Angle Modulation

In angle modulation total phase angle of high carrier freq. is vary in accordance with instantaneous value of modulating s/g. keeping its amplitude constant.

Let us consider unmodulated carrier s/g

$$c(t) = A_c \cos \omega_c t$$

After mod $C(t) = A_c \cos(\omega_c t + \phi)$

Total pase angle

$$\theta(t) = \omega_c t + \phi$$

where

ω_c = carrier freq.

ϕ = some ~~fix~~ phase at $t = 0$

It is classified as-

1. Frequency modulation (FM)
2. Phase modulation (PM)

If the angle modulation occur due to dependence of f_c ~~and~~ on $m(t)$ then it is called as frequency modulation

If the angle modulation occur due to dependence of ϕ on $m(t)$ then it is called as phase modulation.

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① Phase Modulation

Consider before modulation.
unmodulated carrier, $c(t) = A_c \cos \omega_c t$

After modulation, $c(t) = A_c \cos(\omega_c t + \phi)$
Total phase, $\theta(t) = \omega_c t + \phi$

ϕ is vary accordance to message s/g amplitude.
So, ~~as~~ ϕ is directly proportional to $m(t)$

$$\phi \propto m(t)$$

$$\boxed{\phi = k_p\, m(t)}$$

where, k_p equal to phase sensitivity of phase modulation (radian/volt)

k_p define the amount of phase change in carrier for 1 volt change in message s/g.

If message s/g is not present $(m(t) = 0)$ then, $\phi = 0$
~~noo~~ result no modulation is performed.

2. Frequency Modulations -

Frequency before modulation = f_c

After modulation freq. = f_i = Inst. freq.

$$\boxed{f_i = f_c + K_f m(t)}$$

f_i is varry accordance to message s/g.

where, K_f = freq. sensitivity of freq. modu.
Unit of K_f is Hertz/volt.

K_f specifies the amount of freq. change in carrier for 1Volt change in message s/g.

Case 1 - When message s/g is zero

$m(t) = 0$

$f_i = f_c$

Case 2 - $m(t) > 0$

$f_i = f_c + K_f m(t)$

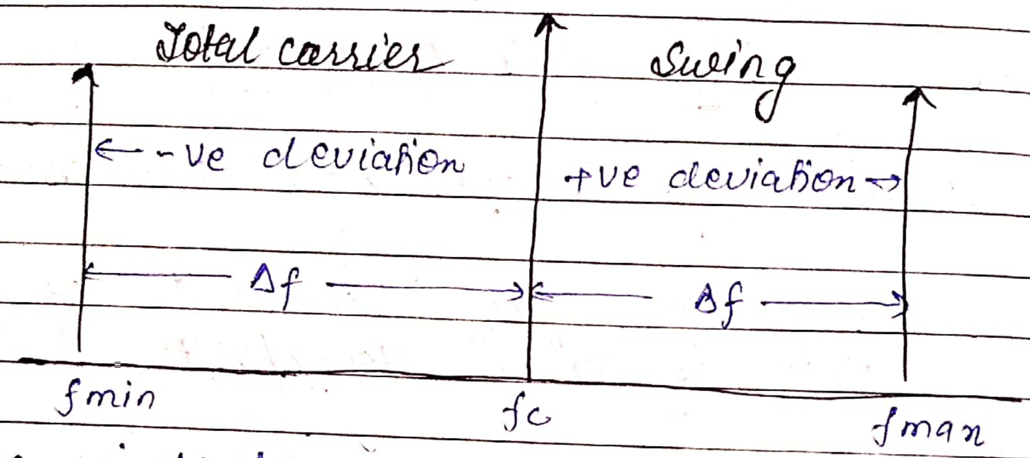
$f_i > f_c$

Case 3 - $m(t) < 0$

$f_i = f_c + K_f m(t)$

$f_i < f_c$

Frequency Deviation - By changing in amplitude of message s/g variation in freq. is obtain. Hence freq. modulation is also known as voltage to freq. conversion.



The instantaneous freq. of freq. modulated s/g vary with time the max change instantaneous freq. from average freq. fc is known as freq. deviation

$$f_i = f_c + K_f\, m(t)$$

where

$$m(t) = A_m \cos \omega_m t$$

Max. deviation = Δf

$$= |K_f A_m|$$

Case 1. $m(t) > 0$

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

$$f_i = f_c + K_f\, m(t)$$

$$f_i = f_c + k_f A_m \cos 2\pi f_m t$$

$$\boxed{f_{max} = f_c + \Delta f}$$

Case 2 : $m(t) < 0$

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

$$f_i = f_c + K_f m(t)$$

$$f_i = f_c - K_f A_m \cos 2\pi f_m t$$

$$\boxed{f_{min} = f_c - \Delta f}$$

Total carrier swing (TCS) -

$$TCS = f_{max} - f_{min}$$

$$= (f_c + \Delta f) - (f_c - \Delta f)$$

$$\boxed{TCS = 2\Delta f}$$

$$\Delta f = K_f A_m$$

$$f_{max} = f_c + \Delta f$$

$$f_{min} = f_c - \Delta f$$

$$TCS = 2\Delta f.$$

Phase modulation - In this type of angle modulation the phase angle (θ) is varying linearly with modulating s/g about unmodulated phase angle $\omega_c t$

This means that instantaneous value of ~~flow~~ phase angle $\theta(t)$ is equal to phase of unmodulated carrier $\omega_c t$ plus time varying component proportional to s/g $m(t)$

Unmodulated carrier $c(t) = A_c \cos \omega_c t$

Phase modulated carriers

$$x_{PM}(t) = A_c \cos \theta_i t$$

where,

$$\theta_i(t) = \text{Total phase angle}$$

$$\theta_i(t) = \omega(t) + \phi$$

In phase modulation,

$$\phi \propto m(t)$$

$$\phi = k_p\, m(t)$$

where

$m(t)$ = modulating s/g with freq. ω_m

$$m(t) = A_m \cos \omega_m t$$

so,

$$\phi = k_p\, m(t)$$

$$\phi = k_p A_m \cos \omega_m t$$

Total phase angle, $\theta_i(t) = \omega_c t + \phi$

$$\theta_i(t) = \omega_c t + k_p A_m \cos \omega_m t$$

Phase modulated s/g

$$x_{PM}(t) = A_c \cos \theta_i(t)$$

$$x_{PM}(t) = A_c \cos [\omega_c t + K_p A_m \cos \omega_m t]$$

~~Phase modulated s/g~~

Modulation index of phase modulated s/g

$$\beta_{PM} = K_p A_m$$

Phase modulation s/g

$$\boxed{x_{PM}(t) = A_c \cos [\omega_c t + \beta_{PM} \cos \omega_m t]}$$

Phase deviation

Total phase angle $\theta_i(t) = \omega_c t + K_p A_m \cos \omega_m t$

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

$$= \frac{d}{dt}\left[\omega_c t + K_p A_m \cos \omega_m t\right]$$

$$= \omega_c - K_p A_m \omega_m \sin \omega_m t$$

$$\Delta \omega_{pm} = K_p A_m \omega_m$$

$$\boxed{\Delta f_{PM} = K_p A_m \omega_m}$$

Frequency modulation -

In this type of angle modulation instantaneous freq. $\omega_i (f_i)$ is varying linearly modulating s/g about ~~at~~ unmodulated freq. $\omega_c (x_c)$ this mean that intantaneous value of angular freq. ω_i is equal to freq. ω_c unmodulated carrier plus time varying component $m(t)$

carrier $c(t) = A_c \cos \omega_c t$

freq. modulated s/g.

