.1 Introduction :

- In baseband pulse transmission, the input data is represented in the form of a discrete PAM signal. These signals are transmitted over a low pass channel.
- However in the digital passband transmission which is discussed in this chapter, the input data modulates a sinusoidal carrier. These signals are transmitted over a bandpass channel.
- The examples of bandpass channels are microwave radio link or a satellite channel.
- There are three basic signaling schemes used in passband data transmission.
  1. Amplitude shift keying (ASK)
  2. Phase shift keying (PSK)
  3. Frequency shift keying (FSK)
- They are special cases of amplitude modulation (AM), phase modulation (PM) and frequency modulation (FM) respectively.

3.1.1 Hierarchy of Digital Modulation Techniques :

The digital modulation techniques are classified into two categories as :

1. Coherent techniques 2. Noncoherent techniques.

1. Coherent techniques :

- In the coherent digital modulation techniques, we have to use a phase synchronized carrier to be generated at the receiver to recover the information signal.
- The frequency and phase of this carrier produced at the receiver should be synchronized with that at the transmitter.
- Coherent techniques are complex but yield better performance.

2. Noncoherent techniques :

- In the noncoherent techniques, no phase synchronized local carrier is needed at the receiver.
- These techniques are less complex.
- But the performance is inferior to that of coherent techniques.

3.1.2 Binary and M-ary Schemes :

- There are two types of digital modulation schemes :
  1. Binary schemes
  2. M-ary schemes.
- In the binary schemes we send any one of the two possible signals during each signaling interval of duration T_b. Examples are ASK, FSK and PSK.

- Whereas in M-ary schemes, we can send any one of the M possible signals during each signaling interval of duration T_b.
- Examples of M-ary schemes are M-ary PSK, M-ary FSK, QPSK, MSK, QASK or QAM etc.
- M-ary schemes need less bandwidth as compared to the binary schemes.
- But the error performance of M-ary schemes is poor as compared to the binary schemes.

3.1.3 Probability of Error (P_e) :

- The most important goal of passband data transmission systems is to design the receiver having minimum value of average probability of error in presence of additive white Gaussian noise (AWGN).
- The value of error probability P_e of a system indicates its performance in presence of AWGN.
- The value of P_e should be as possible.

3.1.4 Power Spectra :

- The features of every method can be fully appreciated if and only if we study the power spectra of the modulated signal.
- It is a graph of power spectral density plotted on Y axis versus frequency (on X axis).
- It gives us information about the bandwidth requirement and cochannel interference.

3.1.5 Bandwidth Efficiency :

The channel bandwidth and transmitted power are the two primary communication resources.

The communication systems should be spectrally efficient.

The **bandwidth efficiency** is defined as the ratio of the data rate (bits/sec) to the effectively utilized channel bandwidth. It is denoted by ρ.

$$\therefore \ \rho = \frac{R_b}{B} \text{ bits / Hz}$$

The bandwidth efficiency is dependent on the following factors

1. Multichannel encoding
2. Spectral shaping.

3.1.6 Modems :

- Modem is a very familiar word to everyone of us. It is used for connecting a computer to a telephone line.
- The telephone lines are designed to carry analog signals and their bandwidth also is limited so they cannot be used for digital data transmission.

- A modem converts the digital data from computers to analog signals and puts it on the telephone lines.
- It is a bi-directional device which converts the analog signals on the telephone lines into digital data when it is used for data reception.

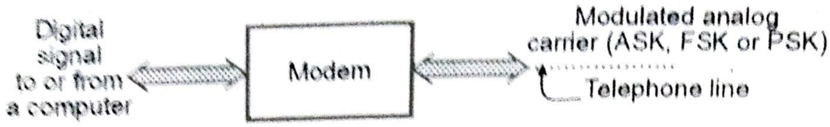


Fig. 3.1.1 : Modem

- Modem is a combination of two words Modulator and Demodulator. The standard modulation techniques used in modem are :
  1. Amplitude shift keying (ASK).
  2. Frequency shift keying (FSK).
  3. Phase shift keying (PSK).

3.2 Digital Continuous Wave Modulation Techniques :

- PCM converts analog message signal into a digital signal. Now we will learn some techniques which convert the digital message signal into an analog signal and then transmits it.
- Such modulation schemes are called as digital carrier modulation schemes.
- This type of digital to analog conversion is essential when the digital message signal is to be sent over a bandlimited channel such as the telephone line.

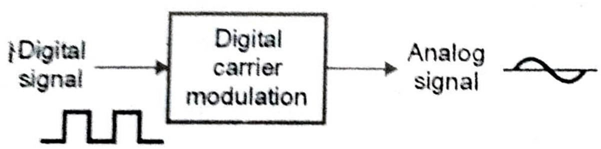


Fig. 3.2.1 : Digital carrier modulation

- The best application of digital carrier modulation is MODEM.
- The modem will modulate the digital data signal from the DTE (computer) into an analog signal.
- This analog signal is then transmitted on the telephone lines.
- The question is **why can't we send the digital signal as it is on the telephone lines** ? Why should we modulate it ?
- Here is the answer for it. The digital data consists of binary 0s and 1s, therefore the waveform changes its value abruptly from high to low or low to high.
- In order to carry such a signal without any distortion being introduced, the communication medium needs to have a large bandwidth.

- Unfortunately the telephone lines do not have high bandwidth. Therefore we have to convert the digital signal first into an analog signal which needs lower bandwidth by means of the modulation process.
- There are three basic types of modulation techniques for the transmission of digital signals.
- These methods are based on the three characteristics of a sinusoidal signal; amplitude, frequency and phase. The corresponding modulation methods are then called as :
  1. Amplitude shift keying (ASK)
  2. Frequency shift keying (FSK)
  3. Phase shift keying (PSK)
  4. Quadrature phase shift keying (QPSK) or 4-psk.
  5. Quadrature amplitude modulation (QAM).
- QPSK is a multilevel modulation in which four phase shifts are used for representing four different symbols.
- At high bit rates, a combination of ASK and PSK is employed in order to minimize the errors in the received data.
- This method is known as "Quadrature Amplitude Modulation (QAM)". Let us discuss these methods one by one.

Fig. 3.2.2 shows the classification of digital to analog modulation systems.

