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LECTURE # 19 PART - III

FREQUENCY MODULATION (FM) DISCRIMINATOR

FM detection is the process of recovery of the original modulating baseband signal m(t) from the FM carrier recieved by the Rx. It involves the process of converting frequency Variations in the receiving FM carrier to corresponding Amplitude Variations. This process is illustrated in figure 16 below.

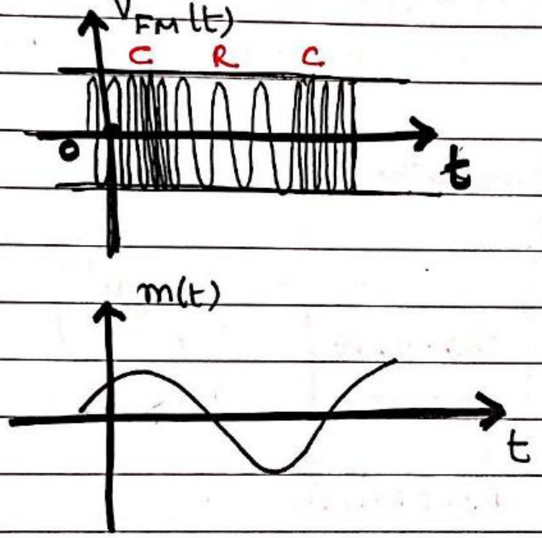

FIGURE 16: FM TO m(t) CONVERSION

FREQUENCY VARIATION IN CARRIER OF RECEIVED FM WAVE.

CORRESPONDING AMPLITUDE VARIATIONS IS THE DETECTED MESSAGE m(t) SIGNAL.

We describe two basic devices for performing frequency demodulation namely frequency discriminator and the zero crossing detector. The frequency demodulator produces an output voltage whose instantaneous amplitude is directly proportional to the instantaneous frequency $f_i(t)$ of the input FM wave as shown in Figure 16.

Basically a Frequency discriminator consists of a slope circuit followed by an Envelope detector. This conversion is done linearly. The Frequency discriminator should be insensitive to incoming carrier amplitude changes if any.

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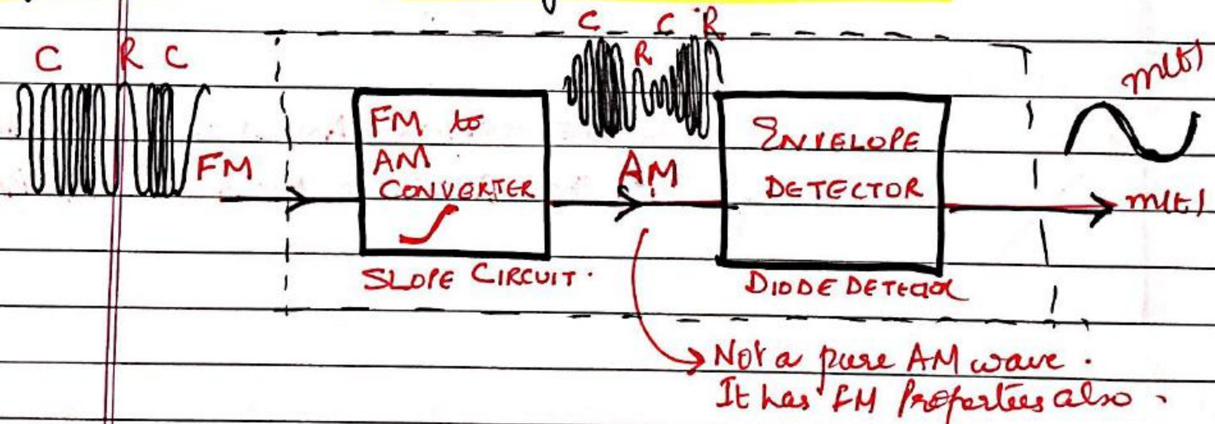
Q.1 What is a slope Detector? Show how it carries out the process of FM to AM conversion?

Soln: The Slope circuit or the slope detector is an essential part of the FM discriminator. It converts input FM to AM wave. The converted AM wave is not a pure AM wave but it also has inherent properties of FM wave. To enable linear conversion, all incoming amplitude variations in the FM wave due to noise or distortion should be removed. The slope circuit is followed by an envelope detector to recover m(t) from the AM wave.

Figure: 17 Frequency Discriminator.



