ANGLE MODULATION

Angle modulation

Frequency modulation

Phase modulation

$V_m \sin \omega t$ — V_m → maximum voltage, ω → Angular frequency (radian), $\omega = 2\pi f$, θ → Phase deviation

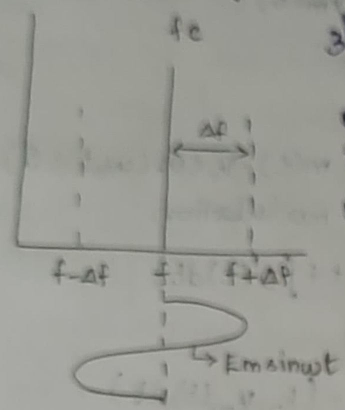
$V_c = V_c \cos(\omega t + \theta)$ Phase deviation

DIRECT FREQUENCY MODULATION

Varying the frequency of constant amplitude carrier directly proportional to amplitude of modulating signal at a rate equal to the frequency of modulating signal.

DIRECT PHASE MODULATION

Varying the phase of constant amplitude carrier directly proportional to amplitude of modulating signal at a rate equal to the frequency of modulating signal.



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INSTANTANEOUS PHASE DEVIATION: (θ)

It is the instantaneous change in phase of carrier signal at a given instance of time and indicates how much the phase of carrier is changing with respect to the reference phase.

INSTANTANEOUS PHASE ($\omega_c t + \theta$)

It is the precise phase of carrier at a given instance of time.

INSTANTANEOUS FREQUENCY DEVIATION:

It is the instantaneous change in frequency of carrier and it is defined as first time derivative of instantaneous phase deviation. It is expressed as $\theta'(t)$ $d\theta/dt$. The unit is radians per second.

INSTANTANEOUS FREQUENCY:

It is the precise frequency of carrier at any instance of time and is defined as first time derivative of instantaneous phase. It is expressed as $\omega_i(t) = \omega_c + \theta'(t)$ $\frac{d}{dt}[\omega_c t + \theta(t)]$. The unit is radians per second.

$V_c \cos[\omega_c t + kV_m(t)]$ } Modulated output of phase

$V_c \cos[\omega_c t + k_1 \int V_m(t)dt]$ } Modulated output of frequency

The output equations are shown for carrier signal $V_c \cos\omega_c t$ and modulating signal $V_m(t)$. If carrier signal is $V_c \cos\omega_c t$ and modulating signal $V_m \cos\omega_m t$, the the equations would be

$V_c \cos[\omega_c t + kV_m \cos\omega_m t]$

$V_c \cos[\omega_c t + k_1 \int V_m \cos\omega_m t\, dt] \Rightarrow V_c \cos[\omega_c t + \frac{kV_m}{\omega_m} \sin\omega_m t]$

compare the above equation with $V_c \cos(\omega t + \theta)$ Base equation, Hence $\frac{kV_m}{\omega_m} \sin\omega_m t$ is the phase deviation.

PROBLEMS:

1. If the signal $v(t) = 20\sin(6.28\times10^6 t + 10\sin 6.283\times10^3 t)$ represents a phase modulated signal, find i) carrier frequency ii) Modulating frequency iii) modulation index iv) peak phase deviation.

Sol: i) $\frac{6.283\times10^6}{2\pi}$ ii) $\frac{6.28\times10^3}{2\pi}$ iii) 10 iv) 10

$= \frac{6.282\times10^3\times10^3}{2\pi}$ $= \frac{6.28\times10^3}{2\pi}$

kHz MHz kHz

$= 1\,MHz$ $= 1\,kHz$

Peak phase deviation = modulation Index

The eqn is in the form of $m(t) = V_c\sin(\omega_c t + k.V_m\sin\omega_m t)$

where carrier frequency $= \frac{\omega_c}{2\pi}$; modulating frequency $= \frac{\omega_m}{2\pi}$

Peak phase deviation $\Delta\theta = k.V_m$

$= 10$ rad

modulation Index = 10

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DEVIATION SENSITIVITY:

$k \rightarrow$ sensitivity for Phase modulation; $k_1 \rightarrow$ sensitivity for frequency modulation

Output of PM $= k.\underset{\text{Input}}{V_m(t)} \rightarrow (1)$ Output of FM $= k_1\underset{\text{Input}}{V_m(t)} \rightarrow (2)$

We know that $f = \frac{d\theta}{dt}$ or $\theta'(t)$

$\theta = \int f dt \Rightarrow \theta = \int\theta'(t)dt \rightarrow (3)$

Modulation output is given by the general equation: $m(t) = V_c\cos(\omega_c t + \theta)$

For phase modulation: (1)

$= V_c\cos(\omega_c t + kV_m(t))$ $\theta = k.V_m(t)$

where $V_c \rightarrow$ Amplitude of carrier signal

$\omega_c \rightarrow$ Angular frequency of carrier

$k \rightarrow$ modulating sensitivity of phase

$V_m(t) \rightarrow$ modulating signal

If input is $V_m(t) = V_m\cos\omega_m t$

$m(t) = V_c\cos(\omega_c t + k.V_m\cos\omega_m t) \rightarrow (4)$

Comparing (4) with general equation,

$\theta = k.V_m\cos\omega_m t$

From this equation, peak phase deviation is given by,

$\Delta\theta = k.V_m$

For Frequency modulation: (3)

$= V_c\cos(\omega_c t + \int\theta'(t)dt)$ $\theta = \int\theta'(t)dt$

Sub $\theta' = k_1V_m(t)$ (2)

