Angle Modulation

- → PM ---- Phase modulation
- → FM ---- frequency modulation

$f(t)$ → $\cos\omega_m t$ / $\sin\omega_m t$ } modulating s/g

$v_c(t)$ = carrier $= A\cos\omega_c t$

$\underbrace{\omega_c}_{= 2\pi f_c} >> \omega_m$

→ f_c : 88 MHz - 108 MHz ---- FM, PM

: 535 KHz - 1605 KHz ---- AM

Phase ... : In phase modulation, the phase of carrier is varied in accordance with the instantaneous value of the amplitude of the modulating s/g. keeping amplitude & the frequency of the carrier fixed.

$v_c(t) = A\cos\omega_c t = A\cos\theta(t)$

$\theta(t) = \omega_c t$

$v_m(t) = f(t)$

$v_{pm}(t) = A\cos\theta_i(t)$

where, $\theta_i = \theta + K_p f(t)$

$= \omega_c t + K_p \cdot f(t)$

$\boxed{v_{pm}(t) = A\cos(\omega_c t + K_p \cdot f(t))}$ General expression of the P.M. signal

if $f(t)$ → modulating s/g $= V_m\cos\omega_m t$

$$\boxed{v_{PM}(t) = A\cos[\omega_c t + m_p \cos\omega_m t]}$$ where $m_p = k_p . V_m$ modulation ind.

FM Sign.:- In frequency modulation the frequency of carrier is varied in accordance with the instant. value of the amplitude of modulating s/g. keep amplitude & the phase of the carrier fixed.

$v_c(t) = A\cos\omega_c t = A\cos\theta(t)$ --- carrier $\qquad \theta = \omega_c(t)$

$f(t)$ -- modulating s/g

$\omega_i = \omega_c + k_f . f(t)$

FM signal

$v_{FM}(t) = A\cos\theta_i(t)$

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

$\theta_i = \int(\omega_c + k_f f(t))dt = \omega_c t + k_f \int_0^t f(t)dt$

$$\boxed{v_{FM}(t) = A\cos\left[\omega_c t + k_f \int_0^t f(t)dt\right]}$$ general expression of FM s/g

if $f(t) = V_m \cos\omega_m t$

$\int_0^t f(t)dt = \frac{V_m}{\omega_m}\sin\omega_m t$

$$\boxed{V_{FM}(t) = A\cos[\omega_c t + m_f \sin\omega_m t]}$$

$m_f = \frac{k_f V_m}{\omega_m}$ --- mod. ind

→ The frequency and phase modulation are inter dependent since any variation in the frequen will cause variation in the phase and vice-versa. Therefore we can't have a pure PM signal or pure FM signal.

→ If we integrate the modulating s/g and allow the carrier for phase modulation the result is FM signal. this method is alway preferred since it reduces the noise in the system.

→ If we differentiate the modulating s/g and allow the carrier for frequency modulation, the result is PM signal. this method is never used since the noise in the system increases due to differentiation.

$f(t)$

↓

$g(t) = \int_0^t f(t)\,dt$

↓

Phase modulation the carrier

↓

FM signal

(NBFM)

Indirect method

or Armstrong's method of FM

$f(t)$

↓

$g(t) = \frac{df(t)}{dt}$

↓

frequency mod. the carrier

↓

PM signal

→ never preferred

Power contained in FM signal

$$v_{FM}(t) = A\cos\left[\omega_c t + k_f \int_0^t f(t)\,dt\right]$$

$$= A\cos[\omega_c t + m_f \sin\omega_m t]$$

$$P = \overline{v^2_{FM}(t)} = A^2 \underbrace{\overline{\cos^2\left[\omega_c t + k_f \int_0^t f(t)\,dt\right]}}_{1/2}$$

$$\boxed{P = \tfrac{1}{2}A^2} \quad \text{--- FM}$$

$$P_t = P_c\left(1 + \frac{m_a^2}{2}\right) \quad \text{--- AM}$$

Ideal; health

→ for AM signal the Total Power required depe... upon the carrier amplitude along with the modulation index. for FM or PM the total ... required for transmission depends purely upon carrier voltage and is independent of mod... index.

