* Binary Phase Shift Keying (BPSK)

N → No. of bits taken at a time

M → No. of combinations can be made $= 2^N$

if , $N = 1$ .... , $M = 2^1 = 2$ → BPSK

if , $N = 2$ ... , $M = 2^2 = 4$ → QPSK

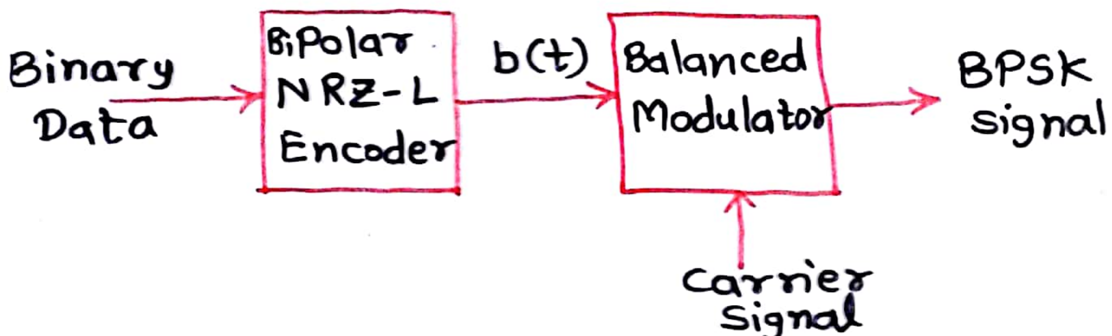
T_b → Bit duration

$\frac{1}{T_b} \rightarrow f_b \rightarrow$ Bit Rate

$\frac{2\pi}{M} \Rightarrow$ phase shift

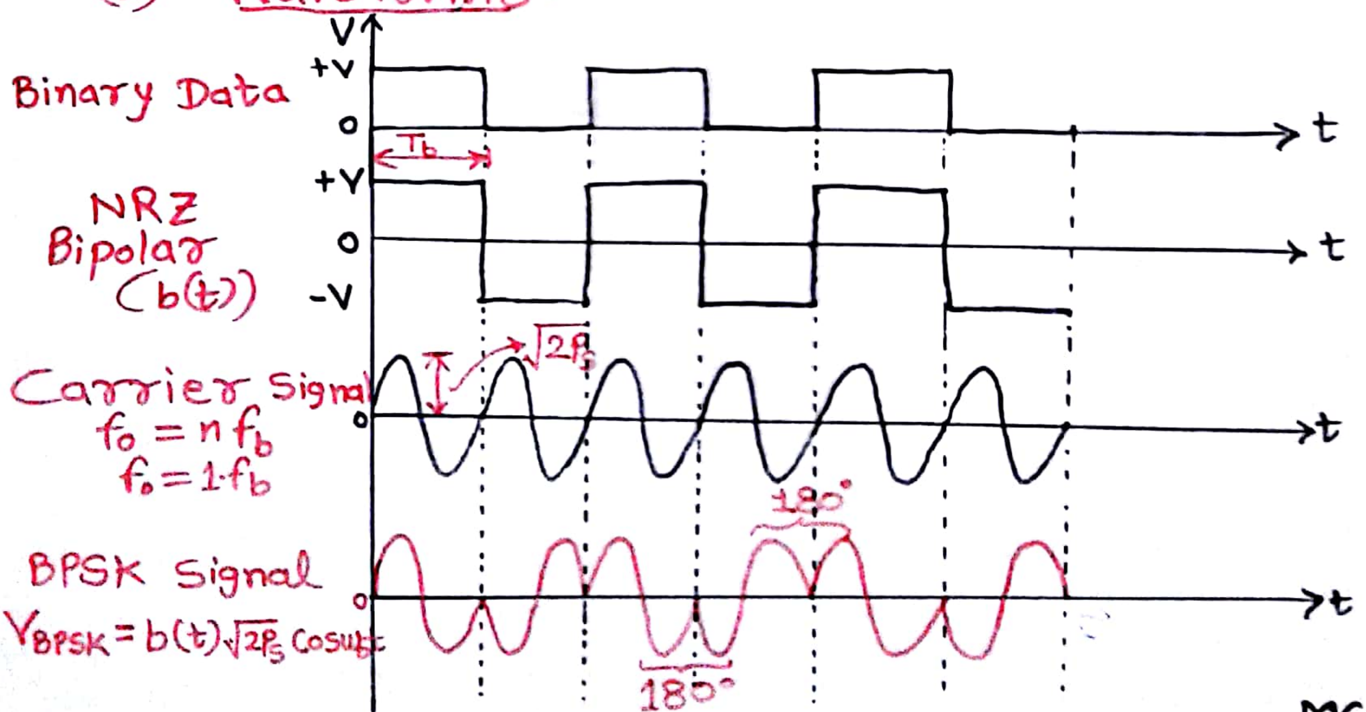
(Here, $\frac{2\pi}{2} = \pi^c = 180°$ shift)

(1) BPSK Modulator :-



$s(t) = \sqrt{2P_s}\cos(\omega_0 t)$

(2) Waveforms :-



MGK

(3) BPSK EQUATION:

$P_s \rightarrow$ Signal Power

$$P_s = \frac{V_{rms}^2}{R} = \left(\frac{V_{Max}}{\sqrt{2}}\right)^2 \frac{1}{R} = \frac{V_m^2}{2R}$$

$$P_s = \frac{V_m^2}{2} \; \ldots\ldots \text{for } R = 1\,\Omega.$$

$V_m^2 = 2P_s$, hence, $\boxed{V_m = \sqrt{2P_s}}$

$$\omega_0 = 2\pi f_0$$

where, $f_0 = n \cdot f_b$

f_0 → Carrier freq.; n → integer; f_b → Bit Rate

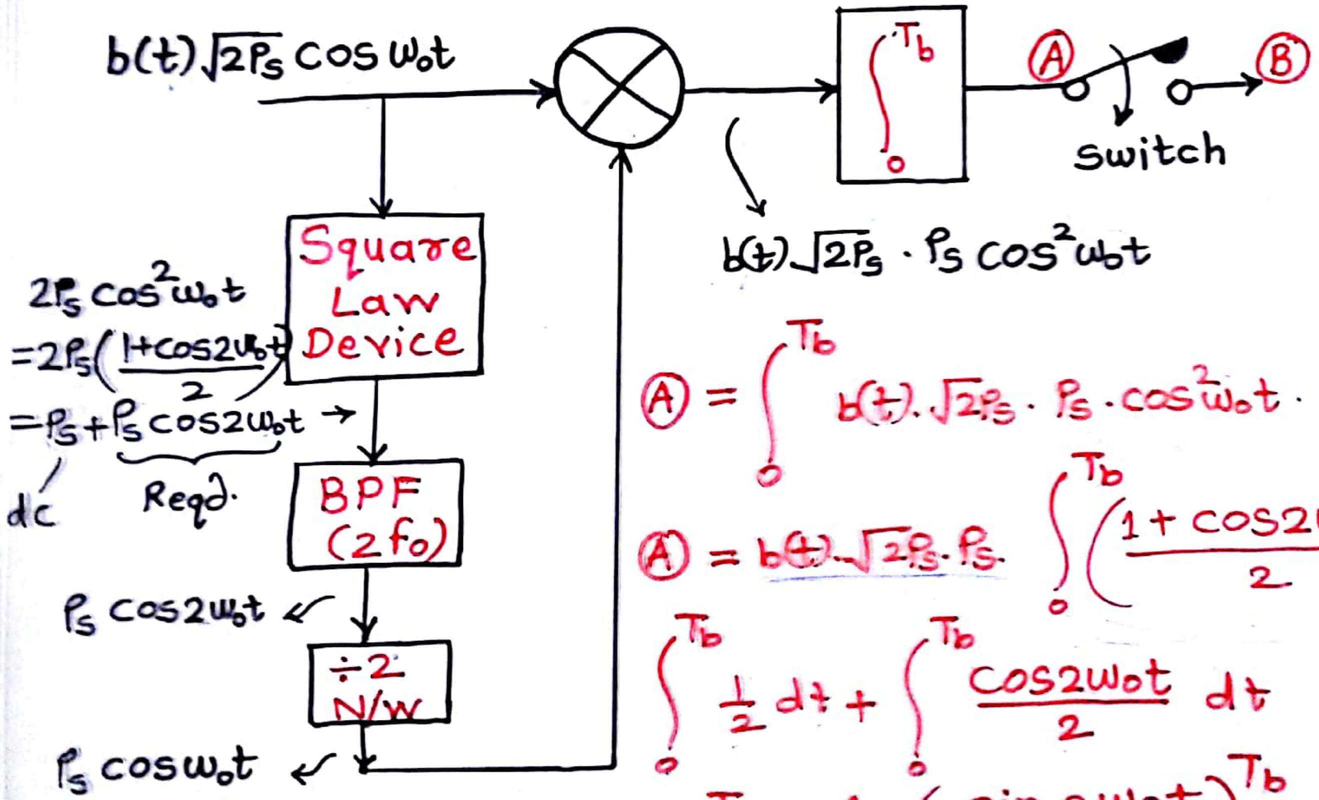
$$\boxed{V_{BPSK}(t) = b(t)\sqrt{2P_s}\cos\omega_0 t}$$

logic 1: $+\sqrt{2P_s}\cos\omega_0 t$

logic 0: $-\sqrt{2P_s}\cos\omega_0 t$

OR $\sqrt{2P_s}\cos(\omega_0 t + \pi)$

(4) BPSK Demodulator:



$$(A) = \int_0^{T_b} b(t)\cdot\sqrt{2P_s}\cdot P_s\cdot\cos^2\omega_0 t\cdot dt$$

$$(A) = b(t)\cdot\sqrt{2P_s}\cdot P_s \int_0^{T_b}\left(\frac{1+\cos 2\omega_0 t}{2}\right)dt$$

$$\int_0^{T_b}\frac{1}{2}\,dt + \int_0^{T_b}\frac{\cos 2\omega_0 t}{2}\,dt$$

$$= \frac{T_b}{2} + \frac{1}{2}\left(\frac{\sin 2\omega_0 t}{2\omega_0}\right)_0^{T_b}$$

$$= \frac{T_b}{2} + \frac{1}{4\omega_0}\left(\sin 2(2\pi f_0 T_b) - \sin(0)\right)$$

$$= \frac{T_b}{2} + \frac{1}{4\omega_0}\left(\sin 2\left(2\pi n f_b \frac{1}{f_b}\right)\right) = \left(T_b/2\right).$$

Thus, $(A) = b(t)\cdot\sqrt{2P_s}\cdot P_s\cdot(T_b/2) = b(t)\cdot K$ — K scaling factor

$(B) = b(t)\cdot K = \pm K$

MGK

(5) Geometrical Representation of BPSK
OR Signal Space Represⁿ OR Signal Constellation Diagram

$$V_{BPSK}(t) = b(t)\cdot\sqrt{2P_s}\cos\omega_0 t$$

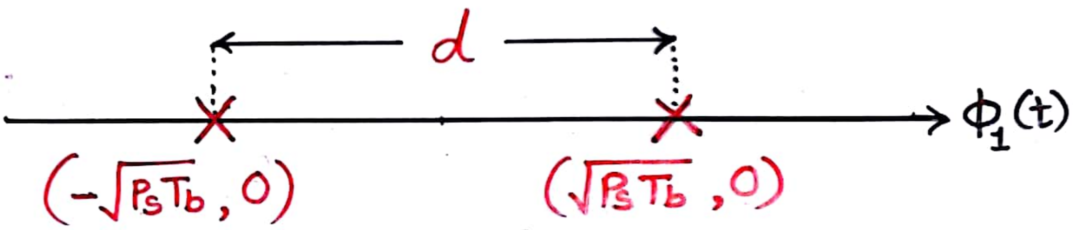
$$= \left[\sqrt{P_s T_b}\; b(t)\right]\cdot \underbrace{\sqrt{\frac{2}{T_b}}\cos\omega_0 t}$$

$$= \left[\sqrt{P_s T_b}\; b(t)\right]\cdot \phi_1(t)$$

$\phi_1(t)$ → orthonormal carrier signal.