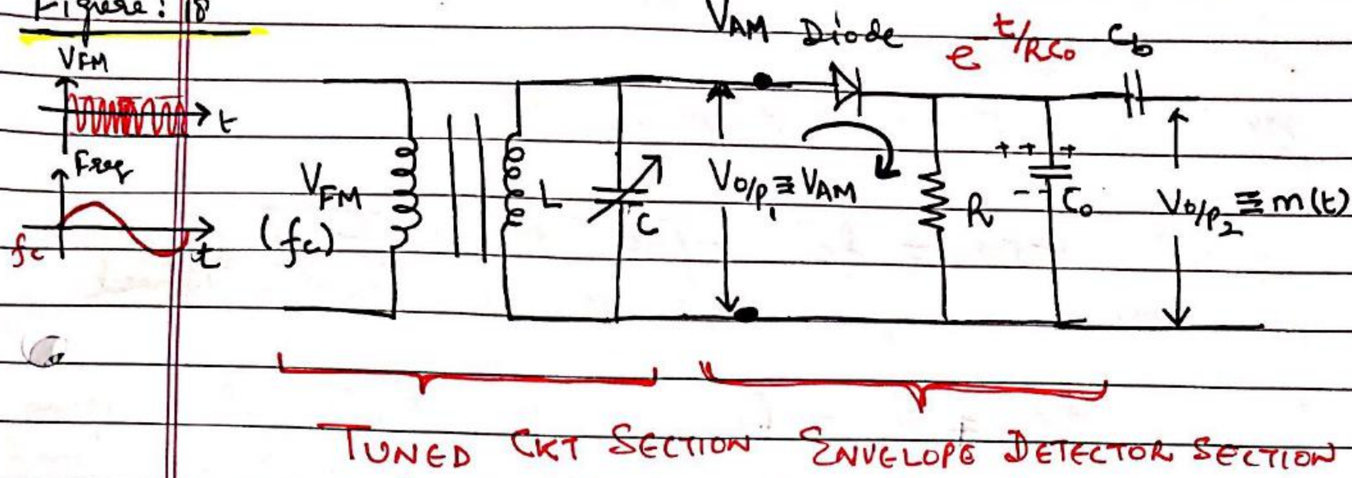
Working of the Slope Circuit (or Slope Detector) & Envelope Detector

The figure 18 shows the circuit diagram of the Frequency Discriminator comprising of the slope circuit followed by Envelope detector.

The slope circuit is a tuned circuit which has a resonant frequency denoted by f_{res}. Any region above or below f_{res} of tuned circuit is chose for FM demodulation.

