dated: 22/05/20

LECTURE # 12 (Part II)

3.3. Frequency Modulation Techniques..

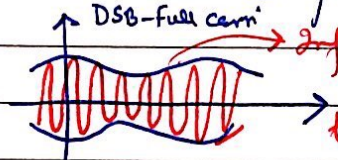
Consider an unmodulated Carrier given by

$$\boxed{V_c(t) = A_c \sin(\omega_c t + \varphi)} \quad \text{--- (1)}$$

where $A_c \rightarrow$ Unmodulated Amplitude of Carrier.
$\omega_c = 2\pi f_c \rightarrow$ Unmodulated frequency of Carrier
$\varphi \rightarrow$ Unmodulated Phase of Carrier.

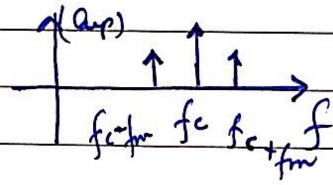
In the AM techniques as discussed in previous lectures (Lectures # 08, 09, 10, 11) the carrier amplitude A_c is varied while frequency f_c and phase φ is unchanged. Specifically in Amplitude Modulation - Standard scheme (DSB - Full Carrier) the Amplitude is varied in accordance to the baseband (message / information) Signal $m(t)$. Hence in AM systems information is present in the carrier amplitude. See Fig(1) below

Fig (1)



Information in envelope variations

RF oscillations exhibit perfect Zero crossing regularity.



Fig(1) DSB-Full Carrier with spectral Components at $f_c \pm f_m$; f_c.

As shown in Fig (1) above, there will be no change in RF cycles. The wavelengths are constant. This means that the AM signal only shows Amplitude variations but no change in RF cycle Time periods.

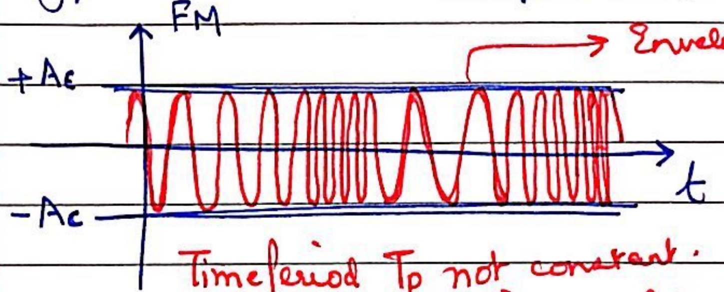
Increases from time (t_1 to t_2), then ...

Q.) Similarly draw DSB-SC signal in time domain and its spectral components. Show that it also shows perfect Zero crossing regularity of each RF cycle.

Q) Repeat for SSB-SC signal in time domain and its spectral components.

On the Contrary an FM signal in time domain carries information in its RF cycle variations. Therefore we should expect that the FM signal in time domain has constant envelope but information is carried in the RF cycle time period variations thus exhibiting a typical Zero crossing irregularity (See Fig(2))

Fig(2)



Time Period T_p not constant.
Information carried in RF cycle variation.

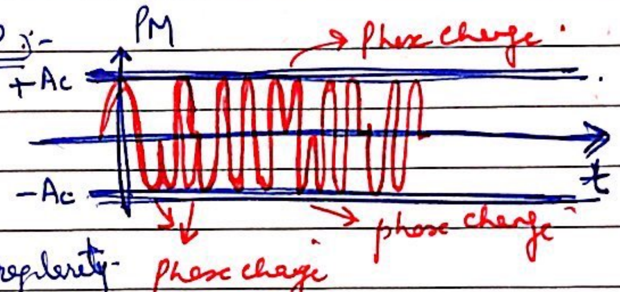
Fig(2): FM signal in time domain with Zero crossing irregularity

