Ex. 6.8.1 : If the data bit sequence consists of the following string of bits, what will be the nature of waveform transmitted by BPSK transmitter ? The data bit sequence is 1 0 1 1 1 0 1 0.

Soln. :

We know that the BPSK signal is given by,

$$V_{BPSK}(t) = \sqrt{2 P_s}\, b(t) \cos \omega_c t$$

where $b(t) = \pm 1$ depending on the digital input signal. The Table P. 6.8.1 lists the values of $b(t)$ and the transmitted signal V_{BPSK} for different bit intervals.

Table P. 6.8.1

Binary signal	1	0	1	1	1	0	1	0
$b(t)$	+1	−1	+1	+1	+1	−1	+1	−1
$V_{BPSK}(t)$	$\cos \omega_c t$	$-\cos \omega_c t$	$\cos \omega_c t$	$-\cos \omega_c t$	$\cos \omega_c t$	$-\cos \omega_c t$	$\cos \omega_c t$	$-\cos \omega_c t$

The transmitted BPSK signal is as shown in Fig. P. 6.8.1.

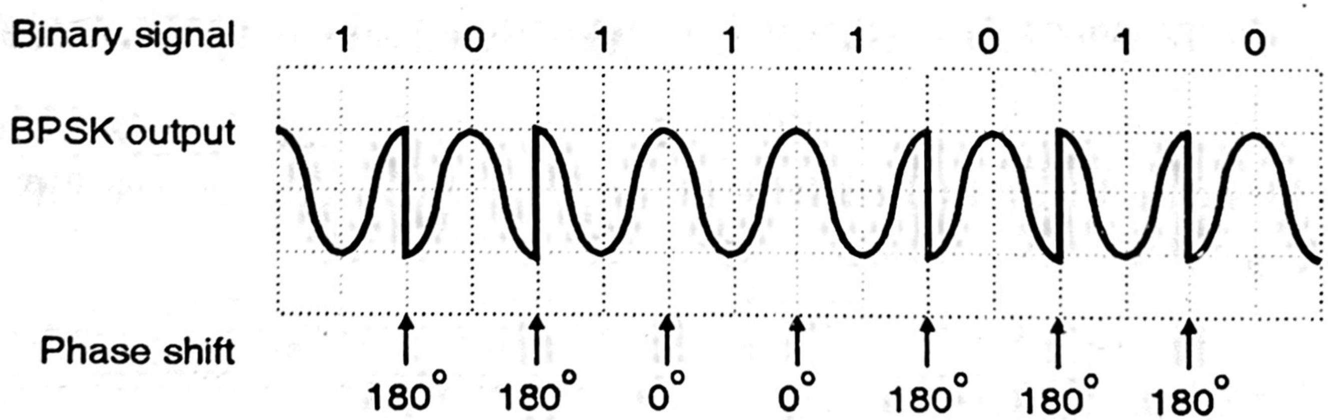

Fig. P. 6.8.1 : Waveforms

6.11 Quadrature Phase Shift Keying (QPSK) :

➤➤➤ [Asked in Exam : May 05, May 07 !!!]

- The modulation schemes discussed so far are all two level modulation. (ASK and BPSK), because they can represent only two states of the digital data (0 or 1).
- Therefore the bit rate and the baud rate are same for these systems. The maximum bit rate which can be achieved using ASK, BFSK or BPSK systems does not meet the requirements of data communication systems.
- This happens due to the limited bandwidth of the telephone voice channel.
- We can keep the baud rate same and increase the bit rate by using multilevel modulation techniques.
- In this type of systems, the data groups are divided into groups of two or more bits and each group of bits is represented by a specific value of amplitude, frequency or phase the carrier.
- QPSK (Quadrature PSK) is an example of such multilevel phase modulation.
- In QPSK system two successive bits in a bit stream are combined together to form a message and each message is represented by a distinct value of phase shift of the carrier.
- The process of combining two successive bits is demonstrated in Fig. 6.11.1

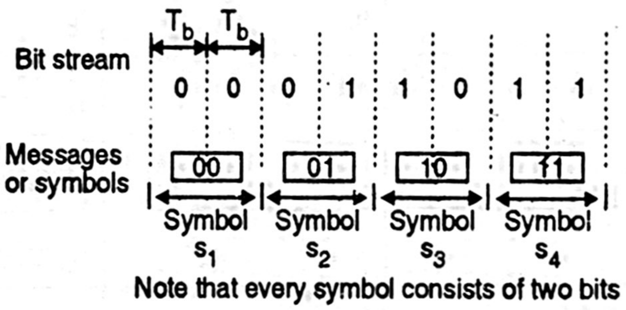

Fig. 6.11.1 : Grouping of bits in QPSK

- Each symbol or message contains two bits. So the symbol duration $T_s = 2\ T_b$.
- These symbols are transmitted by transmitted the same carrier at four different phase shifts as shown in Table 6.11.1 and Fig. 6.11.2.

