Velammal College of Engineering and Technology, Madurai – 625 009

Department of Information Technology

UNIT III DIGITAL COMMUNICATION

Amplitude Shift Keying (ASK) – Frequency Shift Keying (FSK)–Phase Shift Keying (PSK) – BPSK – QPSK – Quadrature Amplitude Modulation (QAM) – Comparison of various Digital Communication System (ASK – FSK – PSK – QAM)

CO3: Explain digital communication techniques

INTRODUCTION TO DIGITALCOMMUNICATION

Digital modulation: Digital Modulation is defined as changing the amplitude of the carrier signal with respect to the binary information or digital signal.

Bit rate is the number of bits transmitted during one second between the transmitter and receiver.

Baud rate is the rate of change of signal on transmission medium after encoding and modulation have occurred.

Bandwidth efficiency : Bandwidth efficiency is the ratio of the transmission bit rate to the minimum bandwidth required for a particular modulation

Advantages of Digital communications

- It has a better noise immunity
- Repeaters can be used between transmitters and receivers
- It becomes simpler and cheaper as compared to the analog communication

Disadvantages of Digital communications

- It requires a larger channel bandwidth
- Delta modulation needs synchronization in case of synchronous modulation

Types of Pass band Modulation

- The digital data can modulate phase, frequency or amplitude of carrier. This gives rise to three basic techniques:
- **Phase Shift Keying (PSK):** The digital data modulates the phase of the carrier.
- **Frequency Shift Keying (FSK):** The digital data modulates the frequency of the carrier.
- **Amplitude Shift Keying (ASK):** The digital modulates the amplitude of the carrier.

3.1 AMPLITUDE-SHIFT KEYING (On-Off Keying)

The simplest digital modulation technique is amplitude-shift keying (ASK), where a binary information signal directly modulates the amplitude of an analog carrier. ASK is similar to standard amplitude modulation except there are only two output amplitudes possible. Amplitude shift keying is sometimes called digital amplitude modulation (DAM).

In this there is only one unit energy carrier and it is switched on or off depending upon the Binary sequence.

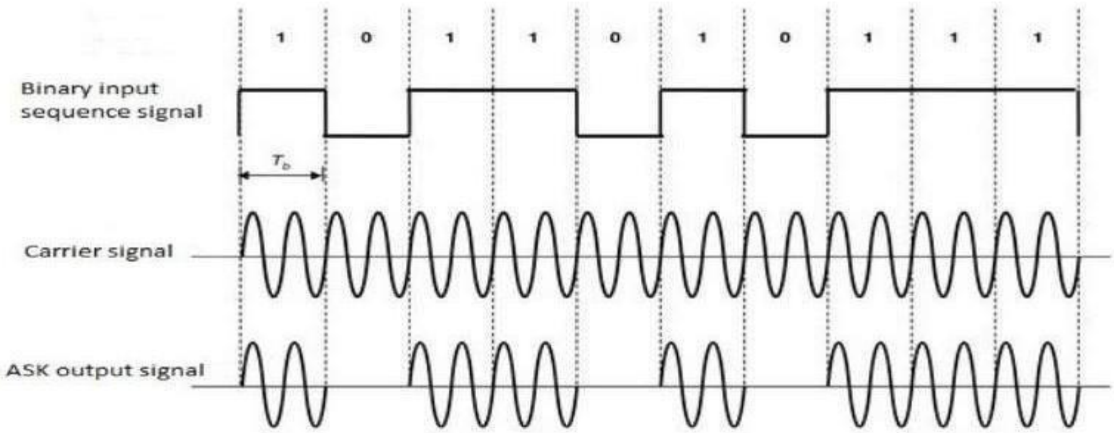
ASK waveform may be represented as

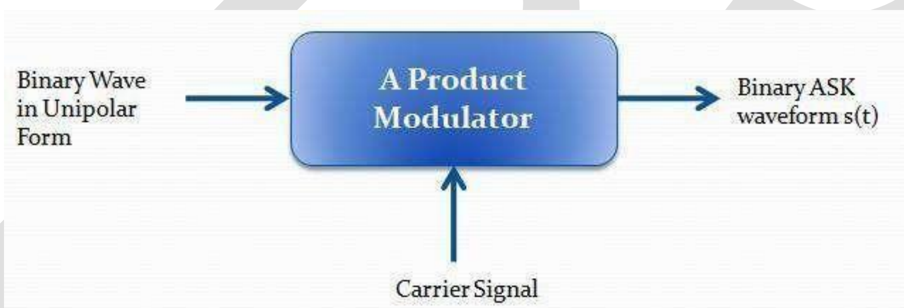
$$s(t) = \begin{cases} A\cos(2\pi f_c t) & ; \text{When bit transmitted is '1'} \\ 0 & ; \text{When bit transmitted is '0'} \end{cases}$$

