UNIT - IV

Frequency Modulation.

Angle modulation is the method of Analog modulation in which either frequency or phase of the carrier wave is varried according to the instantanious value of the message signal.

frequency modulation :-

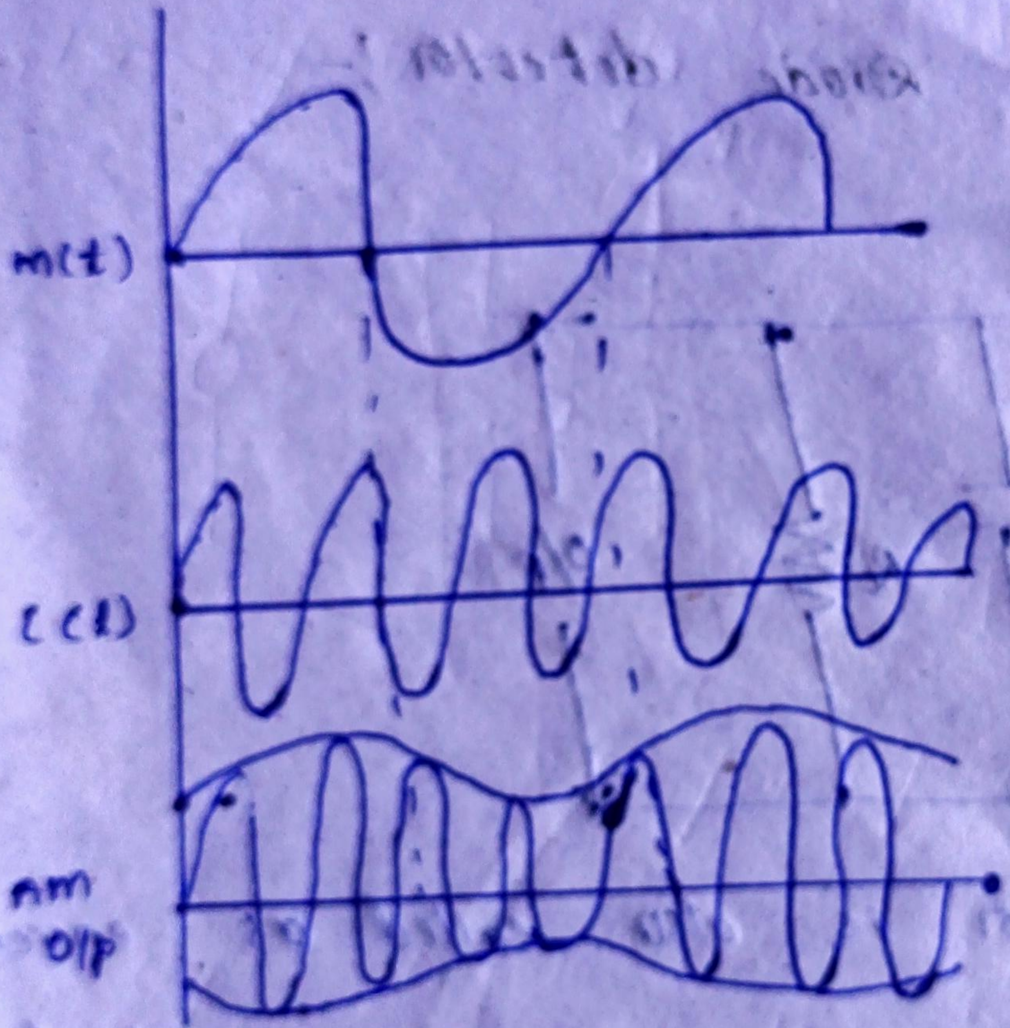
In frequency modulation frequency of the carrier signal is varried in accordance with the instantanious value of the message signal. the Amplitude and phase are remains constant.

→ frequency modulation is one of the angle modulation in which the instantinious frequency $f_i(t)$ is varried linearly with the message signal $m(t)$

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

$K_f \Rightarrow$ frequency senstivity.

→ the fm radio station frequency range is 88 to 108 mega hz.



m(t)
c(t)
am
o/p

→ the process of changing the frequency of fm modulote wave is i.e, during +ve half cycle of message signal the frequency is increases

→ the increasing and decreasing frequency of fm modulator wave is frequency deviation.

→ the deviation of fm modulated frequency from un modulated carrier frequency is called as frequency deviation.

