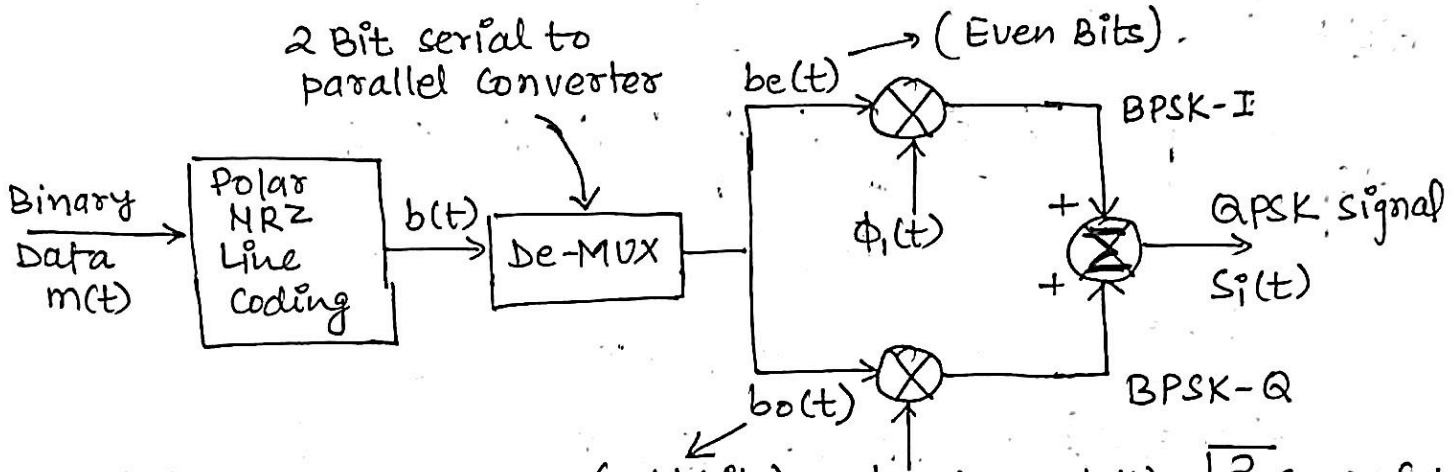
Quadrature phase shift keying (QPSK)

- QPSK is a form of PSK in which two bits are modulated at once. 2 Bits = 1 symbol

Baud Rate, $N_b = \frac{R_b}{2}$ Bauds or symbol/sec

QPSK Transmitter

Let in QPSK modulation scheme, the binary data sequence $b(t) = \{1\ 1\ 0\ 0\ 1\ 0\ 1\ 1\ 1\ 0\ 1\}$. The bit interval is T_b.