For logic 1: $V_{BPSK}(t) = +\sqrt{P_s T_b}\;\phi_1(t)$

For logic 0: $V_{BPSK}(t) = -\sqrt{P_s T_b}\;\phi_1(t)$



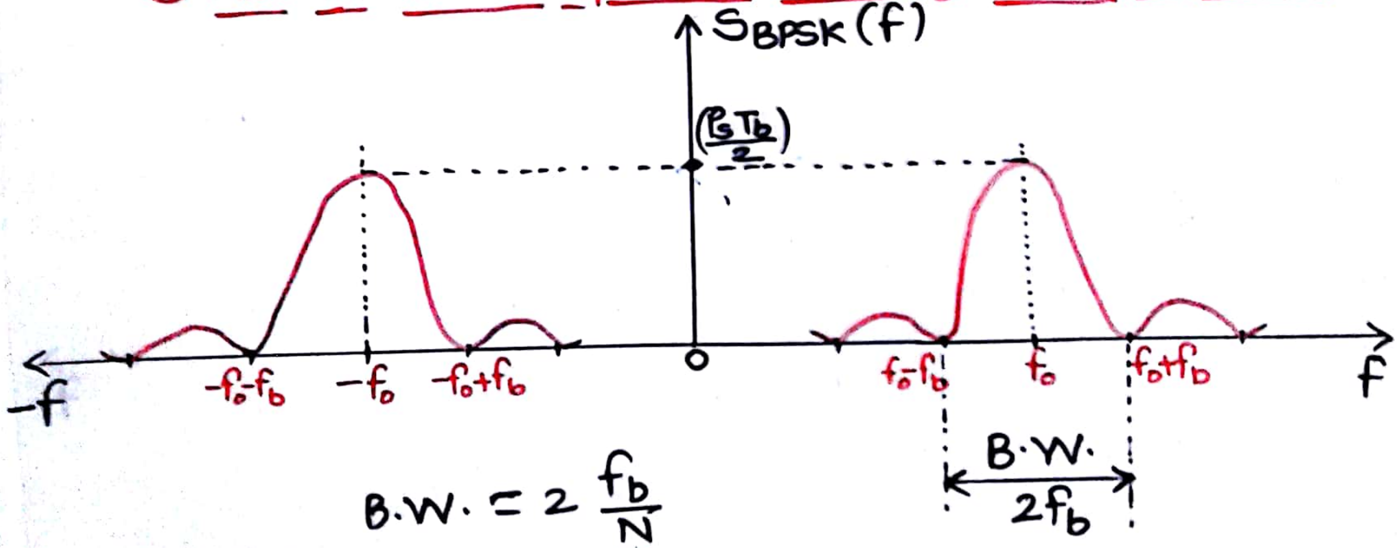
E_b = bit Energy

$\boxed{E_b = P_s T_b}$

$d = 2\sqrt{NE_b}\,\sin(\pi/M)$

$\boxed{d = 2\sqrt{E_b}}$ → Euclidean Distance

(6) Plot of Power Spectral Density (PSD) of BPSK

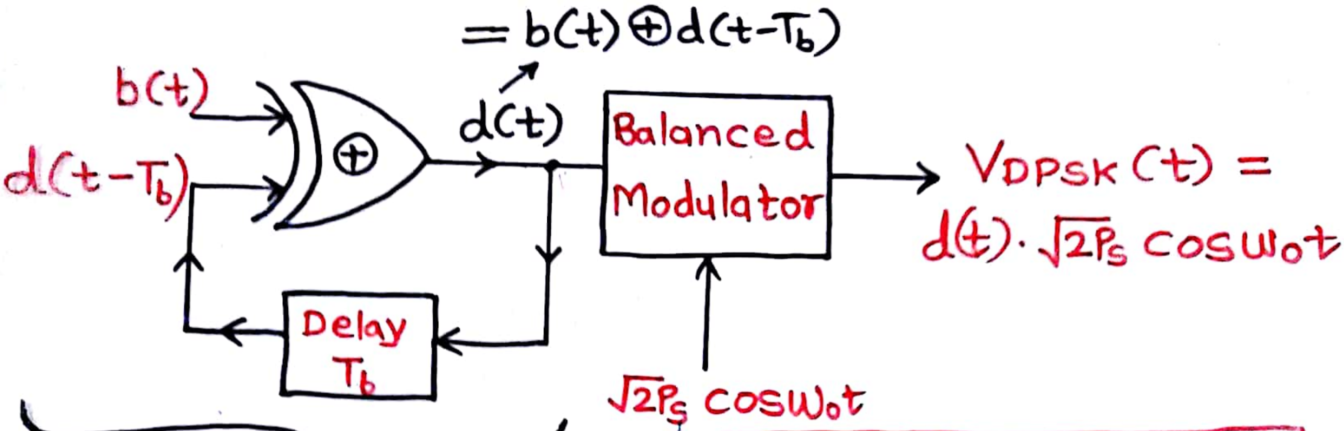


$$\text{B.W.} = 2\,\frac{f_b}{N}$$

$$\boxed{\text{B.W.} = 2f_b}$$

MGK

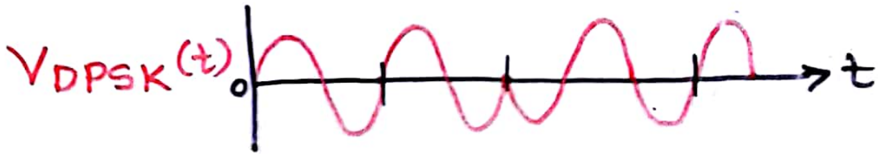
Differential PSK (DPSK)

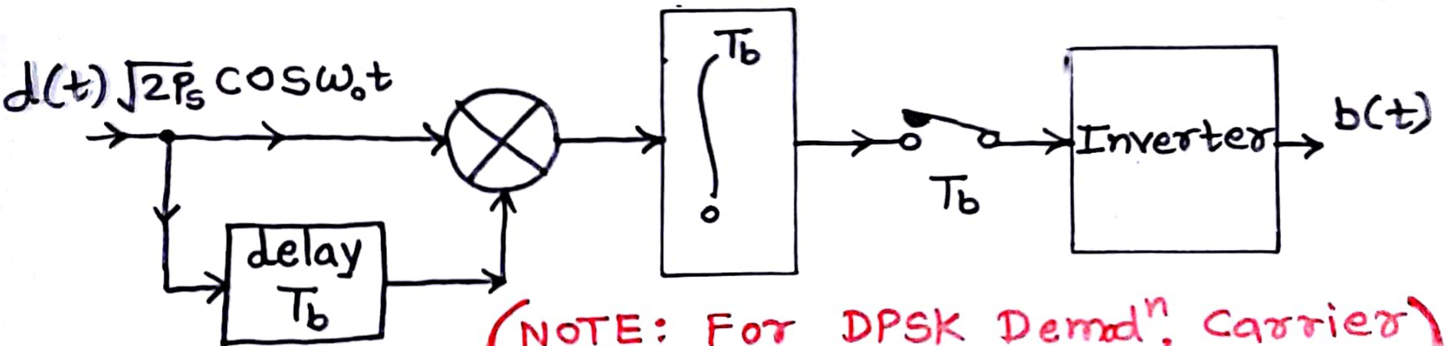


Differential Encoder

$$\boxed{d(t) = b(t) \oplus d(t-T_b)}$$

$b(t) \Rightarrow$	1	0	1	0
$d(t-T_b) \Rightarrow$	0 (Assume)	1	1	0
$d(t) \Rightarrow$	1	1	0	0





(NOTE: For DPSK Demod^n, carrier generation is not reqd $\therefore$ Non-Coherent)

$d(t) \Rightarrow$	1 (+1)	1 (+1)	0 (−1)	0 (−1)
$d(t-T_b) \Rightarrow$	0 (Assume) (−1)	1 (+1)	1 (+1)	0 (−1)
i/p to inverter $\Rightarrow$	−1	+1	−1	+1
o/p of inverter $\Rightarrow$	+1	−1	+1	−1
Logic levels $\Rightarrow$	1	0	1	0

$\Rightarrow b(t)$ //

MGK

* PSD of DPSK $\equiv$ PSD of BPSK
* Geometrical Representation $\equiv$ BPSK.
* Show that polarity inversion doesn't make any difference in DPSK system.

e.g.

$d(t) \Rightarrow$ 1 0 1 1 1 1 0

$d(t-T_b) \Rightarrow$ 1 0 1 1 1 1 0

$b(t) \Rightarrow$ 1 1 0 0 0 1

By changing polarity of $d(t)$

$\overline{d(t)} \Rightarrow$ 0 1 0 0 0 0 1

$\overline{d(t-T_b)} \Rightarrow$ 0 1 0 0 0 0 1

$b(t) \Rightarrow$ 1 1 0 0 0 1

SAME.

* Show that one bit error generates two bit error after detection of the DPSK signal.

one bit error in i/p

$d(t) \Rightarrow$ 1 0 $\boxed{0}$ 1 1 1 0

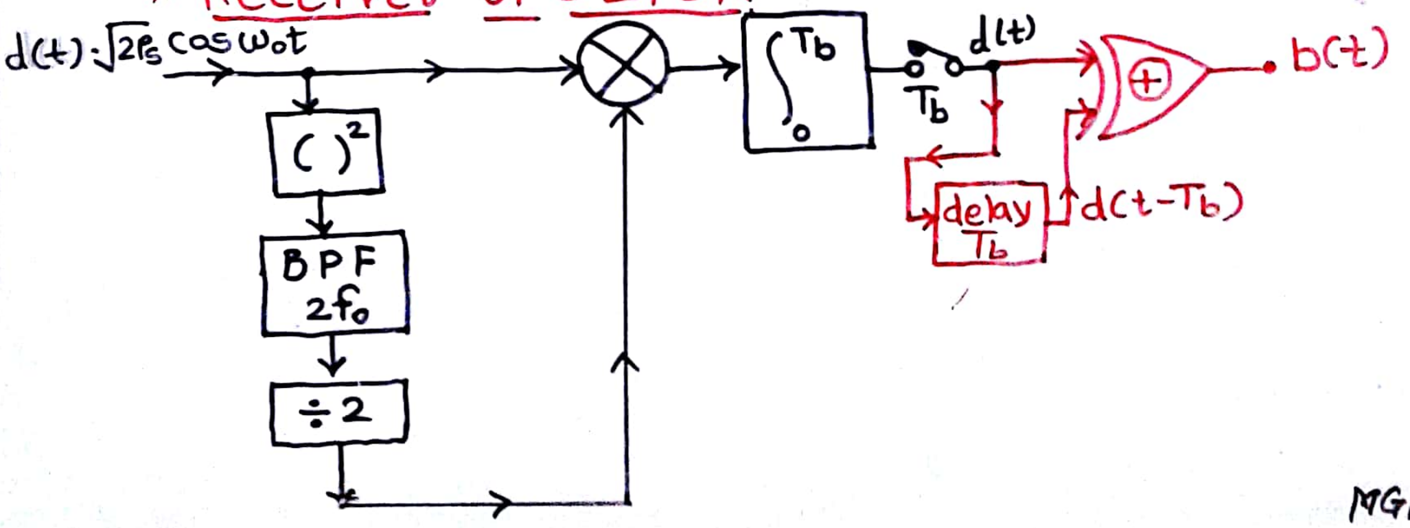
$d(t-T_b) \Rightarrow$ 1 0 0 1 1 1 0

$b(t) \Rightarrow$ 1 $\boxed{0}$ $\boxed{1}$ 0 0 1

Two bit error in o/p.

Differentially Encoded PSK (DEPSK)

* Transmitter is same as DPSK.
* Receiver of DEPSK →



MGK

Quadrature Phase Shift Keying (QPSK)

If $N=1$; $M=2^1=2 \rightarrow$ BPSK

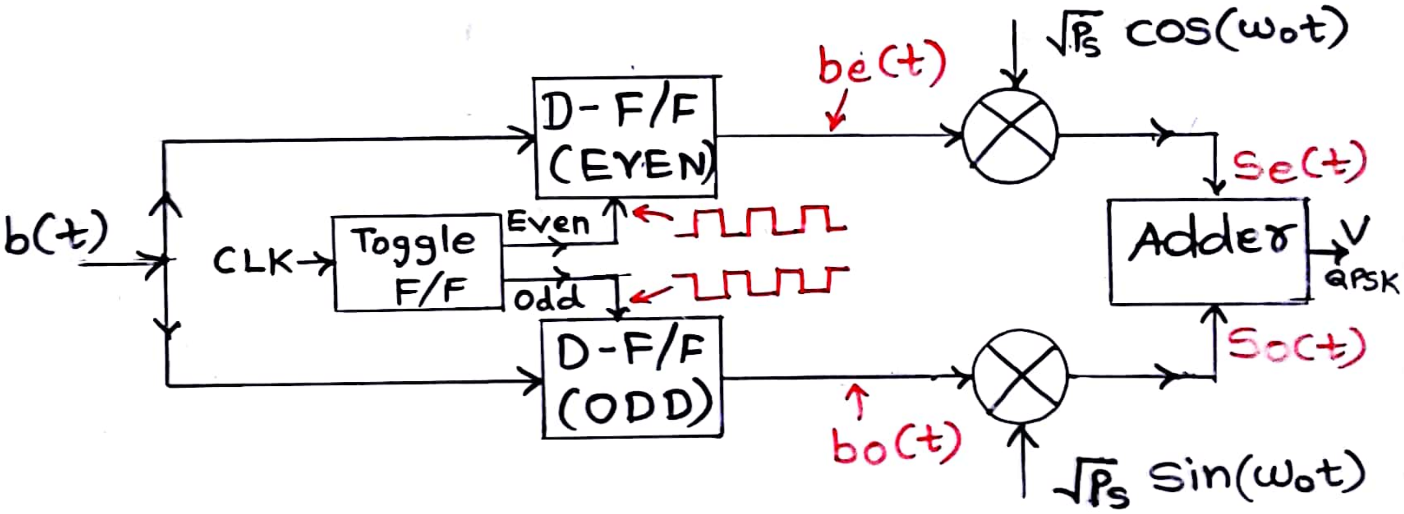
If $N=2$; $M=2^2=4 \rightarrow$ QPSK.

Symbol duration $= T_s = NT_b = 2T_b$.

Symbol Rate $= f_s = \frac{1}{T_s} = \frac{1}{2T_b} = \frac{f_b}{2} = \frac{f_b}{N}$.

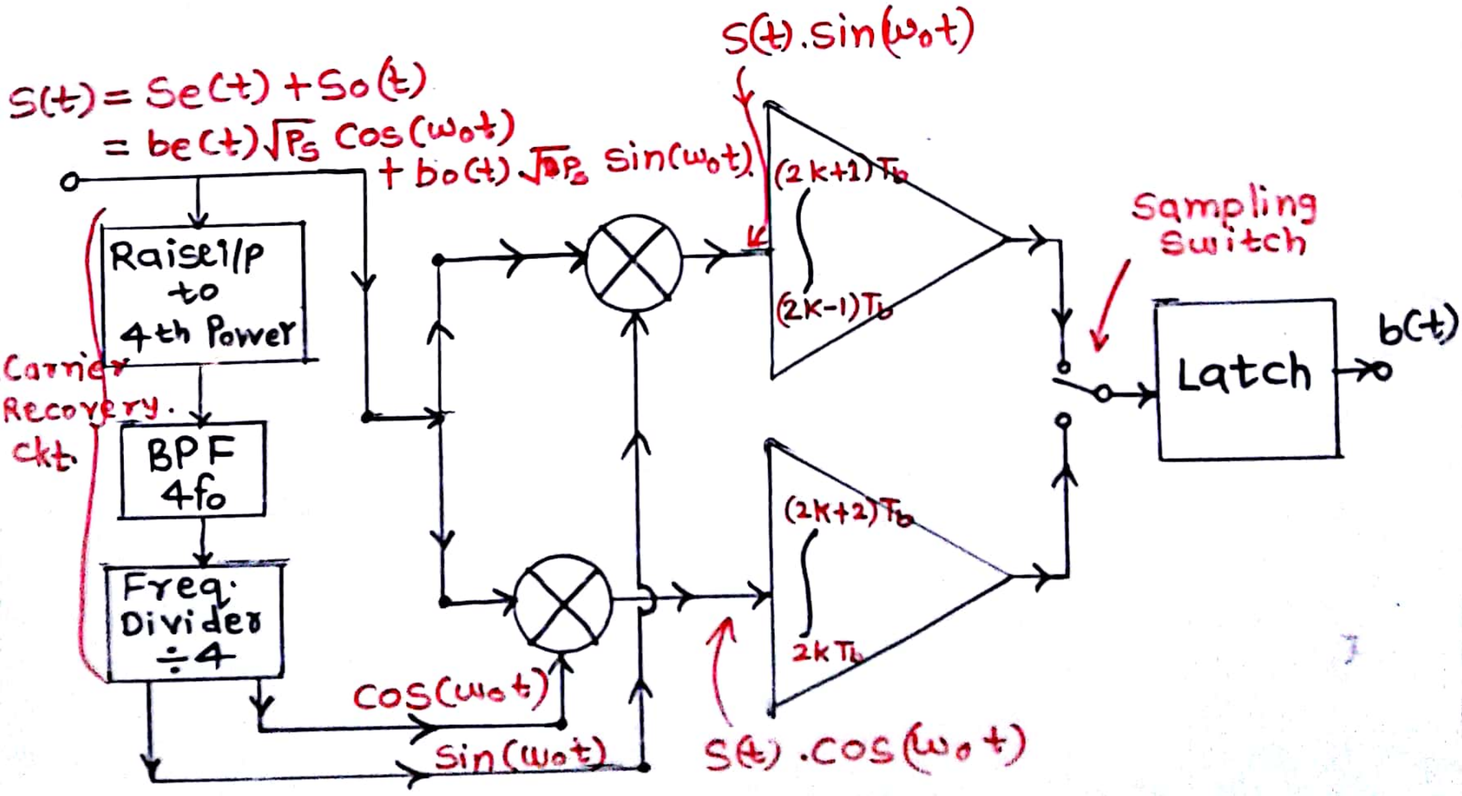
Phase shift $= \phi = \frac{2\pi}{M} = \frac{360^\circ}{4} = 90^\circ$.... QPSK