Symbol	Phase
00	0
01	90
10	180
11	270

Table 6.11.1 : Phase shift in QPSK

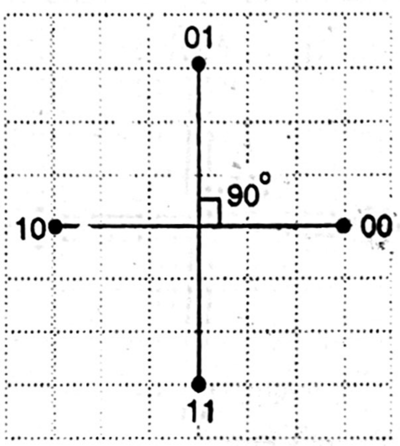

Fig. 6.11.2 : Constellation diagram of QPSK

- Since there are four phase shifts involved, this system is called as quadrature PSK or 4-PSK system.

$$V_{QPSK} = S_2 = \sqrt{2\,P_s}\,\cos\left[\omega_c t + \frac{3\pi}{4}\right] \qquad \text{... for } m = 1$$

- Similarly we can obtain the QPSK output for m = 2 and m = 3.
- As explained earlier we can substitute P_s in terms of symbol energy and symbol time duration as :

$$P_s = E/T$$

The QPSK system of modulation is also called as four state PSK (or simply 4 PSK).

6.11.1 Offset QPSK (OQPSK) or Staggered QPSK Transmitter :

➤➤➤ [Asked in Exam : Dec. 04, Dec. 06, Dec. 07 !!!]

The block diagram of offset QPSK (OQPSK) is shown in Fig. 6.11.4(a). This shows the mechanism by which a bit stream b (t) generates a QPSK signal for transmission.

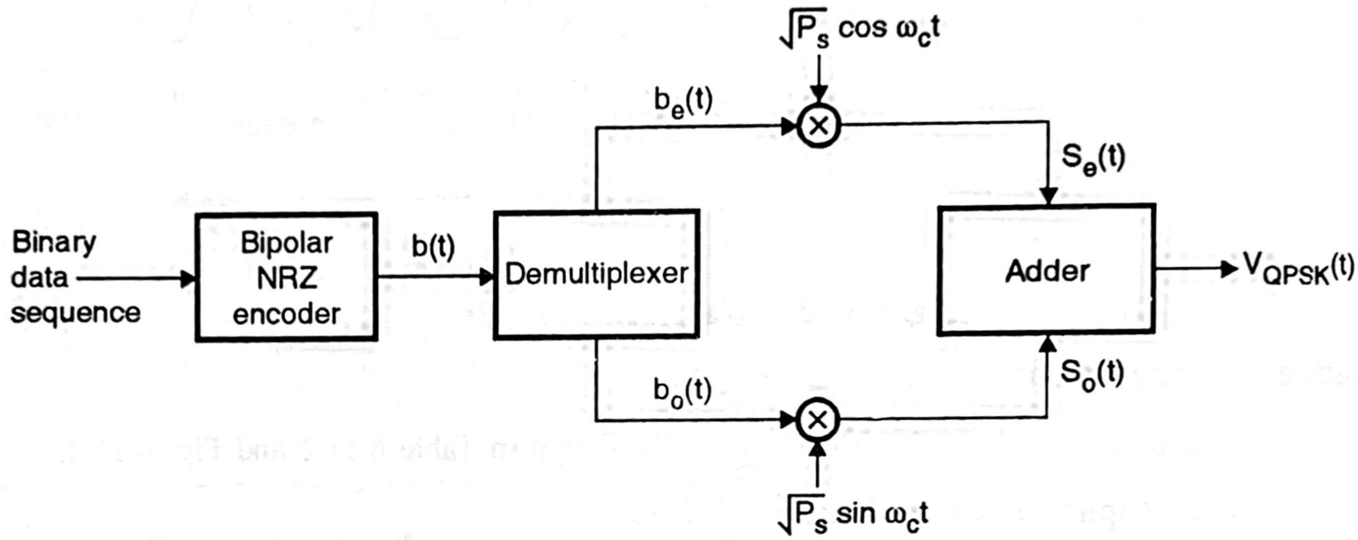

Fig. 6.11.4(a) : An offset QPSK transmitter

Operation of the OQPSK transmitter :