$$\phi_1(t) = \sqrt{\frac{2}{T}}\cos 2\pi f_c t$$

$$\phi_2(t) = \sqrt{\frac{2}{T}}\sin 2\pi f_c t$$

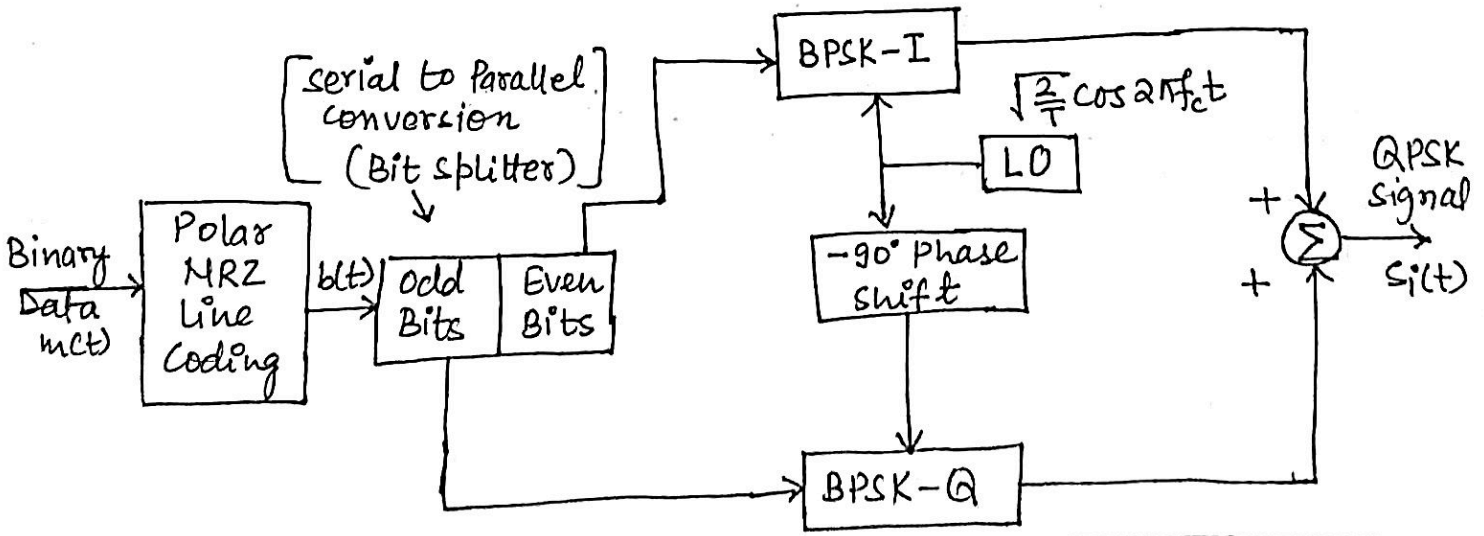
$b(t) = \{1\ 1\ 0\ 0\ 1\ 0\ 1\ 1\ 1\ 0\ 1\}$
(1 2 3 4 5 6 7 8 9 10 11)

