Assignment 3

Q1) Define related to FM

1) Modulation index
It is the ratio of frequency deviation ~~it~~ and the maximum modulating frequency

$$m_f = \frac{\delta}{f_m}$$

2) Frequency deviation
The amount of change in carrier frequency produced by the modulating signal is frequency deviation

3) Deviation Ratio
The modulation index corresponding to maximum deviation and maximum modulating frequency is called deviation ratio.

2) Explain Pre-emphasis and De-emphasis circuits used in FM.

Pre-emphasis and De-emphasis

.Pre and de-emphasis circuits are used only in frequency modulation.
•Pre-emphasis is used **at transmitter** and de-emphasis **at receiver**.

1.Pre-emphasis
•In FM, the noise has a greater effect on the higher modulating frequencies.
•This effect can be reduced by increasing the value of modulation index (m_f), for higher modulating frequencies.
•This can be done by increasing the deviation 'δ' and 'δ' can be increased by increasing the amplitude of modulating signal at higher frequencies.

Definition: The artificial boosting of higher audio modulating frequencies in accordance with prearranged response curve is called pre-emphasis.
•Pre-emphasis circuit is a high pass filter as shown in Fig. 1

1.Pre-emphasis

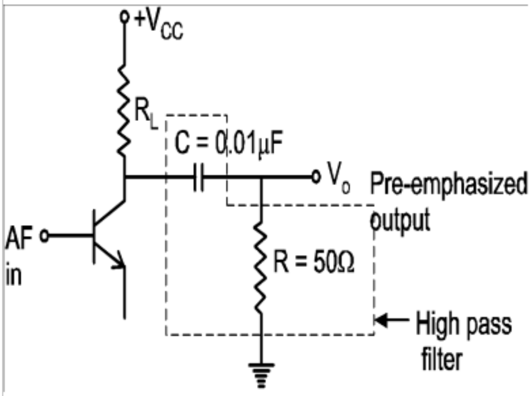


Fig. 1: Pre-emphasis Circuit

As shown in Fig. 1,

- ✔ AF is passed through a high-pass filter, before applying to FM modulator.
- ✔ As modulating frequency (f_m) increases, capacitive reactance decreases and modulating voltage goes on increasing.
- ✔ $f_m \propto$ Voltage of modulating signal applied to FM modulator.

1.Pre-emphasis

Boosting is done according to pre-arranged curve as shown in Fig. 2.

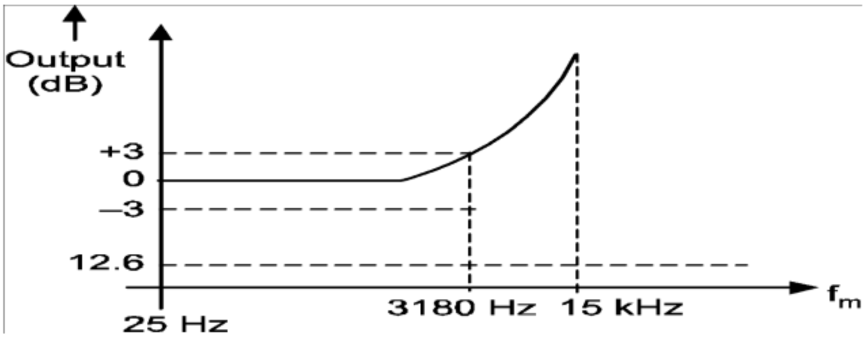


Fig. 2: Pre-emphasis Curve

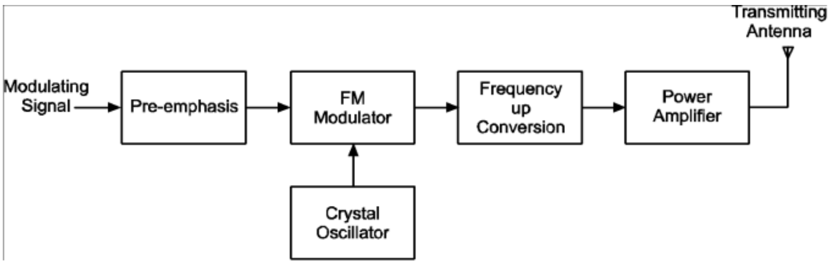


Fig. 3: FM Transmitter with Pre-emphasis

De-emphasis

•De-emphasis circuit is **used at FM receiver**.

Definition: The artificial boosting of higher modulating frequencies in the process of pre-emphasis is nullified at receiver by process called de-emphasis.

•De-emphasis circuit is a low pass filter shown in Fig. 4.