Case (1) OFFSET QPSK TR^r & Receiver

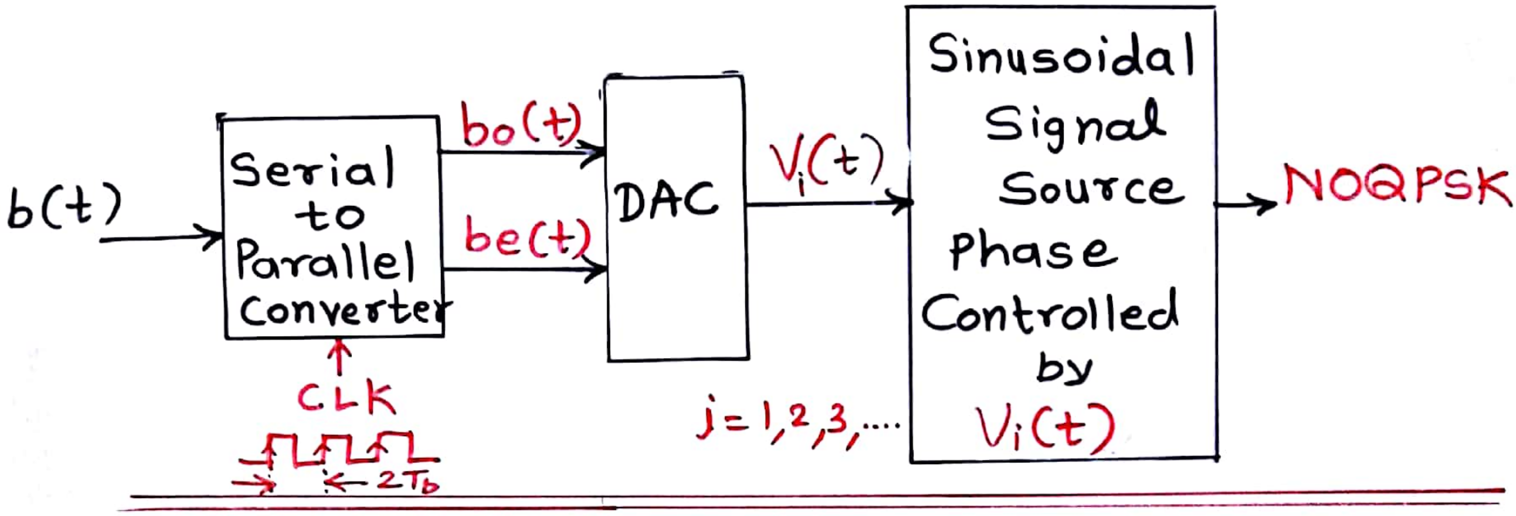


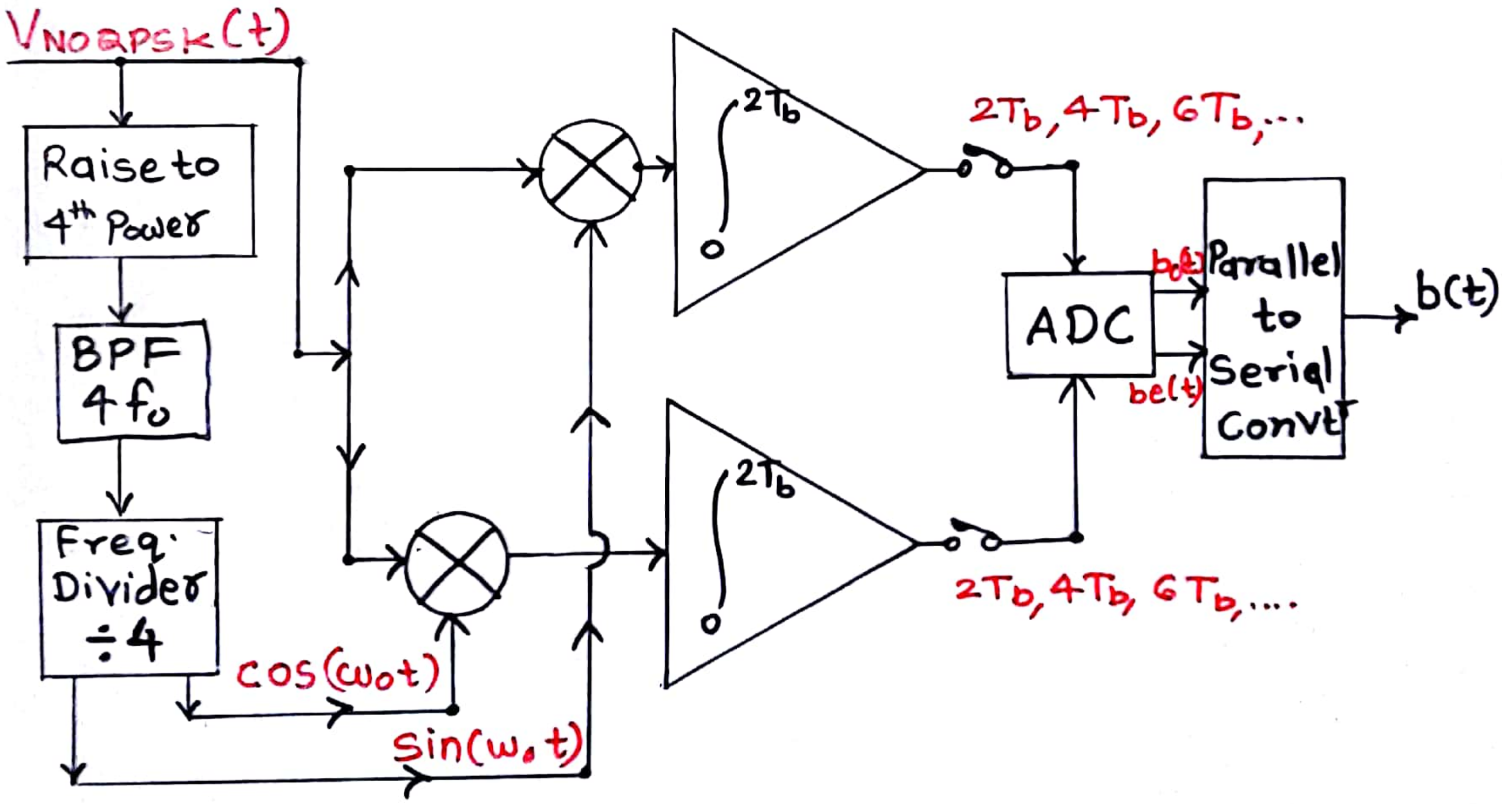
$S(t) = Se(t) + So(t)$

$= be(t)\sqrt{P_s}\cos(\omega_0 t) + bo(t)\sqrt{P_s}\sin(\omega_0 t)$



Case (2): NON OFFSET QPSK TX^r & RX^r :-





* $$\boxed{\begin{aligned} V_{QPSK}(t) &= b_e(t)\sqrt{P_s}\cos(\omega_0 t) \\ &+ b_o(t)\sqrt{P_s}\sin(\omega_0 t) \end{aligned}}$$

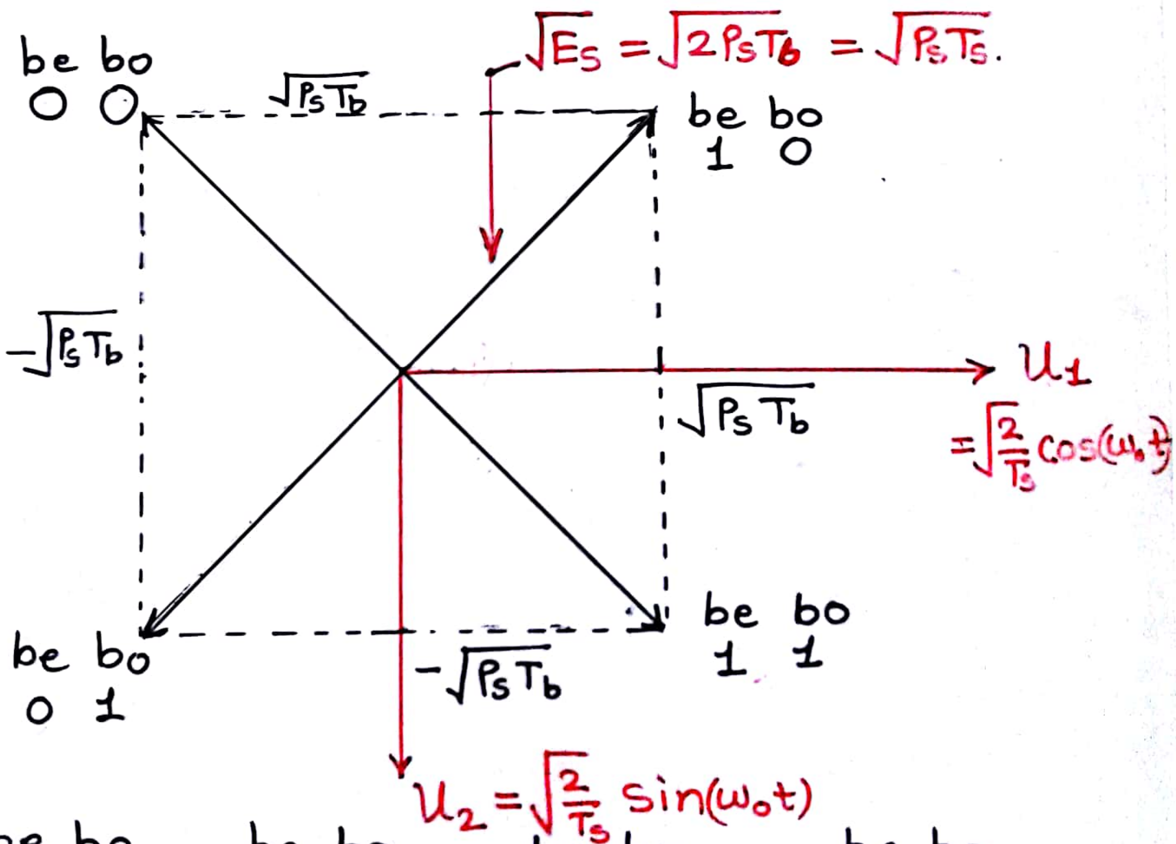
* **Signal Space Diagram:-**

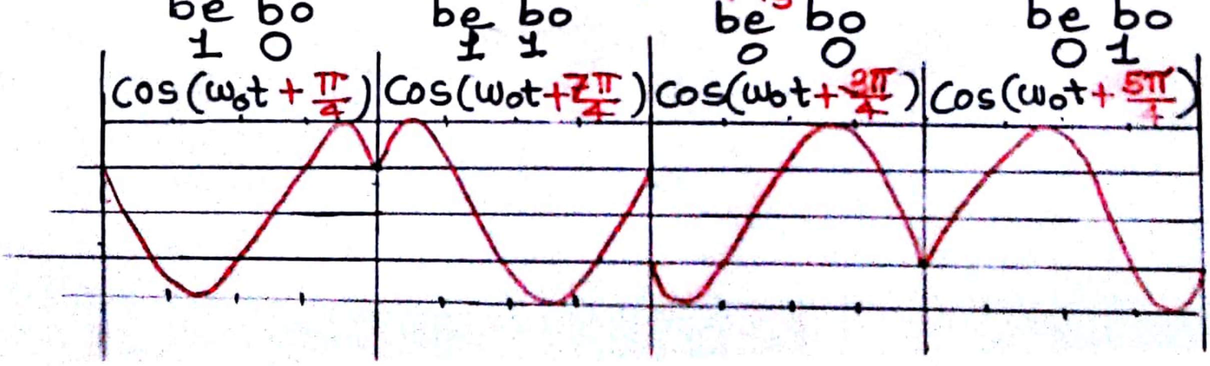
$$\therefore V_{QPSK}(t) = b_e(t) \cdot \frac{\sqrt{P_s}}{\sqrt{2/T_s}} \cdot \sqrt{\frac{2}{T_s}}\cos(\omega_0 t)$$

$$+ b_o(t)\frac{\sqrt{P_s}}{\sqrt{2/T_s}}\sqrt{\frac{2}{T_s}} \cdot \sin(\omega_0 t).$$

