Angle Modulation.

- It is the process by which the angle (frequency/phase) of the carrier signal is changed in accordance with the instantaneous amplitude of modulating or message signal.

Classified into two types such as:

a. Frequency modulation (FM)
b. phase modulation (PM).

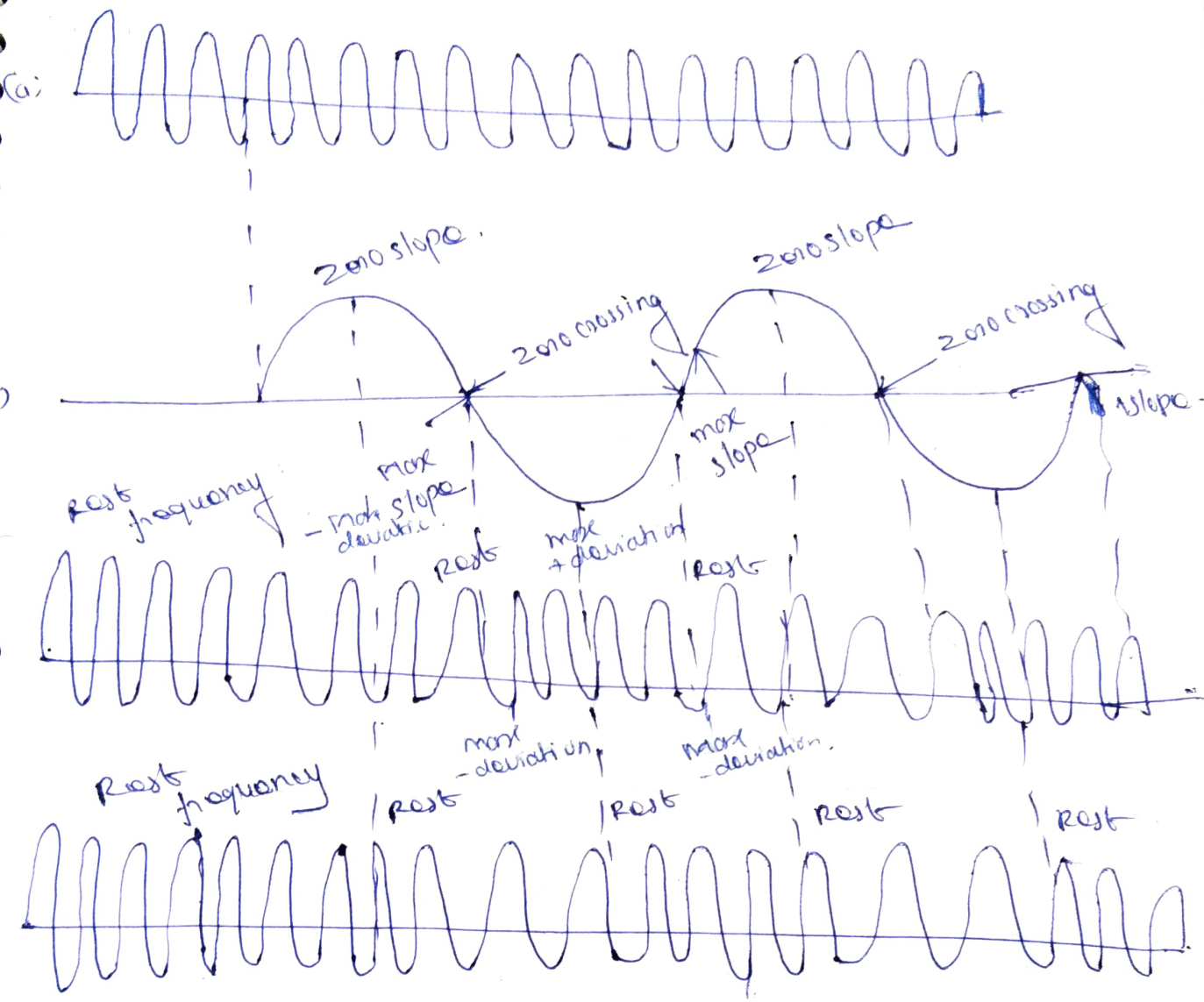
Used for:

- Commercial radio broadcasting
- Television sound transmission.
- Two way mobile radio.
- Cellular radio.
- Microwave and satellite communication system.

equency modulation:

- In FM the carrier amplitude remains constant the carrier frequency varies with the amplitude of modulating signal.
- The amount of change in frequency carrier frequency produced by the modulating signal is known as frequency deviation.

FM & PM Waveforms:-



(a) Unmodulated carrier b) Modulating signal.

c) Frequency modulated wave d) phase modulated wave.

→ In FM, the maximum frequency deviation occurs during the maximum positive and negative peak of the modulating signal.

→ In PM, the maximum frequency deviation occurs during the zero crossing of the modulating signals.

Problem:

1. The output voltage of a transmitter is given by $500(1+0.4\sin 3140t)\sin 6.28\times10^{7}t$. This voltage is fed to a load of 600Ω.

Determine:-

(i) Carrier frequency ii) Modulating frequency

iii) Carrier power iv) Mean power o/p (or) total power.

given:-

Amplitude modulated signal is given by.

$$V_{am}(t) = E_c\left[1+E_m\sin(2\pi f_m t)\right]\sin(2\pi f_c t)$$

$$500\left(1+0.4\sin(2\pi 40t)\right]\sin 6.28\times10^{7}t$$

$E_c = 500$ $m = 0.4$ $\omega_m = 3140$ rad/sec.

$\omega_c = 6.28\times10^{7}$ rad/sec.

(i) Carrier frequency

$$f_c = \frac{\omega_c}{2\pi} = \frac{2\pi f_c \times 6.28\times10^{7}\ \text{rad/sec}}{2\pi}$$

$$\boxed{f_c = 10\ \text{MHz}}.$$

ii) Modulating frequency $f_m = \frac{\omega_m}{2\pi} = \frac{3140}{2\pi} = 500\text{Hz}$

iii) Carrier power $P_c = \frac{E_c^2}{2R} = \frac{(500)^2}{2\times600} = 208.33\text{W}$.

iv) Total power $P_t = P_c\left[1+\frac{m^2}{2}\right]$

$$P_t = 208.33\left(1+\frac{(0.4)^2}{2}\right)$$

$$\boxed{P_t = 225\text{W}}$$

Comparison between FM and PM :

	Frequency modulation	phase modulation
1.	The maximum frequency deviation depends upon amplitude of modulating voltage and modulating frequency.	The maximum phase deviation depends only upon the amplitude of modulating voltage.
2.	Frequency of the carrier is modulated by modulating signal.	phase of the carrier is modulated by modulating signal.
3.	Modulation index is increased as modulation frequency is reduced	modulation index remain same if modulating freq is changed,
4.	FM can be obtained from PM	PM can be derived from FM.
5.	Frequency modulation is used for broadcasting the radio signal.	It is used for data trxion and voice trxion.

Problem 1: A FM wave is represented by the following equation

$$V = 10 \sin\left[5 \times 10^8 t + 4 \sin 1850 t\right]$$

Find (i) Carrier & Modulating frequencies

(ii) Modulation index

(iii) The power dissipated by this FM wave in a 5Ω resistor.

soln:

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

(i) $2\pi f_c = 5 \times 10^8$

$f_c = 79.57$ MHz

(ii) $2\pi f_m = 1850$

$f_m = 199$ Hz

(iii) $\beta = 4$

(iv) $P = \frac{A_c^2}{2R} = \frac{10^2}{2 \times 5} = 10$W

Comparison of WBFM and NBFM:

	WBFM	NBFM
1.	Modulation index is greater than 1 ($\beta > 1$)	Modulation index is less than 1 ($\beta < 1$)
2.	Frequency deviation is 75KHz	Frequency deviation is 5KHz
3.	Modulating frequency range from 30Hz - 15KHz.	Modulating frequency is 3KHz
4.	Bandwidth 15 times of NBFM	Bandwidth is $2f_m$
5.	Noise is more suppressed	less suppressing of noise.
6.	Use: Audio Broadcasting	Use: Mobile communication

Problem 1: An angle modulated wave is described by the equation $v(t) = 10\cos(2\times10^6\pi t + 10\cos 2000\pi t)$. Find a) power of the modulated signal b) Maximum frequency deviation 3) Bandwidth.

