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Internal Assesment Test - II

Sub:	Principles of Communication Systems							Code:	18EC53
Date:	October 2020	Duration:	90 mins	Max Marks:	50	Sem:	5th	Branch:	ECE
Answer All Questions									

No	Question	Marks	CO	RBT
1	Explain single tone frequency modulation. Derive necessary equations. Compare it with AM using phasor diagram.	10	CO1	L2
2	Explain FM demodulation using PLL.	10	CO2	L2
3	FM modulated signal is defined by $$s(t) = 10sin\left(5 * 10^8 t + 4sin\,(1250t)\right)$$ Calculate a) Modulation Index b) Carrier frequency c) Frequency Deviation d) Power generated across 5ohm load.	05	CO2	L3
4	Explain FM stereo multiplexing with the help of block diagram	07	CO2	L2
5	Explain the working of Superheterodyne receiver.	08	CO1	L2
6	Describe the demodulation of FM signal using balanced slope detector.	10	CO2	L2

Solution

1. FM single tone

→ Frequency Modulation is a process of altering the frequency of Carrier signal in accordance with the instantaneous values of message signal by keeping amplitude & phase of Carrier Constant.

Time domain expression:-

- Let the instantaneous value of Carrier signal is

$$c(t) = A_c \cos 2\pi f_c t \longrightarrow (1)$$

- Let the instantaneous value of message signal is

$$m(t) = A_m \cos 2\pi f_c t \longrightarrow (2)$$

- We know that the standard equation of Angle modulated wave is given by,

$$S(t) = A_c \cos \theta_i(t) \longrightarrow (3)$$

where $\theta_i(t)$ = Angle of FM wave (modulated wave)

- We know that the instantaneous frequency $f_i(t)$ of FM signal is given by

$$f_i(t) = f_c + K_f m(t) \quad \text{——— (4)}$$

where. K_f = frequency sensitivity

$m(t)$ = message signal

- We know that the Angular frequency,

$$w_i(t) = \frac{d}{dt}\theta_i(t)$$

$$\Downarrow$$

$$2\pi f_i(t) = \frac{d}{dt}\theta_i(t)$$

$$\therefore f_i(t) = \frac{1}{2\pi}\frac{d}{dt}\theta_i(t) \quad \text{——— (5)}$$

Substitute $f_i(t) = f_c + K_f m(t)$ in equation (5) we get,

$\therefore \quad f_c + k_f m(t) = \frac{1}{2\pi} \frac{d}{dt} \theta_i(t)$

$\therefore \quad \frac{d\,\theta_i(t)}{dt} = 2\pi f_c + 2\pi k_f m(t) \quad —(6)$

⇒ Apply Integral on both sides of equation (6) we get

$$\int \frac{d}{dt}\theta_i(t) = \int [2\pi f_c + 2\pi k_f m(t)]\, dt$$

⇓

$$\theta_i(t) = 2\pi f_c t + 2\pi k_f \int m(t)\, dt \quad —(7)$$

∴ The General equation of FM signal is

$S(t) = A_c \cos \theta_i(t)$ using equation (7)

$$\boxed{S(t) = A_c \cos[2\pi f_c t + 2\pi k_f \int m(t) dt]} \quad —(8)$$

Equation (8) is the general equation of FM signal for any message signal $m(t)$.

for, $m(t) = A_m \cos 2\pi f_m t$

$$\int m(t)\, dt = \int A_m \cos 2\pi f_m t \, dt \qquad \left(\because \int \cos mx\, dx = \frac{\sin mx}{m}\right)$$

$$= \frac{A_m}{2\pi f_m} \cdot \sin 2\pi f_m(t) \quad —(9)$$

∴

$$S(t) = A_c \cos\left[2\pi f_c t + 2\pi k_f \times \frac{A_m}{2\pi f_m} \cdot \sin(2\pi f_m t)\right]$$

$$= A_c \cos\left[2\pi f_c t + \frac{k_f A_m}{f_m} \sin 2\pi f_m t\right]$$

$$\boxed{S(t) = A_c \cos[2\pi f_c t + \beta \sin 2\pi f_m t]} \quad —(10)$$

Equation (10) is the standard equation of FM signal for $m(t) = A_m \cos 2\pi f_m t$; where $\beta = \frac{k_f A_m}{f_m} = \frac{\Delta f_{max}}{f_m}$ ⇐ Modulation Index of FM signal.