$= V_c\cos(\omega_c t + \int k_1.V_m(t)dt)$

If input is $V_m(t) = V_m\cos\omega_m t$

$= V_c\cos(\omega_c t + \int k_1.V_m\cos\omega_m t.dt)$

After integration:

$= V_c\cos[\omega_c t + \frac{k_1V_m}{\omega_m}\sin\omega_m t] \rightarrow (5)$

Comparing (5) with general equation,

$\theta = \frac{k_1V_m}{\omega_m}\sin\omega_m t$

Peak frequency deviation $\Delta\theta = \frac{k_1V_m}{\omega_m}$

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	Frequency modulation	Phase modulation
Modulated wave	$m(t) = V_c\cos[\omega_c t + \frac{k_1V_m}{f_m}\sin(\omega_m t)]$ $m(t) = V_c\cos[\omega_c t + m\sin(\omega_m t)]$ $m(t) = V_c\cos[\omega_c t + \frac{\Delta f}{f_m}\sin(\omega_m t)]$	$m(t) = V_c\cos[\omega_c t + kV_m\cos(\omega_m t)]$ $m(t) = V_c\cos[\omega_c t + m\cos(\omega_m t)]$ $m(t) = V_c\cos[\omega_c t + \Delta\theta\cos(\omega_m t)]$
Deviation sensitivity	k_1 (Hz/V)	k (rad/V)
Deviation	$\Delta f = k_1V_m$ (Hz)	$\Delta\theta = kV_m$ (rad)
Modulating signal	$V_m(t) = V_m\sin(\omega_m t)$	$V_m(t) = V_m\cos(\omega_m t)$

	Frequency modulation	phase modulation
Modulation index	$m = \frac{K_1 V_m}{f_m}$ (No unit) $m = \frac{\Delta f}{f_m}$	$m = k V_m$ (rad) $m = \Delta\theta$ (rad)
Modulating frequency	$\omega_m = 2\pi f_m$ rad/s $\frac{\omega_m}{2\pi} = f_m$ Hz	$\omega_m = 2\pi f_m$ rad/s $\frac{\omega_m}{2\pi} = f_m$ (Hz)
carrier signal	$V_c \cos(\omega_c t)$	$V_c \cos(\omega_c t)$
carrier frequency	$\omega_c = 2\pi f_c$ (rad/s) $\frac{\omega_c}{2\pi} = f_c$ (Hz)	$\omega_c = 2\pi f_c$ (rad/s) $\frac{\omega_c}{2\pi} = f_c$ (Hz)

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FREQUENCY ANALYSIS / FREQUENCY SPECTRUM:

The modulated output for angle modulation is $m(t) = V_c \cos[\omega_c t + m\cos\omega_m t]$ → ①

modulation index

According to Bessel function, $\cos(\alpha + m\cos\beta) = \sum_{n=-\infty}^{\infty} J_n(m)\cos(\alpha + n\beta + n\pi/2)$ → ②

where $J_n(M)$ is called Bessel function.

Modifying ① according to Bessel function, → RHS of ① and LHS of ② is same

$\therefore \alpha = \omega_c t;\ \beta = \omega_m t$

$\therefore$ Bessel function: $m(t) = \sum_{n=-\infty}^{\infty} J_n(m) V_c \cos(\omega_c t + n\omega_m t + n\pi/2)$

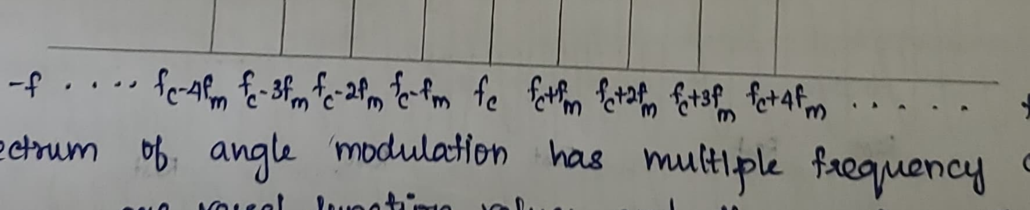
$n=0$ ← $m(t) = J_0(m) V_c \cos(\omega_c t + 0 + 0) +$

$n=1$ ← $J_1(m) V_c \cos(\omega_c t + \omega_m t + \pi/2) +$

$n=-1$ ← $J_{-1}(m)$ ← $-(J_1(m) V_c \cos(\omega_c t - \omega_m t - \pi/2)) \ldots$

Final Equation: $m(t) = J_0(m) \cdot V_c \cos\omega_c t + J_1(m) V_c \cos(\omega_c + \omega_m)t - J_1(m)\cos(\omega_c - \omega_m)t$
$+ J_2(m) V_c \cos(\omega_c t + 2\omega_m t) - J_2(m) V_c \cos(\omega_c t - 2\omega_m t) + \ldots \infty$

SPECTRUM:



The spectrum of angle modulation has multiple frequency components $J_0(m), J_1(m), \ldots$ are vessel function values and these values will vary according to the value of m.