frequency component in FM signal →

$$v_{FM}(t) = A\cos[\omega_c t + m_f \sin\omega_m t]$$

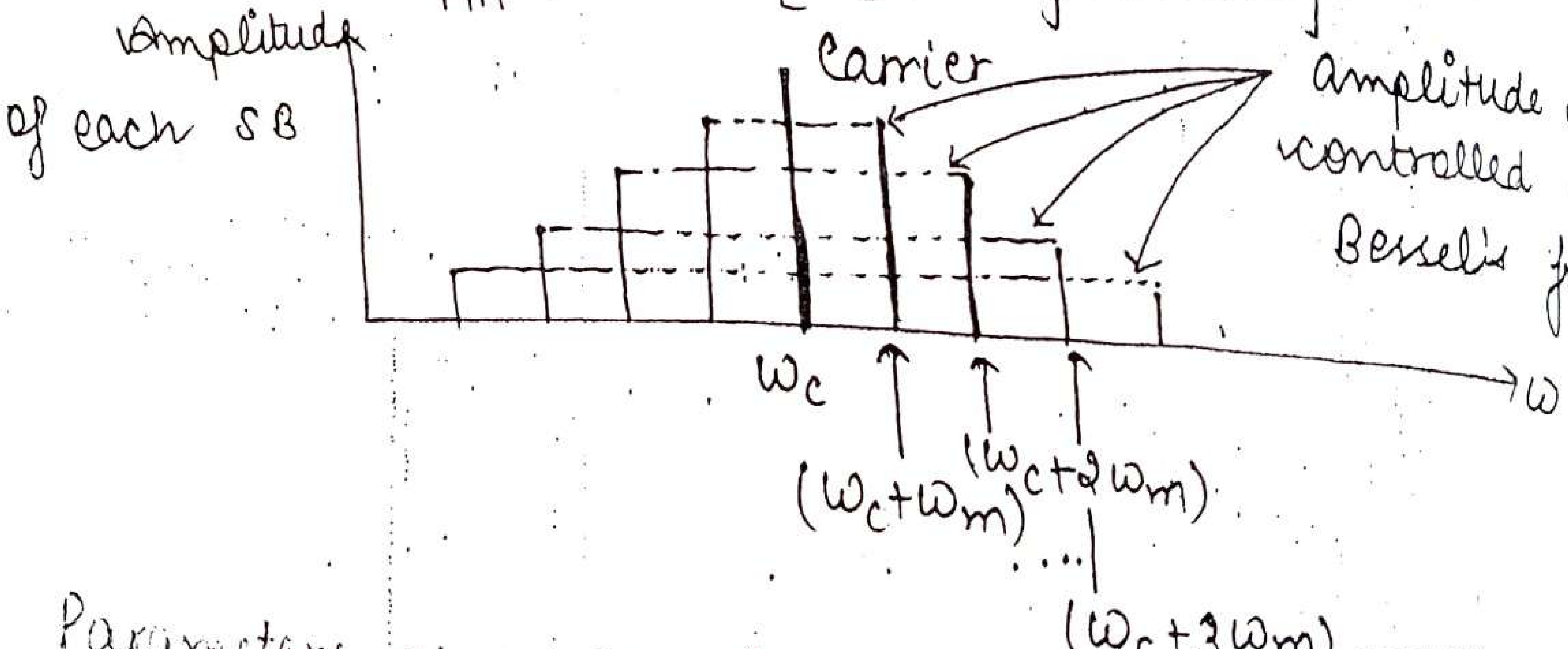
--- infinite no of terms & the mag... depends upon the Bessel's function

⟹ Infinite no of side bands

⟹ infinite Band width for the FM signal

frequency spectrum of FM signal →

$$v_{FM}(t) = A\cos[\omega_c t + m_f \sin\omega_m t]$$



Parameters of the FM signal →

1. ω_m ; f_m ---- modulating frequency
2. m_f --- modulation Index
3. δ --- frequency deviation

$$\delta = m_f \cdot \omega_m \quad \text{---- rad/sec.}$$
$$= m_f \cdot f_m \quad \text{---- Hz}$$