$$f_{res} = \frac{1}{2\pi\sqrt{LC}} \quad (1)$$

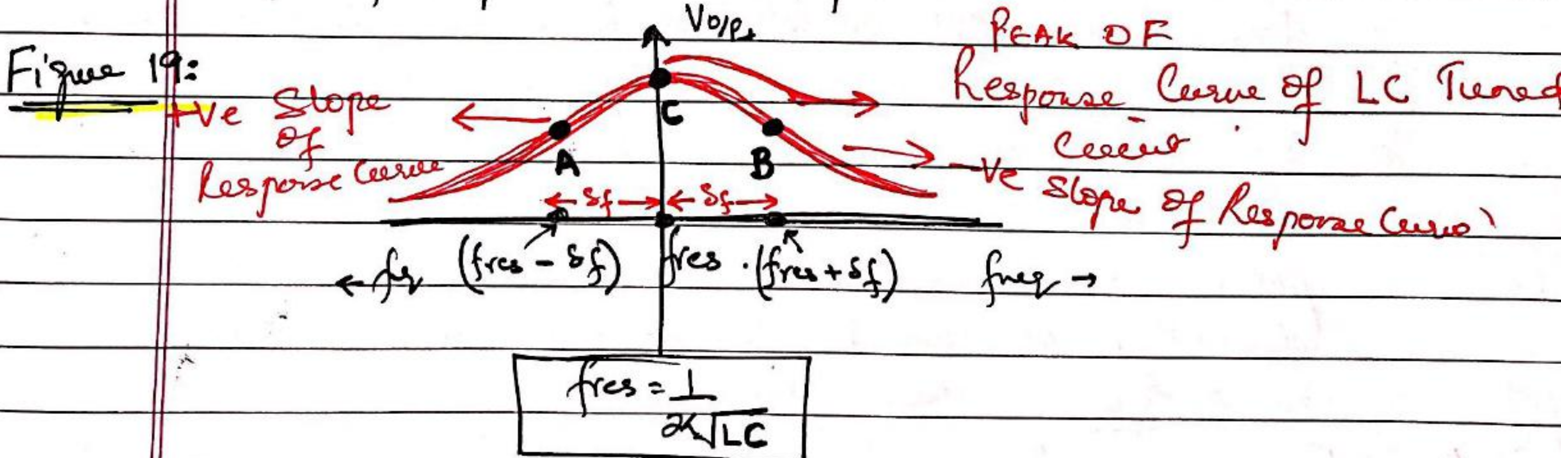
Figure: 18



$$f_{RES} = \frac{1}{2\pi\sqrt{LC}} = (f_c + \delta f) \text{ or } (f_c - \delta f)$$

The capacitor on the front side is variably changing capacitor as the arrow across C indicates. Thus as C is varied then f_{res} can also be varied. Here the tuned circuit is intentionally de-tuned so that f_{res} falls either on +ve slope of response curve or f_{res} falls on -ve slope of response curve of the tuned circuit.

Figure 19:



Position A is a point on +ve slope of Response Curve

Position B is a point on -ve slope of Response Curve

Position C is the Peak Point on the Response Curve.

Referring to the Response Curve shown figure 19, it can be shown that as C (Capacitor) is adjusted and Varied then accordingly Various possible tuning positions are explained.

If incoming FM carrier is f_c then

For

$f_{res} = f_c$ implies position C of response curve. Here Circuit is Tuned.

$f_{res} + \delta f = f_c$ implies −ve slope of response curve. Here Circuit is de-tuned.

$f_{res} - \delta f = f_c$ implies +ve slope of response curve. Here Circuit is de-tuned.

Out of these possibilities the linear conversion from FM to AM is possible only when Tuned Circuit is detuned either by δf above f_{res} (−ve slope) or detuned by δf below f_{res} (+ve slopes). $f_{res} = f_c$ is not at all a favourable choice as this covers the non-linear parabolic curve. We can only employ A side (+ve slope) or B side (−ve slope) but not Curve around position C. Thus it is said that the circuit is deliberately de-tuned to receive the FM carrier (f_c) on either of these linear slopes.

Point A

Figure 20 shows this conversion if Point A on −ve slope of Response curve is employed as the linear portion. Here f_{res} is detuned so that $f_{res} + \delta f = f_c$