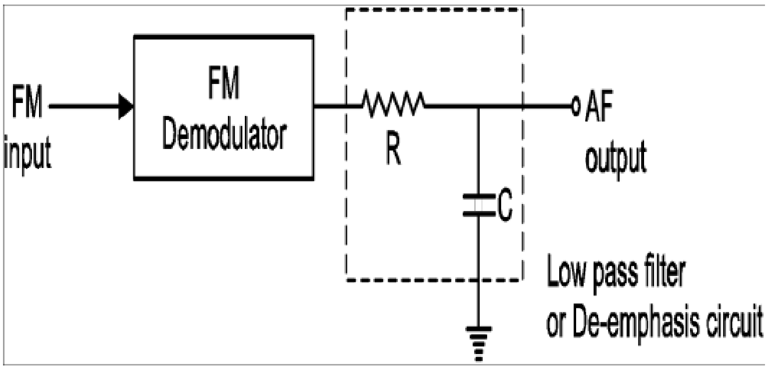


Fig. 4: De-emphasis Circuit

De-emphasis

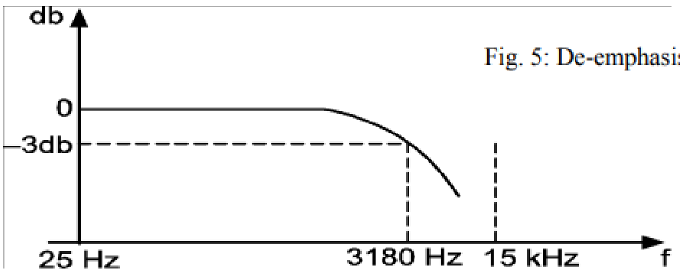


Fig. 5: De-emphasis Curve

- ✔ As shown in Fig.5, de-modulated FM is applied to the de-emphasis circuit (low pass filter) where with increase in f_m, capacitive reactance X_c decreases. So that output of de-emphasis circuit also reduces
- ✔ Fig. 5 shows the de-emphasis curve corresponding to a time constant 50 µs.

De-emphasis in FM Transmitter

The de-emphasis circuit is used after the FM demodulator at the FM receiver shown in Fig. 6.

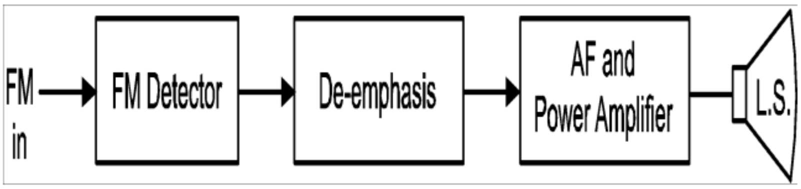


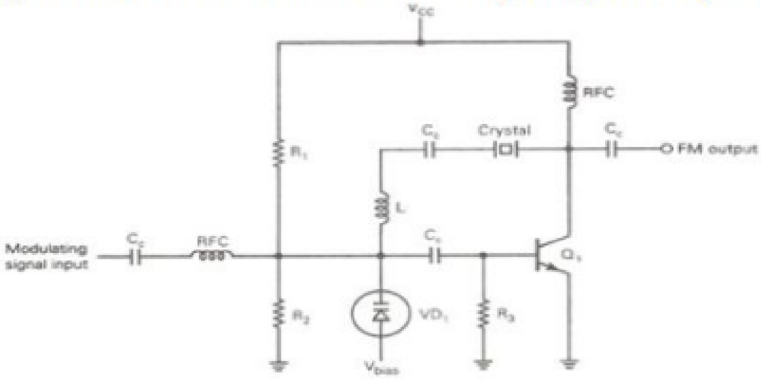
Fig. 6: De-emphasis Circuit in FM Receiver

4) Explain FM generation methods

i) Varactor diode method

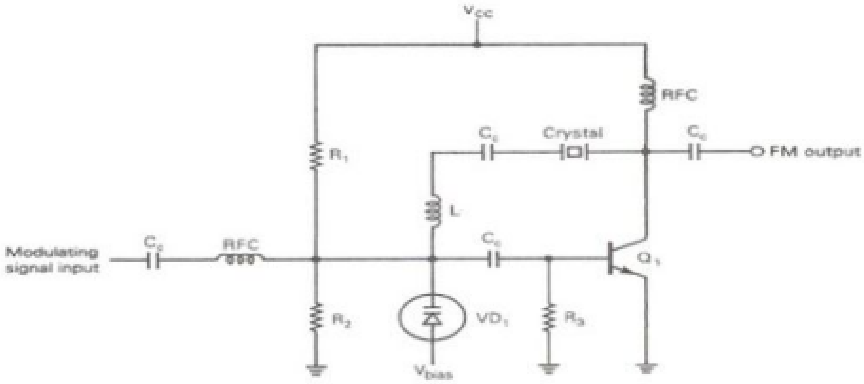
4.7.1.1 : Varactor diode modulator

- Direct FM generator using varactor diode to deviate the frequency of a crystal oscillator :



- R1 and R2 develop a DC voltage that reverse bias the varactor diode VD_1 and determine the resonant frequency of the oscillator.
- external modulating signal voltage added or subtracted from the DC bias, which changes the capacitance of the diode and consequently changes the frequency of the oscillation.

4.7.1.1 : Varactor diode modulator



- positive alternations of the modulating signal increase the reverse bias of VD_1, which decrease its capacitance and increase the frequency of the oscillation.
- negative alternations of the modulating signal decrease the reverse bias of VD_1, which increase its capacitance and decrease the frequency of the oscillation.
- simple to use, stable and reliable but limited peak frequency deviation thus limited use to the low index applications.