Bandwidth →

$$B.W \cong 2(\delta + \omega_m) \quad \text{rad/sec} \quad \text{-- Carson's rule}$$
$$\cong 2(\delta + f_m) \quad \text{Hz}$$

Case-1. <u>Wide Band FM Signal (WBFM)</u> →

$$\boxed{m_f >>> 1}$$

$$BW \cong 2(\delta + \omega_m)$$
$$\cong 2(m_f \omega_m + \omega_m)$$
$$\cong 2\omega_m(m_f + \cancel{1}) \quad \{bcz\ m_f >>> 1\}$$

$$\boxed{\begin{aligned} B.W. &\cong 2\omega_m m_f \\ &\cong 2\delta \end{aligned}} \quad \text{---- Rad/sec}$$

Used for FM broadcast. $\boxed{\delta_{max} \cong \pm 75\ KHz}$

Case-2. <u>Narrow band FM Signal (NBFM)</u> →

$$\boxed{m_f << 1}$$

$$BW \cong 2\omega_m(\cancel{m_f} + 1)$$
$$\boxed{B.W. \cong 2\omega_m} \quad \text{Rad/sec.}$$

---- Same as that of AM-DSB system.

-- contains 2 side bands.

--- used as FM radio in mobiles.

i) Any FM signal contains infinite no of side bands. Therefore ideally the B.W. required for the transmission of FM signal is also ∞. which practically is not available. We then transmitt first few pair of sidebands which contribute significant amount of power. and we neglect those higher side band which contribute only 2-5% of the total power. therefore practically the B.W. required is now finite without compromising quality of the s/g.

) Practically the B.W. Required is given by the carsonn's rule.

iii) In wide band FM, No. of side bands are large in no. where as for narrow band FM we transmit only one pair of side band.

iv) ω_m controls the separation b/w two side bands.

v) the modulation index m_f controls total significant side bands which are being ...

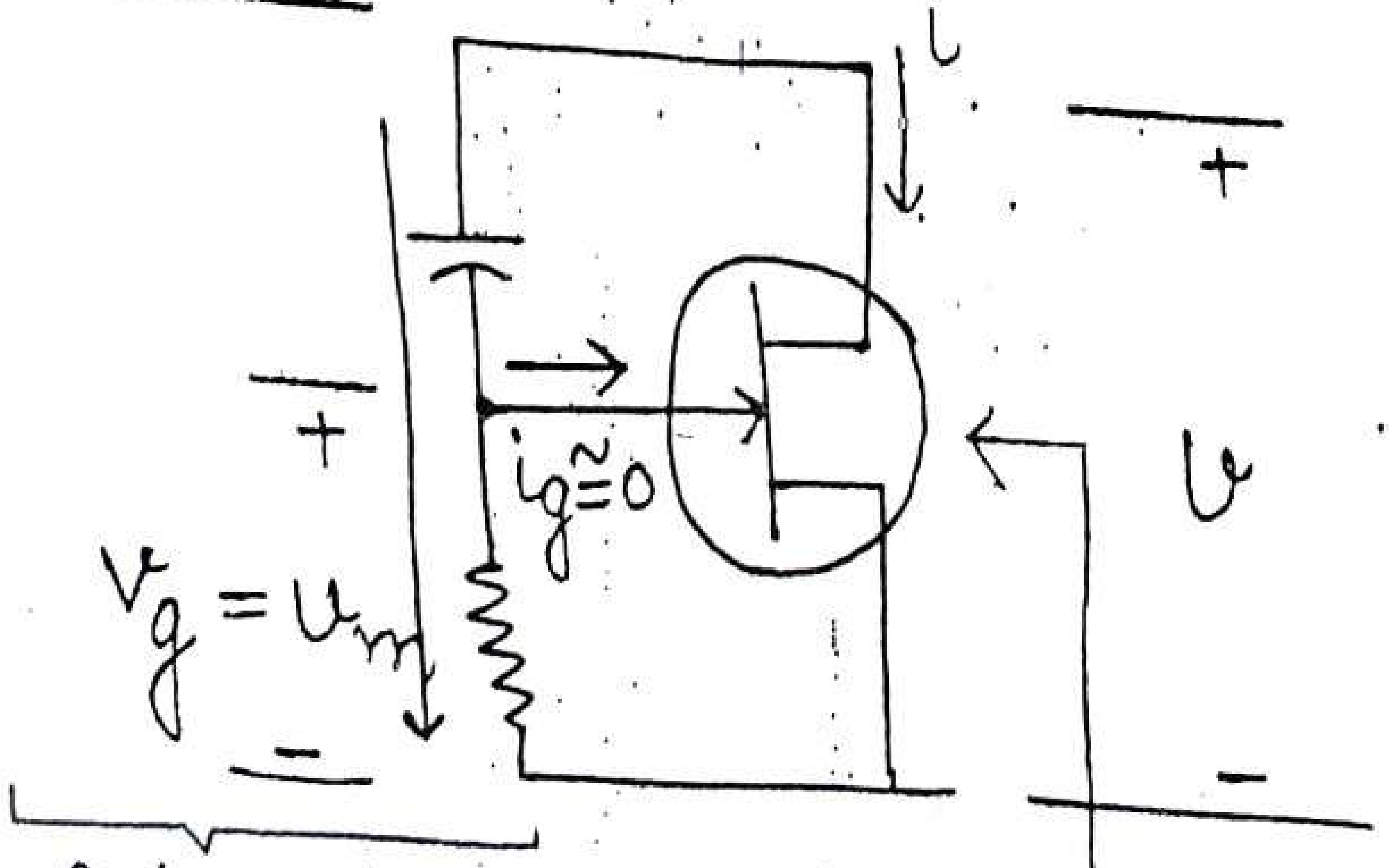
vi) the frequency deviation δ controls the ... width required for the transmission of FM ...