Hence for FM modulation technique we may write (1) as

$$V_c(t) = A_c \sin[\theta_c(t)] \quad \text{--- (2)}$$

where $\theta_c(t) = \varphi + \omega_c t$

In general for analog modulation technique where $[\theta_c(t)]$ angle is varied in accordance to baseband signal then this belongs to the category of Angle Modulation Schemes. Angle Modulation can be of two major types when in $\theta_c(t) \rightarrow f_c$ is Varied according to m(t) called FM. If in $\theta_c(t)$ phase ϕ is varried according to m(t) then it is calle phase modulation (PM). In both FM & PM Ac remains Constant. In general in angle Modulation in both cases (FM as well as PM) the change of frequency and phase parameters will result in charge of angle and hence the name. Here the modulating baseband signal is contained in the angle. PM and FM are not essentially different in the sense that any Variations in phase of a carrier is also accompanied by a corresponding charge in frequency. If one observed a carrier which has been angle modulated by either PM or FM, then it would be impossible to determine whether PM or FM has been used. See Fig(3) below :-



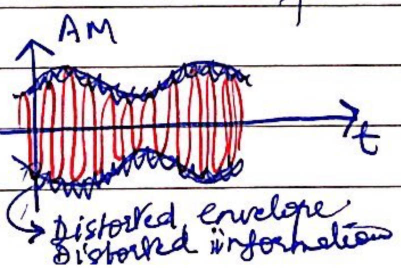
Fig(3)
PM Signal in time domain
with Zero crossing irregularity-

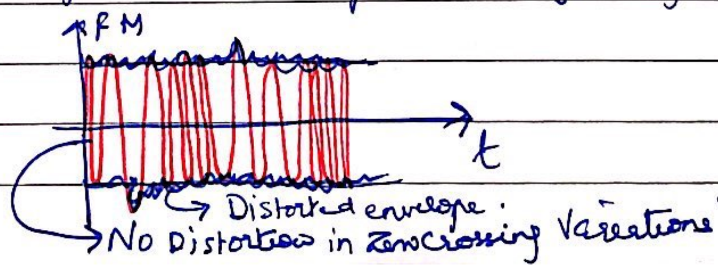
Fig(3)

Merits of FM over AM

(1) FM Systems are highly immune to noise & interference. If Noise distorts an AM signal it can do so by causing unwanted noise inflicted Amplitude Variations in addition to the wanted signal modulation. In FM we have waveform which does not exhibit perfect Zero crossing regularity. Even if noise does occur it distorts the envelope but does not influence the RF cycle Zero crossings that carry the information

Fig(4, a, b)



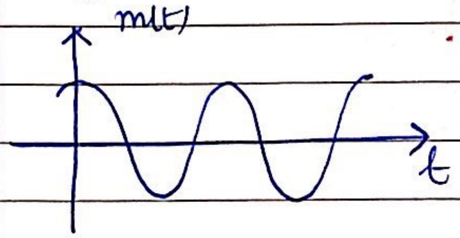


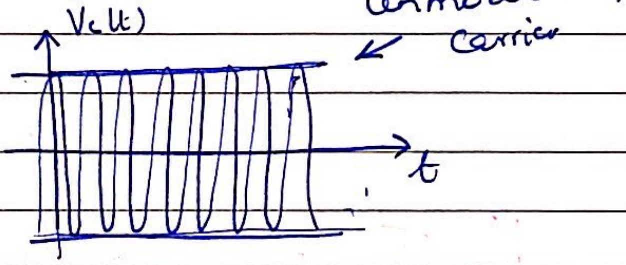
At the receiver of an FM system, a limiter is used that will clip out the distorted portion above and below so that the amplitude limited FM carrier is then converted into a proper FM carrier.

(2) SNR Consideration :- In FM systems SNR is high and can be increased at the cost of system BW. In AM systems SNR can be increased at the cost of increase in modulating power. FM can be achieved at low → power stages of the FM transmitter. AM is achieved at higher modulating power levels.

Q. Draw an FM signal for its Amplitude - time plot and Frequency - time plots in case of the various message signals (m(t)), waveforms shown.

