Introduction to Communication Systems – Digital Modulation

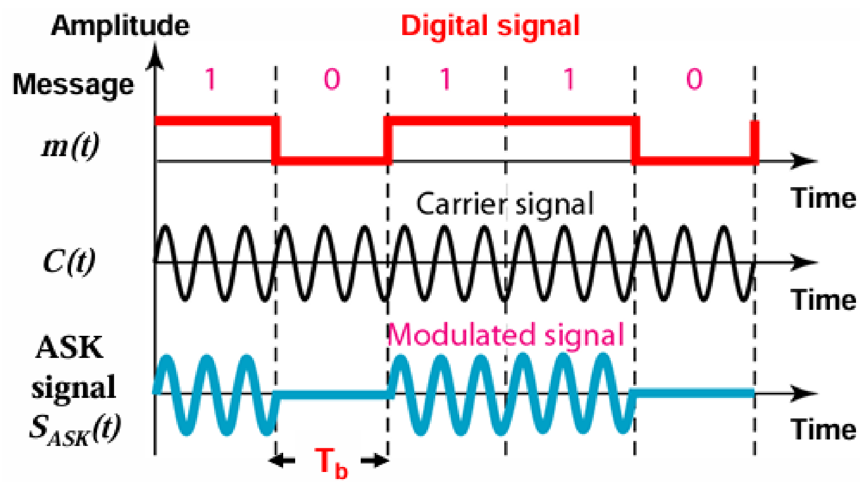
22AIE211 Introduction To Communication & IoT

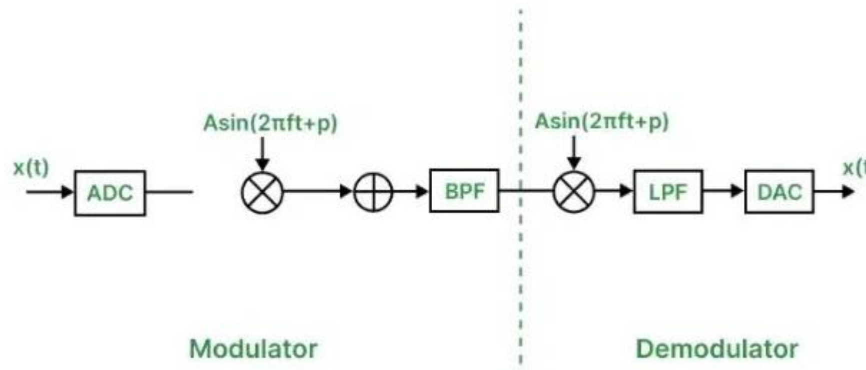
Digital Modulation

- In Analog Modulation, both carrier and message signals are analog waves.
- In Digital Modulation, only the carrier signal is analog and the message signal is in digital form.
- Digital signals are binary values that can take either logic 0 as in zero volts or logic 1 as in any other voltage.
- The modulation process is called Shift Keying.
- Shift Keying means that the amplitude, frequency or phase of the carrier wave is shifted between two or more discrete values rather than varying continuously like Analog Modulation
- Types of Digital Modulation techniques:
    - Amplitude Shift Keying
    - Frequency Shift Keying
    - Phase Shift Keying

Amplitude Shift Keying

- amplitude of the RF carrier is varied in accordance with baseband digital input signal.
- In the fig., binary 1 is represented by carrier signal with some amplitude while binary 0 is represented by carrier of zero amplitude(i.e. no carrier).
- The form of ASK where no carrier is transmitted during the transmission of logic zero is known as OOK modulation (On Off Keying modulation).