2. FM DEMODULATION

FM-demodulation using phase Locked Loop:- (PLL)

phase Locked Loop (PLL) is a negative feedback system that consists of three major components

⟨i⟩ A Multiplier used as a phase detector (or) phase comparator.

⟨ii⟩ A - voltage Controlled oscillator ⟨VCO⟩

⟨iii⟩ A - Loop filter, which is a Low pass filter ⟨LPF⟩

The Block diagram of PLL is shown in Fig.1.

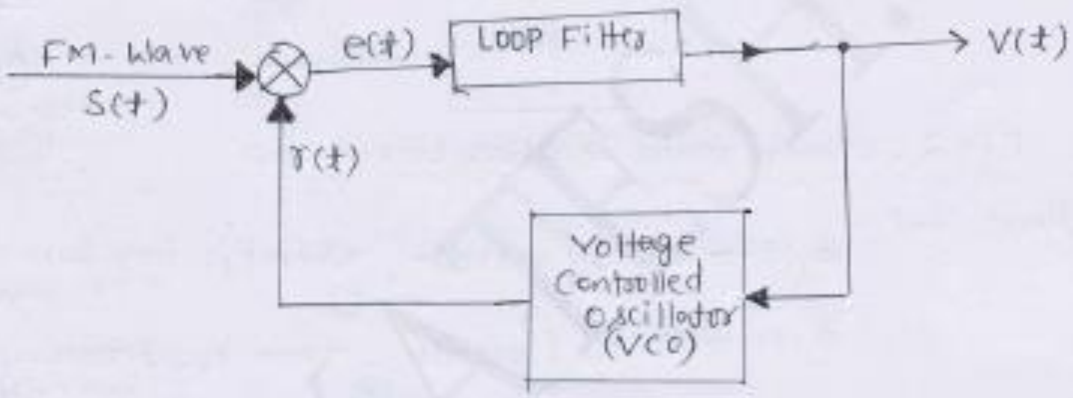


Fig.1: Block diagram of PLL

↳ The VCO output is defined as

$$r(t) = A_v \cos(2\pi f_c t + \phi_2(t)) \quad \text{—①}$$

where $\phi_2(t) = 2\pi K_v \int_0^t v(t)\,dt$.

↳ Then, the incoming signal (FM) (S(t)) and the VCO output r(t) are applied to the multiplier, then it gives error signal,

$$e(t) = r(t) \cdot S(t) \quad \text{—②}$$

where $S(t) = A_c \sin[2\pi f_c t + \phi_1(t)]$ —③

where $\phi_1(t) = 2\pi K_f \int_0^T m(t)\,dt$ —④

The phase locked loop (PLL) is said to be in phase-Lock, when the phase error $\boxed{\phi_e(t)=0}$

