# Chapter :2

## Modulation And Demodulation

### What is Modulation

The process of altering the characteristics of the amplitude, frequency, or phase angle of the high frequency signal in accordance with the instantaneous value of the **modulating** wave is called **modulation**.

High frequency signal is called **carrier signal.** The signal resulting from the process of modulation is called modulated signal.

Carrier signal effectively gives the message signal ride through the transmission medium. The device which modulates the signal is called modulator.

### What is Demodulation

Modulation process performed at the transmitter. Transmitter transmit the modulated signal which reache the receiver via transmission medium. When receiver receives this signal ,it extracts modulating signal from the modulated signal. The process of extracting modulating signal from the modulated signal is called demodulation

Demodulation is also called Detection.

The device which perform demodulation is called demodulator.

## Need of modulation

### 1. Reduction in the height of antenna:

- When the transmission occurs over free pace, the antennae radiate the signal out and receiver receives it. In order to operate efficiently, antennae need to be in order of the magnitude of wavelength of the transmitted signal.
- For the transmission of radio signals, the antenna height must be a multiple of (λ/4).Here λ is the wavelength. Λ =c/f where c is velocity of light and f is the frequency of the signal to be transmitted.
- The minimum antenna height required to transmit a baseband signal of f=10 kHz is calculated as follows:

Minimum antenna height= λ/4 = c/4f=(3* $10_8$108)/(4*10*$10_3$103 )=7500meters i.e. 7.5 km
It is impossible to build antennae this big.

- Now consider a modulated signal at f= 1MHz.The minimum antenna height is given by,

Minimum antenna height= λ/4 = c/4f=(310$_8$108*)/(4*10*10$_6$106 )=75 meter

- This length of the antenna can be built easily and this example clearly shows us how hugely the process of modulation is enabling communication systems.

-**Avoids mixing of signals:**

- This is a point from the practical side of things. Suppose you are transmitting the baseband signal as it is to a receiver, say your friends phone. Just like you , there will be thousands of people of people in the city using their mobile phones.
- There is no way to tell such signals apart and they will interfere with each other leading to a lot of noise in the system and a very bad output.
- By using a carrier wave of high frequencies and allotting a band of frequencies to each message, there is no mixing up of signals and the received signals are absolutely perfect.

**Modulation to overcome hardware limitations:**

- The design of communication system may be considered by the cost and availability of hardware. High frequency hardware are easily and with low cost available in market.
- Modulation permits the designer to place the signal in suitable frequency range that avoids hardware limitations**.**

-**Modulation for efficient transmission:**

- Audio signal information has range of 300 Hz to 3 KHz .Modulation allows us to change information frequency rnge to higher level that is best suited to transmission medium. Satellite communication works in GHz range .Modulation helps to translate lower frequency range to higher frequency range.
- By using modulation to transmit the signals through space to long distances, we have removed the need for wires in the communication systems.
- The technique of modulation helped humans to use wireless equipments.

-**Multiplexing is possible:**

- Multiplexing is a process in which two or more signals can be transmitted over the same communication channel simultaneously. This is possible only with modulation. Due to modulation one can get higher bandwidth.
- The Multiplexing allows the same channel to be used by many signals.

**:**

https://youtu.be/awL6RchPdBE

Above is the link provide to know detail about Modulation and need of modulation.

**Digital Modulation techniques**:

Pulse Code Modulation (PCM), FSK, QPSK, QAM.

## Pulse Code Modulation (PCM):-

Pulse-code modulation (PCM) is used to digitally represent sampled analog signals. It is the standard form of digital audio in computers, CDs, digital telephony and other digital audio applications. The amplitude of the analog signal is sampled at uniform intervals and each sample is quantized to its nearest value within a predetermined range of digital levels.

So there are three main steps in PCM

1 Sampling

2 Quantization

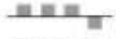
3 Encoding

1 Sampling: The analog signal is divided into discrete samples at the rate based on the nyquist sampling theorem i.e twice the signal bandwidth.

2. Quantization: Quantization is the process of converting an infinite number of possibilities to the finite number of amplitude values.

In PCM information is analog signal which has infinite number of amplitude values. With quantization analog signal is converted in limited number of combinations.