→ the deviation of the frequency of the carrier signal is from low to high (or) high to low is called as carrier swing.

→ the carrier swing is equal to the twice of the frequency deviation.

$$\text{Carrier swing} = 2\Delta f$$

→ Modulation Index:-

It is defined as the ratio of frequency deviation of modulating frequency

$$\text{Modulation Index} = \frac{\Delta f}{f_m}$$

→ If modulation Index is less than 1 then it is called as narrow band fm signal which ~~contains carrier and an infinite number of side~~ consisting of carrier signal upper side band component and lower side band frequency components.

→ If modulation Index is greater that 1 then it is called as wide band fm signal which contains carrier and an infinite number of side band frequency component located symmetrically around the carrier signal.

mathematical representation of fm wave:-

→ In frequency modulation frequency of the carrier signal is varied in accordance with the instantaneous frequency of the message signal (or) modulating signal.

→ the carrier frequency is (f_c) and message signal frequency is (f_m)

→ the frequency at maximum amplitude of the message signal is $\boxed{f_c + \Delta f}$

→ the frequency at minimum amplitude of the message signal is $\boxed{f_c - \Delta f}$

→ the instantaneous frequency of the signal is

$$\omega_i = \omega_c + K_f \cdot x(t)$$

$x(t)$ = message signal.

→ the carrier signal $c(t) = A\cos(\omega_c t + \theta_0)$

$$\phi = \omega_c t + \theta_0$$

$$c(t) = A\cos\phi$$

$$\phi = \omega_c t + \theta_0$$

$$\frac{d\phi}{dt} = \frac{d}{dt}(\omega_c t + \theta_0)$$

$$\frac{d\phi}{dt} = \omega_c + 0$$

$$\frac{d\phi}{dt} = \omega_c$$

→ Instantaneous frequency $= \frac{d\phi_i}{dt} = \omega_i$

$$\int \left(\frac{d\phi_i}{dt}\right) = \int \omega_i \cdot dt$$

$$\phi_i = \int \omega_i \cdot dt$$

$$\phi_i = \int (\omega_c + k_f \, x(t)) \, dt$$

$$\phi_i = \int \omega_c \, dt + \int k_f \, x(t) \, dt$$

$$\phi_i = \omega_c + k_f \int x(t) \, dt$$

then standard expression of the fm wave is

$$s(t) = A \cos \phi_i$$

$$s(t) = A \cos \left[\omega_c t + k_f \int x(t) \, dt\right]$$

$$s(t) = A \cos \left[\omega_c t + k_f \int_0^t x(t) \, dt\right]$$

→ the resultant fm signal $s(t) = A \cos \left[2\pi f_c t + k_f \int_0^t x(t) \, dt\right]$

→ Depending upon the modulation index of fm wave fm signal can be classified into 2 types.

i) narrow band fm

ii) wide band fm

Genaration of fm wave:

→ fm wave can be generated by using two methods that is (i) Direct method (ii) In Direct method.

→ In Direct method the base band modulating signal is directly modulate the carrier signal.

→ the carrier signal is can be genarated with the help of osicllator circuit.

→ the osicillator circuit uses parallel L-C Tuned circuit.

→ the frequency of osicillation of the carrier generation is $\omega_0 = \frac{1}{\sqrt{LC}}$, $f_0 = \frac{1}{2\pi\sqrt{LC}}$

→ the carrier frequency is changes accordance with the modulating signal $x(t)$ that L (or) C value is varied accordance with the $x(t)$

→ the voltage variable capacitor is called as varactor

→ In direct method fm wave can be generated by using reactance modulator.

→ the fm wave can also achived from the voltage controlled devices pindiode, klystron oscillator, multivibrator