The Linear model of PLL for the demodulation of FM-signal is shown in Figure.2

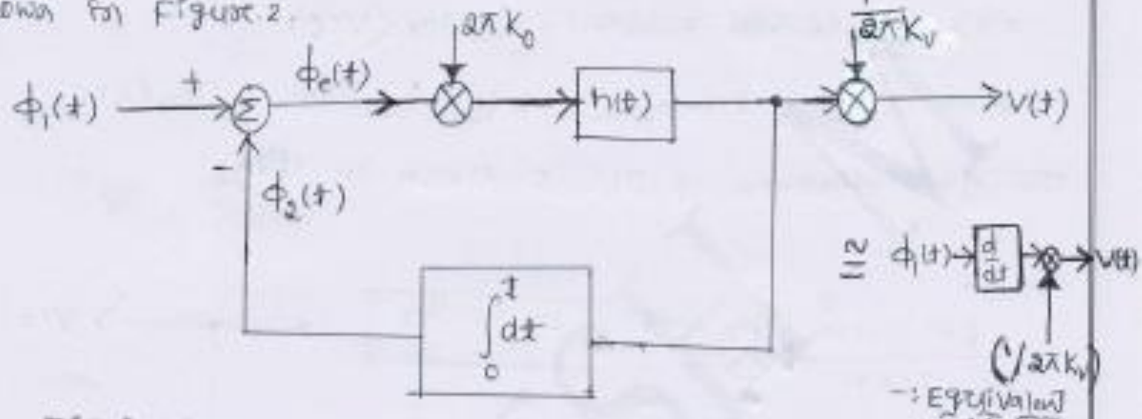


Fig.2 : Linear Model of Phase Locked Loop

We know that, $\phi_1(t) = 2\pi K_f \int_0^t m(t)\,dt$, where K_f = Freq. Sensitivity of FM-wave — ①

$\phi_2(t) = 2\pi K_V \int_0^t v(t)\,dt$, where K_V = Frequency Sensitivity Constant of VCO — ②

From fig.2, $\phi_e(t) = \phi_1(t) - \phi_2(t)$ — ③

W.K.T. For phase-lock mode : $\phi_e(t) = 0$ (Assuming Small error ≃ 0)

∴ Equation (3) ⇒ $0 = \phi_1(t) - \phi_2(t)$

$\therefore \phi_1(t) = \phi_2(t)$

Using equations ① & ② we get

$$2\pi K_f \int_0^t m(t)\,dt = 2\pi K_V \int_0^t v(t)\,dt$$

$$K_f \int_0^t m(t)\,dt = K_v \int_0^t v(t)\,dt \quad —④$$

Differentiating both sides of equation (4), we get (37)

$$k_f m(t) = k_v v(t).$$

$$\therefore v(t) = \frac{k_f}{k_v} \cdot m(t) = K m(t) \quad ; \text{ where } K = \frac{k_f}{k_v}$$

i.e., $v(t) \propto m(t)$

Thus, the output $v(t)$ of the low pass-loop filter $[h(t)]$ is proportional to the original modulating signal.

i.e., The message signal present in FM-modulated wave $s(t)$ is recovered and it is produced at the output of loop filter.

3.

$$s(t) = 10sin\left(5 * 10^8 t + 4sin\,(1250t)\right)$$

Comparing with basic FM equation

$$s(t) = A_c \cos[2\pi f_c t + \beta \sin(2\pi f_m t)]$$

a) Modulation Index = 4

b) Carrier frequency = 79.6MHz

c) Frequency Deviation =index*fm =4*199 =796Hz

d) Power generated across 5ohm load =(Ac^2)/2R = 50/50 =1W

4. FM stereo

Stereo multiplexing is a form of frequency division multi-plexing <FDM> designed to transmit two separate signals [$m_R(t)$ and $m_L(t)$] via the same carrier.

FM-Stereo system consists of :

a) FM-Stereo transmitter

b) FM-Stereo Receiver.

FM-stereo transmitter :-

- Let $m_L(t)$ and $m_R(t)$ denote the two message signals picked up by Left hand and Right hand microphones at the transmitting end of the system, as shown in Fig. 1.
- It uses a pilot carrier frequency, $f_c = 19\,KHz$. Frequency doubler produces sub carrier, $\cos(4\pi f_c t)$.

