Digital modulation techniques :-

info → digital, carrier → analog

A baseband digital signal is used to modulate the sinusoidal carrier. The three basic signaling schemes used :-

1.) Amplitude shift keying
2.) Phase shift keying
3) Frequency shift keying

Digital Modulation techniques hierarchy

1. coherent techniques.
2.) Non-coherent techniques

① In coherent digital modulation techniques, we have to use a phase synchronized carrier to be generated at the receiver to recover the info signal. So the phase & frequency of carrier is synchronised with transmitter.

② In non-coherent, no phase synchronisation of local carrier is needed at receiver.

Binary and M-ary schemes :-

$\{2^N = M \leftarrow M = \text{no. of o/p}\}$

In binary we send any one of the two possible signals during each signaling interval of duration T_b.

In M-ary we send any one of the M-possible signals during each signaling interval of duration T_b.

Amplitude shift keying / ON-OFF keying

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

It is represented as

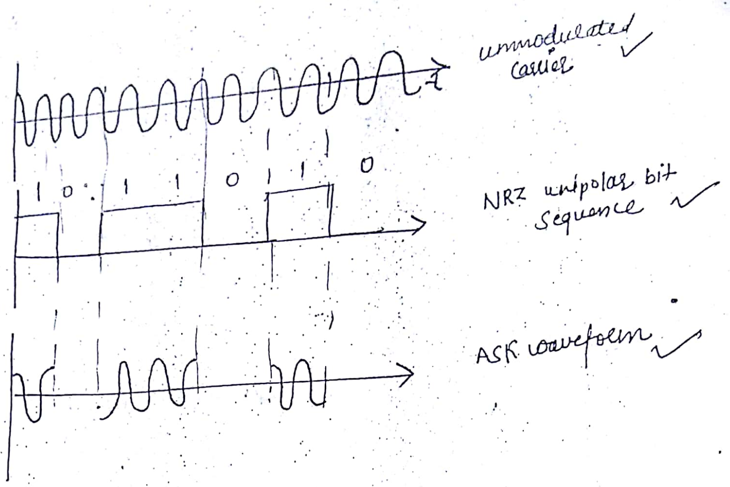
for 1 $\boxed{s(t) = \sqrt{2P_s}\cos(2\pi f_c t)}$

for 0 $s(t) = 0$

P_s = signal Power, $s(t)$ = output (modulated)

Hence, ASK waveform looks like ON-OFF of the signal
So, it is also called ON-OFF keying.

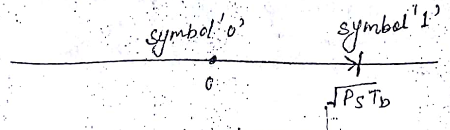
$$B = \frac{f_b}{1} = f_b, \quad Baud = \frac{f_b}{1} = f_b$$



* Signal space diagram of ASK

→ The ASK waveform for symbol '1' is

$$s(t) = \sqrt{P_s T_b} \cdot \sqrt{2/T_b} \cos(2\pi f_c t)$$
$$= \sqrt{P_s T_b}\ \phi_1(t)$$



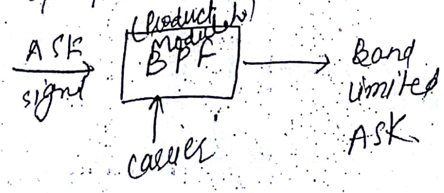
signal space diagram

→ Distance between two signal points is

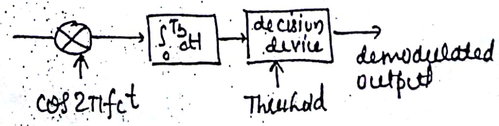
$$d = \sqrt{P_s T_b}$$
$$= \sqrt{E_b}$$

* Generation of ASK signal

↳ Apply binary data and sinusoidal carrier to the inputs of product modulator. The output is ASK waveform.



Demodulation



* Frequency shift keying:

②

→ FSK is constant-amplitude angle-modulation is similar to standard frequency modulation (FM) except the modulating signal is a binary signal that varies between 2 discrete voltage levels rather than continuously changing analog waveform.