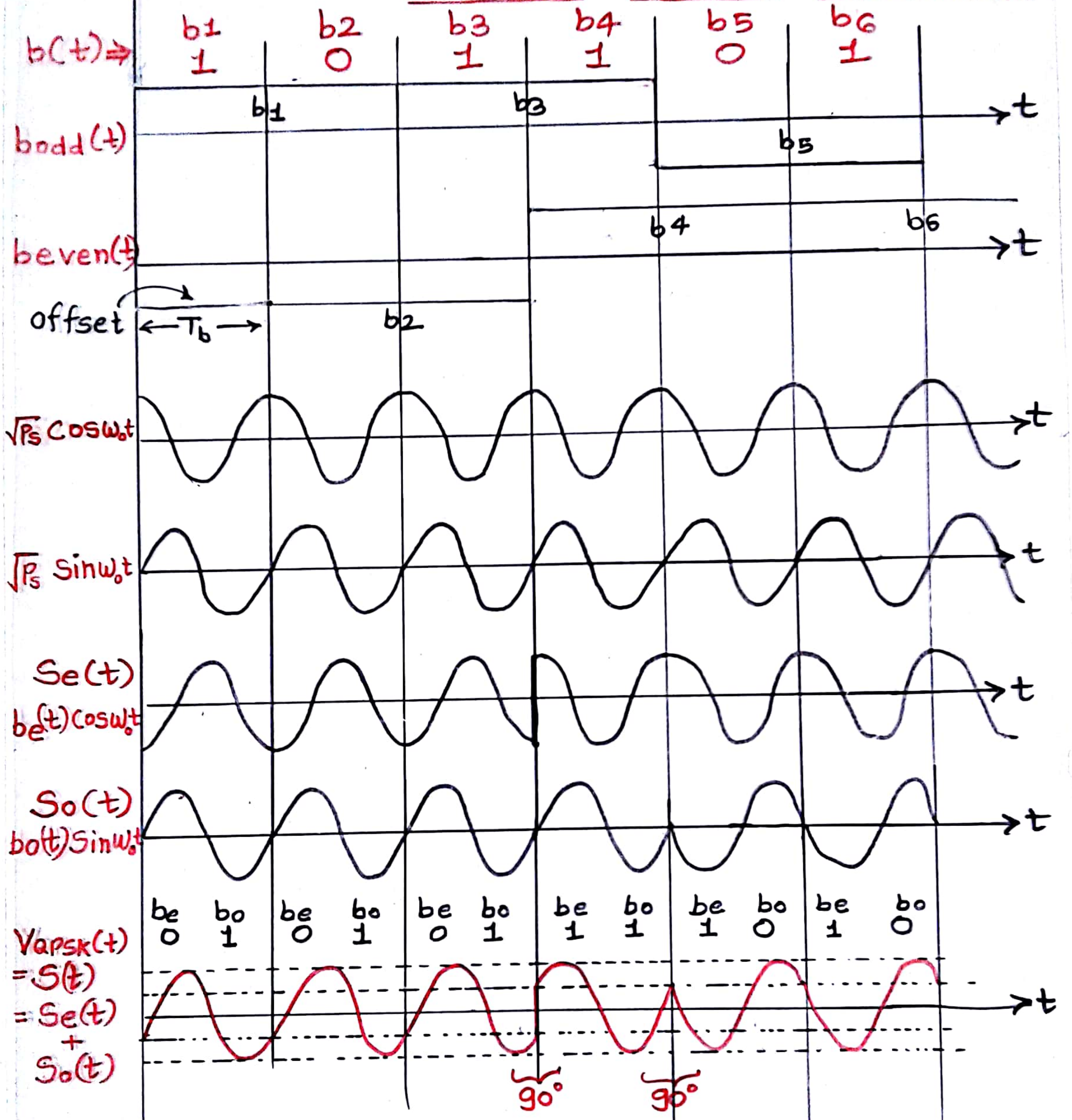
$$\therefore V_{QPSK}(t) = b_e(t)\sqrt{P_s T_b}\ u_1(t) + b_o(t)\sqrt{P_s T_b}\ u_2(t)$$

$$\left\{ \begin{aligned} &T_s = N T_b \\ &T_s = 2T_b \\ &\text{for QPSK} \end{aligned} \right.$$

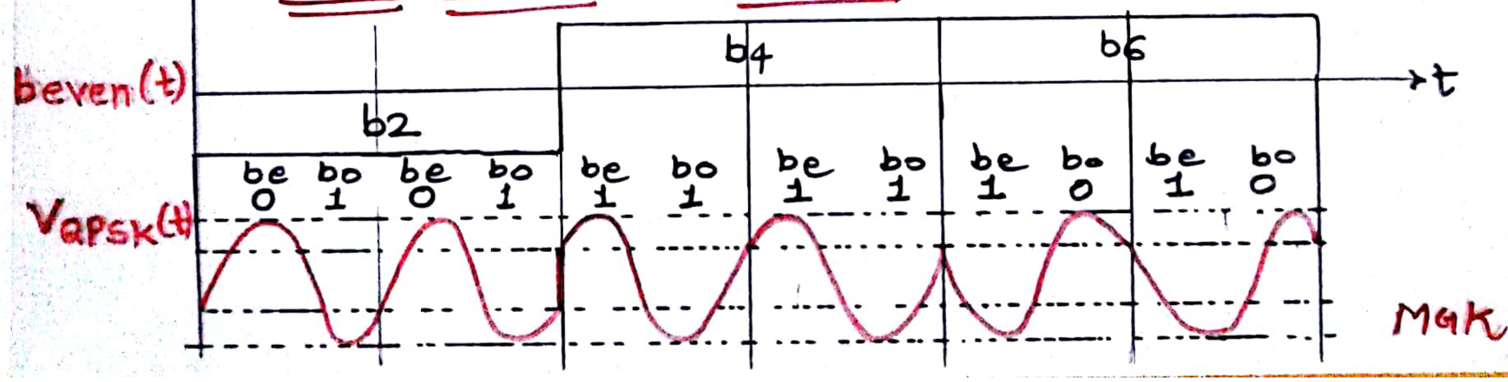




OFFSET QPSK Waveform



NON-OFFSET QPSK

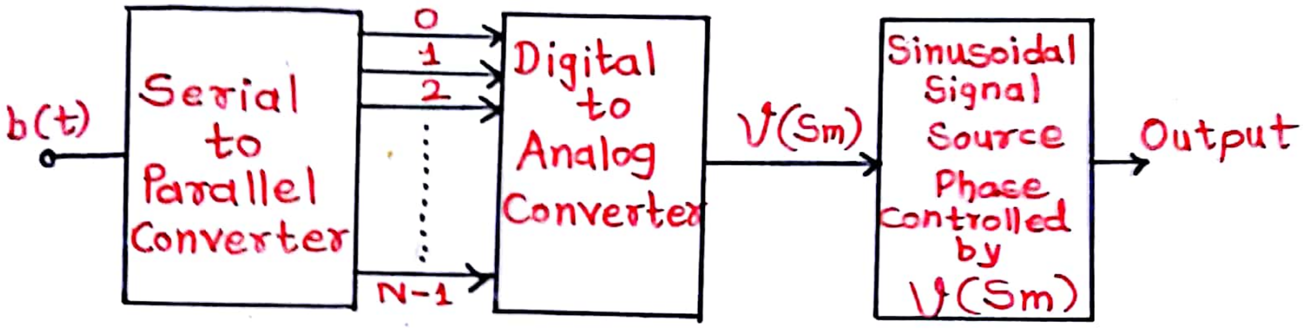


M-ary PSK (MPSK)

$M = 2^N$; Phase Diff. $= \frac{2\pi}{M}$; $T_s = N T_b$

M → No. of Symbols
N → No. of bits

① MPSK Transmitter:-



$$V_{MPSK}(t) = \sqrt{2P_s}\, \cos(\omega_o t + \phi_m)$$

where, ϕ_m = Symbol Phase Angle

$$\therefore \phi_m = (2m+1)\frac{\pi}{M} \quad \ldots (m = 0, 1, 2, \ldots, M-1)$$

$$V_{MPSK}(t) = \left(\sqrt{2P_s}\cos\phi_m\right)\cos\omega_o t - \left(\sqrt{2P_s}\sin\phi_m\right)\sin\omega_o t$$

$$\boxed{V_{MPSK}(t) = P_e \cos\omega_o t - P_o \sin\omega_o t}$$

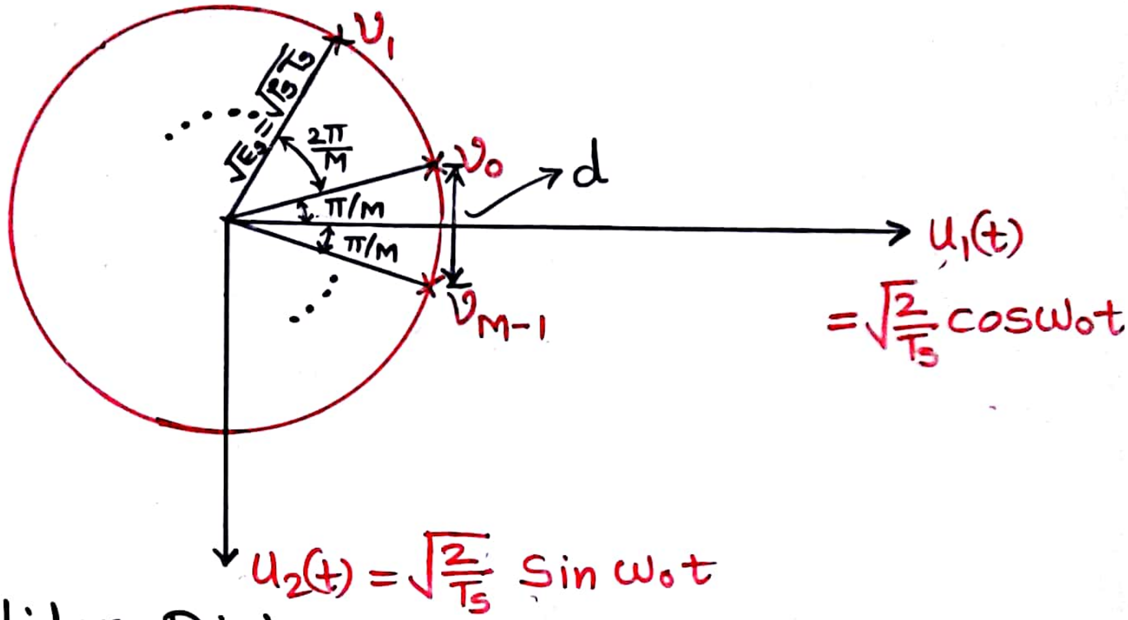
where,

$$P_e = \sqrt{2P_s}\cos\phi_m$$

$$P_o = \sqrt{2P_s}\sin\phi_m$$

Both P_e and P_o can change every $T_s = N T_b$ and can assume any of M possible values.

(2) Signal Space Representation :-



* Eucliden Distance :-

$$\sin(\pi/M) = \frac{(d/2)}{\sqrt{E_s}}$$

$$d = 2\sqrt{E_s}\sin(\pi/M)$$

$$d = \sqrt{4E_s\sin^2(\pi/M)} \quad \ldots \quad E_s = P_s T_s$$

$$d = \sqrt{4NE_b\sin^2(\pi/M)} \qquad = P_s(NT_b)$$

$$= P_s T_b \cdot N$$

$$\therefore E_s = NE_b$$

* Band-width :-

$$B = \frac{2}{T_s} = \frac{2}{NT_b} = \frac{2f_b}{N}$$

Thus, as (No. of bits/symbol) i.e. $N\uparrow$, $BW\downarrow$

$\therefore$ As $N\uparrow$ $BW\downarrow$ as required but,

$N\uparrow$ $\therefore$ $\phi = \frac{2\pi}{M} = \frac{2\pi}{2^N}\downarrow$

Symbol duration $(T_s = NT_b)\uparrow$

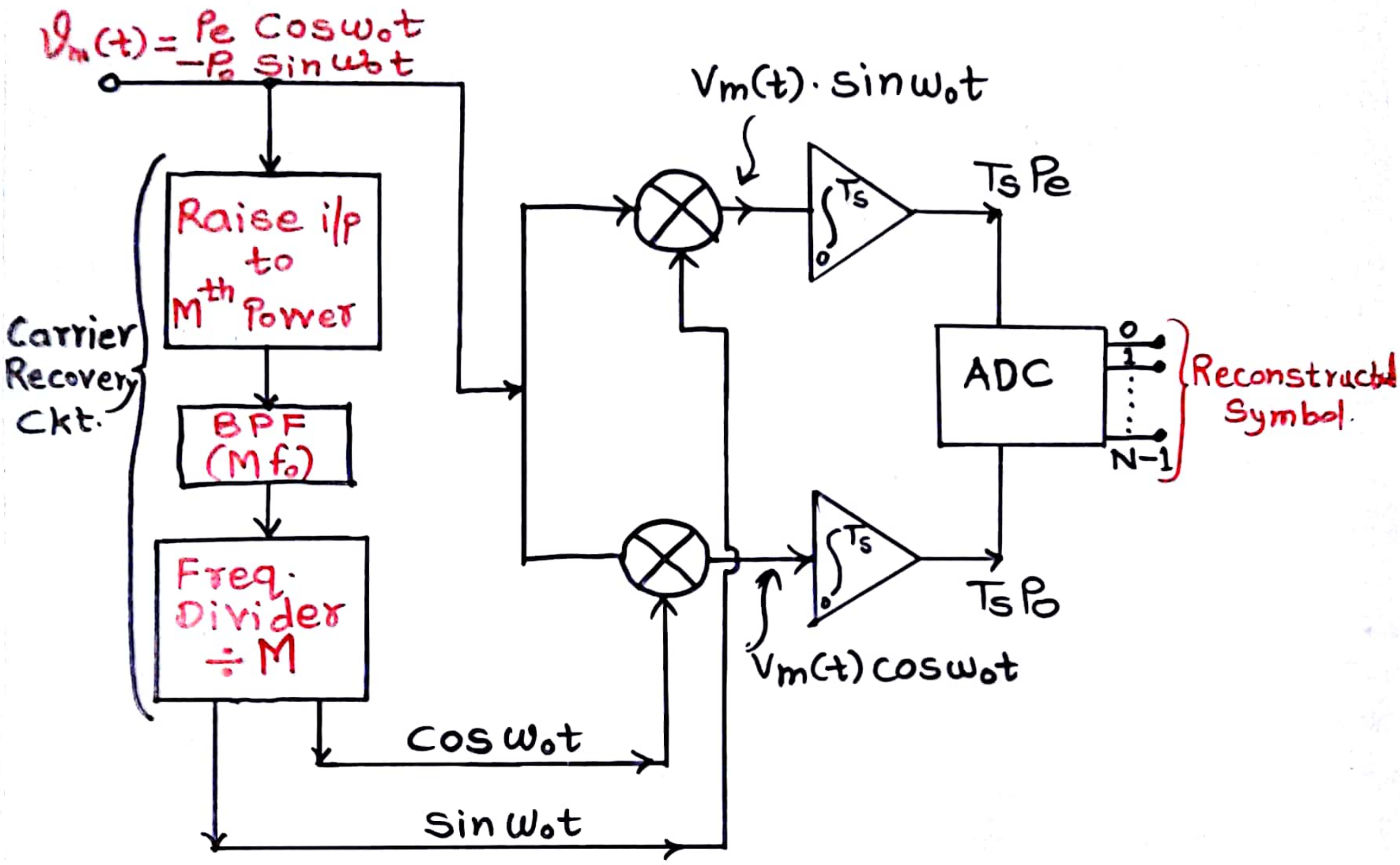
$M = 2^N \uparrow$; $d\downarrow$

$\therefore$ Symbols will be closely spaced.

$\therefore$ Probability of Error (P.E.) $\uparrow$.