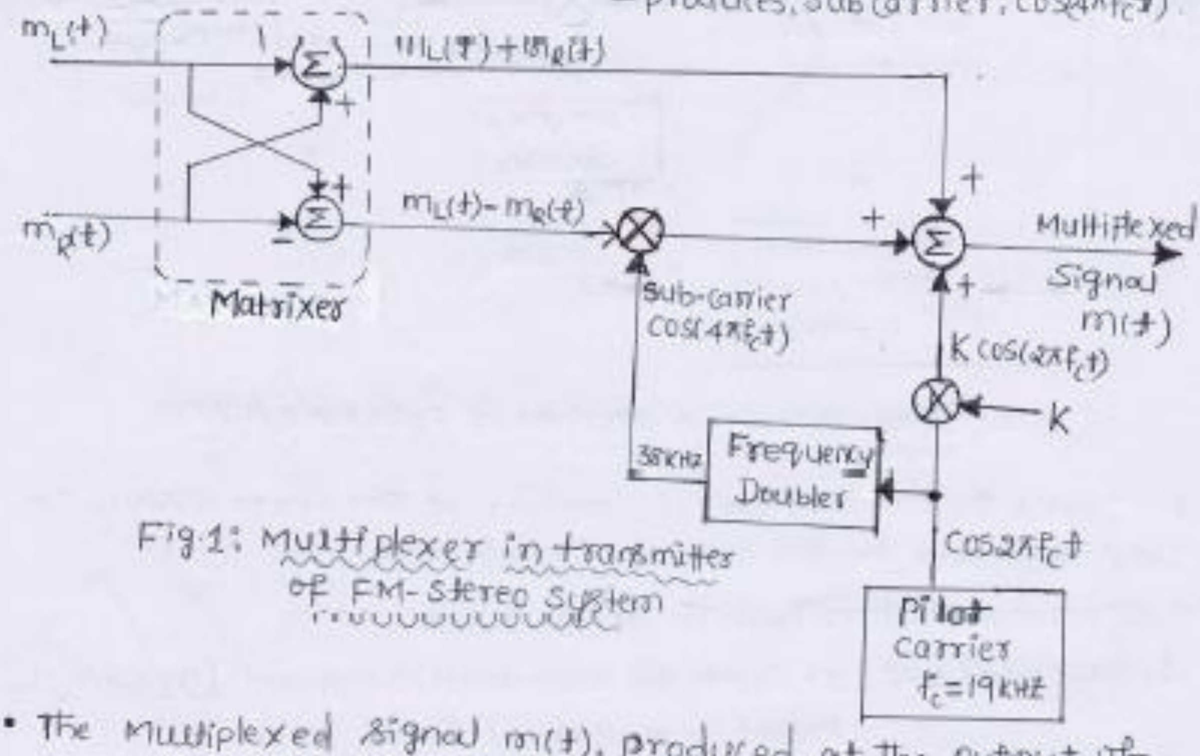


Fig.1: Multiplexer in transmitter of FM-Stereo System

- The Multiplexed signal $m(t)$, produced at the output of multiplexer in transmitter of FM stereo system is,

$$m(t) = \underbrace{[m_L(t)+m_R(t)]}_{\text{Baseband signal ①}} + \underbrace{[m_L(t)-m_R(t)]\cos 4\pi f_c t}_{\text{DSBSC signal ② } 2f_c = 38KHz} + \underbrace{K\cos(2\pi f_c t)}_{\text{Pilot carrier signal ③ } f_c = 19KHz} \quad \text{--- (i)}$$

- Multiplexed signal, m(t) consists of three different signals 28

1. $[m_L(t)+m_R(t)] \Rightarrow$ sum of $m_L(t)$, $m_R(t)$ generated by the simple matrixer. It is baseband signal.
2. $[m_L(t)-m_R(t)]\cos(4\pi f_c t) \Rightarrow$ DSBSC-signal produced by the product modulator.
3. $K.\cos(2\pi f_c t) \Rightarrow$ pilot carrier signal multiplied by a constant 'K'.