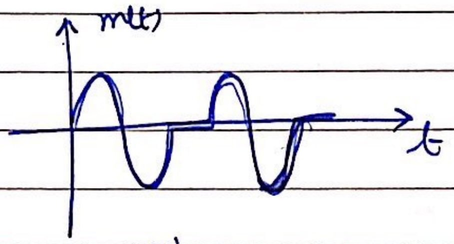
(i)



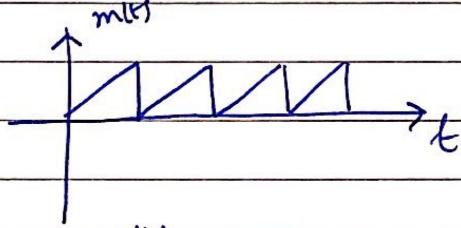


UNMODULATED CARRIER AMPLITUDE - TIME PLOT.

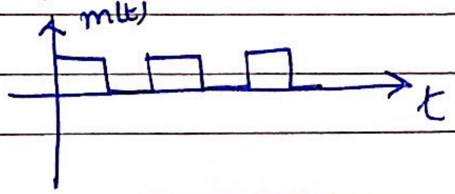
(ii)



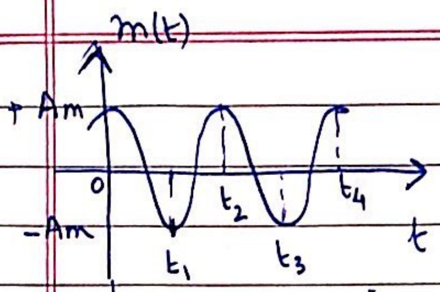
(iii)



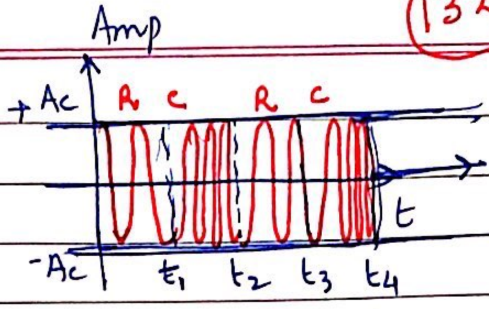
(iv)



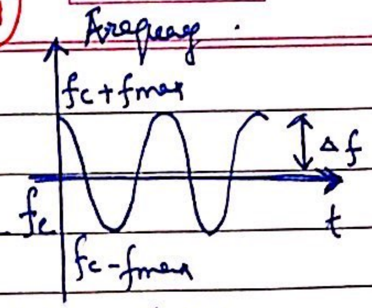
(i)



Modulating Signal

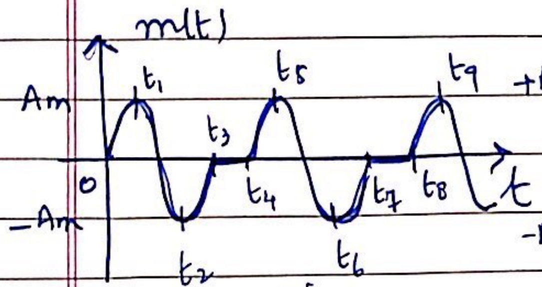


Modulated Carrier
Amp_time plot

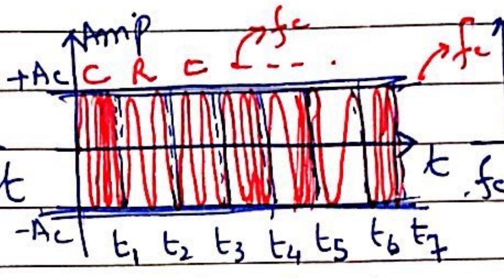


Modulated Carrier
Frequency_time Plot.