$f_c = f_{res} - \delta f.$

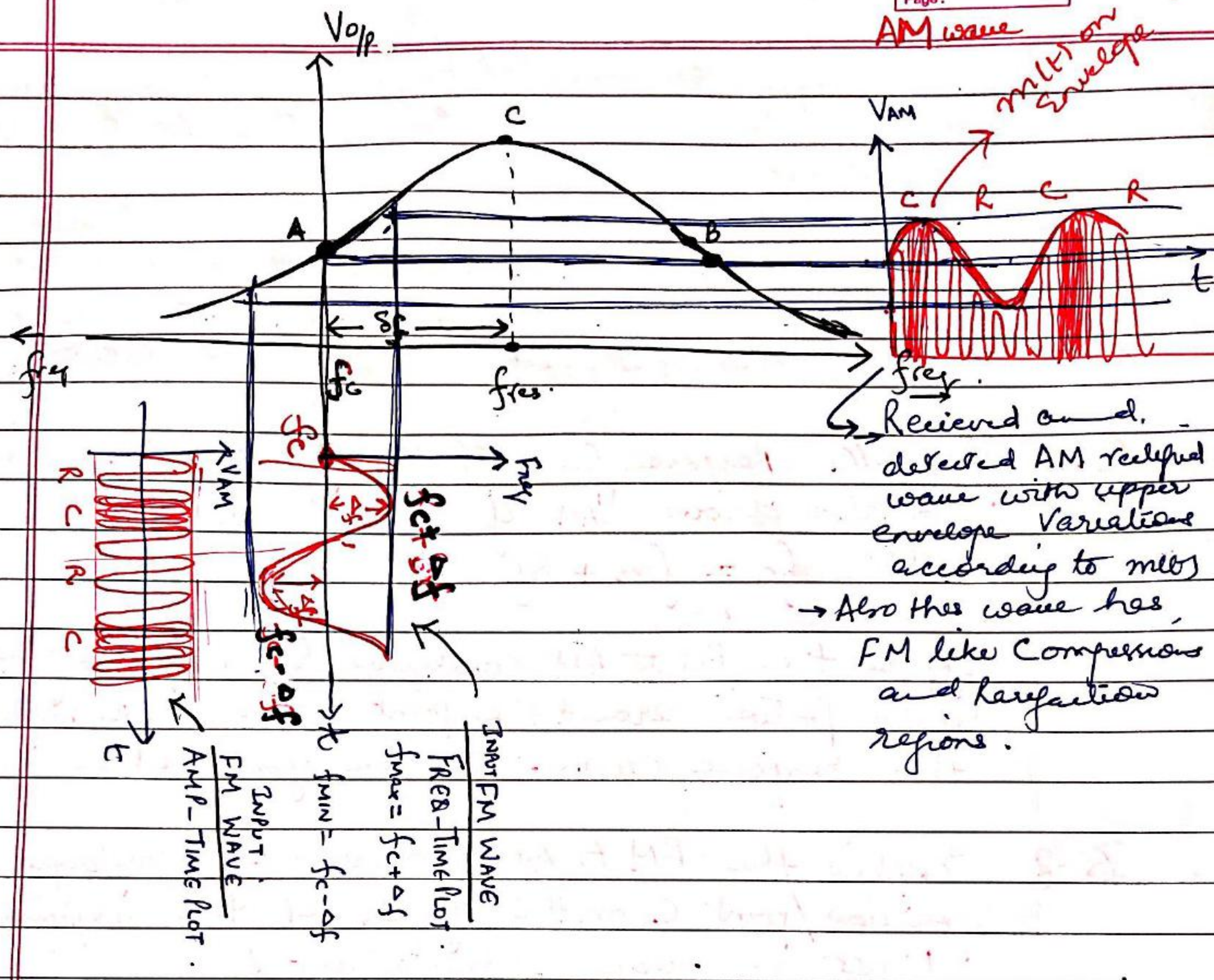


Figure 20: Portion A of +ve linear slope of tuned circuit has been used by detuning fres so that $f_c = f_{res} - \delta f$.

The figure 20 above shows that input FM wave has a frequency-time plot with excursion Δf above and below resting carrier freq f_c to cover the entire linear portion around point A. Result of the transfer on the response curve is the AM wave drawn to the right (top side). The AM wave has above envelope with m(t) variations and it also has rf cycles with zero crossing irregularities same as the input FM wave.

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The VAM signal so generated is then fed to the Envelope detector to carry out the routine AM to m(t) conversion as explained Earlier.
The Vo/p2 is the VAM voltage when fed to the Envelope detector with R, C load. The RC load should be of suitable time constant as was explained in case of lecture covering the working of an Envelope Detector.

Q.2 Draw the Response Curve of the parallel LC Circuit and also draw VAM if fres is de-tuned so that $f_c = f_{res} + \delta f$.

OR

Explain the FM to AM conversion by employing the linear portion around the point B on the -ve slope of the response curve. What are your observations?

Q.3 Explain the FM to AM Conversion by employing the position/point C on the peak of the response curve. What are your Observations?

Q.4 Why is not point C feasible for using for FM to AM conversion?

Q.5 What do you observe if frequency deviation Δf is very large & in case of $f_{res} - \delta f = f_c$ (point A).

OR

What do you observe if frequency deviation Δf is very large in case of $f_{res} + \delta f = f_c$ (point B).

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Demerits of Slope detector

The slope detector is not however a suitable demodulator for following reasons :

(1) It is inefficient (Explain Why?)
HINT: If Δf is very large then figure shows that frequency swings up & down to even the non-linear portions of resonance curve around point A or point B. So this detector can be used strictly only for Δf small. This implies that since $\beta = \Delta f / f_m$, Hence only small β-FM wave can be used.

(2) It is linear only along a limited frequency range

(3) It reacts to unwanted amplitude changes as well. That is why a limiter is used prior to FM discriminator to remove these unwanted amplitude variations.

(4) The circuit has poor sensitivity (Why?)

The slope detector is not used at all because of its very poor and limited linear range. This type of slope detector is used only to understand the operation of a Balanced slope detector.

Q.6 What is a balanced slope detector? How does it overcome the limitations of a single tuned slope detector?