ii) FET Reactance method

Basic FM reactance Modulator

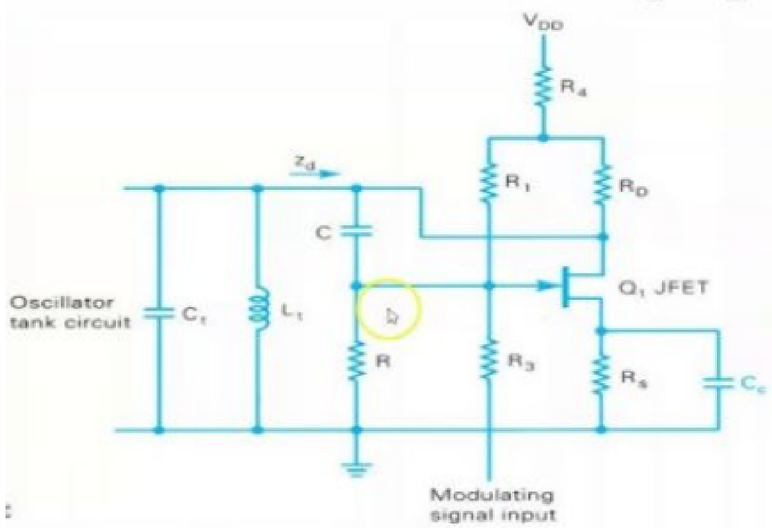


Fig a) Schematic Diagram of JFET reactance modulator

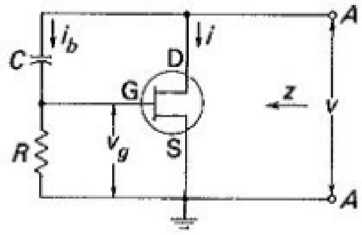


Figure b) AC equivalent Circuit

- The Circuit shown in figure b is the basic circuit of a FET reactance modulator which behaves as a three terminal reactance that may be connected across the tank circuit of the oscillator to be frequency modulated.

It can be made inductive or capacitive by a simple component change. The value of this reactance is proportional to the transconductance of the device, which can be made to depend on the gate bias and its variations. Note that an FET is used in the explanation here for simplicity only. Identical reasoning would apply to a bipolar transistor or a vacuum tube, or indeed to any other amplifying device.

Theory of reactance modulators: In order to determine z, a voltage v is applied to the terminals A – A between which the impedance is to be measured, and the resulting current i is calculated. The applied voltage is then divided by this current, giving the impedance seen when looking into the terminals. In order for this impedance to be a pure reactance (it is capacitive here), two requirements must be fulfilled. The first is that the bias network current i_b must be negligible compared to the drain current. The impedance of the bias network must be large enough to be ignored. The second requirement is that the drain-to-gate impedance (X_C here) must be greater than the gate-to-source impedance (R in this case), preferably by more than 5:1. The following analysis may then be applied:

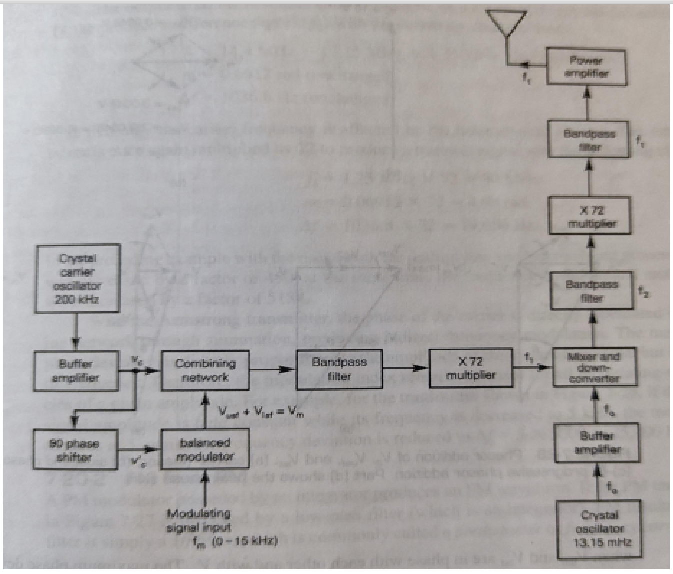
iii) Armstrong method

4.9.2 : Indirect FM Transmitter

- with Armstrong transmitter, the phase of the carrier is directly modulated in the combining network producing indirect frequency modulation.
- the magnitude of peak phase deviation (i.e. the modulation index) is directly proportional to the amplitude of the modulating signal but independent of its frequency ($m = KV_m$).
- the modulation index remains constant for all modulating signal frequencies of given amplitude.

4.9.2 : Indirect FM Transmitter

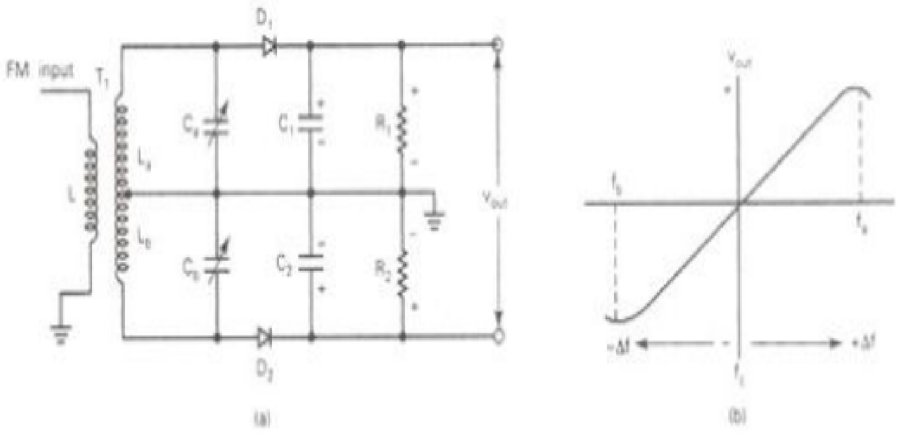
- Indirect FM transmitters produce an output waveform in which the phase deviation is directly proportional to the modulating signal.
- Consequently, the carrier oscillator is not directly deviated. As a result, the stability of the oscillators can be achieved without using an AFC circuit.
- Block diagram for wideband ***Armstrong indirect FM transmitter*** :
  - low frequency sub-carrier f_c is phase shifted 90° and fed to a balanced modulator. It is mixed with the modulating signal f_m.
  - the output from the balanced modulator is DSBSC wave that is combined with the original carrier in a combining network to produce a low-index, phase-modulated waveform.