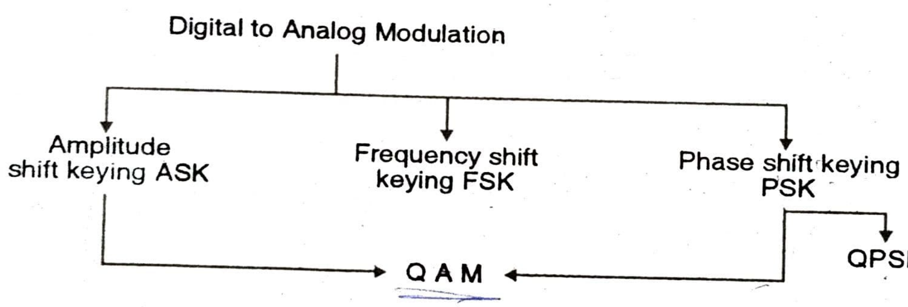


Fig. 3.2.2 : Types of digital to analog modulation

Need of Modulation :

- The modem will modulate the digital data signal from the DTE (computer) into an analog signal.
- This analog signal is then transmitted on the telephone lines.
- The question is **why can't we send the digital signal as it is on the telephone lines** ? Why should we modulate it ?
- Here is the answer for it. The digital data consists of binary 0s and 1s, therefore the waveform changes its value abruptly from high to low or low to high.
- In order to carry such a signal without any distortion being introduced, the communication medium needs to have a large bandwidth.
- Unfortunately the telephone lines do not have high bandwidth. Therefore we have to convert the digital signal first into an analog signal which needs lower bandwidth by means of the modulation process.

- Digital to analog modulation is demonstrated in Fig. 3.2.3.

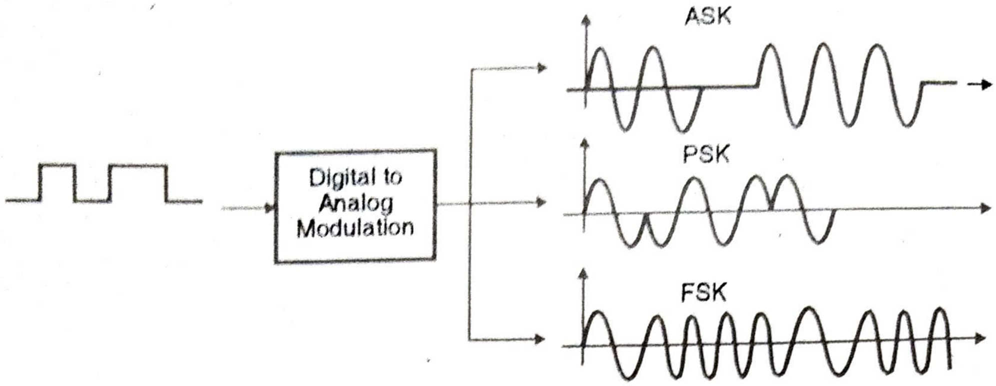


Fig. 3.2.3 : Digital to analog modulation

Advantages and Disadvantages of CW Modulation :

1. The advantage of CW modulation techniques such as ASK, PSK, FSK etc. used for transmission of data is that we can use the telephone lines for transmission of high speed data. Due to the use of CW modulation the BW requirement is reduced.
2. The disadvantage of CW modulation is we need to use a MODEM alongwith every computer. This makes the system costly and complex.

3.3 Amplitude Shift Keying (ASK) :

Definition :

ASK is the digital ~~carrier~~ modulation technique in which the amplitude of the sinusoidal carrier will take one of the two predetermined values in response to 0 or 1 value of digital input signal.

Generation and waveforms :

- Amplitude shift keying (ASK) is the simplest type of digital CW modulation. Here the carrier is a sinewave of frequency f_c. We can represent the carrier signal mathematically as follows :

$$e_c = \sin(2\pi f_c t) \qquad \dots (3.3.1)$$

- The digital signal ~~from the computer~~ is a unipolar NRZ signal which acts as the modulating signal. The ASK modulator is nothing but a multiplier followed by a band pass filter as shown in Fig. 3.3.1(a).
- Due to the multiplication, the ASK output will be present only when a binary "1" is to be transmitted.
- The ASK output corresponding to a binary "0" is zero as shown in Fig. 3.3.1(b).

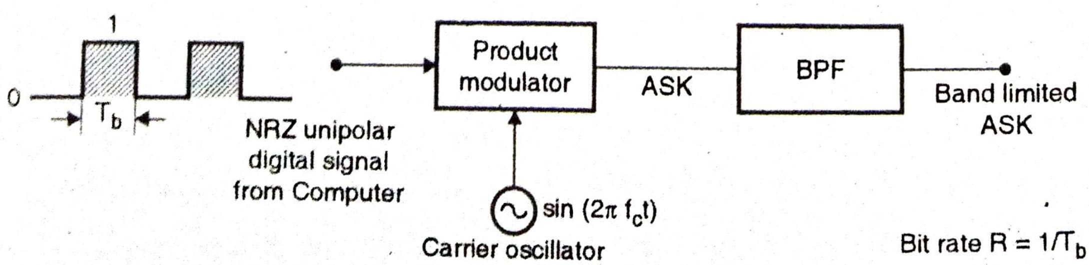


Fig. 3.3.1(a) : ASK generator

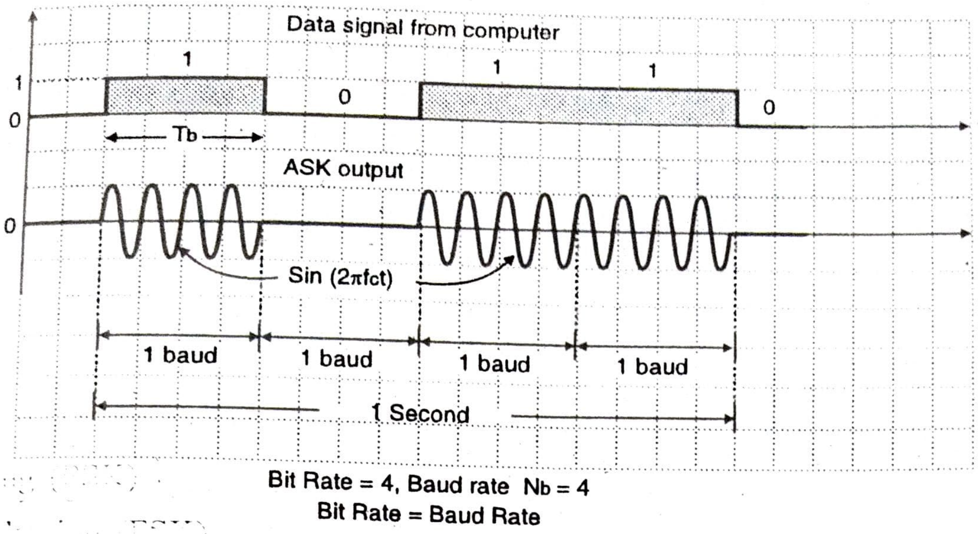


Fig. 3.3.1(b) : ASK waveforms

- From the waveforms of Fig. 3.3.1(b) we can conclude that the carrier is transmitted when a binary 1 is to be sent and no carrier is transmitted when a binary 0 is to be sent.
- The ASK signal can be mathematically expressed as follows :

$$V_{ASK}(t) = d \sin(2\pi f_c t) \quad \text{... (3.3.2)}$$

where d = data bit which can take values 1 or 0.