$$\cancel{x_{FM}(t) = A_c \cos \theta_i t} \quad \cancel{A_c \cos \omega_i t}$$

$$x_{FM}(t) = A_c \cos \theta_i t$$

In FM

$$\omega_i = \omega_c + K_f m(t)$$

$$\omega_i = \frac{d \theta_i t}{dt}$$

$$\theta_i(t) = \int \omega_i \, dt$$

$$\theta_i(t) = \int (\omega_c + K_f m(t)) \, dt$$

$$= \omega_c t + \int K_f m(t) \, dt$$

$$= \omega_c t + K_f \int m(t) \, dt$$

FM.

$$x_{FM}(t) = A_c \cos [\omega_c t + K_f \int m(t) \, dt]$$

let us consider, $m(t) = A_m \cos \omega_m t$

$$x_{FM}(t) = A_c \cos[\omega_c t + K_f \int A_m \cos \omega_m t \, dt]$$

$$= A_c \cos[\omega_c + K_f A_m \int \cos \omega_m t \, dt]$$

$$= A_c \cos[\omega_c t + \frac{K_f A_m}{\omega_m} \sin \omega_m t]$$

modulation index FM,

$$\beta_{FM} = \frac{K_f A_m}{\omega_m} = \frac{\Delta \omega}{\omega_m} = \frac{\Delta f}{f_m}$$

$$\boxed{x_{FM}(t) = A_c \cos[\omega_c t + \beta_{FM} \sin \omega_m (t)]}$$

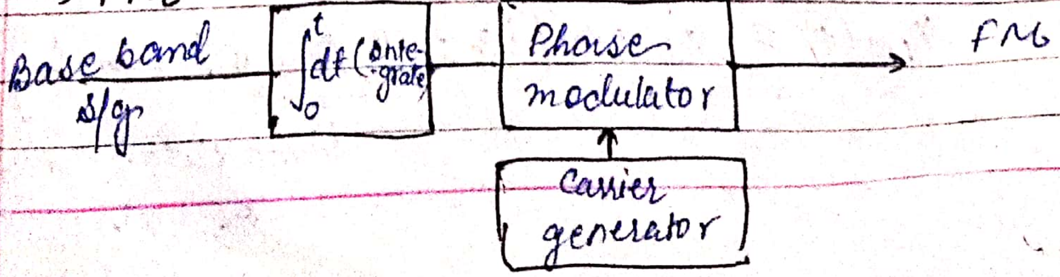
Relation b/w PM and FM

The $x_{PM}(t) = A_c \cos[\omega_c t + K_p m(t)]$

$$x_{FM}(t) = A_c \cos[\omega_c t + K_f \int m(t) \, dt]$$

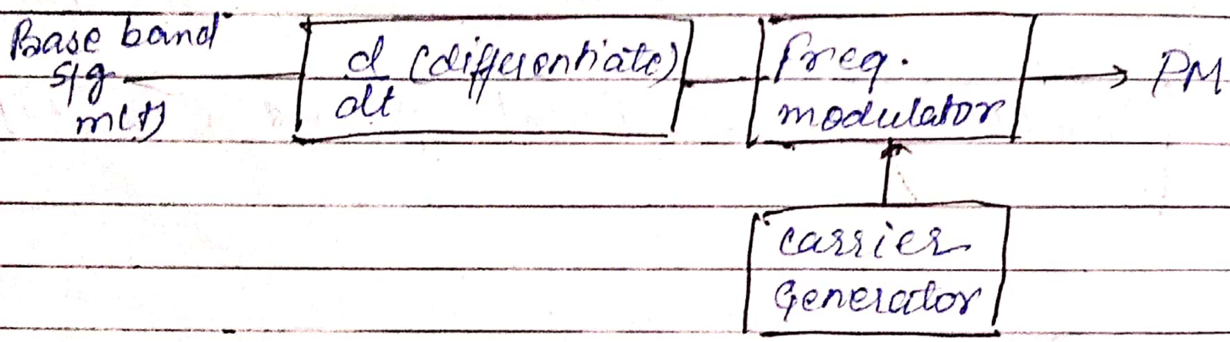
The phase modulation and freq. modulation are closely related in sense that net effect of both in variation in total phase angle.

PM → FM



In phase modulation angle vary linearly with total phase angle (M T) m(t) whereas in FM angle vary wit linearly with integral part of m(t).
In other word, we can get freq. modulation s/g by using phase modulated providing them at first stage modulating s/g integrated & then apply to phase modulation.

Generation of PM from FM



We can generate a PM wave using freq. modulation provided that m(t) differenetiated and then apply to freq. modulator.

Types of FM

General freq. modulated s/g.

$$x_{FM}(t) = A_c \cos[\omega_c t + \underbrace{\beta_{FM}}_{\text{modulation index of FM}} \sin \omega_m t]$$

Depending upon the value of β_{FM} (modulation index of freq. modulated s/g) There are 2 type of FM.

1. Narrow band FM ($\beta_{FM} < 1$)
2. Wide band FM ($\beta_{FM} > 1$)

General freq. modulated s/g

$$x_{FM}(t) = A_c \cos[\omega_c t + \beta_{FM} \sin \omega_m t]$$

$$= A_c [\cos \omega_c t \cos(\beta_{FM} \sin \omega_m t) - \sin \omega_c t (\beta_{FM} \sin \omega_m t)] \quad (1)$$

Case 1 - Narrow band FM ($\beta_{FM} < 1$)

Assume

$\cos \theta = 1$ $\qquad$ $\sin \theta = \theta$

$\theta \to 0$ $\qquad$ $\theta \to 0$

$\cos(\beta_{FM} \sin \omega_m t) = 1$ $\qquad$ $\sin(\beta_{FM} \sin \omega_m t)$

$\beta_{FM} \to 0$ $\qquad$ $= \beta_{FM} \sin \omega_m t$

$\beta_{FM} \to 0$

from eq. (1)

$$x_{NBFM}(t) = A_c [\cos \omega_c t - \sin \omega_c t \, \beta_{FM} \sin \omega_m t]$$

$$= A_c \cos \omega_c t - A_c \beta_{FM} \sin \omega_c t \sin \omega_m t$$

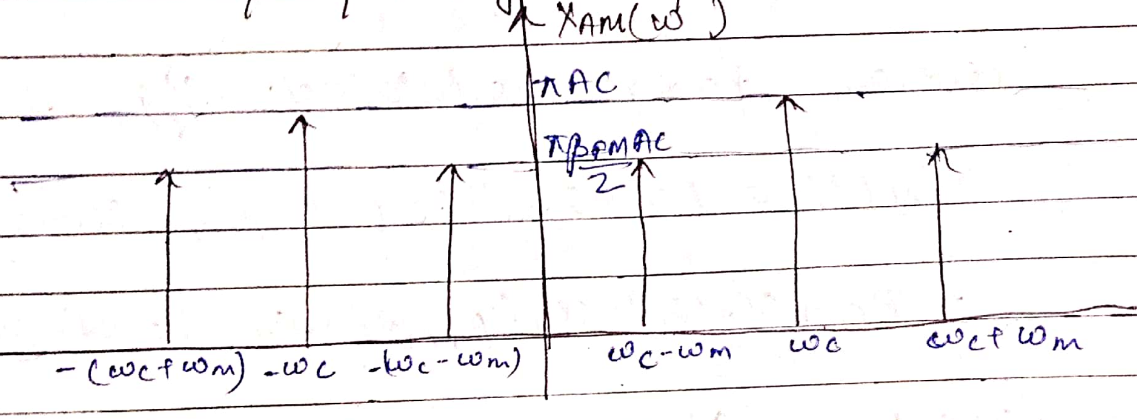
$$= A_c \cos \omega_c t - \frac{A_c \beta_{FM}}{2} \{\cos(\omega_m t - \omega_c t) - \cos(\omega_m t + \omega_c t)\}$$