5) Explain FM demodulators with neat circuit diagram

i) Balanced slope detector

2) Balanced Slope Detector



Balanced slope detector: (a) schematic diagram; (b) voltage-versus-frequency response curve

- Balanced slope detector is simply two single-ended slope detector connected in parallel and fed 180° out of phase.
- Phase inversion accomplished by centre tapping secondary windings of T_1.
- Tuned circuits (L_a, C_a & L_b, C_b) perform an FM-to-AM conversion.
- Balanced peak detectors (D_1, C_1, R_1 & D_2, C_2, R_2) remove the information from the AM envelope.
- L_a & C_a is tuned to frequency f_a that is above the IF centre frequency f_c.
- L_b & C_b is tuned to frequency f_b that is below the IF centre frequency f_c.

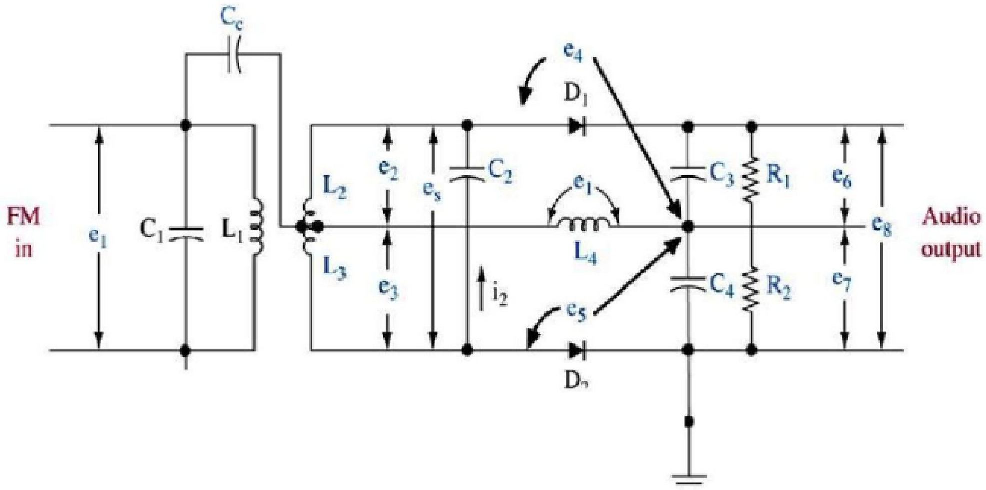
- **Operation**

Balanced slope detector: (a) schematic diagram; (b) voltage-versus-frequency response curve

  - the IF centre frequency f_c falls exactly halfway between the resonant frequency of the two tuned circuits.
  - at f_c, the output voltage from the tuned circuits are equal in amplitude but opposite in polarity. I.e. the rectified voltage across R_1 & R_2, when added, produce an output voltage $V_{out} = 0$.
  - when IF deviates above the resonance, the top tuned circuit produces higher output voltage than the lower tuned circuit, and V_{out} goes positive.
  - when IF deviates below the resonance, the output voltage from lower tuned circuit is larger than the voltage from top tuned circuit, and V_{out} goes negative.

ii) Foster seeley demodulator (Phase Discriminator)

FOSTER-SEELEY DISCRIMINATOR

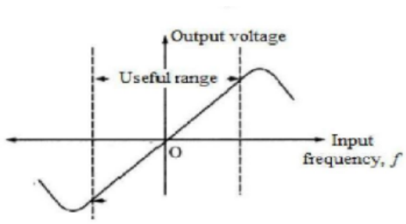


Foster Seeley Discriminator

- sometimes called as Phase shift Discriminator is a tuned circuit frequency discriminator whose operation is very similar to that of the balanced slope detector.
- The capacitance values for Cc, C1 and C2 are chosen such that they are short circuits for IF center frequency.
- Therefore the right side of L2 is at ground potential and the IF signal (Vin) is fed directly (in phase) across L3(VL3)
- The incoming IF is inverted 180 degree by transformer T1 and divided equally between La and Lb.
- At the resonant frequency of the secondary tank circuit (the IF center frequency), the secondary current (Is) is in phase with the total secondary voltage (Vs) and 180 degree out of phase with VL3.
- Also because of loose coupling the primary of T1 acts as an inductor and the primary current Ip is 90 degree out of phase with Vin. And because magnetic induction depends on primary current, the voltage induced in the secondary is 90 degree out of phase with Vin (VL3)
- Therefore Vla and Vlb are 180 degree out of phase with each other and in quadrature or 90 degree out of phase with Vl3.
- The voltage across the top diode (VD1) is vector sum of VL3 and VLa. And the voltage across the bottom diode VD2 is the vector sum of VL3 and Vlb.The corresponding vector diagrams are shown in figure a).