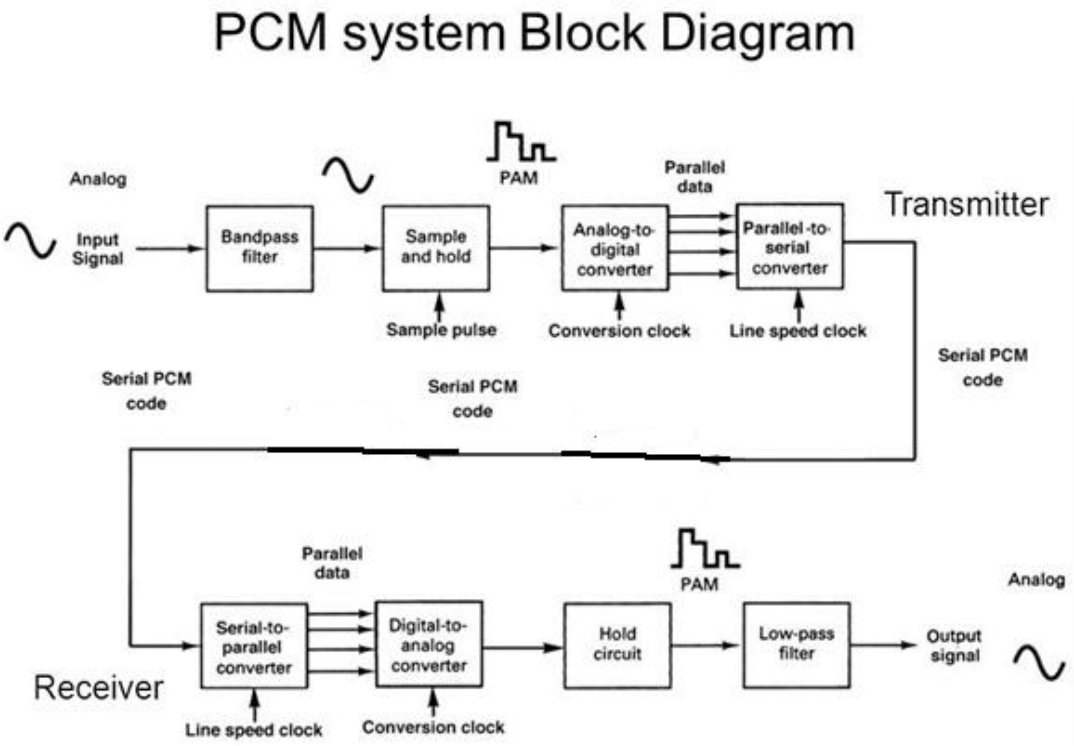
Assigning PCM codes to absolute magnitudes is called quantizing.

| Digit | Binary equivalent | Pulse code waveform |
|---|---|---|
| 0 | 0000 |  |
| 1 | 0001 |  |
| 2 | 0010 |  |
| 3 | 0011 |  |
| 4 | 0100 |  |
| 5 | 0101 |  |
| 6 | 0110 |  |
| 7 | 0111 |  |
| 8 | 1000 |  |
| 9 | 1001 |  |
| 10 | 1010 |  |
| 11 | 1011 |  |
| 12 | 1100 |  |
| 13 | 1101 |  |
| 14 | 1110 |  |
| 15 | 1111 |  |

Example

3.Encoding: The quantized samples are coded into binary bits.

## Block Diagram of Transmitter and Receiver of PCM




- PCM transmitter consist of bandpass filter , sampler or sample and hold circuit , analog to digital converter and parallel to serial converter.
- The analog input is applied to the band pass filter which removes high frequency components.
- The signal is periodically sampled and converted into digital data using ADC.
- The digitally converted data is in a parallel form . With the help of parallel to serial converter ,it is converted into serial fashion,which is then transmitted over transmission channel.
- In the receiver the serial to parallel converter converts serial pulses received from the transmission line to parallel PCM code .The DAC converts the parallel PCM code to analog to replicate the original analog signal.

**Applications of PCM**

i. It used in telephone system to transmit voice signal over digital transmission media.
ii. Transmission of binary data between computers.

iii. Commercial carrier systems like Bell systems carrier used PCM.

**Limitations of PCM**

i. High frequency signal are not suitable for PCM
ii. A large amount of binary has tobe transmitted
iii. If number of quantizing levels are increased the signal can be reproduce better, but this increase in number of bits per sample.
iv. Noise can be affected the bit information being transmitted.