Soln: $v(t) = 10\cos(2\times10^6\pi t + 10\cos 2000\pi t)$

$A_c = 10 \quad \beta = 10 \quad 2\pi f_c = 2\times10^6\pi$

$f_c = 10^6$

$2\pi f_m = 2000\pi$

$f_m = 1000\,Hz$

iii) $B = 2(\Delta f + f_m)$ (max)

$B = 22\,KHz$

(i) $P = \frac{A_c^2}{2R}$ $\quad R = 1\Omega$

$P = \frac{100}{2} = 50W$

(ii) $\beta = \frac{\Delta f}{f_m}$

$\Delta f = \beta \times f_m$

$\Delta f = 10 \times 1000\,Hz$

Type of Modulation	Modulating signal	Angle modulated wave s(t)
(a) phase	$V_m(t)$	$s(t) = A_c \cos[2\pi f_c t + k_p V_m(t)]$
(b) Frequency	$V_m(t)$	$s(t) = A_c \cos[2\pi f_c t + 2\pi k_f \int_0^t V_m(t)\,dt]$
(c) phase	$V_m \cos(\omega_m t)$	$s(t) = A_c \cos[2\pi f_c t + k_p V_m \cos\omega_m t]$
(d) Frequency	$V_m \cos(\omega_m t)$	$s(t) = A_c \cos[2\pi f_c t + \beta \sin\omega_m t]$

Summary:

Modulated wave $\rightarrow s(t) = A_c \cos\left[2\pi f_c t + \frac{k_f A_m}{f_m} \sin(\omega_m t)\right]$ FM

(OR)

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

Modulated wave $\rightarrow s(t) = A_c \cos[2\pi f_c t + k_p A_m \cos(2\pi f_m t)]$

(OR)

$\rightarrow s(t) = A_c \cos[2\pi f_c t + A\theta \cos(2\pi f_m t)]$

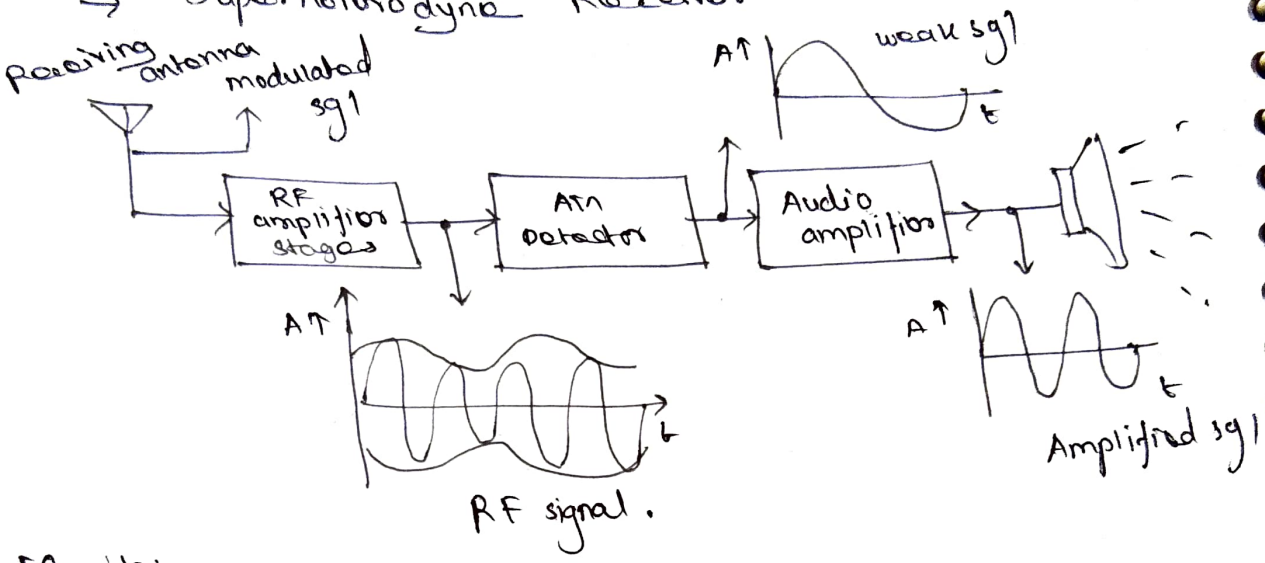
Deviation sensitivity	k_f (Hz/V)	k_p (rad/V)
Deviation	$A_f = k_f A_m$ (Hz)	$A\theta = k_p A_m$ (rad)
Modulation index	$\beta = \frac{k_f A_m}{f_m}$ (unitless)	$\beta = k_p A_m$ (rad)
(OR)	$\beta = \frac{A_f}{f_m}$	$\beta = A\theta$ (rad)
Modulating signal	$m(t) = A_m \sin 2\pi f_m t$	$A_m \cos(2\pi f_m t$
Carrier signal	$V_c \cos(2\pi f_c t)$	$V_c \cos(2\pi f_c t$
Modulating frequency	$\omega_m = 2\pi f_m$ rad/s	$\omega_n = 2\pi f_m$ rad/

AM Receiver:

→ It receives the RF signal and recover the original sgl.

→ Tuned Radio Frequency Receiver

→ Superheterodyne Receiver.



Merits:-

1. Flexible for single frequency
2. High sensitivity.

Demerits:

1. It required multiple stage of RF amplifier
2. Gain is non-linear over wide range of frequencies

Generation of FM using phase modulator

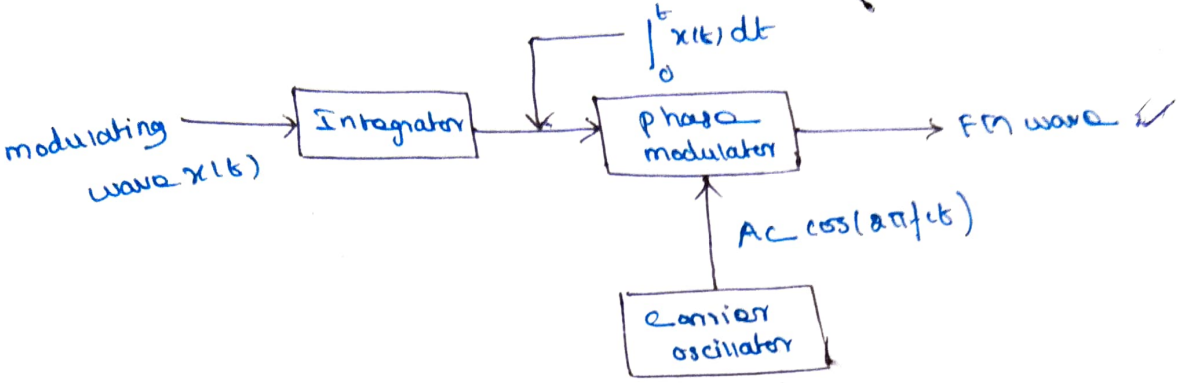


Fig (a) Generation of FM using PM.

FM wave is actually a PM wave having a modulating signal $\int_0^t x(t)dt$ instead of $x(t)$.

This means that we can generate FM wave by applying the integrated version of $x(t)$ to a phase modulator.

$$\text{FM wave} = s(t) = A_c \cos\left[2\pi f_c t + 2\pi k_f \int_0^t x(t)dt\right]$$

Generation of PM using a frequency modulator.