FM-Stereo Receiver :-

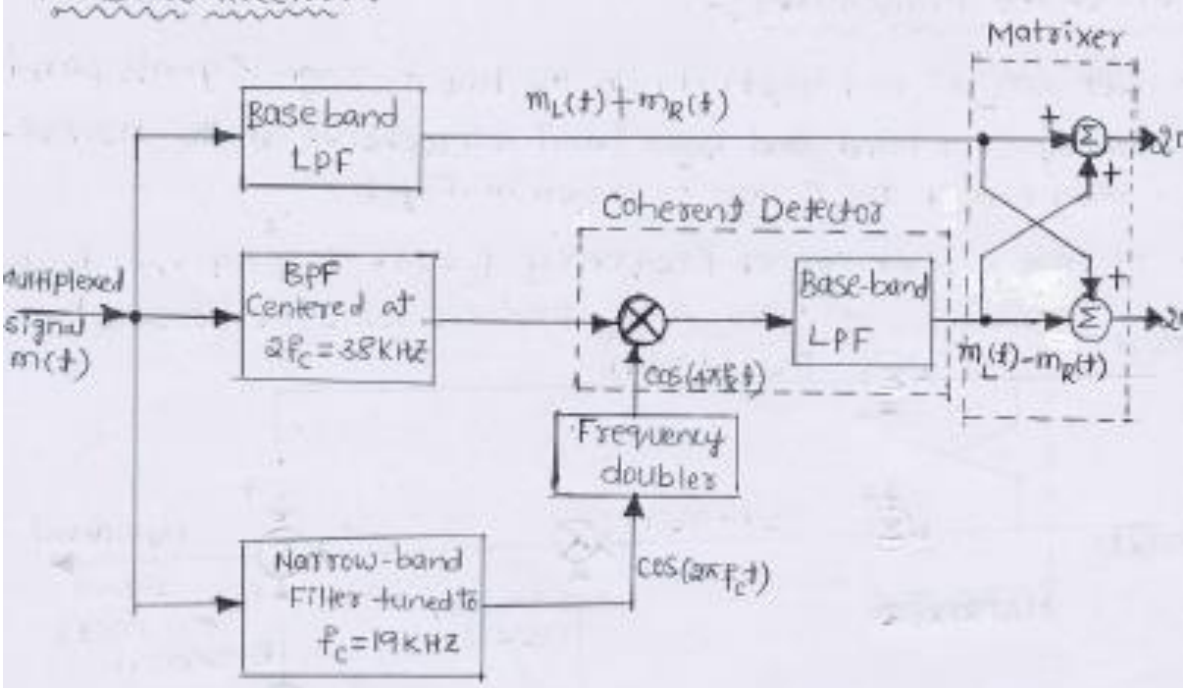


Fig 2: Demultiplexer in receiver of FM-stereo system

Fig. 2 shows the demultiplexer in receiver of FM-stereo system. It is used to recover the two message signals $m_L(t)$ and $m_R(t)$.