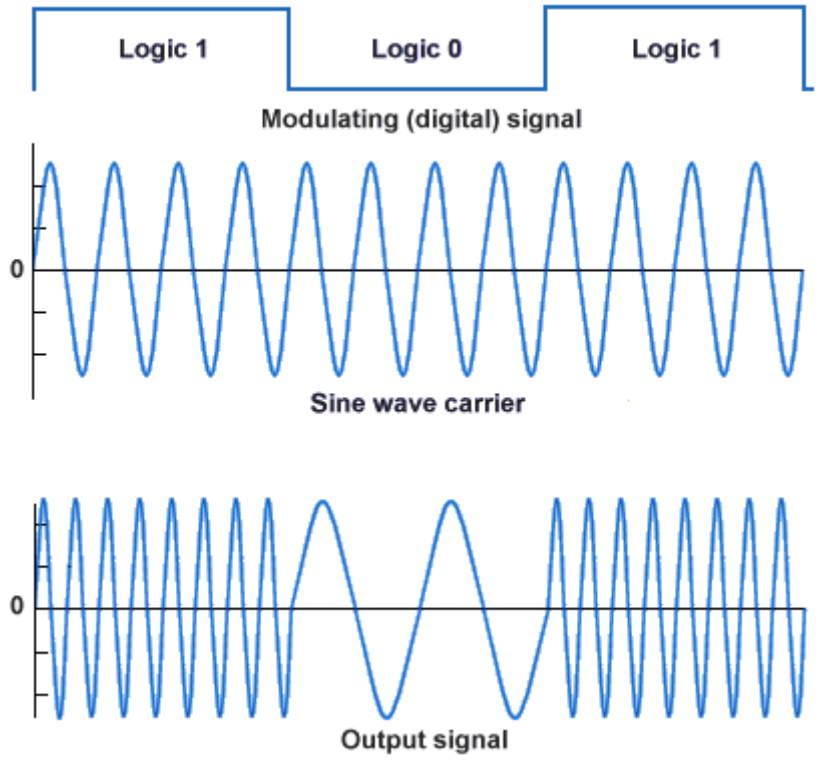
## Digital Type Modulation Techniques

## FREQUENCY SHIFT KEYING (FSK)

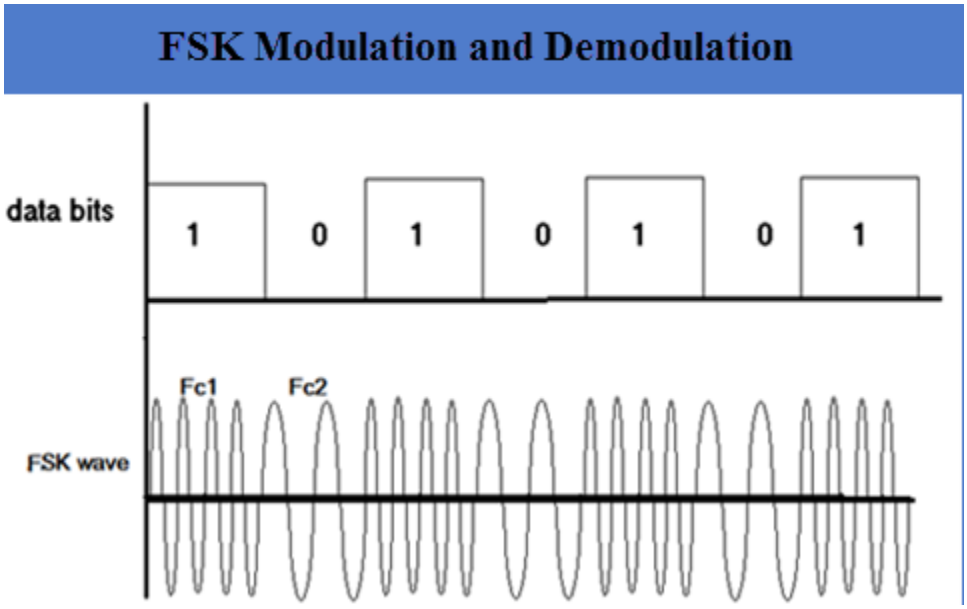
**Frequency Shift Keying (**FSK) FSK is the digital modulation technique in which the frequency of the carrier signal varies according to the digital signal changes. FSK is a scheme of frequency modulation.