Foster Seeley Discriminator

- The figure shows that the voltages across D1 and D2 are equal. Therefore at resonance I1 and I2 are equal and C1 and C2 charge to equal magnitude voltages except with opposite polarities. Consequently Vout = Vc1-Vc2 = 0 V.
- When the **IF goes above resonance (XL > Xc)** the secondary tank circuit impedance becomes inductive and the secondary **current lags the secondary voltage** by some angle Θ, which is proportional to the magnitude of the frequency deviation. Corresponding diagram is shown in fig b) (vector Diagram b) The figure shows the vector sum of the voltage across D1 is greater than the vector sum of the vector sum of voltages across D2.
- Consequently **C1 charges while c2 discharges** and Vout goes positive.
- When **IF goes below resonance (XL< Xc),** the secondary **current leads the secondary voltage** by some angel Θ, which is again proportional to the magnitude of the change in frequency. The corresponding phasors are shown in figure c). It can be seen that the vector sum of the voltage across D1 is now less than the sum of the voltage across D2.
- Consequently **C1 discharges while C2 charges** and Vout goes negative.
- A Foster Seeley Discriminator is tuned by injecting a frequency equal to the IF center frequency,



Foster-Seeley…

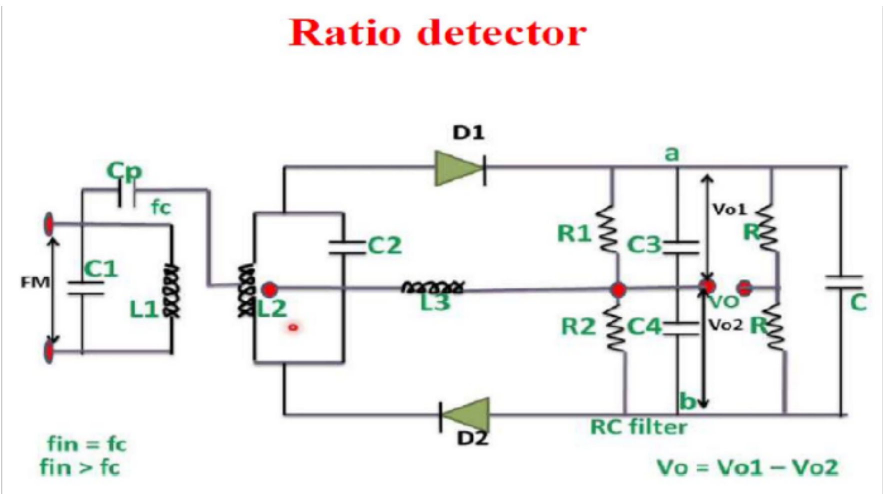
Advantages:

- Tuning procedure is simpler than balanced slope detector, because it contains only two tuned circuits and both are tuned to the same frequency .
- Better linearity, because the operation of the circuit is dependent more on the primary to secondary phase relationship which is very much linear.

Limitations:

It does not provide amplitude limiting. So in the presence of noise or any other spurious amplitude variations, the demodulator output respond to them and produce errors.

iii) Ratio detector



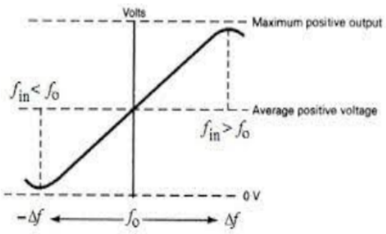
Ratio Detector

- The Ratio detector has one major advantage over the slope detector and Foster Seely discriminator. A Ratio detector is relatively **immune to amplitude variations** in its input signal.
- As with Foster Seely discriminator, a ratio detector has a single tuned circuit in the transformer secondary.
- Therefore the operation of a ratio detector is similar to that of Foster Seeley discriminator.
- Voltage vectors for D1 and D2 are identical to those of the foster Seely discriminator circuit shown.
- However with the ratio detector, one diode is reserved (D2) and current (Id) can flow around the outermost loop of the circuit.
- Therefore after several cycles of the input signal, shunt capacitor Cs, charges to approximately the peal voltage across the secondary winding of T1.

Ratio Detector

- The reactance of Cs is low, and Rs simply provides a dc path for diode current.
- So Time constant of Rs and Cs is sufficiently long so that rapid changes in amplitude of input signal due to thermal noise or other interfacing signals are shorted to ground and have no effect on the average voltage across Cs.
- Consequently C1 and C2 charge and discharge proportional to frequency changes in the input signal and are relatively immune to amplitude variations.
- Also the output voltage from a ratio detector is taken with respect to ground and for diode polarities as shown in diagram, the average output is positive.
- At resonance, the output voltage is divided equally between C1 and C2 and redistributed as the input frequency is deviated above and below resonance.
- Therefore changes in Vout are due to the changing ratio of the voltage across C1 and C2 while the total voltage is clamped by Cs.

Ratio Detector



- It can be seen that at resonance, Vout is not equal to)v but rather to one half of the voltage across the secondary windings of T1.
- Because the ratio detector is relatively immune to amplitude variations, it is often selected over a discriminator.
- However the discriminator produces a more linear output voltage versus frequency response curve.

Ratio Detector

Similar to the Foster-Seeley discriminator .

(i) The direction of diode is reversed.

(ii) A large capacitance C_s is included in the circuit.

(iii) The output is taken different locations.

Advantages:

- Easy to align.
- Good linearity due to linear phase relationship between primary and secondary.
- Amplitude limiting is provided inherently. Hence additional limiter is not required.

6) A single tone FM signal is given by VFM = 10 sin (16 Pi x 10^6t + 20 sin 2 Pi x 10^3 t)
Calculate :
(a) Maximum frequency deviation
(b) BW of FM using Carson's rule // yeh check karlo ek baar.

