14.3.23

Direct FM and PM modulators:

PM modulator = Difference followed by an FM modulator

PM demodulator = FM demodulator followed by an Integrator.

FM modulator = Integrator followed by an phase modulator

FM demodulator = PM modulator followed by an differentiator.

Frequency spectrum of angle modulated wave

* Single frequency modulation - Infinite no. of Side band frequency.
* Each sideband frequency is displaced from the carries by an integral multiple of the modulating signal frequency
* $m(t) = V_c \cos(\underbrace{\omega_c t}_{\alpha} + m \underbrace{\cos(\omega_m t)}_{\beta})$
* By equating Bessel's relation,

$$\cos(\alpha + m\beta) = \sum_{n=-\infty}^{\infty} J_n(m) \cos\left(\alpha + n\beta + \frac{n\pi}{2}\right)$$

$$m(t) = V_c \sum_{n=-\infty}^{\infty} J_n(m) \cos\left(\omega_c t + n\omega_m t + \frac{n\pi}{2}\right)$$

Expanding: (no of sideband expansion)

$$m(t) = V_c \Big\{ J_0(m)\cos(\omega_c t) + J_1(m)\cos\left((\omega_c+\omega_m)t + \frac{\pi}{2}\right) - J_1(m)\cos\left((\omega_c-\omega_m)t - \frac{\pi}{2}\right) + J_2(m)\cos\left((\omega_c+2\omega_m)t + \pi\right) - J_2(m)\cos\left((\omega_c-2\omega_m)t - \pi\right) + J_3(m)\cos\left((\omega_c+3\omega_m)t + 3\frac{\pi}{2}\right) - J_3(m)\cos\left((\omega_c-3\omega_m)\left(-3\frac{\pi}{2}\right)\right) + \dots J_n(m) \Big\}$$

where, m,

ω_m,

V_c

$J_0(m)$ - carrier component

$J_1(m)$ - 1st set of side band frequency component

* Set of side band frequency

sequence $(f_c \pm f_m, f_c \pm 2f_m, f_c \pm 3f_m, \dots f_c \pm nf_m)$

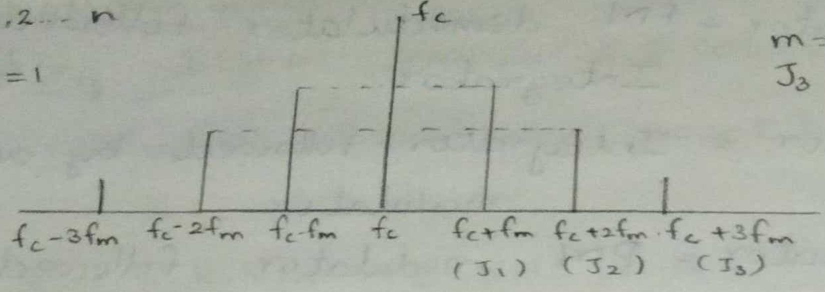
1st order   2nd order

* To find Amplitude of side band frequency: $J_n(m)$ value fi...

$$J_n(m) - \left(\frac{m}{2}\right)^n \left[\frac{1}{n} - \frac{(\frac{m}{2})^2}{1!(n+1)!} + \frac{(\frac{m}{2})^4}{2!(n+2)!} - \frac{(\frac{m}{2})^6}{3!(n+3)!}\right]$$

$m = 0, 1, 2 \ldots n$

$m = 1$



$m = 1$	$m > 1$	$m < 1$
J_3	$J_3 >$	J_1

amplitude gradually dicrease

$m \leq 1$ - narrow band $m > 1$ wide band

15.3.23 **Bandwidth Requirement of Angle modulation:**

* BW can't be accomodated in narrower like amplitude modulation.
* BW = function of modulating frequency and modulation index.

BW = 2 fm Hz → Low index modulation

BW = 2 (n x fm) → higher index modulation $2 \times \Delta f$

n = no of set of side band frequency Produces

* Carson's Rule :

→ BW = 2 (Δf + fm) Hz fm - modulating frequency, Δf - frequency deviation.

→ Low m.I $f_m > \Delta f$

High m.I $f_m < \Delta f$

→ 98%

1. For an FM modulation with a peak Δf = 10 KHz, a modulating signal frequency fm = 10 KHz and a carrier frequency fc = 500 KHz. V_c = 10 V and a determine a) actual minimum BW from the Bessel function table b) approximate max BW using Carson's rule c) plot the o/p frequency spectrum for the Bessel approximation

Deviation Ratio $= \frac{\Delta f_{max}}{f_{max}}$

$J(0) = 0.77$
$J(1) = 0.44$
$J(2) = 0.11$
$J(3) = 0.2$

a) modulation index $m = \frac{\Delta f}{f_m} = \frac{10\ kHz}{10\ kHz}$

$m = 1$

2. Given fm and Pm modulated with the following parameter

17.3.23

FM modulator	Phase modulator
Deviation Senstivity $k_f = 1.5$ kH	Deviation senstivity $K = 0.75$ rad/V
carrier frequency $f_c = 500$ kHz	$f_c = 500$ kHz
modulating signal $V_m = 2\ \sin(2\pi 2kt)$	modulating signal $V_m = 2\ \sin(2\pi 2kt)$

a) Determine modulation index & sketch the spectrum for both modulator b) change the modulating signal frequency amplitude for both modulators to four volt & repeat for (a). (c) Change the modulating signal frequency for both modulators to 1kHz and repeat for (a)