General expression for FSK

$$v_{fsk}(t) = V_c \cos[2\pi [f_c + v_m(t)\,\Delta f]\, t]$$

V_c = peak analog carrier amplitude (Volt)
f_c = analog carrier center frequency (Hz)
Δf = peak change in analog carrier frequency (Hz)
$v_m(t)$ = binary input signal (V)

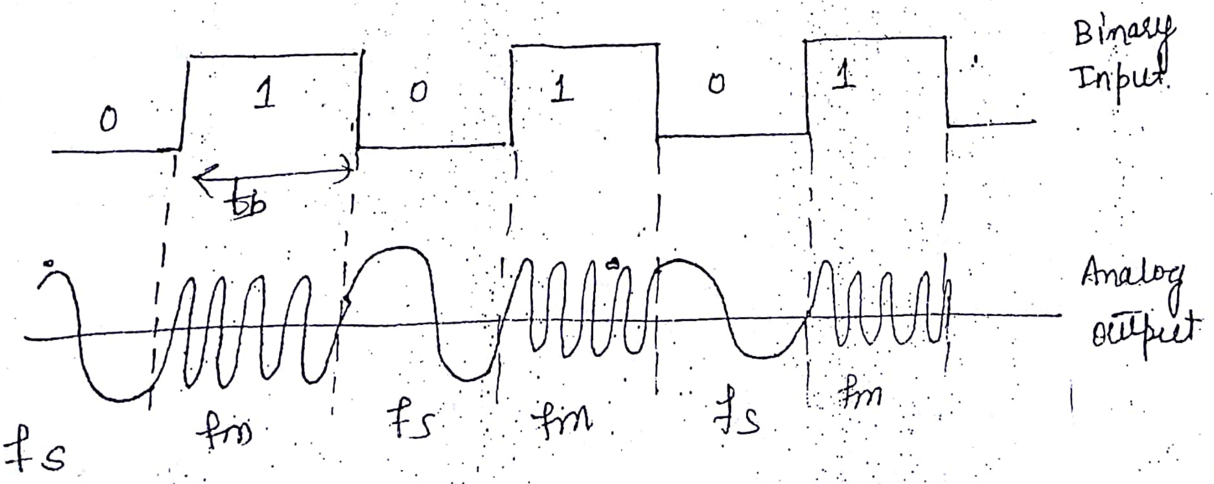
- for logic 1 input, $v_m(t) = +1$; logic 0 input $v_m(t) = -1$

$$v_{fsk}(t) = V_c \cos[2\pi (f_c + \Delta f) t] \quad \text{logic } 1.$$
$$v_{fsk}(t) = V_c \cos[2\pi (f_c - \Delta f) t] \quad \text{logic } 0.$$

- 2 frequencies are there, mark frequency f_m and space frequency f_s.

$$f_s = f_c - \Delta f, \quad f_m = f_c + \Delta f$$

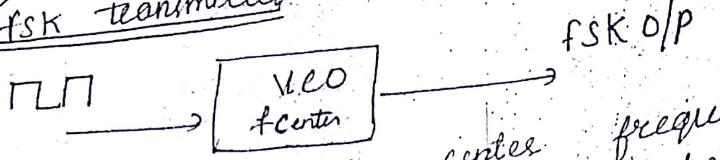
$$\underline{\underline{f_m - f_s = 2\Delta f}}$$



Baud = f_b, Bandwidth $= |(f_s + f_b) - (f_m - f_b)|$

$$= |f_s - f_m| + 2 f_b$$
$$= 2(\Delta f + f_b)$$

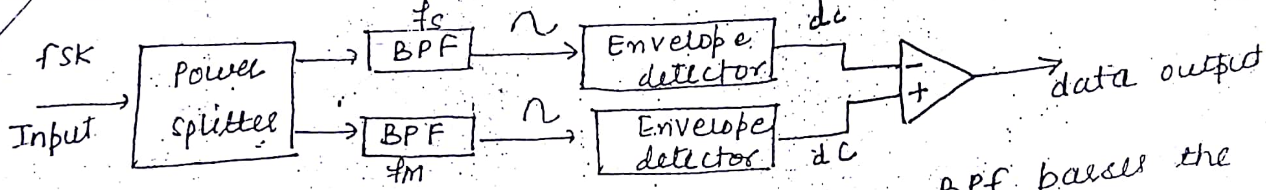
① fSK transmitter



→ VCO is used. The center frequency (fc) is choosen such that it falls midway between mark & space frequency.