V= Asin(w_ct+mfsinw_mt)
Comparing, mf = 20
fm=1kHz

Freq dev = mf*fm=20kHz

Carsons Rule=> B.W = 2(freq dev(max)+fm(max))= 2(20+1)=42kHz

Assignment 4

1) Explain i) Fidelity ii) Sensitivity iii) Selectivity with respect to AM receiver

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3. Fidelity - The ability of receiver to reproduce all the freq. components of ~~a~~ message signal.
It should be always high to avoid distorsion

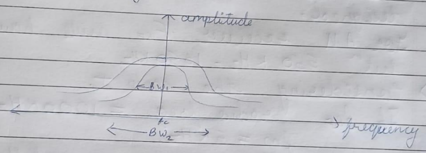
signal.

* Characteristics of radio receiver.

1. Selectivity - Ability of receiver to select desired signal & reject unwanted signal.
It depends upon quality factor (Q) and is given by,

$$Q = \frac{f_c}{BW}$$

Q ↑ → selectivity ↑ (good).



It depends on sharpness of the curve.

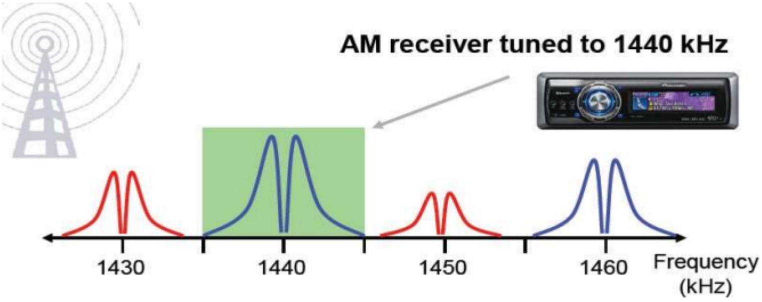
2. Sensitivity - Ability of receiver to pick weak signal & ampify it.
It depends upon the gain of the amplifier.

Sensitivity

- Ability to amplify weak signals.
- Minimum RF signal level that can be detected at the input to the receiver and still produce a usable demodulated information signal.
- Broadcast receivers/ radio receivers should have reasonably high sensitivity so that it may have good response to the desired signal
- But should not have excessively high sensitivity otherwise it will pick up all undesired noise signals.
- It is function of receiver gain and measures in decibels.

Selectivity

- Selectivity of radio receiver is its ability to differentiate desired signal from unwanted signals.



Fidelity

- Ability of a communication system to produce an exact replica of the original source information at the output of the receiver.

- Radio receiver should have high fidelity or accuracy.

- For high fidelity, it is essential to have a **flat frequency response** over a wide range of audio frequencies when amplified.

2) Explain the concept of Image frequency and Double spotting and also explain how to reject image frequency.

Image freq. and its rejection.

In a standard broadcast receiver the local osc^n freq. is made higher than the incoming signal freq. For reasons that will become apparent, it is made equal at all times to the signal freq. plus the intermediate freq.

$$f_o = f_s + f_i$$

If the freq. f_{si} manages to reach the mixer such that,

$$f_{si} = f_o + f_i \longrightarrow (1)$$

i.e. $f_{si} = f_s + f_i + f_i \quad \because f_o = f_s + f_i$

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

where, f_{si} = image freq.

Then this freq. will also produces f_i when mixed with f_o. This IF signal can also be amplified by the IF stage, & will also provide interference. The term 'f_{si}' is called as image freq. & is defined as the signal freq. plus twice the intermediate freq. i.e. $f_{si} = f_s + 2f_i$.

Double Spotting

- Same stations get picked up at two different nearby points, on the receiver dial.
- Due to inadequate image frequency rejection.
- Harmful, since a weak station can be masked by the reception of a strong station at the same point.
- Can be reduced by increasing front end selectivity of the receiver.
- Including the RF amplifier stage helps in avoiding double spotting.

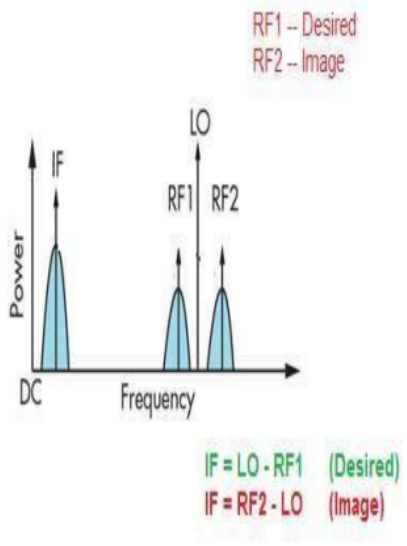


Image Frequency rejection Ratio

$$IFRR = \alpha = \frac{Gain\,at\,signal\,freq}{Gain\,at\,image\,freq} = \sqrt{1+Q^2\rho^2}$$

Where Q= Loaded Q of the tuned ckt.

$$\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}}$$

If two tuned ckts are there then

$$IFRR = \alpha 1 * \alpha 2$$

(A) Image freq. rejection.

To avoid interference due to image freq. signal it is necessary that these signals do not reach the mixer. This can be achieved firstly by using the no. of tuned ckts. betn the antenna & mixer & secondly by using there selectivity against image freq. signals.

4) Explain what should be the choice of IF for AM

Choice of Intermediate freq.

The following are the major factors affecting the choice of Intermediate freq. in a particular system.

1) If the IF is too high, poor selectivity & poor adjacent channel rejection.