$J_0(m)$ → Carrier frequency component; $J_1(m)$ → First set of side frequency
$J_2(m)$ → Second set of side frequency.
⋮

PROBLEM:

1. Find carrier frequency, Modulating frequency, modulation index, maximum deviation for FM where $E_{FM}(t) = 12\sin[6\times10^8 t + 5\sin(1250t)]$

Sol:

$f_c = \frac{6\times10^8}{2\pi} = \frac{6\times10^2\times10^6}{2\pi} = 95.5\,Mhz$

$m = 5$

$f_m = \frac{1250}{2\pi} = 198.94\,hz$

Deviation $= \Delta f = k_1 V_m$

Given: $\frac{k_1 V_m}{f_m} = 5$

$\therefore \Delta f = 5\times f_m = 5\times198.94 = 994.71\,hz$.

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MON

FM & PM DEMODULATORS

⇒ PM modulator - differentiator followed by a FM modulator

⇒ PM demodulator - FM demodulator followed by an integrator.

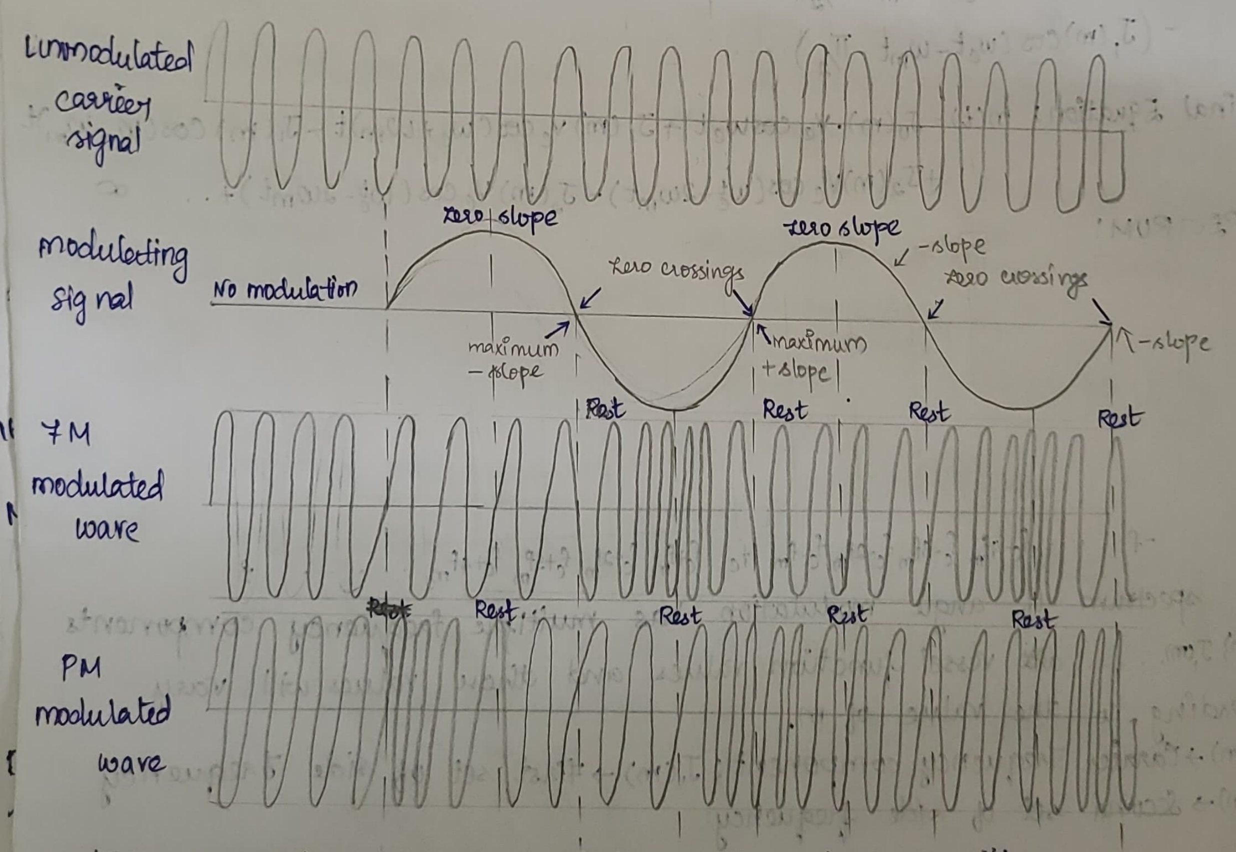
⇒ FM modulator - Integrator followed by PM modulator

→ FM demodulator - PM demodulator followed by a differentiator.

PROBLEMS:

1. Draw FM & PM output waveform with their input waveforms.
2. Calculate deviation ratio if maximum peak deviation is 5 khz and modulating frequency is 2.5 khz maximum.
3. For an FM modulator with modulation index $m = 1$, modulating signal $V_m(t) = V_m\sin(2\pi1000t)$. Then $V_c(t) = 10\sin(2\pi500 0t)$. Find i) No. of sets of side frequencies ii) Their amplitudes iii) Draw the frequency spectrum for the given signal.

1.



FM modulated signal → High ⇒ Negative maximum input   Low ⇒ positive maximum input

PM modulated signal → High ⇒ Zero crossing with + slope   Low ⇒ Zero crossing with - slope.

2. Deviation ratio = $\frac{\Delta f}{f_m(max)} = \frac{5}{2.5} = 2$ (No unit)

3. $V_m(t) = V_m \sin 2\pi 1000t$; $V_c(t) = 10 \sin(2\pi 500kt)$; $m = 1$

$m(t) = J_n(m) V_c \cos(\omega_c t + n\omega_m t + n\pi/2) \Rightarrow \sum_{n=0}^{3} J_n(m) V_c \cos(2\pi 500t + n\, 2\pi 1000t + n\frac{\pi}{2})$

According to Bessel functions,

$J_0 = 0.77$; $J_1 = 0.44$; $J_2 = 0.11$; $J_3 = 0.02$.