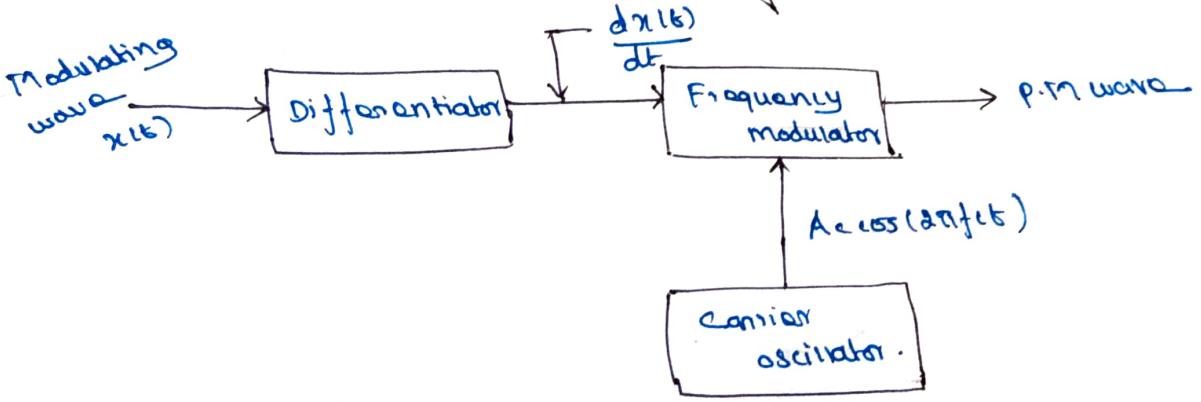


Fig (b) Generation of P.M wave using FM.

The modulating signal is first passed through a differentiator and then applied to a frequency modulator.

At the o/p of the differentiator, we get the differentiated version of modulating signal i.e $\frac{dx(t)}{dt}$.

Hence, output of the frequency modulator will be

$$s(t) = A_c \cos\left\{2\pi f_c t + 2\pi k_f \int_0^t \left(\frac{dx(t)}{dt}\right)\right\}$$

$$s(t) = A_c \cos\left[2\pi f_c t + 2\pi k_f x(t)\right]$$

Substituting $2\pi k_f = k_p$, we get

$$s(t) = A_c \cos\left[2\pi f_c t + k_p x(t)\right]$$

which is the expression for a PM wave. ✓

Modulation index:

$$m_f = \frac{\text{Frequency deviation}}{\text{Modulating frequency}}$$

$$\beta = \frac{\Delta f}{f_m}$$

Deviation Ratio:

$$DR = \frac{\text{Maximum deviation}}{\text{Maximum modulating frequency}}$$

Percentage Modulation of FM wave:

$$\%\ \text{Modulation} = \frac{\text{Actual frequency deviation}}{\text{Maximum allowed deviation}}$$

Frequency Modulation: (or) single Tone Modulation.

We express the resulting angle modulated wave as $s(t) = A_c \cos[\theta_i(t)]$ → (1)

Let the sinusoidal modulating signal defined by

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

The instantaneous frequency of the resulting FM signal $f_i(t) = f_c + k_f m(t)$ → (3)

Sub eqn (2) into (3) we get

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

where $\boxed{A_f = k_f A_m}$

$$\therefore f_i(t) = f_c + A_f \cos(2\pi f_m t).$$

A_f ← frequency deviation.

Instantaneous frequency of the angle modulated signal,

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

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

$$\theta_i(t) = 2\pi \int_0^t f_i(t)\, dt.$$

$$= 2\pi \int_0^t f_c + A_f \cos(2\pi f_m t)\, dt$$

$$= \int_0^t 2\pi f_c + 2\pi A_f \cos(2\pi f_m t)\, dt.$$

$$= 2\pi f_c t + 2\pi \cdot \Delta f \sin(2\pi f_m t) \cdot \frac{1}{2\pi f_m}$$

$$\theta_i(t) = 2\pi f_c t + \frac{\Delta f}{f_m} \sin(2\pi f_m t) \longrightarrow (4)$$

The ratio of the frequency deviation (Δf) to modulating frequency f_m is called as modulation index.

$$\beta = \frac{\Delta f}{f_m}$$

$$\therefore \theta_i(t) = 2\pi f_c t + \beta \sin(2\pi f_m t) \longrightarrow (5)$$

$\therefore$ Sub eqn (5) into (1) we get

$$\boxed{s(t) = A_c \cos\left[2\pi f_c t + \beta \sin(2\pi f_m t)\right]}$$

Types of FM:

1. Narrow band FM, for which β is small compared to one radian. $\beta \ll 1$
2. Wideband FM, for which β is large compared to one radian. $\beta \gg 1$

→ FM signal can be generated by first integrating m(t) and then using the result as the i/p to a phase modulator.

→ PM signal can be generated by first differentiating m(t) and then using the result as the i/p to a FM.

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PAGE NO:
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CLASS NO:

TITLE: FM Generation using Varactor Diode Modulator. (Direct method)

OBJECTIVE:

Student able to learn about FM generation.

APPLICATIONS:

1. FM Radio Broadcasting.

UNIVERSITY QUESTIONS:

1. Explain the direct method of FM generation. 8M NOV/DEC 2016.

NOTES

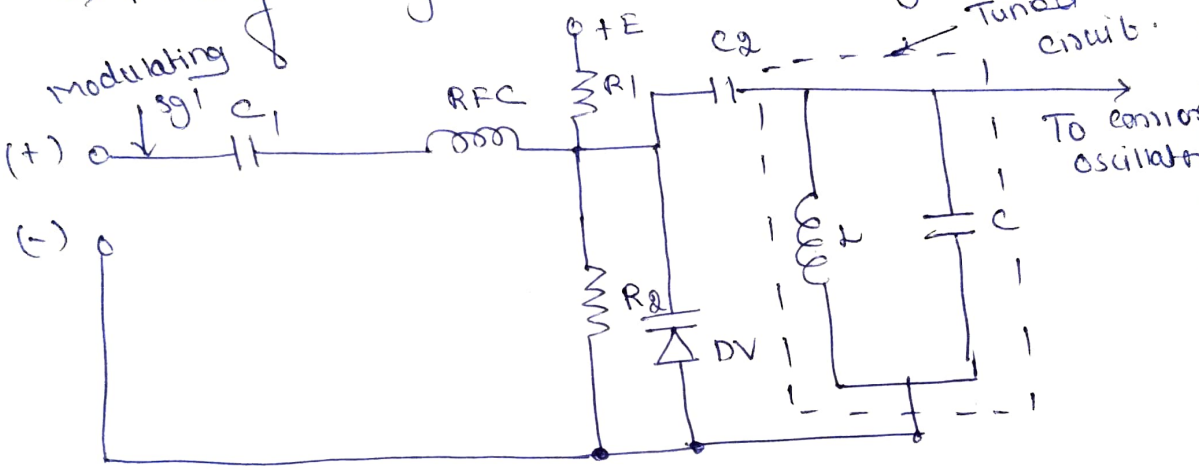
Varactor diode Modulator - operation.

- Varactor diode capacitance depends upon the fixed bias set by R_1 and R_2 and the RF modulating signal.
- Either R_1 (or) R_2 is made variable, so that centre Carrier frequency can be adjusted over a narrow range.
- To prevent the Carrier signal from getting into the modulating signal by Radio frequency choke.
- Reverse bias applied to the Varactor diode at modulating signal is positive side.

→ Negative modulating signal subtracts from the bias to increase the capacitance range.

→ Local oscillator frequency change due to temperature effects by the tuned circuit of L and C.

→ Finally it generated the FM signal.



Fig(a) Varactor Diode Modulator.

Generation of FM signals

Two method: To generating frequency modulated signals.

a] Direct FM

b] Indirect FM.

