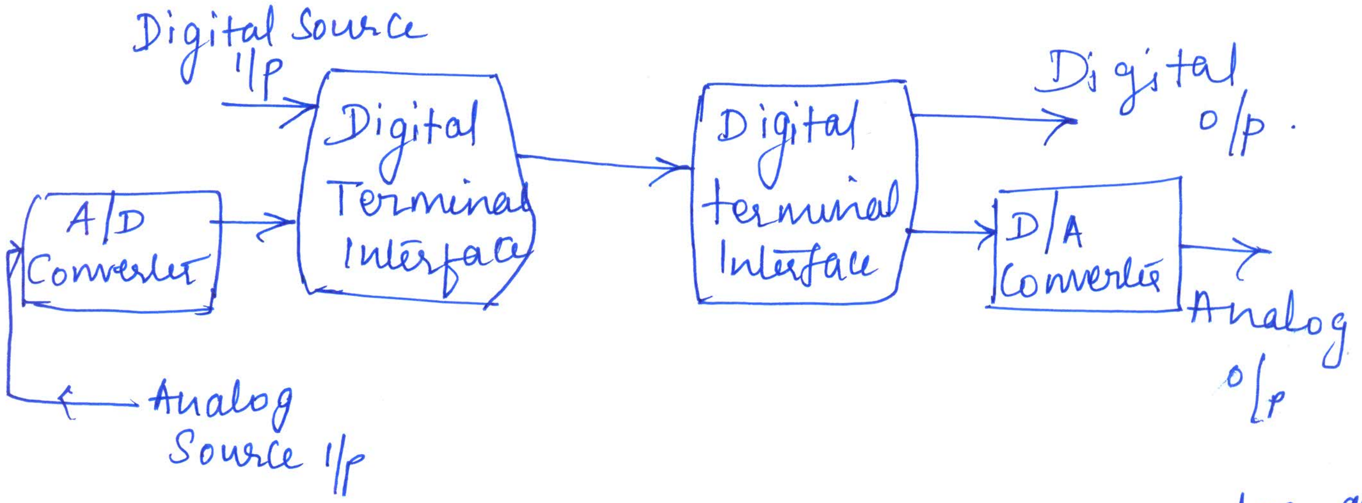
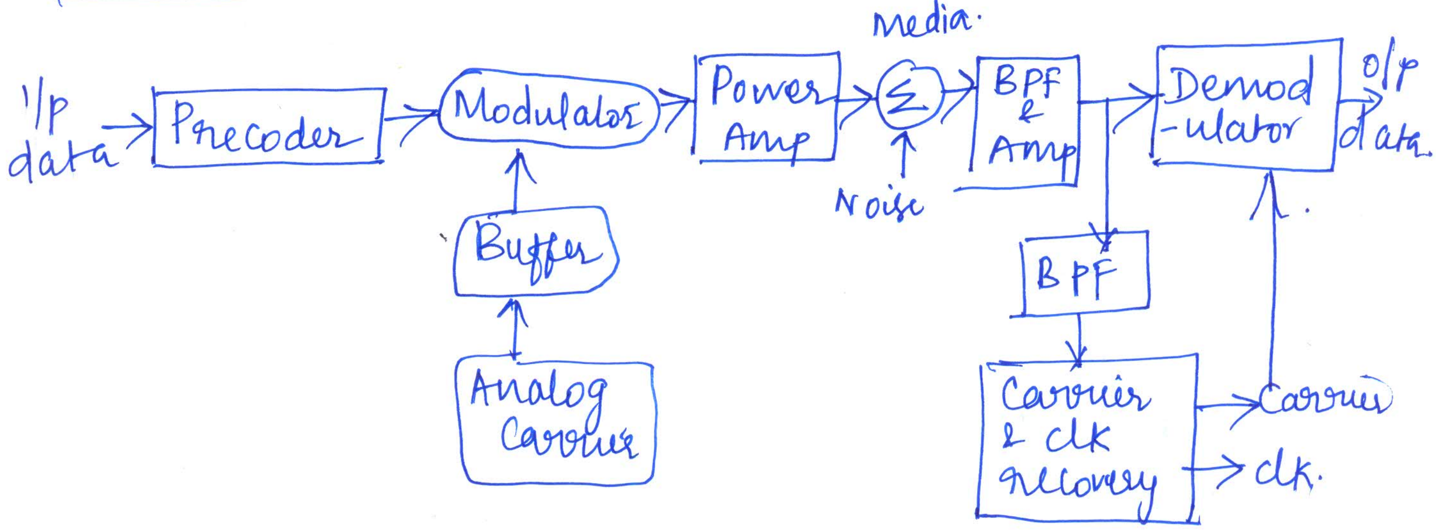
UNIT-II DIGITAL COMMUNICATION

Digital transmission systems :-



* Original information can be in analog or digital form.
* A/D converter converts analog into digital.
* digital signal is transmitted over a suitable medium and received by a receiver.
* D/A → converts digital into analog form.

Digital Radio System :-



SHANNON LIMIT FOR INFORMATION CAPACITY

Information Capacity :- It is a measure of how much information can be propagated through a communications system and it is a function of bandwidth and transmission time.

The most basic digital symbol used to represent information is the binary digit or bit.

Bit rate :- It is the number of bits transmitted during one second. It is expressed in bits per sec. (R).

Hartley's law :- Law is $I \propto B.T$.

where I - Information capacity (bps)

B - Bandwidth (Hz)

T - Transmission time (s).

From the Eqn, it can be seen that the information capacity is a linear function of bandwidth and transmission time and is directly proportional to both.

* Shannon's limit for information capacity is $I = B\log_2(1 + S/N)$ → Shannon's Information capacity theorem.

B → Bandwidth (Hz)

S/N → Signal to noise power ratio.

or

$$I = 3.32 B \log_{10}(1 + S/N).$$

* Trade off Between Bandwidth and SNR:

i) If the channel is noiseless, $N=0$.

$$I = B\log_2\left(1+\frac{S}{0}\right)$$

$$\frac{S}{N} \Rightarrow \text{Infinite}.$$

$$I \Rightarrow \text{Infinite}.$$

∴ Noiseless channel will have an infinite capacity.

ii) Assume that white gaussian noise is present. $S/N \neq \alpha$ $N = N_0B$.

We conclude that an ideal system with infinite bandwidth has a finite channel capacity. It is denoted by I_α

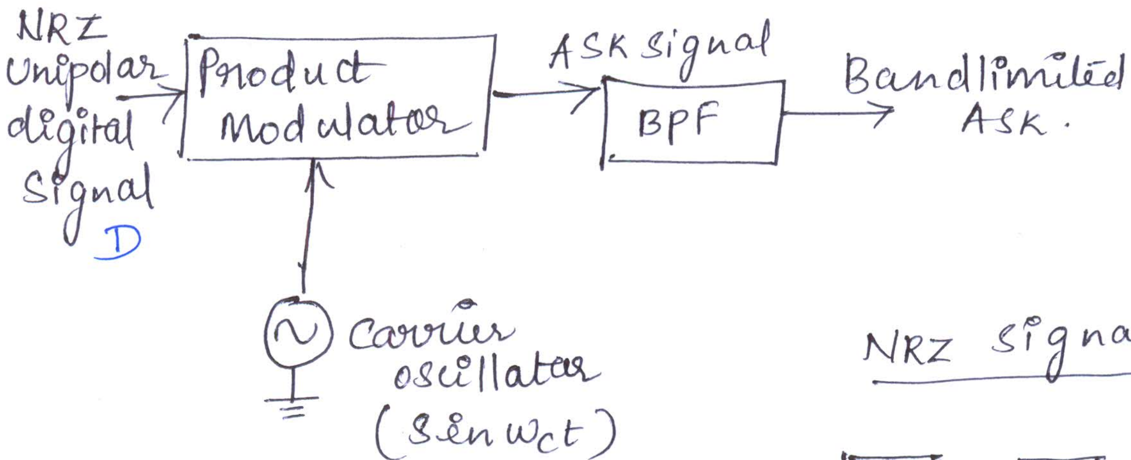
$$I_\alpha = 1.44\, S/N_0.$$

Digital Modulation Techniques

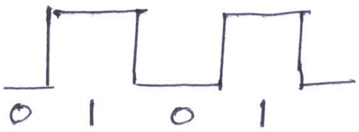
* Transmission of digital signal.
* Types
  i) Digital amplitude modulation or Amplitude Shift Keying (ASK)
  ii) FSK or BFSK - Binary FSK
  iii) PSK or BPSK - Binary PSK
  iv) QPSK - Quadrature PSK
  v) QAM. - Quadrature AM.