$m(t) = V_c [J_0(m)\cos\omega_c t + J_1(m)\cos(\omega_c + \omega_m)t^{+\pi/2} - J_1(m)\cos(\omega_c - \omega_m t)t^{-\pi/2} + J_2(m)\cos(\omega_c t + 2\omega_m t)$
$- J_2(m)\cos(\omega_c t - 2\omega_m t) + J_3(m)\cos(\omega_c t + 3\omega_m t) - J_3(m)\cos(\omega_c t - 3\omega_m t) + \dots]$

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BESSEL FUNCTION TABLE:

$J_n(m) = \left(\frac{m}{2}\right)^n \left[1 - \frac{(m/2)^2}{1!(n+1)!} + \frac{(m/2)^4}{2!(n+2)!} + \dots\right]$

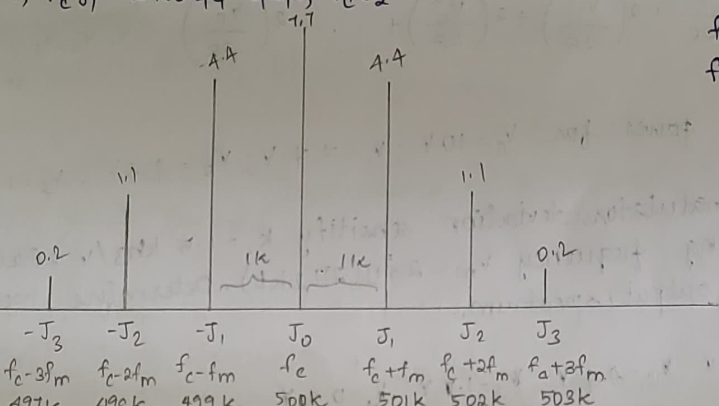
3. i) from bessel function table, $m = 1$; $J_0 = 0.77$ $J_1 = 0.44$ $J_2 = 0.11$ $J_3 = 0.02$

$\therefore$ No. of sets of side frequencies = 3

ii) Amplitude of side frequencies = $V_c J_n$

$V_c J_0 = 10 \times 0.77 = 7.7V$; $V_c J_1 = 10 \times 0.44 = 4.4V$; $V_c J_2 = 10 \times 0.11 = 1.1V$; $V_c J_3 = 10 \times 0.02 = 0.2V$

iii)



$f_c = 500k = 500000$
$f_m = 1000$
$f_c + f_m = 501k$
$f_c - f_m = 499k$
$f_c + 2f_m = 502k$
$f_c - f_m = 498k$
$f_c + 3f_m = 503k$
$f_c - 3f_m = 497k$

BANDWIDTH REQUIREMENT FOR ANGLE MODULATION:

for bandwidth calculation using bessel function,
$BW = n \times 2f_m$. Using Carson's rule, $B = 2(\Delta f + f_m)$,

PROBLEMS:

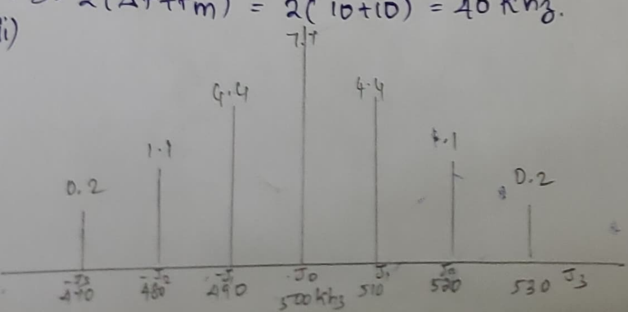
1. For an FM modulator with peak frequency deviation $\Delta f = 10khz$, modulating signal frequency $f_m = 10khz$; $V_c = 10V$ and $f_c = 500khz$. Find i) Actual minimum bandwidth from bessel function table ii) Approximate bandwidth using carson's rule. iii) Draw the spectrum of FM output.

Sol: i) $BW = n \times 2f_m$

To find n, $m = \frac{\Delta f}{f_m} = \frac{10}{10} = 1$ $\therefore n = 3$. $BW = 3 \times 2 \times 10 = 60khz$.

ii) $B = 2(\Delta f + f_m) = 2(10 + 10) = 40khz$.

iii)



$V_c J_0 = 10 \times 0.77 = 7.7V$
$V_c J_1 = 10 \times 0.44 = 4.4V$
$V_c J_2 = 10 \times 0.11 = 1.1V$
$V_c J_3 = 10 \times 0.02 = 0.2V$

$f_c = 500khz$ $f_m = 10khz$
$f_c + f_m = 510khz$
$f_c - f_m = 490khz$
$f_c + 2f_m = 500 + 20 = 520khz$
$f_c - 2f_m = 480khz$
$f_c + 3f_m = 530khz$
$f_c - 3f_m = 470khz$

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TYPES OF FM:

Narrow band FM – If modulation index m is less than 1, low index

Wide band FM – If modulation index m is between 1 and 10, medium index; If modulation index m is greater than 10, high index

POWER CALCULATION FOR PM & FM:

The output equation is given by $m(t) = V_c \cos(\omega_c t + \theta)$

From the above equation, average power can be calculated as $P_t = \frac{m(t)^2}{R}$

$$P_t = \frac{V_c^2 \cos^2(\omega_c t + \theta(t))}{R} \qquad \cos^2\theta = \frac{1+\cos 2\theta}{2}$$

$$P_t = \frac{V_c^2}{R}\left[\frac{1+\cos 2(\omega_c t+\theta(t))}{2}\right] \Rightarrow \frac{V_c^2}{2R} + \frac{V_c^2 \cos 2(\omega_c t + \theta(t))}{2R}$$

The second term can be equated to zero as it has very minimal compared to carrier power.