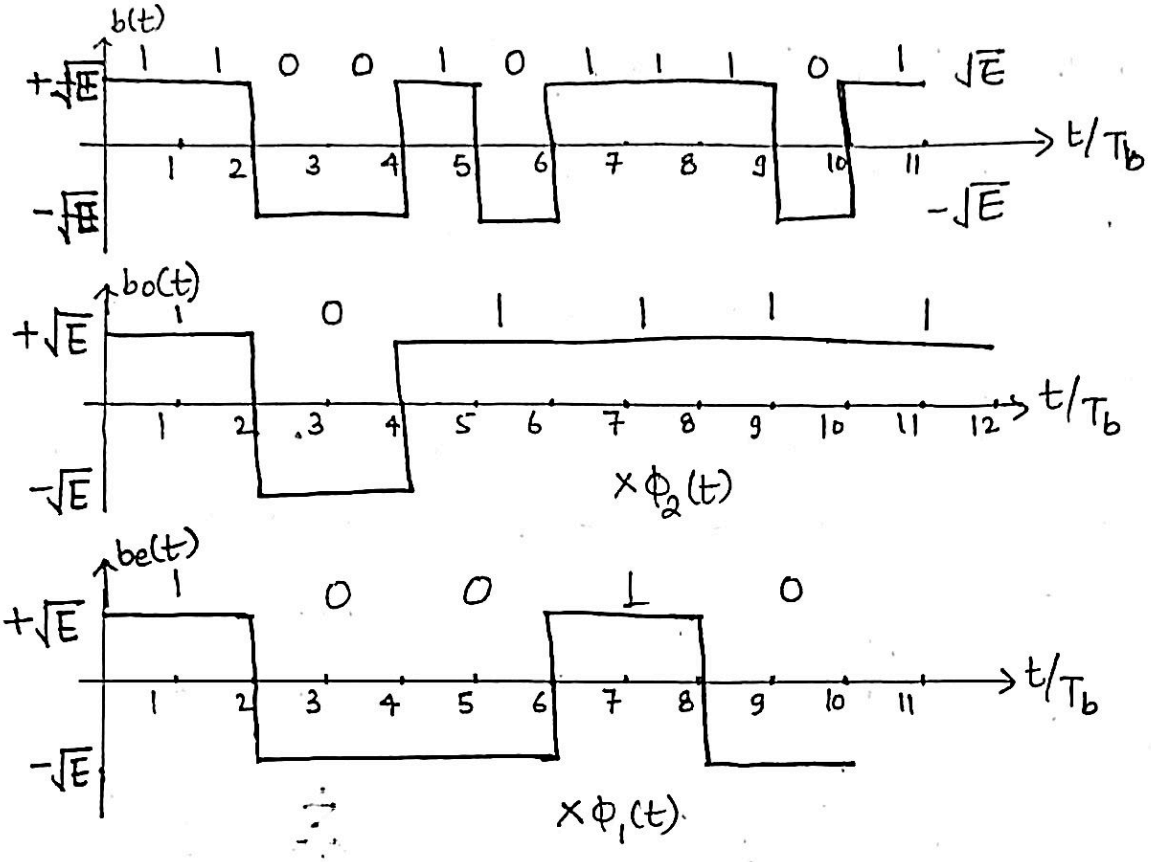
$be(t) = \{1\ 0\ 0\ 1\ 0\}$

$bo(t) = \{1\ 0\ 1\ 1\ 1\ 1\}$

$T = 2T_b$ (T: Symbol duration; T_b: Bit duration)

- The function of the De-MUX is to divide the binary wave produced by polar NRZ level encoder into two seperate binary waves, - odd-numbered dibits and even-numbered dibits.





$$S_i(t) = S_1(t) + S_2(t) = b_e(t)\,\phi_1(t) + b_o(t)\,\phi_2(t)$$

$$S_i(t) = \sqrt{\frac{2E}{T}} \cos\left[2\pi f_c t + (2i-1)\frac{\pi}{4}\right] \qquad 0 \le t \le T$$

$i = 1, 2, 3, 4$

$T = 2T_b$ and E = Symbol Energy or transmitted signal energy per symbol

2-Bit = 1 Symbol
or
Dibit

0	0
0	1
1	0
1	1

$i = 1, 2, 3, 4$

$i = 1 \quad S_1(t) = \sqrt{\frac{2E}{T}} \cos\left[2\pi f_c t + \frac{\pi}{4}\right]$

$i = 2 \quad S_2(t) = \sqrt{\frac{2E}{T}} \cos\left[2\pi f_c t + \frac{3\pi}{4}\right]$

$i = 3 \quad S_3(t) = \sqrt{\frac{2E}{T}} \cos\left[2\pi f_c t + \frac{5\pi}{4}\right]$

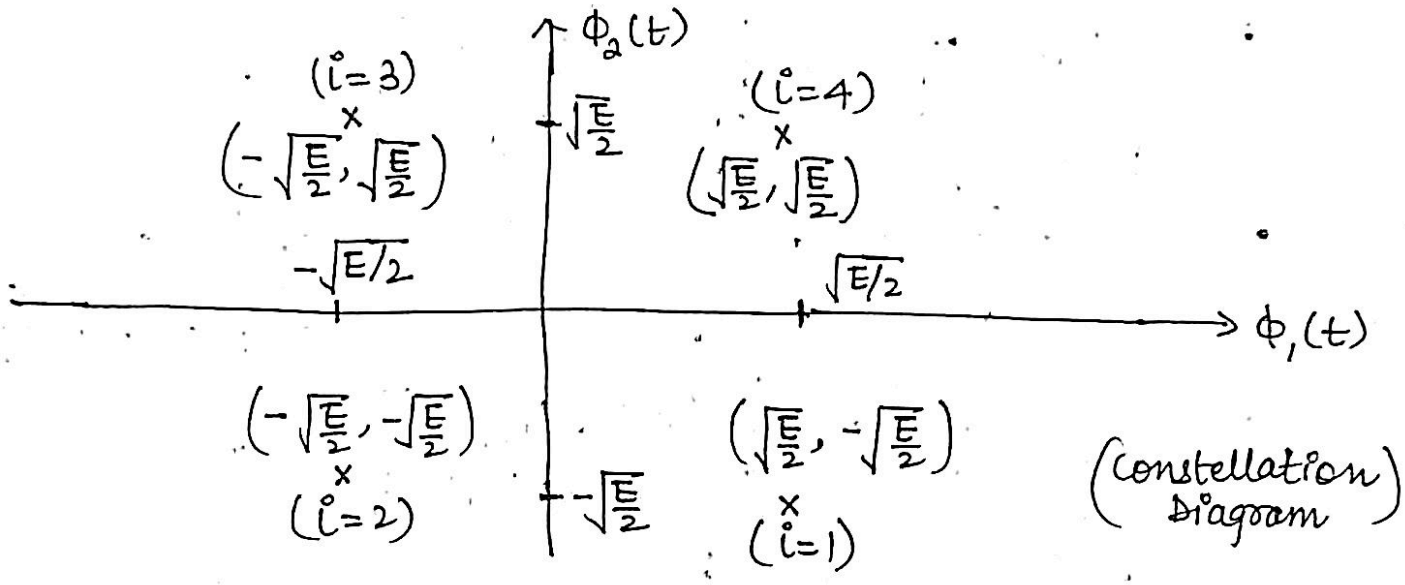
$i = 4 \quad S_4(t) = \sqrt{\frac{2E}{T}} \cos\left[2\pi f_c t + \frac{7\pi}{4}\right]$