Signal s(t) contains some complete cycles of carrier frequency (fc).
Hence the ASK waveform looks like an On-Off of the signal. Therefore, it is also known as the On-Off Keying (OOK)

Generation of ASK Signal

ASK signal may be generated by simply applying the incoming binary data and the sinusoidal carrier to the 2 inputs of a product modulator.





The resulting output will be a ASK wave form and the modulation causes the shift of the base band spectra.

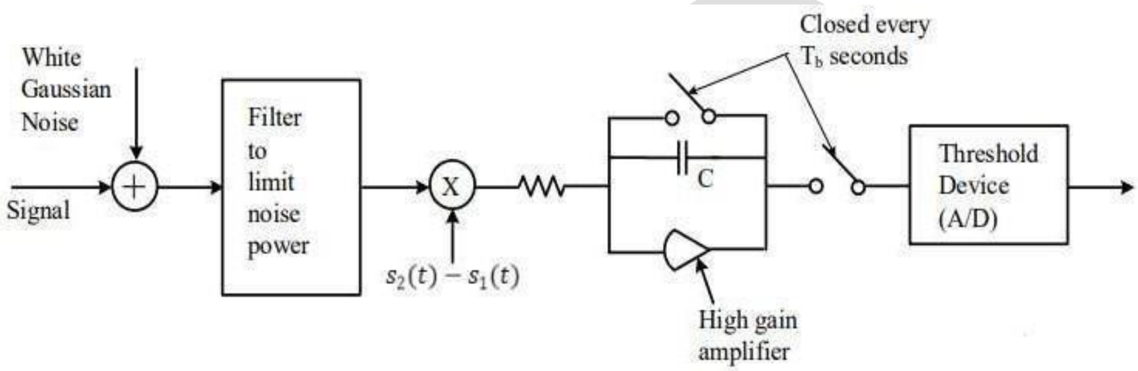
Demodulation of ASK

Coherent Detection of ASK (Integrate and Dump):

- The input to the receiver consists of an ASK signal that is corrupted by AWGN.
- The receiver integrates the product of the signal plus noise & a copy of the noise free signal over one signal interval.

Assume that the local signal is carefully synchronized with the frequency & phase of the carrier received.

$$s_2(t) - s_1(t) = Acos(2\pi f_c t)$$



Output of integrator is compared against a set threshold and at the end of each signaling interval the receiver makes the decision about which of the 2 signals s_1(t) or s_2(t) was present at its input during the signaling interval. Errors might occur in the demodulation process because of noise. Assume

$$s_1(t) = 0$$

$$s_2(t) = Acos(2\pi f_c t)$$

$$s_2(t) - s_1(t) = Acos(2\pi f_c t)$$

The signaling components of the receiver output at the end of the signaling interval are

$$s_{01}(kT_b) = \int_0^{T_b} s_1(t)[s_2(t) - s_1(t)]dt = 0$$

$$s_{02}(kT_b) = \int_0^{T_b} s_2(t)[s_2(t) - s_1(t)]dt = \frac{A^2}{2} T_b$$

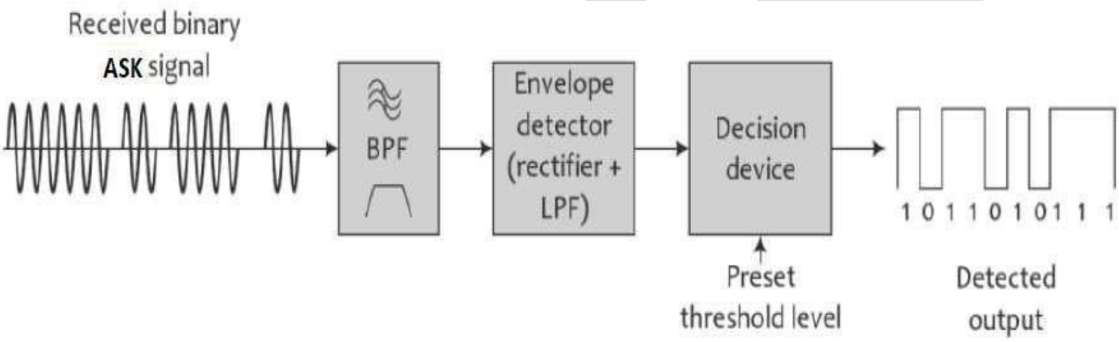
The optimum threshold of the receiver is

$$V_{th} = \frac{s_{o1}(kT_b) + s_{o2}(kT_b)}{2} = \frac{A^2}{4} T_b$$

The receiver decodes the kth transmitted bit as 1 if the output at the k^{th} signaling interval is greater than V^{th}, as a '0' otherwise.