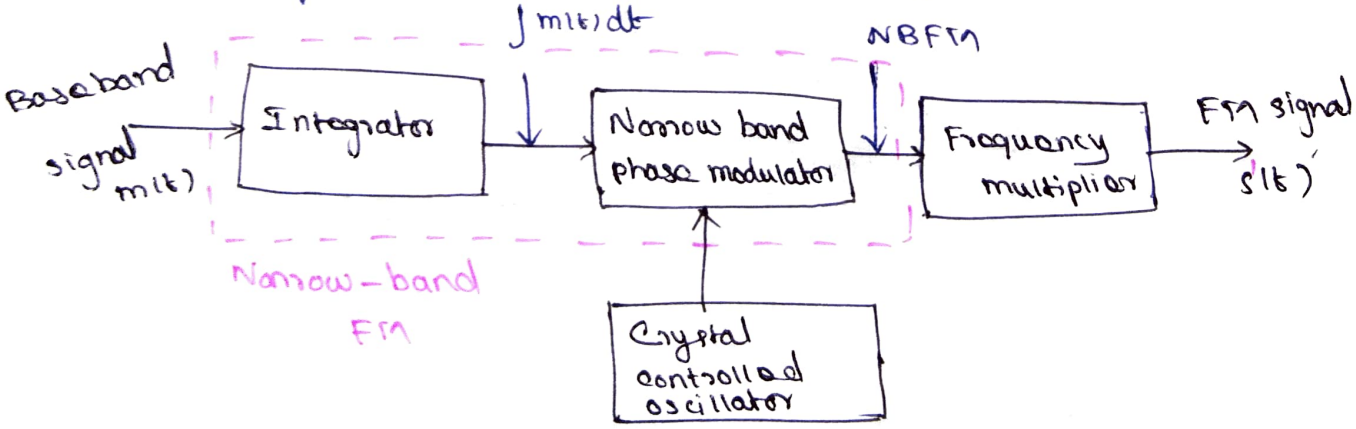
a] Direct FM:

In the direct method the carrier frequency is directly varied in accordance with the input baseband signal.

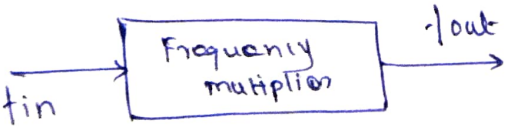
b] Indirect FM: (Armstrong method)

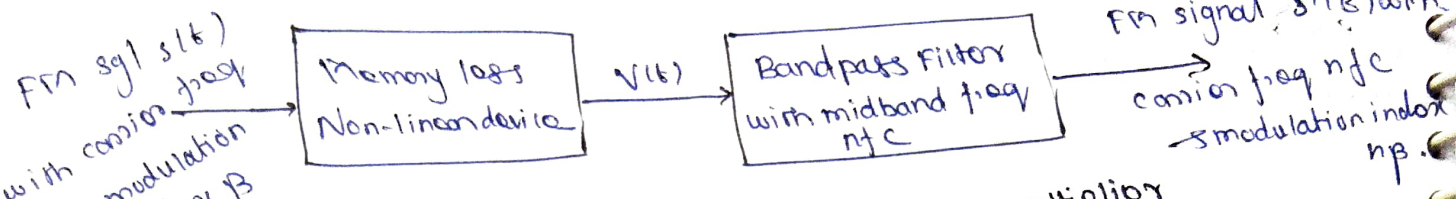
Armstrong method of FM generation is one of the indirect method in which the modulating signal is integrated and then using a stable crystal oscillator it is phase modulated as a result NBFM is obtained.

Then by using frequency multipliers the desired wideband FM is obtained. Frequency mutipliers is a non-linear device which multiplies the input frequency and produces wide band FM signal at o/p.



(a) Indirect method of generating a WBFM sgl.





(b) Block diagram of frequency multiplier

A simple square law device for example. It can multiply the frequency by a factor of 2, in the above diagram of frequency multiplier a non-linear device is followed by a BPF.

→ Frequency multiplier increases the frequency deviation as well as carrier frequency. It is called indirect method because FM is generated from PM.

The input output relation of such a Non linear device may be expressed as,

$$V(t) = a_1 s(t) + a_2 s^2(t) + \cdots + a_n s^n(t) \quad \longrightarrow (1)$$

where

$a_1, a_2 \ldots a_n \rightarrow$ co-efficient of device operating points

n – higher order non linearity.

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

(or)

$$s(t) = A_c \cos\left[2\pi f_c t + 2\pi k_f \int_0^t m(t)\,dt\right]$$

$$\therefore V(t) = a_1 A_c \cos\left[2\pi f_c t + \beta \sin(2\pi f_m t)\right] + a_2 A_c^2 \cos^2 \left[2\pi f_c t + \beta \sin(2\pi f_m t)\right] + \cdots + a_n A_c^n \cos^n\left[2\pi f_c t + \beta \sin(2\pi f_m t)\right]$$

Advantages:-

a) FM is generated from PM indirectly

Problem7: A carrier is frequency modulated with sinusoidal signal of 2KHz, resulting in a maximum frequency deviation of 5 KHz. Find (i) Modulation index (ii) Bandwidth of FM modulated signal.

Solution:

$f_m = 2\,KHz \qquad \Delta f = 5\,KHz$

(i) Modulation index $\beta = \frac{\Delta f}{f_m} = \frac{5K}{2K}$

$$\boxed{\beta = 2.5}$$

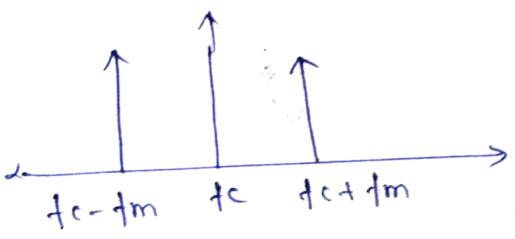
(ii) Bandwidth of FM modulated signal $BW = 2(\Delta f + f_m)$

$= 2(5 \times 10^3 + 2 \times 10^3)$

$$\boxed{B = 14\,KHz}$$

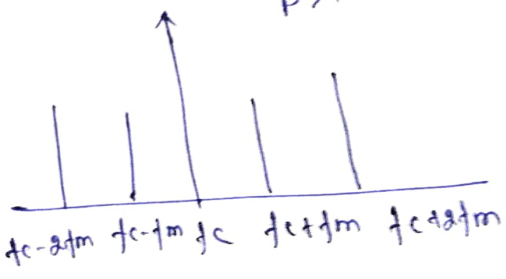
FM spectrum:

For NBFM $\beta < 1$



(a)

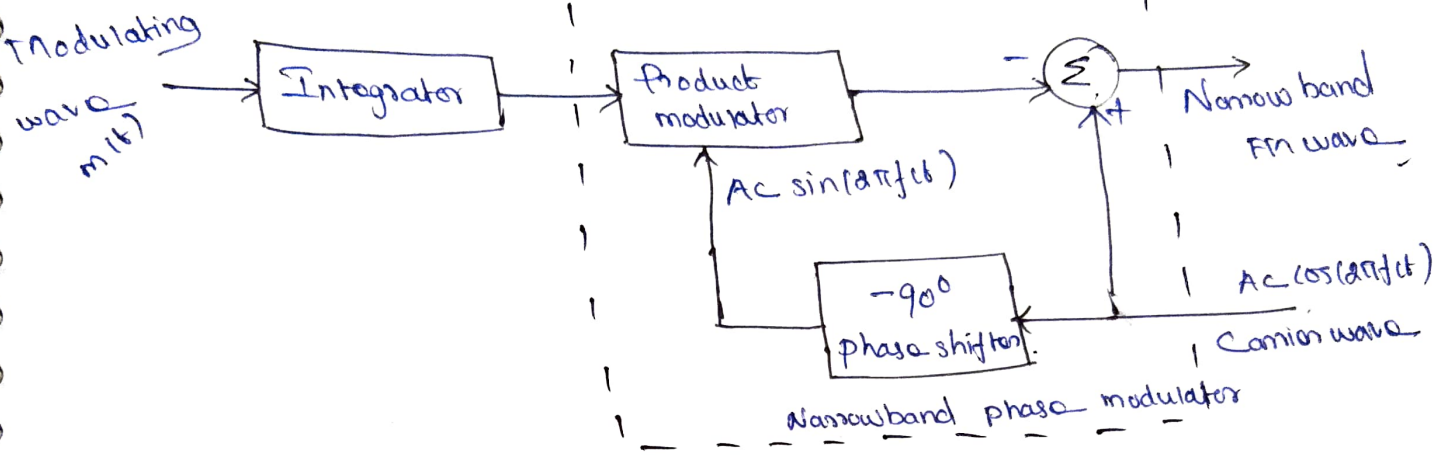
$\beta > 10$



(b)

Narrow band Frequency Modulation:

→ Narrow band FM, For which β is small compared to one radian $\beta \ll 1$.



Fig(a) Generating a narrowband FM signal.