Amplitude Shift Keying or ASK or DAM

ASK Generator or modulator :-



NRZ signal



$T_b \rightarrow$ Bit time is the reciprocal of bitrate. $\therefore$ Bitrate $R = 1/T_b$

Let the carrier signal be $\sin w_c t$ or $\sin 2\pi f_c t$.
Let the digital I/p be NRZ unipolar signal.
From the block diagram, carrier is transmitted only when binary 1 is to be sent.
No carrier is transmitted when binary '0' is applied.

ASK signal can be expressed as,

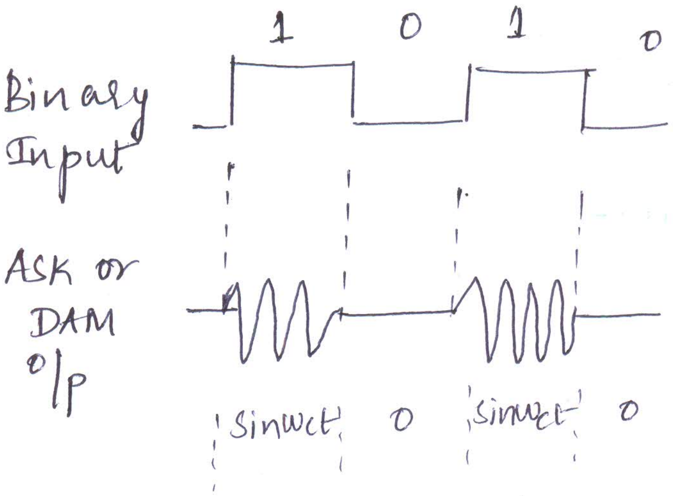
$$V_{ASK}(t) = D \cdot \sin w_c t.$$

$D \rightarrow$ data 0 or 1.

$$\therefore V_{ASK}(t) = \begin{cases} \sin w_c t, & d = 1 \\ 0, & d = 0. \end{cases}$$

Other Name: On-off Keying method.

Wave form :



- Bit 0 or 1 represent one symbol.
- Rate of symbol transmission is the baud rate.
- Baud rate = Bit rate.

Baud rate (N_b) : The rate of change of a signal on the transmission medium after encoding and modulation have occured.

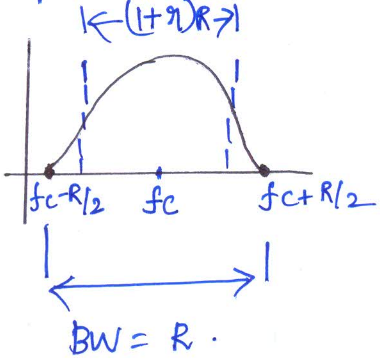
$$\text{Baud} = 1/t_s$$

$t_s \rightarrow$ time of one signalling element.

Transmission BW of ASK :

BW of ASK is dependent on the bit rate R,

$\therefore R = 1/T_b$ $\therefore$ The maximum BW required for an ASK is $\boxed{BW_{max} = R \ (Hz)}$



$\therefore$ Transmission BW can be restricted by a filter.

$\therefore$ $BW = (1+r)R$

$\downarrow$

factor related to filter characteristics.

Bit rate interms of baud rate :

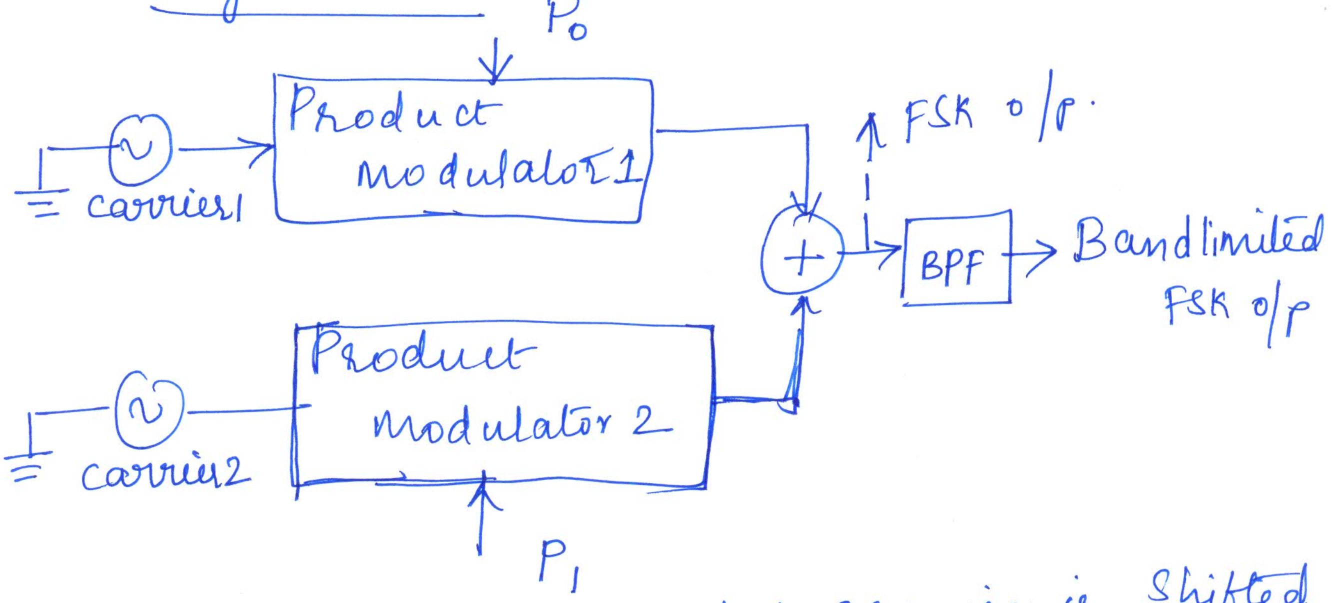
WKT, $BW = R$

if $R = N_b$

$$\boxed{BW = N_b}$$

FREQUENCY SHIFT KEYING (FSK):

FSK generator : Transmitter or modulator.



The frequency of a sinusoidal carrier is shifted between two discrete values.

Two oscillators produce sinusoidal carrier frequency f_1 and f_0.

carrier 1 − $\sin 2\pi f_0 t$

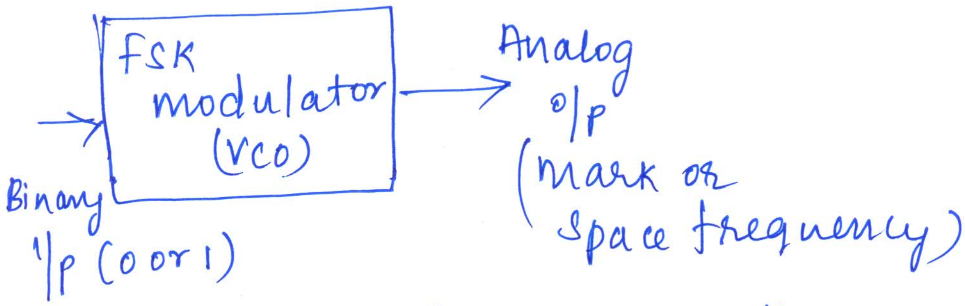
carrier 2 − $\sin 2\pi f_1 t$

FSK signal can be expressed as,

$$V_{FSK}(t) = P_0 \sin 2\pi f_0 t + P_1 \sin 2\pi f_1 t.$$

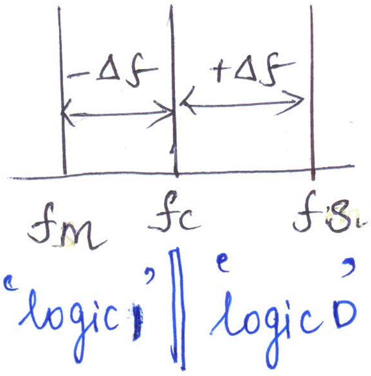
$P_0 = 0,\ P_1 = 1 \Rightarrow$ o/p is $\sin 2\pi f_1 t$

$P_0 = 1,\ P_1 = 0 \Rightarrow$ o/p is $\sin 2\pi f_0 t$.



With binary FSK, the carrier frequency is shifted by the binary I/p data.

As the binary I/p signal changes from logic 0 to logic 1, then O/p shifts between two frequencies, mark or logic 1 frequency and space or logic 0 frequency.



∴ frequency deviation

$$2\Delta f = f_m - f_s$$

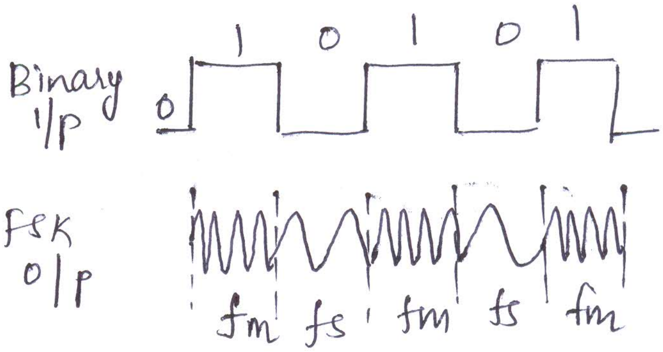
$$\Delta f = \frac{|f_m - f_s|}{2}$$

It is half the difference b/w mark & space frequencies.