Non-Coherent ASK detection

This scheme involves detection in the form of 'rectifier' & 'low pass filter'.



Block Diagram of Noncoherent ASK Demodulator

Input to the receiver is

$$v(t) = s(t) + n_i(t)$$

Where, $n_i(t)$ represents AWGN with zero mean at the receiver input.

$$v(t) = \begin{cases} A\cos(\omega_c t) + n_i(t)\,; When\ b_k = 1 \\ n_i(t) \qquad ; When\ b_k = 0 \end{cases}$$

The filter output will be

$$Y(t) = A_k \cos(\omega_c t) + n(t)$$

Advantages and

Disadvantages of ASK

Advantages

1. Simple to design, easy to generate and detect.
2. Requires low Bandwidth
3. Requires less energy to transmit the binary data.

Disadvantages

Susceptible to sudden amplitude variations due to noise and interference.

Applications of ASK

1. Mostly used for very low-speed data rate (upto 1200bps) requirements on voice grade lines in telemetry applications.
2. Used to transmit digital data over optical fibre for LED –based optical transmitters.
3. Wireless infrared transmissions using a directed beam or diffuse light in wireless LANs applications.

FREQUENCY SHIFT KEYING (FSK), MINIMUM SHIFT KEYING (MSK)

Minimum Shift Keying (MSK): The minimum frequency space that allows the 2 fsk representing symbols 0s and 1s. Thus CP (Continuous Phase) FSK signal with a deviatio n ratio if one half is defined as MSK.

Frequency Shift Keying (FSK): Frequency Shift Keying is the as changing amplitude of the carrier signal with respect to the binary information or digital signal.

The advantages of Minimum Shift Keying:

MSK base band waveform are smoother compared with QPSK MSK signals have continuous phase It does not have any amplitude variation

- In Binary FSK, the frequency of the carrier is shifted according to the binary symbol. Phase unaffected.

That is there are 2 different frequency signals according to binary symbols.

- Let there be a frequency shift by Ω.
  If b(t)=1, then

$$s_H(t) = \sqrt{2P_s}\cos(2\pi f_c + \Omega)\, t$$

b(t)=0, then

$$s_L(t) = \sqrt{2P_s}\cos(2\pi f_c - \Omega)\, t$$

Hence there is increase or decrease in frequency by Ω.
Conversion table for BFSK representation

b(t) Input	d(t)	$P_H(t)$	$P_L(t)$
1	+1V	+1V	0V
0	-1V	0V	+1V

FSK equ can be written as

$$s(t) = \sqrt{2P_s}\cos[(2\pi f_c + d(t)\Omega)t]$$

Hence if symbol '1' is to be transmitted then the carrier frequency will be

$$f_c + \frac{\Omega}{2\pi}$$

If the symbol '0' is to be transmitted then the carrier frequency will be

$$f_c - \frac{\Omega}{2\pi}$$

Thus

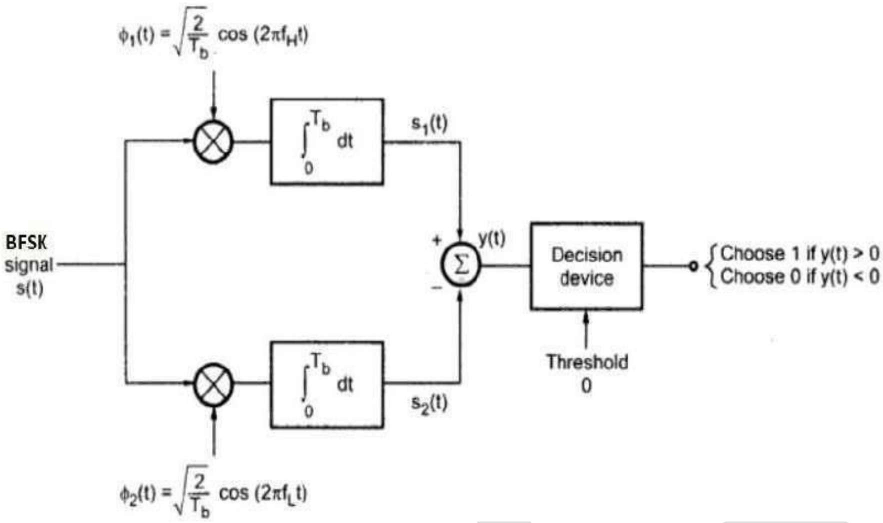
$$f_H = f_c + \frac{\Omega}{2\pi} \ldots\ldots symbol\ '1'$$