MGK

* MPSK Receiver :-



MGK

Binary Frequency Shift Keying (BFSK)

$$V_{BFSK}(t) = \sqrt{2P_s}\ \cos\left[\omega_o t + d(t)\,\Omega\, t\right]$$

where, $d(t) \Rightarrow +1$ or -1

$+1$ → logic 1, -1 → logic 0

$$\therefore\ S_H(t) = \sqrt{2P_s}\ \cos(\omega_o + \Omega)t$$

&

$$S_L(t) = \sqrt{2P_s}\ \cos(\omega_o - \Omega)t$$

$$\omega_H = (\omega_o + \Omega) \quad \omega_L = (\omega_o - \Omega)$$

where, $\Omega \Rightarrow$ Const. offset in freq.

b(t) i/p	d(t) NRZ	$P_H(t)$	$P_L(t)$.
1	+1 V	+1 V	0 V
0	−1 V	0 V	+1 V

$\therefore$ $P_H(t)$ is same as $b(t)$.

& $P_L(t)$ is inverted version of $b(t)$.

$P_H(t)$ and $P_L(t)$ are unipolar signals

$$S_H(t) = \sqrt{2P_s}\ \cos(\omega_H t)$$

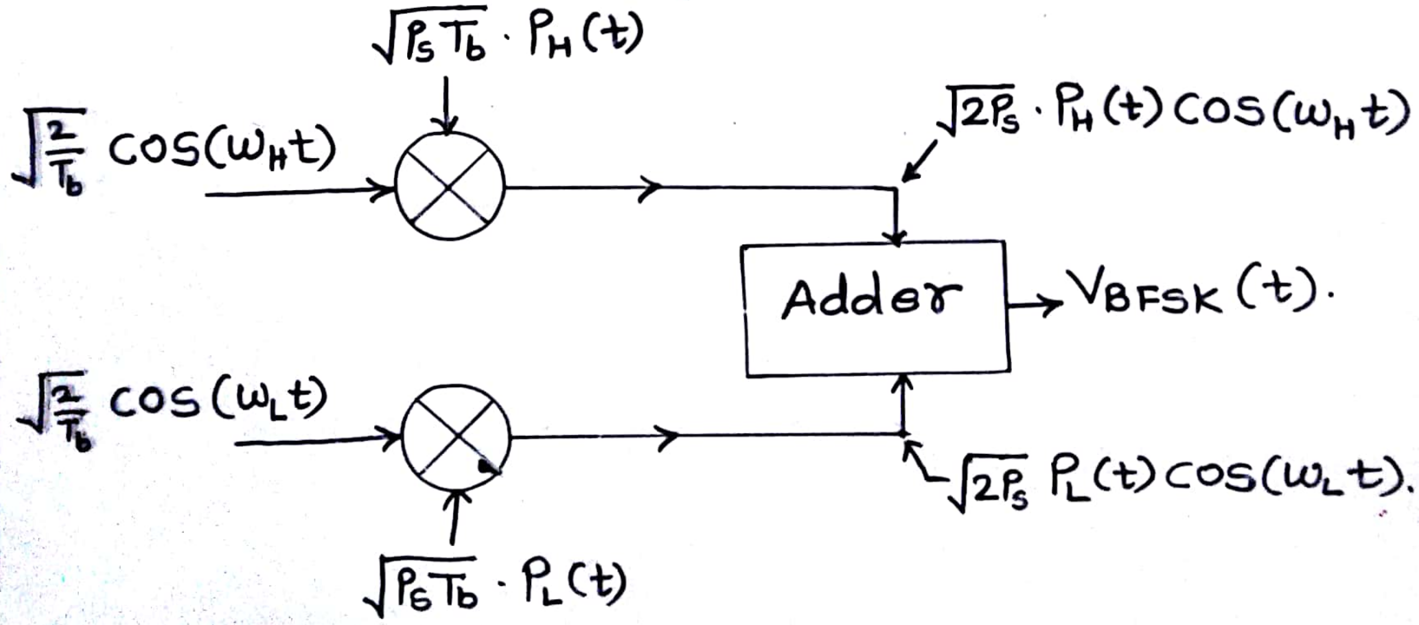
$$S_H(t) = \sqrt{P_s T_b}\ \underbrace{\sqrt{\frac{2}{T_b}}\ \cos(\omega_H t)}$$

$$\boxed{S_H(t) = \sqrt{P_s T_b}\ P_H(t)\cdot \phi_1(t)}$$

$$S_L(t) = \sqrt{2P_s}\ \cos(\omega_L t).$$

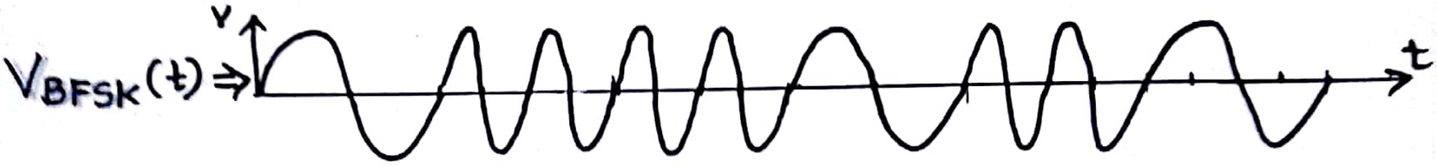
$$= \sqrt{P_s T_b}\ \underbrace{\sqrt{\frac{2}{T_b}}\ \cos(\omega_L t)}$$

$$\boxed{S_L(t) = \sqrt{P_s T_b}\cdot P_L(t)\cdot \phi_2(t)}$$

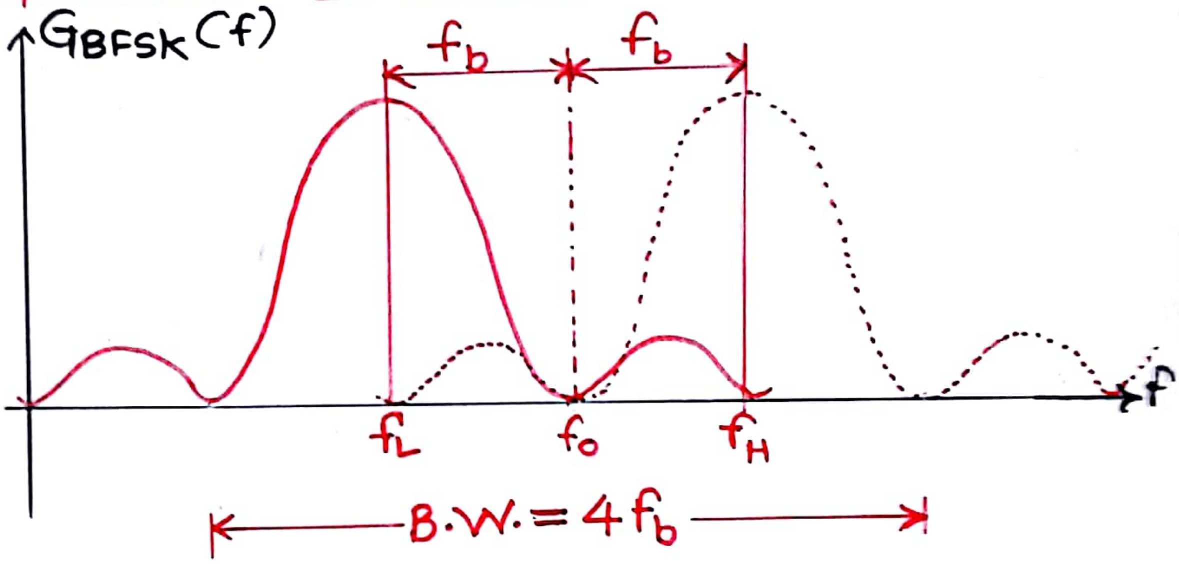


* Waveforms :-

$b(t) \Rightarrow$ 0 1 1 0 1 0



* Spectrum of BFSK :



* Signal Space Representation :-

Case 1 :- For Orthogonal BFSK :

For orthogonal BFSK, the two carrier frequencies for ($\phi_1(t)$ and $\phi_2(t)$) at f_H & f_L must be integer multiple of baseband ferq. (f_b)

$f_H = mf_b$

$f_L = nf_b$

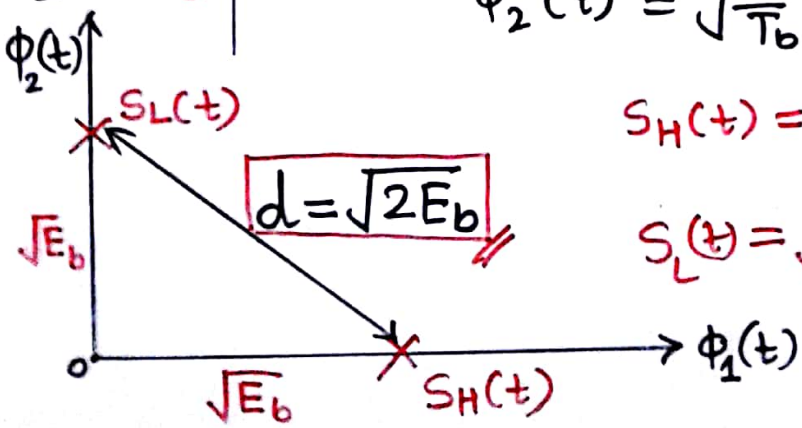
Now,

$$\phi_1(t) = \sqrt{\frac{2}{T_b}} \cos(\underbrace{2\pi m f_b t}_{\omega_H (t)})$$

$$\phi_2(t) = \sqrt{\frac{2}{T_b}} \cos(\underbrace{2\pi n f_b t}_{\omega_L t})$$

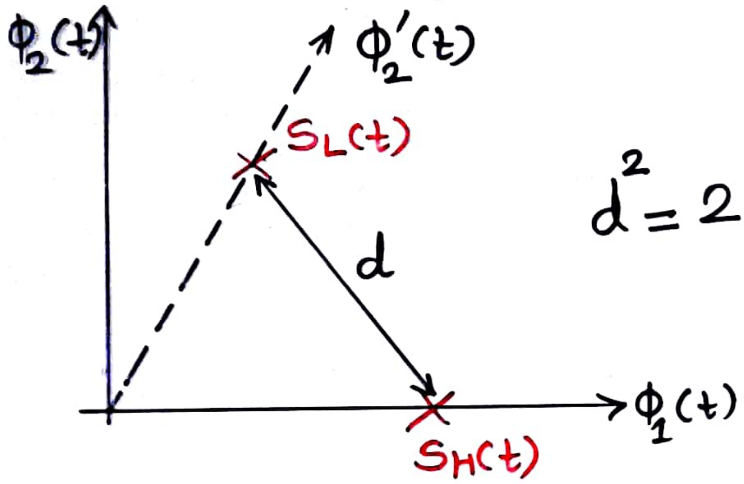
$$S_H(t) = \sqrt{P_s T_b}\ \phi_1(t) = \sqrt{E_b}\ \phi_1(t)$$

$$S_L(t) = \sqrt{P_s T_b}\ \phi_2(t) = \sqrt{E_b}\ \phi_2(t)$$



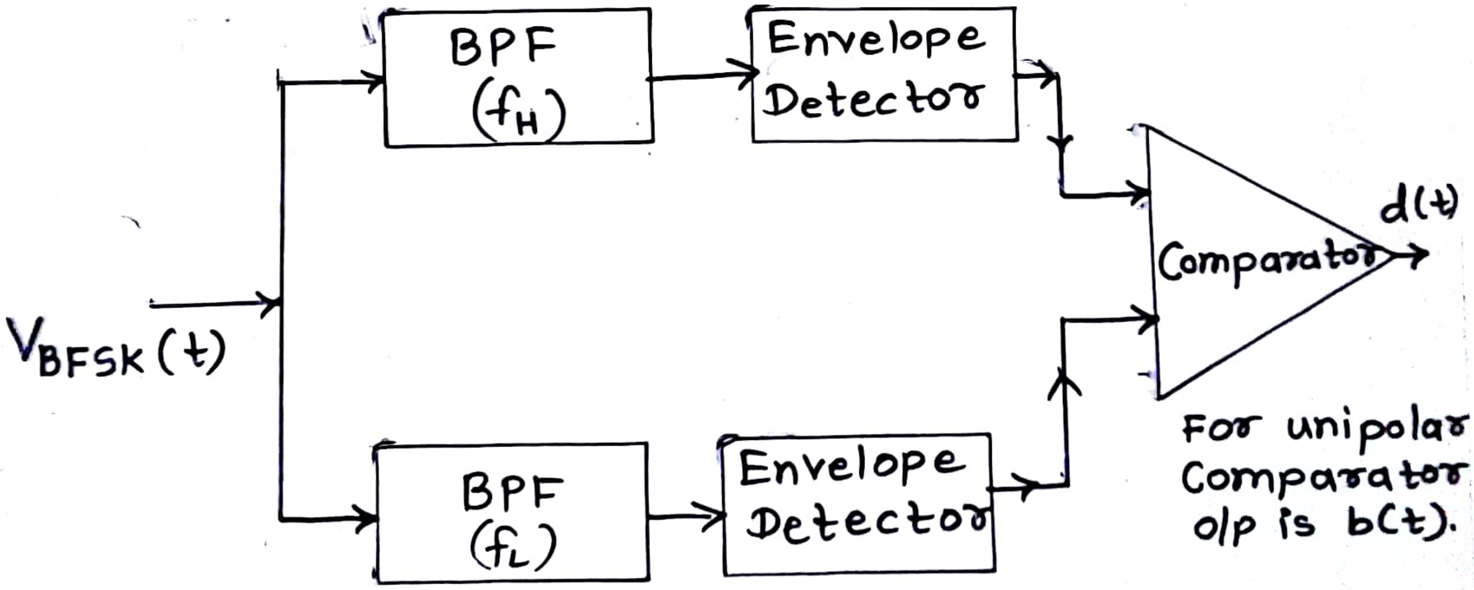
Case(2) For Non-Orthogonal BFSK

Whenever the carriers $\phi_1(t)$ and $\phi_2(t)$ are non-orthogonal then $S_H(t)$ and $S_L(t)$ will NOT lie exactly on axes $\phi_1(t)$ and $\phi_2(t)$.