The output of a FSK modulated wave is high in frequency for a binary High input and is low in frequency for a binary Low input. The binary **1s** and **0s** are called Mark and Space frequencies.

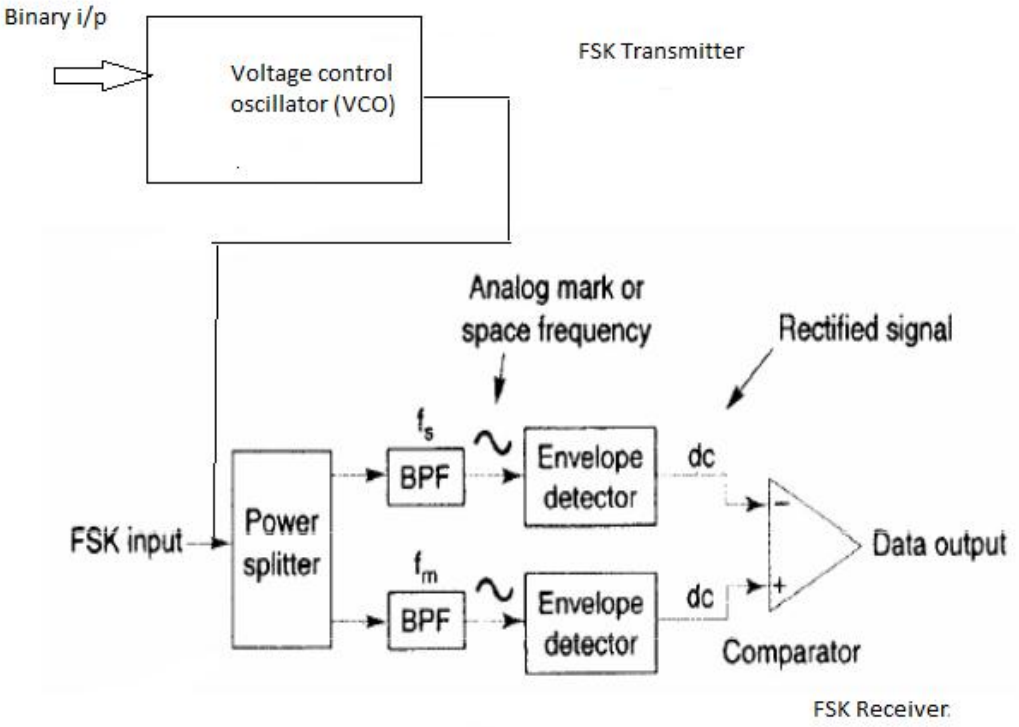
The following image is the diagrammatic representation of FSK modulated waveform along with its input.




## Example:To Draw FSK signal for data 1010101




**Where Fc1 is mark frequency for binary data 1 and Fc2 is space frequency for binary data 0.**




**Block Diagram of FSK transmitter and Receiver**

FSK Transmitter/modulator

FSK modulator is simply an oscillator whose frequency is can change according to binary data input.

When binary 1 input is applied VCO output oscillates with frequency Fc1 called **mark frequency** and when binary 0 is applied VCO output oscillates with frequency Fc2 called **space frequency.**

FSK Receiver/Demodulator

- Received fsk signal is duplicated using power splitter
- It is then simultaneously applied to two band pass filters (BPF).Two filters are tuned for mark and space frequency respectively.
- Therefore at the output of upper BPF ,only mark frequency will occur. And space frequency will occur at output of lower BPF
- Envelope/ Amplitude detector detects the wave and gives logic high output.
- When space frequency is present ,lower Envelope/ Amplitude detector gives output and When mark frequency is present ,upper Envelope/ Amplitude detector gives output .
- Outputs of both amplitude detector drives the comparator inputs.
- The comparator compares both the signals and its output is either logic high or logic low.
- Thus circuit gives logic 1 output for mark input frequency and logic 0 output for space input frequency.

**Limitations of FSK**

- FSK suffers from poor error performance
- So it is seldom used for high performance digital systems.