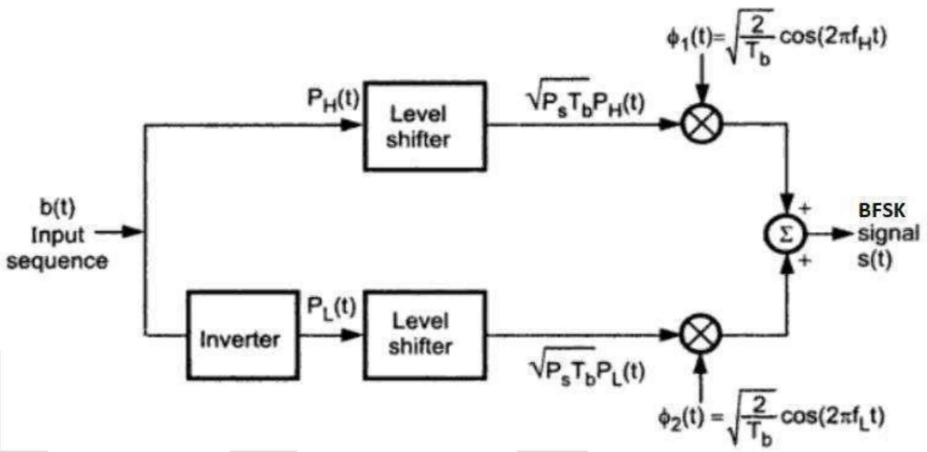
$$f_L = f_c - \frac{\Omega}{2\pi} \ldots\ldots symbol\ '0'$$

Generation of BFSK

- $P_H(t)$ is same as b(t) and $P_L(t)$ is inverted version of b(t)
- $P_H(t)$ and $P_L(t)$ are Unipolar signals.

The level shifter converts '+1' to $\sqrt{PsTb}$ and the zero level is unaffected.