$$\therefore \quad V_{ASK}(t) = \sin(2\pi f_c t) \quad \text{when } d = 1$$

$$\text{and} \quad V_{ASK}(t) = 0 \quad \text{when } d = 0 \quad \text{... (3.3.3)}$$

The speed of txⁿ using ASK is limited by physical characteristics of txⁿ media

3.3.1 Baud Rate (N_b) :

- For ASK we use 1 bit (0 or 1) to represent one symbol. So the rate of symbol transmission i.e. the baud rate. For the definitions of bit rate and baud rate refer chapter 4.
- N_b will be same as bit rate R as shown in Fig. 3.3.1(b).

$$\therefore \quad \text{Baud rate} = \text{Bit rate}$$

3.3.2 Transmission Bandwidth of the ASK Signal :

- The bandwidth of ASK signal is dependent on the bit rate R. Where bit rate $R = 1/T_b$ as shown in Fig. 3.3.1(a). For a bit rate of "R" bits/sec. the maximum bandwidth required for an ASK signal is

$$BW_{(max)} = R \text{ Hz.} \quad \text{... (3.3.4)}$$

- The frequency spectrum of an ASK signal is shown in Fig. 3.3.1(c) which shows that the spectrum consists of the carrier frequency f_c with upper and lower sidebands.

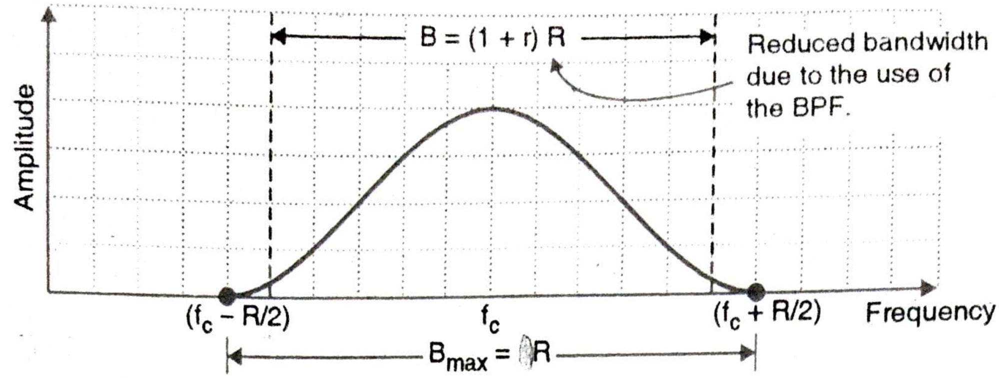


Fig. 3.3.1(c) : Frequency spectrum of an ASK signal

- The transmission bandwidth BW of the ASK signal can be restricted by using a filter. The restricted value of bandwidth is given as :

$$BW = (1 + r) R \quad \text{... (3.3.5)}$$

where "r" is a factor related to the filter characteristics and its value lies between 0 and 1.

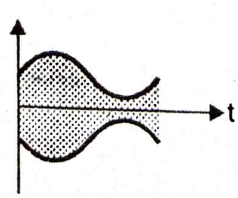
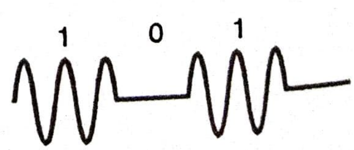
- f_c is the carrier frequency i.e. frequency of the sine wave being transmitted.

3.3.3 Merits and Demerits and Applications of ASK :

The advantage of using ASK is its simplicity. It is easy to generate and detect. However its disadvantage is that it is very sensitive to noise, therefore it finds limited application in data transmission. It is used at very low bit rates, upto 100 bits/sec.

3.3.4 Comparison of AM and ASK :

Table 3.3.1 : Comparison of AM and ASK

Sr. No.	Parameter	AM	ASK
1.	Variable characteristics of the carrier.	Amplitude	Amplitude
2.	Nature of modulating signal.	Modulating signal is analog	Modulating signal is digital
3.	Modulated signal shape.		

Sr. No.	Parameter	AM	ASK
4.	Variation in the carrier amplitude.	Continuous variation in accordance with the amplitude of modulating signal.	Carrier ON or OFF depending on whether a 1 or 0 is to be transmitted.
5.	Number of sidebands produced.	Two	Two
6.	Bandwidth	$2 f_m$	$(1+r)R$
7.	Noise immunity	Poor	Poor
8.	Application	Radio broadcasting	Data transmission at low bit rate
9.	Detection Method	Envelope	Envelope

3.4 Frequency Shift Keying (FSK) :

- In "frequency shift keying (FSK)", the frequency of a sinusoidal carrier is shifted between two discrete values.
- One of these frequencies (f_1) represents a binary "1" and the other value (f_0) represents a binary "0".
- The representation of digital data using FSK is as shown in Fig. 3.4.1(b). Note that there is no change in the amplitude of the carrier.