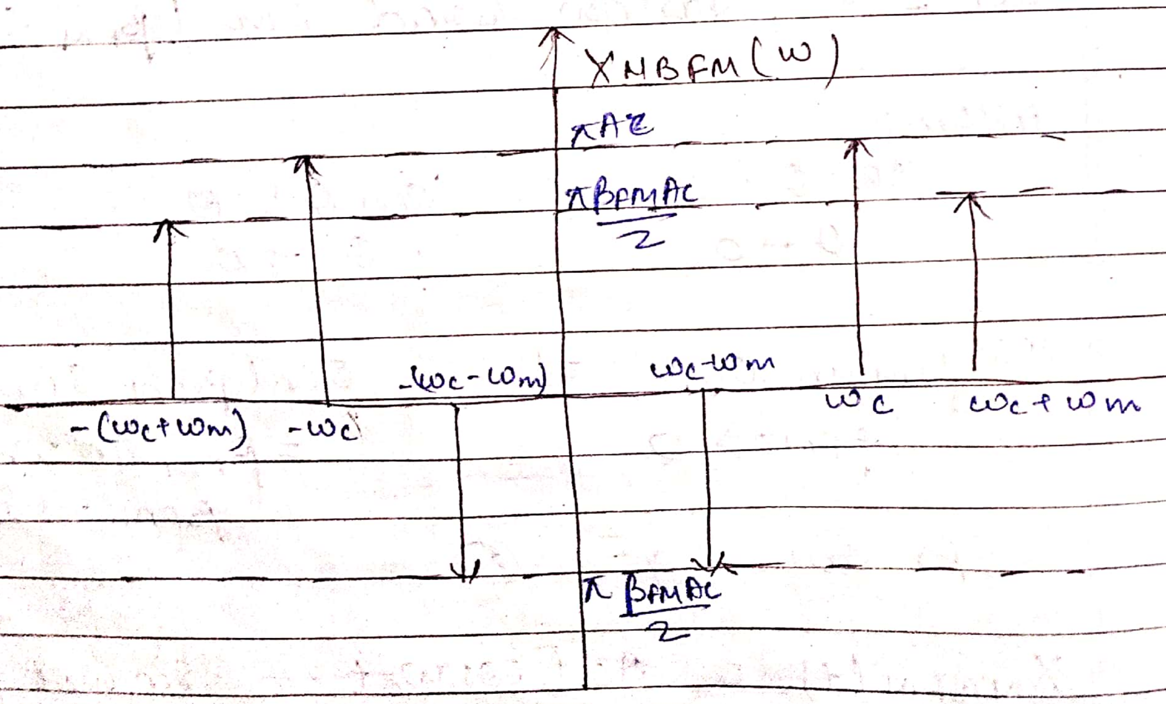
$$x_{NBFM}(t) = A_c \cos \omega_c t - \frac{A_c \beta_{FM}}{2} \cos(\omega_m t - \omega_c t) + \frac{A_c \beta_{FM}}{2} \cos(\omega_m t + \omega_c t)$$

$$X_{AM}(t) = A_c \cos\omega_c t + \frac{mA_c}{2}\cos(\omega_c - \omega_m) + \frac{mA_c}{2}\cos(\omega_c + \omega_m)$$

Frequency response of NBFM

Ist AM frequency response.



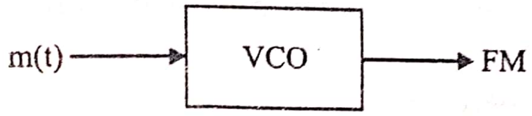


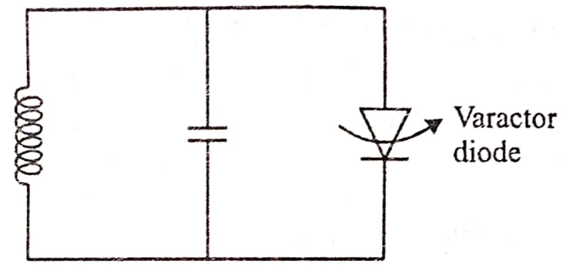
Q.11. Describe the different FM modulator?

Solution : **FM Modulators**

The frequency of the carries is varied according to amplitude change in the modulating signal. There are two method for generation of FM waves.

1. Direct Method : In the type of angle modulation, the frequency of the carrier is varied directly by the modulating signal. This means, an instantaneous frequency is directly proportional to amplitude of the modulating signal.





$$f_c = \frac{1}{2\pi\sqrt{LC}}$$

The basic concept of FM is to vary the carries frequency in accordance with modulating signal. The carrier is generated by and LC oscillator & carries frequency can be varied by varying either L or C of tank circuit. The oscillator whose frequency is varied in accordance with modulating signal is known as voltage control oscillator (VCO).

Disadvantages

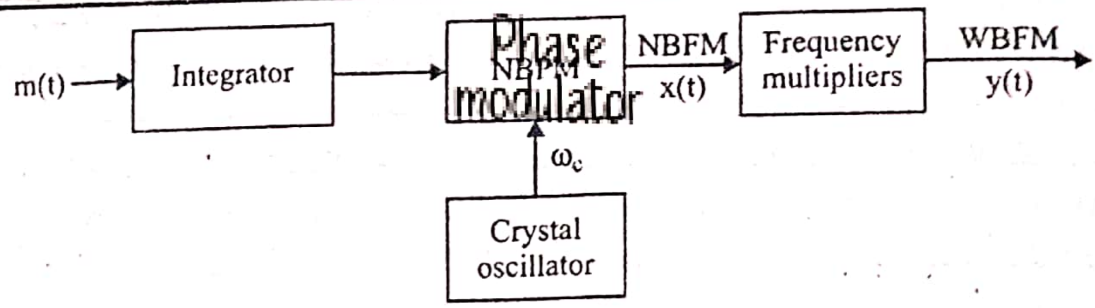
Most LC oscillator are not stable enough to carrier frequency. The carrier frequency usually vary due to temperature variation, agin components etc. So instead of using LC oscillator since they provide highly stable carrier frequency. So a very small frequency deviation is possible.

2. Indirect Method (Armstrong Method) : In this type of modulation FM is obtained by phase modulation of the carrier. Instantaneous phase of the carrier is directly proportional to the amplitude of the modulating signal.

$$x(t) = A_c \cos[w_c t + \beta_{FM} \sin w_m t]$$

$$y(t) = x^2(t)$$

$$= A_c^2 \cos^2 [w_c t + \beta_{FM} \sin w_m t]$$



$$= \frac{A_c^2}{2}[1 + \cos(2w_c t + 2\beta_{FM} \sin w_m t)]$$

In the Armstrong method frequency stability of a higher order can be obtained because the crystal oscillator can be used as a carrier generator. The basic principle of this method is to generate a narrowband FM indirectly by using the phase modulation technique, and then converting this NBFM to WBFM. The distortion is low in NBFM as the modulation index is small. The phase modulation is preferred because of its easy generation schemes. The multiplier circuit, apart from multiplying the carrier frequency, also increases the frequency deviation and thus the NBFM is converted into WBFM.

We can't generate of WBFM directly because the use of crystal oscillator, hence frequency deviation is very small & hence bandwidth is small so first generate NBFM then WBFM.

Q.12. What is FM detection?

Ans.

