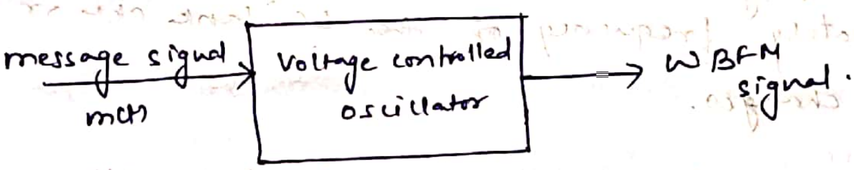
Generation of FM :-

1. Direct method
2. Indirect method.

1. Direct method :-

- It is called as direct method because we are generating WBFM directly using VCO (voltage controlled oscillator)

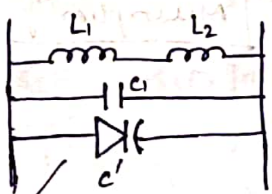
VCO produces an o/p signal, whose frequency is proportional to the i/p signal voltage., which is similar to the definition of FM wave.



→ In VCO, an LC tank circuit is used for producing oscillations. Here a varicap diode is used in place of capacitor in tank circuit.

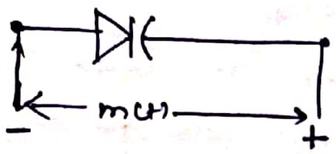
~~A varactor (varicap) diode is used in place of~~ the capacitor

→ A varactor (varicap) diode is a type of semiconductor diode whose capacitance across the junction can be varied by varying the voltage across the junction.



$$f_0 = \frac{1}{2\pi\sqrt{(L_1+L_2)(C'+C}}$$

Varactor diode operates in reverse bias region.



Capacitance of varicap

$C_T = \frac{\epsilon A}{\omega}$, $C_T \propto \frac{1}{\omega}$

Here, if the reverse bias voltage of the diode is increased, then the size of depletion width (ω) increases. Likewise, if reverse voltage of diode is decreased, then ω↓

∴ with ω ↑ ⇒ C_T ↓

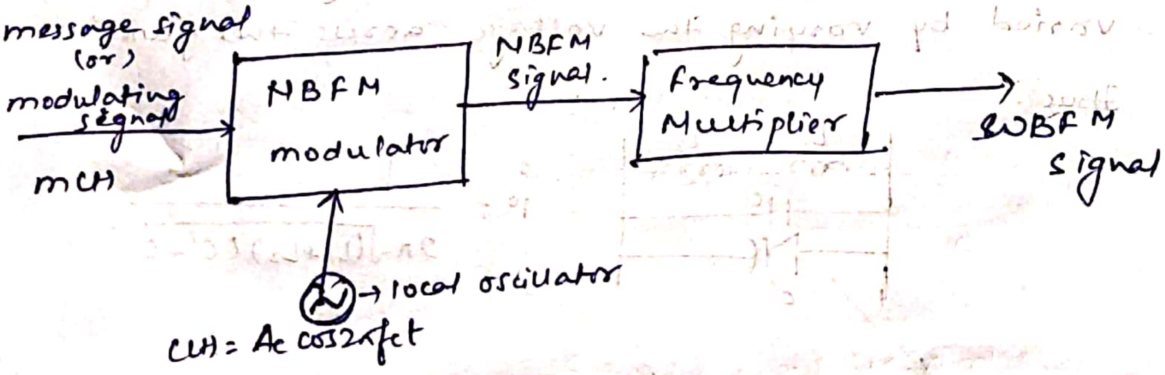
ω ↓ ⇒ C_T ↑

Now, with the i/p varying i/p voltage capacitance is varying and due to change in capacitance ultimately frequency of the LC tank ckt or VCO also changes.

∴ $f_i \propto m(t)$ ⇒ $f_i = f_c + k_f m(t)$
↓
instantaneous frequency of FM signal.

Indirect method:-

- In this method, first we will generate NBFM wave and then with the help of frequency multipliers we will get WBFM wave.



→ NBFM modulator:-

standard eqⁿ of FM:-

$$s(t) = A_c \cos\left(2\pi f_c t + 2\pi k_f \int m(t)\, dt\right)$$

$$\Rightarrow s(t) = A_c \cos 2\pi f_c t \cos\left(2\pi k_f \int m(t)\, dt\right) - A_c \sin(2\pi f_c t) \sin\left(2\pi k_f \int m(t)\, dt\right) \quad -(1)$$