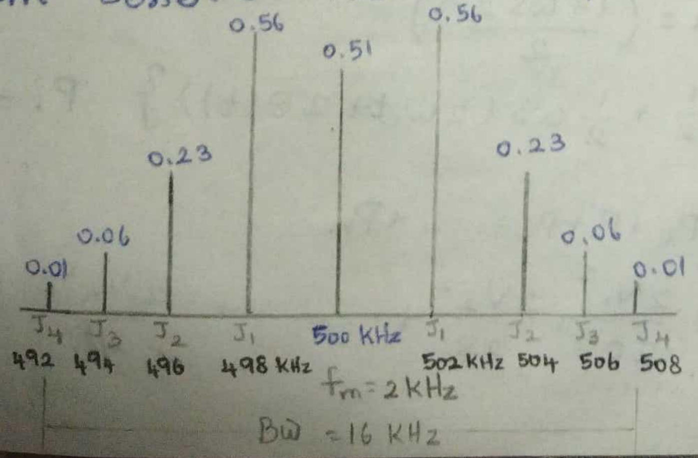
FM

$$mI = \frac{KV_m}{f_m} = \frac{1.5\ kHz \times 2}{2kHz} = \frac{1500 \times 2}{2} = 1.5$$

PM

$$mI = KV_m = 0.75 \times 2 = 1.5$$

From bessel's table $n = 4$



$BW = 2nf_m$

$= 2 \times 4 \times 2 = 16$

FM

$V_m = 4 \sin(2\pi 2Kt)$

$mI = \frac{1.5\ KHz \times 4}{2\ KHz} = 3.0$

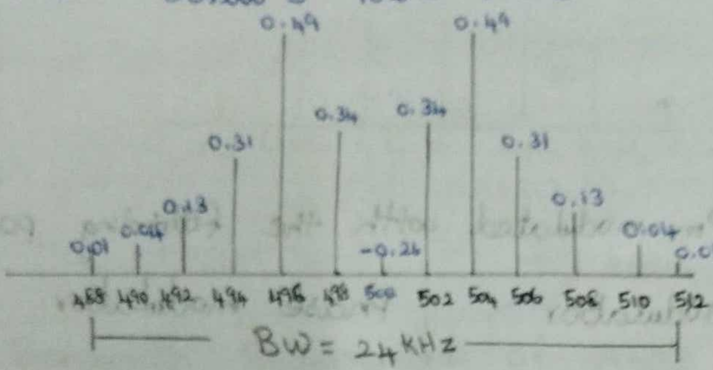
PM

$V_m = 4 \sin(2\pi 2Kt)$

$mI = 0.75 \times 4 = 3.0$

From Bessal's table $n = 6$

$J_0 = -0.26$
$J_1 = 0.34$
$J_2 = 0.49$
$J_3 = 0.31$
$J_4 = 0.13$
$J_5 = 0.04$
$J_6 = 0.01$



Amplitude ↑ - BW ↑

f_m ↓ - BW ↓

$BW = 2 \times 6 \times 2 = 24$ KHz

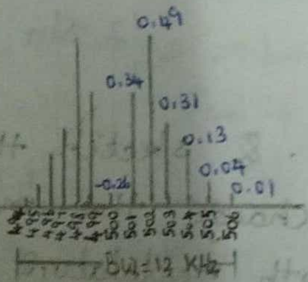
c) $f_m = 1KHz$

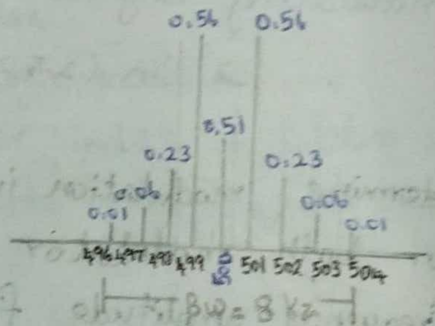
FM

$mI = \frac{1.5\ KHz \times 2}{1\ KHz} = 3$

PM

$mI = 0.75\ KHz \times 2 = 1.5$





$BW = 2 \times 6 \times 1 = 12$ KHz

$BW = 2 \times 4 \times 1 = 8$ KHz

Power of Anglemodulation :

* $P = VI = \frac{V^2}{R} = I^2R$
* carrier power $= P_c = \frac{V_c^2}{2R}$ watts
* Total transmission power in Angle modulation

modulated signal Amplitude change

$P_i = \frac{m(t)^2}{R}$ watts $\quad P_i = \frac{V_c^2}{R} \cos^2(\omega_c t + \theta(t))$