Detection of FM Signal

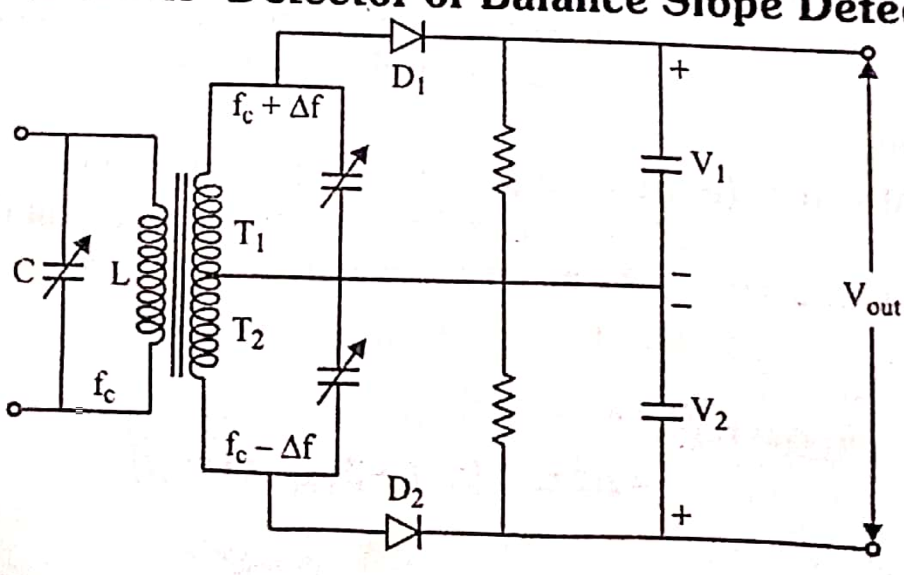
The FM receivers are also super heterodyne receivers. But they have different types of demodulators or detector. FM receivers have amplitude limiters which are absent in AM receivers. The AGC (Automatic Gain Controller) System of FM receiver is different than that of AM receivers. RF amplifiers, mixers local oscillators IF amplifiers, audio amplifier etc. all are present in FM receivers. The detection of FM is totally different compared to AM. The FM detector should be able to produce the signal whose amplitude is proportional to the deviation in the frequency of FM signal. Thus the job of FM detector is almost similar to frequency to voltage connecter.

Q.13. Describe the following FM detector

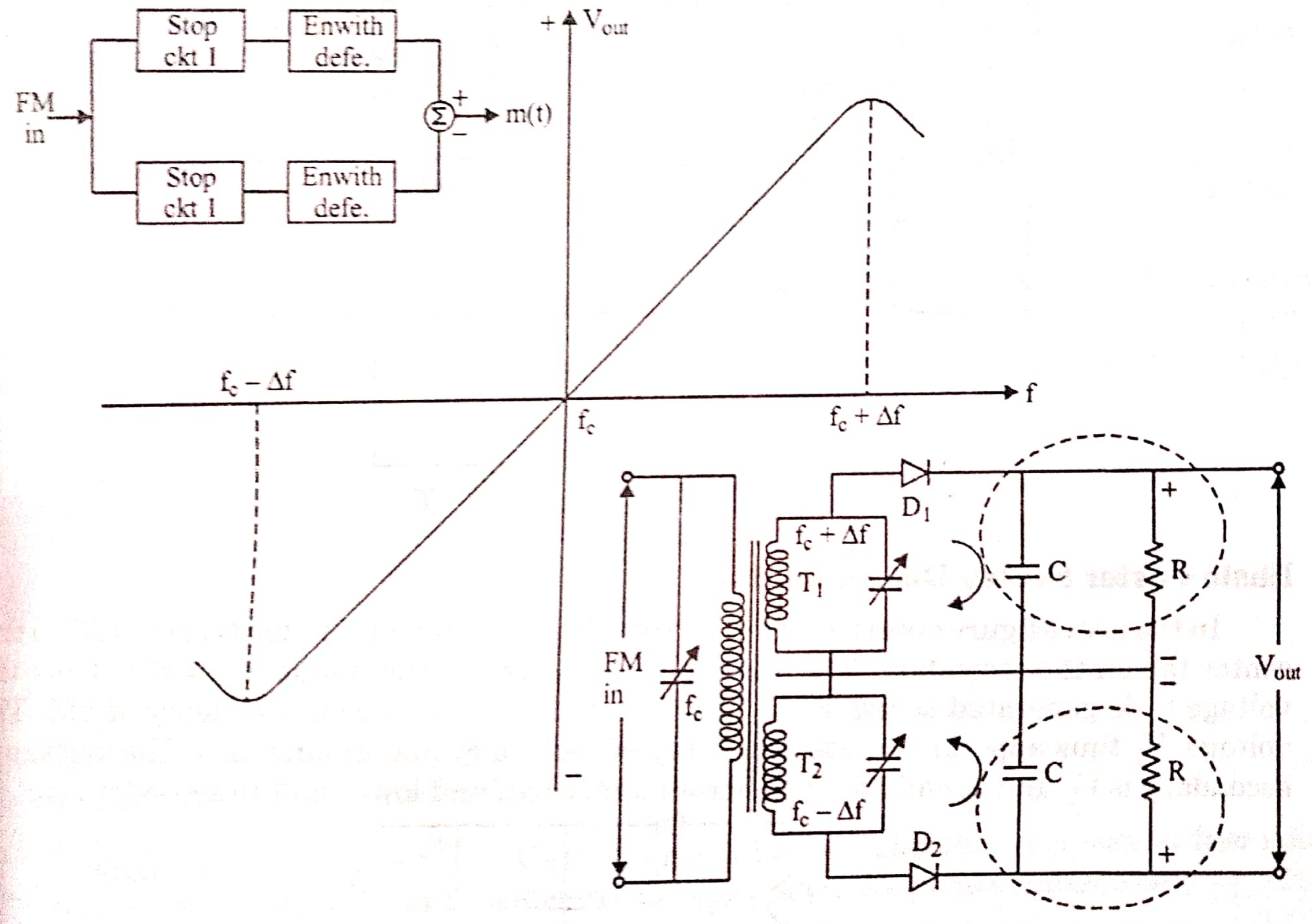
1.Balance slope **2. Foster seeley discrimination**

3. Ratio detector **4. PLL FM demodulator**

Ans. **Round Travis Detector or Balance Slope Detector**



It consist of two identical circuit connected back to back. The FM signal is applied to the tuned LC circuit. Two tuned LC circuits are connected in series. The inductance of this secondary tuned LC circuit is coupled with the inductance of the primary LC circuit. Thus it forms a tuned transformer. In the above figure, the upper tuned circuit is shown as T_1 and lower tuned circuit is shown as T_2. The input side LC circuit is tuned of f_c carrier frequency. T_1 is tuned to $f_c + \Delta f$, which represents highest frequency. And lower LC circuit T_2 is tuned to $f_c - \Delta f$, which represent the minimum frequency of FM signal. The input FM signal is couple to T_1 and T_2 180° out of phase. The secondary side tuned circuits are connected to diodes D_1 and D_2 with Rc loads. The total output V_{out} is equal to difference between V_1 and V_2 since they subtract.