Let the modulating signal represents

$$m(t) = Am \cos(2\pi fmt)$$

This modulator involves splitting the carrier wave $Ac \cos(2\pi fct)$ into two paths. one path is direct, the other path contain a -90^0 phase shifting N/W and a Product modulator, the combination of which generates a DSB-SC modulated signal. The difference b/w these two signal produces a narrowband FM signal.

Analysis:

FM wave $s(t)$ can be written as

$$s(t) = Ac \cos\left[2\pi fct + \beta \sin(2\pi fmt)\right] \longrightarrow (1)$$

Expand the above equation using formula.

$$\because \left[\cos(A+B) = \cos A \cos B - \sin A \sin B\right]$$

$$s(t) = A_c\left[\cos(2\pi f_c t)\cos(\beta\sin(2\pi f_m t)) - \sin(2\pi f_c t)\cdot\sin(\beta\sin(2\pi f_m t))\right] \longrightarrow (3)$$

In Narrow band FM: $\beta << 1$

Since the value of β is very small for NBFM

$$\therefore \cos(\beta\sin(2\pi f_m t)) \simeq 1 \quad [\text{where } \cos\theta = 1 \text{ if } \theta \text{ is small}]$$

and

$$\sin[\beta\sin(2\pi f_m t)] \simeq \beta\sin(2\pi f_m t) \quad [\text{where } \sin\theta = \theta \text{ if } \theta \text{ is small}]$$

Taylor series expansion: $\beta^2 << 1 \quad \beta^3 << 1$

$$\cos\theta = 1 - \frac{\theta^2}{2!} + \frac{\theta^3}{3!} \ldots \quad \text{if the } \theta \text{ value is small}$$

$$\sin\theta = \theta - \frac{\theta^3}{6} + \frac{\theta^5}{5!} \ldots$$

Substitute the above approximation in eqn (3) the resultant equation $s(t)$ becomes

$$s(t) = A_c\left[\cos(2\pi f_c t) - \underbrace{\sin 2\pi f_c t}_{A}\cdot\underbrace{\beta\sin(2\pi f_m t)}_{B}\right]$$

Expand the above equation (4) using Formula $\longrightarrow (4)$

$$\sin A\sin B = \frac{1}{2}\left[\cos(A-B) - \cos(A+B)\right]$$

$$s(t) = A_c\left[\cos(2\pi f_c t) - \frac{\beta}{2}\cos(f_c - f_m)2\pi t + \frac{\beta}{2}\cos(f_c + f_m)2\pi t\right]$$

$$s(t) = A_c\cos 2\pi f_c t - \frac{\beta\cdot A_c}{2}\cos 2\pi(f_c - f_m)t + \frac{\beta\cdot A_c}{2}\cos 2\pi(f_c + f_m)$$

FM

$$s(t) = A_c\cos 2\pi f_c t + \frac{\beta\cdot A_c}{2}\cos 2\pi(f_c + f_m)t - \frac{\beta\cdot A_c}{2}\cos[2\pi(f_c$$

AM

$$S_{am}(t) = A_c\cos 2\pi f_c t + \frac{m\cdot E_c}{2}\cos 2\pi(f_c + f_m)t + \frac{m\cdot E_c}{2}\cos 2\pi[f_c$$

Wideband Frequency Modulation

- In WBFM, For which β is large compared to one radian $\boxed{\beta > 1}$

Def

FM wave is given by

$$s(t) = A_c \cos\left[2\pi f_c t + \beta \sin(2\pi f_m t)\right] \longrightarrow (1)$$

Eqn (1) can be rewritten by using exponential form:

$$s(t) = A_c \, Re\left[e^{j(2\pi f_c t + \beta \sin(2\pi f_m t))}\right]$$

$$s(t) = Re\left[A_c \exp(j 2\pi f_c t) \exp(j \beta \sin(2\pi f_m t))\right] \longrightarrow (2)$$

where

$\tilde{s}(t)$ is the complex envelope of the FM signal $s(t)$ defined by

since:

$e^{j\theta} = \cos\theta + j\sin\theta$

$\cos\theta = Re[e^{j\theta}]$

$$\tilde{s}(t) = A_c \exp[j\beta \sin(2\pi f_m t)] \longrightarrow (3)$$

Sub eqn (3) into (2) we get

$$s(t) = Re\left[\tilde{s}(t) \exp(j 2\pi f_c t)\right] \longrightarrow (4)$$

Expand $\tilde{s}(t)$ in the form of a complex Fourier series:

$$\tilde{s}(t) = \sum_{n=-\infty}^{\infty} C_n \exp(j 2\pi n f_m t) \longrightarrow (5)$$

where

$C_n \rightarrow$ Fourier co-efficient.

$$C_n = f_m \int_{-1/2 f_m}^{+1/2 f_m} \tilde{s}(t) \exp(-j 2\pi n f_m t)\, dt \longrightarrow (6)$$

sub eqn (3) into (6) we get

$$C_n = f_m A_c \int_{-\frac{1}{2}f_m}^{\frac{1}{2}f_m} \exp(j\beta \sin 2\pi f_m t) \cdot \exp(-j2\pi n f_m t)\, dt$$

$$C_n = f_m A_c \int_{-\frac{1}{2}f_m}^{\frac{1}{2}f_m} \exp(j\beta \sin 2\pi f_m t - j2\pi n f_m t)\, dt \longrightarrow (7)$$

put

$$x = 2\pi f_m t$$

$$dx = 2\pi f_m dt \Rightarrow dt = \frac{dx}{2\pi f_m}$$

when

$$t = -\tfrac{1}{2} f_m \quad x = 2\pi f_m \times -\tfrac{1}{2} f_m$$

$$\boxed{x = -\pi}$$

$$t = +\tfrac{1}{2} f_m \quad x = 2\pi f_m \times \frac{1}{2 f_m}$$

$$\boxed{x = \pi}$$

$$\therefore C_n = \frac{f_m A_c}{2\pi f_m} \int_{-\pi}^{\pi} \exp[j\beta \sin x - jxn]\, dx$$

$$C_n = \frac{A_c}{2\pi} \int_{-\pi}^{\pi} \exp[j\beta \sin x - jxn]\, dx. \longrightarrow (8)$$

since:

$$J_n(\beta) = \frac{1}{2\pi} \int_{-\pi}^{\pi} \exp(j\beta \sin x - jnx)\, dx$$ Bessel function of nth order.

$$C_n = A_c \cdot J_n(\beta) \longrightarrow (9)$$

sub eqn (9) into (5)

$$\tilde{s}(t) = A_c \sum_{n=-\infty}^{\infty} J_n(\beta) \exp(j2\pi n f_m t) \longrightarrow (10)$$

Sub eqn (10) in (4)

$$s(t) = Re \cdot Ac\left[\sum_{n=-\infty}^{\infty} J_n(\beta) \exp(j2\pi(f_c + nf_m)t\right]$$

Interchanging the order of summation and evaluation of real part in right side.

$$s(t) = Ac\sum_{n=-\infty}^{\infty} J_n(\beta)\, Re\left[\exp(j2\pi(f_c+nf_m)t\right]$$

$$s(t) = Ac\sum_{n=-\infty}^{\infty} J_n(\beta)\cos(2\pi(f_c+nf_m)t)$$

Taking Fourier Transform above eqn, we get

$$S(f) = \frac{Ac}{2}\sum_{n=-\infty}^{\infty} J_n(\beta)\left[\delta(f-f_c-nf_m)+\delta(f+f_c+nf_m)\right]$$

Formula:

$$\cos(2\pi f_c t) \xrightarrow{F.T} \frac{1}{2}\left[\delta(f-f_c)+\delta(f+f_c)\right]$$

Properties of Bessel Function:

1. $J_n(\beta) = (-1)^n J_{-n}(\beta)$ for all n

2. small value of modulation index β

$$J_0(\beta) \simeq 1$$

$$J_1(\beta) \simeq \beta/2$$

$$J_n(\beta) \simeq 0$$

3. $$\sum_{n=-\infty}^{\infty} J_n^2(\beta) = 1$$

Transmission Bandwidth of FM signals.