**Applications of FSK**

- Low cost
- Used in low performance MODEMS

## Phase Shift Keying (PSK)

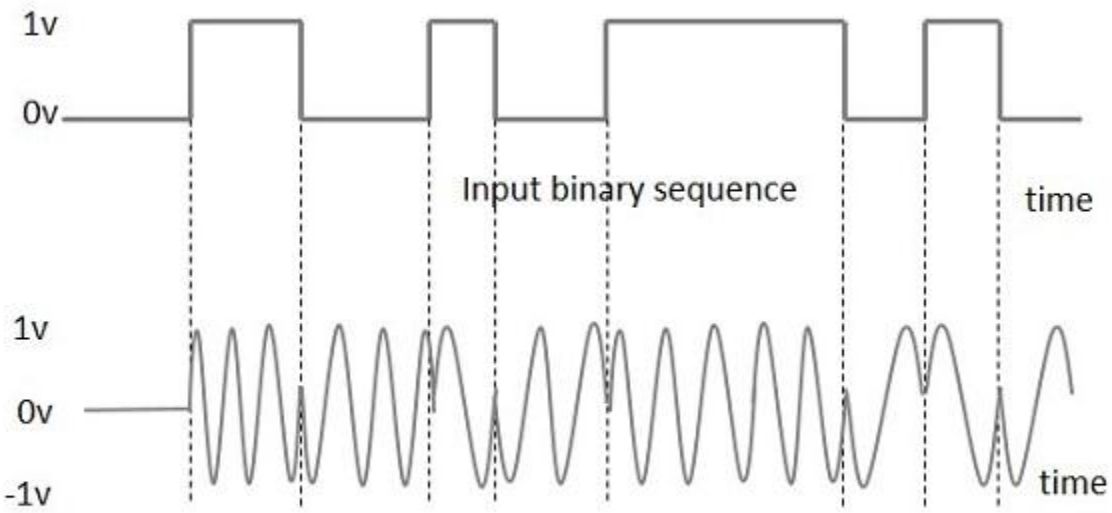
Phase shift keying is type of angle modulation. Here phase of analog carrier signal changes according to digital information.

## Binary Phase Shift Keying (BPSK)

This is also called as 2-phase PSK or Phase Reversal Keying. In this technique, the sine wave carrier takes two phase reversals such as 0° and 180°.

The modulation of BPSK is done using a balance modulator, which multiplies the two signals applied at the input. For a zero binary input, the phase will be **0°** and for a high input, the phase reversal is of **180°**.

Following is the diagrammatic representation of BPSK Modulated output wave along with its given input.




BPSK Modulated output wave

The output sine wave of the modulator will be the direct input carrier or the inverted 180°phaseshifted180°phaseshifted input carrier, which is a function of the data signal.

## Quadrature Phase Shift Keying (QPSK)

This is the phase shift keying technique, Here four phases are used for signal transmission , phase difference between each is 90°. In which the sine wave carrier takes four phase reversals such as 0°, 90°, 180°, and 270°.

To produce four input combinations two binary bits are required then possible conditions are 00, 01 ,10 ,11.Combination of two bits called dibit.

Following truth table shows one example of QPSK

| Binary input | | OPSK Output Phase |
|---|---|---|
| Q | I | |
| 0 | 0 | $45^0$ |
| 0 | 1 | $135^0$ |
| 1 | 0 | $315^0$ |
| 1 | 1 | $225^0$ |

## Constellation and phase diagram (vector)

A phasor diagram shows all the legal output phases of a PSK system.

