DATA COMMUNICATION

CONSTELLATION DIAGRAM AND QUADRATURE AMPLITUDE MODULATION

Constellation Diagram

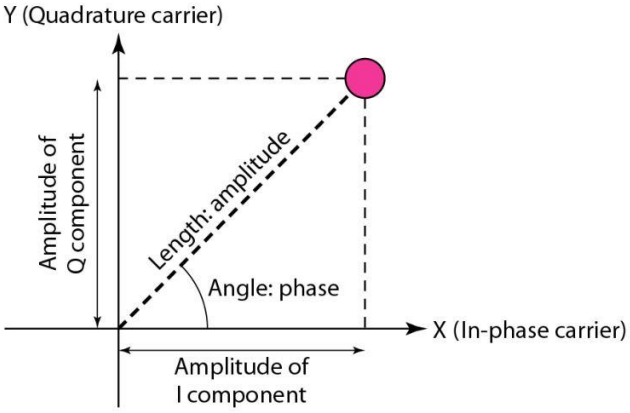
Introduction:

The word ‘constellation’ generally means a group of stars that are associated with different patterns like Scorpion or a Giant turtle. But here in data communication we are not interested in Giant turtles! We are interested in signals. In constellation diagram, we will use the idea of representing a star with a dot. But the dot will be used to represent a signal in data communication.

In data communication we transmit series of 0s and 1s, we have to transmit them using analogue wave forms, so we have to change some characteristics of analogue wave to encode combinations of 0s and 1s. We need to know those analog signals and the changing characteristics they have. Constellation Diagram helps us to represent a signals with those information.

The diagram:

Constellation diagram represents a signal in 2 dimensional XY plane.



This diagram helps us to determine amplitude and phase of a signal element. From each of the diagram we can deduce four information about a signal. In this diagram.

1. The I component, called “in-phase”, is shown in the horizontal axis. X represents the In-phase component.

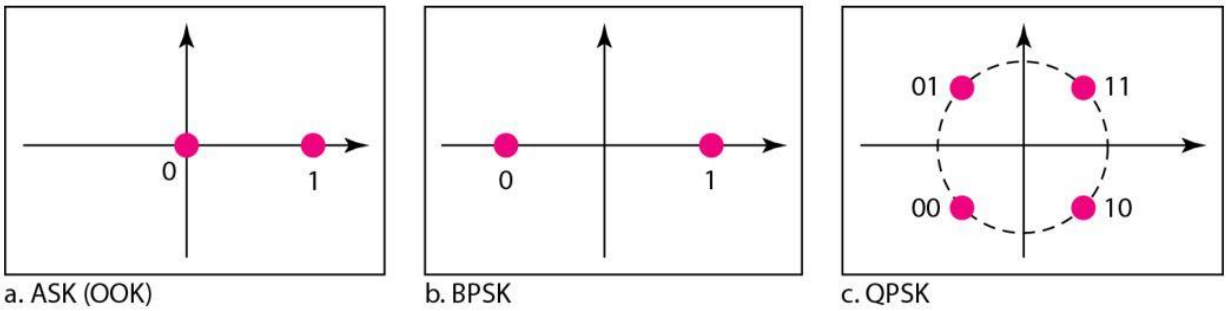
2. The Q component, called “quadrature”, is shown in the vertical axis, Y represents the Quadrature phase component.

3. The length of the line that connects the dot with the zero point (origin) of the diagram represents the peak amplitude.

4. The angle the line makes with the X axis is the phase of the signal element.

All the information we need, can easily be found on a constellation diagram.

Example:



a. ASK(OOK): The representation of ASK in constellation diagram has two dots. In ASK the signal can represent two different types of data and the representation of both can be done by only changing the amplitude. Binary 0 is represented by amplitude of 0V and binary 1 is represented by 1V in the diagram. As the carrier is in phase. There is no change in the angle.
b. BPSK: Binary phase shift keying uses NRZ scheme to represent signal. The NRZ has two extreme values that are 1 and -1 represents 0s and 1s in binary respectively. This can be achieved in analogue signal by changing the phase with 0 degree to 180 degree. In constellation diagram we can represent the Binary one or 1 volt by 0 degree and Binary zero or -1 volt by 180 degree.
c. QPSK: Quadrature phase shifting uses two carriers. These two carriers are used to represent a combination of binary number. For example the binary 11 is created by two signal elements, one represented by in phase carrier and other one is represented by quadrature carrier. The argument is similar for other three points but by differing phases we can represent different data in binary which is represented by constellation diagram.