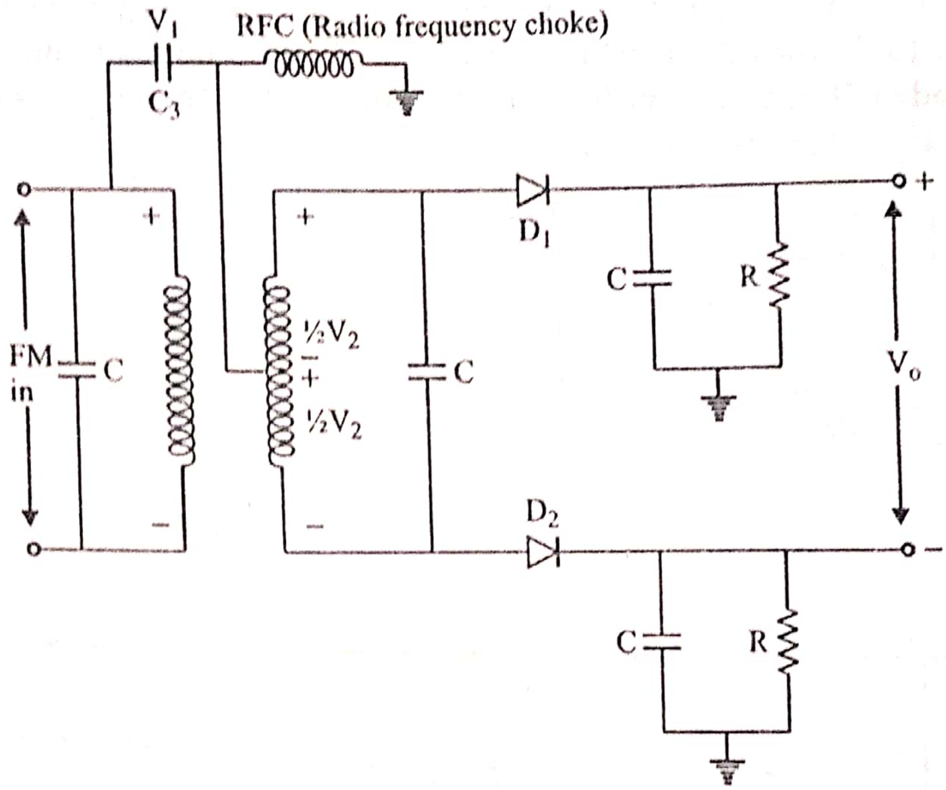


The above figure shown the characteristics of the balance slope detector. It shows V_{out} when the input frequency is equal to f_c both T_1 and T_2 produce the same voltage. Hence V_1 and V_2 are identical and they subtract each other. There fore V_{out} is zero. When the input frequency is $f_c + \Delta f$, the upper circuit T_1 produces maximum voltage since it is tuned to this frequency. Whereas lower circuit T_2 is tuned to $f_c - \Delta f$ which is quite away from $f_c + \Delta f$. Hence T_2 produces minimum voltage. Hence the output V_1 is maximum where V_2 is minimum. There fore $V_{out} = V_1 - V_2$ is maximum positive of $f_c + \Delta f$.

When input frequency is $f_c - \Delta f$, the lower circuit T_2 produce maximum signal since it is tuned to it. But upper circuit T_1 produces minimum signal. Hence rectified outputs V_2 is maximum and V_1 is minimum. Therefore output $V_{out} = V_1 - V_2$ is maximum –ve for $f_c - \Delta f$.

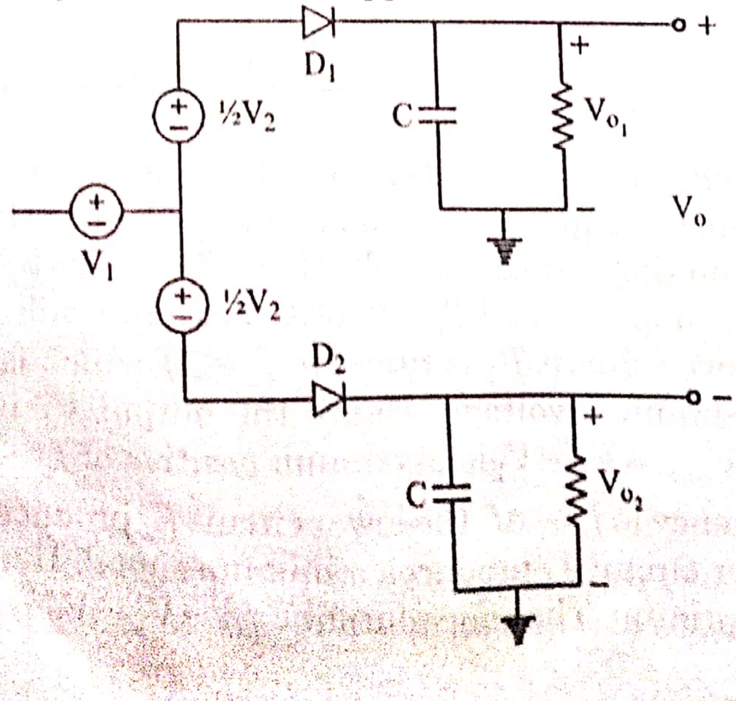
2. Foster seeley Discriminator (Phase Discriminator)

The phase shift between the primary and secondary voltages of the tuned transformer is a function of frequency. It can be shown that the secondary voltage lags primary voltage by 90° at the carrier center frequency. This carrier frequency (f_c) is the resonance frequency of the transformer. Foster seeley discriminator utilizes this principle for FM detection.



Basic Foster Seeley Discriminator

In the above figure observe that primary voltage is coupled through C_3 and RFC to center tap on the secondary. The capacitor C_3 passes are the frequency of FM. Thus voltage V_1 is generated across RFC. RFC offers high impedance to frequency of FM. voltage V_1 thus apperars across center tap of secondary and ground also. The voltag secondary is V_2 and equally divided across upper half and lower half to secondary coi



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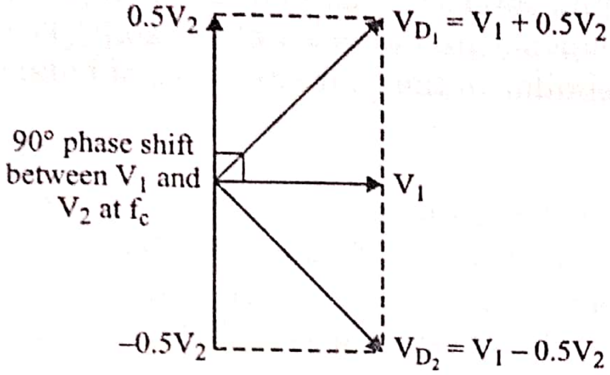
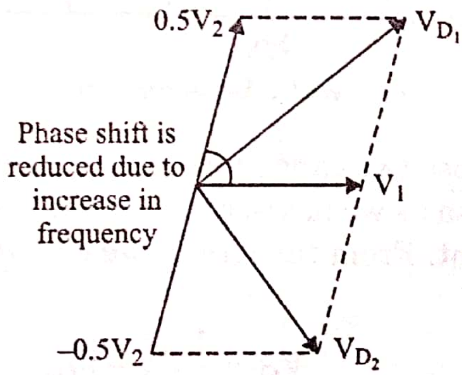
Voltage Generator Equivalent Circuit

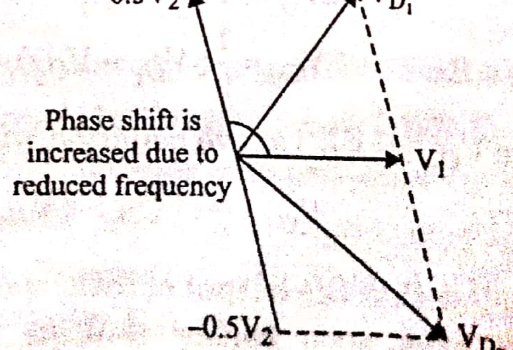


In this figure observe that the voltage across diode D_1 is $V_{D_1} = V_1 + 0.5\, V_2$ and that across D_2 is $V_{D_2} = V_1 - 0.5\, V_2$. The output of upper rectifier is V_{O_1} and lower rectifier is V_{O_2}. The net output $V_0 = V_{01} - V_{02}$. Since $V_{O_1} = |V_{D_1}|$ and $V_{O_2} = |V_{D_2}|$, output $V_{O_1} = |V_{D_1}| - |V_{D_2}|$. Thus the net output depends upon the difference between megnitudes of V_{D_1} and V_{D_2}. At the centre frequency, both V_{D_1} and V_{D_2} will be equal. Since V_2 will have 90° phase shift with V_1.

In the above figure the vector addition is and it shows that $V_{D_1} = |V_{D_2}|$ Hence the net output of the discriminator will be zero. Now consider the situation when input frequency increase above f_c. Hence the phase shift between V_1 and V_2 reduces. Therefore $|V_{D_1}|$ is grater then $|V_{D_2}|$.