vii) The FM System is a ~~high~~ hi-fi (high fidelity) system and therefore such system has the ... to reproduce the s/g having same quality which the s/g was initially transmitted.

viii) Generation of WBFM signal →

Reactance modulator

Principle →



$$g_m = \frac{i}{v_g} \quad \text{---- i)}$$

$$v_g = \frac{R}{R+\frac{1}{j\omega C}} \, v$$

$$v_g = \frac{Rv}{R-jX_c}$$

gate voltage or Modulating signal

$$Z_{out} = \frac{v}{i} = ?$$

$$Z_{out} = \frac{v}{i} \quad \text{---- iii)}$$

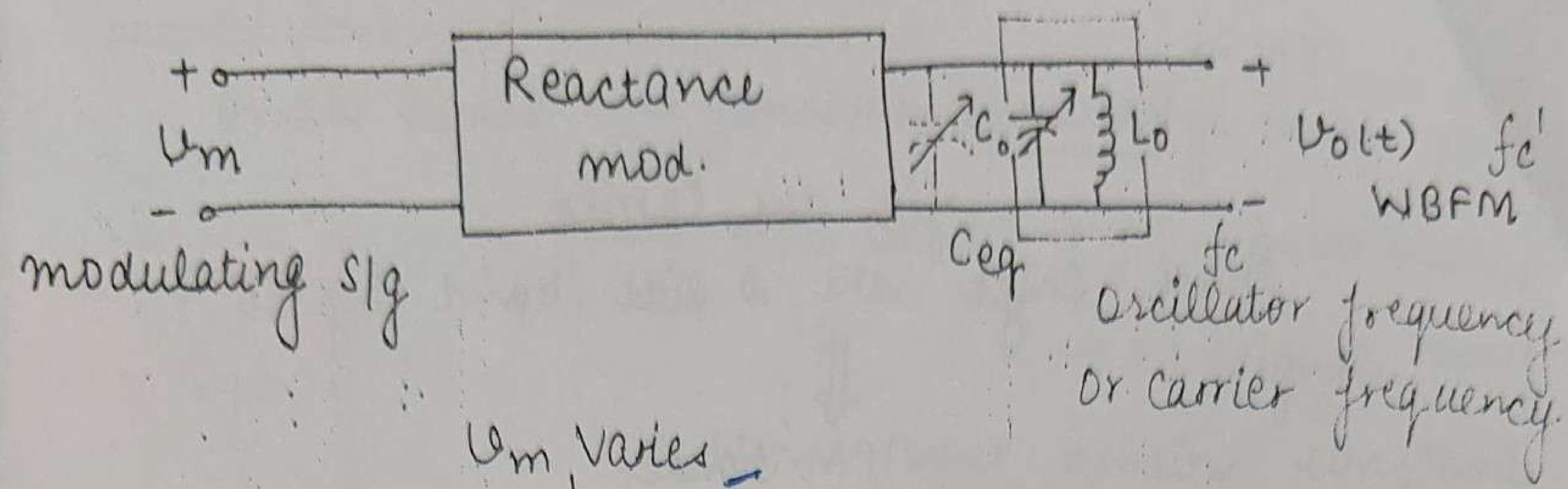
$$g_m = \frac{i\,(R-jX_c)}{Rv}$$

$$\frac{v}{i} = \frac{(R-jX_c)}{Rg_m} = Z_{out} \quad \text{---- } (R \ll X_c)$$

$$Z_{out} \simeq \frac{-jX_c}{g_m R} = \frac{1}{+j g_m \omega C R} \simeq \frac{1}{j\omega C_{eq}}$$

$$\boxed{C_{eq} = g_m R C}$$

— Purely Reactive ...



v_m varies

$$\downarrow$$

$g_m = \frac{i}{v_m}$ varies

$$\downarrow$$

$C_{eq} = g_m R_C$ varies

$$\downarrow$$

$$C = C_0 + C_{eq}$$
$$= C_0 + g_m R_C \text{ varies}$$

$$\downarrow$$

$$f_c' = \frac{1}{2\pi\sqrt{L_0(C_0+C_{eq})}} \text{ varies} \Rightarrow \text{WBFM signal}$$

i) Using this ckt the frequency of the output signal varies in accordance with instaneous value of the amplitude of modulating signal. therefore the F.M. signal is generated. since they may be large variation for the amplitude of the i/p signal, the frequency deviation at the output may also be large and therefore this results in wide band FM signal.

Generation of Narrow band FM signal →

-- Indirect Method

-- Armstrong's Method

Principle → $v_m(t)$ ---- modulating signal

$\downarrow$ Integrate it $\int_0^t v_m(t)\,dt = g(t)$

$\downarrow$

Phase modulate the carrier using $g(t)$

$\downarrow$

NBFM signal

PM →

Option-1,

fix the carrier

Phase shift the 2 side band by 90°

⇓

PM signal.