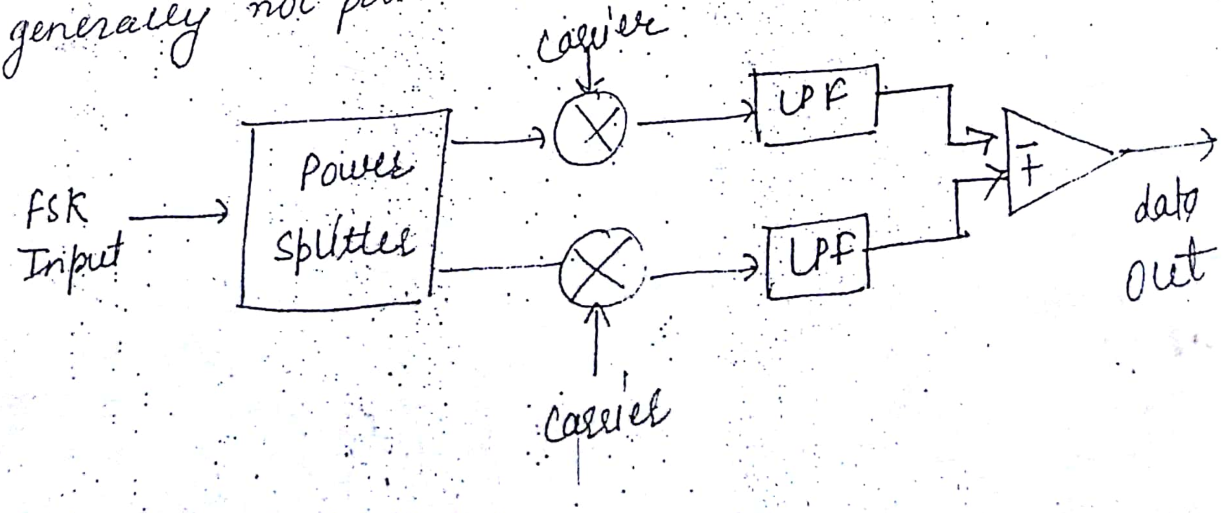
→ Logic 1 input shifts the center frequency to Mark frequency & logic 0 input shifts it to space frequency.

② fSK Receiver



The power-splitter passes the signal & BPF passes the respective frequency signal through it. The Envelope detector indicate the total power in each passband, and the comparator responds to the largest of two powers. This is non-coherent detection as no frequency involved in demodulation process is synchronized either in phase or frequency or both with incoming fSK signal.

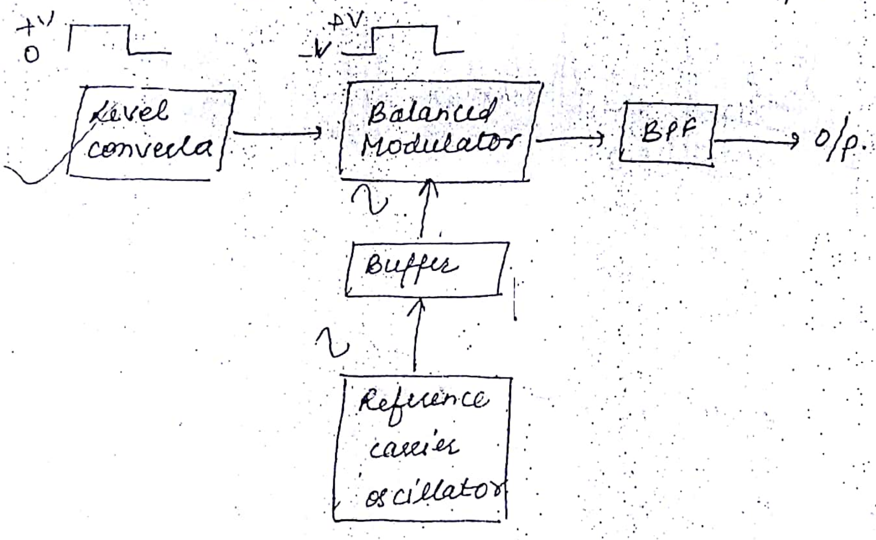
In coherent detection the incoming fSK is multiplied by a recovered carrier signal that has exact same phase & frequency as the transmitter reference. But this is generally not possible. So this is seldom used.