Truth table:

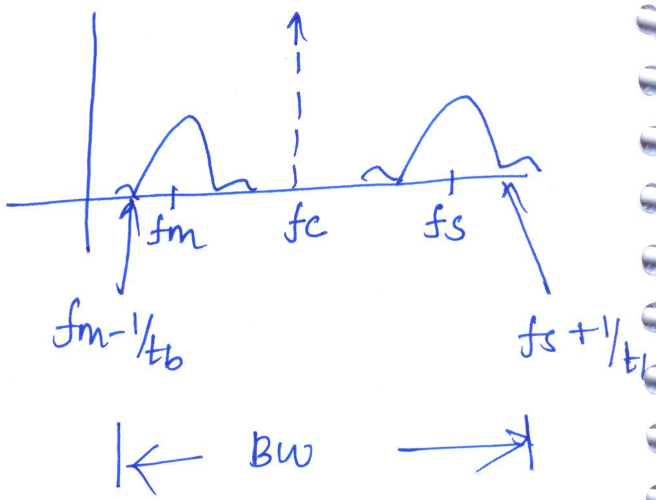
Bin I/p	Frequency o/p
0	Space(f_s)
1	Mark(f_m)

Waveforms



WKT $f_m = f_c - \Delta f$

$f_s = f_c + \Delta f$



$BW = f_s + \frac{1}{t_b} - f_m + \frac{1}{t_b}$

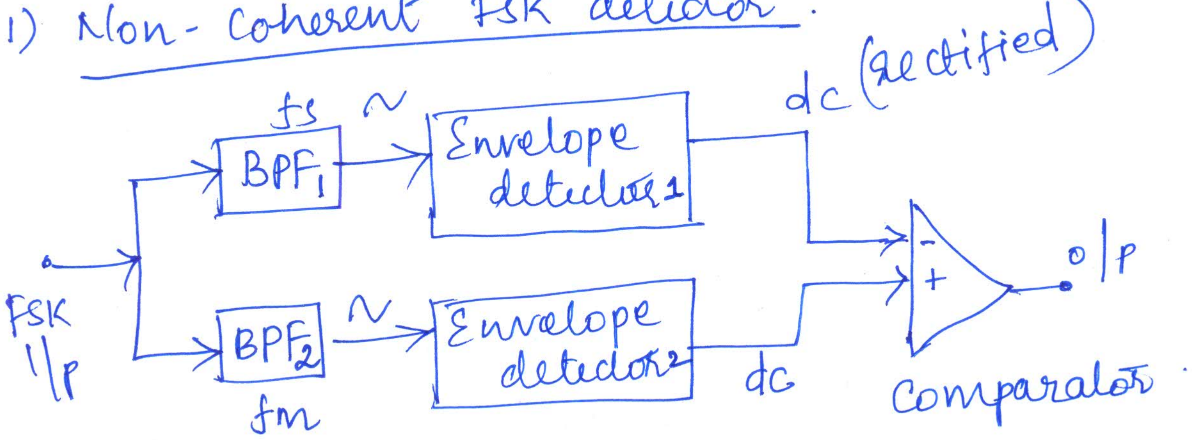
$= f_s - f_m + 2/t_b$

$= 2\Delta f + 2 f_b$

$\boxed{BW = 2(\Delta f + f_b)}$

FSK Receiver : or Demodulator or detector.

1) Non-Coherent FSK detector :

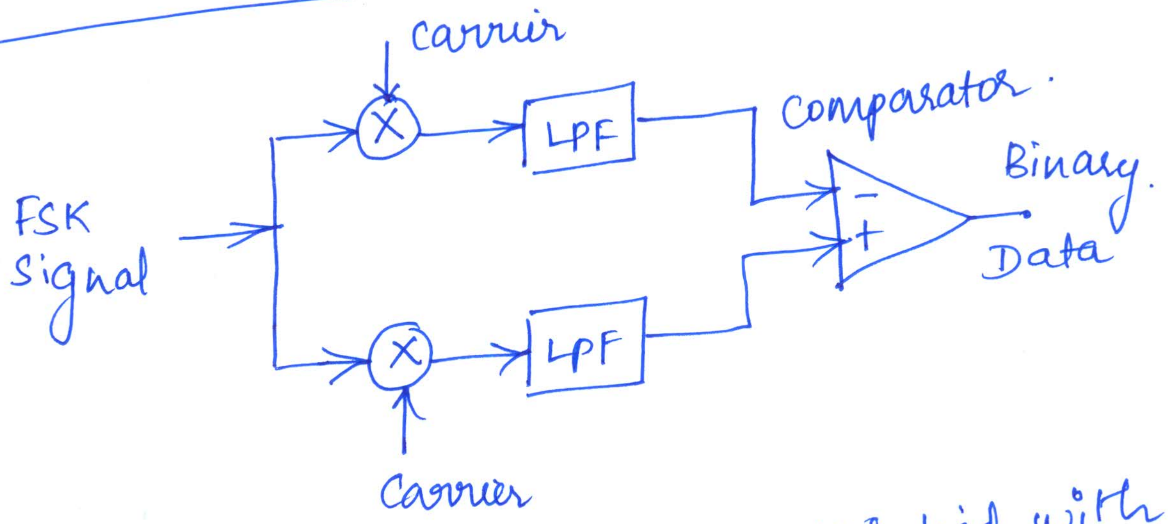


The respective BPF passes only mark or the space frequency on to its respective envelope detector. Envelope detector indicate total power in each pass band and the Comparator responds to the largest of two powers.

Envelope detector → diode detectors which rectify & filter their i/p's. (dc vtg ∝ to ac i/p)

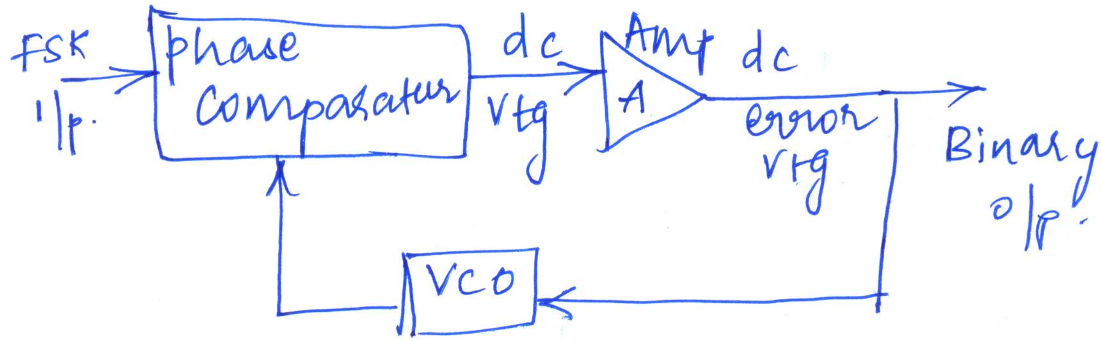
Received BFSK signal is fs, then it passes to ED1 through BPF1 and O/P of BPF2 is zero. Then the comparator O/P will be positive representing logic 1.
otherwise, BFSK is fm, O/P of BPF1 is zero, comparator O/P be zero represents logic 0.
Thus original data is recovered by the receiver.

2) COHERENT FST DEMODULATOR:-



The incoming FSK signal is multiplied with the recovered carrier signals. This signal has exactly the same frequency and phase of the reference carrier at the transmitter. The frequencies fm & fs are not continuous. Filtered O/ps are applied to comparator. Comparator O/P is a digital signal.

3) FSK Demodulation using PLL.



As the FSK frequency shifts b/w mark & space frequencies. The dc error voltage at the o/p of the phase comparator follows the frequency shift.

Corresponding to the two i/p frequencies, there will be two values of dc error voltage. Thus we get binary data at the o/p.