2) A high value of Intermediate freq. rises Tracking difficulties.

3) As the intermediate freq. is lowered image freq. rejection becomes poor.

(4) If the IF is very low the freq. stability of local osc. must be made correspondingly higher because any freq. drift is now larger proportion of the lower IF than the higher IF.

5) IF must not fall within the tuning range of the receiver, or else the instability will occured & hytrodyne whistle will be heard, making it possible to tuned the freq. band

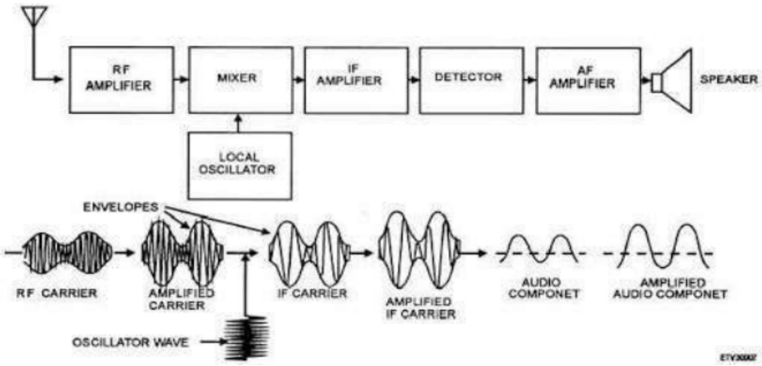
5) What are the disadvantages of Tuned RF receivers? And Explain superhetrodyne receiver with block diagram.

Disadvantages of TRF

- It is very difficult to design at high frequency.
  - Difficult to design tunable RF stages.
  - Difficult to obtain high gain RF amplifiers
  - It has poor audio quality.

- This is mainly due to
  - Instability
  - Variation in BW
  - Poor Selectivity

Superhetrodyne Receiver



Superhetrodyne Receiver

- Superhetrodyn receivers convert all incoming signals to a lower frequency, known as **the intermediate frequency (IF),** at which a single set of amplifiers is used to provide a fixed level of selectivity and sensitivity.
- The key circuit is the **mixer** - act as a simple amplitude modulator to produce sum and difference frequencies.
- Heterodyne means to **mix** two frequencies together in a nonlinear device or to **translate** one frequency to another using nonlinear mixing.

(1) RF amplifier – It is termed voltage amplifier coupled through the antenna to the mixer. It selects the desired signal from the antenna & amplifies then this stage improves the sensitivity & selectivity of the radio receiver. It also isolates local oscillator circuitry from the antenna there by previewing the local oscillator energy.

(2) Mixer & local oscillator (convertor stage)
It is a convertor stage in superhytrodyne receiver. The RF amplifier, mixer & local oscillator are gonged together to produce intermediate frequency at the output of mixer which is always 455 kHz
($f_i = f_o - f_s$)

(3) IF amplifier – IF amplifier is a tuned voltage amplifier i.e operated in class A with fixed rheostat load in most of receiver. The gain is provided by IF amplifier

(4) Detector – The amplified signal is fed to the detector or demodulator. It receives the original information from the amplitude modulated wave.

MW band freq = 550 kHz, SW band freq = 3 – 30 MHz

(5) Audio & Power amplifier –
Audio amplifier amplifies the incoming signal. Power amplifier generates the required power to drive the loud speaker.

(6) Loudspeaker – It converts electrical energy into sound energy.

6) Compare TRF and Super heterodyne receiver.

COMPARISON

TRF Receiver

- No frequency conversion
- No IF frequency
- Instability , variation in BW and poor selectivity due to high frequencies
- Difficult to design tunable RF stages.
- Rarely used

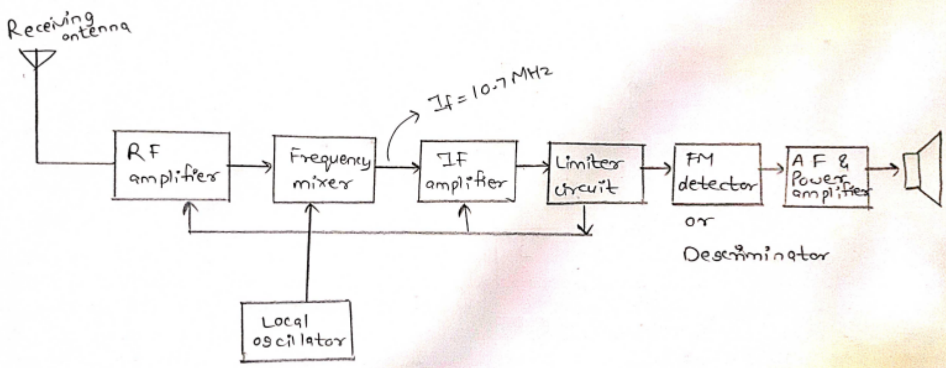
Super hetrodyne Receiver

- Frequency conversion
- Downconvert RF signal to lower IF frequency
- No instability, variation in BW and poor selectivity as IF introduced.
- Main amplifixcation takes place at IF
- Mostly used

7) Explain FM Receiver with block diagram

* Super hytrodyne FM radio receiver :-

* Block diagram-



To remove undesired amplitude variation we use limiter ckt.

* Superhytrodyne FM radio receiver-

(1) RF amplifier - RF amplifier raises the signal level appreciablely before the signal is fed to the mixer & descriminate against the image signal.
The main purpose of this amplifier is to reduce the noise which could otherwise be a problem because of the large bandwidth needed for FM. It is also required to match the i/p impedance of the receiver to that of antenna.