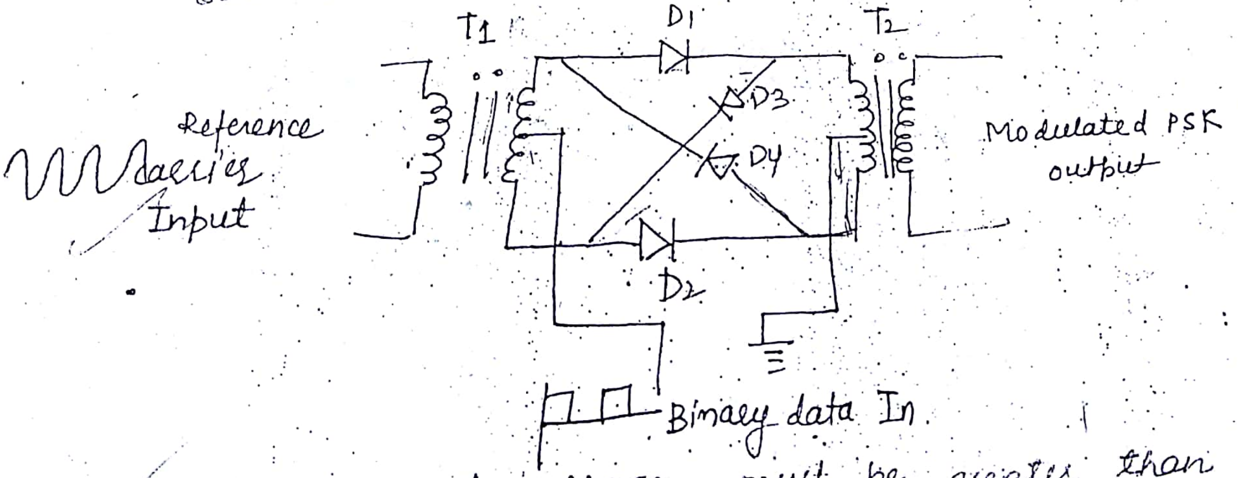
PSK (Phase shift Keying)

- This is constant amplitude digital modulation.
- The input binary information is encoded into groups of bits before modulating the carrier.

BPSK :- Here N=1 and M=2. Hence two phases are possible for carrier. One phase represents a logic 1 and other phase represents logic 0. (N = No. of bits, M = number of phases)



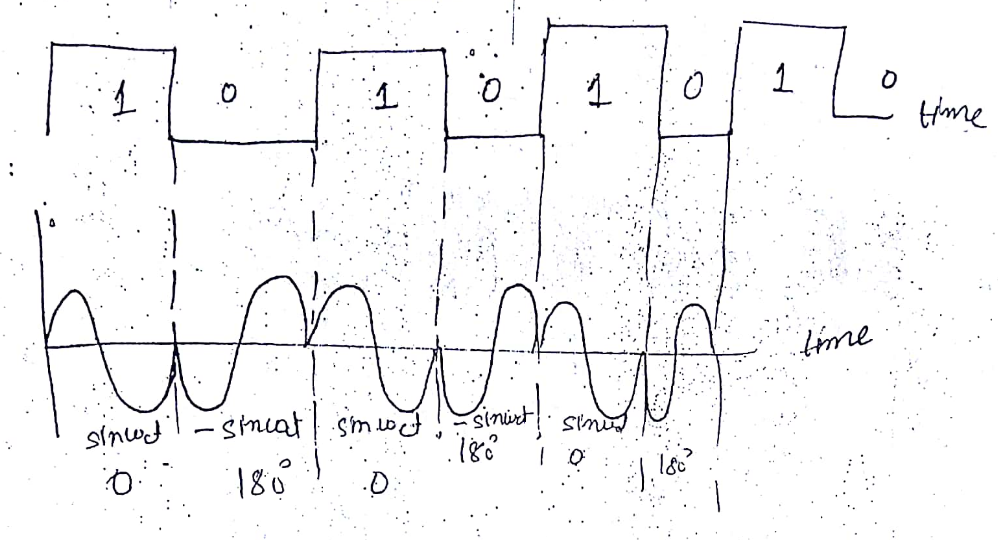
→ The balanced modulator acts as a phase reversing switch.