Hence, $P_t = \frac{V_c^2}{2R}$.

Considering side frequencies, total power can be written as $P_t = P_0 + P_1 + P_2 \dots P_n$ where n = no. of side frequencies.

$$\therefore P_t = \frac{V_c^2}{2R} + 2\left(\frac{V_1^2}{2R}\right) + 2\left(\frac{V_2^2}{2R}\right) + \dots 2\left(\frac{V_n^2}{2R}\right)$$

where $V_c \rightarrow$ Carrier Voltage

$V_1, V_2, V_3 \dots V_n \rightarrow$ voltage of side frequencies

PROBLEMS:

1. Find the total power for $V_c = 10V$; $V_1 = 7.7\ V$; $V_2 = 4.4V$; $V_3 = 1.1\ V$; $V_4 = 0.2\ V$ and $R = 500\ \Omega$
2. For an FM modulator, deviation sensitivity $k_1 = 1.5\ kHz/V$; Carrier frequency = 500 kHz; modulating frequency $V_m = 2\sin(2\pi 2kt)$. Determine modulation index and draw the output spectrum.

1.

Sol: $V_c = 10\ V$ $V_1 = 7.7V$ $V_2 = 4.4\ V$ $V_3 = 1.1\ V$ $V_4 = 0.2\ V$

$$P_t = \frac{V_c^2}{2R} + 2\left(\frac{V_1^2}{2R}\right) + 2\left(\frac{V_2^2}{2R}\right) + 2\left(\frac{V_3^2}{2R}\right) + 2\left(\frac{V_4^2}{2R}\right) \Rightarrow \frac{10^2}{2\times500} + 2\left(\frac{7.7^2}{2\times500}\right) + 2\left(\frac{4.4^2}{2\times500}\right) + 2\left(\frac{1.1^2}{2\times500}\right) + 2\left(\frac{0.2^2}{2\times500}\right)$$

$$= 0.1 + 0.11858 + 0.03872 + 0.00242 + 8\times10^{-5} = 0.2598\ W$$

2. $k_1 = 1.5\ kHz/V$; $f_c = 500\ kHz$; $V_m = 2\sin(2\pi 2kt)$.

$$m = \frac{k_1 V_m}{f_m} = \frac{\cancel{1.5 \times 2}}{\cancel{2\times10^3}} = \cancel{0.0015} = \frac{1.5\times10^3 \times 2}{2\times10^3} = 1.5$$

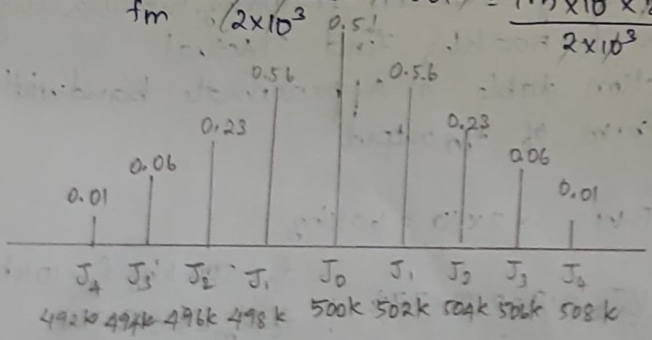
when $m = 1.5$; $n = 4$

$J_0 = 0.51$ $J_1 = 0.56$ $J_2 = 0.23$

$J_3 = 0.06$ $J_4 = 0.01$

$f_c = 500000$

$f_m = 2000$



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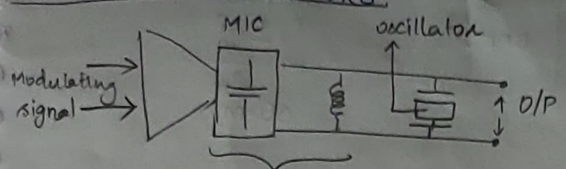
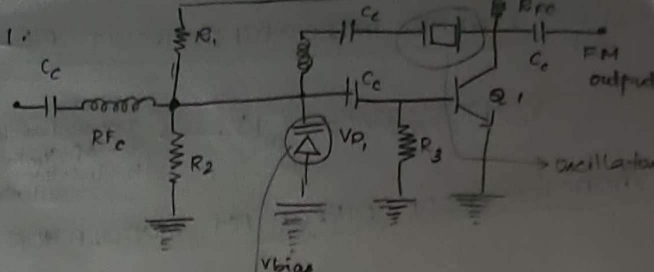
DIRECT FM MODULATORS:



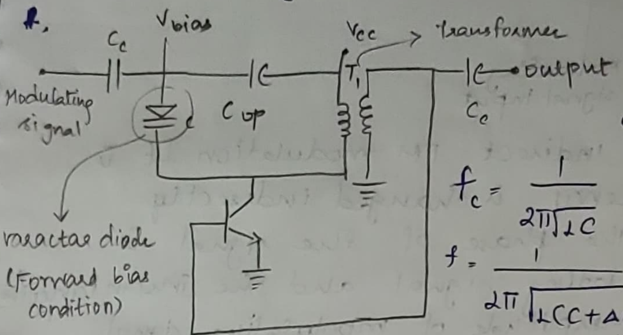


There are 3 common methods for producing direct FM modulation.
1. Varactor diode modulator
2. FM reactance modulator (JFET)
3. Linear integrated circuit direct FM modulator

varactor diode (reverse bias condition)

$C_c \rightarrow$ coupling capacitor (Removes unwanted noise)

1.