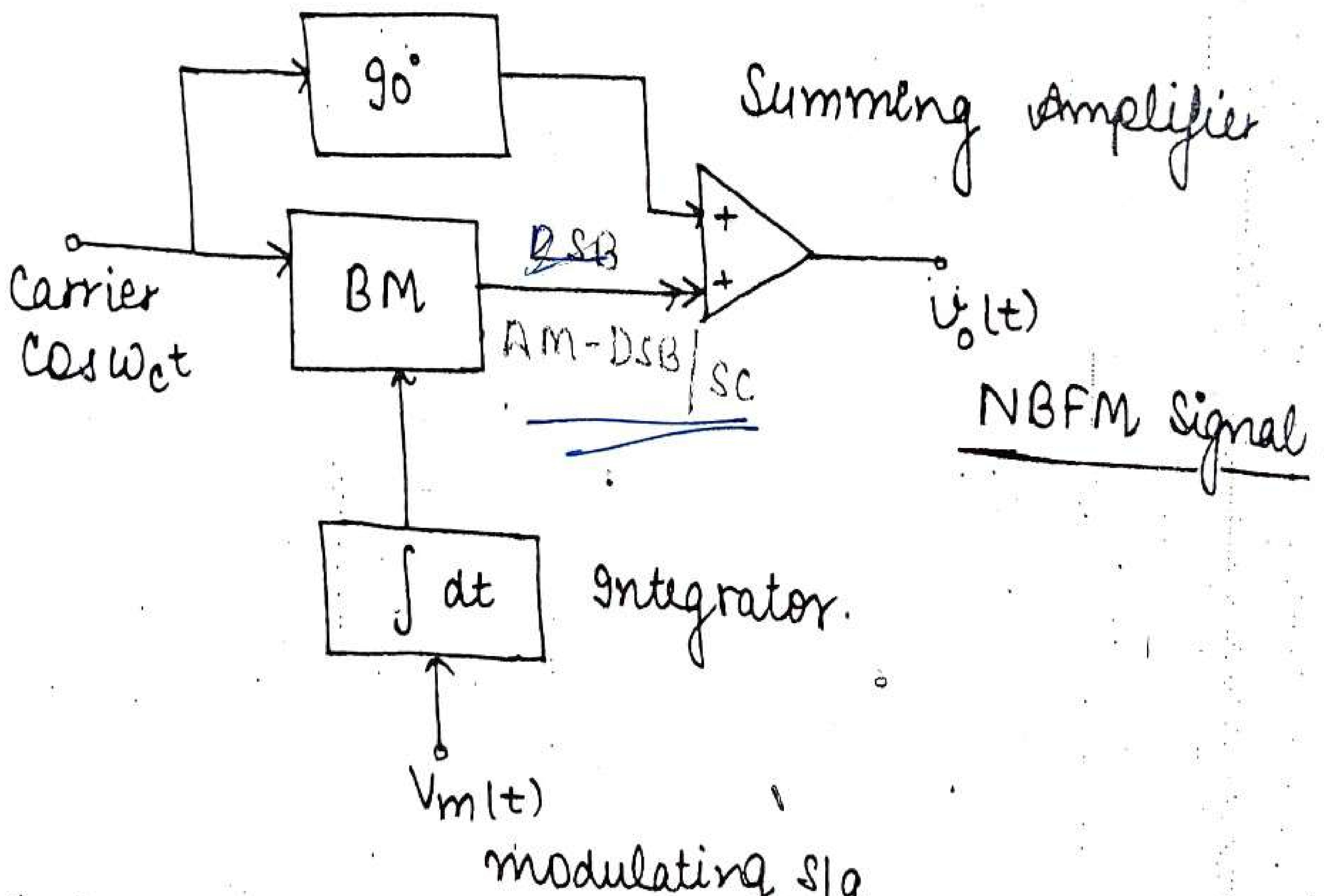
Option-2, fix the 2 side band

Phase shift the carrier by 90°.

⇓

PM signal

* 2nd option is better, bcz both side band have [cut off] frequency and much typical to provide phase [cut off] of 90° both.



* In the NBFM if we add up frequency modulator, then we get WBFM....

→ The generation of NBFM signal has more compli[cut off] circuitary as compaired to generation of wide band FM signal.....

→ The wide band FM signal can then also be gene[cut off] from the narrow band FM signal by passing the s/g through series of frequency multiplier

Pre-emphesis & de-emphesis →

→ Audio signal ⟶ fundamental + Large no. of Harmonic

⟶ Side Band ↑ → f ↑ → amplitude ↓

→ S ↓ (signal Power)

⟶ Noise Power remains constant

⟶ f ↑ ⟶ $\left(\frac{S}{N}\right)$ ↓

FMd Syber

(ωt + 90°)