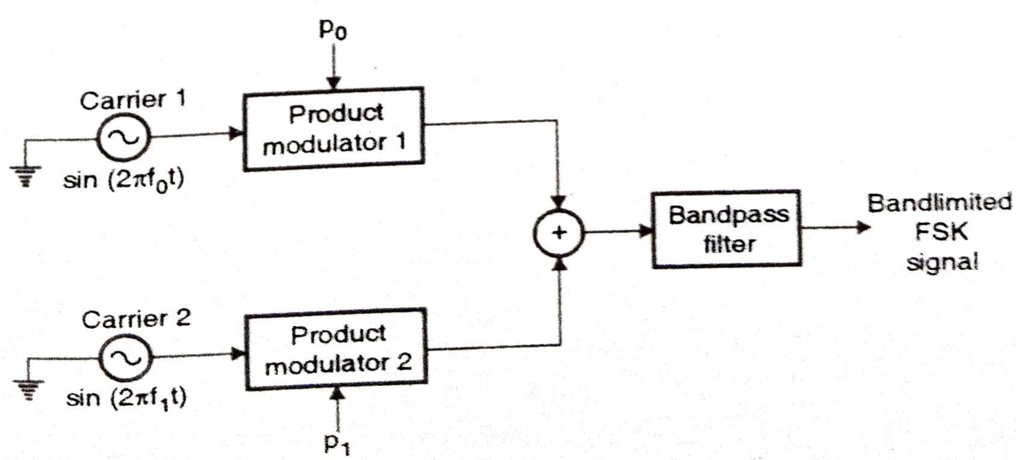
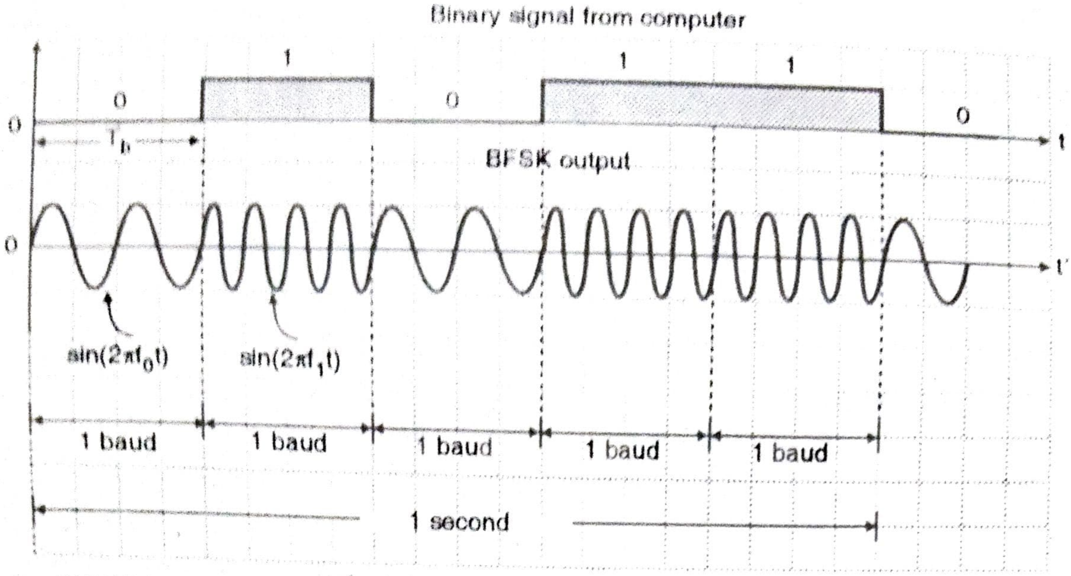


Fig. 3.4.1(a) : FSK generation



Bit rate = 5, Baud rate = 5

Fig. 3.4.1(b) : Representation of digital signal using FSK

FSK Generation :

- Refer to the FSK generator shown in Fig. 3.4.1(a). It consists of two oscillators which produce sinewaves at frequencies f_1 and f_0, respectively.
- The oscillator outputs are applied to the inputs of two multipliers (product modulators).
- The other input to the two multipliers are the signals p_1 and p_0. The relation between p_1, p_0 and the data bit d (t) is as follows :

Data bit to be transmitted	Value of d (t)	Value of p_0	Value of p_1
binary 0	– 1	1	0
binary 1	+ 1	0	1

- When a binary "0" is to be transmitted, $p_0 = 1$ and $p_1 = 0$ therefore the output of the first modulator only is present and the frequency of the transmitted signal is "f_0".
- Similarly when a binary "1" is to be transmitted, $p_0 = 0$ and $p_1 = 1$ therefore the output of the other multiplier only is present and the frequency of the transmitted signal is "f_1".
- The binary FSK signal is mathematically represented as :

$$\boxed{V_{BFSK}(t) = p_0 \cdot \sin(2\pi f_0 t) + p_1 \sin(2\pi f_1 t)} \quad \text{... (3.4.1)}$$

3.4.1 Frequency Spectrum of Binary FSK Signal :

- From the Equation (3.4.1) we can conclude that the FSK signal can be considered to be comprising two ASK signals, with the carrier frequencies f_1 and f_0.
- Therefore the frequency spectrum of the FSK signal is as shown in Fig. 3.4.1(c).

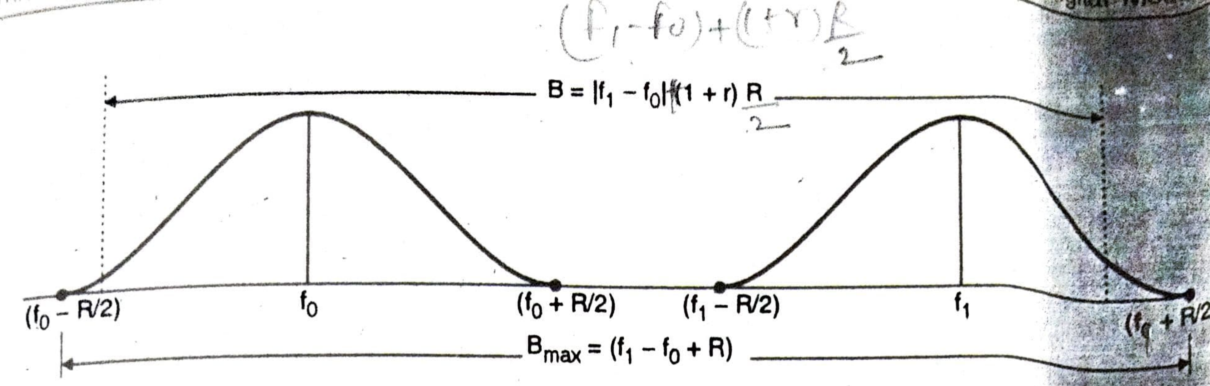


Fig. 3.4.1(c) : Frequency spectrum of a binary FSK signal

3.4.2 Bandwidth of FSK Signal :

- The bandwidth of FSK signal is dependent on the pulse width T_b or bit rate $R = 1/T_b$ and the separation between the frequencies f_0 and f_1, as shown in Fig. 3.4.1(c).
- The maximum bandwidth of FSK system is given by

$$B_{max} = \left(f_1 + \frac{R}{2}\right) - \left(f_0 - \frac{R}{2}\right)$$

$$= (f_1 - f_0 + R) \qquad \text{... (3.4.2)}$$

- The bandwidth can be restricted by using a bandpass filter. The restricted bandwidth is given as :

$$B = |f_1 - f_0| + (1 + r)\frac{R}{2} \qquad \text{... (3.4.3)}$$

Where "r" is the factor related to the filter characteristics and its value lies between 0 and 1.