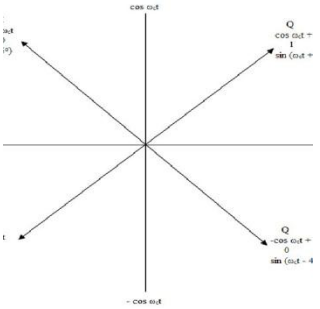
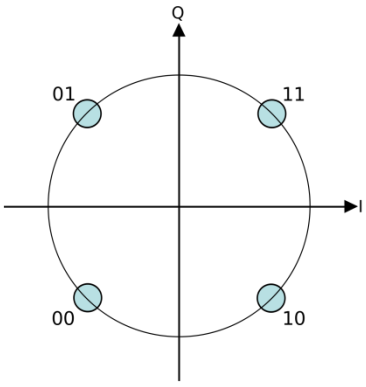
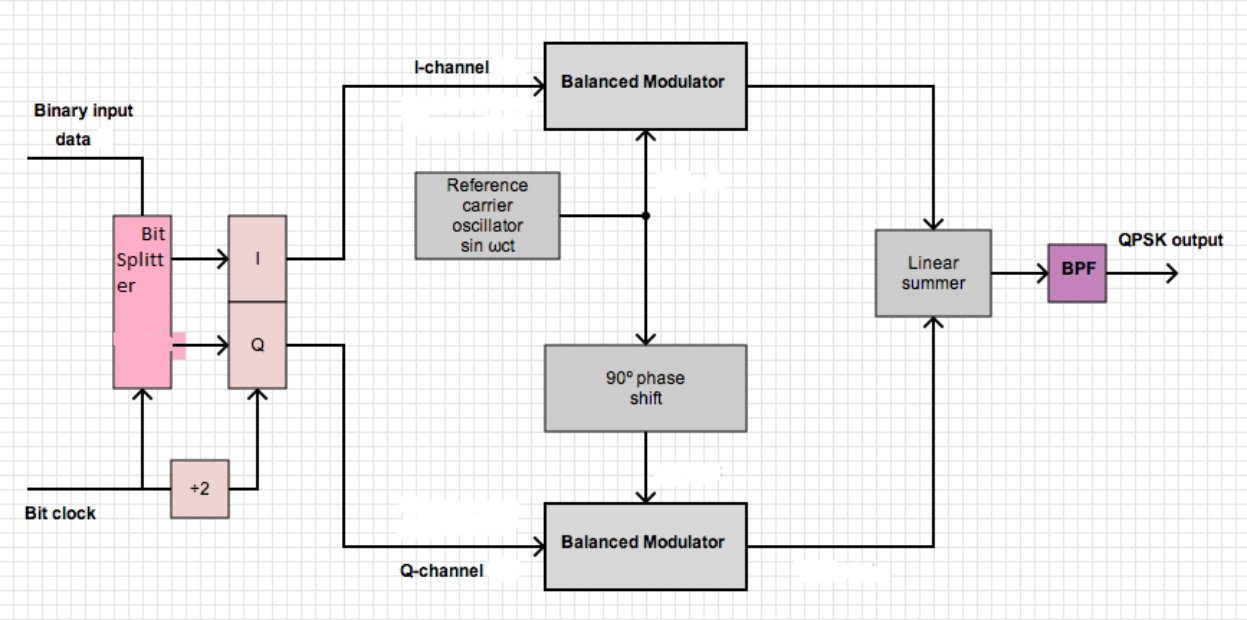


Diagram which just shows endpoints of vector is called constellation diagram.