(2) Frequency mixer - It performs the usual function of mixing or hytrodyne that signal frequency voltage & the local oscillator voltage to produce the difference voltage and frequency voltage which is the intermediate frequency voltage.
Since FM broadcast takes place either in VHF or UHF band simple transistor frequency converter is not used. The IF frequency is used in FM receiver higher than in AM receiver operating in short wave. Typical value of IF 10.7 MHz.

Teacher's Sign.:

Date

(3) Local oscillator - A separate local oscillator is always used. UHF, it is preferred to keep the local oscillator frequency smaller than signal frequency by an amount equal to IF.

(4) IF amplifier → A multistage IF amplifier is used to provide large gain because due to large bandwidth the gain per stage may be low. The use of stagger tuned and single tuned circuit are found to produce more gain bandwidth product than the conventional double tuned circuit.

(5) Limiter - The IF amplifier is followed by limiter which limits the IF voltage to predeter mixed level & thus removes all the amplitude variations which may be incidently caused due to change in the transmission path or by manmade statics or by natural statics

(6) FM detector - To extract the original audio frequency voltage from the frequency modulated carrier voltage descriminator is used as a FM detector.

(7) Audio amp & power amplifier - The output of FM detector is fed to an audio frequency small signal amp and power amplifier. The output audio voltage is then fed to the loudspeaker. In FM broadcast the maximum modulating frequency permitted 15 kHz & Hence the audio amplifier must be designed to accomodate such large bandwidth.

Teacher's Sign.:

3) In an AM radio receiver the loaded Q of the antenna circuit at the input to the mixer is100.If the intermediate frequency is 455 KHz, calculate the image frequency and its rejection at 1MHz.

including RF amplifier stage

$f_i = 455$ kHz
$f_s = 1$ MHz

$Q = 100$

$f_{si} = f_s + 2f_i = 1\times10^6 + 2(455\times10^3) = 1.91$ MHz

$\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}} = \frac{1.91}{1} - \frac{1}{1.91} = 1.386$

Image rejection ratio

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

$= \sqrt{1+(100)^2(1.39)^2}$

$= 139$

In dB $\rightarrow$ $20\log_{10}(139)$

$= 42.86$ dB

$f_{si} = 1.91$ MHz

$\alpha_{dB} = 42.86$ dB

Assignment 5

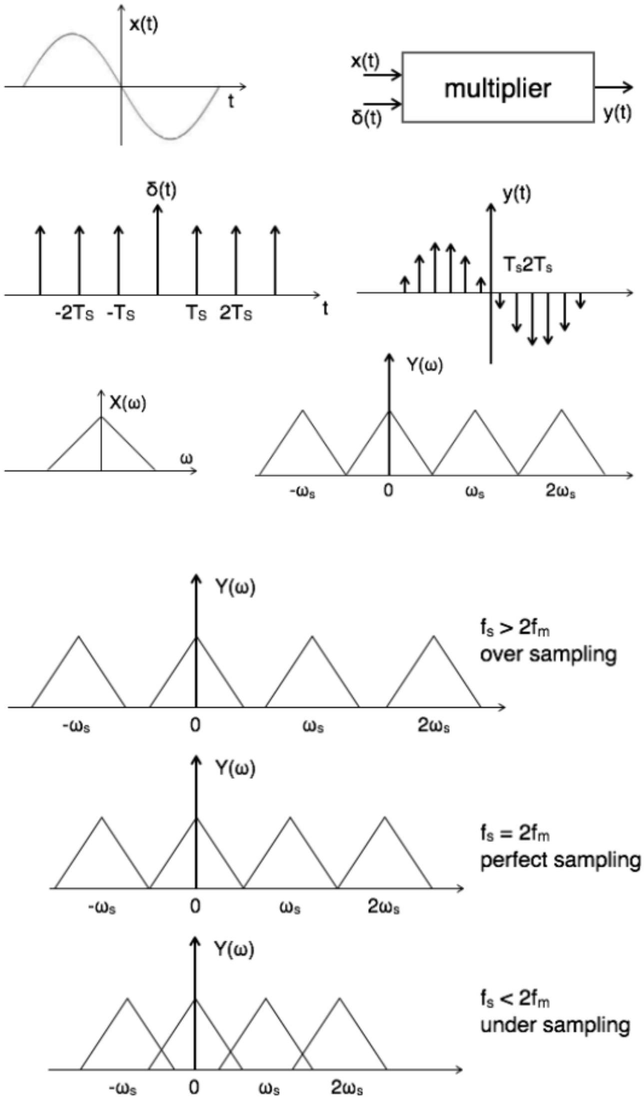
1) State and prove Sampling Theorem for low pass band limited signal

- **Sampling theorem:** A band limited signal with no spectral components beyond f_m, can be uniquely determined by values sampled at uniform intervals of

$$\boxed{T_s \leq \frac{1}{2f_m}}$$

communications; the sampling theorem: *Let m(t) be a signal which is bandlimited such that its highest frequency spectral component is f_M. Let the values of m(t) be determined at regular intervals separated by times $T_s \leq 1/2f_M$ that is, the signal is periodically sampled every T_s seconds. Then these samples m(nT), where n is an integer, uniquely determine the signal, and the signal may be reconstructed from these samples with no distortion.*

The time T_s is called the *sampling time.* Note that the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