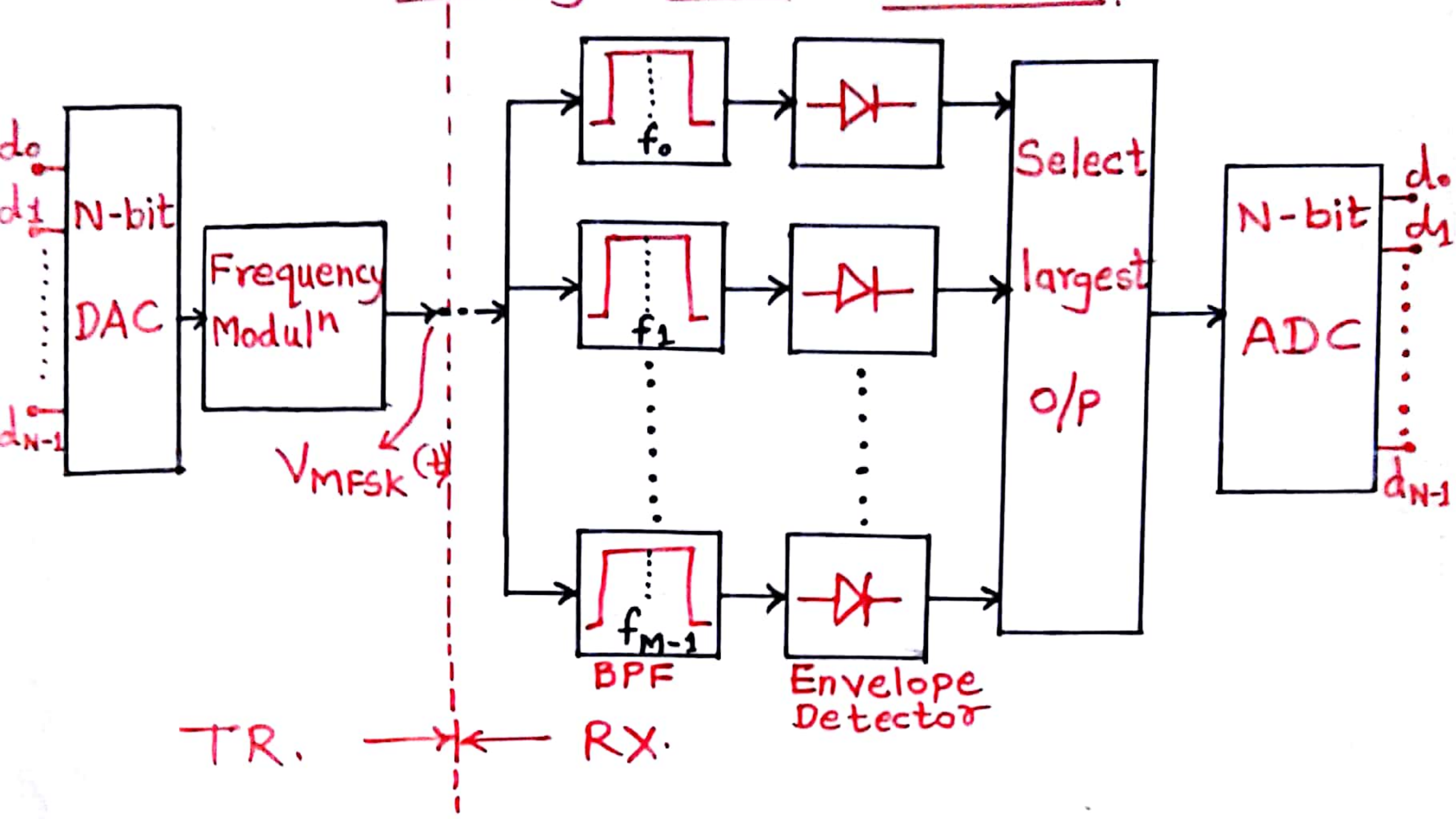
$$d^2 = 2E_b\left[1 - \frac{\sin(\omega_H - \omega_L)T_b}{(\omega_H - \omega_L)T_b}\right]$$

* BFSK Receiver:-



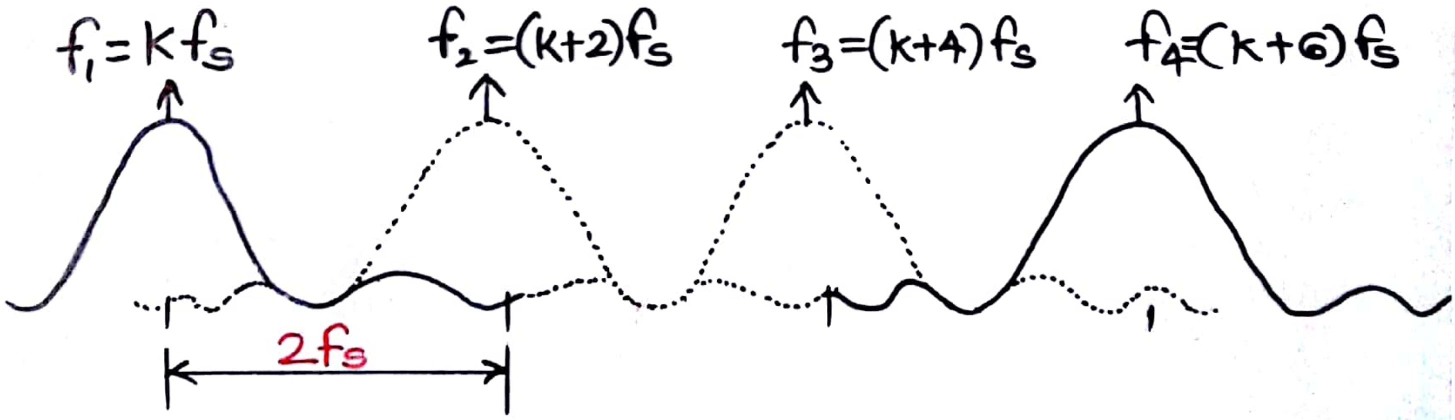
For unipolar Comparator o/p is b(t).

M-ary FSK (MFSK)



* **Spectrum:-**

For minimum P.E., the frequencies f_1, f_2, f_{M-1} are selected such that they are mutually orthogonal i.e. Even Harmonics of f_s.



* **Bandwidth:-**

$$B = 2Mf_s$$

$$B = 2(2^N)\frac{f_b}{N}$$

$$\boxed{B = 2^{N+1}\frac{f_b}{N}}$$

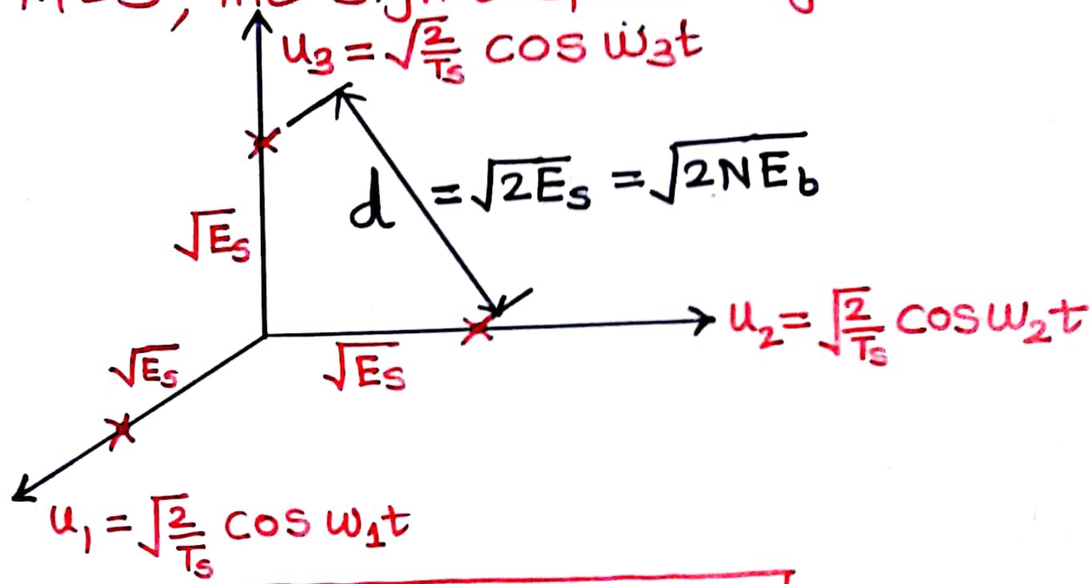
Hence:

B.W. requirement of MFSK is more than MPSK
MPSK

* Signal Space Diagram :-

There will be M-mutually orthogonal co-ordinate axes for M-ary FSK.

For M=3, the signal space diagram is →



$$\boxed{d = \sqrt{2E_s} = \sqrt{2NE_b}}$$

As N ↑, M ↑, P.E. ↓ .

* Advantages of MFSK :-

(1) More Noise immunity

(2) Probability of error is reduced with increase in M

* Disadvantages :-

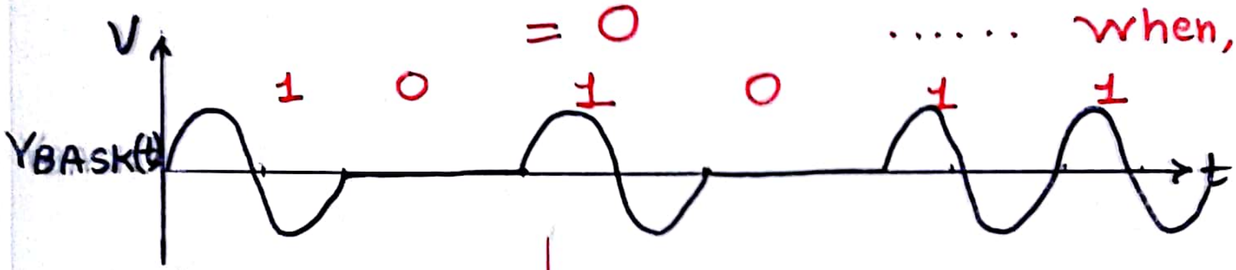
Requires more B.W. than MPSK.

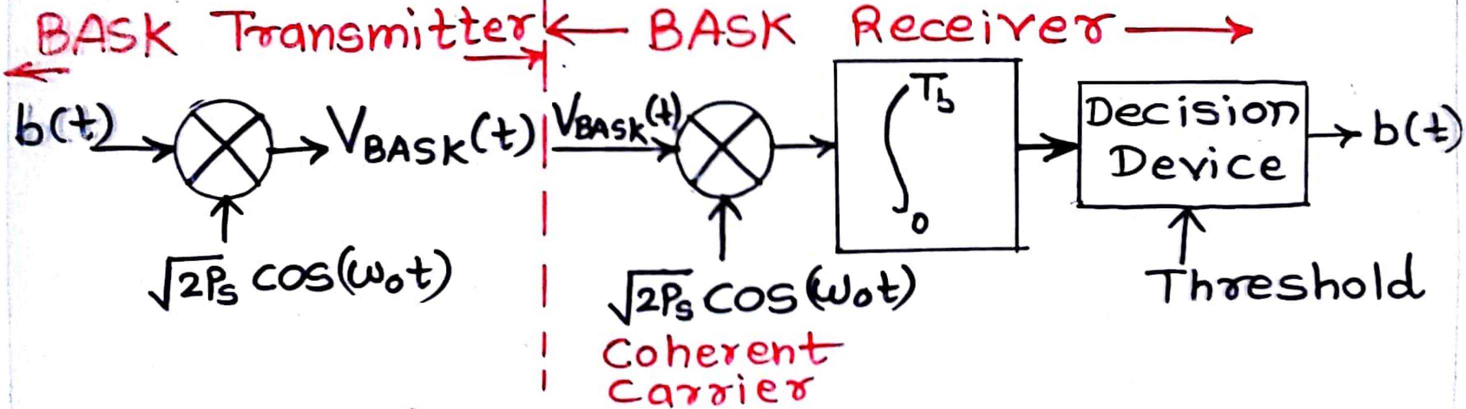
Binary Amplitude Shift Keying (BASK) or ON-OFF Keying

$$\boxed{V_{BASK}(t) = b(t)\sqrt{2P_s}\cos(\omega_0 t)}$$

$= \sqrt{2P_s}\cos(\omega_0 t)$ ..... when, $b(t) = 1$ (logic)

$= 0$ ...... when, $b(t) = 0$ (logic)





* Signal Space Diagram:-

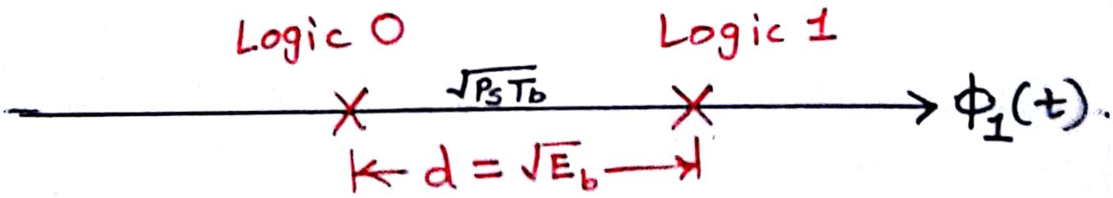
$$S(t) = b(t)\cdot\sqrt{2P_s}\cos\omega_0 t = b(t)\cdot\sqrt{P_s T_b}\underbrace{\sqrt{\frac{2}{T_b}}\cos(\omega_0 t)}.$$

$$\therefore S(t) = b(t)\sqrt{P_s T_b}\ \phi_1(t).$$

$\therefore S(t) = \sqrt{P_s T_b}\ \phi_1(t)$ ..... $b(t) = 1$ (Logic)

&

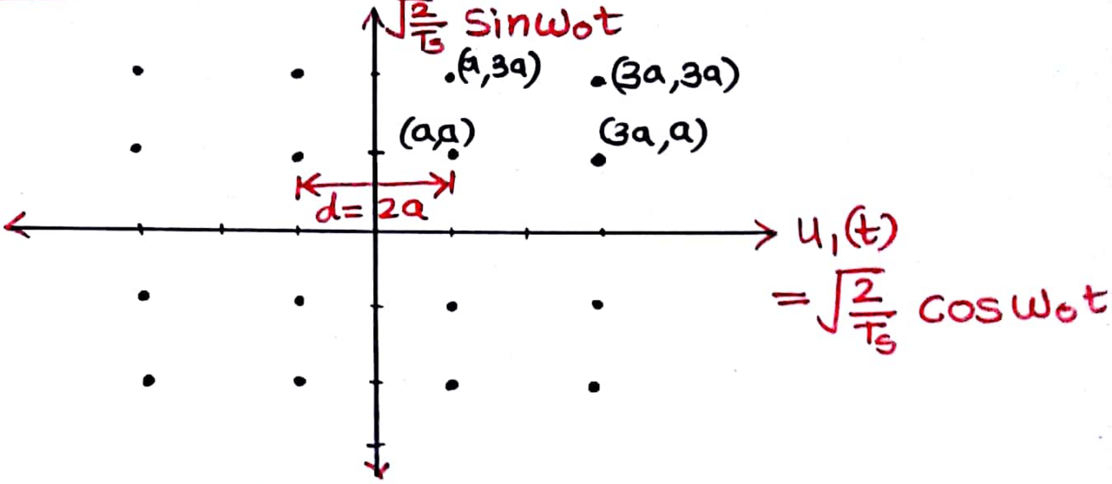
$S(t) = 0$ .... $b(t) = 0$ (Logic)



* PSD is same as BPSK.