- The separation between f_1 and f_0 is kept at least $2R/3$. Substitute this value in Equation (3.4.3) to get

$$B_{max} = \frac{2}{3}R + R = \frac{5R}{3} \qquad \text{... (3.4.4)}$$

- This shows that FSK requires larger bandwidth than ASK and PSK (to be discussed next).

3.4.3 Bandwidth for FSK in terms of Baud Rate :

- For FSK also bit rate is equal to baud rate.
- We can imagine the FSK spectrum to be a combination of two ASK spectrums centered at frequencies f_H and f_L as shown in Fig. 3.4.1(d).

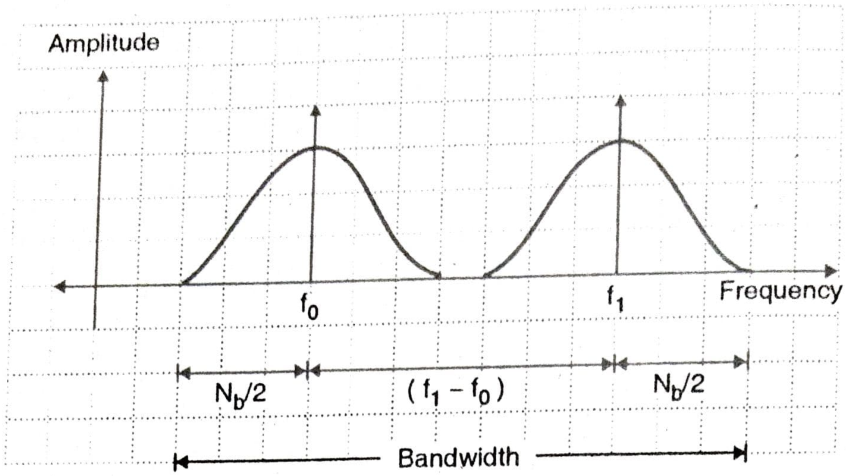


Fig. 3.4.1(d) : Spectrum of FSK

- From Fig. 3.4.1(d) the expression for bandwidth is given by

$$BW = \frac{N_b}{2} + (f_1 - f_0) + \frac{N_b}{2} = (f_1 - f_0) + N_b \quad ...(3.4.5)$$

Where N_b = baud rate = bit rate = f_b

- Minimum bandwidth will correspond to the situation in which $(f_1 - f_o) = N_b$

$$\therefore \quad BW\ (min) = N_b + N_b = 2\ N_b \quad ...(3.4.6)$$

3.4.4 FSK Detection :

The FSK receiver block diagram is as shown in Fig. 3.4.1(e). It is supposed to regenerate the original digital data signal from the FSK signal at its input.

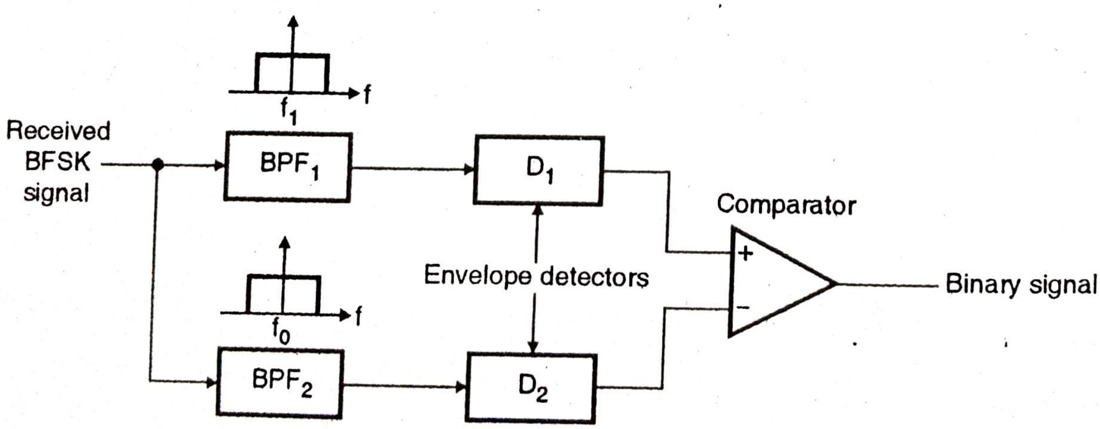


Fig. 3.4.1(e) : FSK receiver

The receiver consists of two band pass filters one with center frequency "f_0" and the other with a center frequency of "f_1". The envelope detectors are simple diode detectors which rectify and filter their inputs, to generate a dc voltage proportional to the ac input.

Suppose a binary "1" is received. That means the received signal will be

$$V_{BFSK}(t) = \sin(2\pi f_1 t) \quad ...(3.4.7)$$

- Thus the BPF_1 will pass this signal to D_1. The output of BPF_2 will be 0, hence the output of D_2 is zero. Therefore the comparator output will be positive representing a logic "1".
- Similarly if a binary "0" is received, the received FSK signal will have a frequency "f_0". The output of BPF_1 will be zero.
- The BPF_2 will pass this signal to D_2 to produce a proportional dc voltage. Output of D_1 is zero. Therefore comparator output will be zero which represents a logic "0". Thus the original data is recovered by the receiver.

3.4.5 Advantages of FSK :

1. FSK is relatively easy to implement.
2. It has better noise immunity than ASK. Therefore the probability of error free reception of data is high.

3.4.6 Disadvantages of FSK :

1. The major disadvantage is its high bandwidth requirement as discussed earlier.
2. Therefore FSK is extensively used in low speed modems having bit rates below 1200 bits/sec.
3. The FSK is not preferred for the high speed modems because with increase in speed, the bit rate increases.
4. This increases the channel bandwidth required to transmit the FSK signal.
5. As the telephone lines have a very low bandwidth, it is not possible to satisfy the bandwidth requirement of FSK at higher speed. Therefore FSK is preferred only for the low speed modems.

Application :

FSK is used for the low data rate MODEMs.