## QPSK Modulator

### Block Diagram of QPSK Modulator



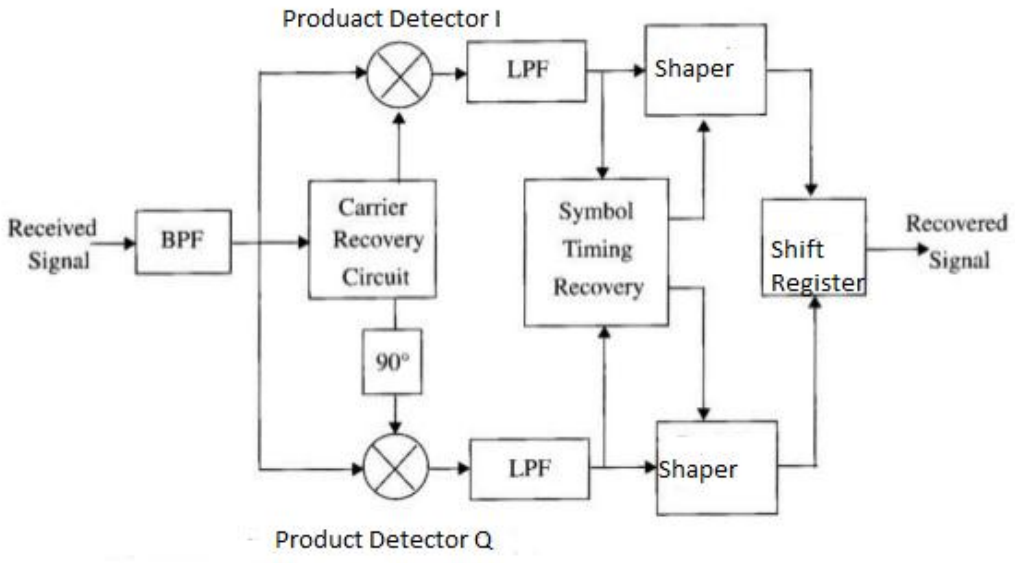

### Working of QPSK modulator is as below

1. A dibit (two bit information signal is inputted serially.
2. Then it is splitted by the bit splitter which concert data into parallel.
3. One bit is directed to the I channel and other is to the Q channel.
4. The I bit modulates carrier that is in phase with the reference oscillator('I' is for In phase channel)
5. The Q bit modulates carrier that is $90^0$ out of phase with the reference oscillator('Q' is for Quadrature i.e $90^0$ phase)
6. When splitted signal is applied to the balance modulator I and Q ,each one generate two phases output whether signal is logic 0 or logic 1.
7. The $90^0$ out of phase signal of I and Q modulator is combine in linear summer.
8. Consequently one can get 4 phases of $45^0$,$135^0$ ,$225^0$ , $325^0$

## QPSK Demodulator

### Block Diagram of QPSK Demodulator

# QPSK Demodulator




**The working of** QPSK Demodulator is as below

1. The incoming QPSK signal may be in any one of the 4 possible output phases.
2. The same QPSK signal is directed to I and Q product detector and the carrier recovery circuit.
3. carrier recovery circuit produce the original transmitted carrier signal.
4. This carrier signal is applied to the product detector I and is shifted $90^0$ before applied to the product detector Q.
5. Outputs of the two product detector generates the original I and Q bits.
6. The outputs are filtered and shaped into the dibit.
7. The two bits are combined in a shift register and shifted out to produce the originally transmitted binary signal.

## QAM ( Quadrature Amplitude Modulation)

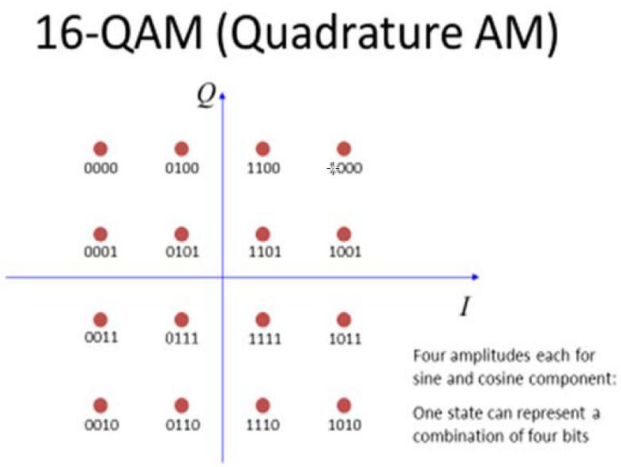
Till now we studied modulation techniques in which only one parameter i.e either amplitude or frequency or phase of carrier signal varies according to information signal. If more than one parameter is varied then transmission speed can further be increased . QAM uses phase and amplitude change of carrier signal.It uses in new high speed MODEM to achive higher bit rate.

In 16 QAM 4 bits are grouped together to form symbols.Thus 16 QAM transmits 4 bits at a time.