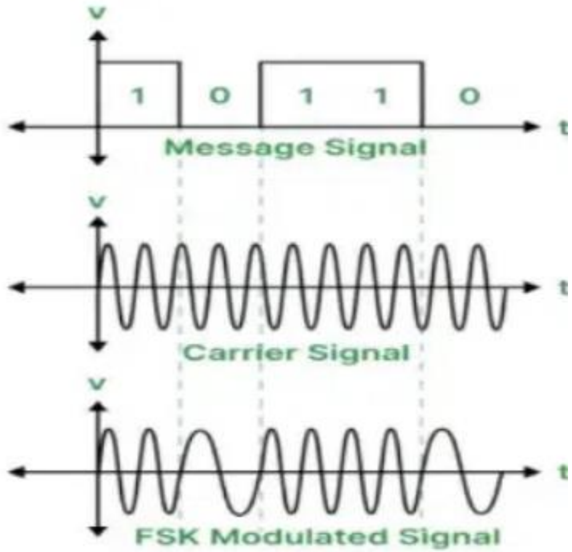


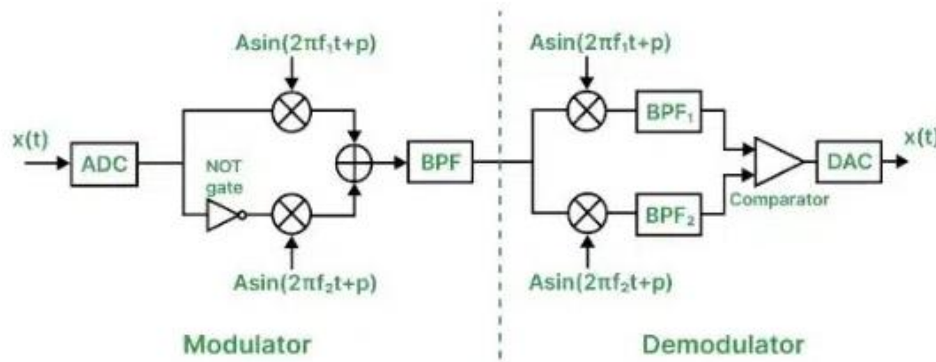


- s(t) = A2* cos(2*π*fc*t) for Binary Logic-1
  s(t) = A1* cos(2*π*fc*t) for Binary Logic-0
  Here A2>A1

Frequency Shift Keying

- frequency of the RF carrier is varied in accordance with baseband digital input.
- In the fig., binary 1 and 0 is represented by two different carrier frequencies.





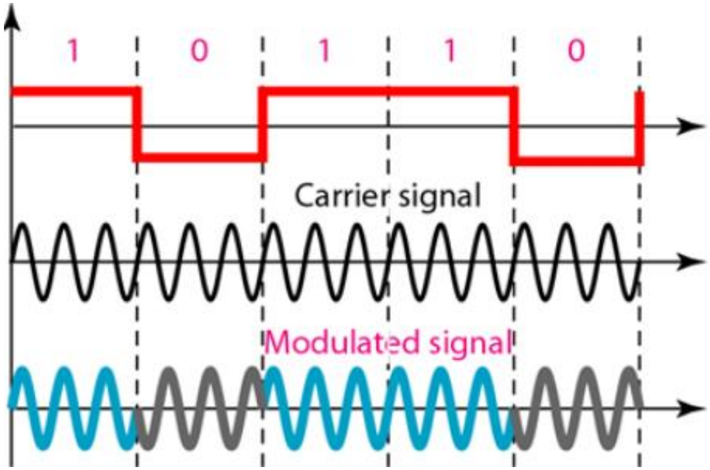
- Binary FSK can be represented by following equation:
  $s(t) = A^* \cos(2^*\pi^*f1^*t)$ for Binary 1
  $s(t) = A^* \cos(2^*\pi^*f2^*t)$ for Binary 0

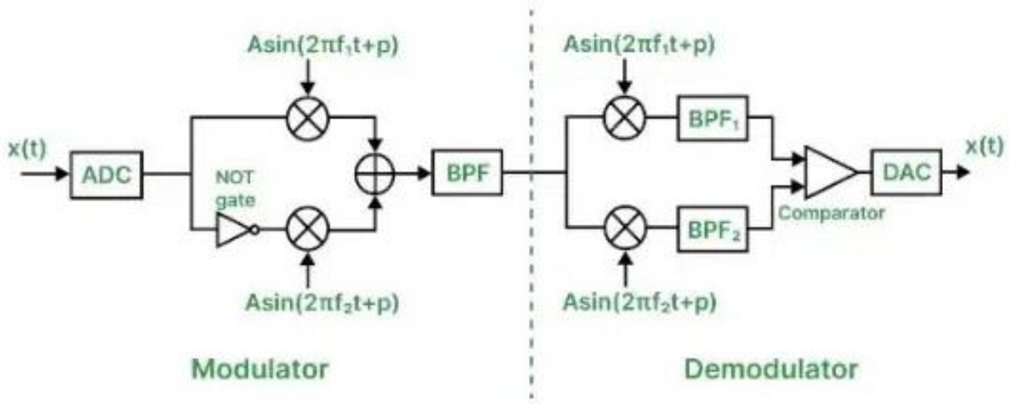
Phase Shift Keying

- phase of the RF carrier is changed based on digital input.