$$s_i(t) = \sqrt{\frac{2E}{T}} \cos\left[2\pi f_c t + (2i-1)\frac{\pi}{4}\right]$$

$$= \sqrt{\frac{2E}{T}} \left[\cos 2\pi f_c t \cdot \cos\left\{(2i-1)\frac{\pi}{4}\right\} - \sin 2\pi f_c t \cdot \sin\left\{(2i-1)\frac{\pi}{4}\right\}\right]$$

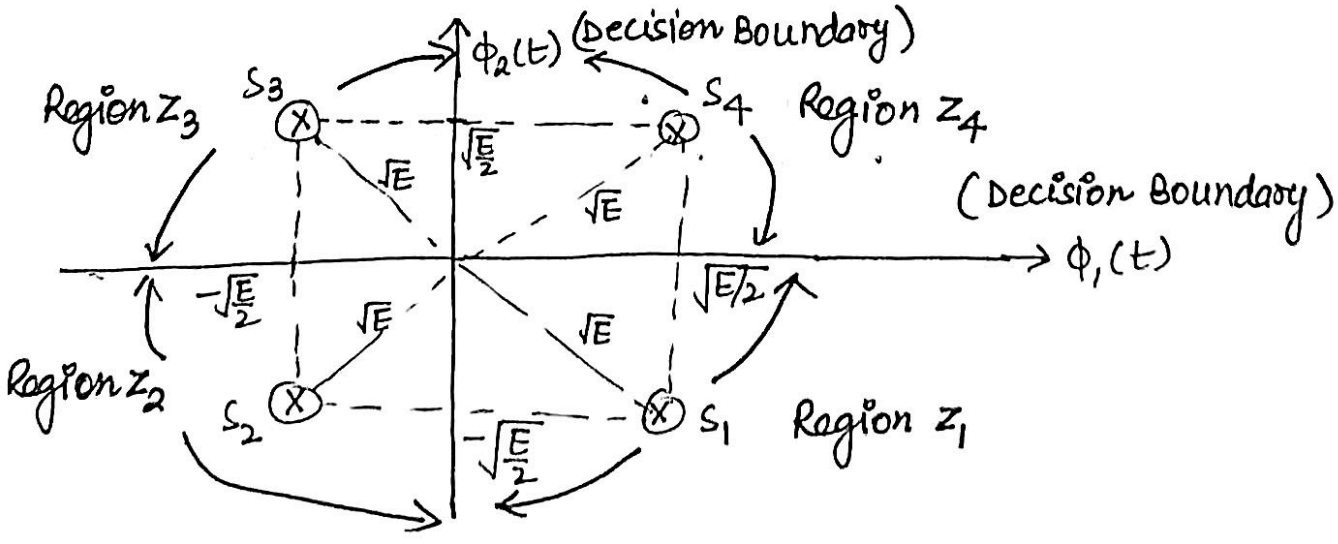
$$s_i(t) = \sqrt{E}\cos\left\{(2i-1)\frac{\pi}{4}\right\}\phi_1(t) - \sqrt{E}\sin\left\{(2i-1)\frac{\pi}{4}\right\}\phi_2(t)$$

$N=2$, $M=4$, $0 \le t \le T$ and $i = 1, 2, 3, 4$



(Constellation Diagram)

i	Phase Angle	Message coordinates s_{i1}	s_{i2}	Dibit	
1	$\pi/4$	$\sqrt{\frac{E}{2}}$	$-\sqrt{\frac{E}{2}}$	1	0 (s_1)
2	$3\pi/4$	$-\sqrt{\frac{E}{2}}$	$-\sqrt{\frac{E}{2}}$	0	0 (s_2)
3	$5\pi/4$	$-\sqrt{\frac{E}{2}}$	$\sqrt{\frac{E}{2}}$	0	1 (s_3)
4	$7\pi/4$	$\sqrt{\frac{E}{2}}$	$\sqrt{\frac{E}{2}}$	1	1 (s_4)