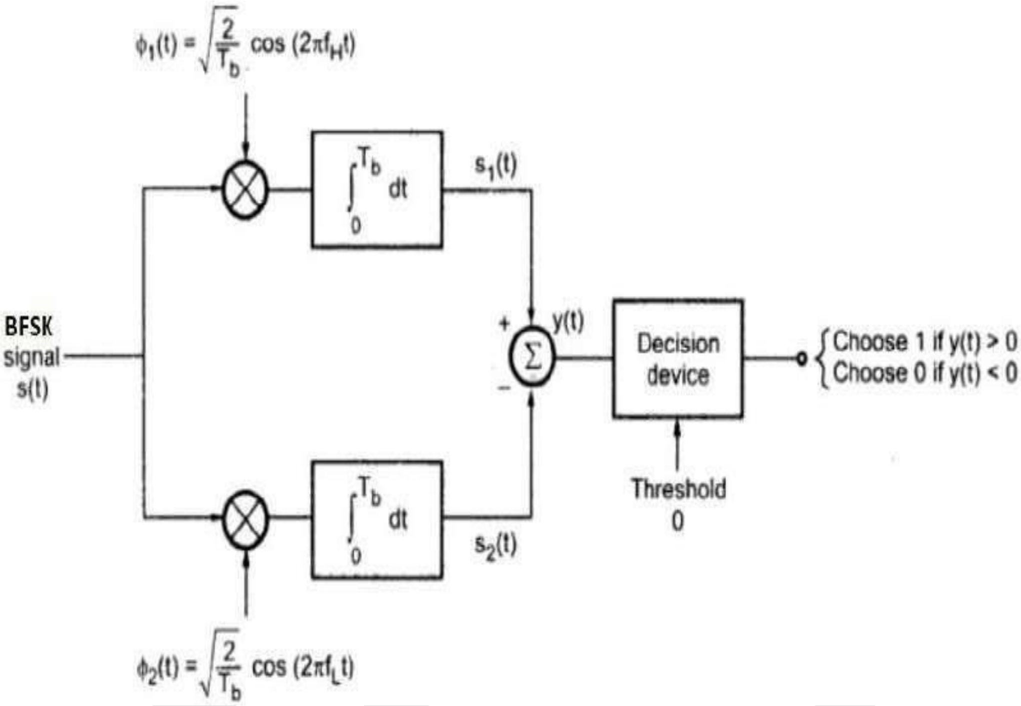




- √ The two carrier signals φ1(t) or φ2(t) are used which are orthogonal to each other. fH-fL=2fb
- √ Further there are product modulators after the level shifters
- √ The adder then adds the 2 signals coming from the multipliers, but outputs from the multipliers are not possible at the same time. This is because PH(t) and PL(t) are complementary to each other

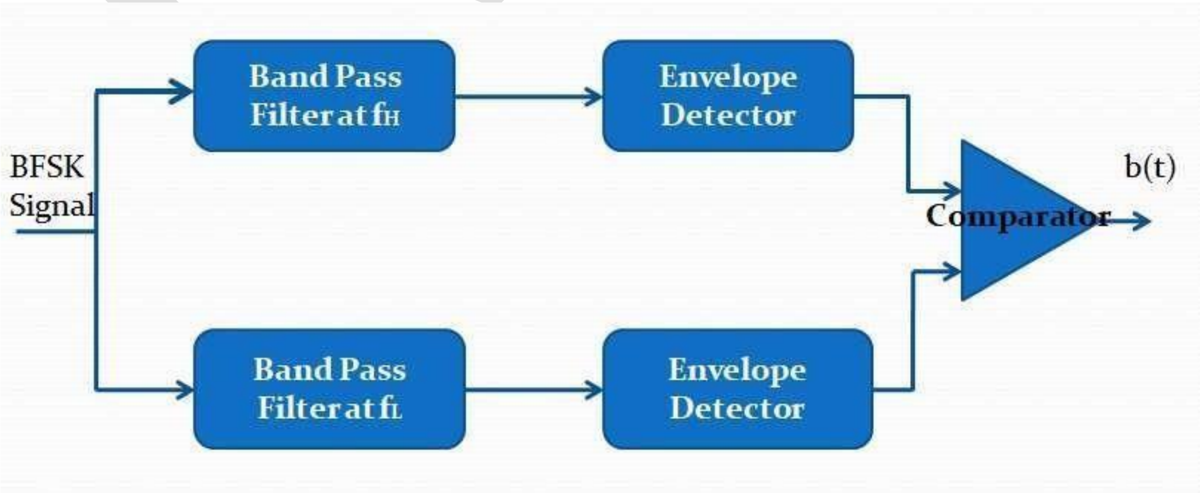
Coherent Detection of BFSK Signal

The incoming FSK signal is multiplied by a recovered carrier signal that has the exact same frequency and phase as the transmitter reference. However, the two transmitted frequencies (the mark and space frequencies) are not generally continuous; it is not practical to reproduce a local reference that is coherent with both of them. Consequently, coherent FSK detection is seldom used.



Non-coherent Detection of BFSK Signal

The FSK input signal is simultaneously applied to the inputs of both band pass filters (BPFs) through a power splitter. The respective filter passes only the mark or only the space frequency on to its respective envelope detector. The envelope detectors, in turn, indicate the total power in each pass band, and the comparator responds to the larger of the two powers. This type of FSK detection is referred to as non-coherent detection.



Advantages and Disadvantages of FSK

Advantages

- It is less susceptible to errors than ASK.
- Better noise immunity than ASK.
- Peak frequency offset is constant and always at its maximum.
- The highest fundamental frequency is equal to half the information bit rate.
- Relatively easy to implement.

Disadvantages

- Not efficient in terms of transmission bandwidth requirement
- It has poorer error performance than PSK or QAM.

Applications of FSK

- Used in low-speed modems (up to 1200bps) over analog voice-band telephone lines.
- Finds applications in pager systems, HF radio tele-type transmission systems, andLANs using coaxial cable

Binary Phase Shift Keying

- Principle of BPSK
- In BPSK the binary symbol '1' and '0' modulate the phase of the carrier.