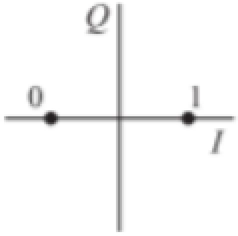
Binary phase shift keying (BPSK)

- In the figure, Binary 1 is represented by 0 degree phase of the carrier and binary 0 is represented by 180 degree phase of the RF carrier.



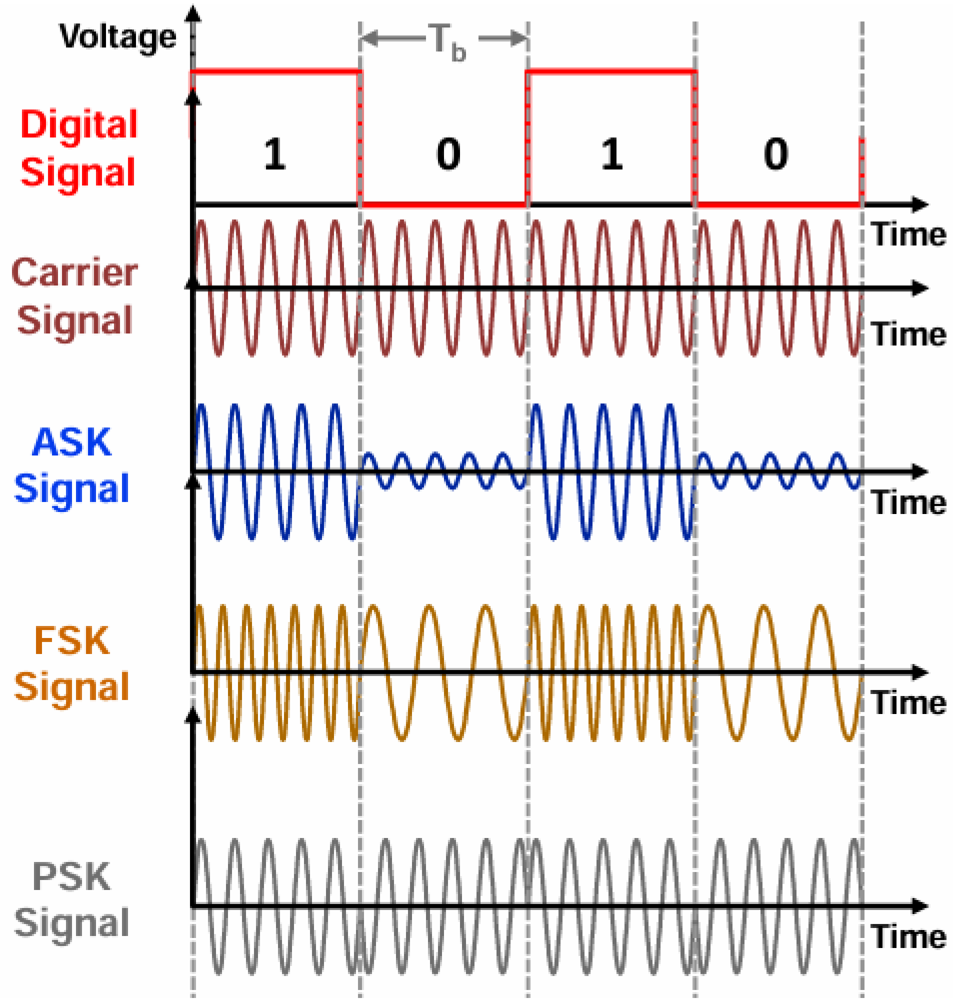


- Binary PSK can be represented by following equation :
  If $s(t) = A*\cos(2*\pi*fc*t)$ for Binary 1 then
  $s(t) = A*\cos(2*\pi*fc*t + \pi)$ for Binary 0