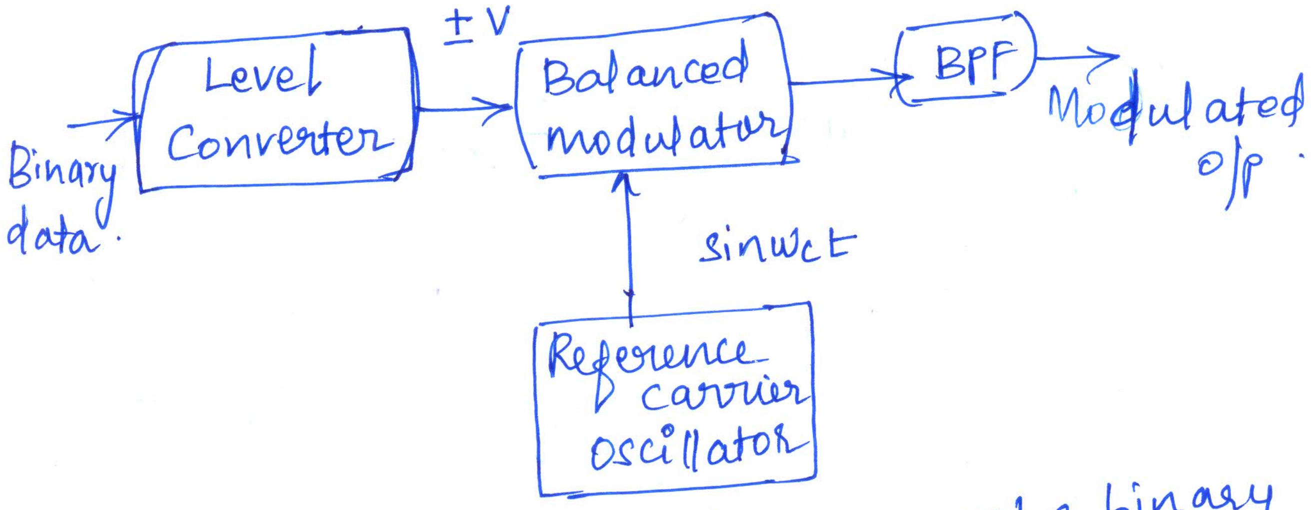
PHASE SHIFT KEYING [PSK or BPSK]

The phase of the carrier signal is varied according to the binary input signal. More efficient than the other modulation methods, therefore it is used for high bit rates.

BPSK :- The carrier phase is changed between 0° and 180° by the bipolar signal.

Other Name :- Phase reversed keying or Biphase modulation

BPSK generator : (Transmitter)



Level Converter is used to convert a binary data into NRZ signal. (bipolar signal).

Balanced modulator is used to multiply carrier signal and ±V.

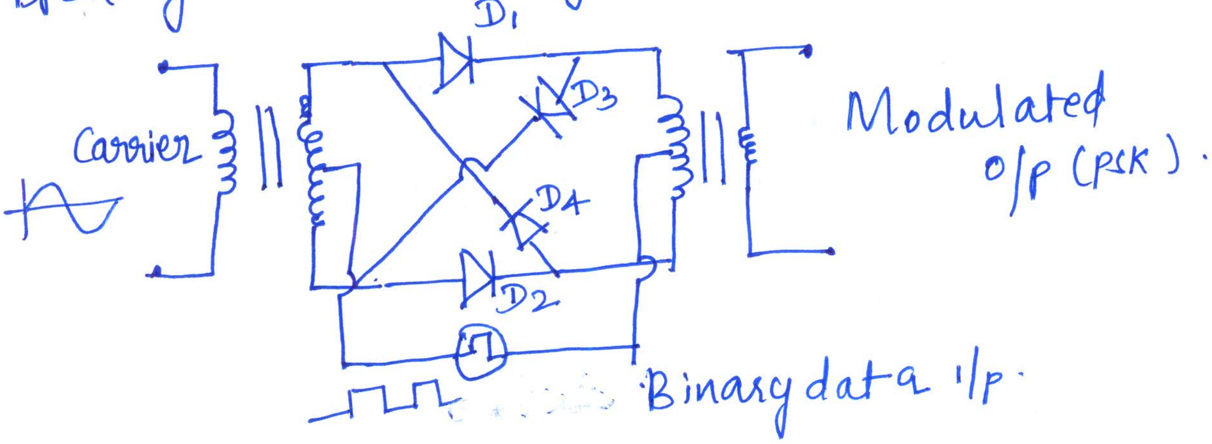
Two o/p phases are possible for a single carrier frequency signal.

Balanced modulator is used as a phase reversing switch.

Binary 0 to logic '0' → Negative

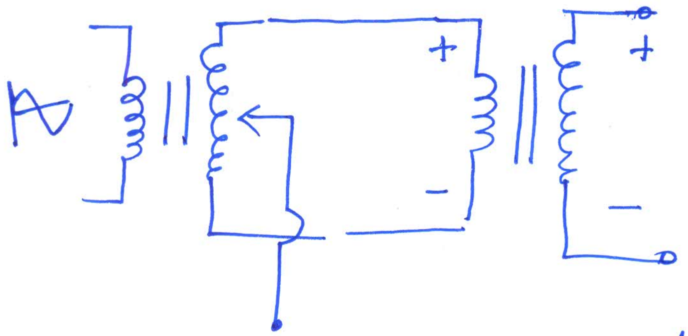
Binary 1 to logic 1 → Positive.

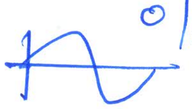
BPSK generator using Balanced ring modulator (diodes) :



Logic 1 I/p :

D_1 and $D_2 \Rightarrow FB \Rightarrow$ Short Circuited.



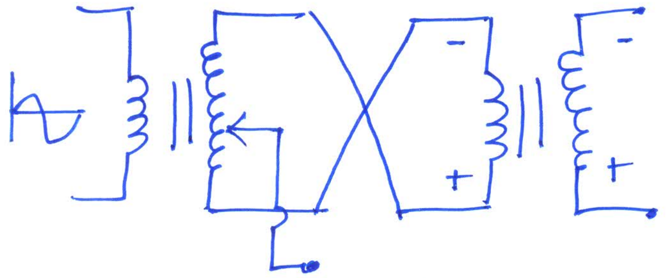


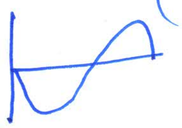
o/p $(+\sin w_c t)$.

+V = Bin 1

* o/p signal is inphase with the carrier I/p signal.

Logic '0' I/p :





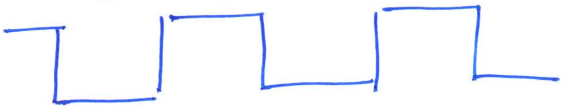
$(-\sin w_c t)$

-V Bin 0

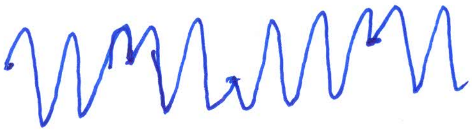
o/p signal is out of phase with the carrier.

0 1 0 1

I/p.



o/p.



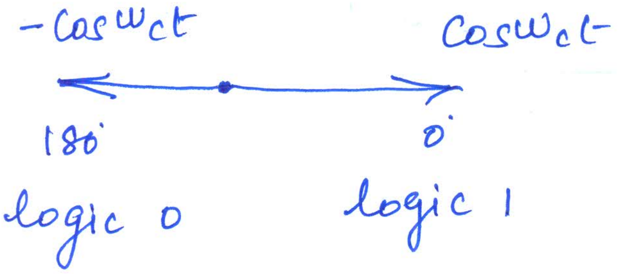
i.e. $\sin 2\pi f_c t \cdot \sin 2\pi f_a t$

$$= \frac{\cos 2\pi(f_c - f_a)t - \cos 2\pi(f_c + f_a)t}{2}$$

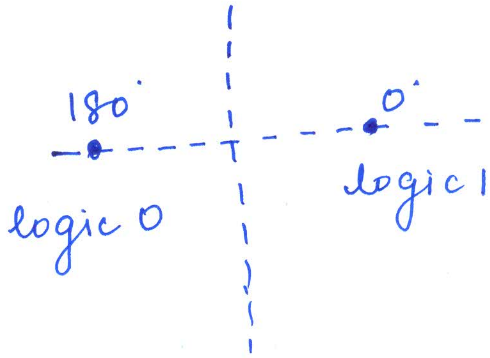
Truth table

Binary I/p	Phase o/p
logic 0	180°
logic 1	0°

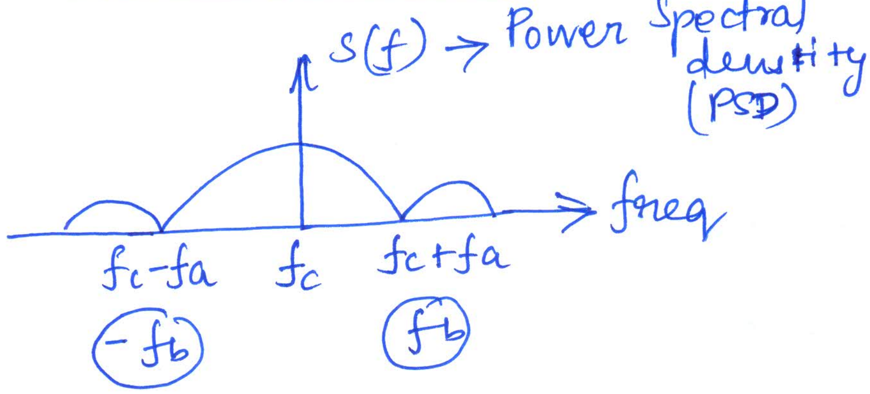
Phasor diagram :