- The input binary sequence is first converted into a bipolar NRZ signal, b (t). The value of b (t) = + 1 V for a logic 1 input and b (t) = – 1 V when the binary input is equal to 0.

Binary input	NRZ signal b (t)
0	– 1 V
1	+ 1 V

- The demultiplexer will divide b (t) into two separate bit streams named b_o (t) and b_e (t). The bit stream b_e (t) consists of only the even numbered bits i.e. 2, 4, 6, ... as shown in Fig. 6.11.5, whereas the b_o (t) bit stream consists of only the odd numbered bits i.e. 1, 3, 5, ... as shown in Fig. 6.11.5.

- If the symbol 00 is to be transmitted then we have to transmit a carrier at 0° phase shift. If 01 is to be transmitted, then the same carrier is transmitted with a phase shift of 90°.
- Similarly the message 10 and 11 are transmitted by transmitting the carrier at 180° and 270° respectively.
- This concept will be clear after referring to the QPSK waveform of Fig. 6.11.3.

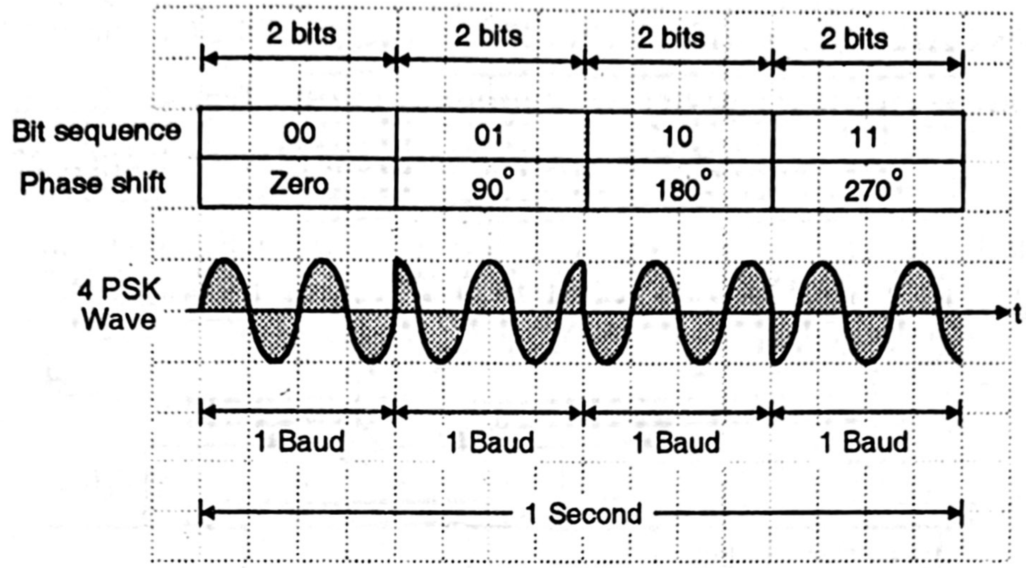

Fig. 6.11.3 : Waveforms of QPSK

Alternative representation :

An alternate representation of QPSK symbols is shown in Table 6.11.2 and Fig. 6.11.4.

Sr. No.	Symbol	Input successive bits		Phase shift in the carrier
		A	B	
1.	S_1	1	0	$\pi/4$ rad
2.	S_2	0	0	$3\pi/4$ rad
3.	S_3	0	1	$5\pi/4$ rad
4.	S_4	1	1	$7\pi/4$ rad.