The features of 16 QAM are

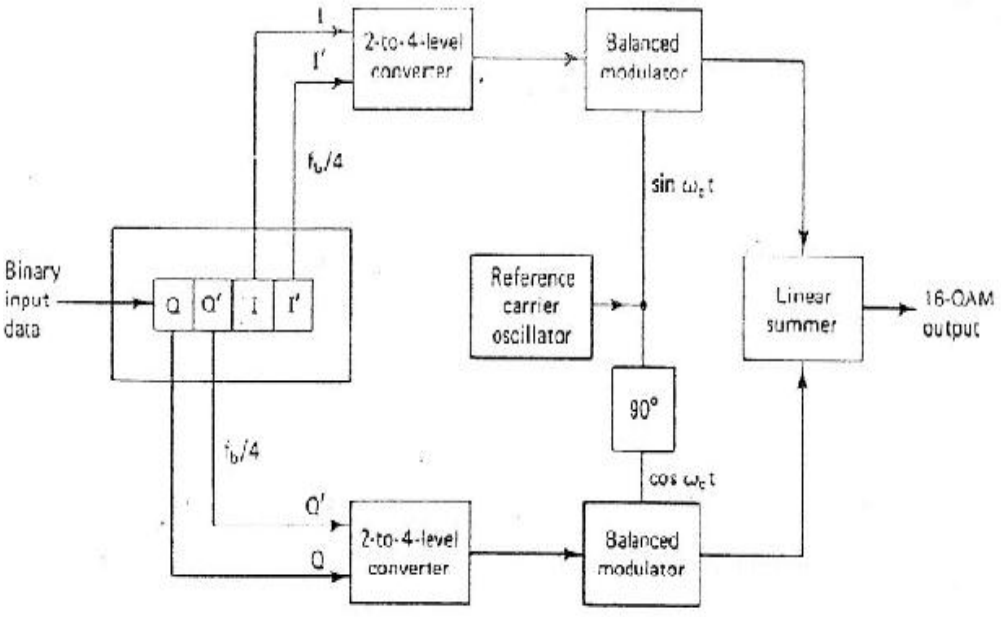
1. There are two carriers with the same frequency, but having phase difference of $90^0$.
2. Two carriers are amplitude modulated independently.
3. 16 QAM processes 4 bits at a time,so it is 4 time efficient.

The constallation diagram of 16 QAM is as below.




# 16 QAM Modulator

The block diagram of 16 QAM modulator is as below.

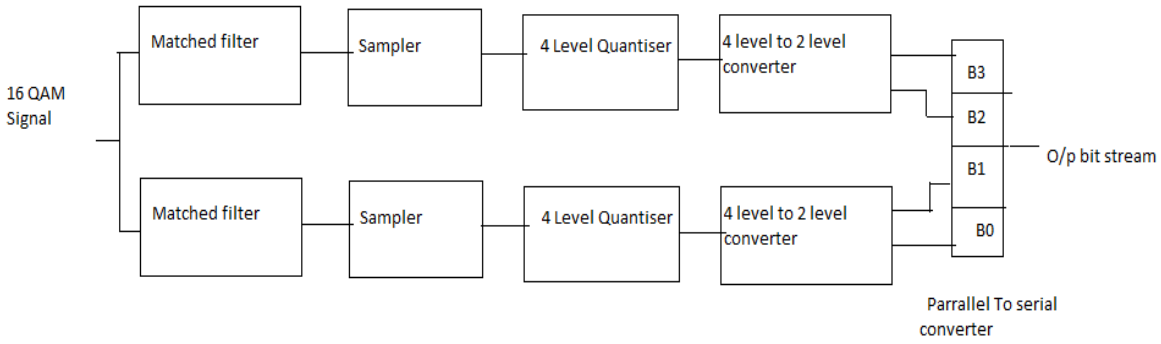


Working of 16 QAM is as follows

1. The four binary bits are inputted serially
2. These bits are outputted parallel using bit splitter.In the form of I, I',Q,Q'
3. Bits I,I' drive upper 2 to 4 level converter while Q,Q' drive lower one.
4. I and Q bits determine the polarity of the output of 2 to 4 level converter.
5. I' and Q' bits determine the magnitude (logic 1 =0.821 v and logic 0 = 0.22v).
6. Thus two polarities and two magnitudes are possible at the output of each converter.They are + or – 0.22 v and + or -0.821 v
7. Variable amplitude signal is applied to the balance modulator for which another input is carrier signal. Balance modulator I receives carrier signal directly while balance modulator Q receives $90^0$ phase shift carrier signal.
8. Each balance modulator produces four outputs for each converter output.
9. The linear summer combines the output from I and Q channel balance modulator and produces 16 outputs for 16 QAM.

# 16 QAM Demodulator

Block diagram of 16 QAM is as below




working of 16 QAM is as below

1. When 16 QAM input signal is received ,it is first applied to match filters and samplers.
2. The four level quantiser then approximate each output to the nearest of four level.
3. A 2 to 4 bit converter then generate the bits in each channel according to the conversion .
4. The two bits from each channel are combine in a parallel to serial converter to produce a serial output of bit stream.