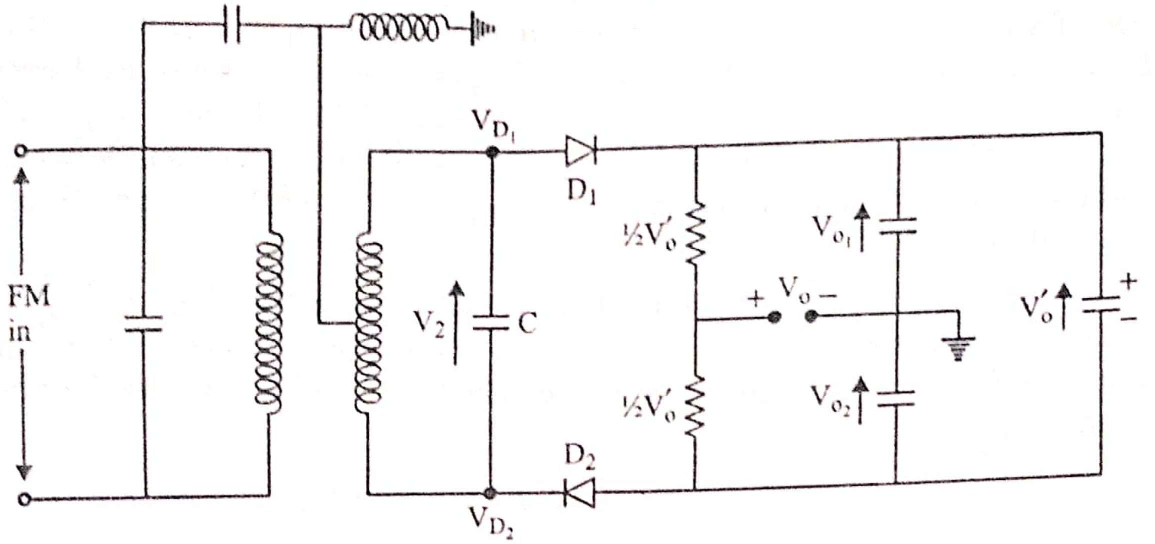
Hence the net output $V_O = |V_{D_1}| - |V_{D_2}|$ will be $+ve$. Thus the increase in frequency increase output voltage. Now consider the situation when frequency reduces below f_c. This makes $|V_{D_1}|$ is less then $|V_{D_2}|$.



Hence the output $V_O = |V_{D_1}| - |V_{D_2}|$ will be –ve. Thus the faster seeley discriminator produces output depending upon the phase shift. The linearly of the output depends upon the linearly between frequency and induced phase shift. The characteristics of the faster seeley discriminator is similar to the characteristics of balance slope detection.

3. Ratio Detector

Ratio detector can be obtained by slight modifications in the faster-seeley discriminator. The above diagram shows the diode D_2 is revered and output is taken from different points. In the above circuit the regular conversion from frequency to phase shift and phase shift to amplitude takes place as in faster-seeley discriminator. The polarity of voltage in the lower capacitor is reversed, since connections of diode D_2 are reversed.



Radio Detector Circuit

Hence the voltages V_{O_2} across two capacitors add. And we know that when V_{O_1} increased, V_{O_2} decreases and Vice-versa as we have seen is faster seeley circuit, since V_0 is sum of V_{O_1} and V_{O_2}, it remains constant. From the circuit we can write two equations for the output voltage V_O.

$$V_O = \frac{1}{2}V_O^1 - V_{O_2}$$

$$V_O = \frac{1}{2}V_O^1 + V_{O_1}$$

Adding the above two equation.

$$2V_O = V_{O_1} - V_{O_2}$$

$$V_O = \frac{1}{2}(V_{O_1} - V_{O_2})$$

Since $V_{O_1} = |V_{D_1}|$ and $V_{O_2} = |V_{D_2}|$ above equation will be

$$V_O = \frac{1}{2}(|V_{D_1}| - |V_{D_2}|)$$

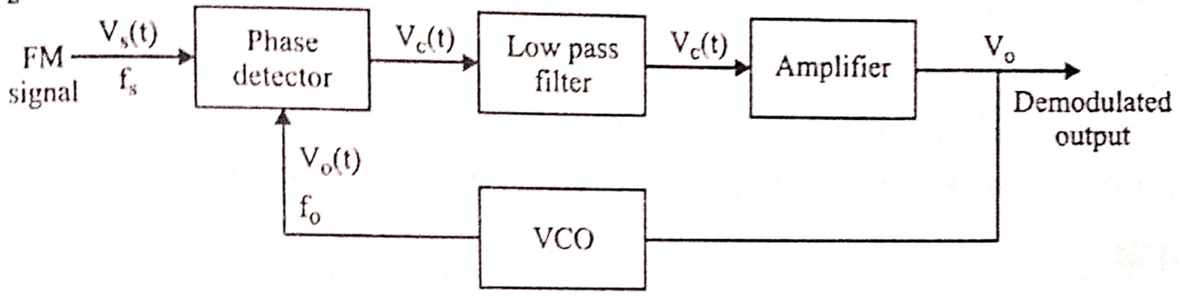
The above equation show that the output of ratio detector is half compared to that of foster-Seeley circuit. We have seen earlier that as frequency increases above for

$|V_{D_1}| > |V_{D_2}|$ have output V_O is $+Ve$. Similarly if frequency decreases below f_c, $|V_{D_1}| > |V_{D_2}|$. Hence output V_O is $-Ve$. The ratio detector has the advantage of reduced fluctuation in the output voltage compared to Foster-Seeley circuit.

4. PLL (Phase Locked Loop) FM Demodulator

The output frequency of VCO is equal to the frequency of unmodulated carriers. The phase detector. generator the voltage which is proportional to difference between the FM signal and VCO output. The voltage is filtered and amplified. It is required modulating voltage. Here frequency carriers is not required in VCO since it is already done at transmitter. In this demodulator no need of tuned circuits.

Perfect locking is achieved when the two S/G are having in some frequency & a phase diff. of $\pi/2$ between them.



Let
$$Y_S(t) = A\cos w_c t$$
$$Y_O(t) = B\cos(w_c t + \theta)$$
$$Y_e(t) = AB\cos w_i t\cos(w_c + \theta)$$
$$= \frac{AB}{2}\cos(w_i t + w_c)t + \theta) + \cos[(w_i - w_c) - \theta]$$
$$Y_e(t) = \frac{AB}{2}\cos[(w_i - w_c) + \theta]$$

when
$$w_c t = w_O$$
$$V_e(t) = \frac{AB}{2}\cos\theta$$

When $\theta = \pi/2\, V_e(t) = \theta$ is for perfect PLL.

State of operation

1. Free running
2. Capture
3. Phase lock.

Q.14. Explain the approximately compatible SSB system.

Ans. **Approximately Compatible SSB Systems**

In precisely compatible AM following requirements are to be fulfilled :

(i) Envelope of AM should excetly reproduce the baseband signal.

(ii) If highest baseband frequency is f_m, then the frequency range of modulated signal would extend upto $f_c + f_m$.

These two requirements about envelope shape and spectral range are not always fulfilled by precisely compatible system. Hence approximately compatible systems are designed which are relaxed for these two requirements. These approximately compatible systems are used commercially.

SSB-AM

Principle : The angle modulated carries is further amplitude modulated. It gives rise to SSB-AM.

Modulator : The modulating signal modulates the amplitude and carries phase both. The relationship between phase and modulating signal is nonlinear. Such modulation is not strictly SSB, because it generates multiple side bands. But all these sidebands are produced on same side of the carries.

Advantages

(i) Best suitable is SSB for speech or music.

(ii) All side tones, except predominant one fall off sharply in power content.

SSB-FM

Principle : It is obtained by adding amplitude modulation to frequency modulat signal.

Demodulations : The SSB-FM signal can be demodulated using a standard limi discriminotor. The lower or upper sideband can be removed by proper adjustment amplitude modulation

Ques. In a FM system when audio freq. is 500 Hz and AF voltage is 2.4 V and the deviation is 4.8 KHz if the AF voltage is now rise 7.2 V what is new deviation. If the AF voltage is rise to 10 V while AF is drop to 200 Hz what is deviation. Find the modulation index in each ~~phase~~ case.