The Balanced Slope Detector is also called a Balanced frequency discriminator. The circuit uses two slope detectors T_1 & T_2, connected back-to-back to the opposite ends of a centre tapped transformer and hence it is fed 180° out of phase. The top secondary is tuned by δf above f_c ie $f_{res_{T_1}} = f_c + \delta f$. Thus $f_c + \delta f$ is the resonant frequency designated as $f_{res_{T_1}}$ for top slope detector (T_1)

Similarly the lower circuit (T_2) is detuned below f_c by same value of frequency δf. This means the resonant frequency of lower circuit (T_2) designated as

$$f_{res_{T_2}} = f_c - \delta f$$

In other words we can say that incoming FM carrier f_c is δf below $f_{res_{T_1}}$ while the f_c is δf above $f_{res_{T_2}}$. This further implies that f_c is as far from $f_{res_{T_1}}$ as it is from $f_{res_{T_2}}$. Each tuned circuit T_1 & T_2 is connected to an Envelope Diode Detector with RC load.

The output is taken from the series combination of the two loads so that it is sum of individual inputs

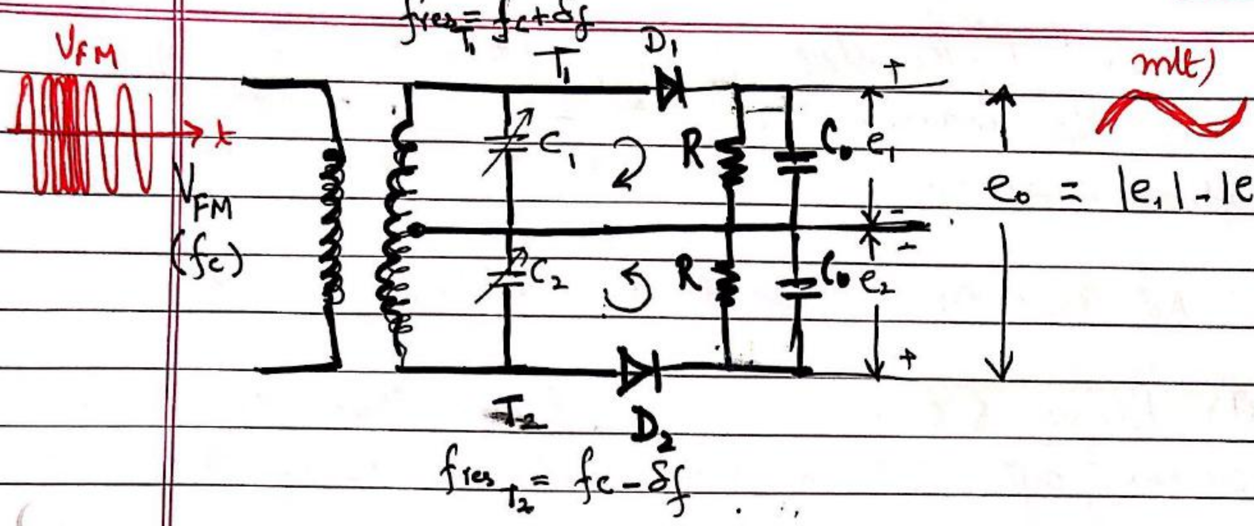
ie $e_0 = |e_1| + |e_2|$

where e_1 is output of T_1 &

e_2 is output of T_2

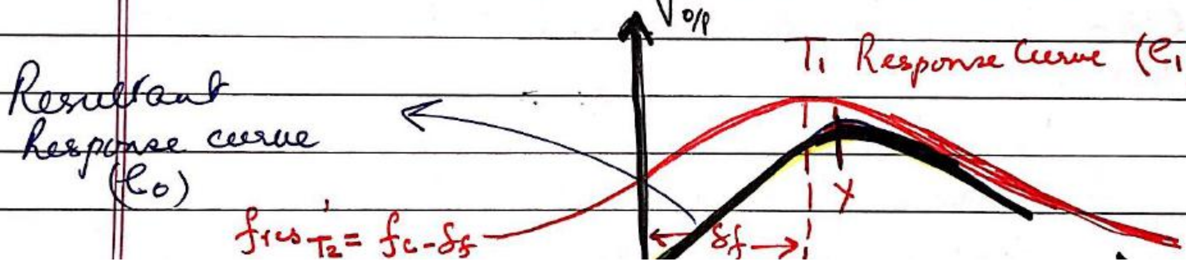
Hence there is a change in o/p e_0 due to a change in magnitude of response across ckts T_1 & T_2