$\cos^2 A = \left(\frac{1 + \cos 2A}{2}\right)$

$P_i = \frac{V_c^2}{R} \left\{\frac{1}{2} + \frac{1}{2} \cos(2\omega_c t + 2\theta(t))\right\} \quad P_i = \frac{V_c^2}{2R}$

But, $P_i = P_0 + P_1 + P_2 + \ldots + P_n$

$P_i = \underbrace{\frac{V_c^2}{2R}}_{\text{modulated carrier power}} + \underbrace{\frac{2V_1^2}{2R}}_{\text{1st band power}} + \frac{2V_2^2}{2R} + \ldots + \underbrace{\frac{2V_n^2}{2R}}_{n^{th}\text{ band power}}$

24.3.23

FM & PM modulators :

Direct FM : directly change the frequency of input signal. capacitance $\propto \frac{1}{\text{frequency}}$

* Varactor diode modulator * FM Reactance modulator
* Linear circuit direct FM modulator.

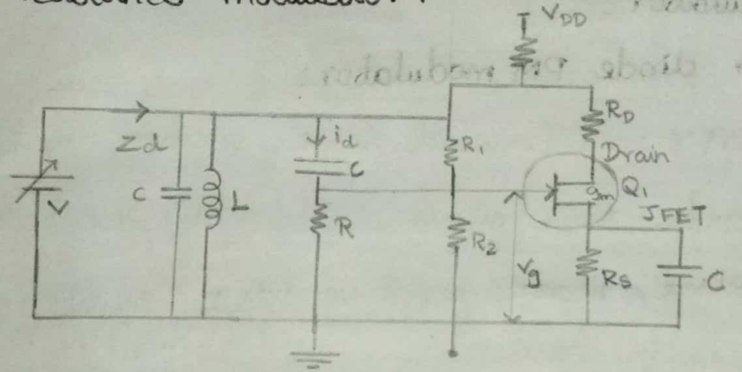
Indirect FM modulator :

Direct PM modulator :

* Varactor diode PM modulator * Transistor PM modulator

Indirect PM modulator :

FM reactance modulator :



diode - rectify

R, C time freq. comp

$V_g = i_g R$

$i_g = \frac{V}{R - jX_c}$

$V_g = \left(\frac{V}{R - jX_c}\right) \times R$

modulating signal input

$i_d = g_m V_g$

$i_d = g_m \times \left[\frac{V}{R - jX_c}\right] \times R$

$Z_d = \frac{V}{i_d}$

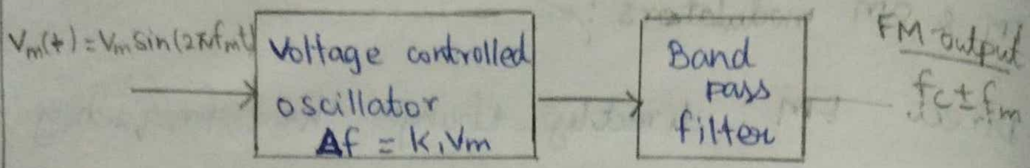
Z_d = Impedance of input Oscillator.

$X_c = \frac{1}{2\pi f c}$

$$Z_d = \frac{V}{g_m \times \frac{V}{R - jX_c} \times R} = \frac{R - jX_c}{g_m R}$$

$$Z_d = - \frac{\cancel{X} j}{2\pi f_m \underbrace{g_m}_{V_g \text{ depend}} R_c}$$

Linear Integrated Direct FM modulator



* Stable, direct proportional to input modulator
* FM $_{output}$ = $f_c + k_1 f_m$
* Low power, Several components involved
* MC1376, DIP IC, 1.4 MHz to 14 MHz
* Peak frequency deviation about 150 kHz

PM modulator:

Varactor diode PM modulator:

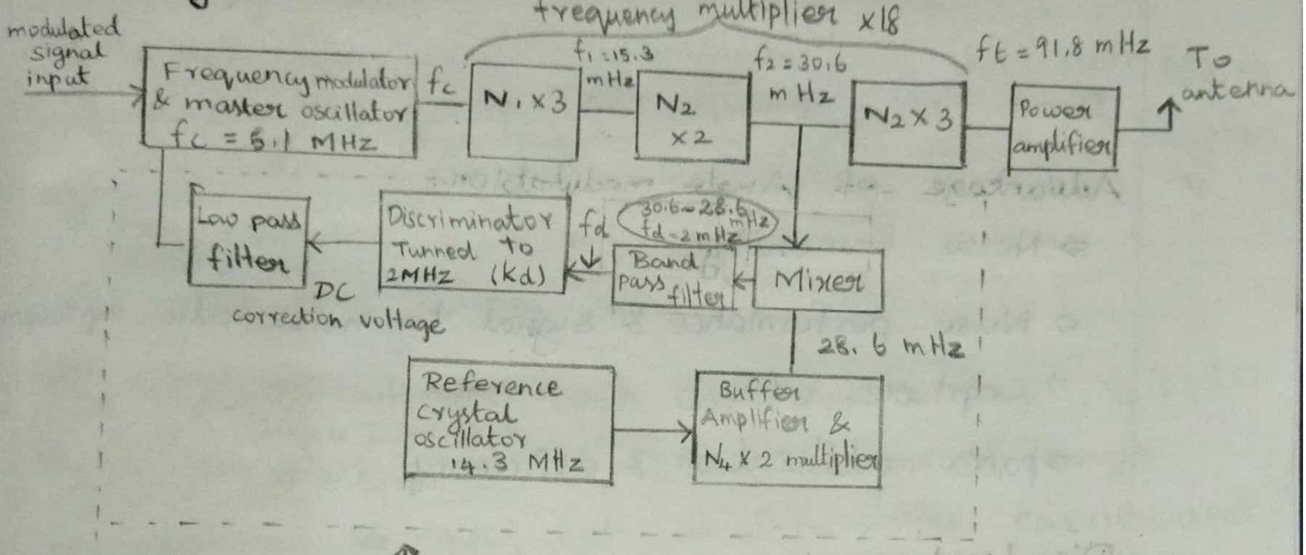
* If it's a forward biase, positive input signal is passed the output modulated signal is increase
* reversed biase, negative input signal is passed freq is increase.
* forward - negative freq decrease
* reversed - positive freq decrease