FM-stereo demultiplexer consists of 3-filters,

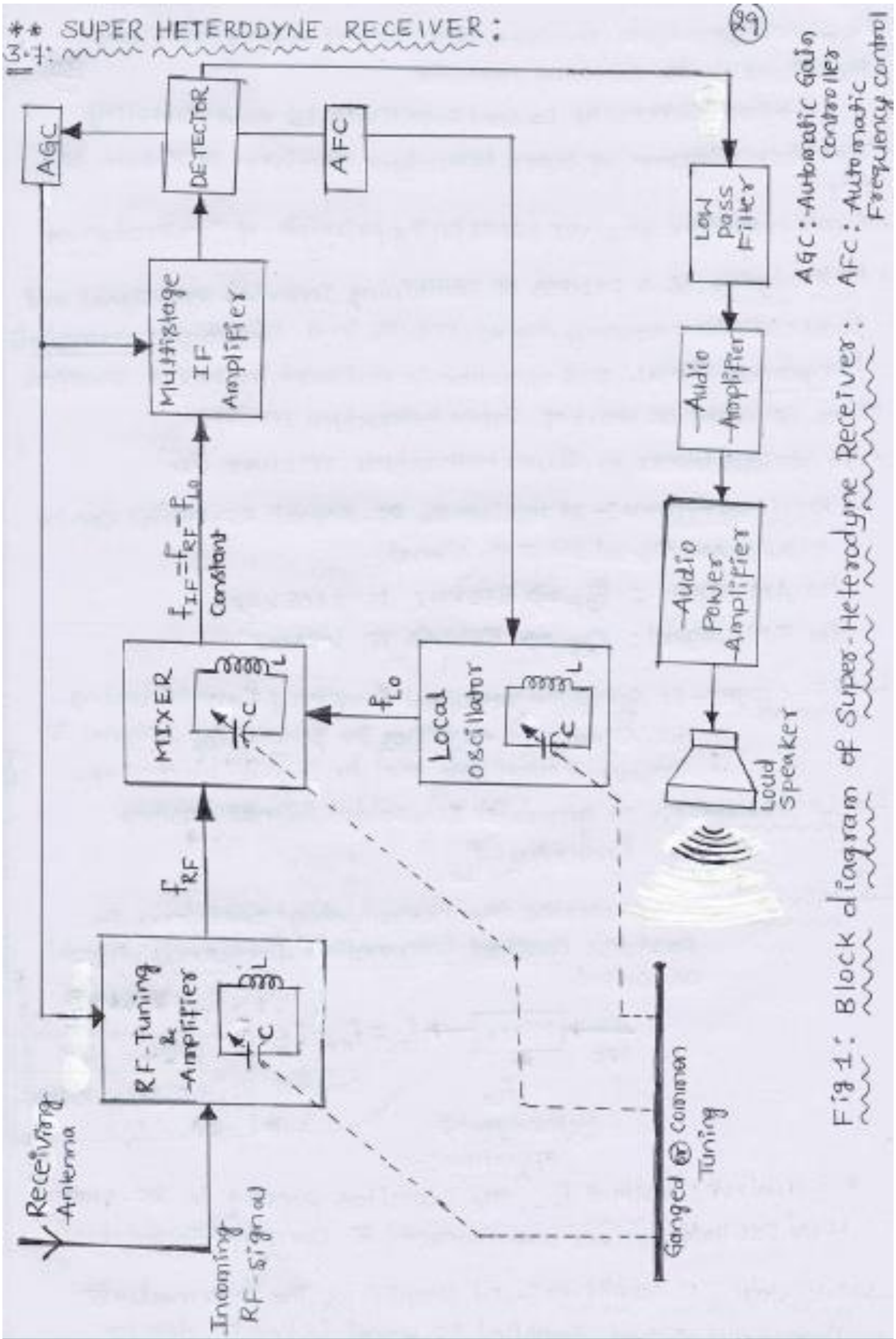
1. Baseband LPF : It selects the base-band component $[m_L(t)+m_R(t)]$ present in multiplexed signal m(t).
2. BPF : (Bandpass filter) :- It selects the DSBSC-signal.
3. Narrowband filter:- It selects the pilot carrier signal, $\cos(2\pi f_c t)$.

Frequency doubler produces the required subcarrier signal, $\cos(4\pi f_c t)$ for coherent detection of DSBSC-signal.

Coherent Detector, recovers the difference signal $[m_L(t)-m_R(t)]$.

Finally the Matrixer, produces the required signals $2m_L(t)$ and $2m_R(t)$.

5. Superheterodyne



- The Superheterodyne receiver, is a special type of receiver that fullfills the following features
  - ↳ Good Selectivity ↳ Good Sensitivity ↳ Good Stability.
- The block diagram of Super-heterodyne receiver is shown in Fig.1.
- Super-heterodyne receiver works on the principle of "heterodyning".
- Heterodyning, is a process of combining Incoming RF-signal and Local oscillator frequency signal, results in a Constant Intermediate frequency signal. This operation is performed in Mixer. Therefore Mixer is called as Heart of Super-heterodyne receiver.
- The various blocks in Superheterodyne receiver are.