Here also Envelope diode detectors are used for FM to AM conversion in each circuit to provide resultant e_0.



$$e_0 = |e_1| - |e_2|$$

Figure 21 : A Balanced Slope Detector with two tuned Ckts T_1 & T_2 de-tuned or off-tuned by same frequency measure and connected back to back.



demodulated by the slope detector. When the incoming fi(t) of V_{FM} wave is equal to fc much ~~higher~~ higher excursions are allowed around fc

Merits:- Main Advantages of Balanced slope detector is that

(1) Linear S curve is much larger than the linear curve offered by a single slope detector.

(2) This type of slope detector provides excellent linearity compared to single tuned circuit type discriminator because the distortion caused by even harmonics is balanced out in such arrangements

Demerit:- The slope detectors in balanced configuration are perfect for increasing linearity range & for operations only if T_1 & T_2 circuit components are identical. Which however is always ~~an~~ impossible to achieve perfectly.

Q.7 Draw the block diagram of an FM detector Rx and briefly explain the function of each block.

Ans. The FM detector Receiver block diagram is shown in figure 23. The function of each block is briefly explained as follows:-

(1) Limiter:- The input of the FM Receiver is a Frequency Modulated Carrier (fc). Because of Various factors such as noise picked up in channel

or noise picked within the transmitter circuitry or frontend Rx circuitry & because of any type of distortions, this FM wave may be distorted. This can be observed as Amplitude variations (unwanted) on top & lower envelope of FM carrier. The distortion should be removed otherwise these variations in amplitude will also be present in the detected signal at later stages.

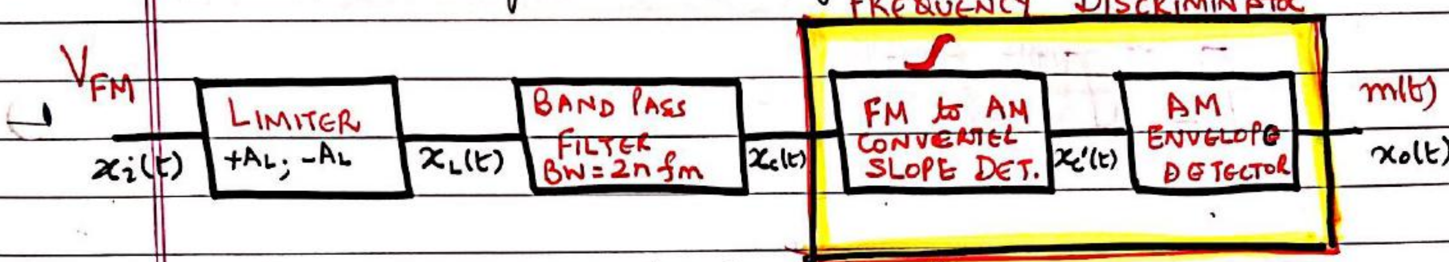


Figure 23: Block Diagram of FM Detector Rx.