7.3.23 Direct FM transmitter:

1. Crosby direct FM Tr/..
2. Phase locked loop FM Tr/..

* Crystal oscillator frequency is fixed
* For medium and high FM / PM transmission - cannot use crystal oscillator.

1. Crosby direct FM transmitter



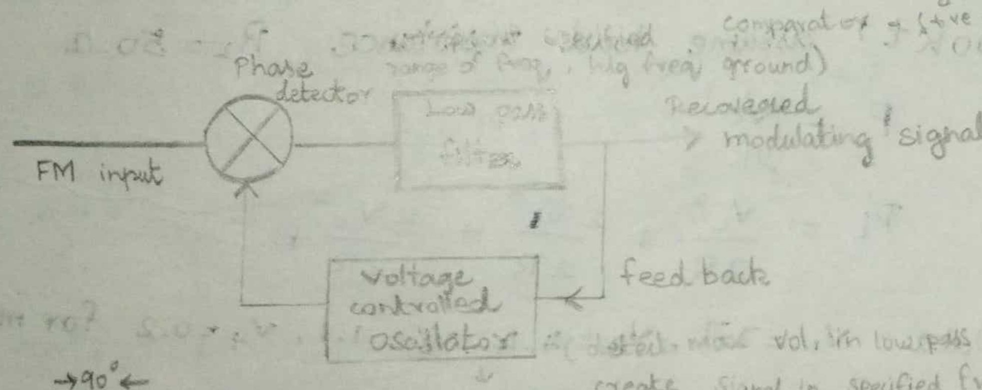
Automatic frequency control loop (AFC)

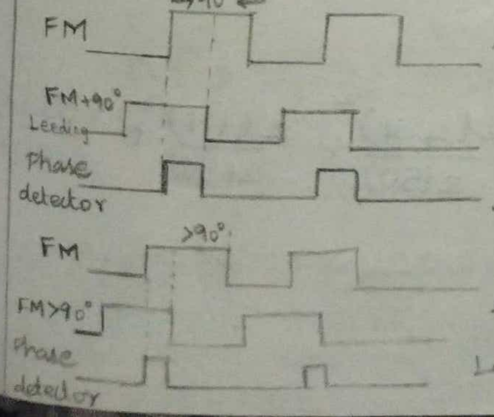
maximum $\Delta f = \frac{75 \text{ KHz}}{18} = 4166.7 \text{ Hz}$ (modulating signal freq)
(max allowed transmission range)

maximum m.I $= \frac{4166.7}{15} = 0.27778$ (allowed max modulated i/p frequency $f_c = 15$ KHz)

maximum m.I at antenna $= 0.27778 \times 18 \equiv 5$

28.3.23 2. Phase looked loop FM Transmitter:

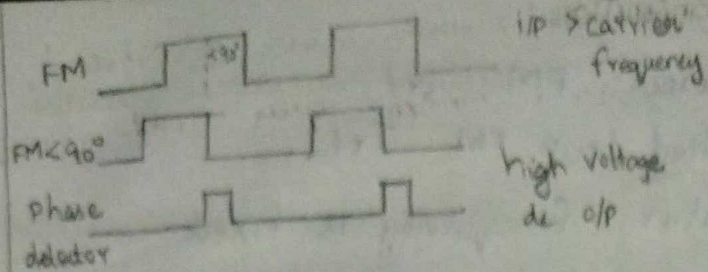


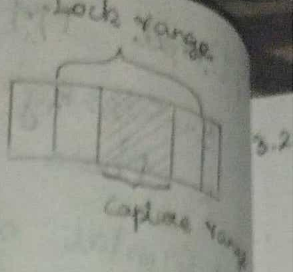


no modulation carrier frequency

I/P < carrier frequency frequency

Low voltage dc o/p





Lock range - controlled oscillator filtered the specified range of … after that no deviation in freq