Constellation diagram

ASK, FSK, PSK



Voltage
T_b
Digital Signal
1
0
1
0
Time
Carrier Signal
Time
ASK Signal
Time
FSK Signal
Time
PSK Signal
Time

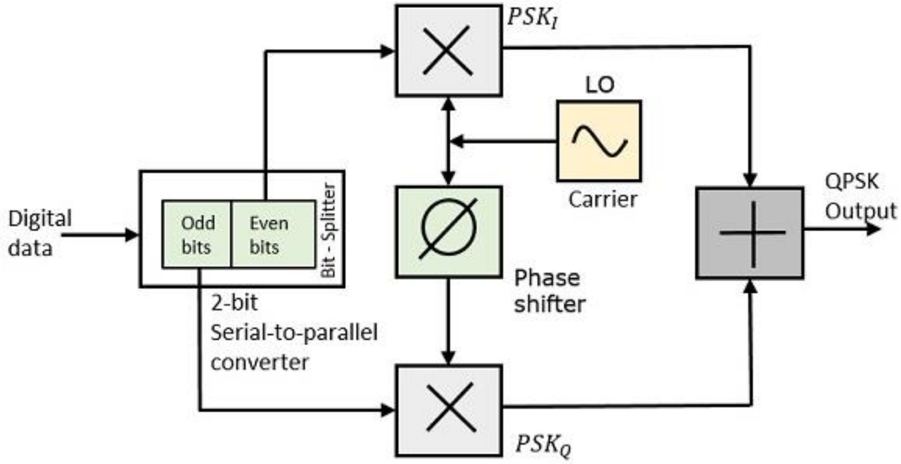
Quadrature phase shift keying (QPSK)/4PSK

- QPSK has twice the bandwidth efficiency of BPSK, since two bits are transmitted in a single modulation symbol.
- the phase of the sine wave carrier takes four phase reversals such as 0°, 90°, 180°, and 270° where each value of phase corresponds to a unique pair of message bits

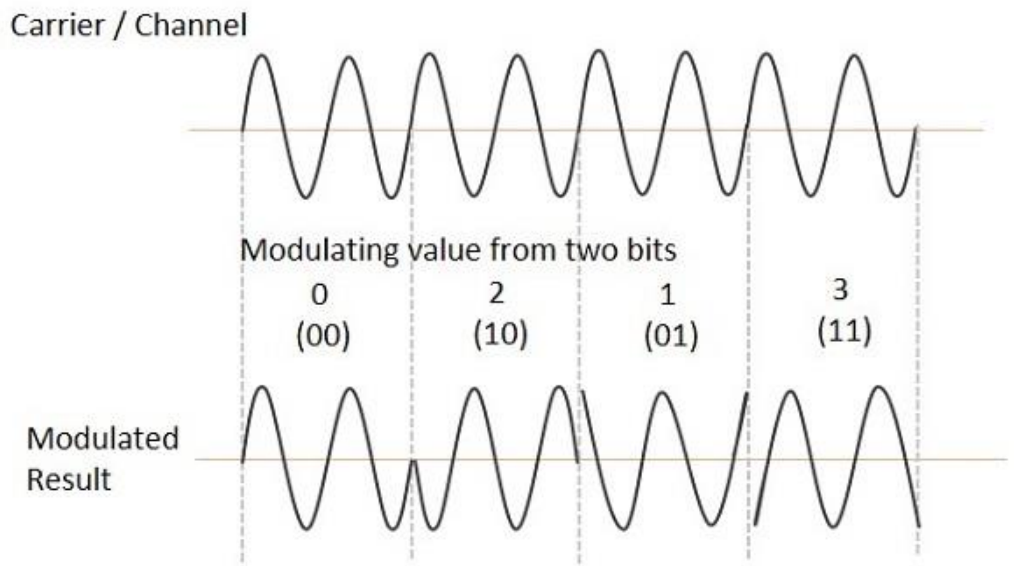
QPSK Modulator

- The QPSK Modulator uses a bit-splitter, two multipliers with local oscillator, a 2-bit serial to parallel converter, and a summer circuit. Following is the block diagram for the same.