Given,

$f_m = 500 Hz$

$A_m = 2.4 V$

$\Delta f = 4.8 KHz$

$$\beta_{FM} = \frac{4.8 \times 10^3}{500} = 9.6$$

$$\boxed{\beta_{FM} = 9.6}$$

$\Delta f = \beta_{FM} \times f_m$

$= 9.6 \times 500$

$\Delta f = 4800$

$\beta_{FM} = \frac{K_f A_m}{\omega_m}$

$\beta_{FM} = \frac{\Delta f}{f_m} = \frac{4.8 \times 10^3}{500} = 9.6$

$\cancel{\Delta f = K_f A_m}$

$\cancel{K_f = \frac{4.8 \times 10^3}{2.4}}$

$\Delta f = K_f A_m$

$K_f = \frac{\Delta f}{A_m} = \frac{4.8}{2.4}$

$K_f = 2 KHz$

$A_m = 7.2 V$

$\Delta f = K_f A_m$

$= 2 \times 10^3 \times 7.2$

$$\boxed{\Delta f = 14.4 KHz}$$

~~$A_m = 10 V$~~

$\beta_{FM} = \frac{\Delta f}{f_m} = \frac{14.4 \times 10^3}{500}$

$$\boxed{\beta_{FM} = 28.8}$$

$A_m = 10\,V$

$f_m = 200\ Hz$

$$\beta_{FM} = \frac{\Delta f}{f_m}$$

$\Delta f = K_f A_m$

$= 2 \times 100$

$\boxed{\Delta f = 20\ kHz}$

$$\beta_{FM} = \frac{20 \times 10^3}{200} = 100$$

$\boxed{\beta_{FM} = 100}$

. What is the modulation index of FM s/g having carrier swing 100 KHz when the modulating s/g has freq. of 8 KHz

Given

TCS f_c = 100 KHz

f_m = 8 KHz

TCS = $2\Delta f$

$$\Delta f = \frac{100}{2}$$

$\Delta f = 50\ KHz$

$$\beta = \frac{50}{8} = 6.25$$

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Q. A 107.6 MHz carrier freq. is freq. modulated by 7 KHz sine wave the resultant FM s/g has freq. deviation 50 KHz. Determine the following
1. carrier swing of FM s/g.
2. Highest & lowest freq. attained by modulated s/g.
3. Modulation index of modulated s/g.

Given, $f_c = 107.6\ MHz$
$f_m = 7\ KHz$
$\Delta f = 50\ KHz$

1. $TCS = 2\Delta f$
$= 2 \times 50\ KHz$
$\boxed{TCS = 100\ KHz}$

2. $f_{max} = f_c + \Delta f$
$= 107.6 \times 10^6 + 50 \times 10^3$
$= 107650\ KHz$
$\boxed{f_{max} = 107.65\ MHz}$

$f_{min} = f_c - \Delta f$
$= 107.6 \times 10^6 - 50 \times 10^3$
$= 107550\ KHz$
$\boxed{f_{min} = 107.55\ MHz}$

3. $\beta_{FM} = \frac{\Delta f}{f_m} = \frac{50}{7} = 7.14$

$\boxed{\beta_{FM} = 7.14}$

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Power of NBFM

$$P_t = \frac{A_c^2}{2} + \frac{\left(\frac{\beta_{FM} A_c}{2}\right)^2}{2} + \frac{\left(-\frac{\beta_{FM} A_c}{2}\right)^2}{2}$$

$$= \frac{A_c^2}{2} + \frac{\beta_{FM}^2 A_c^2}{8} + \frac{\beta_{FM}^2 A_c^2}{8}$$

$$= P_c + \frac{\beta_{FM}^2}{4} \cdot P_c + \frac{\beta_{FM}^2}{4} P_c$$

$$P_t = P_c + \beta_{FM}^2 \cdot P_c / 2 = P_c\left(1 + \frac{\beta_{FM}^2}{2}\right)$$

$$\boxed{P_t = P_c\left[1 + \frac{\beta_{FM}^2}{2}\right]}$$

The narrow band FM s/g is similar to AM s/g except in narrow band FM the lower band is 180 out of phase w.r.t carrier as well as upper side band.

Time domain representation of FM

Modulating s/g,

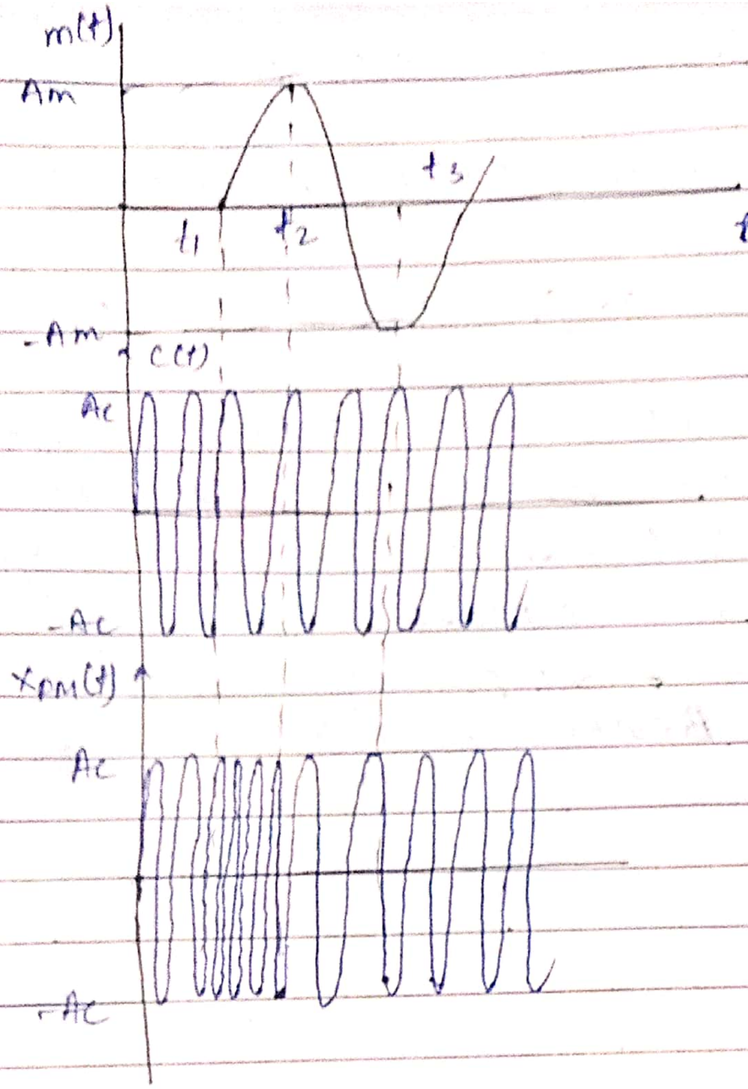
$m(t) = A_m \cos \omega_m t$

Carrier, $c(t) = A_c \cos \omega_c t$

FM s/g,

$x_{FM}(t) = A_c \cos\left[\omega_c t + K_f \int m(t)\,dt\right]$

$f_i = f_c + K_f\, m(t)$



$f_i = f_c + k_f m(t)$

$f_c > f_i$

$t = \frac{1}{f_i}$ (compress)

when $f_c < f_i$
(expand)

Wide band FM ($\beta_{FM} >> 1$)

Since the changing freq. cause the time require to complete one half of the cycle to differ from the time require to complete next half cycle so that actual wave is distorted sinusoidal oscillation the higher mathematical analysis using bessel function shows that distorted oscillation corresponding to the wave with sinusoidal Oscillation.