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

$$f = \frac{1}{2\pi\sqrt{L(C+\Delta C)}}$$

$$\Delta f = |f_c - f|$$

PROBLEMS:

1. Determine the frequency of carrier signal and modulated output if $L = 100 \times 10^{-3}$ mH & $C = 1000 \times 10^{-6}$ mF, $\Delta C = 10$ mF

Sol: $f_c = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{316.22\times}} = \frac{1}{2\pi \times 316.22 \times 10^{-3}}$

$= 0.503$ Hz

$f = \frac{1}{2\pi\sqrt{L(C+\Delta C)}} = \frac{1}{2\pi\sqrt{100\times10^{-3}(1010\times10^{-6})}} = 0.5001$ Hz

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TUE

In DC circuits

$R = \frac{V}{I}$

Resists the flow of current

In AC circuits

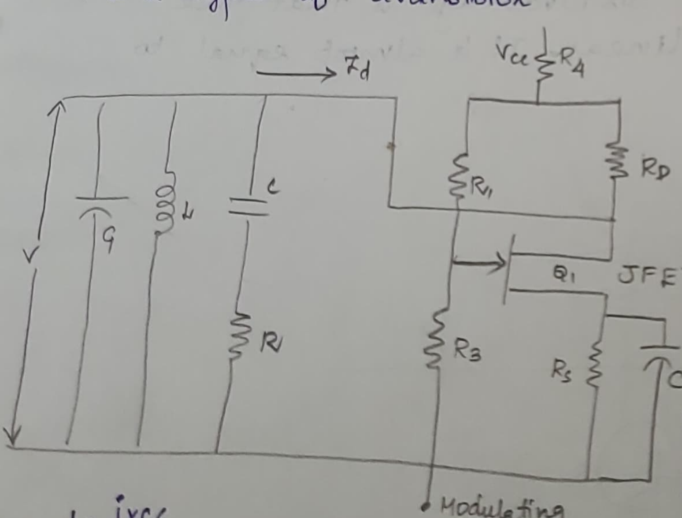
$Z = \frac{V}{I}$ Reactance

Impedence

Impendence — R Resistance, L Inductance $X_L =$, C capacitance X_C

JFET: Junction field effect transistor

It is a typed of transistor



Diode
varactor diode
transistor
JFET

Gate voltage → Gate current

$V_g = i_g \cdot R \rightarrow$ (1)

$i_g = \frac{V}{R - jX_C} \rightarrow$ (2)

Sub (2) in (1)

$V_g = \left(\frac{V}{R - jX_C}\right) R \rightarrow$ (3)

If inductance, $R = R + jX_L$

If capacitance, $R = R - jX_C$

$g_m \rightarrow$ trans conductance $= 1/R$

We know that $i = \frac{V}{R} = V\left(\frac{1}{R}\right)$ $\quad i_d = g_m V_g \rightarrow$ (4)

drain current

Sub (3) in (4)

$i_d = g_m\left(\frac{V}{R - jX_C}\right) R \rightarrow$ (5)

We need

drain impedence $\leftarrow Z_d = \frac{V}{i_d} \rightarrow$ (6)

Rearranging (5)

$$\frac{V}{i_d} = \frac{R - jX_C}{R g_m}$$

$$Z_d = \frac{1 - jX_C/R}{g_m} \qquad X_C = \frac{1}{2\pi f_m C}$$

$$= \frac{1 - \cancel{\frac{2\pi f_m C}{R}}}{g_m} \Rightarrow \frac{1 - \frac{j}{2\pi f_m C R}}{g_m}$$

$$\therefore Z_d = \frac{1}{g_m}\left(1 - \frac{j}{2\pi f_m C R}\right)$$

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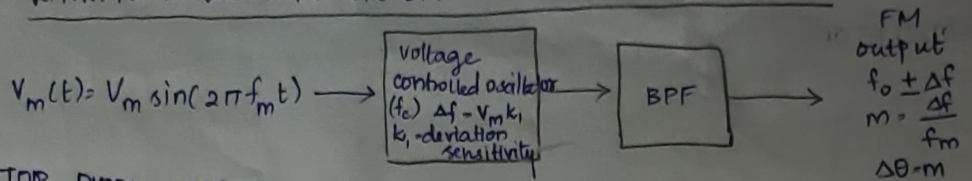
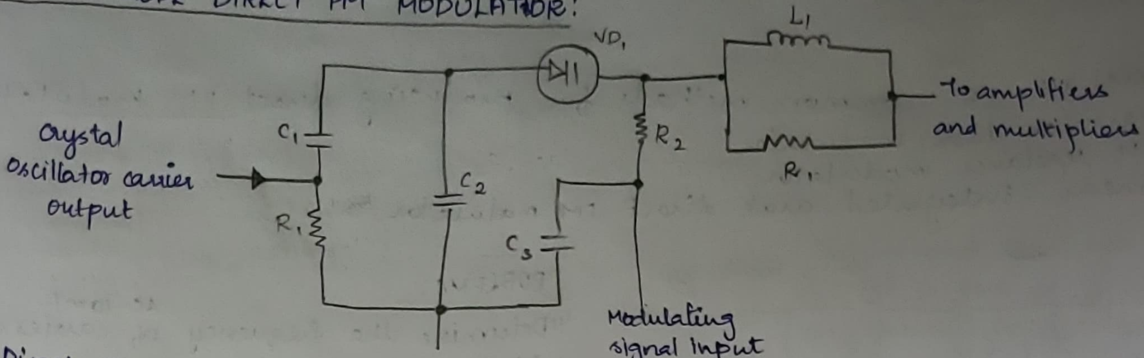
LINEAR INTEGRATED-CIRCUIT DIRECT FM MODULATORS:



VARACTOR DIODE DIRECT PM MODULATOR:

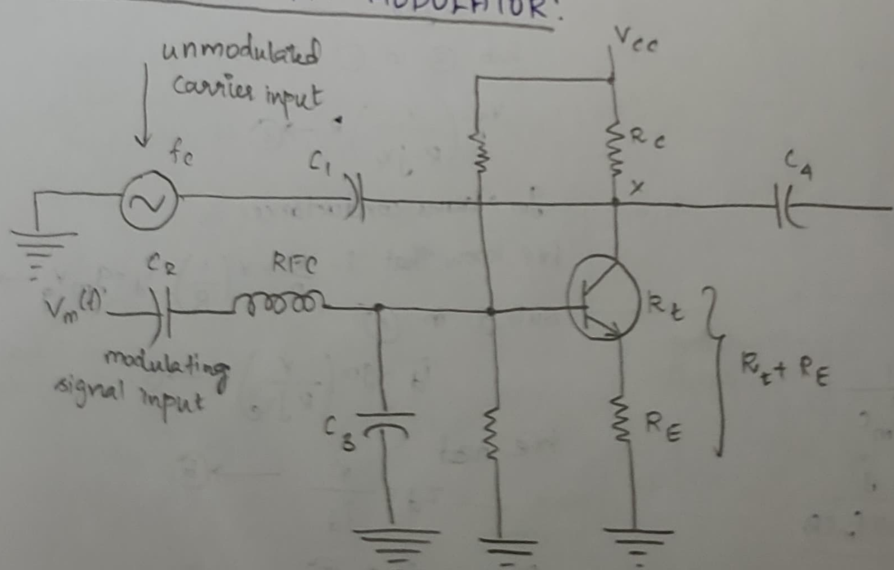


Direct PM modulation is also called indirect FM modulation. It is an angle modulation in which the frequency is changed indirectly corresponding to the modulating signal. The phase of the signal is directly changed with respect to modulating signal and the instantaneous phase is directly proportional to the amplitude of modulating signal.

The modulator circuit consists of a varactor diode combined in series with a inductor circuit (the induced coil L_1, resistor R_1). The combined series-parallel resonance circuit appears in series with the output carrier signal of the crystal oscillator. The modulating signal input is connected to the varactor diode.

The advantage of direct PM modulator circuit is that it uses buffered crystal for carrier output. The frequency is more stable than other indirect constituents. The disadvantage is that the capacitance to voltage ratio is non linear. It is almost equal to square root.

TRANSISTOR DIRECT PM MODULATOR:



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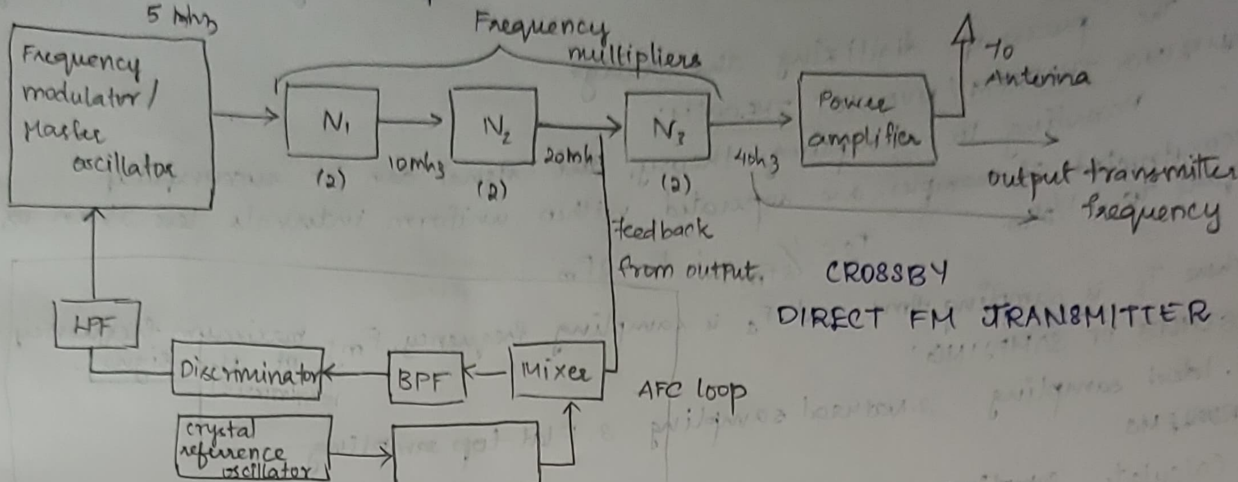
FM TRANSMITTER:

- Direct FM transmitter
  - Crosby direct FM transmitter
  - PLL / Phase Lock loop direct FM transmitter
- Indirect FM transmitter
  - Armstrong indirect FM transmitter

AFC - Auto frequency control ; LPF - Low pass filter ; BPF → Band pass filter
N_1, N_2, N_3 → frequency multipliers



CROSSBY DIRECT FM TRANSMITTER

PROBLEMS:

1. for crossby direct FM transmitter, frequency multiplication = 20 and transmit carrier frequency (f_t) = 88.8 mhz. Determine i) Master oscillator carrier frequency ii) frequency deviation at the output of modulator if frequency deviation at antenna = 75 khz. iii) Deviation ratio at the output of modulator if f_m = 15 khz. iv) Deviation ratio at the transmitter side.