For NBFM

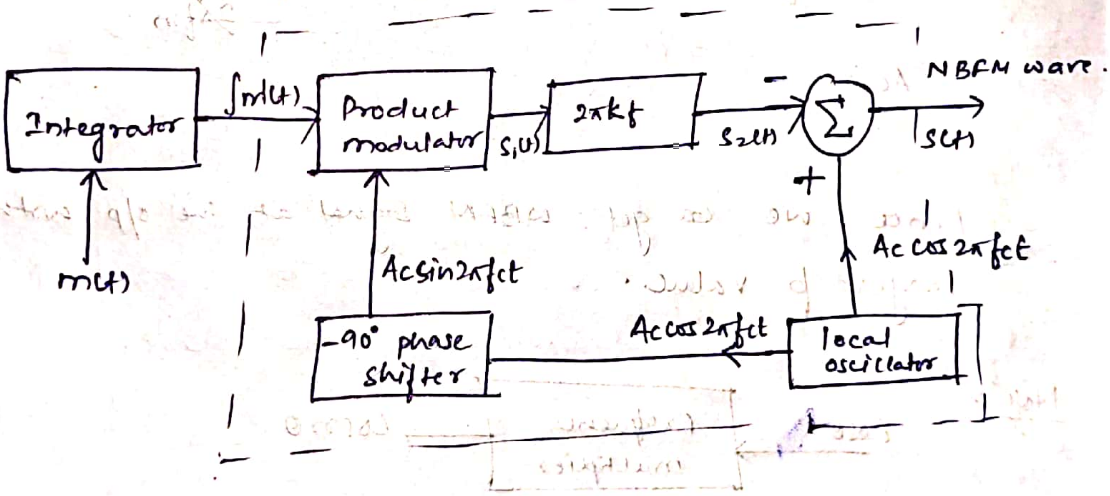
$$\left|2\pi k_f \int m(t)\right| << 1.$$

let $2\pi k_f \int m(t) = \theta$.

if θ is small, then $\cos\theta \simeq 1$ & $\sin\theta \simeq \theta$

∴ eqⁿ (1) becomes:-

$$s(t) = A_c \cos 2\pi f_c t - A_c \sin 2\pi f_c t \cdot \left(2\pi k_f \int m(t)\, dt\right)$$



Here, o/p of product modulator:-

$$S_1(t) = A_c \cdot \sin 2\pi f_c t \cdot \int m(t)\, dt$$

And, $S_2(t) = A_c \sin 2\pi f_c t \left(2\pi k_f \int m(t)\, dt\right)$

And, finally summer o/p

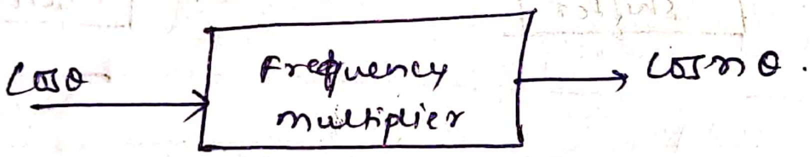
$$s(t) = A_c \cos 2\pi f_c t - A_c \sin 2\pi f_c t \left(2\pi k_f \int m(t)\, dt\right)$$

Now, coming to WBFM generation :-

We know that the modulation index (β) of NBFM is less than one ($\beta \leq 1$). Hence, in order to get the required β of WBFM, we choose the frequency multiplier value.

Frequency multiplier is a ~~no~~ non linear device or we can say that its a square law device followed by a Band pass filter which produces an o/p signal whose frequency and modulation index gets multiplied 'n' times.

Note :-



General exp. of single-tone FM signal :-

$$S_{NBFM}(t) = A_c \cos\{\underbrace{2\pi f_c t + \beta \sin 2\pi f_m t}_{\theta}\} ;$$

o/p of Freq. Multiplier :-

$$S_{WBFM}(t) = A_c \cos\{2\pi \underline{n f_c} t + \underline{n\beta} \sin 2\pi f_m t\}$$

i/p of freq. multiplier ⟶ o/p

f_c ⟶ nf_c

β ⟶ $n\beta$

f_m ⟶ f_m (no change).

& $\Delta f = \beta f_m$

So, new $\Delta f = n\Delta f$

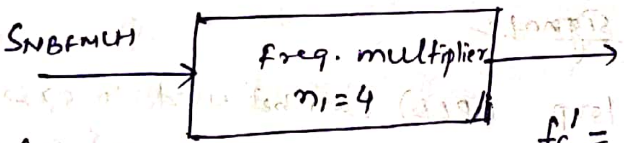
Example :-

$S_{NBFM}(t) = 10\cos\{2\pi \times 10^6 t + 0.2\sin 2\pi \times 2\times 10^3 t\}$

this FM signal is passed through two freq. multipliers of $n_1 = 4$ and $n_2 = 5$ respectively.

Find Bandwidth and Tx power at both multiplier o/p.

Soln :-



$f_c = 10^6$ Hz

$f_m = 2\times 10^3$ Hz

$\beta = 0.2 < 1$

$\Delta f = 0.4$ KHz

$f_c' = 4\times 10^6$ Hz

$f_m = 2\times 10^3$ Hz

$\beta = 0.8 < 1$ (NBFM)

$\Delta f = 1.6$ KHz

As the o/p is a NBFM.