↳ Receiving Antenna :- It receives the RF-signal. RF-signal can be either AM-signal (or) FM-signal.

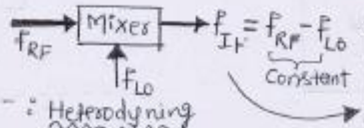
for AM-signal : $f_{RF} \Rightarrow$ 535 KHZ to 1605 KHZ

for FM-signal : $f_{RF} \Rightarrow$ 88 MHZ to 108 MHZ

↳ RF-stage :- It selects the required frequency from incoming RF-signal and Amplifies the selected f_{RF} signal to required amplitude level for further processing.

↳ Local oscillator :- It generates Sinusoidal signal having frequency 'f_{Lo}'.

↳* Mixer* : It performs the heterodyning operation. & produces constant intermediate frequency signal as output.



:: Heterodyning operation :-

	AM	FM
f_{IF}	455 KHZ	10.7 MHZ

*To achieve constant f_{IF}, the capacitors present in RF-stage, Local oscillator, Mixer are connected to Common (or) Ganged tuner.

↳ Multistage IF-Amplifier :- It amplifies the intermediate frequency signal. Amplified IF-signal is fed to detector.

↳ Detector :- It detects the message signal present in amplified IF-signal.

↳ Low pass filter :- It eliminates any higher order harmonics present in detector output. It produces the required base-band signal at audio-frequency (AF)

↳ Audio Amplifier :- It amplifies the AF-signal to the required amplitude level.

↳ Audio power Amplifier :- It boosts the power level of amplified AF-signal to a power level suitable to drive the Loud-Speaker.

↳ Loud-Speaker :- It converts electrical signal to physical sound signal.

Note : • In AM-superheterodyne receiver, $f_{IF} = f_{RF} - f_{Lo} = 455$ KHZ.

• In FM-superheterodyne receiver, $f_{IF} = f_{RF} - f_{Lo} = 10.7$ MHZ.

6. Balanced Slope Detector

(i) Frequency descriminator (or) Balanced slope Detector :-

- The Balanced slope detector Consists of two slope detector circuits. The Block diagram of Frequency descriminator (or) balanced slope detector is shown in Fig.1 and its equivalent circuit diagram is shown in Fig.2.

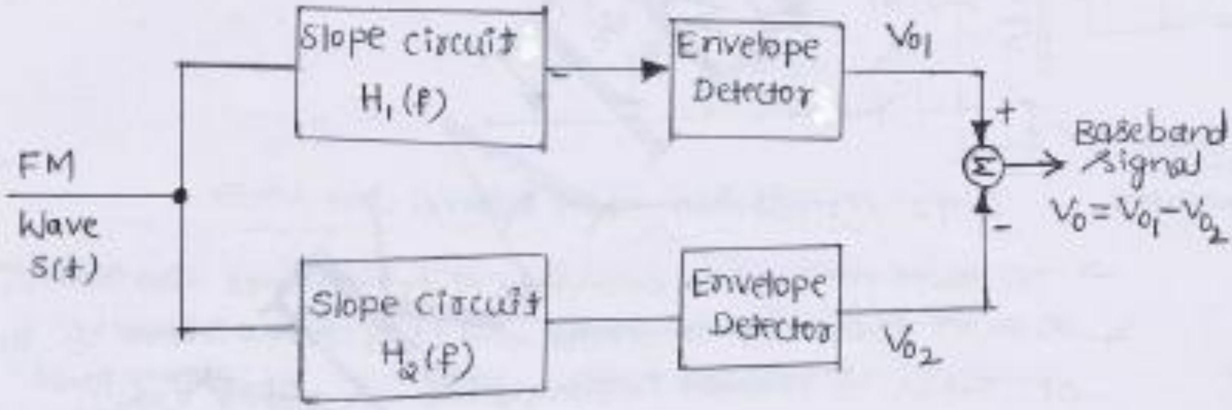


Fig 1: Block diagram

The output voltage of frequency descriminator is,
(or) (Balanced slope detector)

$$V_0 = V_{01} - V_{02} = \begin{cases} 0 & ; f_{in} = f_c \\ +ve & ; f_{in} > f_c \\ -ve & ; f_{in} < f_c \end{cases} \quad \text{—— (1)}$$

where, f_{in} = Frequency of FM-wave
f_c = carrier frequency (unmodulated carrier).