Table 6.11.2

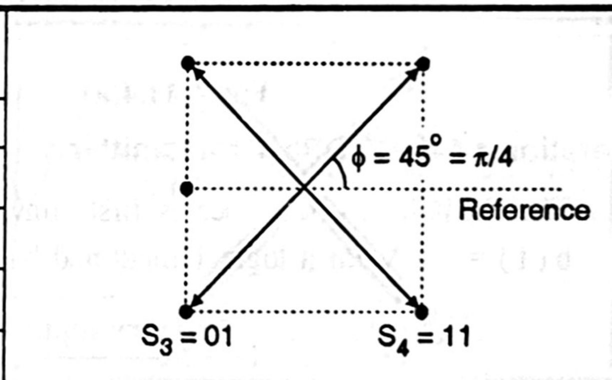

Fig. 6.11.4

Mathematical representation of QPSK :

- A QPSK signal can be represented mathematically as :

$$V_{QPSK}(t) = \sqrt{2P_s}\cos\left[\omega_c t + (2m+1)\frac{\pi}{4}\right], \quad m = 0, 1, 2, 3$$

- By substituting the values of m from 0 to 3 we get the four messages listed in Table 6.11.2

$$\text{i.e.} \quad V_{QPSK} = S_1 = \sqrt{2P_s}\cos\left[\omega_c t + \frac{\pi}{4}\right] \quad \text{... for } m = 0$$