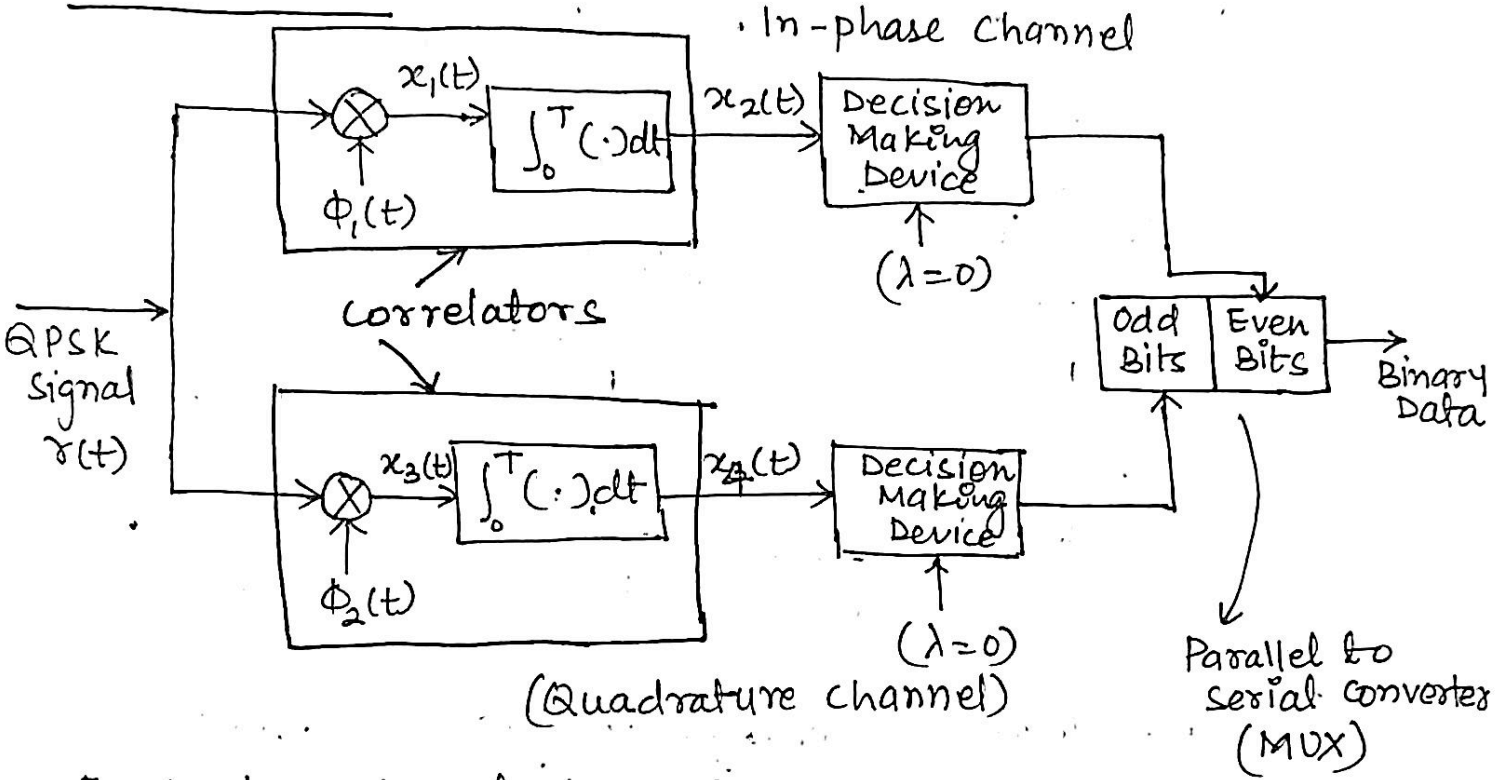


From signal space diagram, the distance

$$d_{12} = 2\sqrt{\frac{E}{2}} = \sqrt{2E} = d_{23} = d_{34} = d_{41}$$

$$d_{13} = d_{24} = 2\sqrt{E}$$

QPSK Receiver



For In-phase channel

if $x_2(t) > 0$, decision is made in favor of symbol 1

if $x_2(t) \leq 0$, " " " 0

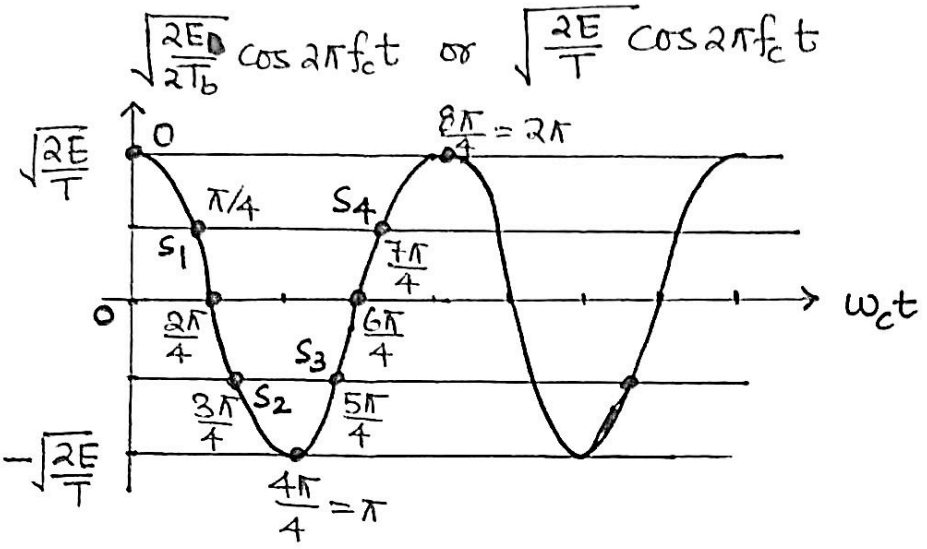
For Q-channel

if $x_4(t) > 0$, decision is made in favor of symbol 1