Capture - input modulated signal freq range detect in … range

29.3.23

Direct FM - Indirect PM , Direct PM - Indirect FM

2m Advantage of Angle modulation:

⇒ Noise immunity

⇒ Noise performance & signal to noise ratio improvement

⇒ Capture effect (lock range carrier signal + captured side band signal)

⇒ power untilization & efficiency (high power utilize)

Disadvantage :

⇒ Bandwidth (high bw high power require so use perfect filter)

⇒ Circuit complexity & cost (AM - Sometimes diode is enough in circuit, but Angle mod. complex)

1. Determine the unmodulated carrier signal power for the FM modulator with a mI $m=1$ and a modulated signal $V_m(t) = V_m \sin(2\pi 1{,}000t)$, $V_c(t) = 10\sin(2\pi 500kt)$ assume load resistance $R_L = 50\Omega$

$$P = \frac{V_c^2}{2R}$$

$$P_i = \frac{V_c^2}{2R} + \frac{2V_1^2}{2R} + \frac{2V_2^2}{2R} + \ldots\ldots$$

Data ; $V_1 = 7.7$, $V_2 = 4.4$, $V_3 = 1.1$, $V_4 = 0.2$ for $m=1$

$N=4$ (number of side band frequency)

$$P_i = \frac{(10)^2}{2(50)} + \frac{2(7.7)^2}{2(50)} + \frac{2(4.4)^2}{2(50)} + \frac{2(1.1)^2}{2(50)} + \frac{2(0.2)^2}{2(50)}$$

0.0008

$= 1 + 1.1858 + 0.3872 + 0.0242 + 0.0008$

$= 2.598$

1.3.23 → In master oscillator harmonic sound or noise is create to rectify this prblm using phase locked loop

* Phase locked loop - Specified range of frequency is locked this only transmitted.

Indirect FM Transmitter:

Armstrong indirect FM transmitter:

differenciate

=> low level freq - modulating signal + phase shift carr. sig

=> high range of deviation ($\because \downarrow$ + crystal osc freq) => compress

=> freq converter => subtract $12.8 - 10.9 = 1.9$

92 - 108 MHz (range o/p)

2. The equation of an angle modulated voltage $V(t) = 10 \cos(10^8 t + 3 \sin 10^4 t)$. i) what forms of angle modulation is this? (ii) calculate the carrier and modulating frequencis (iii) Calculate the modulation index, deviation (Δf), and power decipated in a $100\,\Omega$ resister.

i) Structure is a angle modulation. it may be either frequency or phase modulation. can't determine specific.

ii) $2\pi f_c = 10^8 \Rightarrow f_c = \frac{10^8}{2\pi} = \frac{10^8}{2} \times \frac{7}{22} = 1.59 \text{ MHz}$

$2\pi f_m = 10^4 \Rightarrow f_m = \frac{10^4}{2\pi} = \frac{10^4}{2} \times \frac{7}{22} = 1.59 \text{ KHz}$

iii) modulation index $m_I = K.V_m = 3$

$\Delta f \Rightarrow \frac{K.V_m}{f_m} = m = \frac{\Delta f}{f_m} \Rightarrow \Delta f = m f_m = 3 \times 1.59$

$\Delta f = 4.77 \text{ KHz}$

power $= \frac{V_c^2}{2R} = \frac{(10)^2}{2(100)} = \frac{1}{2} = 0.5$ watts.

3. An FM transmitter has a reset frequency $f_c = 96 MHz$ deviation sensitivity $K_1 = 4 KHz/v$. Determine the frequency deviation for a modulating signal $V_m(t) = 8 \sin(2\pi \times 200 t)$. determine the m.I

$V_m = 8$ $\quad f_m = 2000 Hz$

$$\Delta f = K_1 V_m = 4 KHz \times 8 = 32 KHz$$

$$m.I = \frac{\Delta f}{f_m} = \frac{32 \times 10^3 Hz}{2000 Hz} = \frac{32}{2} = 16$$

4. Determine the deviation ratio. & worst case BW for a FM Signal with a max. deviation $\Delta f_{(max)} = 25 KHz$ and max. modulated signal $f_{m(max)} = 12.5 KHz$

$$f_{m(max)} = 12.5 KHz, \quad \Delta f_{(max)} = 25 KHz$$

Deviation ratio. $DR = \frac{\Delta f_{max}}{f_{max}} = \frac{25}{12.5} = 2$

$$BW = (2(\Delta f_{max} + f_{max})) = 2(25 + 12.5)$$
$$= 2(37.5) = 75.0 KHz$$

5. For an FM modulator with 40 KHz, frequency deviation & modulating frequency $f_m = 10 KHz$. determine BW using Both Bessels table and Carson's rule.

$$\Delta f = 40 KHz, \quad f_m = 10 KHz$$

$$BW = 2(\Delta f + f_m) = 2(40 + 10) = 100 KHz$$

$$m I = \frac{\Delta f}{f_m} = \frac{40}{10} = 4$$

So no of side band frequency $n = 7$

$$BW = 2 \times n f_m = 2 \times 7(10) = 140 KHz$$

6. For an FM modulator with an unmodulated carrier amplitude $V_c = 20 V$, a m I $m = 1$, $R_L = 10 \Omega$ determine the power in the modulated carrier & each side band frequency and sketch the power spectrum for modulated wave