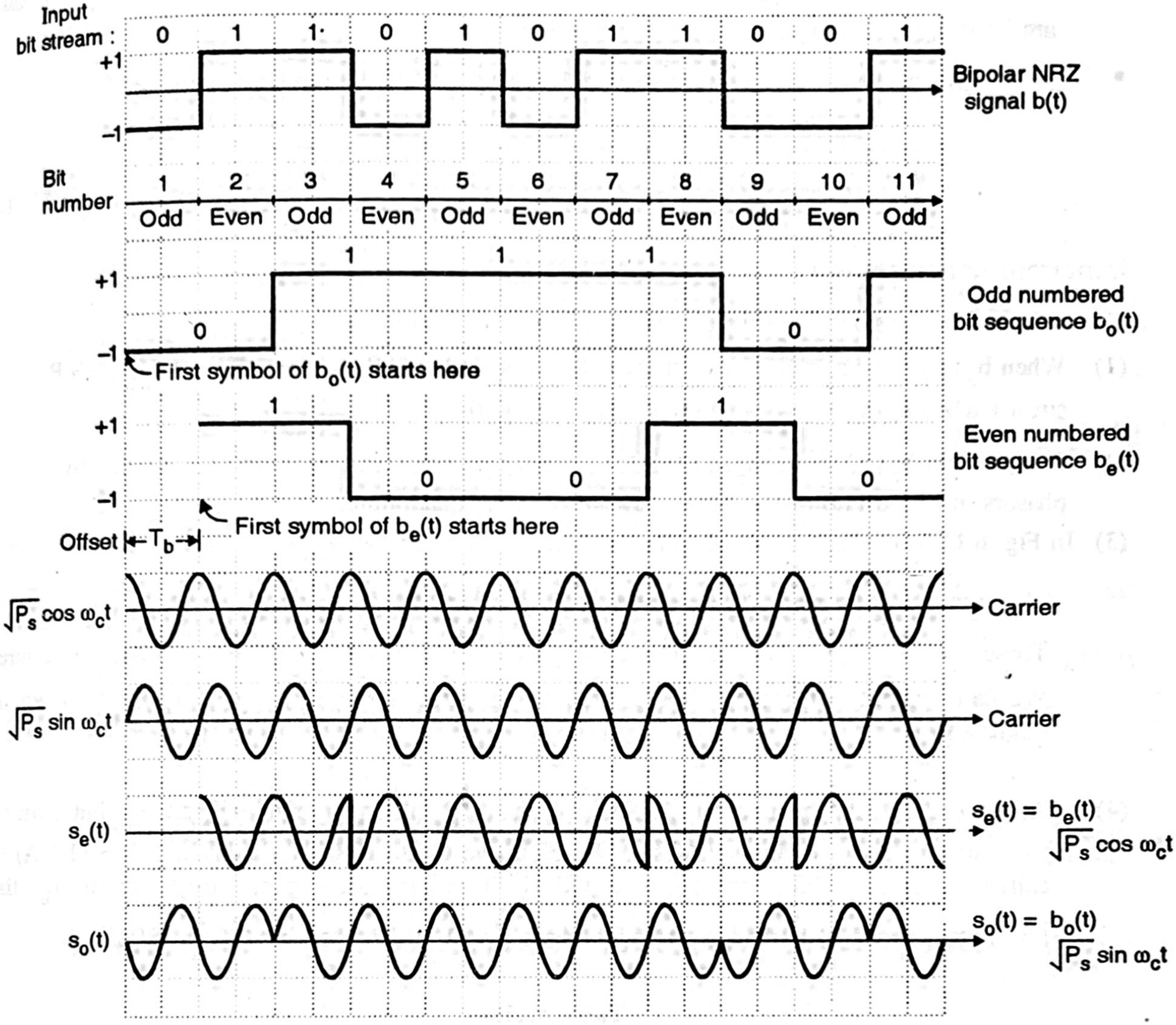

Fig. 6.11.5 : Waveforms for OQPSK transmitter

- Each bit in the even or odd bit stream will be held for a period of $2\,T_b$ seconds. This duration is called as "symbol duration" T_s. Thus every symbol contains two bits.
- As shown in Fig. 6.11.5, the first odd bit (bit 1) will occur before the first even bit (bit 2). Therefore the even bit stream $b_e(t)$ will start with a delay of one bit period after the first odd bit. This delay is equal to one bit period T_b as shown in Fig. 6.11.5. This delay is called as "offset" and therefore the name of this system is offset QPSK. Due to this offset, the bit streams $b_o(t)$ and $b_e(t)$ cannot change their levels at the same instant of time.
- The bit streams $b_e(t) = \pm 1$ V is superimposed on a carrier $\sqrt{P_s}\cos\omega_c t$ and the bit stream $b_o(t) = \pm 1$ V is superimposed on a carrier $\sqrt{P_s}\sin\omega_c t$, by the use of two multipliers (i.e.

balanced modulators), to generate two signal $s_e(t)$ and $s_o(t)$ respectively. These two signals are basically BPSK signals.

- These signals are then added together to generate the QPSK output signal $V_{QPSK}(t)$.

$$\boxed{\therefore\ V_{QPSK}(t) = \sqrt{P_s}\ b_o(t) \sin \omega_c(t) + \sqrt{P_s}\ b_e(t) \cos \omega_c t} \qquad ...(6.11.1)$$

Important conclusions :

The important conclusions from the discussion till now are as follows :

(1) When $b_o(t) = 1$ i.e. representing a logic 1 then $s_o(t) = \sqrt{P_s} \sin \omega_c t$ and $s_o(t) = -\sqrt{P_s} \sin \omega_c t$ when $b_o(t) = -1$ which represents a logic 0.

(2) Similarly for $b_e(t) = \pm 1$, $s_e(t) = \pm\sqrt{P_s} \cos \omega_c t$. These four signals are represented by phasors in Fig. 6.11.6 and as seen, they are in phase quadrature.

(3) In Fig. 6.11.6, we have drawn the phasors corresponding to the $V_{QPSK}(t)$ where :

$$V_{QPSK}(t) = s_o(t) + s_e(t)$$

These four possible output signals are of equal amplitude $\sqrt{2 P_s}$ and are in phase quadrature. We can identify them by their corresponding values of $b_o(t)$ and $b_e(t)$, as shown in Table 6.11.3.

(4) At the end of each bit interval i.e. after a period T_b, either b_o or b_e will change but both of them will not change simultaneously. Therefore the QPSK system shown in Fig. 6.11.4(A) is called as offset QPSK or staggered QPSK. Therefore after every time period T_b, the transmitted signal, if it changes, changes phase by 90° rather than by 180° in BPSK.

Table 6.11.3

Symbol s(t)	$b_o(t)$	$b_e(t)$	V_{QPSK}	Quadrant
01	-1	1	$-\sqrt{P_s} \sin \omega_c t + \sqrt{P_s} \cos \omega_c t$	I
00	-1	-1	$-\sqrt{P_s} \sin \omega_c t - \sqrt{P_s} \cos \omega_c t$	II
10	$+1$	-1	$\sqrt{P_s} \sin \omega_c t - \sqrt{P_s} \cos \omega_c t$	III
11	$+1$	$+1$	$\sqrt{P_s} \sin \omega_c t + \sqrt{P_s} \cos \omega_c t$	IV