So, $BW = 2f_m = 2\times 2\times 10^3$

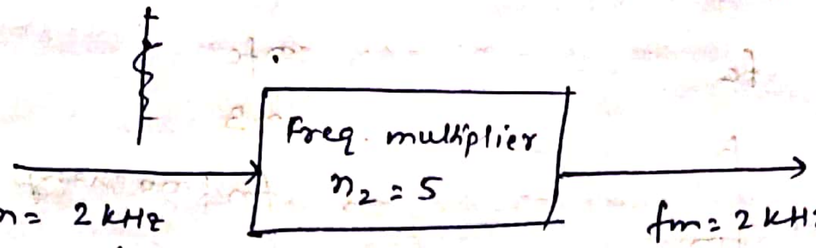
$\boxed{BW = 4\text{ KHz}}$

And Power; $P_t = P_c\left(1 + \frac{\beta^2}{2}\right)$

$= \frac{A_c^2}{2R}\left(1 + \frac{\beta^2}{2}\right)$

$= \frac{100}{2}\left(1 + \frac{0.64}{2}\right) = 66$ W

$\therefore \boxed{P_t = 66\text{W}}$



$f_m = 2$ kHz
$f_c = 4 \times 10^6$ Hz
$\beta = 0.8$ (NBFM)
$\Delta f = 1.6$ kHz

$f_m = 2$ kHz
$f_c'' = 20 \times 10^6$ Hz
$\beta'' = 4 > 1$ (WBFM)
$\Delta f = 8$ kHz

Now, as o/p is WBFM

So, $BW = (\beta + 1) \times 2 f_m$

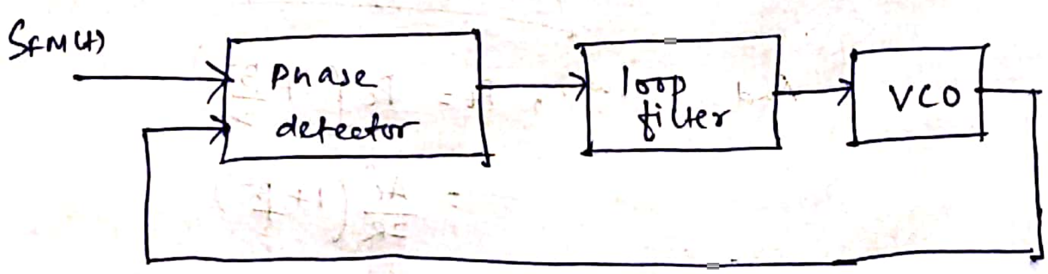
$= 5 \times 4 = 20$ kHz

$BW = 20$ kHz

And, $P_t = \frac{A_c^2}{2R} = \frac{100}{2} = 50$ W.

Demodulation of FM signal :-

A phase-locked loop (PLL) can be used to create a complex but high performance circuit for FM demodulation. A PLL can "lock onto" the frequency of an incoming waveform. It does this by combining a phase detector, a low-pass filter and VCO into a negative feedback system.



Here, phase detector produces a dc voltage which is proportional to the phase diff. b/w i/p signal ~~and~~ having freq fin and feedback signal having frequency fout.

- It is a multiplier which produces two frequencies at its o/p
  - sum of frequencies (fin + fout)
  - diff. of frequencies (fin - fout).

→ The LPF smoothes the signal, which then becomes the control signal for VCO. Thus, if the frequency of the incoming signal is constantly increasing or decreasing, the VCO control signal has to increase and decrease accordingly to ensure that the VCO o/p freq. remains equal to the i/p frequency. (this is termed as LOCK mode).

→ We use the o/p from the ~~to~~ low pass filter as a demodulated signal where it gives an o/p whose amplitude variations correspond to the i/p - frequency variations.

→ This is how a PLL accomplishes frequency demodulation.

Note:-

1. The frequency of FM signal changes continously w.r.t message signal voltage variations. So, to maintain freq. synchronization, Local oscillator of synchronous detector is replaced by VCO.

And, the message signal is taken as i/p of VCO from LPF.

As, $S_{FM}(t) = A_c \cos\{2\pi f_1 t + \underbrace{2\pi k_f \int m(t)dt}_{\phi_1}\}$

&

$V_{co}(VCO)\,o/p = A_v \cos\{2\pi f_2 t + \underbrace{2\pi k_v \int m(t)dt}_{\phi_2}\}$

For perfect synchronization and reconstruction of message signal:

i) f_1 should be made equal to f_2 i.e,

$$f_1 = f_2$$

then PLL is said to be in LOCK mode.

ii) $\phi_1(t)$ should be made equal to $\phi_2(t)$

$$\phi_1(t) = \phi_2(t)$$

then PLL is said to be in CAPTURE mode