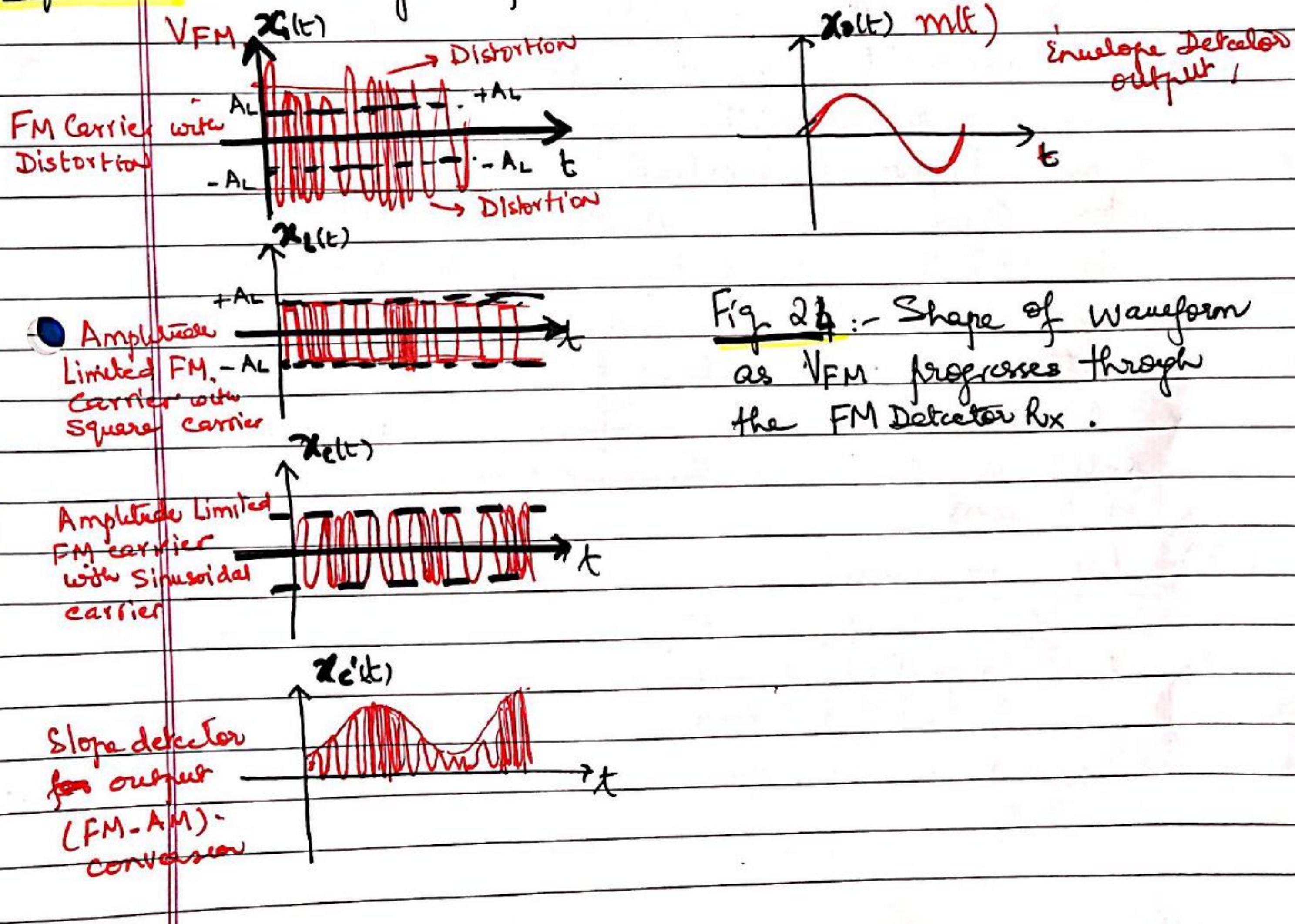


Fig. 24 :- Shape of waveform as V_{FM} progresses through the FM Detector Rx.

(219)

The limiter is designed in figure to clip these distortions above $+A_L$ & $-A_L$ in $V_{FM}(t)$ ie $x_i(t)$ shown in figure 24. The output will be $x_L(t)$. $x_L(t)$ is now amplitude limited (Clipped) FM carrier with peak amplitude of $+A_L$ & $-A_L$ and due to clipping sinusoidal signals have become square shaped.

(2) Bandpass filter:- Input to bandpass filter is $x_L(t)$ shown above. For efficient demodulation this square FM carrier should be converted to sinusoidal FM carrier. This can be achieved by using a BP filter. The bandpass (BP) filter blocks all higher harmonics & frequency components that impart the square shape. However the bandwidth (BW) of BP filter should be equal to FM BW ie $2nf_m$ so that the FM related spectrum is not attenuated. FM nature has to be maintained in the sinusoidal carrier. Therefore $(BP\ filter)_{BW} = 2nf_m$. $x_c(t)$ is shown as sinusoidal FM carrier.

(3) Frequency Discriminator

This has been already explained as it performs two important functions resulting in

$x_c'(t) \rightarrow$ FM to AM converted signal

$x_o(t) \rightarrow$ Envelope detected message signal m

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Q.8

Q.8 Write Short notes ON Zero Crossing Detectors used for FM demodulation.

Q.9 Write short notes on Phased locked loop (PLL) demodulator.

Assignment No: 5.

Submit the following Questions :-

Q.2 on pg. 213.

Q.3 on pg. 213

Q.4 on pg. 213

Q.5 on pg. 213.

Q.8 on pg. 220

Q.9 on pg. 220.