- This method is popular known as Balanced slope detector.

* The equivalent circuit diagram is shown in Fig.2. It consists of,

↳ Center-tapped transformer :• Its primary is tuned to frequency of FM-signal. "$f_c \pm \Delta f$". (Intermediate frequency)
• It produces 180° out-of-phase voltages at secondary windings

↳ The upper part of the secondary of transformer, consists of Diode-Envelope detector and it is tuned above 'f_c' by Δf. That is its resonant frequency is "$f_c + \Delta f$" [upper tuned filter]

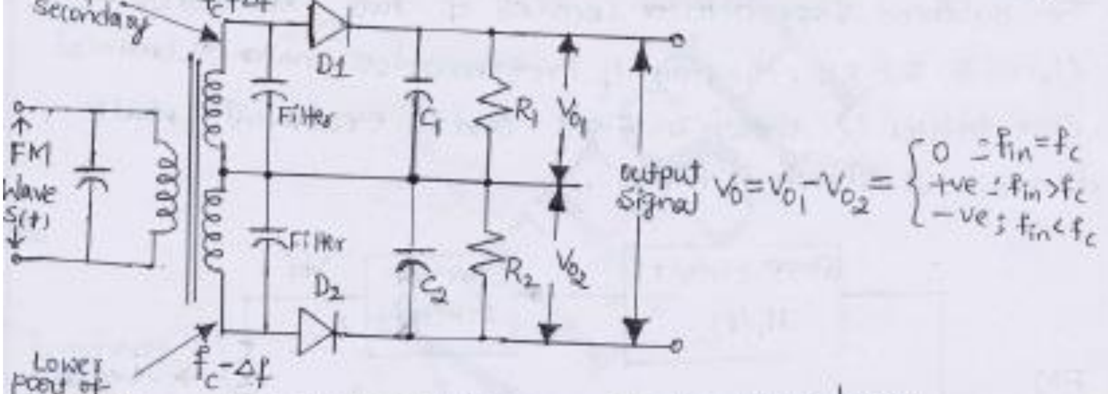


Fig2: Circuit diagram of Balanced slope detector

↳ The lower part of the secondary of transformer also consists of similar diode envelope detector and it is tuned below 'f_c' by Δf. That is its resonant frequency is "$f_c - \Delta f$". [Lower Tuned filter]

↳ It produces the required output voltage (Baseband message signal) $V_0 = m(t)$ as shown in Equation(1).

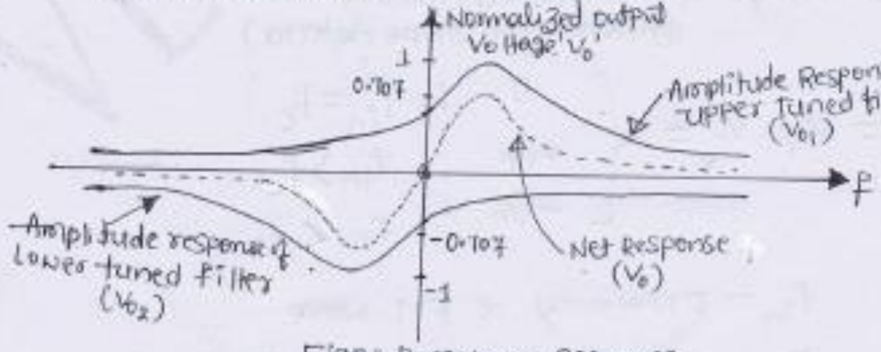


Fig3: Frequency Response