1. Low index modulation (Narrow band FM)

$\beta < 1$ $(f_m >>> \Delta f)$ $B = 2f_m$ (Hz) For small β

2. High index modulation (Wide band FM)

$\beta > 10$ $(\Delta f >> f_m)$

For large β: Bandwidth $= 2\beta f_m$

$$= 2 \times \frac{\Delta f}{f_m} \times f_m$$

$$B = 2\Delta f$$

3. Actual bandwidth

$B = 2nf_m$

where n is no. of significant sidebands.

4. Carson's rule

$$B = 2(\Delta f + f_m) = 2f_m\left(\frac{\Delta f}{f_m} + 1\right)$$

$$B = 2f_m(\beta + 1)$$

Carson rule approaches correct limits for both very large and very small β.

Narrow band FM (NBFM)

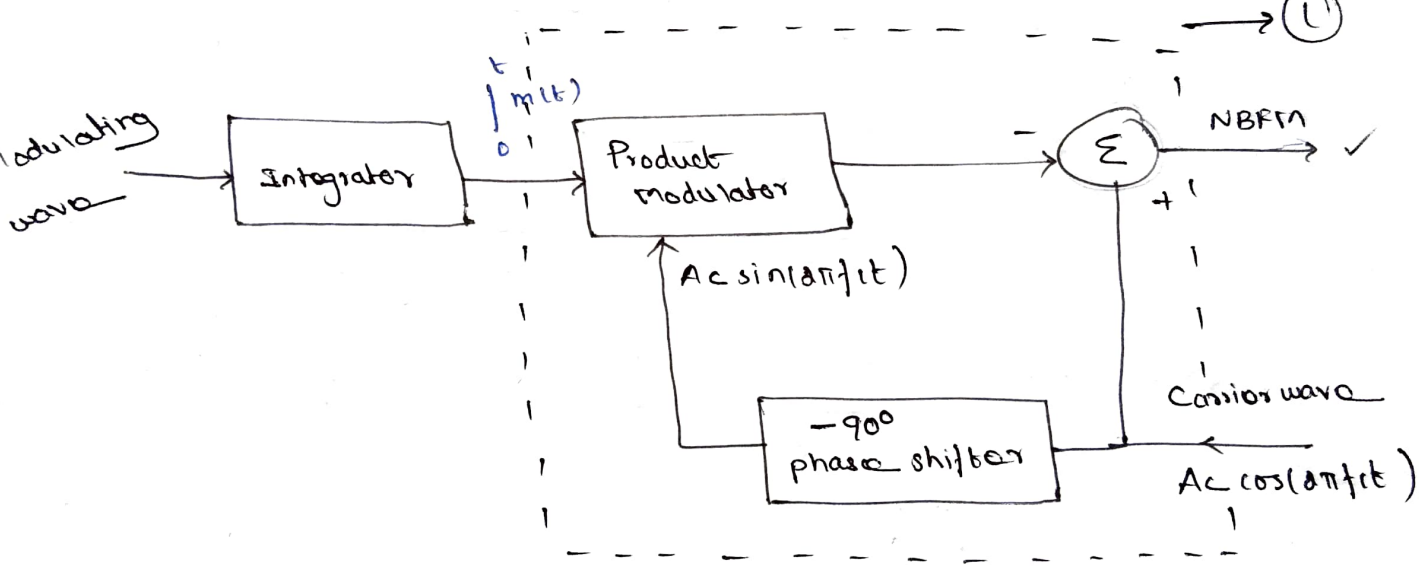
→ A NBFM is the FM wave with a small bandwidth, the modulation index β of NBFM is small as Compared to one radian.

→ Thus NBFM has a narrow bandwidth which is equal to twice the message bandwidth.

Analysis:-

The time domain expression for an FM wave is given by ✓

$$s(t) = A_c \cos\left[2\pi f_c t + \beta \sin(2\pi f_m t)\right] \quad \rightarrow (1)$$



NBFM

By using trignometric function.

$$\cos(A+B) = \cos A \cos B - \sin A \sin B$$

where $A = 2\pi f_c t \qquad B = \beta \sin(2\pi f_m t)$

$$s(t) = A_c \cos(2\pi f_c t) \cdot \cos(\beta \sin(2\pi f_m t)) - A_c \sin(2\pi f_c t) \sin(\beta \sin 2\pi f_m t)$$

$\rightarrow (2)$

In NBFM, β is small, Hence it is possible to approximate,

$$\cos(\beta \sin 2\pi f_m t) \approx 1$$
$$\sin(\beta \sin 2\pi f_m t) \approx \beta \sin 2\pi f_m t \quad \Big\} \rightarrow (3)$$

Substituting eqn (3) in (2) we get

$$s(t) = A_c \cos 2\pi f_c t - A_c \sin 2\pi f_c t \cdot (\beta \sin 2\pi f_m t)$$

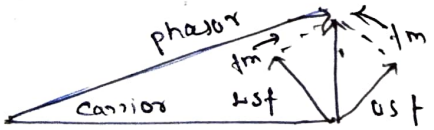
$$s(t) = A_c \cos(2\pi f_c t) - \beta A_c \sin(2\pi f_c t) \cdot \sin(2\pi f_m t) \rightarrow (4)$$

W.K.T

$$\sin A \sin B = \frac{1}{2}\cos(A-B) - \frac{1}{2}\cos(A+B)$$

$$s(t) = A_c \cos(2\pi f_c t) - \frac{\beta \cdot A_c}{2}\{\cos 2\pi (f_c - f_m)t - \cos 2\pi (f_c + f_m)t\}$$

$$s(t) = \underbrace{A_c \cos(2\pi f_c t)}_{\text{carrier part}} - \frac{\beta \cdot A_c}{2}\underbrace{\cos 2\pi (f_c - f_m)t}_{\text{LSF part}} + \frac{\beta \cdot A_c}{2}\underbrace{\cos 2\pi (f_c + f_m)t}_{\text{upper side part}}$$



phasor diagram of a NBFM ✓

This is NBFM wave.

Modulation index:

$$\beta = \frac{\text{Frequency deviation}}{\text{Modulating Frequency}} = \frac{\Delta f}{f_m}$$

Bandwidth of FM:

The FM wave consists infinite no. of side bands Thus bw of a FM sg/ is infinite

$$B = 2\left[\Delta f + f_m\right]$$

FM Demodulators

Introduction:

→ Frequency demodulation is the process at the receiver side.

→ It is used to recover the original modulating signal from a frequency modulated signal.

→ The Electronic Circuits that perform the FM demodulation process are called FM detectors.

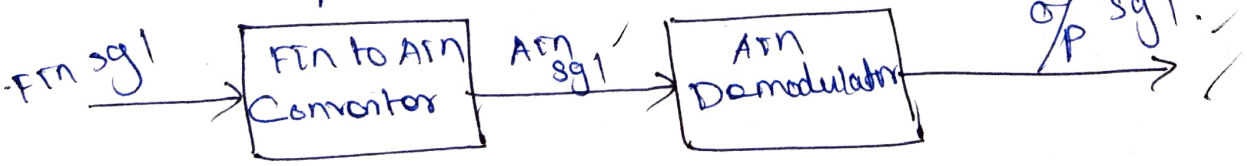
Functions of FM Detector:

The FM detector performs the extractions of the message signal in two steps.

1] It first converts the frequency modulated signal into a corresponding amplitude modulated signal by using freq dependent circuit. That is whose o/p voltage depends on i/p freq. such circuits are called as freq discriminator.

2] The original modulating signal is recovered from this AM signal by using a linear diode Envelope detector.

Freq. discriminator



Fig(a) A general FM demodulator.

→ simple RL CKt can be used as discriminator but this circuit has a poor sensitivity as compared to a tuned LC ckt.

→ Freq. discriminator suffer from threshold effects.