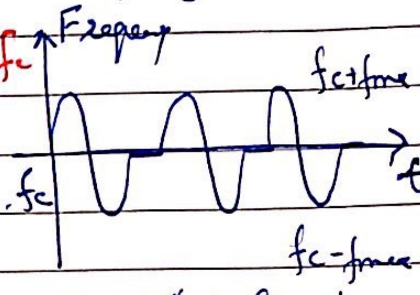
(ii)



Modulating Signal

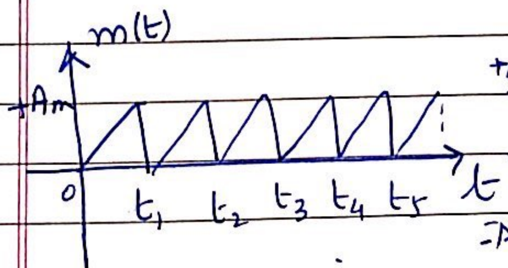


Modulated Carrier
Amp_time Plot

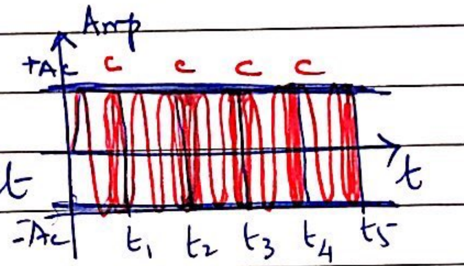


Modulated Carrier
Frequency_time plot.

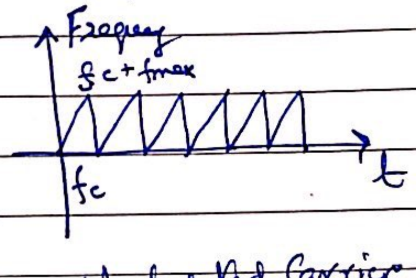
(iii)



Modulating Signal

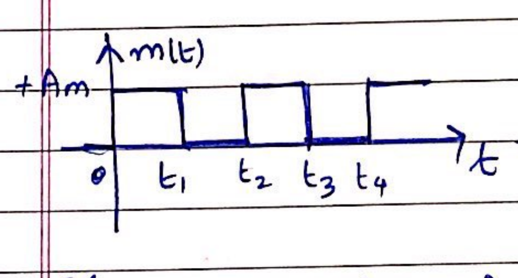


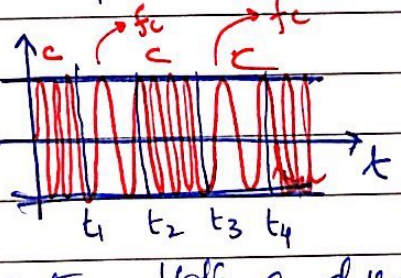
Modulated Carrier
Amp_time Plot

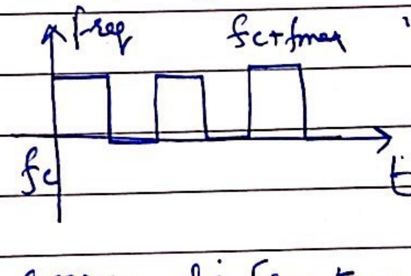


Modulated Carrier
Frequency_time Plot.

(iv)







Observe the above Amp_time plots and the corresponding Freq_time plots of the different examples. Overall main observations are:-

(i) Envelope of FM signals remains constant

(ii) Amp_time plot of each examples shows successive regions of compressions (C) and Rarefractions (R). eg. in example (i) Carrier frequency reduces from time (0 to t_1), then Carrier frequency increases from time (t_1 to t_2), then Carrier freq. again reduces form time

(t_2 – to t_3) so resulting into successive regions of frequency compressions, then Rarefactions, then Compression etc. This is also observed in the Frequency – time plot. Where m(t) signal increases in Amplitude, frequency also increases. Where m(t) decreases in Amplitude, the carrier frequency also decreases. So that we can say

Freq – Modulated Carrier frequency [$f_c(t)$] i.e. it is a function of time. and that

$$\boxed{f_c(t) \propto m(t)}$$

Thus the FM frequency – time plot is tracing out same shape as the modulating signal amplitude variations. In other words the m(t) shape is carried by the FM carrier frequency.