- At the modulator's input, the message signal's even bits (i.e., 2nd bit, 4th bit, 6th bit, etc.) and odd bits (i.e., 1st bit, 3rd bit, 5th bit, etc.) are separated by the bits splitter and are multiplied with the same carrier to generate odd BPSK (called as PSKI) and even BPSK (called as PSKQ). The PSKQ signal is anyhow phase shifted by 90° before being modulated.



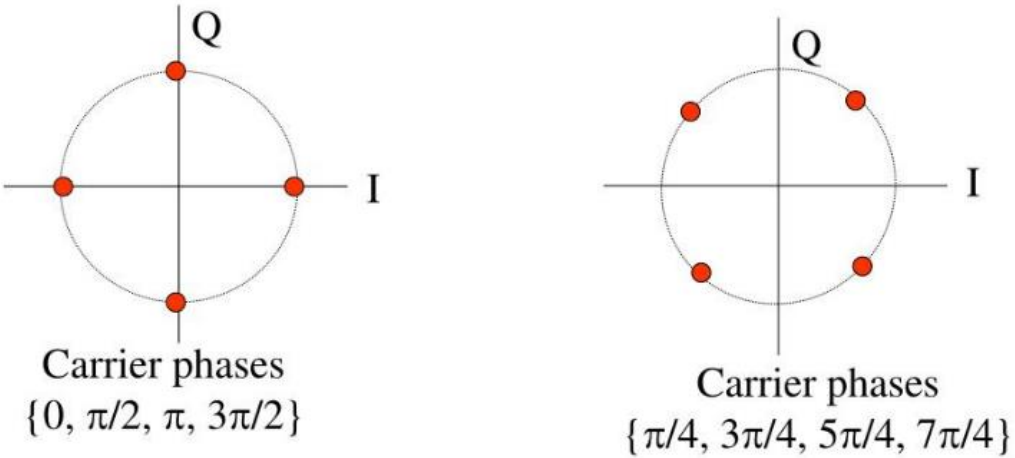
The QPSK waveform for two-bits input is as follows, which shows the modulated result for different instances of binary inputs.



- The bit error probability of QPSK is identical to BPSK, but **twice as much data can be sent in the same bandwidth**. Thus when compared with BPSK, QPSK provides **twice the spectral efficiency** with exactly the same enegy efficiency

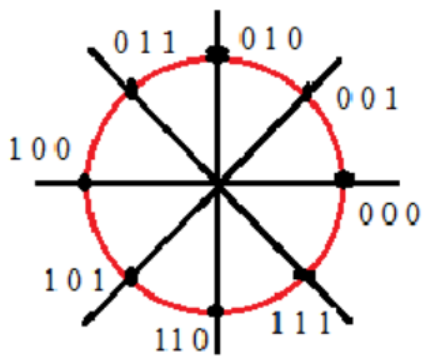
QPSK Constellation Diagram

- The constellation diagram shows all the possible symbols that can be transmitted by the system as a collection of points.
- In a frequency or phase modulated signal, the signal amplitude is constant, so the points lie on a circle around the origin.

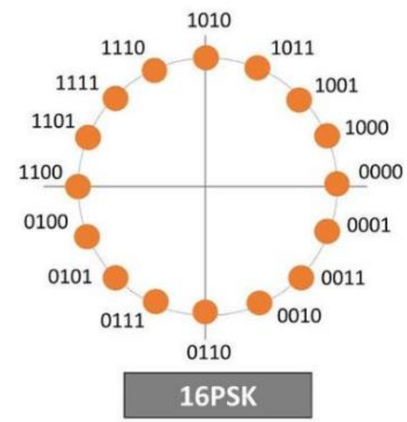


- Quadrature Phase Shift Keying has twice the bandwidth efficiency of BPSK since 2 bits are transmitted in a single modulation symbol