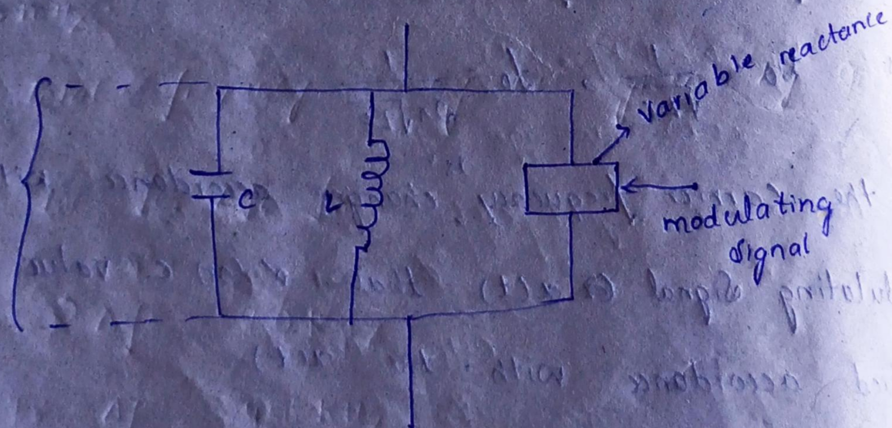
Reactance modulator :-

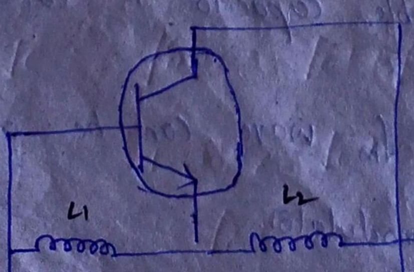
method

→ In direct fm genaration instaneous frequency of the carrier signal is directly propotinal to the message signal.

→ A voltage control can be Implemented by sinsodiual osiclattor with ~~at~~ unit circuit having 'Q' factor.

→ the frequency of the osicillator is changed by implimented variation in the reactive comprahence





the Instanteous frequency of fm wave is

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

the varator diode is reverse bias its depends upon the reverse voltage applied across the capacitence is $C(t)$.

$$C(t) = C + C_{Varator}$$

$C(t)$ is the effective capacitance of the fixed unit circuit.

→ sensitivity of varator capacitence is change into the voltage.

$$C(t) = C - K_c\, x(t).$$

$$f_i(t) = \frac{1}{2\pi\sqrt{(L_1+L_2)\,C(t)}}$$

$$f_i(t) = \frac{1}{2\pi\sqrt{(L_1+L_2)(C - K_c\, x(t))}}$$

$$f_i(t) = \frac{1}{2\pi\sqrt{(L_1+L_2)C - (L_1+L_2)K_c\, x(t)}}$$

$$f_i(t) = \frac{1}{2\pi\sqrt{(L_1+L_2)C\left(1 - \frac{K_c\, x(t)}{C}\right)}}$$

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

$$f_i(t) = \frac{f_0}{\left(1 - \frac{K_c\, x(t)}{c}\right)^{1/2}}$$

$$f_i(t) = f_0 \left(1 - \frac{K_c\, x(t)}{c}\right)^{-1/2}$$

$$f_i(t) = f_0 \left(1 + \frac{K_c\, x(t)}{2c}\right)$$

$$f_i(t) = f_0 + \frac{f_0 K_c\, x(t)}{2c}$$

$$\boxed{K_f = \frac{f_0 K_c}{2c}}$$

$$\boxed{f_i(t) = f_0 + K_f \cdot x(t)}$$

Qns

→ for an fm signal maximum frequency f_{max} is given by 1.5 mHz.

→ the total frequecy swing is given by 900 KHz

→ find the f_c, Δf_c f_{min}.

$$2\Delta f = 900 \text{ KHz}$$

$$\Delta f = 450 \text{ KHz}$$

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

$$1.5\text{MHz} = f_c + 450 \text{ KHz}$$

$$f_c = 1.5 \text{ MHz} - 450 \text{ KHz}$$

$$f_c = 1.5 \times 10^6 - 450 \times 10^3$$

$$f_c = 1.5 \times 10^3 \times 10^3 - 450 \times 10^3$$

$$= 1500 \times 10^3 - 450 \times 10^3$$

$f_c = 1500\ KHz - 450\ KHz$

$= 1050\ KHz$

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

$= 1050 - 450$

$= 600\ KHz$

→ A carrier wave frequency $f_c = 1MHz$, with a voltage of 20V used to modulate a signal of frequency 1 KHz with voltage of 10 volts find the (i) modulation index (ii) frequencies of the modulated wave (iii) Band width.