Let the carrier be

$$s(t) = A\cos(2\pi f_c t)$$

'A' represents peak of the sinusoidal carrier

$$A = \sqrt{2P_s}$$

When the symbol is changed, then phase of the

carrier is changed by 180° Consider, for symbol

'1'

$$s_1(t) = \sqrt{2P_s}\cos(2\pi f_c t)$$

For symbol '0'

$$s_2(t) = \sqrt{2P_s}\cos\,(2\pi f_c t + \pi)$$

Therefore

$$s_2(t) = -\sqrt{2P_s}\cos\,(2\pi f_c t)$$

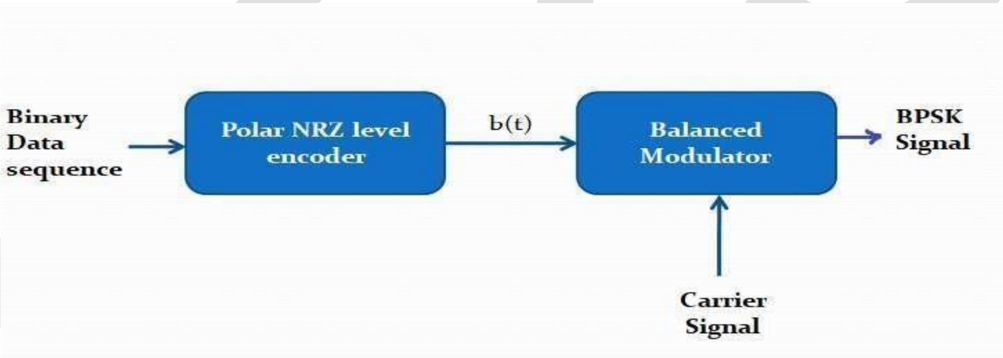
Which implies

$$s(t) = b(t)\sqrt{2P_s}\cos\,(2\pi f_c t)$$

Where b(t)=+1; for symbol '1'

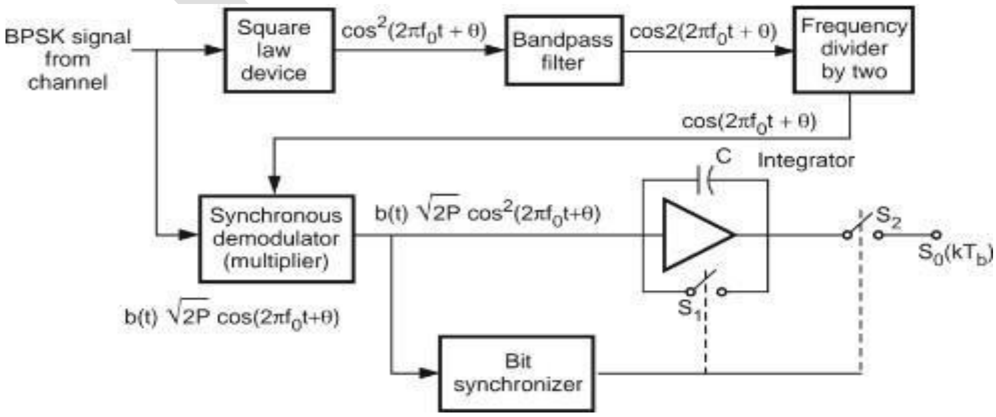
b(t)=-1; for symbol '0'

Generation of BPSK



Coherent Reception of BPSK Signal

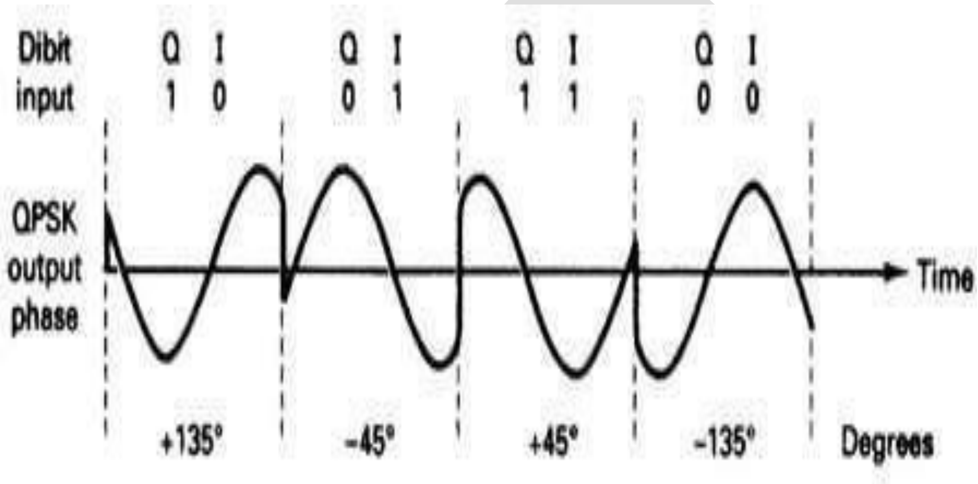
Operation of the receiver



Quadrature Phase Shift Keying (QPSK)

This is the phase shift keying technique, in which the sine wave carrier takes four phase reversals such as 45°, 135°, -45°, and -135°.