Constellation diagram shows the entire scheme in a nice, easy and compact representation. It particularly helps us when we have two carrier in a signal. We can then run different types of analysis based on the diagrams.

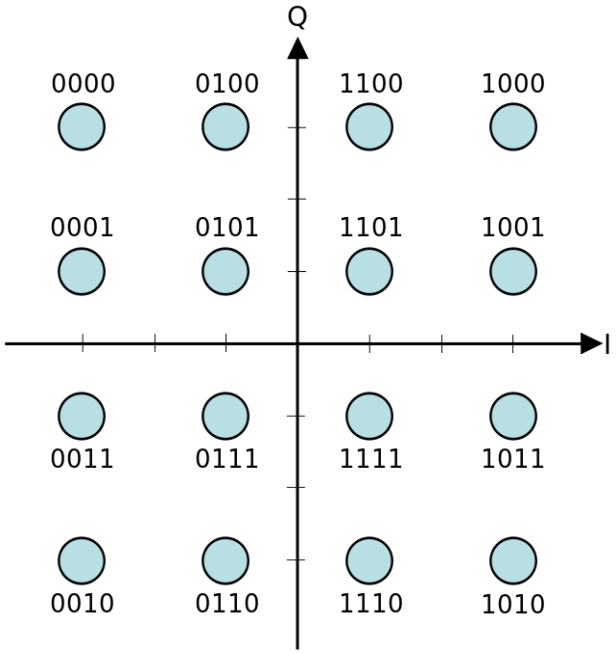
To know more:

1. https://en.wikipedia.org/wiki/Constellation_diagram
2. http://www.radio-electronics.com/info/rf-technology-design/quadrature-amplitude-modulation-qam/8qam-16qam-32qam-64qam-128qam-256qam.php
3. https://www.youtube.com/watch?v=Zh7qRwt2dOo

Quadrature amplitude modulation

Quadrature amplitude modulation:

Digital signals needs to be converted to analogue signals to be transmitted from sender to receiver. We change the characteristics of analogue signal to represent a particular digital signal with it. The three main characteristics of analogue signal we're interested in are Amplitude, Phase and Frequency. We can change any one of them to represent different types of combination of binary data. Changing the Phase of analogue signal to send data is known as Phase-Shift-Keying (PSK) and changing the Amplitude of analogue signal to send data is known as Amplitude-Shift-Keying (ASK).



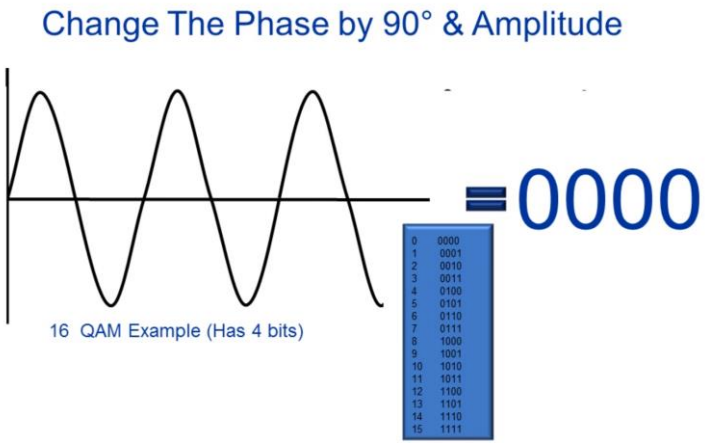
The ASK and PSK alone can represent limited number of bits because the variation of Phase or Amplitude are limited to their potential. But if we can combine both scheme together we can transmit more data more efficiently. This is where QAM or Quadrature Amplitude Modulation comes into play.

The QAM is the combination of two digital-to-analogue modulation scheme, they are Amplitude-Shift-Keying (ASK) and Phase-Shift-Keying (PSK). We can easily represent more digital data by changing both amplitude and phase. This opens up more combinations to represent, thus allowing us to use the analogue signal more effectively.