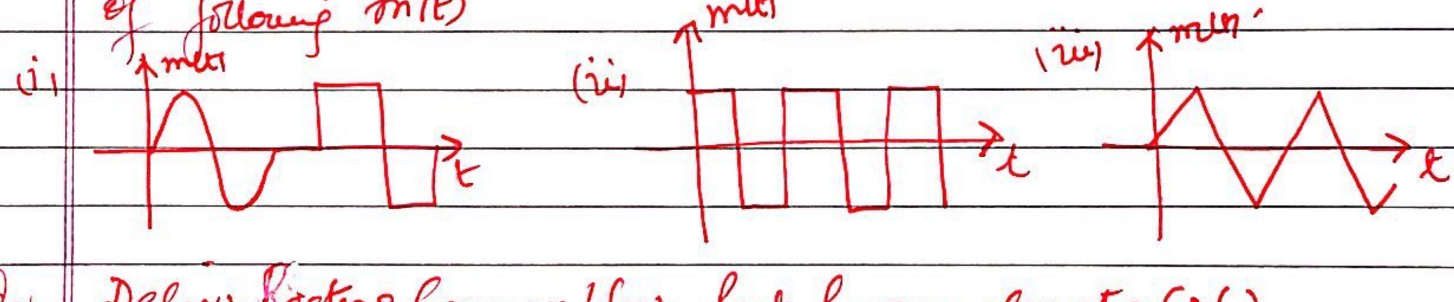
Here f_c → the unmodulated carrier is also called the resting frequency.

Δf → This is called the peak frequency deviation.

$\Delta f = f_{c\,max} - f_c$

$2\Delta f$ = Carrier Swing $= (f_c + f_{max}) - (f_c - f_{max})$
$= 2 f_{max}$.

Q. Draw Amp – time plot and Corresponding Freq – time plot of following m(t)



Q. Define :- Resting frequency (f_c), Peak frequency deviation (Δf), Carrier Swing, Modulation Index (β), frequency Sensitivity (K_f).

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Frequency Sensitivity (k_f)

From the Frequency - time plots it is observed that

If modulating signal $\rightarrow m(t)$
If instantaneous value of carrier $\rightarrow f_c(t)$

The due to FM ; $\boxed{f_c(t) \propto m(t)}$

Now peak value of $m(t) = A_m$ (See Examples of m(t) on pg. 134)
& Peak value of Carrier freq deviation $= \Delta f$

$$\therefore \quad \Delta f \propto A_m.$$

or

$$\boxed{\Delta f = k_f A_m} \quad \text{——— (3)}$$

units :- Hz volts.

Frequency Sensitivity :- $\boxed{k_f = \Delta f / A_m}$ is defined as the
Formula

Frequency Sensitivity and is expressed in Units of

Units :- k_f (Hz/Volt).

k_f depends on the Frequency Modulator. It indicates how much of Shift in frequency is produced by the Frequency Modulator Equipment per change in modulating Signal voltage.

Modulation Index of FM wave (β) or (m_f)

Just as we define the modulation index for an AM wave similarly the modulation index for FM wave is also defined and is denoted as β or m_f

$$\boxed{\beta = \frac{\Delta f \rightarrow Hz}{f_m \rightarrow Hz}} \quad \text{——— (4)}$$

∴ Unitless also f_m is the modulated frequency.

Substitute $\Delta f = k_f A_m$ from (3).

$$\therefore \boxed{\beta = \frac{k_f A_m}{f_m}}$$

β is preferred to be large for significant implementation of FM scheme. To achieve this either

(i) f_m should be small
or
(ii) A_m should be large.

Whether β is large or small will greatly influence the B.W of FM wave.

Unlike (m) of AM signal, β permissible is greater than 1.

Q. Compare and contrast the meaning of MI of AM signal ie m and the MI of FM wave ie (β).

Q. How does m influence the Power of AM wave and How does β influence the power of FM wave

Q. How does m influence the Spectrum & Hence the B.W of AM wave. How does β influence the Spectrum and hence B.W of FM wave