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General FM modulated eq.

$$x_{FM}(t) = A_c \cos[\omega_c t + \beta_{FM} \sin \omega_m t]$$

$$= A_c [\cos \omega_c t \cos(\beta_{FM} \sin \omega_m t) - \sin \omega_c t \sin(\beta_{FM} \sin \omega_m t)]$$

Here $\cos(\beta_{FM} \sin \omega_m t)$ and $\sin(\beta_{FM} \sin \omega_m t)$ are periodic with fundamental freq. f_m. The fourier transform of each of the s/g is an impulse train with impulse as integer multiple of ω_m and amplitude proportional Bessel function of first type

Q. A angle modulated S/g with carrier freq. $\omega_c = 2\pi 10^5$ is described by eq. $x_{PM} = 10 \cos [\omega_c t + 5 \sin 3000\pi t + 10 \sin 2000\pi t]$

Determine

1. Power of modulated S/g
2. freq. deviation of $= 35 KHz$
3. B.W of PM $= 11.6$

$x_{PM} = 10 \cos [\omega_c t + 5 \sin 3000\pi t + 10 \sin 2000\pi t]$

$\theta_i t = \omega_c t + 5 \sin 3000\pi t + 10 \sin 2000\pi t$

$\frac{d\theta_i t}{dt} = \omega_c + 15000\pi \cos 3000\pi t + 20000\pi \cos 2000\pi t$

$$\omega_i = \omega_c + 15000\pi \cos 3000\pi t + 20000\pi \cos 2000\pi t$$

$$\Delta\omega = 15000\pi + 20000\pi$$
$$= 35000\pi$$

$$\Delta f = \frac{\Delta\omega}{2\pi} = \frac{35000\pi}{2\pi} = 17500$$

$$\Delta f = 17.5\,KHz$$

$$\cancel{f_{max} = 2\pi f_m}$$

$$2\pi f_{max} = 3000\pi t$$

$$f_{max} = 1500$$

Q. A PM modulator has phase deviation sensitivity of 2.5 rad/V and the modulating s/g.

$m(t) = 2\cos(2\pi\, 2000t)$

Determine

peak phase deviation and phase modulation index.

$K_p = 2.5\ \text{rad/V}$

$A_m = 2$

$f_m = 2000\ \text{Hz}$

$\omega_m = 2\pi \times 2000$

$\Delta f = K_p A_m \omega_m$

$= 2.5 \times 2 \times 2000 \times 2\pi$

$\boxed{\Delta f = 62.8\ \text{KHZ}}$

$\beta_{PM} = K_p A_m$

$= 2.5 \times 2$

$\boxed{\beta_{PM} = 5.0}$

Consider a freq. modulated s/g is given by,

Q. $x_{FM}(t) = 20\cos[2\pi 10^6 t + 0.1\sin(10^4 \pi t)]$

Given, $K_f = 10\pi$. Derive the expression for modulating s/g

~~Find m(t)~~

Given, $K_f = 10\pi$

$A_c = 20$

$\omega_c = 2\pi \times 10^6 t$

$\beta_{FM} = 0.1$

$\omega_m = 10^4 \pi$

$$\beta_{FM} = \frac{K_f A_m}{\omega_m}$$

$$A_m = \frac{0.1 \times 10^4 \times \pi}{10^3 \pi}$$

$$A_m = 100 \,\text{V}$$

$$m(t) = A_m \cos \omega_m t$$
$$= 100 \cos 10^4 t$$

Q. Given a angle modulated s/g
$x_c t = 10 \cos[10^8 \pi t + 5 \sin 2\pi (10^3) t]$
Determine max. phase deviation and max. freq. deviation.

$A_c = 10$
$\omega_c = 10^8 \pi$
$\beta_{FM} = 5$
$\omega_m = 2\pi \times 10^3$
~~$\Delta f = K_f A_m \cos$~~
$\theta_i = 10^8 \pi t + 5 \sin 2\pi (10^3) t$
$= 10^8 \pi + 10^4 \pi \cos 2\pi 10^3 t$
$\frac{d\theta_i}{dt} = 10^8 \pi + 10^4 \pi$

Given, $A_c = 10$
$\omega_c = 10^8 \pi$
$\beta_{FM} = 5$
$\omega_m = 2\pi\, 10^3$

$\beta_{FM} = 10^4 \pi$
$\beta_{FM} = K_f A_m = 10^4 \pi$
$\Delta f_m = 10^4 \pi$
$\Delta \omega_m = 10^4 \pi$

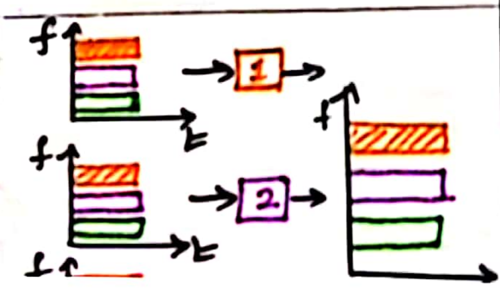
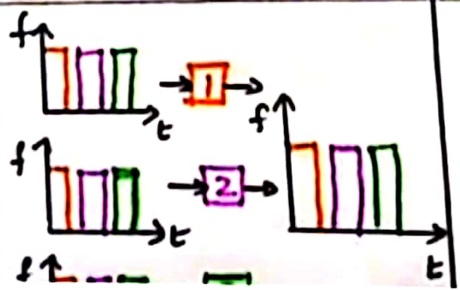
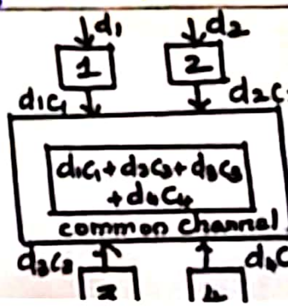
~~$\Delta f = K_f A_m \omega_m$~~

$$\theta_i = 10^8 \pi t + 5 \sin 2\pi (10^3) t$$
$$\frac{d\theta_i}{dt} = 10^8 \pi + 10^4 \pi \sin 2\pi (10^3) t.$$

$$\beta_{FM} = K_f A_m = 10^4 \pi$$
$$\Delta f_m = 10^4 \pi \text{ Hz}$$
$$\Delta \omega_m = 10^4 \pi \text{ Hz}$$

Ans. -

S.No.	FDMA	TDMA	CDMA
1.	Overall bandwidth is shared among a number of stations.	Time sharing of satellite transponder takes place.	Sharing of both bandwidth and time takes place.
2.	Inter-modulation products are generated due to interference between adjacent channels. This is due to nonlinearity of transponder amplifiers.	There can be an interference between the adjacent time slots due to incorrect synchronization.	Both type of interferences are present.
3.	Synchronization is not required.	Synchronization is necessary.	Synchronization is not required.
4.	No code word is required.	No code word is required.	Code word is necessary
5.	Guard bands between adjacent channels are necessary.	Guard times between adjacent time slots are necessary.	Both guard band and guard times are necessary.

Frequency Division Multiple Access (FDMA)	Time Division Multiple Access (TDMA)	Code Division Multiple Access (CDMA)
* FDMA shares a single BW among multiple stations by dividing it into sub-channels.	It shares the time slot & transmission through satellite	CDMA shares both BW and time among multiple stations, with separate unique code
* Each station is allocated with frequency band for all the time to send data	* There is a time slot given each station to transmit data	* It allows each station to transmit data over the entire frequency all the time.
* Codeword is not required	* Codeword is not required	* Each user is assigned with a unique code sequence
		
* Synchronization is not required	Synchronization is required	not required
* It uses continuously signals for data transmission	It uses signals in bursts for data transmission	It uses digital signals.
* It requires guard bands between adjacent bands	It requires the guard time & the adjacent time slots	CDMA requires both guardband and guard time
* Low datarate	Medium datarate	High datarate.
* Limited cell capacity	Restricted cell capacity	No capacity restriction
* High cost	Low cost	High installation cost & Low operation cost
* Less flexible	Moderate flexible	Highly flexible

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