Sol:- Given that $f_c = 1MHz$, $V_c = 20$ volts

$f_m = 1\ KHz$, $V_m = 10$ volts.

i) modulation index $= \frac{V_m}{V_c}$

$= \frac{\cancel{20}}{\cancel{10}} = \frac{10}{20} = \frac{1}{2} = 0.5$

(ii) $f_{max} = 1MHz + 1KHz = 1\times10^6 + 1\times10^3$

$= 1\times10^3\times10^3 + 1\times10^3$

$= 1000\times10^3 + 1\times10^3$

$= 1000\ KHz + 1\ KHz$

$= 1001\ KHz$

$f_{min} = 1000KHz - 1KHz = 999\ KHz$.

(iii) Band width = 2×1 KHz = 2 KHz

→ A modulating signal $m(t) = 10 \cos(2\pi \times 10^3 t)$ is amplitude modulate with carrier signal $c(t) = 50 \cos(2\pi \times 10^5 t)$. find (i) the modulation index (ii) carrier power and total transmit power of the AM wave.

(i) Given that

$$m(t) = 10 \cos(2\pi \times 10^3 t)$$

$$c(t) = 50 \cos(2\pi \times 10^5 t)$$

$$V_m = 10V, \quad V_c = 50V$$

$$f_m = 10^3 Hz, \quad f_c = 10^5 Hz$$

$$m = \frac{V_m}{V_c}$$

$$m = \frac{10}{50} \Rightarrow 0.2$$

(ii) $P_c = \frac{V_c^2}{2R}, R = 1\Omega$

$$P_c = \frac{50 \times 50}{2 \times 1}$$

$$P_c = 1250 \text{ watt}$$

$$P_T = P_c\left[1 + \frac{m^2}{2}\right]$$

$$= 1250\left[1 + \frac{(0.2)^2}{2}\right]$$

$$P_T = 1275 \text{ watt}.$$

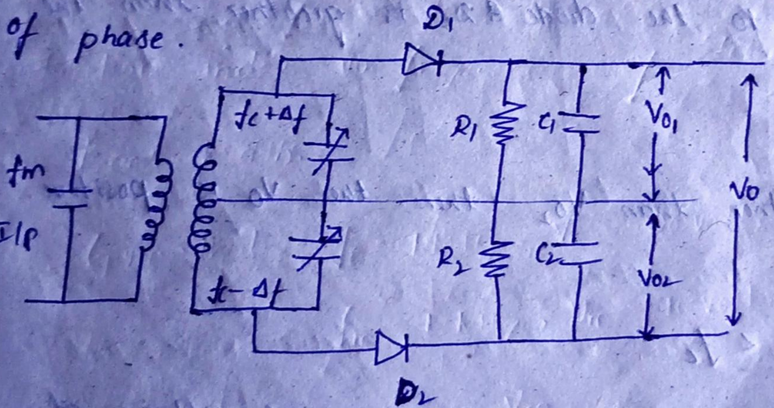
detection of f_m wave:-

→ f_m wave can be deducted by using Balanced modulator.

→ In detection to convert the frequency modulated signal into modulating signal (or) message signal.

→ It consists of the slope detector circuits (two) the input tranformers is ~~[illegible]~~ center taped secondary

→ the input voltage of two slope detectors are 180° out of phase.



→ It consists of three windings that is primary winding and secondary upper & secondary lower.

→ primary winding is ~~unit to~~ puned to f_c

→ Secondary upper winding is puned to $f_c+\Delta f$

→ Secondary lower winding is puned to $f_c-\Delta f$.

→ the net output voltage of circuit is $V_o = V_{o1} - V_{o2}$

1) $f_{in} = f_c$

When the input frequency is equal to the f_c the induced Voltage at T_1 winding is equal to the T_2 winding then the voltages of both diodes are same then output voltage is $V_0 = 0$.

2) $f_c < f_{in} < f_c + \Delta f$

→ It is the range of frequencies the induced voltage at T_1 winding is higher than the T_2 winding

→ Input voltage to the diode D_1 is greather than the diode D_2

→ V_{01} is greather than V_{02} then the V_0 is positive.

3) $f_c - \Delta f < f_{in} \leq f_c$

→ It is the range of frequencies the induced voltage at T_1 winding is lower than the T_2 winding.

→ Input voltage to the diode D_1 is lower than the Input voltage of the diode D_2

→ V_{01} is less than V_{02} then the V_0 is Negative.

→ If the output frequency outside the range is $f_c - \Delta f$ to $f_c + \Delta f$ then the output voltage will fall due to the reduction in the tuned circuit response.