Constellation diagram



Spectrum of BPSK :



Bandwidth

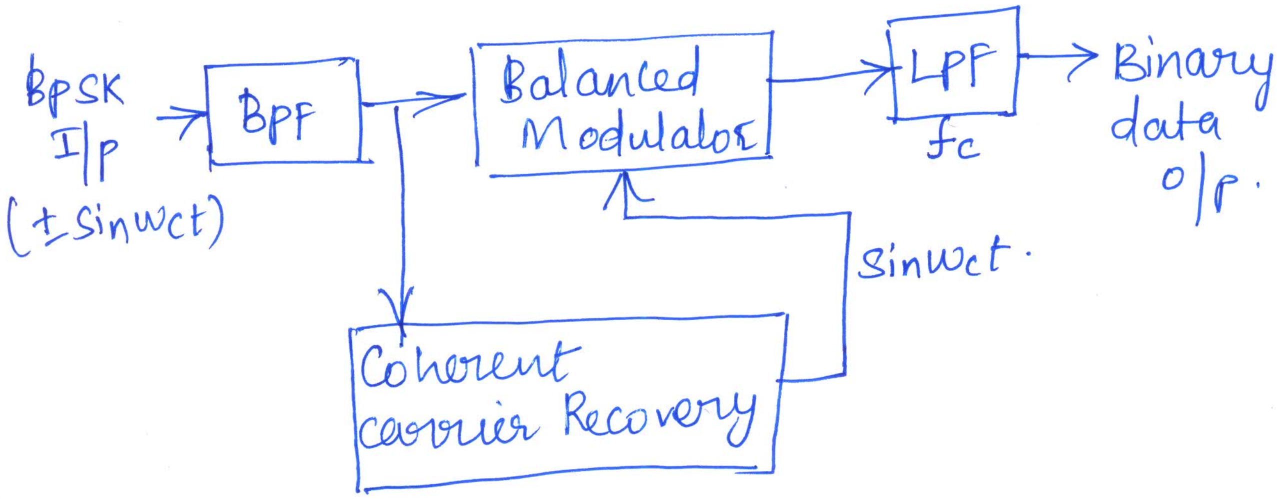
$$= 2f_a$$

$$= \frac{\cancel{2} f_b}{\cancel{2}}$$

$$B_{max} = f_b$$

$\sin 2\pi f_a \rightarrow$ fundamental frequency of binary signal.

BPSK Receiver :



① I/p signal is $+\sin w_c t$:

Modulator O/p is $\Rightarrow \sin w_c t \cdot \sin w_c t = \sin^2 w_c t$

$$= \frac{1 - \cos 2 w_c t}{2}$$

$$= \frac{1}{2} - \frac{\cos 2 w_c t}{2}$$

After filtering, $\Rightarrow \frac{1}{2}$ = +ve o/p.

= logic 1.

($\cos 2 w_c t$ is filtered by LPF)

② I/p signal is $-\sin w_c t$,

O/p is $-\sin^2 w_c t$

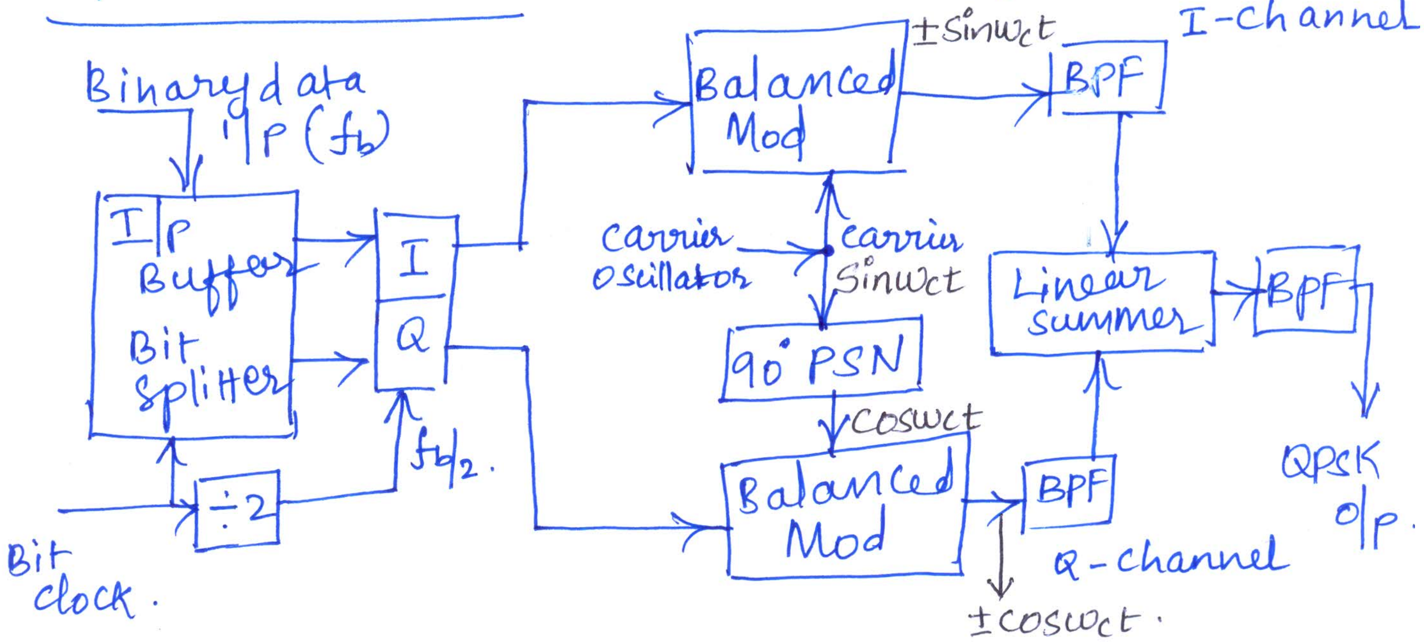
$$= -\left[\frac{1 - \cos 2 w_c t}{2}\right]$$

After filtering $= -1/2$ = -Ve o/p = logic 0.

QUADRATURE PHASE SHIFT KEYING (QPSK)

* M-ary encoding scheme, four o/p phases are possible, Binary i/p data are combined into group of 2 bits called dibits.
* 4 o/p phases are 45°, 135°, −45°, −135°.
* 2 bits I/p produce one o/p phase change. Therefore the rate of change at the o/p (baud rate) is one-half of the I/p bit rate.

QPSK Modulator: (Transmitter):

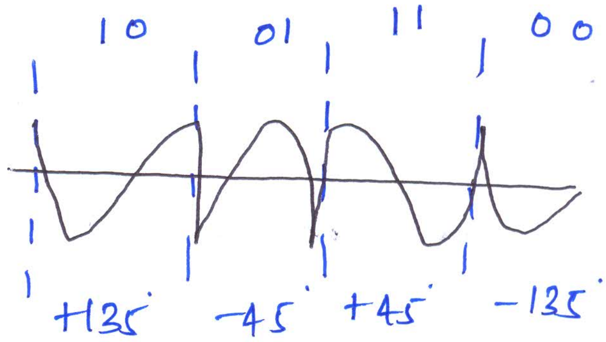


- Two bits are clocked into Bit splitter.
- Both bits are serially inputted and parallely outputted. One bit to I channel and other to Q-channel.
- I bit modulates a carrier that is inphase with the reference carrier.
  Q bit modulates a carrier that is out of phase with the reference carrier.

logic 0 = −1 v (−ve) & logic 1 = +1 v (+ve).