3.5 Phase Shift Keying (PSK) :

Phase shift keying (PSK) is the most efficient of the three modulation methods.

Therefore it is used for high bit rates. In PSK, phase of the sinusoidal carrier is changed according to the data bit to be transmitted.

Fig. 3.5.1(a) shows the simplest form of PSK called Binary PSK (BPSK). The carrier phase is changed between 0° and 180° by the bipolar digital signal. A bipolar NRZ signal is used to represent the digital data from the DTE.

The BPSK signal can be represented mathematically as :

$$V_{BPSK}(t) = \sin(2\pi f_c t) \text{ when binary "0" is to be represented}$$

and $V_{BPSK}(t) = -\sin(2\pi f_c t)$

$= \sin(2\pi f_c t + \pi)$ when binary "1" is to be represented.

- Combining the two conditions we can write

$$\boxed{V_{BPSK}(t) = d \sin(2\pi f_c t)} \quad \text{... (3.5.1}$$

where $d = \pm 1$

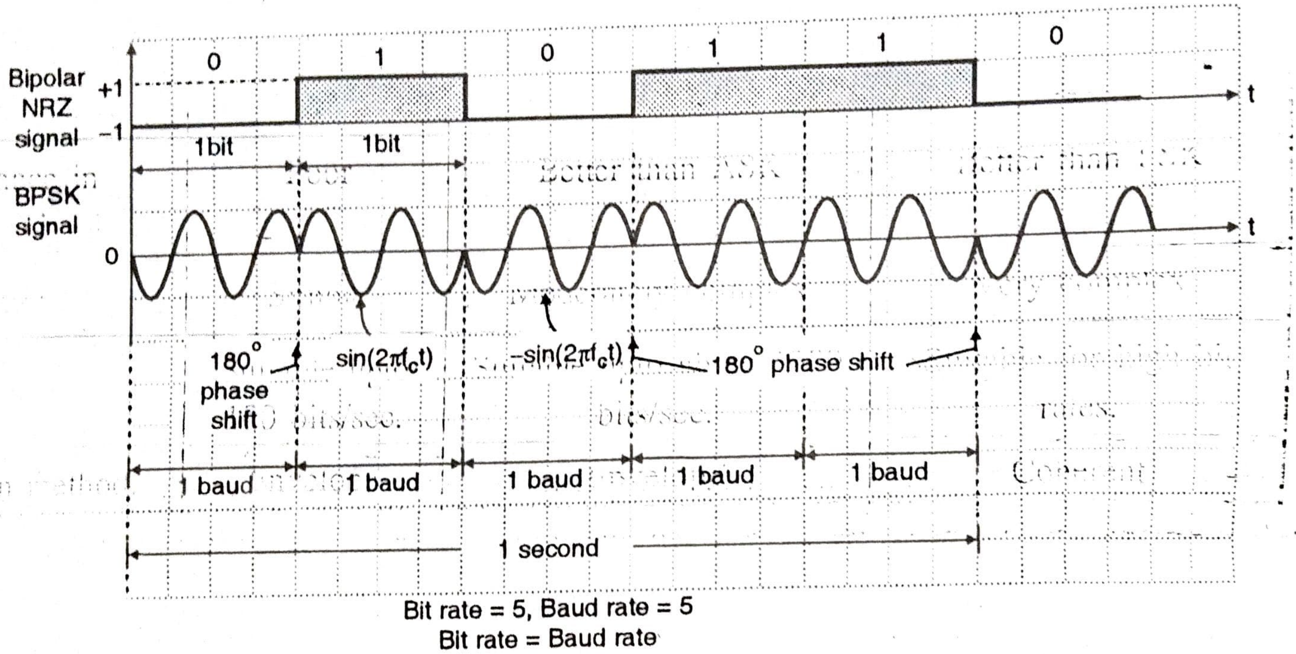


Fig. 3.5.1(a) : Binary phase shift keying (BPSK)

3.5.1 BPSK Generation :

- The BPSK generation takes place as shown in Fig. 3.5.1(b).

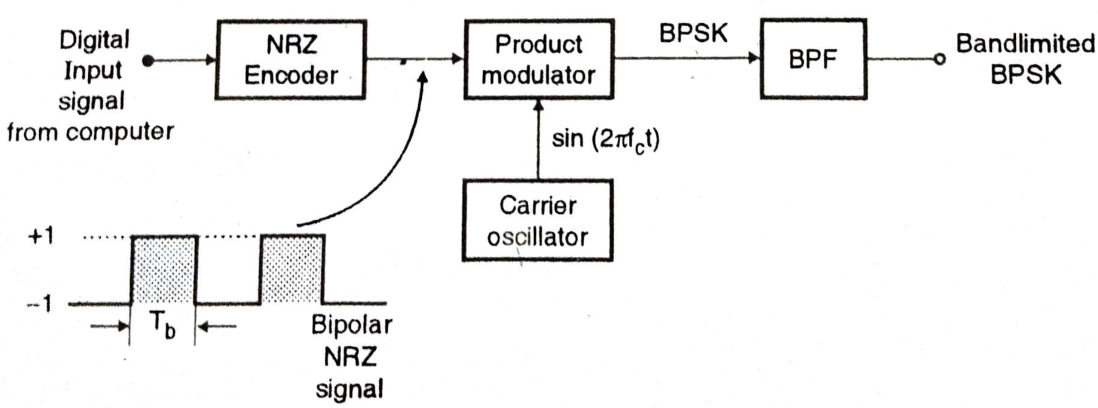


Fig. 3.5.1(b) : BPSK generation

The binary data signal (0s and 1s) is converted into a NRZ bipolar signal by an NRZ encoder, which is then applied to a multiplier (balanced modulator). The other input to the multiplier is the carrier signal $\sin(2\pi f_c t)$.

- The data bits 0s and 1s are converted into a bipolar NRZ signal "d" as shown in the following table.

Digital signal	Bipolar NRZ signal	BPSK output
Binary 0	d = 1	$V_{BPSK}(t) = \sin(2\pi f_c t)$
Binary 1	d = – 1	$V_{BPSK}(t) = -\sin(2\pi f_c t)$

3.5.2 Coherent BPSK Receiver :

- The coherent BPSK receiver is as shown in Fig. 3.5.2. Let the received BPSK signal be represented by $x(t)$.
- Then $x(t)$ is applied to a correlator consisting of a multiplier and an integrator.