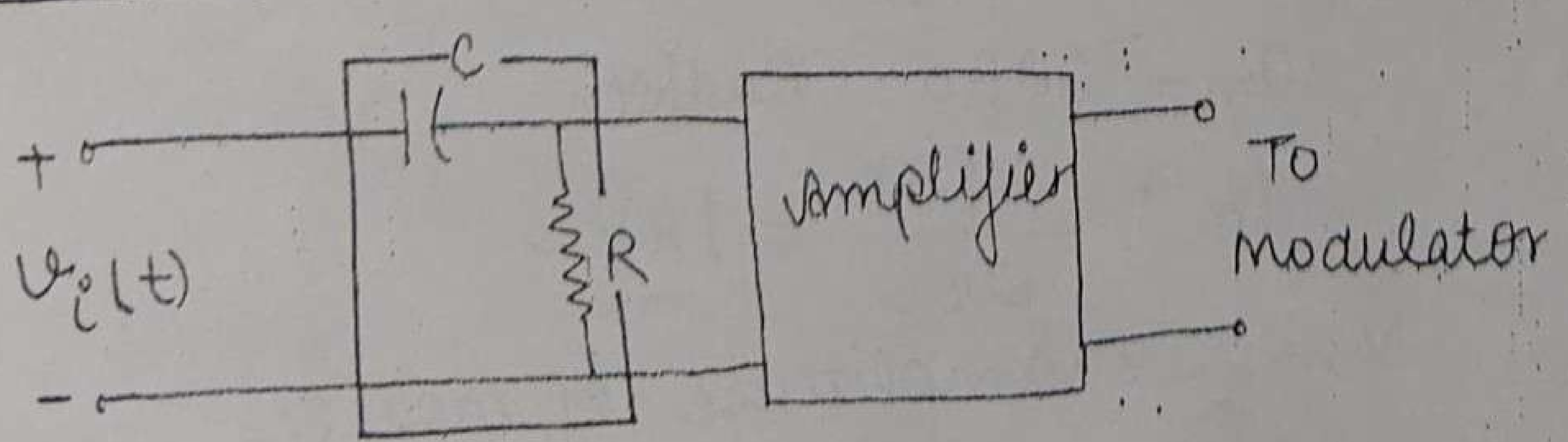
Hence corresponding to high frequency components the signal to noise ratio has low value.

Therefore these high frequency components are boosted or emphesized before the transmission of sig takes place. this is done by using a preemphesis ckt and is used at the transmitting end before the modulation takes place.

Since the Relative sig to noise ratio for various frequency component has been disturbed then those high frequency components which were initially boosted are now broad down to the same level so that relative sig to noise ratio for various frequency component is maintained to have same quality of sig.

This is done by using a deemphesis ckt and is used at the Receiving end just after demodulation takes place.

Pre-emphesis ckt →

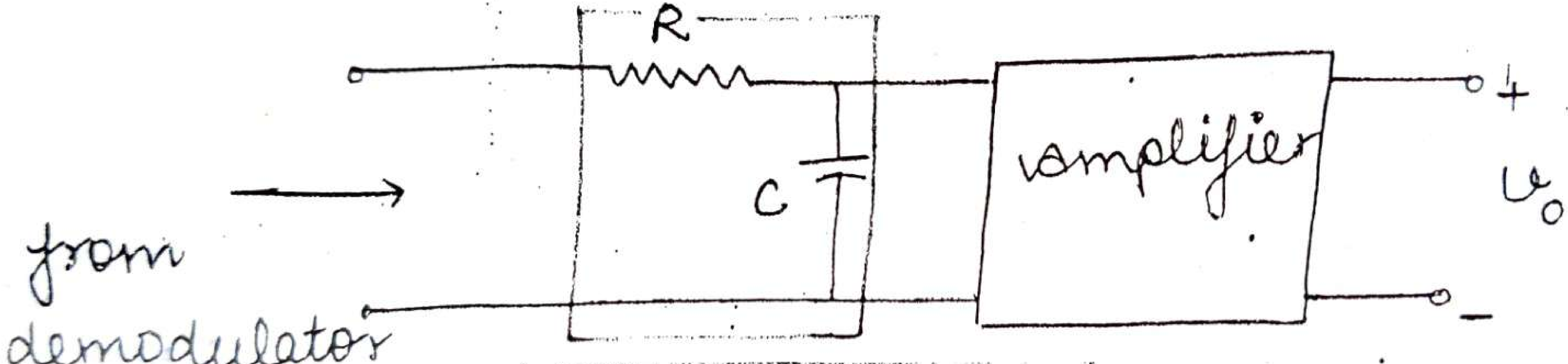


$T = RC \cong 75 \mu sec.$

Used at the transmitting end before modulator

De-emphasis ckt →

used at the Receiving end just after Demodulator



$\boxed{T = RC \sim 75\,\mu sec}$

* by arranging the value of R + C at Receiver we get the valumme as we like by suppr the low frequency components.