Truth table

Binary i/p Q	Binary i/p I	o/p phase
0	0	−135°
0	1	−45°
1	0	+135°
1	1	+45°



Bit rate in I or Q channel is equal to one half of the input data rate $f_b/2$.

one half of $f_b/2 = f_b/4$.

$$o/p = \sin w_a t \cdot \sin w_c t$$

$$f_a = f_b/4.$$

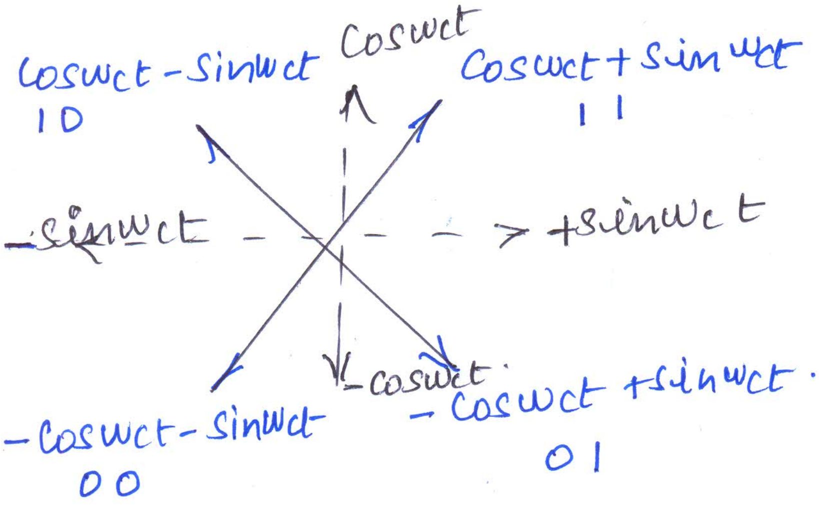
$$= \underbrace{\sin 2\pi \frac{f_b}{4} t}_{\sin B} \quad \underbrace{\sin 2\pi f_c t}_{\sin A}.$$

$$= \frac{1}{2}\left[\cos 2\pi\left(f_c - \frac{f_b}{4}\right)t - \cos 2\pi\left(f_c + \frac{f_b}{4}\right)t\right]$$

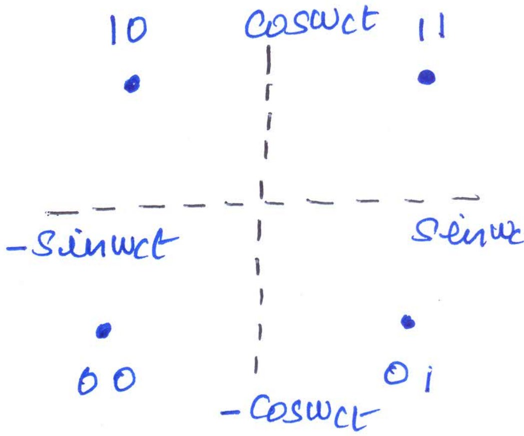
Spectrum: $f_c + f_b/4$ to $f_c - f_b/4$.

$$BW = 2\frac{f_b}{4} = \frac{f_b}{2}$$ //.

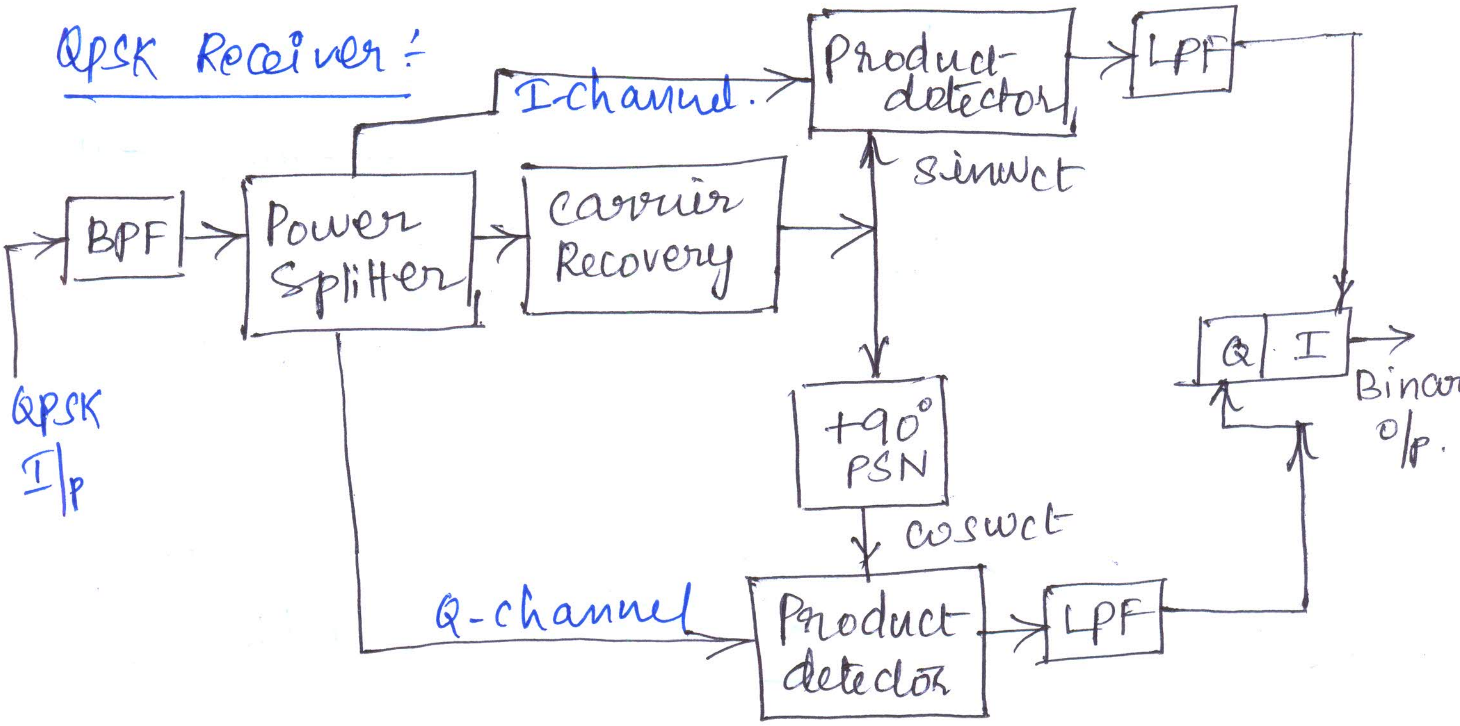
Phasor diagram



Constellation



QPSK Receiver :-



I channel:

Consider I/p is $-\sin\omega_c t + \cos\omega_c t$

Product detector (Multiplier) $= (-\sin\omega_c t + \cos\omega_c t) \times \sin\omega_c t$

$$= -\sin^2\omega_c t + \sin\omega_c t \cdot \cos\omega_c t$$

$$= -\left[\frac{1-\cos 2\omega_c t}{2}\right] + \left[\frac{\sin(\omega_c+\omega_c)t + \sin(\omega_c-\omega_c)}{2}\right]$$

$$= \frac{-1}{2} + \underbrace{\frac{1}{2}\cos 2w_ct + \frac{1}{2}\sin 2w_ct}_{\text{filtered out}} + \underbrace{\frac{1}{2}\sin 0}_{\text{zero}}.$$

filtering,

$$= \frac{-1}{2} = -ve \text{ (logic 0)}.$$

Q channel:

$$= (-\sin w_ct + \cos w_ct)\cos w_ct.$$

$$= \cos^2 w_ct - \sin w_ct \cos w_ct.$$

$$= \frac{1}{2} + \underbrace{\frac{1}{2}\cos w_ct - \frac{1}{2}\sin 2w_ct}_{\text{filtered}} - 0$$

$$= +\frac{1}{2}\ (+ve) = \text{logic } 1.$$

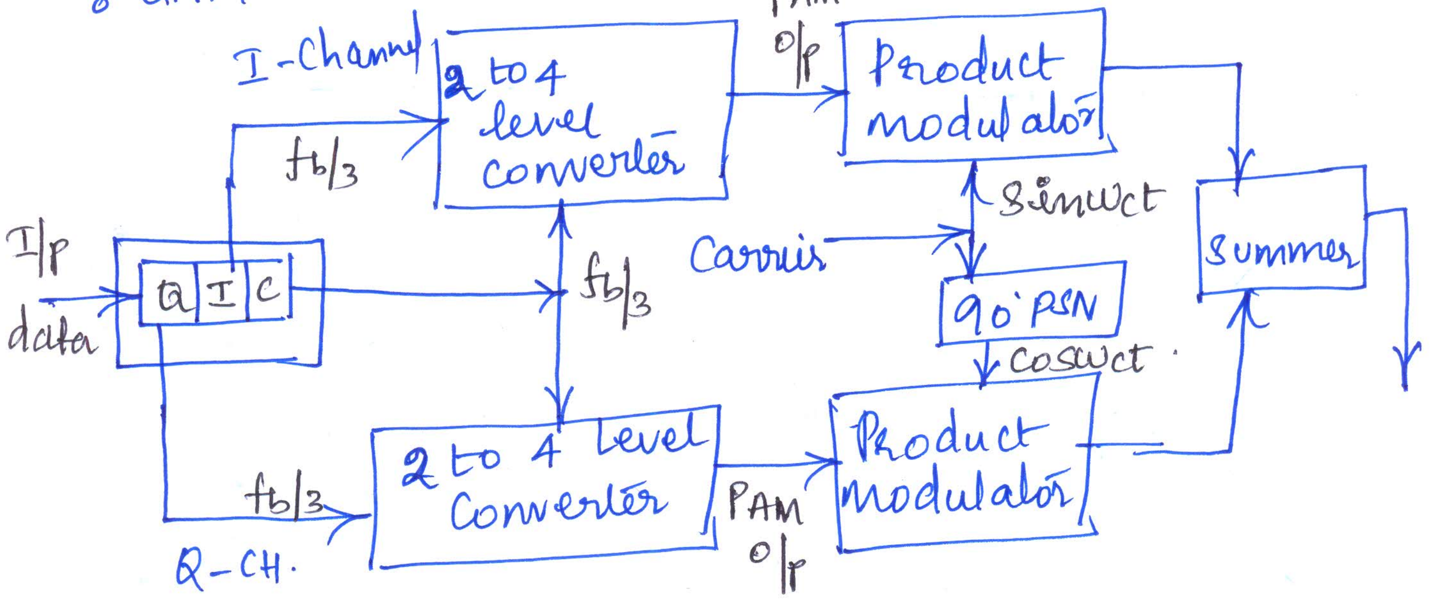
QUADRATURE AMPLITUDE MODULATION (QAM).