$n = 3$. $m = 1$, $V_c = 20$ V, $R_L = 10\ \Omega$

power $P_c = \frac{V_c^2}{2R} = \frac{(20)^2}{2(10)} = 20$ watts

$P_t = P_c + \frac{2V_1^2}{2R} + \frac{2V_2^2}{2R} + \frac{2V_3^2}{2R} + \frac{2V_4^2}{2R}$

$V_1 = 7.7$
$V_2 = 4.4$
$V_3 = 1.1$
$V_4 = 0.2$

$= 20 + \frac{(4.4)^2}{10} + \frac{(1.1)^2}{10} + \frac{(0.2)^2}{10} + \frac{(7.7)^2}{10}$

$= 20 + 1.936 + 0.121 + 0.004 + 5.929$

$P_t = 22.061$ watts +

$J_0 = 0.77$
$J_1 = 0.44$
$J_2 = 0.11$
$J_4 = 0.02$

$V_0 = 0.77 \times 20 = 15.4$

$V_1 = 0.44 \times 20 = 8.8$

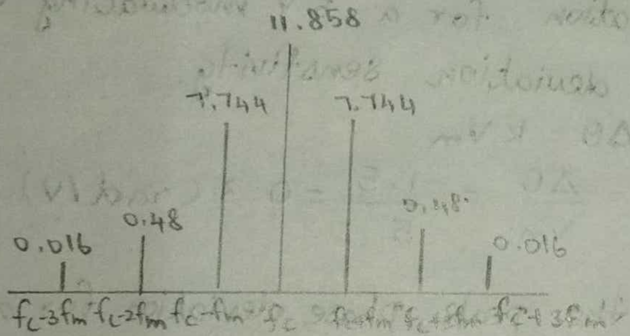
$V_2 = 0.11 \times 20 = 2.2$

$V_3 = 0.02 \times 20 = 0.4$

$P_t = \frac{(15.4)^2}{2\times10} + \frac{2(8.8)^2}{2\times10} + \frac{2(2.2)^2}{2\times10} + \frac{2(0.4)^2}{2\times10}$

$= 11.858 + 7.744 + 0.484 + 0.016$

$P_t = 20.102$



7. Using Crosby FM transmitter model, the total freq. multiplication of 20 & a transmit carrier freq. $f_t = 88.8$ MHz (a) determine oscillator center frequency. (b) frequency deviation at the o/p of the modulator for a Δf of 75 kHz at the antenna. (c) determine the deviation ratio at the o/p of the modulator for a max. modulating signal freq. $f_m = 15$ kHz then. (e) determine the deviation ratio at the antenna.

a) Carrier oscillator frequency.

given
$f_t = 88.8$ MHz

Qst
$f_{max} = 15$ KHz

$N_1 N_2 N_3 = 20$

$\Delta f = 75$ KHz

$$f_c = \frac{f_t}{N_1 N_2 N_3} = \frac{88.8 \text{ MHz}}{20} = 4.44 \text{ MHz}$$

b) frequency deviation $\Delta f_{max} = \frac{\Delta f_{antenna}}{N_1 N_2 N_3} = \frac{75 \text{ KHz}}{20}$

$= 3.75 \text{ KHz}$

c) deviation ratio $= \frac{\Delta f_{max}}{f_m} = \frac{3.75 \text{ KHz}}{15 \text{ KHz}} = 0.25$

d) DR at antenna $= 20 \times 0.25 = 5$

8. If a freq. modulator produces 4 KHz of freq. deviation for a 10 V modulating signal. determine deviation senstivity.

$\Delta f = 4 \text{ KHz}, \quad V_m = 10V$

$$K = \frac{\Delta f}{V_m} = \frac{4 \times 10^3}{10} = 400 \text{ (Hz/V)}$$

9. If a phase modulator produces 1.5 gradient of phase deviation for a 5 V modulating signal. determine deviation senstivity.

$\Delta\theta = K V_m$

$$K = \frac{\Delta\theta}{V_m} = \frac{1.5}{5} = 0.3 \text{ (rad/V)}$$

10. Determine the peak phase deviation for a PM modulator with deviation sensitivity K = 2 rad/V & a modulating Signal $V_m = 4 \sin(2\pi 1000t)$