if $x_4(t) \leq 0$, " " " 0

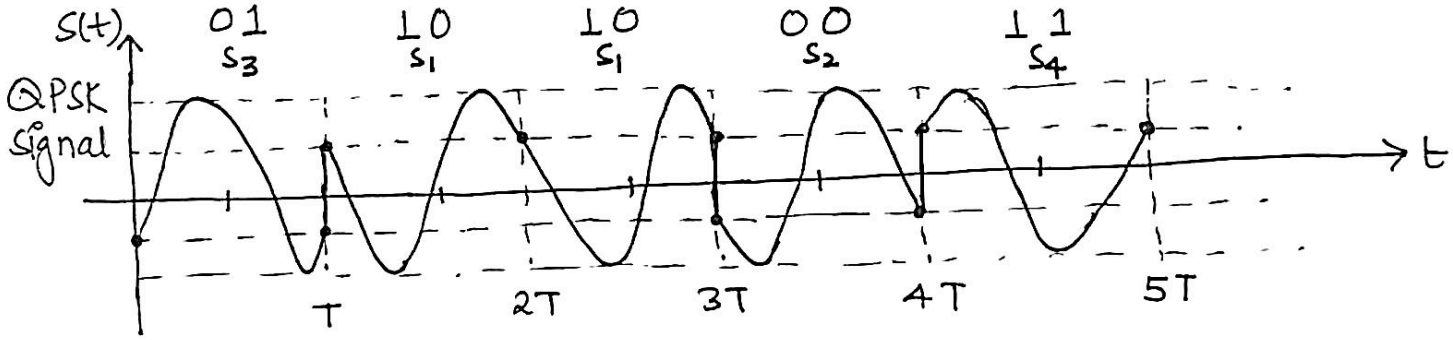
- Multiplexer (MUX) combines the two binary sequences produced by the pair of decision devices.

QPSK Waveforms



$\cos(\omega_c t + \phi) \Rightarrow$ Represents $\cos\omega_c t$ with ϕ radian left shift.

Binary Sequence $b(t) = \{0,1,1,0,1,0,0,0,1,1\}$



Practical Applications:-

- WLAN IEEE 802.11b (2Mbps, 5.5Mbps, 11 Mbps)
- 3G WDMA
- DVB-T (with OFDM)