QAM is a form of digital modulation where the digital information is contained in both amplitude and phase of the transmitted carrier.

M-ary encoding technique.

M = 8, 8 QAM modulator is not having a constant amplitude signal.

8-QAM Transmitter :



* Incoming data is divided into group of 3bits → I, Q, C bit streams.
* I & Q determine the polarity of PAM.
* C channel determine the magnitude.
* Magnitude of I & Q of PAM signal are equal.
* The direct modulation of carrier in quadrature is involved, then system is called as QAM. Hence noise immunity will improve if the signal vectors differ in phase as well as in amplitude.

Truthtable : (I/Q channel)

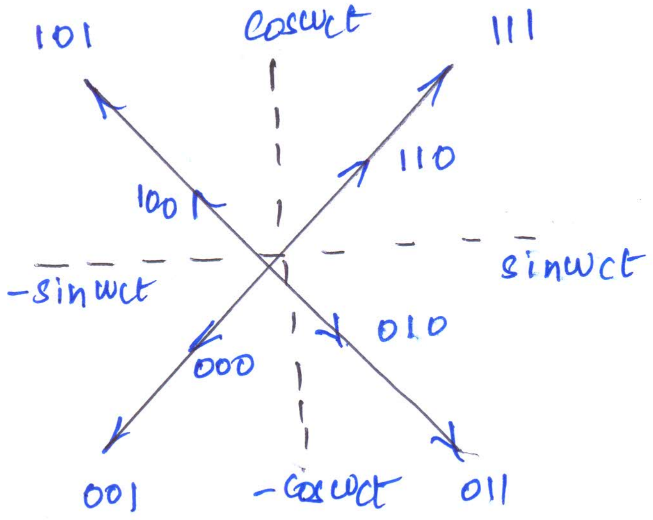
I/Q	C	O/P
0	0	-0.541 V
0	1	-1.307 V
1	0	+0.541 V
1	1	+1.307 V

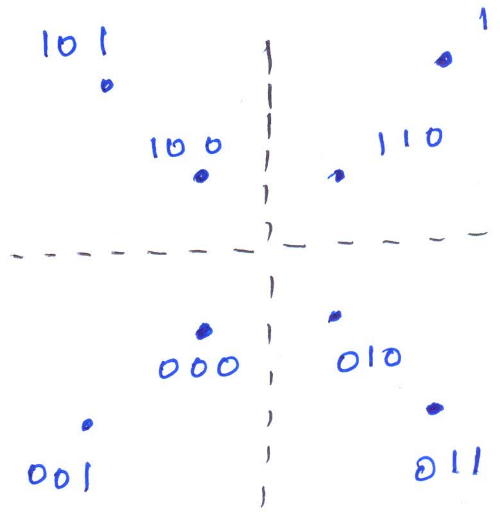
8-QAM Truth table

Binary I/P			8 QAM O/P	
Q	I	C	Amp	phase
0	0	0	0.765	-135°
0	0	1	1.848	-135°
0	1	0	0.765	-45°
0	1	1	1.848	-45°
1	0	0	0.765	+135°
1	0	1	1.848	+135°
1	1	0	0.765	+45°
1	1	1	1.848	+45°

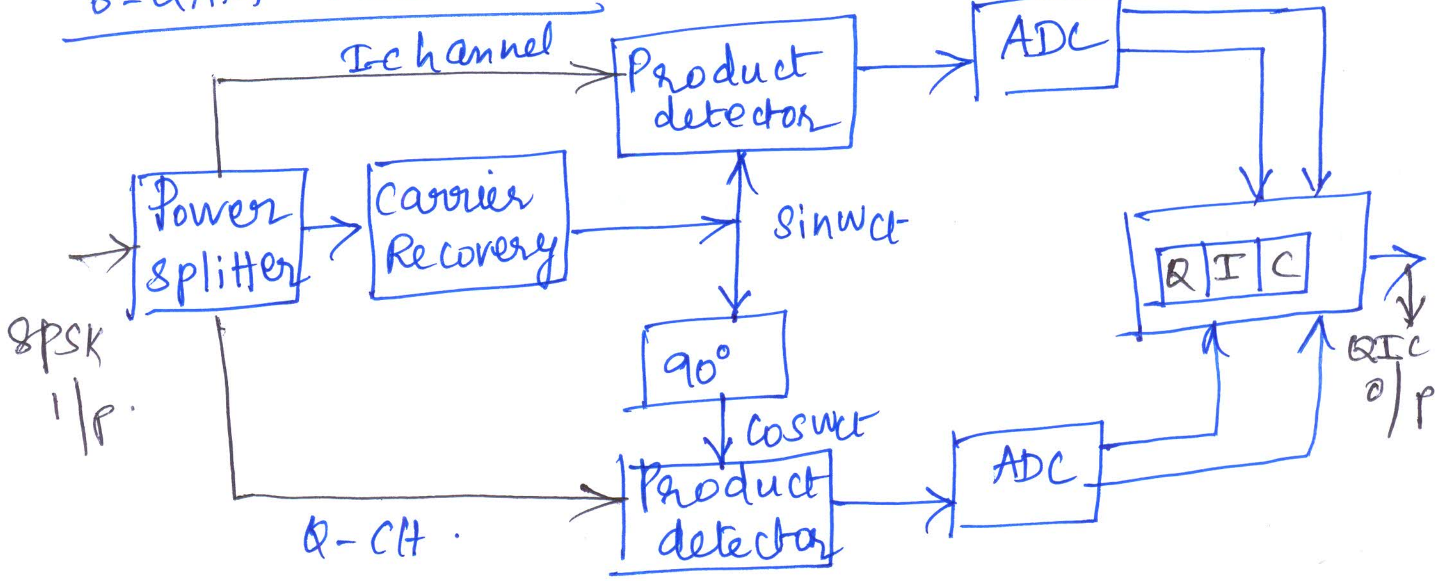
Phasor diagram

Constellation





8-QAM-Receiver:



Bandwidth Efficiency :- or Information density.

It is used to compary the performance of one digital modulation technique to another. It is the ratio of transmission bit rate to the minimum bandwidth required for a modulation scheme.

ie BW Efficiency $\frac{(bPS)}{(Hz)}$ = $\frac{\text{transmission rate}}{\text{minimum BW}}$.

CARRIER RECOVERY: or Phase referencing:

It is the process of extracting a phase coherent reference carrier from a received signal.

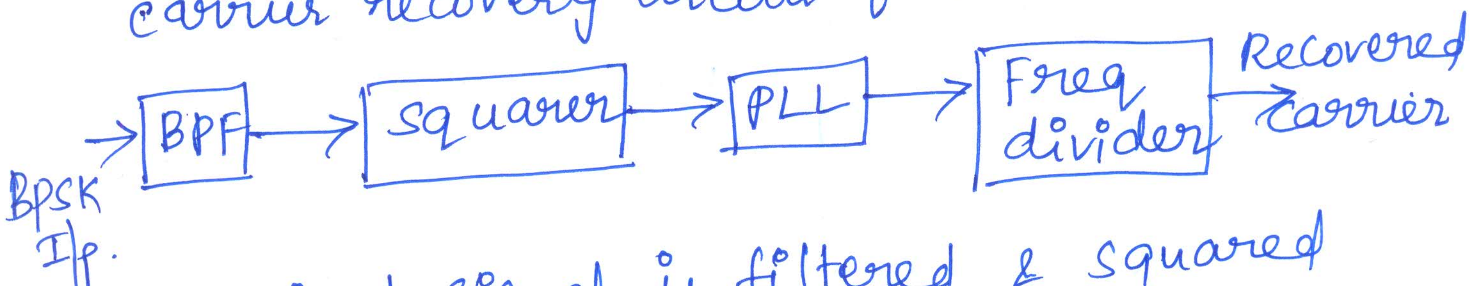
function: To determine the absolute phase of the received carrier, it is necessary to produce a carrier at the receiver that is phase coherent with the transmit reference oscillator.

Methods: 1) Squaring loop
2) costas loop.

Squaring loop!

It is the common method of acheiving carrier recovery for BPSK.

carrier recovery circuit for BPSK Receiver:



1) Received signal is filtered & squared
2) filtering reduces the spectral width of the received noise
3) Squaring circuit removes the modulation and also generates the second harmonic of the carrier frequency.
4) This harmonic is phase tracked by PLL.