If these kinds of techniques are further extended, PSK can be done by eight or sixteen values also, depending upon the requirement. The following figure represents the QPSK waveform for two bits input, which shows the modulated result for different instances of binary inputs.

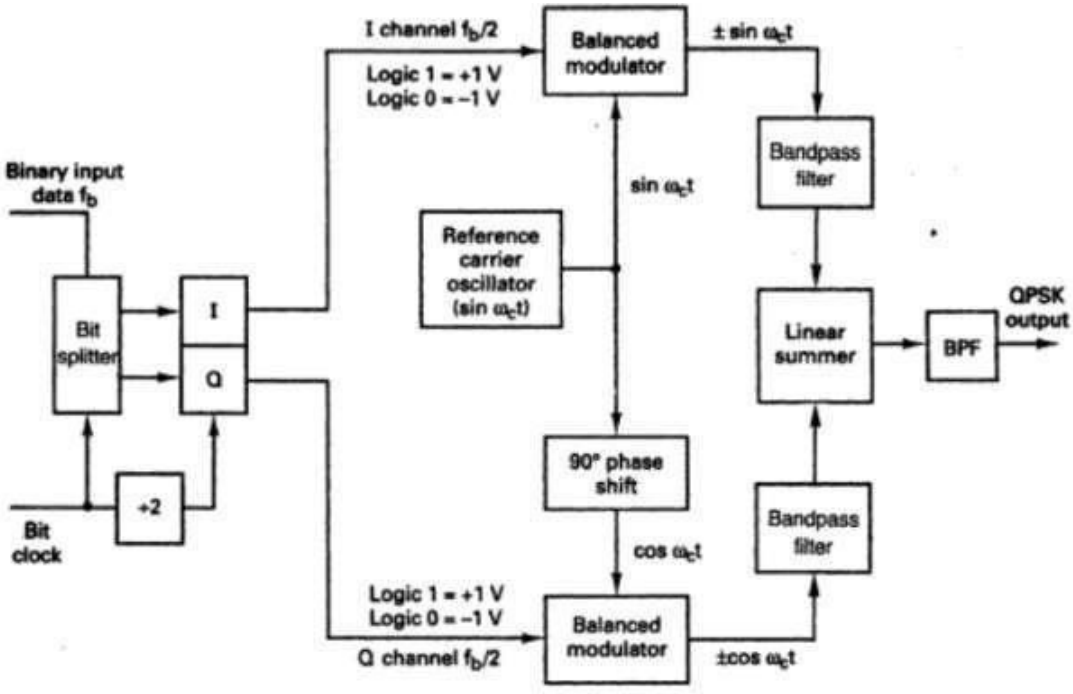


QPSK transmitter

A block diagram of a QPSK modulator is shown in Figure below. Two bits (a dibit) are clocked into the bit splitter. After both bits have been serially inputted, they are simultaneously parallel outputted.

The I bit modulates a carrier that is in phase with the reference oscillator (hence the name "I" for "in phase" channel), and the Q bit modulate, a carrier that is 90° out of phase. For a logic 1 = + 1 V and a logic 0= - 1 V, two phases are possible at the output of the I balanced modulator (+sin ωct and - sin ωct), and two phases are possible at the output of the Q balanced modulator (+cos ωct), and (-cos ωct).

When the linear summer combines the two quadrature (90° out of phase) signals, there are four possible resultant phasors given by these expressions: + sin ωct + cos ωct, + sinωct - cos ωct, -sin ωct + cos ωct, and -sin ωct - cos ωct.