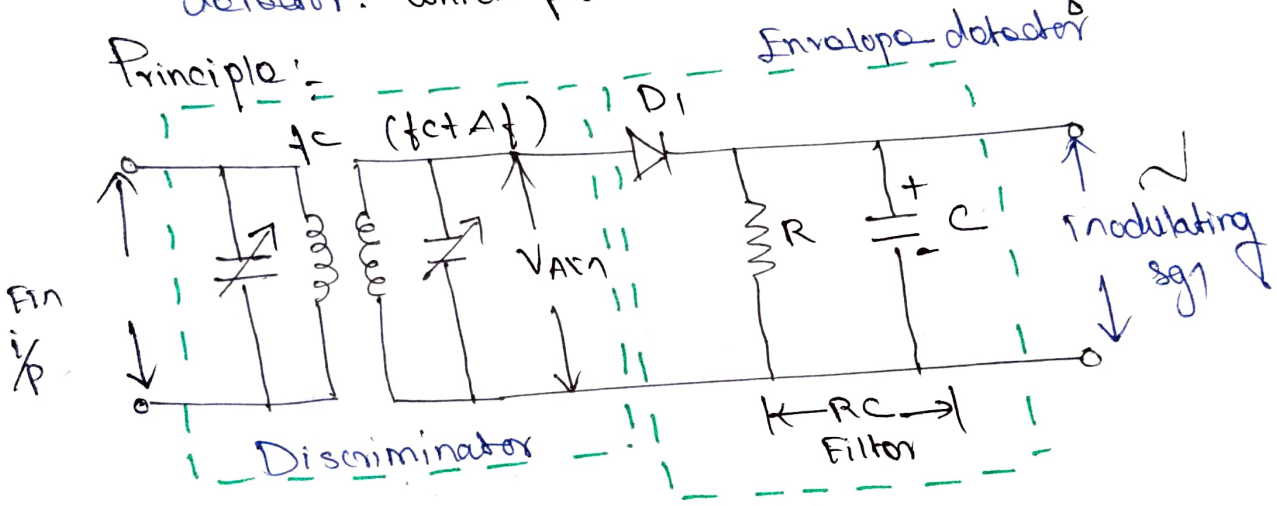
Types of FM Discriminator

1. Slope Detectors (or) single tuned discriminator
2. phase Discriminator → Foster seeley discriminator.

a] Simple slope Detectors:-

→ The circuit consists of a single tuned circuit which is slightly tuned from the carrier freq fc. This converts the FM signal into AM signal and then this AM signal is detected by an Envelope detector. which produces the modulating signal.

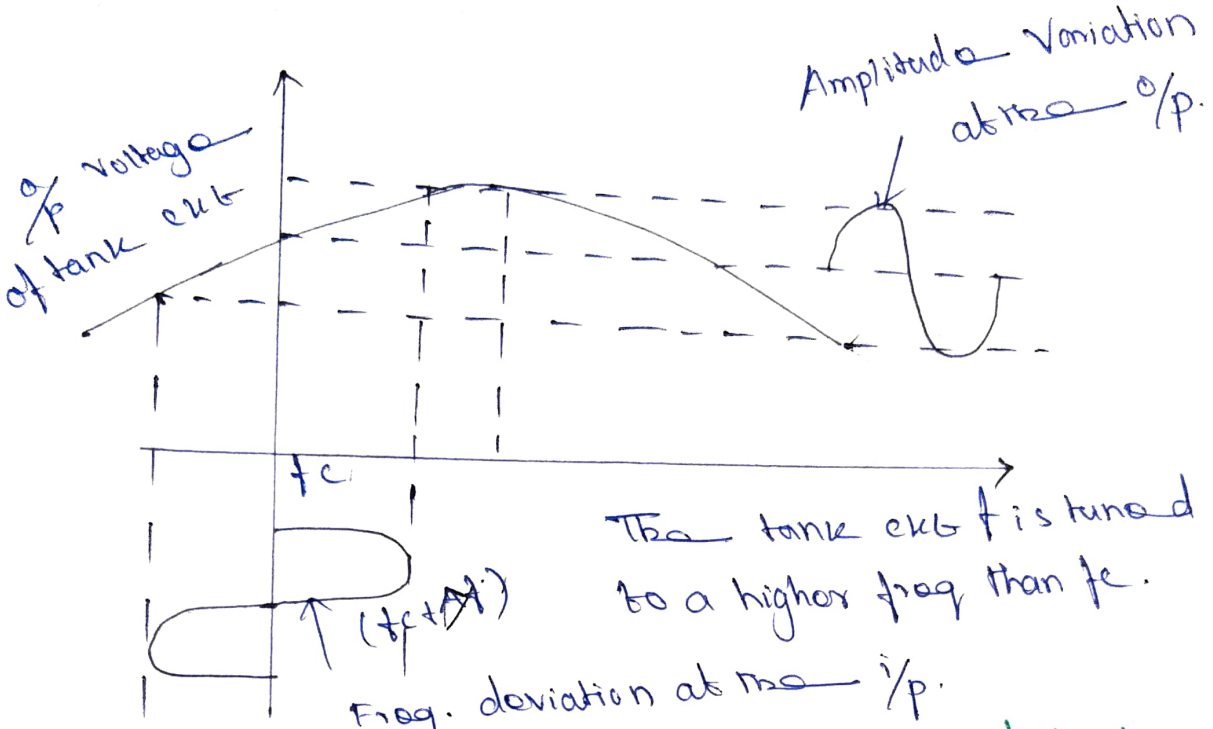
Principle:-



Fig(a) Simple slope detector.

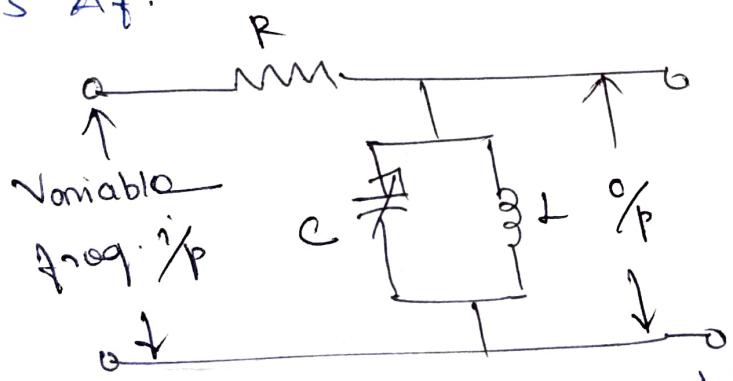
→ The AM signals from the o/p of the discriminator is applied to the i/p of the envelope detector with an RC load with proper time constant.

→ At the o/p of envelope detector, the original base band signal is obtained.



Fig(b) Characteristics of a slope detector.

→ Consider a tuned ckt and FM signal is applied to it as i/p. The center or carrier freq of the FM sgl is fc and the freq deviation is Δf.



Fig(c) Tuned ckt.

1st ckt tuned to a fc and then it is tuned to a freq slightly different from the carrier freq. (fc+Δf).

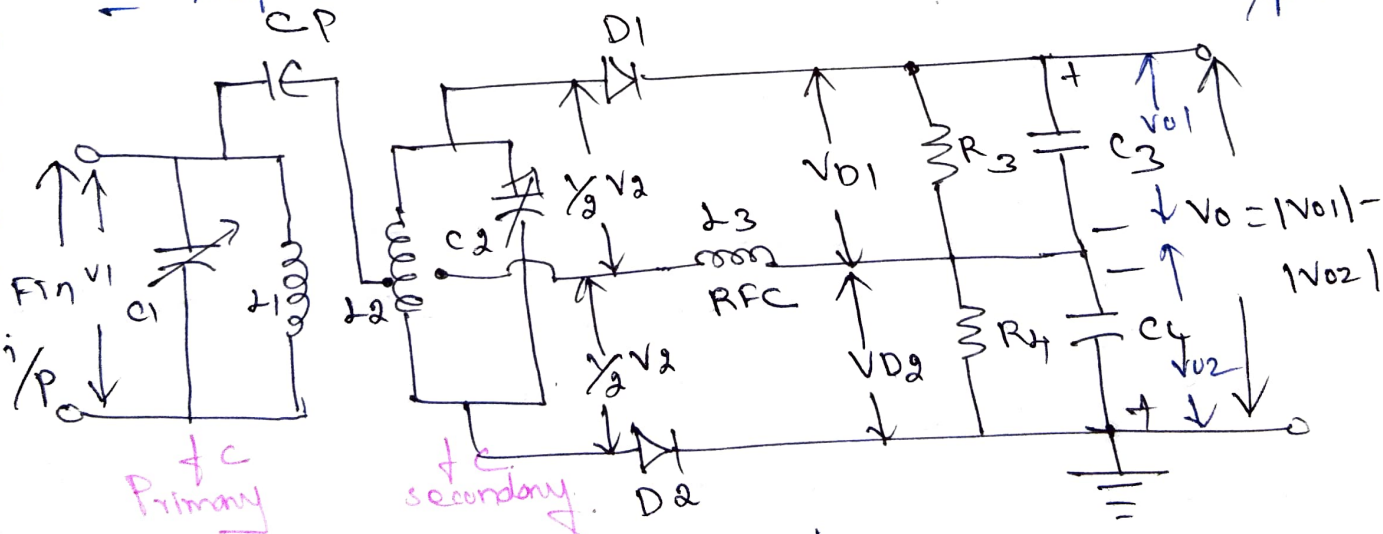
Adv:
→ Amplitude of the o/p voltage of the tank ckt depends on the freq deviation of the i/p sgl