- Similarly we have 8PSK, 16PSK



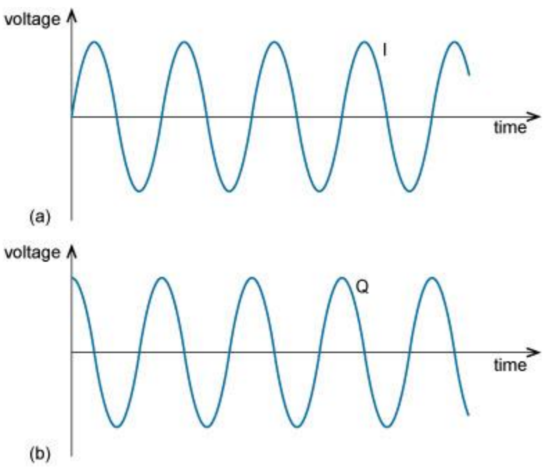
b) 8-PSK Constellation



- 16PSK has less spacing between the constellation points and is therefore more affected by noise.

Quadrature Amplitude Modulation

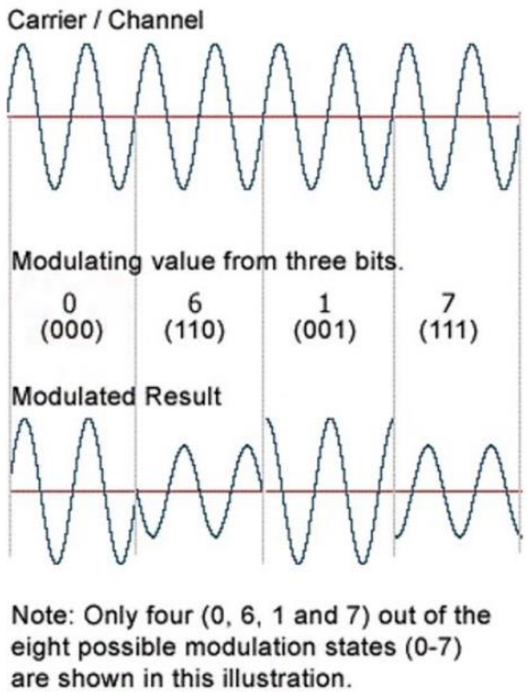
- QAM utilizes both amplitude and phase components to provide a form of modulation that is able to provide high levels of spectrum usage efficiency.
- QAM is a signal in which two carriers shifted in phase by 90 degrees (i.e. sine and cosine) are modulated and combined. As a result of their 90° phase difference they are in quadrature and this gives rise to the name.