→ Value of Input voltage must be greater than the value of peak carrier voltage. This ensures that digital input controls the on/off state of diode D1 to D4.

Binary I/p	O/p phase
Logic 0	180°
Logic 1	0°

w.r.t reference (I/p)

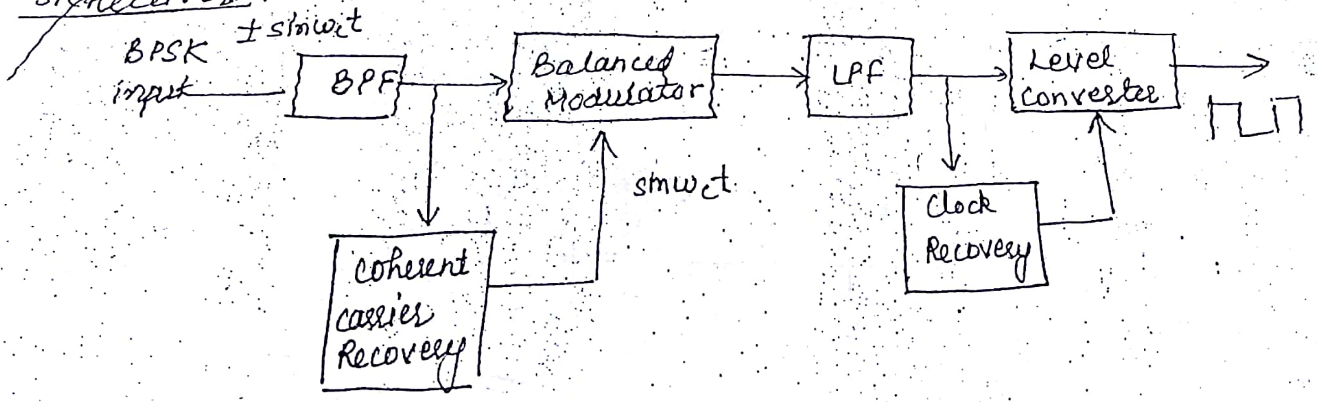


BPSK output $= [\sin(2\pi f_a t)] \times [\sin 2\pi f_c t]$

$$= \frac{1}{2}\cos[2\pi(f_c - f_a)t] - \frac{1}{2}\cos[2\pi(f_c+f_a)t]$$

Minimum BW $= 2f_a \quad ((f_c+f_a) - (f_c - f_a))$

PSK Receiver



$$\text{output} = (\sin\omega_c t)(\sin\omega_c t)$$
$$= \sin^2\omega_c t$$
$$= \frac{1}{2}(1 - \cos 2\omega_c t)$$
$$= \frac{1}{2} - \underbrace{\frac{1}{2}\cos 2\omega_c t}_{\text{filtered out}} \qquad = +\frac{1}{2} = \text{Logic } 1$$