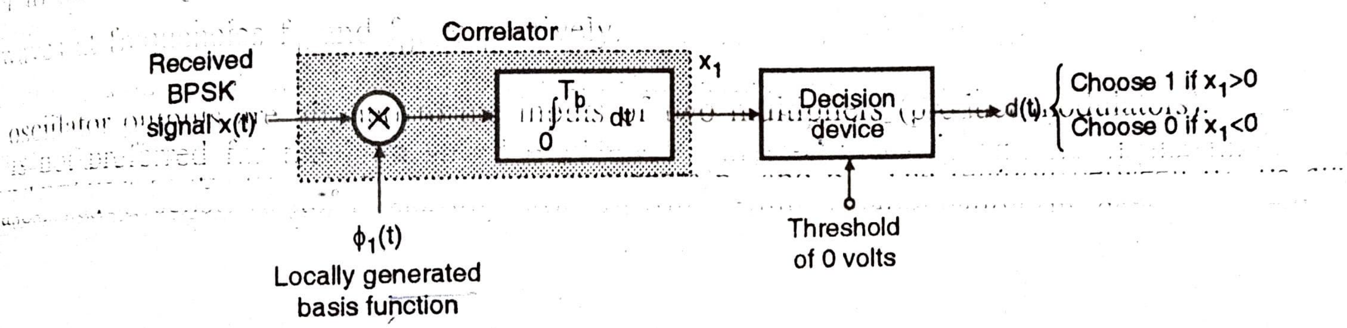


Fig. 3.5.2 : Coherent BPSK receiver

- The correlator is also supplied with a locally generated coherent reference signal $\phi_1(t)$ which is also called as the basis function.

$$\phi_1(t) = \sqrt{\frac{2}{T_b}} \cos(2\pi f_c t) \quad \text{...(3.5.2)}$$

- The correlator output x_1 is compared with the threshold of "0" volts by the decision device.
- If $x_1 > 0$, then the receiver decides that the received bit is 1 and if $x_1 < 0$ then it makes the decision in favour of symbol 0.

3.5.3 Frequency Spectrum of BPSK (Power Spectral Density) :

- The expression for the BPSK signal is very similar to the expression for ASK signal except for the data variable "d" takes values ± 1.
- The frequency spectrum of BPSK signal is as shown in Fig. 3.5.3.

- The maximum bandwidth of the BPSK signal is given as

$$B_{max} = \left(f_c + \frac{R}{2}\right) - \left(f_c - \frac{R}{2}\right)$$

$$= R \qquad \text{...(3.5.3)}$$

where $R = 1/T_0$ i.e. the bit rate.

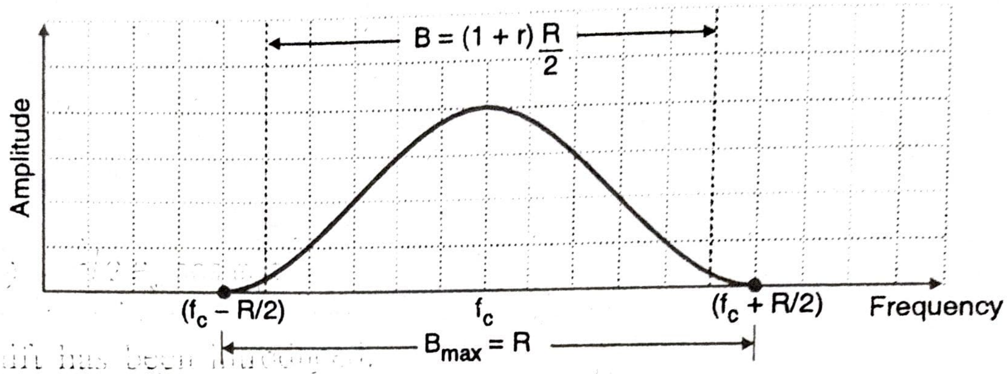


Fig. 3.5.3 : Spectrum of BPSK signal

- The bandwidth can be restricted by using a filter. The restricted bandwidth is given as :

$$\boxed{B = (1+r)\frac{R}{2}} \qquad \text{...(3.5.4)}$$

Where "r" depends on the transmission filter characteristics. "r" takes values between 0 and 1.

3.5.4 Advantages of BPSK :

1. BPSK has a bandwidth which is lower than that of a BFSK signal.
2. BPSK has the best performance of all the systems in presence of noise. It gives the minimum possibility of error.
3. BPSK has a very good noise immunity.

3.5.5 Disadvantage of BPSK :

The only disadvantage of BPSK is that generation and detection of BPSK is not easy. It is quite complicated.

3.5.6 Applications :

- Phase shift keying is the most efficient of the three modulation methods and it is used for high bit rates even higher than 1800 bits/sec.
- Due to low bandwidth requirement the BPSK modems are preferred over the FSK modems, at higher operating speeds.

5.5.7 Comparison of Digital Modulation Systems :

Sr. No.	Parameter	Binary ASK	Binary FSK	Binary PSK
1.	Variable characteristic.	Amplitude	Frequency	Phase
2.	Bandwidth (Hz)	2R	$\lvert f_1 - f_0 \rvert + (1 + r) R$	$(1 + r) R$
3.	Noise immunity.	low	high	high
4.	Error probability	high	low	low
5.	Performance in presence of noise.	Poor	Better than ASK	Better than FSK
6.	Complexity	Simple	Moderately complex	Very complex
7.	Bit rate	Suitable upto 100 bits/sec.	Suitable upto about 1200 bits/sec.	Suitable for high bit rates.
8.	Detection method	Envelope	Envelope	Coherent

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.

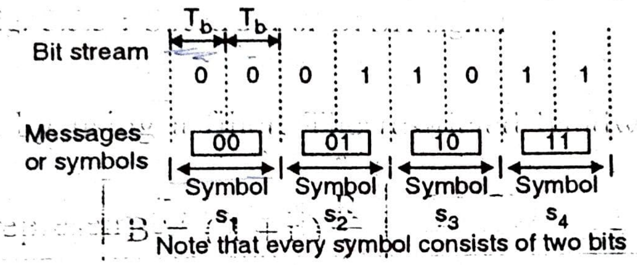


Fig. 3.7.1 : Grouping of bits in QPSK

- 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. 3.7.1.
- 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 3.7.1 and Fig. 3.7.2.