Sol: $f_t = 88.8$ mhz, multiplier = 20 (N)

i) $f_c = \frac{88.8}{20} = 4.44 \times 10^6$ hz.

ii) $f_t = 75$ khz $f_c = \frac{75}{20} = 3.75$ khz. (frequency deviation)

iii) Deviation ratio = $\frac{\Delta f \rightarrow \text{frequency deviation}}{f_m} = \frac{3.75}{15} = 0.25$.

iv) Deviation ratio at modulator = 0.25
Deviation ratio at transmitter = 0.25 × 20 = 5

6/4/23 THUR X

1. An angle modulated signal is described by $x_c(t) = 10\cos[2\pi(10^6)t + 0.1\sin(10^3)\pi t]$. Considering $x_c(t)$ as PM signal with $k_p = 10$. find m(t). (Modulating signal).

Sol: $V_m(t) = kV_m \cos(\omega_m t)$ $V_m = 0.1$ $\omega_m = 10^3\pi$ $kV_m = 0.1$

$= 10 \times 0.1 \cos(10^3\pi)t$

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

2. Calculate the BW of FM signal whose frequency deviation is 75 khz and signal frequency is 2.5 khz.

Sol: $\Delta f = 75$ khz. $f_m = 2.5$ khz $BW = 2(\Delta f + f_m) = 2(75+2.5) = 2(77.5) = 155$ khz //.

3. A 107.6 Mhz carrier is frequency modulated by a 7khz sine wave. The resultant FM signal has a frequency deviation of 50 khz. Determine the modulation index of the FM wave.

Sol: $f_c = 107.6$ Mhz $f_m = 7$ khz $\Delta f = 50$ khz. $m = \frac{\Delta f}{f_m} = \frac{50}{7} = 7.142$ //.

10/4/23 MON

11,12, 03, 63, (11/4/23)

UNIT-3 DIGITAL MODULATION

ADVANTAGES OF DIGITAL COMMUNICATION:

1. Better noise immunity
2. Flexible & adaptable
3. Multiplexing & processing becomes easier
4. Error correction & decoding becomes more effective

SAMPLING:

The process of measuring instantaneous value of continuous signal (Analog signal) and making into discrete form (Digital form). The process of digitalizing is called sampling.

QUANTIZATION:

The process of digitizing the range.

SAMPLING THEOREM / NYQUIST THEOREM:

According to sampling theory, the signal can be successfully reconstructed, if samples are seperated within uniform intervals less than or equal to $1/2f_m$.

$$T_s \le \frac{1}{2f_m} \; ; \; F_s = 2F_m \quad \Big\} \text{ Satisfying criteria}$$

where T_s is sampling time and F_s is sampling frequency, F_m - maximum frequency of the signal.

METHODS OF SAMPLING:

1. Ideal sampling
2. Natural sampling
3. Flat-top sampling

PROBLEMS:

1. Calculate sampling frequency & maximum frequency if samples are taken for every 5 milliseconds from the information signal of time period 15 ms.

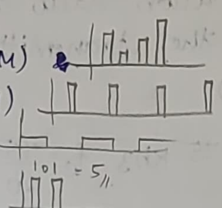
sol:

$$F_s = \frac{1}{T_s} \Rightarrow F_s = \frac{1}{3\times10^{-3}} = 0.333\times10^3 = 0.333\text{ khz} \qquad F_m = \frac{1}{T} = \frac{1}{15\times10^{-3}} = 0.066\text{ khz}$$

11/4/23 TUE

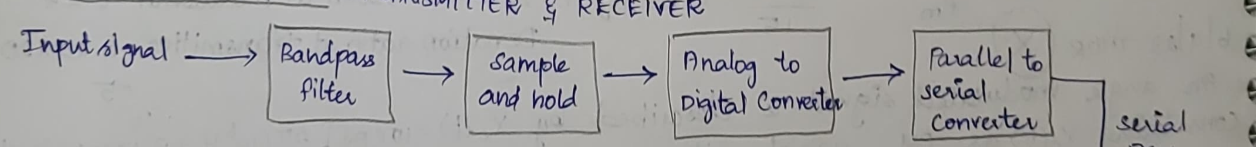
PULSE MODULATION TYPES:

1. Pulse amplitude modulation (PAM)
2. Pulse position modulation (PPM)
3. Pulse width modulation (PWM)
4. Pulse code modulation (PCM)



PULSE CODE MODULATION:

PULSE CODE MODULATION: TRANSMITTER & RECEIVER



PROBLEMS:

1. Calculate the line speed of PCM if sampling rate is 8 khz and 8 bits are sampled for every sample.

sol:

linespeed = sampling rate × bits per sample

$$= 8\times10^3 \times 8 = 64\times10^3 \text{ bits per second.}$$