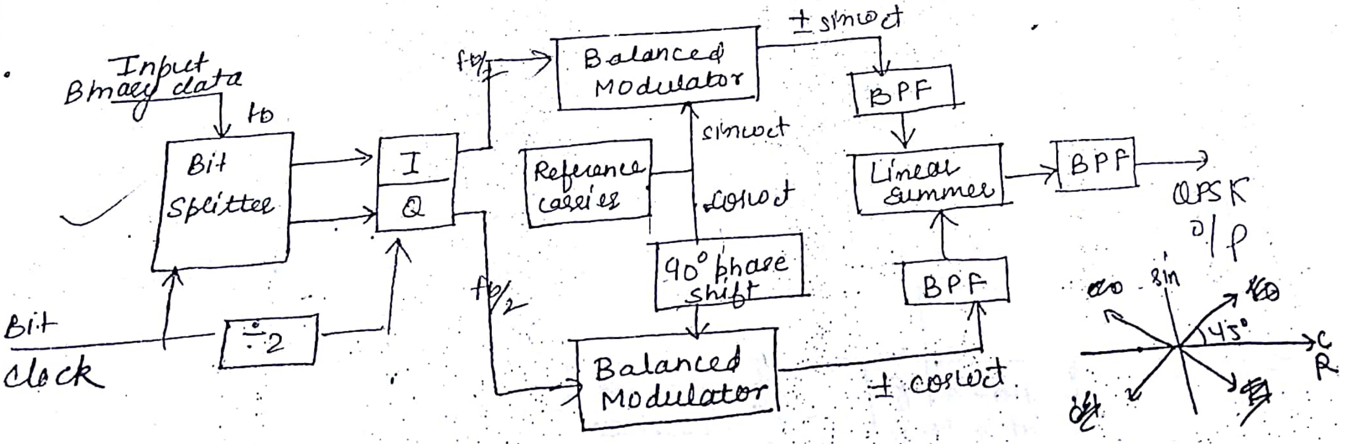
→ If input signal of $-\sin\omega_c t$

$$o/p = -(\sin\omega_c t).(\sin\omega_c t)$$
$$= -\sin^2\omega_c t$$
$$= -\frac{1}{2}(1-\cos 2\omega_c t)$$
$$= -\frac{1}{2} + \frac{1}{2}\cos 2\omega_c t$$
$$= -\frac{1}{2} = \text{logic } 0$$

QPSK (M-ary encoding) $N=2$, $M=4$

→ With this four output phases are possible for a single carrier frequency.

→ for 4 o/p conditions, 4 i/p conditions must be there, hence we use combinations of input called dibits



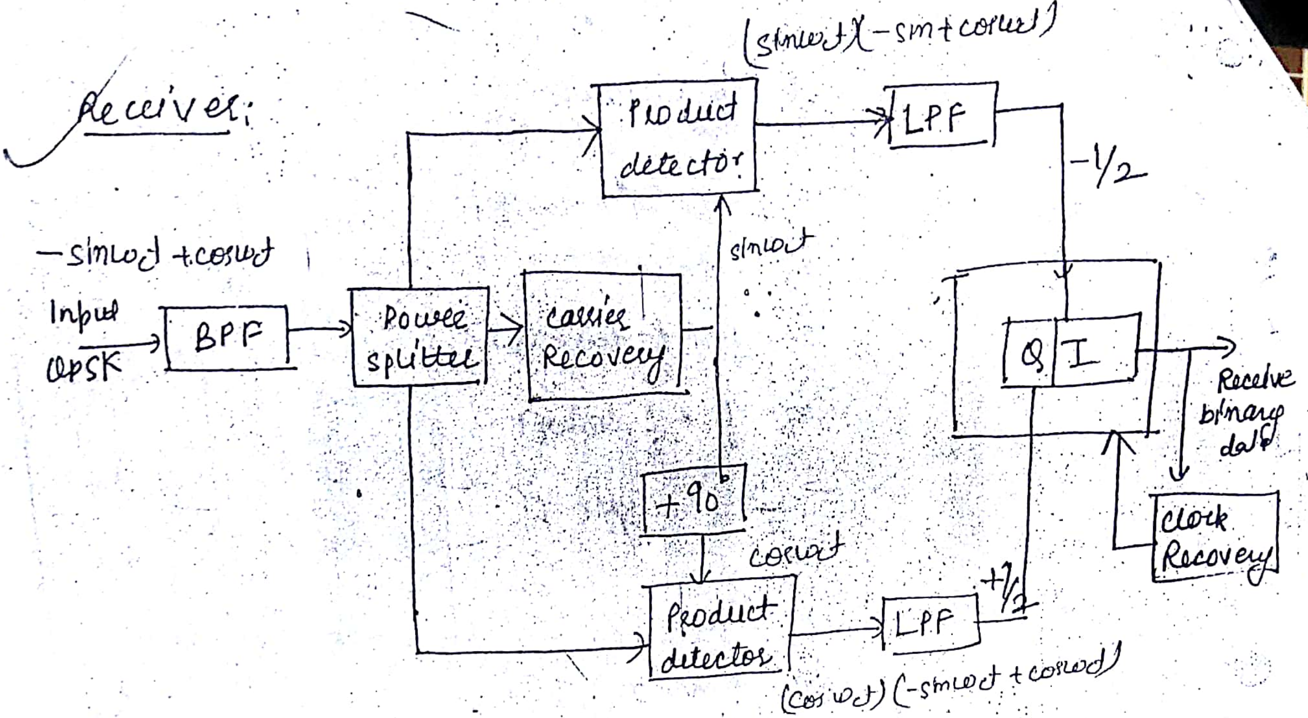
→ After serial input, the bits come out parallely, one bit is directed to I-channel and other to Q channel. I bit modulates carrier which is in phase and Q-channel modulates carrier 90° out of phase.