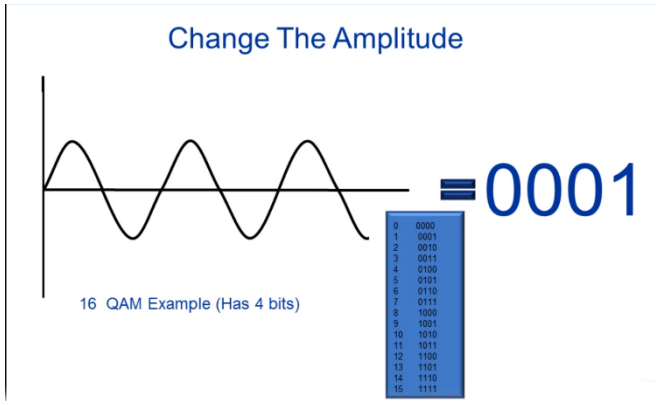
There are numerous variations of QAM out there. Above is an example of 16-QAM. By 16 it means that it can represent 16 different data by changing its phase and amplitude. There are also 4-QAM and also 256-QAM.

By changing the phase 90 degree and by changing the amplitude we can have 4 bit symbol giving us 16 qualm or 16 different permutations for example.

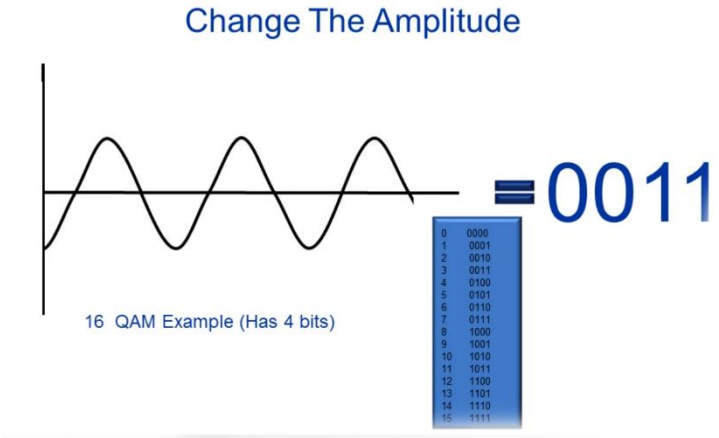
Change the phase by 90 degree and amplitude, we can represent 0000



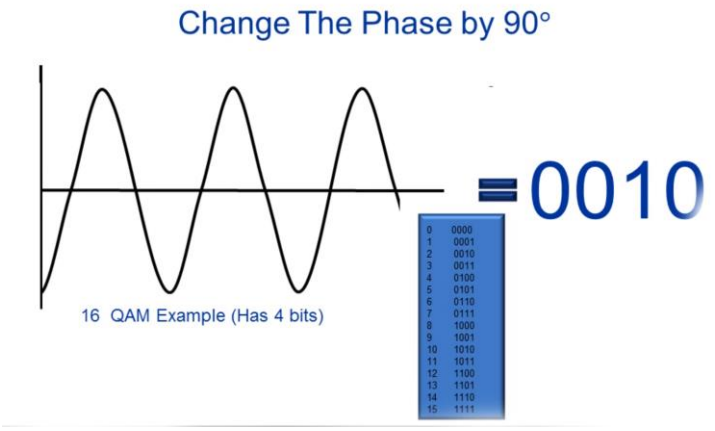
Changing the amplitude but don't change the phase, we can represent 0001



Change the amplitude, but don't change the phase we can represent 0011



Change the phase by 90 degree, don't change the amplitude we can represent 0010



And so on…..So by simply by changing the phase and the amplitude we can represent 16 different symbols representing 16 bits.

Bandwidth and Coding Schemes for QAM:

Bandwidth needed for QAM transmission is same as ASK and PSK transmission. Also QAM has same advantages as PSK over ASK. QAM can use many different types of scheme of choice it can be NRZ, NRZ-I or even AMI.

Comparison with other modes:

As there are other modes out there. To get a clear idea about QAM we need to compare it with others modes before making our decision. Some communications systems these days dynamically change the modulation scheme depending upon the requirements and conditions. So it's better to have a comparison between different schemes. The below table shows the comparison between different modulations:

SUMMARY OF TYPES OF MODULATION WITH DATA CAPACITIES				
MODULATION	BITS PER SYMBOL	ERROR MARGIN		COMPLEXITY
OOK	1	1/2	0.5	Low
BPSK	1	1	1	Medium
QPSK	2	1 / √2	0.71	Medium
16 QAM	4	√2 / 6	0.23	High
64QAM	6	√2 / 14	0.1	High

To know more:

1. https://www.youtube.com/watch?v=d7l5NbFfBiU
2. https://en.wikipedia.org/wiki/Quadrature_amplitude_modulation
3. http://www.radio-electronics.com/info/rf-technology-design/quadrature-amplitude-modulation-qam/theory-equations.php