Symbol	Phase
00	0
01	90
10	180
11	270

Table 3.7.1 : Phase shift in QPSK

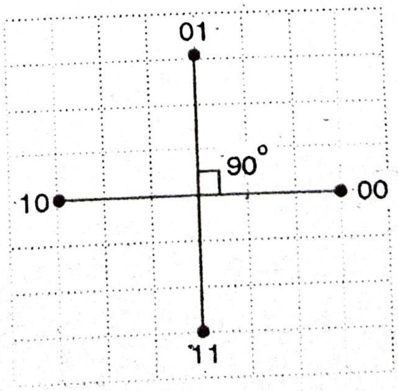


Fig. 3.7.2 : Constellation diagram of QPSK

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

- 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. 3.7.3.

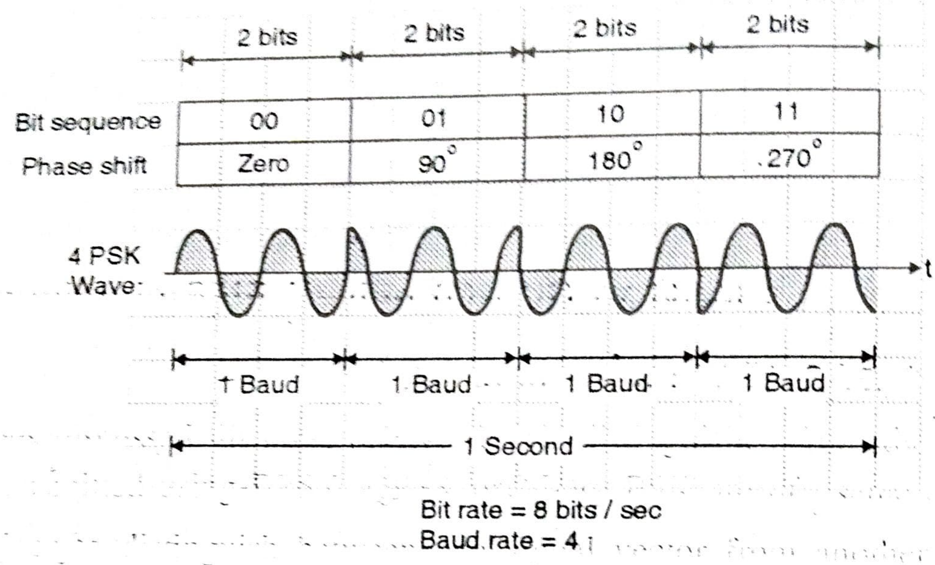


Fig. 3.7.3 : Waveforms of QPSK

Baud rate :

As illustrated in Fig. 3.7.3, the baud rate for QPSK is half of the bit rate.

3.7.1 Advantages of QPSK :

1. Very good noise immunity.
2. Baud rate is half the bit rate therefore more effective utilization of the available bandwidth of the transmission channel.
3. Low error probability.

Due to these advantages the QPSK is used for very high bit rate data transmission.

3.7.2 Disadvantage :

The generation and detection of QPSK is complex.

3.7.3 QPSK is better than PSK :

The QPSK is better than PSK because :

1. Due to multilevel modulation used in QPSK, it is possible to increase the bit rate to double the bit rate of PSK without increasing the bandwidth.
2. The noise immunity of QPSK is same as that of PSK system.
3. Available channel bandwidth is utilized in a better way by the QPSK system than PSK system.

Applications :

1. High speed modems.
2. Digital TV.
3. Communication between earth stations and space shuttles.

Ex. 3.7.1 : What are the phase states of the carrier when the bit stream.
1 0 0 1 1 0 1 1 0 0
is applied to a QPSK modulator.

Soln. :

Step I : Divide the input data stream into groups of two bits i.e. dibits.

1 0 | 0 1 | 1 0 | 1 1 | 0 0 |

Step II : Phase shift to each dibit as follows :

Modulator input	1 0	0 1	1 0	1 1	0 0
Phase state	180°	90°	180°	270°	0°

3.7.4 Comparison of BPSK and QPSK :

Sr. No.	Parameter/characteristics	BPSK	QPSK
1.	Variable characteristics of the carrier.	Phase	Phase
2.	Type of modulation	Two level (binary)	Four level
3.	Type of representation.	A binary bit is represented by one phase state.	A group of two binary bits is represented by one phase state.
4.	Bite rate/baud rate	Bit rate = baud rate	Bit rate = 2 baud rate
5.	Detection method	Coherent	Coherent
6.	Complexity	Complex	Very complex
7.	Applications	Suitable for applications that need high bit rate	Suitable for applications needing very high bit rates.

Ex. 3.7.2 : 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,

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

where $b(t) = \pm 1$ depending on the digital input signal. The Table P. 3.7.2 lists the values of $b(t)$ and the transmitted signal V_{BPSK} for different bit intervals.

Table P. 3.7.2

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. 3.7.2.

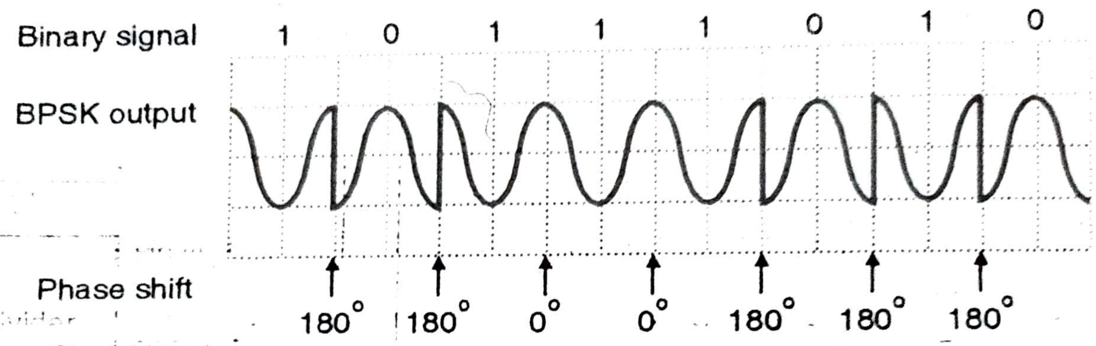


Fig. P. 3.7.2

Ex. 3.7.3 : For the following data stream draw the QPSK (4 PSK) signal. 11010001

Soln. :

The required waveform is shown in Fig. P. 3.7.3. Note that the carrier frequency has not been changed at all. Only the phase shift is being changed according to the symbol.

Bit stream	1 1	0 1	0 0	0 1
symbol	S_4	S_2	S_1	S_2
Phase shift	270°	90°	0°	90°