Bits		phase
Q	I	
0	0	-135
0	1	-45
1	0	+135
1	1	+45

$$o/p = \pm\sin\omega_c t \pm \cos\omega_c t$$

(4 phases are possible)

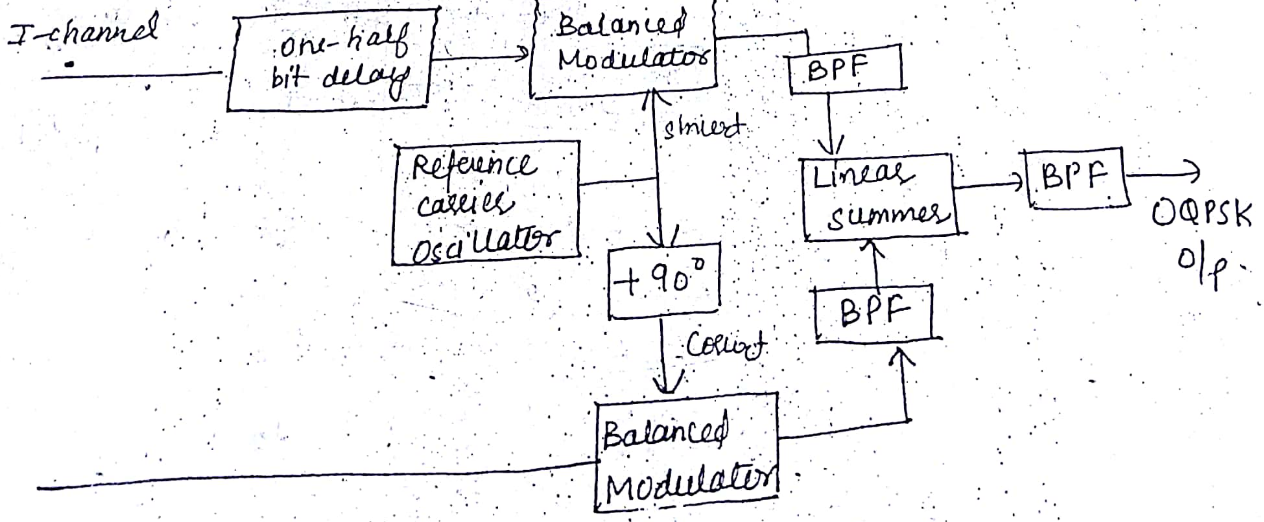
Receiver:



o/p = $I = -\frac{1}{2}V$ (logic 0) = 0
$Q = \pm\frac{1}{2}V$ (logic 1) = 1

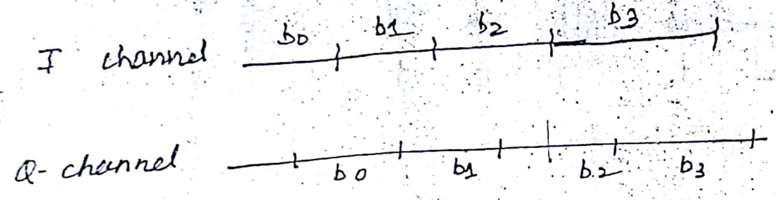
OQPSK :-

↳ Here the bit waveform are offset or shifted in phase from each other by one-half of bit time



- → Changes in I-channel occurs at midpoints of Q-channel bits & vice-versa, so there is never more than a single bit change in dibit code & therefore, there is never more than 90° shift in output phase.

- → In QPSK change in input dibit from 00 to 1 1 causes change in 180° in output phase. so, an advantage of OQPSK is <u>limited phase shift</u>.



✳ <u>DPSK</u> (differential phase shift keying)

→ The information is contained in difference between two successive signaling elements

<u>DBPSK Transmitter</u>