$\Delta\theta = K V_m \qquad V_m = 4, K = 2$

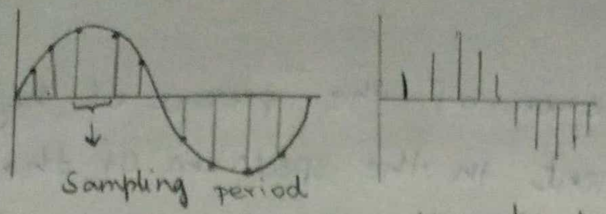
$= 2 \times 4 = 8$ rad

5.4.2023 Analog signal → Sampling → quantization → encoding → digital code

Sampling - is a process of continuous ~~dis~~ time signal into continuous discrete time signal

quantization - discreate time signal into discreate signal
(truncate) rounding

Encoding - discreate signal into digital code/Signal



only take amplitude

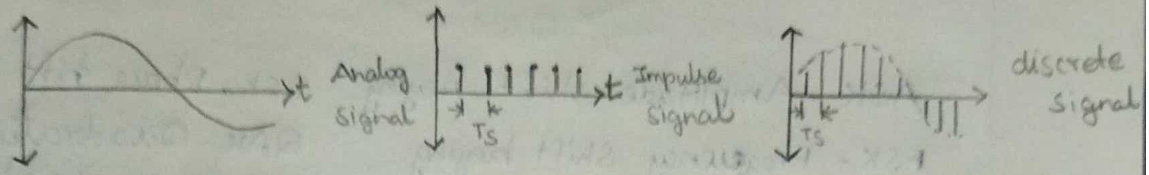
Sampling period

continuous discrete time signal   discreate time signal

Given $5V \Rightarrow \frac{5V}{2^3} = 8$ division of 5V (no of sampling ↑ output shape should be clear)

1.4.23 **Sampling :**

* continuous time signal into discrete time signal.



Ts - sampling perid $f_s = \frac{1}{T_s}$ = sampling frequency

Sampling theoram : (Nyquest Criteria)

* $f_s \geq 2 f_{input}$

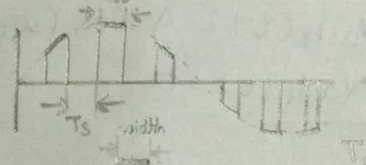
Aliasing : * $f_s < 2 f_{input}$

Types of sampling :

1. * Ideal sampling (instantaneous signal in a particular time)
2. * Natural sampling (cause quantization prblm)
3. * Flat top sampling

1. $x(t) \longrightarrow \otimes \longrightarrow x_s(t) = x(t)\,\delta(t)$

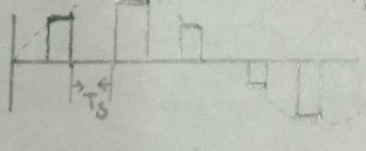
2.



(no of instant pair ⇒ variation of instant multiply ↑→ width differ)

T_w = width

3.



(starting instant sample value for full width ⊓→ same value

Sampling theoram:

If the highest frequency contained in an analog signal $x_a(t)$ is f_{max} and the signal is sampled at a rate $f_s > 2 f_{max}$ or $2 f_{input}$ then $x_a(t)$ can be exactly recovered from it's sample values using the interpolation function.

Aliasing

The phenomenon of the presence of high frequency component in the spectrum of the original analog signal is called Aliasing or simply foled over. sample freq is twice that of input freq

12.4.23 **Digital modulation**: → Info / msg signal in form of Digital

digital signal $V(t) = V \sin(2\pi f t + \theta)$

ASK → QAM ← FSK, PSK

ASK - Amplitude shift keying
PSK - Phase shift keying
FSK - Frequency Shift keying
QAK - Quadrature Amplitude Shift keying

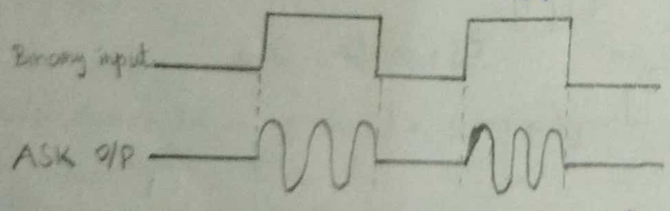
* Bit Rate: No of bits per second (no. of bits passed)
* Baud: Time taken to transmission per second $\left\{ \frac{f_b}{N} \right\}$
* M-ary (level): no. of levels (condition) $m = 2^n$, n - no of bits in each level

Amplitude Shift keying:

$V_{ask}(t) = (1 + V_m(t)) \left(\frac{A}{2} \cos(\omega_c t)\right)$

V_{ask} - amplitude of shift keying wave; $V_m(t)$ - Digital message signal; $\frac{A}{2}$ - Analog carrier amplitude; ω_c - Analog carrier frequency

* $V_m(t) = +1$; Logic '1'
  -1 ; Logic '0'
* at $V_m(t) = +1$, $V_{ask}(t) = A\cos(\omega_c t)$
  at $V_m(t) = -1$, $V_{ask}(t) = 0$



Baud Rate, Bit rate $= \frac{f_b}{N} = f_b$

Bandwidth $B = f_b$

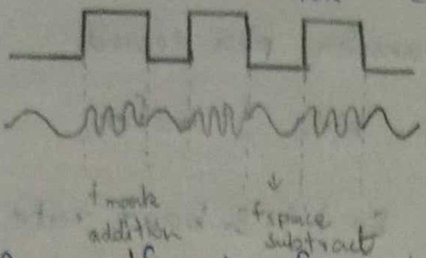
Frequency shift keying:

$V_{fsk}(t) = V_c \cos(2\pi(f_c + V_m \Delta f)t)$

$V_m(t) = +1$ logic '1'
-1 logic '0'

At $V_m(t) = +1$, $V_{fsk} = V_c \cos(2\pi(f_c + \Delta f)t)$

At $V_m(t) = -1$, $V_{FSK} = V_c \cos(2\pi(f_c - \Delta f)t)$



$f_{space} = 0 \quad f_c - \Delta f$

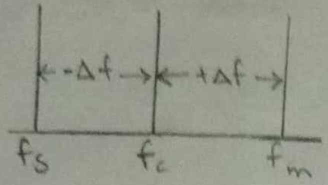
$f_{mark} = 1 \quad \Delta f + f_c$

* $\Delta f = \dfrac{|f_{mark} - f_{space}|}{2}$

frequency deviation

$B = 2(\Delta f + f_b)$

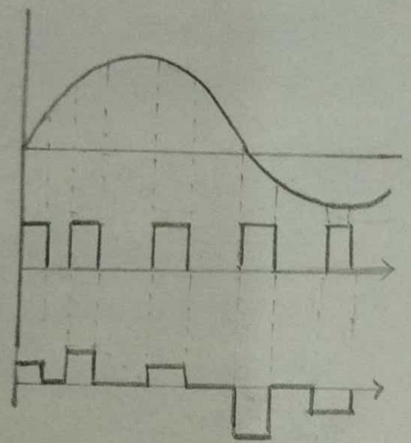
f_b = no. of bits per second

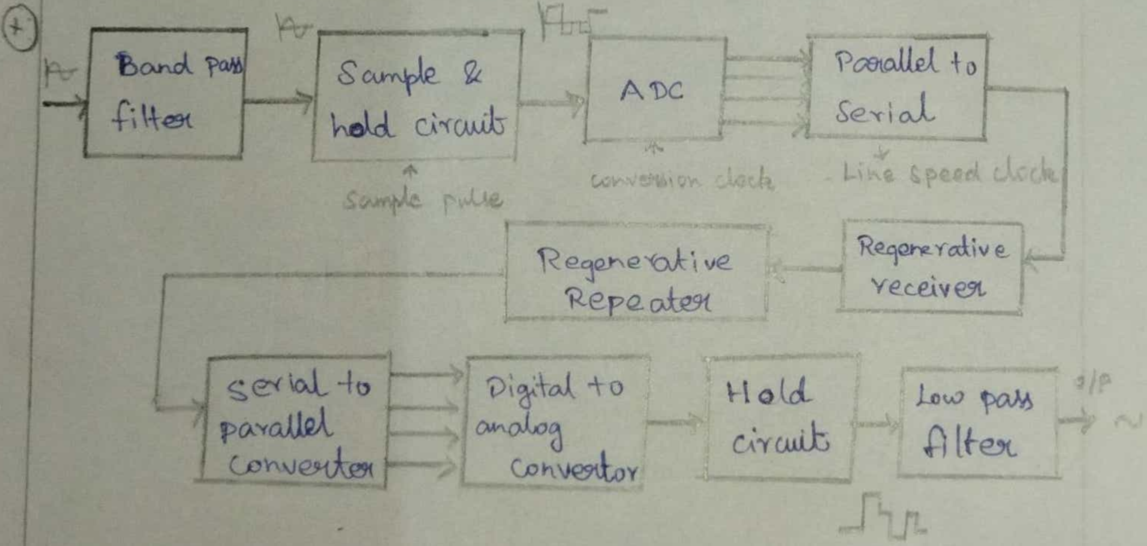


17.4.23 10m

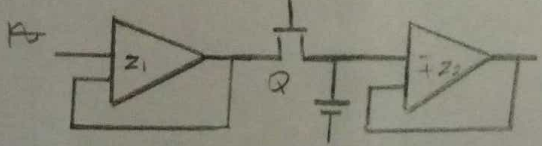
Pulse code modulation:

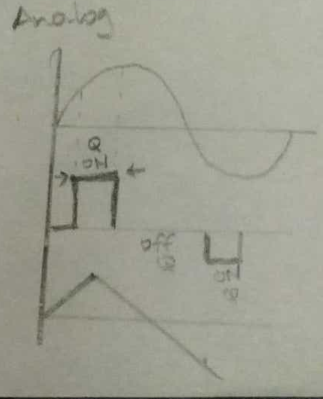
* convert discrete value to digital value.





Sample and Hold circuit:





Apperture time (sampling period)

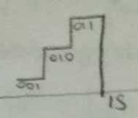
Multilevel (signal level)

Bitrate - no. of bits transfer per second

Baudrate - no. of levels - bits transfer.

Binary - only one level so bit & baud rate are Same.

3 signal levels {



bitrate = 9

baud - 9x3

= 27 h

Multilevel.

$N = \log_2 3$ $\quad 5V = \frac{5V}{2^3} = \frac{5}{8}$

$= 3.32 \log 8$ levels

$= 2.99$ (3 bit in each level)..