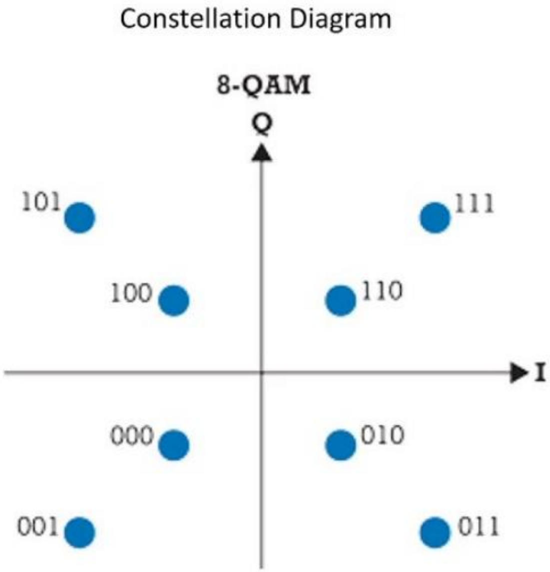


$$I = A\,Sin\,\phi$$
$$Q = A\,Cos\,\phi$$

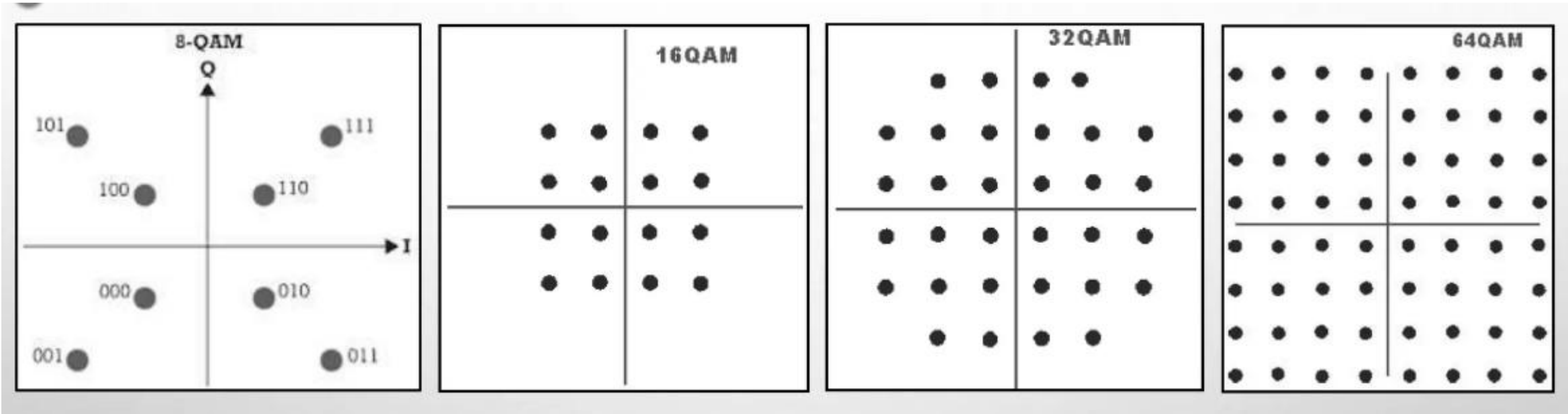
- Often one signal is called the In-phase or “I” signal, and the other is the quadrature or “Q” signal.
- The resultant overall signal consisting of the combination of both I and Q carriers contains of both amplitude and phase variations.

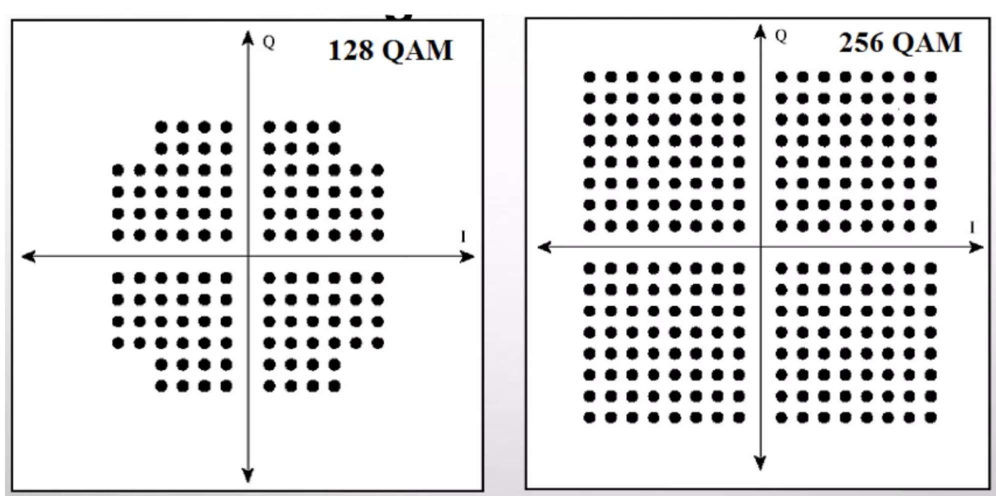
• 8QAM waveform & constellation





QAM constellation diagrams





ADVANTAGES

- Bandwidth Efficiency: Transmit two signals (each of bandwidth B) at 2B.
- More data can be transferred.
- Bit rate is increased without increasing the bandwidth by increasing the value of M.
- If data-rates beyond those offered by 8-PSK are required, it is more usual to move to QAM since it achieves a greater distance between adjacent points in the I-Q plane by distributing the points more evenly

QAM Applications

- Radio communications and data delivery applications.
- 64 QAM and 256 QAM are often used in digital cable television and cable modem applications.
- 16 QAM and 64 QAM are currently used for digital terrestrial television using DVB - Digital Video Broadcasting.

Summary

- ASK
- FSK
- BPSK
- QPSK
- QAM