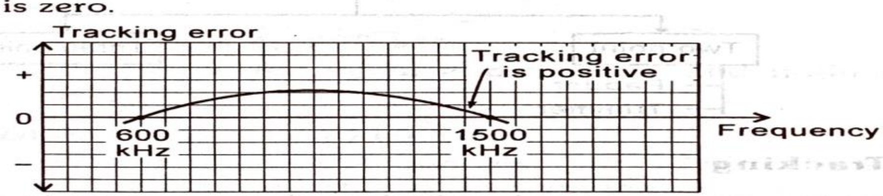


Fig. 7.7 : Error in padder tracking.

Note : *The frequencies at which tracking error is zero depends on the value of capacitors. Here 600 kHz and 1500 kHz are taken as example.*

5. Two Point Tracking Tracking

7.5.2 Trimmer Tracking

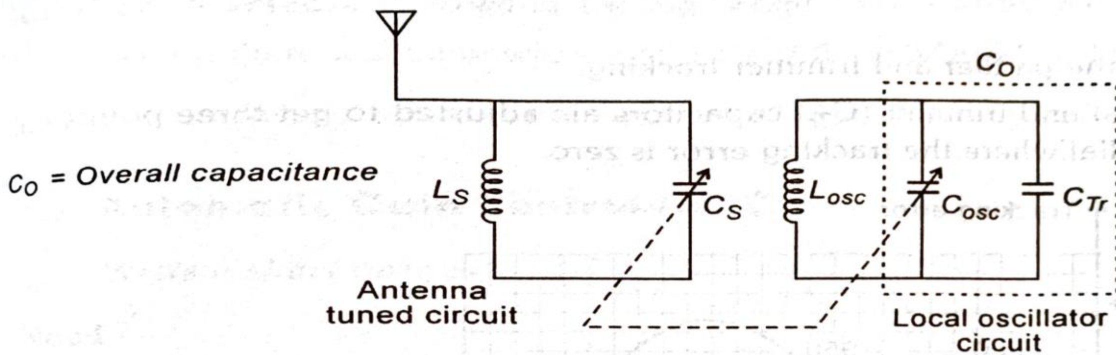


Fig. 7.8 : Trimmer tracking.

- A trimmer capacitor (C_{Tr}) is connected in parallel with C_{osc}.
- Thus, the overall capacitance is

$$C_O = C_{Tr} + C_{osc} \quad \text{and is greater than } C_{osc}$$

- Thus, the tracking error is –ve.
- The trimmer capacitor is adjusted to have two points on the frequency dial where the tracking error is zero.

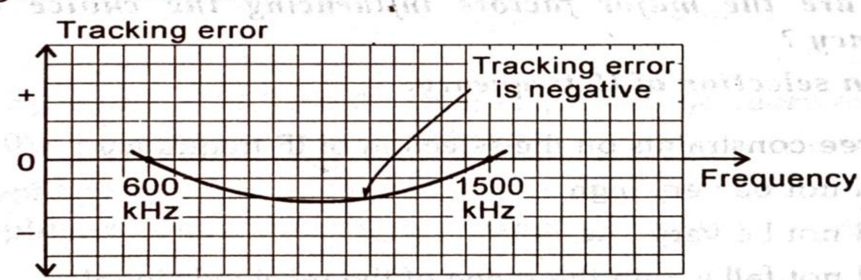


Fig. 7.9 : Error in trimmer tracking.

5. Three point Tracking

7.5.3 Three Point Tracking

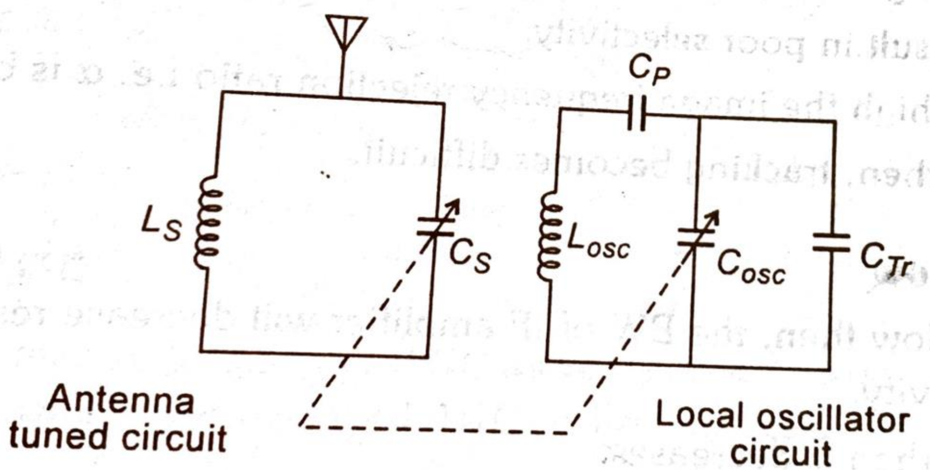


Fig. 7.10 : Three point tracking.

Three point Tracking

Refer figure 7.10.

- This combines the padder and trimmer tracking.
- The padder (C_P) and trimmer (C_{Tr}) capacitors are adjusted to get three points on the frequency dial where the tracking error is zero.

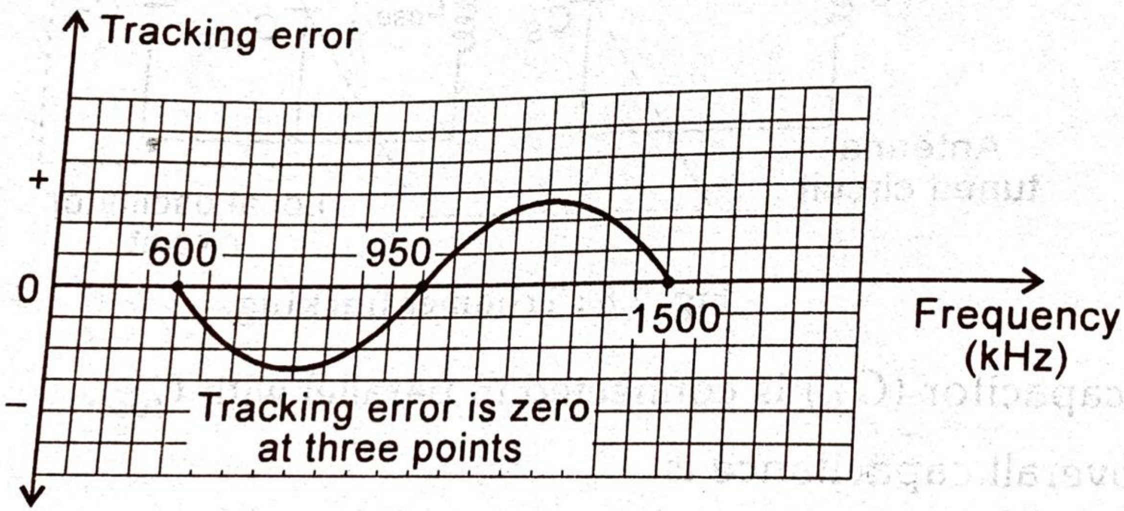


Fig. 7.11 : Three point tracking error .