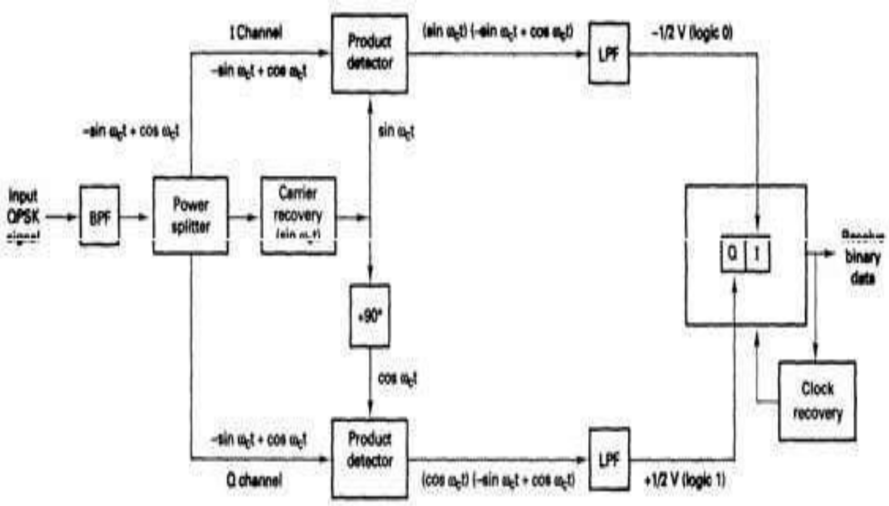


QPSK Receiver

The power splitter directs the input QPSK signal to the I and Q product detectors and the carrier recovery circuit. The The carrier recovery circuit reproduces the original transmit carrier oscillator signal.

The recovered carrier must be frequency and phase coherent with the transmit reference carrier. The QPSK signal is demodulated in I and Q product detectors, which generate the original I and Q data bits. The outputs of the product detectors are fed to the bit combining circuit, where they are converted from parallel I and Q data channels to a single binary output data stream.

The incoming QPSK signal may be any one of the four possible output phases shown in above figures.



To illustrate the demodulation process, let the incoming QPSK signal is -sin ωct + cosωct. Mathematically, the demodulation process is as follows.

The received QPSK signal (-sin ωct + cos ωct) is one of the inputs to I product detector. The other input is the recovered carrier (sin ωct). The output of the I product detector is

$$Q = \underbrace{(-\sin \omega_c t + \cos \omega_c t)}_{\text{QPSK input signal}}\underbrace{(\cos \omega_c t)}_{\text{carrier}}$$

$$= \cos^2 \omega_c t - (\sin \omega_c t)(\cos \omega_c t)$$

$$= \frac{1}{2}(1 + \cos 2\omega_c t) - \frac{1}{2}\sin(\omega_c + \omega_c)t - \frac{1}{2}\sin(\omega_c - \omega_c)t$$

$$Q = \frac{1}{2} + \underset{\text{(filtered out)}}{\frac{1}{2}\cos 2\omega_c t} - \frac{1}{2}\sin 2\omega_c t - \underset{\text{(equals 0)}}{\frac{1}{2}\sin 0}$$

$$= \frac{1}{2}\text{V(logic 1)}$$

Again, the received QPSK signal (-sin ωct + cos ωct) is one of the inputs to the Q product detector. The other input is the recovered carrier shifted 90° in phase (cos ωct). The output of the Q product detector is

$$I = \underbrace{(-\sin \omega_c t + \cos \omega_c t)}_{\text{QPSK input signal}} \underbrace{(\sin \omega_c t)}_{\text{carrier}}$$

$$= (-\sin \omega_c t)(\sin \omega_c t) + (\cos \omega_c t)(\sin \omega_c t)$$

$$= -\sin^2 \omega_c t + (\cos \omega_c t)(\sin \omega_c t)$$

$$= -\frac{1}{2}(1 - \cos 2\omega_c t) + \frac{1}{2}\sin(\omega_c + \omega_c)t + \frac{1}{2}\sin(\omega_c - \omega_c)t$$

(filtered out) (equals 0)

$$I = -\frac{1}{2} + \frac{1}{2}\cos 2\omega_c t + \frac{1}{2}\sin 2\omega_c t + \frac{1}{2}\sin 0$$

$$= -\frac{1}{2}\text{V (logic 0)}$$

Comparison of various Digital Communication System (ASK – FSK – PSK – QAM)

ASK	FSK	PSK
1] Information is in amplitude variations.	Information is in frequency variations.	Information is in phase variations.
2] Less Bandwidth as compared.	More Bandwidth as compared.	Less to moderate Bandwidth.
3] Poor Noise immunity.	Better Noise immunity.	Better Noise immunity.
4] Synchronization is not required.	Synchronization is not required.	Synchronization is essential.
5] Effect of DC is more.	Effect of DC component is less.	Effect of DC component is less.
6] More power required.	Moderate power required.	Less-moderate power required.
7] Low bit rate application	Moderate bit rate application.	High bit rate application.
8] Simple Implementation.	Moderately complex Implementation.	Very complex Implementation.