5) The VCO o/p frequency from PLL is divided by 2 and it is used as the phase reference for the product detectors.

Ex: BPSK o/p's are $\pm \sin \omega_c t$.

Squarer i/p is $+\sin \omega_c t$

o/p is $\sin^2 \omega_c t$

$$= \frac{1 - \cos 2\omega_c t}{2}$$

$$o/p = \frac{1}{2} - \frac{1}{2}\cos 2\omega_c t$$

$\boxed{\text{over all o/p} = \cos 2\omega_c t}$.

||ly i/p is $-\sin \omega_c t$

$\boxed{\text{over all o/p is } \cos 2\omega_c t}$.

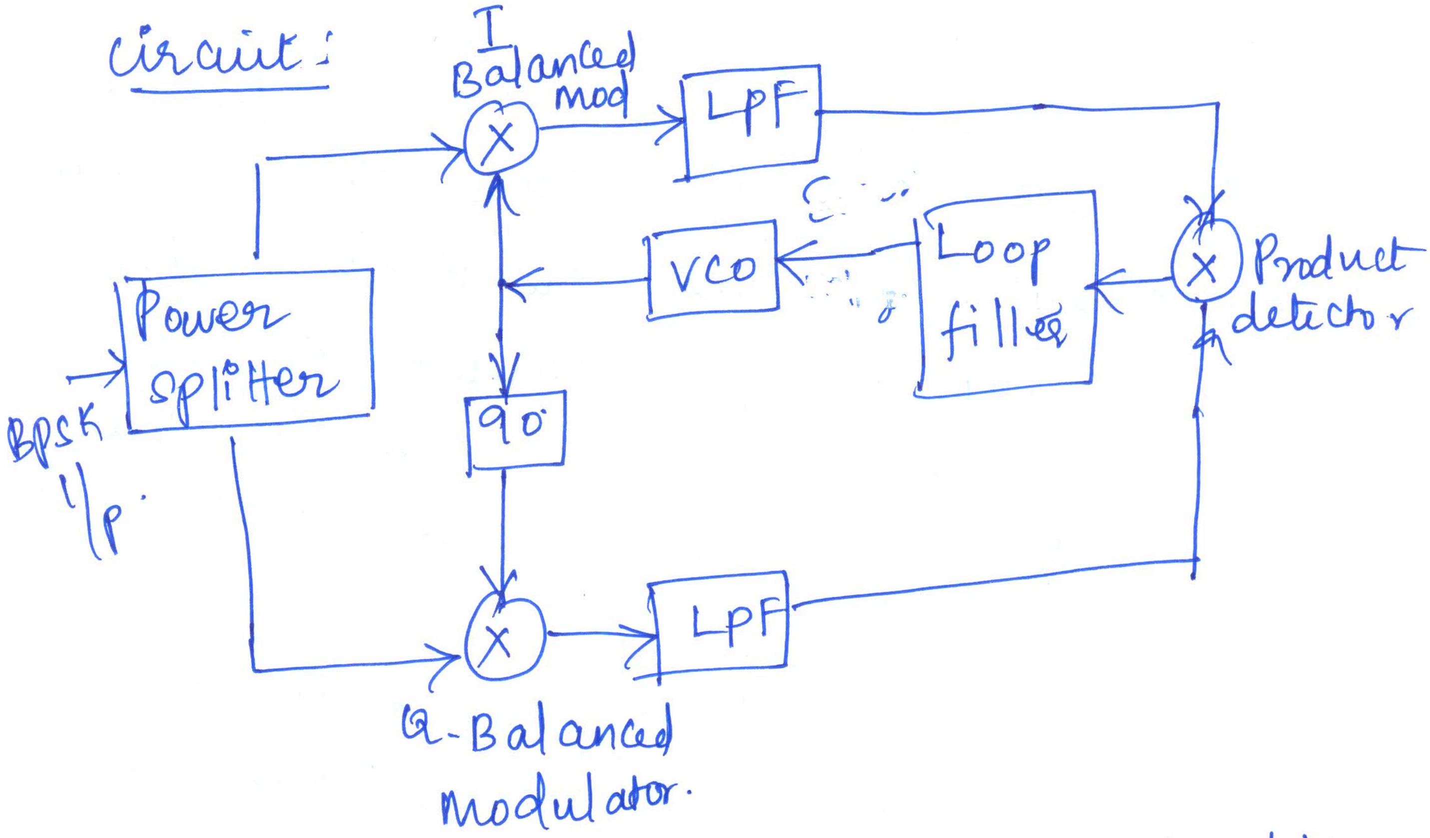
o/p from the squaring circuit contained constant voltage $\frac{1}{2}$V and $\cos 2\omega_c t$.

Costas loop:

Other name is quadrature loop.

Costas loop produces the same results as a squaring circuit followed by an ordinary PLL in place of BPF.

Circuit :



→ Recovery scheme uses two parallel tracking loops (I & Q) simultaneously to derive the product of I & Q components of the signal that drive the VCO.

→ In phase (I loop) uses VCO as in a PLL.

→ Q loop uses 90° shifted VCO signal.

→ Once the frequency of VCO is equal to suppressed carrier frequency, the product of I & Q signals will produce an error voltage proportional to phase error in VCO.

→ Error voltage controls the phase & frequency of VCO.

DIFFERENTIAL BPSK : (DBPSK) or (DPSK).

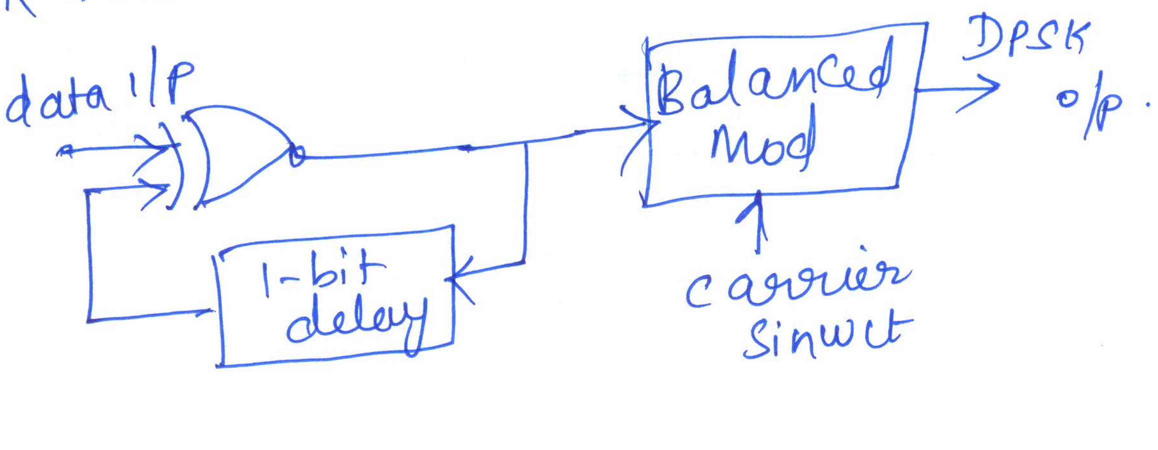
→ It is an alternative form of digital modulation, where the binary i/p information is contained in the difference b/w two successive signalling elements rather than the absolute phase.

Two basic operation in DPSK is
1) differential encoding 2) Phase shift keying.

→ It is not necessary to recover a phase coherent carrier. A received signalling element is delayed by one signalling element.

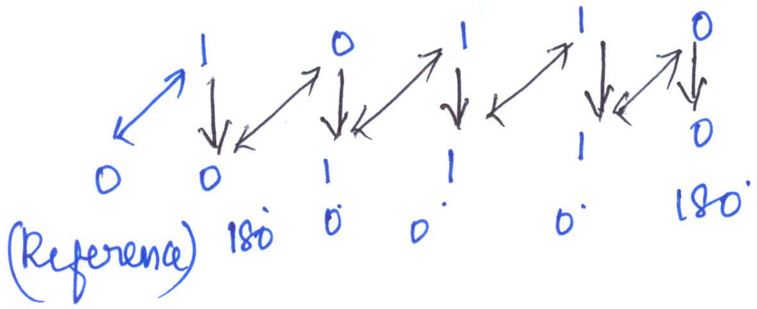
→ The difference in the phase of these two elements determine the logic condition of the data.

DPSK transmitter :-



An incoming information bit is XNORed with preceding bit prior to enter the modulator.

Initial reference bit should be assumed.



XNOR o/p

first bit	Reference bit	o/p
1	1	1
0	0	1
0	1	0
1	0	0

If XNOR o/p is 1, Balanced modulator op is $+\sin \omega_c t$.

" " " " 0, " " $-\sin \omega_c t$.

DPSK Receiver :