Scanned by CamScanner

16 QAM / 16 QASK / 16 QAPSK



① Es = Energy of symbol

$$= \frac{a^2+a^2+a^2+9a^2+9a^2+a^2+9a^2+9a^2}{4}$$

$$= \frac{40a^2}{4}$$

$E_s = 10a^2 \quad \therefore \boxed{a = \sqrt{0.1E_s}}$

② $d = 2a = 2\sqrt{0.1E_s} = 2\sqrt{0.1NE_b}$

$\therefore d = 2\sqrt{0.1\times 4E_b}$

For 16QAM $M = 16 = 2^N$ $\therefore N = 4$

$\therefore \boxed{d = 2\sqrt{0.4E_b} \quad d = \sqrt{1.6E_b}}$ → For 16 QAM.

③ For QPSK:→

$d = 2\sqrt{NE_b}\sin\frac{\pi}{M}$

$\therefore d = 2\sqrt{2E_b}\sin\frac{\pi}{4}$

$\therefore \boxed{d = 2\sqrt{E_b}}$

Hence $(d)_{16QAM} < (d)_{QPSK}$

④ For 16-MPSK,

$d = 2\sqrt{NE_b}\sin\frac{\pi}{M}$

$\therefore d = 2\sqrt{4E_b}\sin\left(\frac{180}{16}\right)$

$\therefore \boxed{d = 2\sqrt{0.15E_b}}$

Hence, $(d)_{16QAM} > (d)_{16MPSK}$

⑤ B.W. of QAM :- same as MPSK.

$B.W. = 2\frac{f_b}{N} = 2\frac{f_b}{4}$

$\therefore \boxed{B.W. = f_b/2}$

B.W. of BPSK $= \frac{2f_b}{N} = \frac{2f_b}{1}$

$\boxed{B.W. = 2f_b}$

Hence, B.W. (16 QAM) is one fourth of B.W. (BPSK)

M4K

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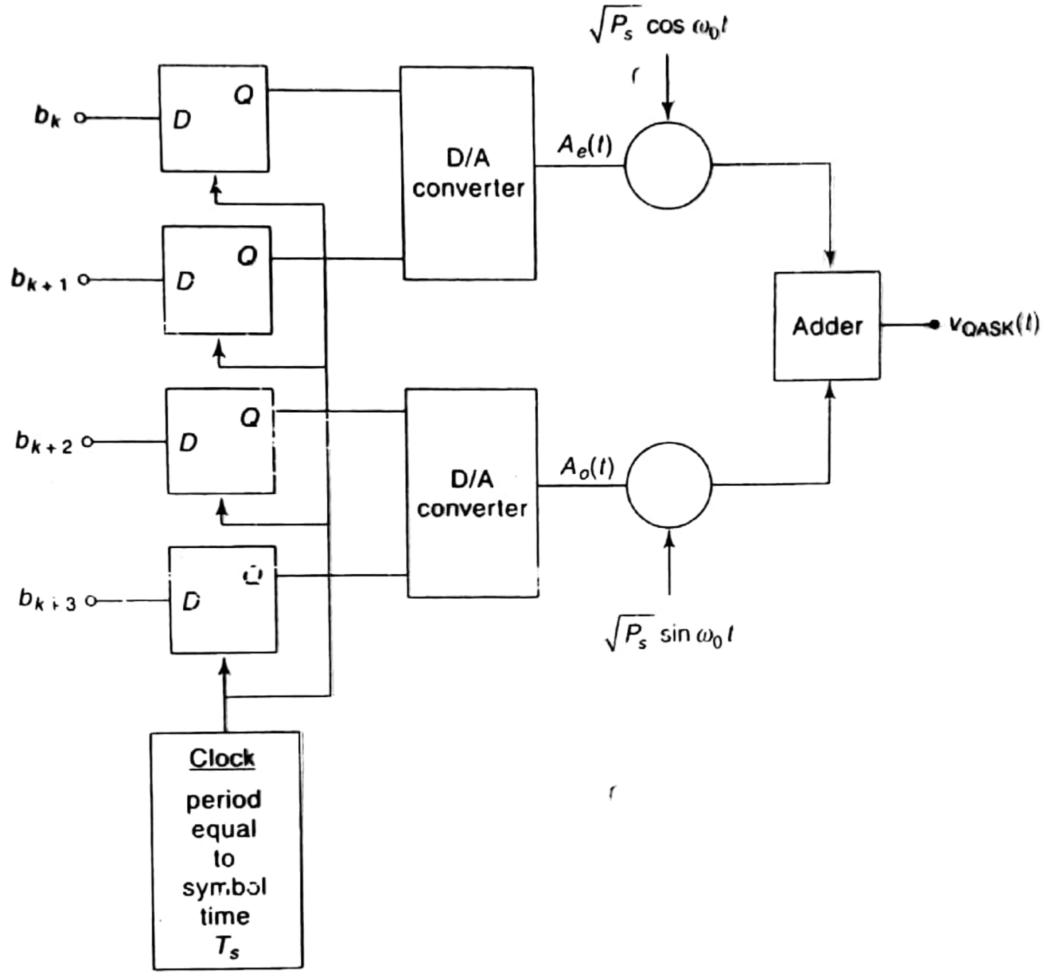

Fig. 6.19 Generation of QASK signal.

$$\overline{A_e^2} = \overline{A_o^2} = 1$$

Thus each of the quadrature terms in Eq. (6.7.8) conveys on the average, one half of the total transmitted power.

Bandwidth of a QASK Signal The power spectral density and bandwidth of a QASK can be calculated by the procedure applied in the case of M-ary PSK, since Eq. (6.41) is similar to Eq. (6.22). Thus, we have that the power spectral density is (see Prob. 6.18)

$$G_{QASK}(f) = \frac{P_s T_s}{2}\left[\frac{\sin \pi(f - f_0)T_s}{\pi(f - f_0)T_s}\right]^2 + \frac{P_s T_s}{2}\left[\frac{\sin \pi(f + f_0)T_s}{\pi(f + f_0)T_s}\right]^2$$

where $T_s = NT_b$. The bandwidth of the QASK signal is

$$B = 2f_b/N$$

which is the same as in the case of M-ary PSK. For the present case of QASK with N corresponding to 16 possible distinguishable signals we have $B_{QASK(16)} = f_b/2$ which is one fourth of the bandwidth required for binary PSK.

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SK Receiver The QASK receiver shown in Fig. 6.20 is similar to the QPSK receiver 13. As in QPSK, a local set of quadrature carriers for synchronous demodulation is by raising the received signal to the fourth power, extracting the component at frequency en dividing the frequency by 4. In the present case, since the coefficients A_e and A_o are d value, it behoves us to inquire whether there is still a recoverable carrier. We have

$$v_{QASK}^4(t) = P_s^2(A_e(t) \cos \omega_0 t + A_o(t) \sin \omega_0 t)^4 \tag{6.47}$$

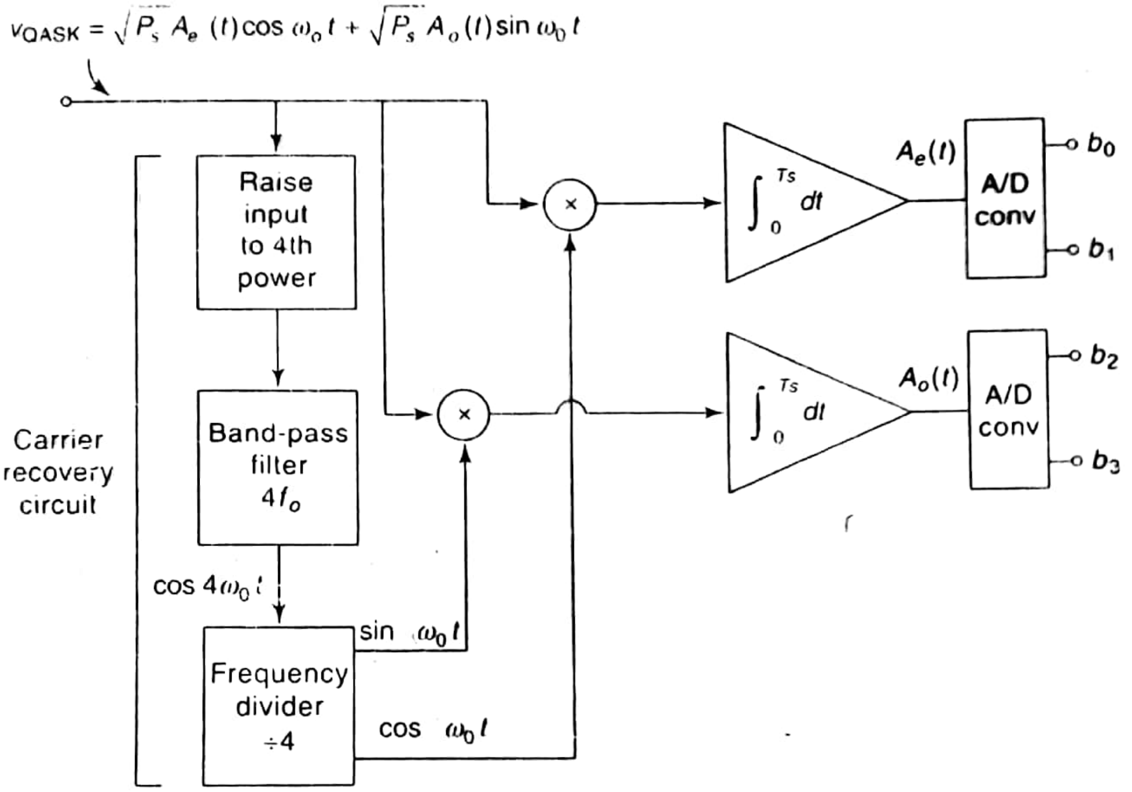

Fig. 6.20 The QASK receiver.

Minimum Shift Keying (MSK)

(*) Explain: MSK is FSK system.

(i) $V_{MSK}(t) = \sqrt{2P_s}\, C_H(t) \sin\omega_H t + \sqrt{2P_s}\, C_L(t) \sin\omega_L t$

where,

$C_H = \dfrac{b_o + b_e}{2}$; $C_L = \dfrac{b_o - b_e}{2}$

$\omega_H = \omega_o + \Omega$; $\omega_L = \omega_o - \Omega$

(ii) if, $b_o = b_e$; $C_L = 0$; $C_H = b_o = \pm 1$
if, $b_o = -b_e$; $C_H = 0$; $C_L = b_o = \pm 1$

(iii) Depending on b_o and b_e in each bit interval, transmitted signal is at angular Frequency at ω_H and ω_L i.e. FSK //.

(*) Why it is called as 'MSK'?

In MSK, two freq. f_H and f_L are chosen in such a way that two possible signals are orthogonal over the bit interval T_b.

i.e. $$\int_0^{T_b} (\sin\omega_H t \cdot \sin\omega_L t)\, dt = 0$$

i.e. $$\frac{1}{2}\int_0^{T_b} \left[\cos(\omega_H+\omega_L)t - \cos(\omega_H-\omega_L)t\right] dt = 0$$

i.e. $$\frac{1}{2}\left[\frac{\sin(\omega_H+\omega_L)T_b}{(\omega_H+\omega_L)} - \frac{\sin(\omega_H-\omega_L)T_b}{(\omega_H-\omega_L)}\right] = 0$$

Now,

$$\frac{\sin(\omega_H+\omega_L)T_b}{(\omega_H+\omega_L)} = 0 \quad \& \quad \frac{\sin(\omega_H-\omega_L)T_b}{(\omega_H-\omega_L)} = 0$$

i.e. $\sin(\omega_H+\omega_L)T_b = 0 \quad \& \quad \sin(\omega_H-\omega_L)T_b = 0$

i.e. $(\omega_H+\omega_L)T_b = m\pi \quad \& \quad (\omega_H-\omega_L)T_b = n\pi$

i.e. $2\pi(f_H+f_L)T_b = m\pi \quad \& \quad 2\pi(f_H-f_L)T_b = n\pi$

$\omega_H = \omega_0 + \Omega$ where, $\Omega = \frac{2\pi}{4T_b} = 2\pi\frac{f_b}{4}$

$\therefore 2\pi f_H = 2\pi f_0 + 2\pi\frac{f_b}{4}$

$$\therefore \boxed{f_H = f_0 + \frac{f_b}{4}} \rightarrow (1) \quad \& \quad \boxed{f_L = f_0 - \frac{f_b}{4}} \rightarrow (2)$$

Now, $2\pi(f_H+f_L)T_b = m\pi$

$$\boxed{2(f_H+f_L) = mf_b} \rightarrow (3)$$

$$\& \quad \boxed{2(f_H-f_L) = nf_b} \rightarrow (4)$$

using (1) and (2), $f_H+f_L = 2f_0$

$\& \quad f_H - f_L = \frac{2f_b}{4}$

Substituting in eqn. (3) & (4) we get,

From (3) →

$2(2f_0) = mf_b$

$$\therefore \boxed{f_0 = \frac{mf_b}{4}}$$

From (4) →

$2\left(2\frac{f_b}{4}\right) = nf_b$

$$\therefore \boxed{n=1}$$

Substituting in eqn. (1) & (2) we get,

$$\boxed{f_H = (m+1)\frac{f_b}{4}} \rightarrow (5)$$

$$\boxed{f_L = (m-1)\frac{f_b}{4}} \rightarrow (6)$$

Since $n=1$, $(f_H-f_L) = \frac{f_b}{2}$, so f_H & f_L are as close together as possible for orthogonality to prevail. Thus, this system is called as '<u>Minimum Shift Keying</u>'