Dis:
1. Simple and inexpensive
2. It is inefficient
3. It is linear only over a limited freq range.

Foster Seeley Discriminator
[Phase Discriminator]

Introduction:- It uses a double tuned RF Transformer to convert freq variations in the received fm sgl to amp variations.

- In the primary and the secondary windings both, are tuned to the same center freq 'f_c' of the incoming sgl but the voltages applied to the two diodes D_1 and D_2.
- They vary depending on the frequency of the i/p sgl. This is due to the change in phase shift b/w the primary and secondary windings depending on the i/p freq.
- Here the secondary voltage lags primary voltage by 90° at the center freq (f_c).
- Amp. variations are then rectified and filtered to provide dc o/p.



Fig(a) Foster-Seeley discriminator.

RFC ← This kind of inductor will allow DC current to pass through but block AC current in the RF.

- The primary voltage is coupled through c.t to the centre tap on the secondary. RFC offers high impedance to frequencies of FTH.
- The voltage of secondary is V_2 and equally divided across upper half and lower half of the secondary coil.

Observe the voltage across diode D_1

$$V_{D1} = V_1 + 0.5V_2$$

$$V_{D2} = V_1 - 0.5V_2$$

- The o/p of upper rectifier (R_3C_3) is V_{o1} and lower rectifier (R_4C_4) is V_{o2} then the o/p voltage is

$$V_o = |V_{o1}| - |V_{o2}|$$

$V_{D1} \simeq V_{o1}$

$V_{D2} \simeq V_{o2}$

Adv:-

1. It is much easier to align the ckt.
2. Only two tuned circuits are necessary and both are tuned to same freq. (fc)
3. Linearity is better.

Dis:-

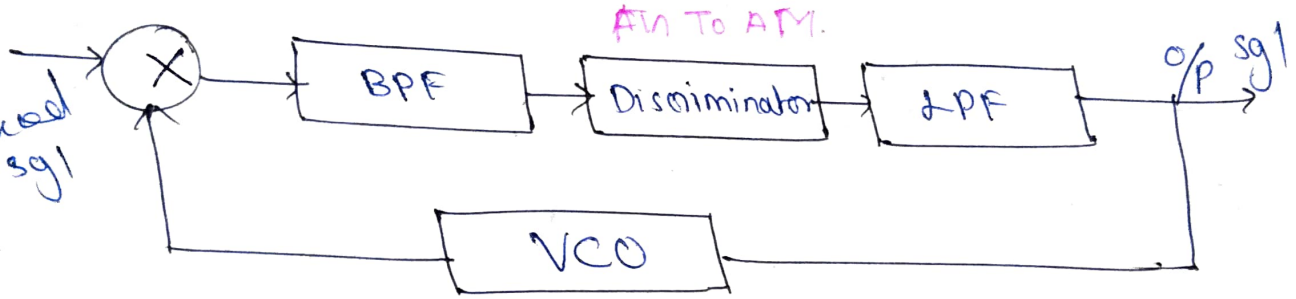
1. It does not provide any amplitude limiting
2. Error distortion is occur.

PLL as FM Demodulator

Introduction:-

A different approach to FM signal demodulation is to use feedback in the FM Demodulator to narrow the b.w of the FM detector and to reduce the noise power at the o/p of the demodulator.

A VCO path is employed in the feedback system and the FM discriminator is placed in direct path.



Fig(a) FMFB demodulator.

The bandwidth of the discriminator and the subsequent low pass filter are designed to match the b.w of the message sgl.

The o/p the LPF is desired message sgl

This type of FM demodulator is called as FM demodulator with feedback (FMFB).

Define:-

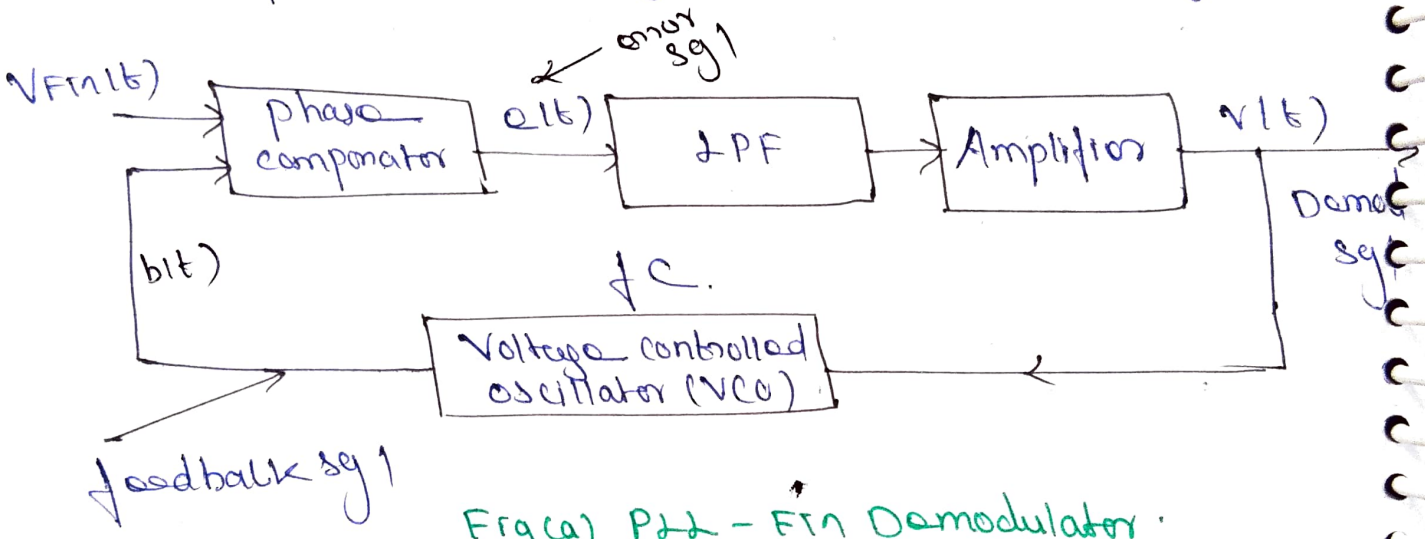
A PLL is used to synthesize new frequencies which are a multiple of a reference freq, with the same stability as the ref freq.

Demodulation of FM If PLL is locked to a FM sgl The VCO tracks the instantaneous freq of the i/p sgl.

phase lock-loop - FM

→ PLL is a negative feedback system and its primarily used in tracking the phase and freq of the carrier component of an incoming FM sig.

→ It is also useful for demodulating FM signals in presence of large noise and low signal power.



Frg(a) PLL - FM Demodulator.

phase comparator :-

→ It produces an average freq % voltage e(t) that is linear function of the phase difference b/w the two i/p sigs.

VCO :-

→ It is an electronic sine wave generator. It is freq controlled by the external control voltage. Thus VCO is a kind of freq modulator.

LPF :-

→ LPF allows the low freq components and also removes much of the noise.

→ The filtered sig is amplified.

Applications :-