MGK

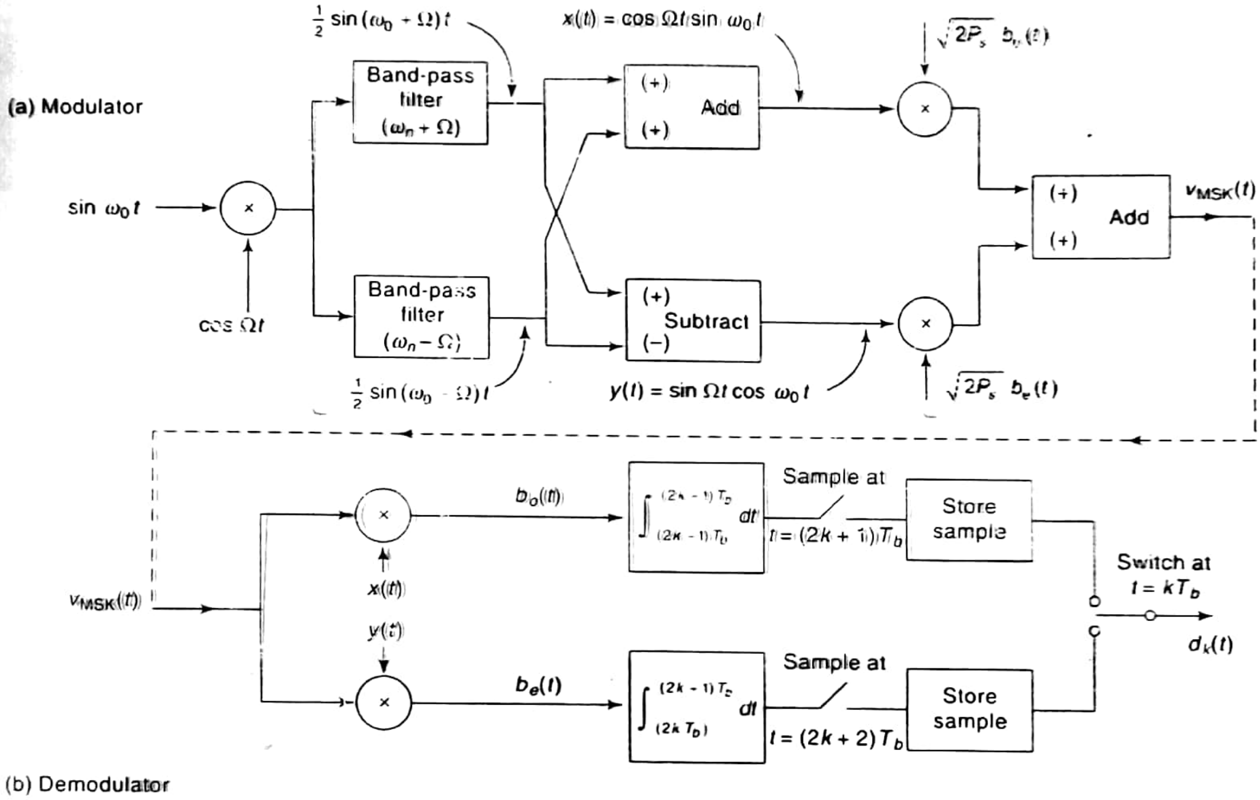

Fig. 6.33 Method of modulating and demodulating MSK.

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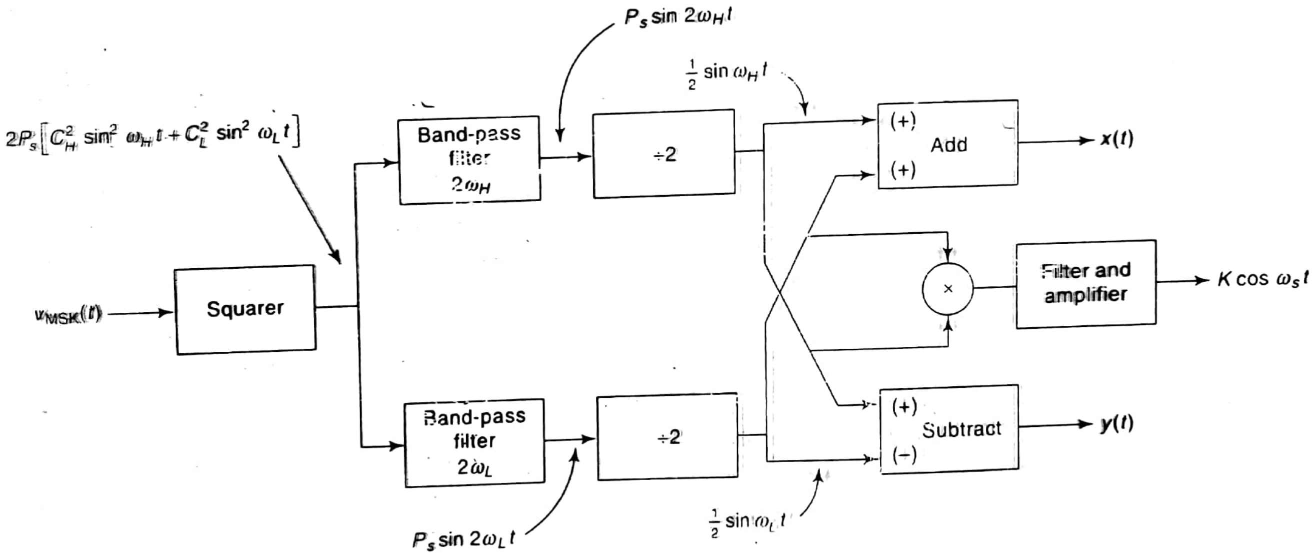

Fig. 6.34 Technique to regenerate $x(t)$ and $y(t)$.

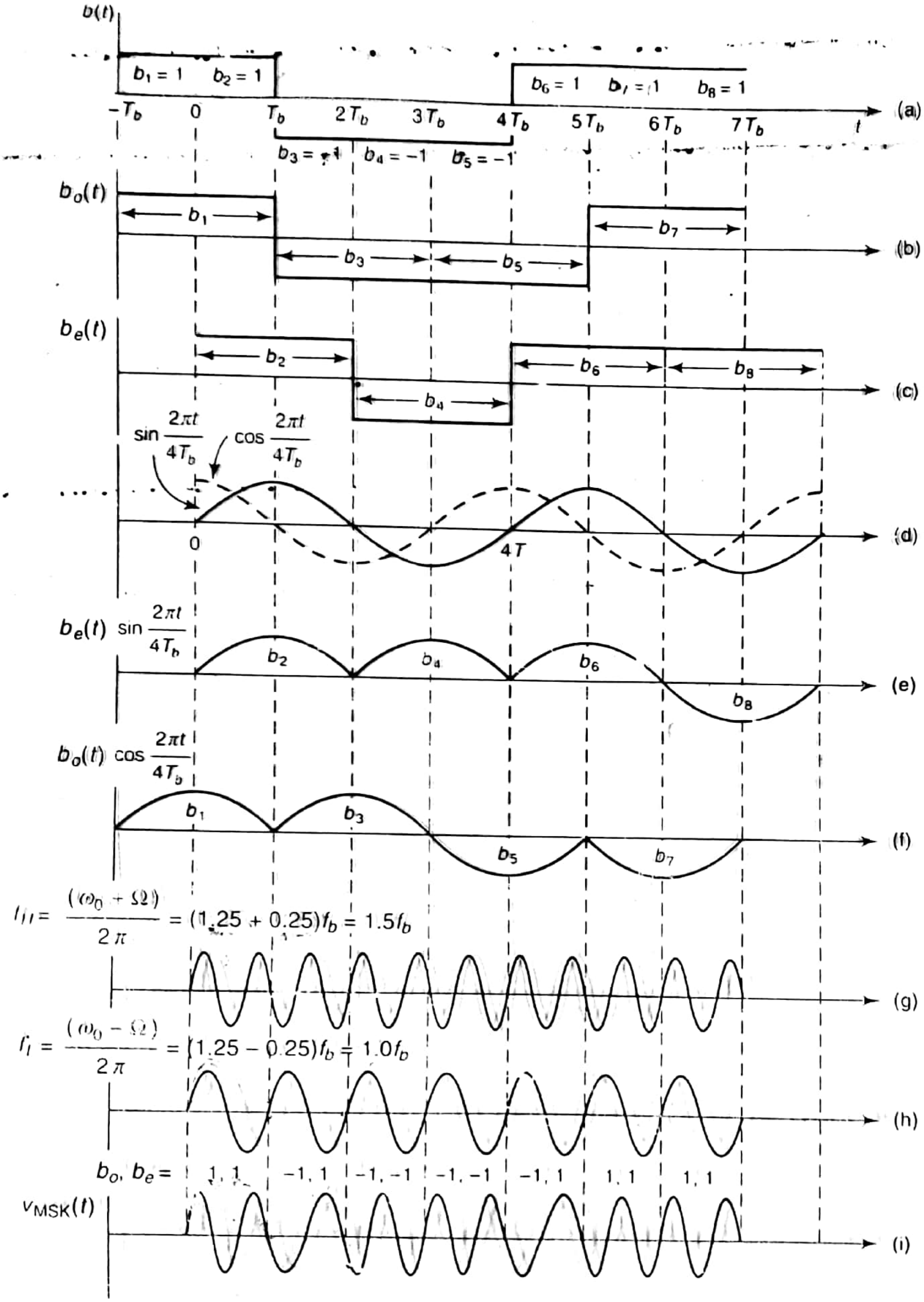

Fig. 6.29 MSK waveforms.

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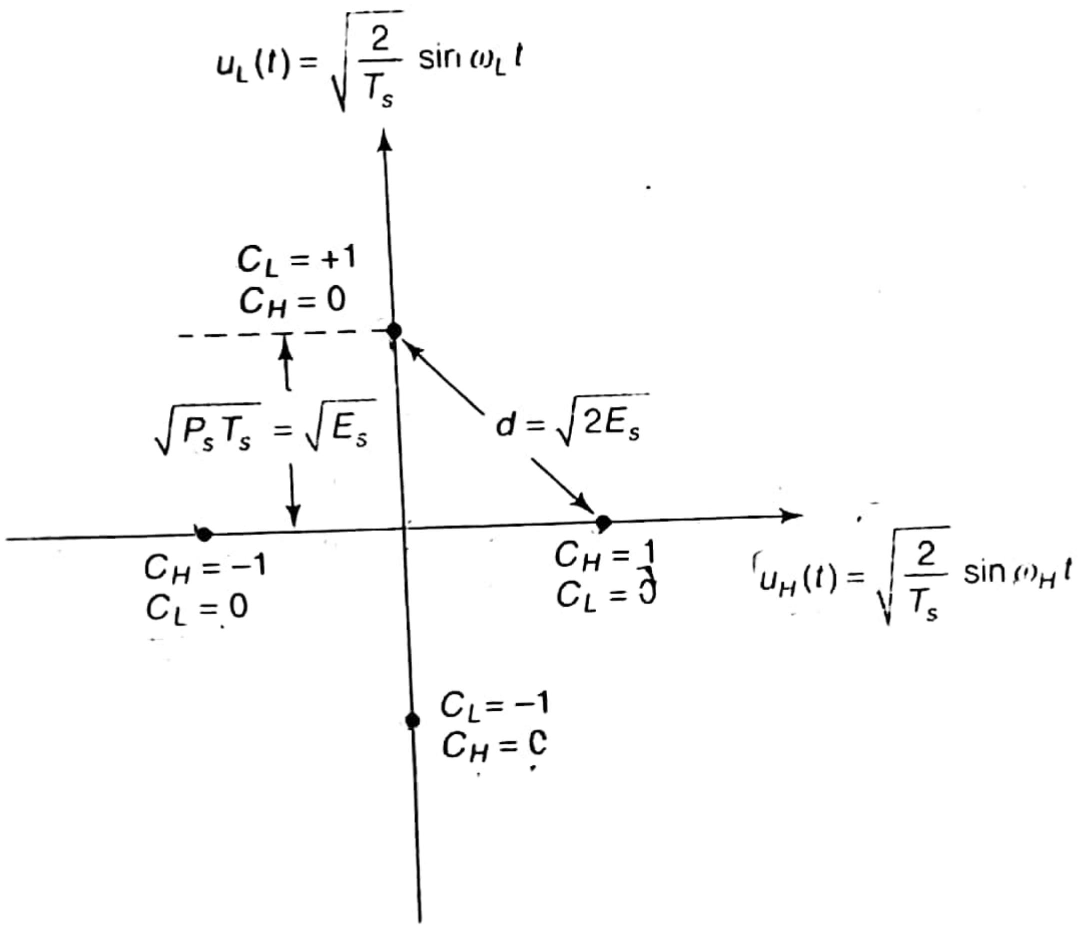


Fig. 6.30 Signal space representation of MSK.

* Phase Continuity in MSK

$$V_{MSK}(t) = \sqrt{2P_s}\, C_H(t) \sin\omega_H t + \sqrt{2P_s}\, C_L(t) \sin\omega_L t$$

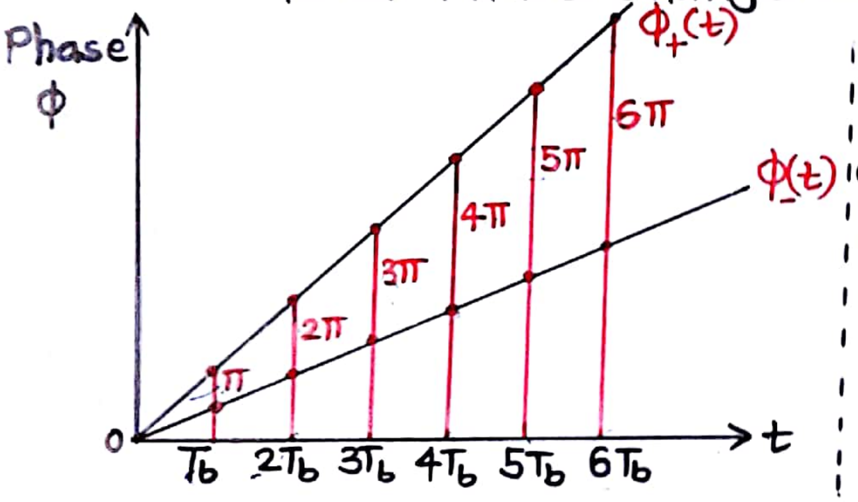
$$= b_o(t)\sqrt{2P_s} \sin[\phi(t)]$$

where, $\boxed{\phi(t) = \omega_o t + b_o(t)\, b_e(t)\, \Omega t}$

$\phi_+(t) = (\omega_o + \Omega)t$ .... $b_o(t) \cdot b_e(t) = +1$

$\phi_-(t) = (\omega_o - \Omega)t$ .... $b_o(t) \cdot b_e(t) = -1$

$\therefore$ Total Phase change $= 2\Omega t = 2\left(\frac{2\pi}{4T_b}\right)t = K\pi$ integer



Explaination:-
(i) During even time, Total phase change $= 2\pi, 4\pi, 6\pi, \ldots\ldots$ implies No Phase Change i.e. Phase continuity.

(ii) During odd time, total phase change $= \pi, 3\pi, 5\pi, \ldots\ldots$ But, from eq^n (1) the coefficient $b_o(t)$ of $\sqrt{2P_s}\sin[\phi(t)]$ helps here. Whenever there is phase change the $b_o(t)$ also changes sign, resulting an additional π phase change

$\therefore$ Net phase change = Zero $\therefore$ Phase continuity.

* PSD of MSK:-