QUADRATURE AMPLIDUDE MODULATION

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INTRODUCTION -QAM

- Quadrature Amplitude Modulation or QAM is a form of modulation which is widely used for modulating data signals onto a carrier used for radio communications. It is widely used because it offers advantages over other forms of data modulation such as PSK, although many forms of data modulation operate along side each other.
- Quadrature Amplitude Modulation, QAM is a signal in which two carriers shifted in phase by 90 degrees are modulated and the resultant output consists of both amplitude and phase variations. In view of the fact that both amplitude and phase variations are present it may also be considered as a mixture of amplitude and phase modulation.

Definition-QAM

Forms of phase shift keying

- What is phase shift keying?
- Although phase modulation is used for some analog transmissions, it is far more widely used as a digital form of modulation where it switches between different phases. This is known as phase shift keying, PSK, and there are many flavours of this.
- Quadrature amplitude modulation(QAM)
- It is even possible to combine phase shift keying and amplitude keying in a form of modulation known as quadrature amplitude modulation, QAM.
- The list below gives some of the more commonly used forms of phase shift keying, PSK, and related forms of modulation that are used:
  - PSK - Phase Shift Keying
  - BPSK - Binary Phase Shift Keying
  - QPSK - Quadrature Phase Shift Keying
  - O-QPSK - Offset Quadrature Phase Shift Keying
  - 8 PSK - 8 Point Phase Shift Keying
  - 16 PSK - 16 Point Phase Shift Keying
  - QAM - Quadrature Amplitude Modulation
  - 16 QAM - 16 Point Quadrature Amplitude Modulation
  - 64 QAM - 64 Point Quadrature Amplitude Modulation
  - MSK - Minimum Shift Keying
  - GMSK - Gaussian filtered Minimum Shift Keying

ANALOG & DIGITAL -QAM

- Quadrature amplitude modulation, QAM may exist in what may be termed either analog digital formats. The analog versions of QAM are typically used to allow multiple analog signals to be carried on a single carrier. For example it is used in PAL and NTSC television systems, where the different channels provided by QAM enable it to carry the components of chroma or colour information. In radio applications a system known as C-QUAM is used for AM stereo radio. Here the different channels enable the two channels required for stereo to be carried on the single carrier.
- Digital formats of QAM are often referred to as "Quantised QAM" and they are being increasingly used for data communications often within radio communications systems. Radio communications systems ranging from cellular technology through wireless systems including WiMAX, and Wi-Fi 802.11 use a variety of forms of QAM, and the use of QAM will only increase within the field of radio communications.

Advantages and Disadvantages of QAM

- Advantages:
- QAM appears to increase the efficiency of transmission for radio communications systems by utilising both amplitude and phase variations,
- Drawbacks
- more susceptible to noise because the states are closer together so that a lower level of noise is needed to move the signal to a different decision point. Receivers for use with phase or frequency modulation are both able to use limiting amplifiers that are able to remove any amplitude noise and thereby improve the noise reliance. This is not the case with QAM.
- The second limitation is also associated with the amplitude component of the signal. When a phase or frequency modulated signal is amplified in a radio transmitter, there is no need to use linear amplifiers, whereas when using QAM that contains an amplitude component, linearity must be maintained. Unfortunately linear amplifiers are less efficient and consume more power, and this makes them less attractive for mobile applications.

QAM applications

- QAM is in many radio communications and data delivery applications. However some specific variants of QAM are used in some specific applications and standards.
- For domestic broadcast applications for example, 64 QAM and 256 QAM are often used in digital cable television and cable modem applications. In the UK, 16 QAM and 64 QAM are currently used for digital terrestrial television using DVB - Digital Video Broadcasting. In the US, 64 QAM and 256 QAM are the mandated modulation schemes for digital cable as standardised by the SCTE in the standard ANSI/SCTE 07 2000.
- In addition to this, variants of QAM are also used for many wireless and cellular technology applications.

Constellation diagrams for QAM

- Quadrature amplitude modulation, QAM, when used for digital transmission for radio communications applications is able to carry higher data rates than ordinary amplitude modulated schemes and phase modulated schemes. As with phase shift keying, etc, the number of points at which the signal can rest, i.e. the number of points on the constellation is indicated in the modulation format description, e.g. 16QAM uses a 16 point constellation.
- When using QAM, the constellation points are normally arranged in a square grid with equal vertical and horizontal spacing and as a result the most common forms of QAM use a constellation with the number of points equal to a power of 2 i.e. 2, 4, 8, 16 . . . .
- By using higher order modulation formats, i.e. more points on the constellation, it is possible to transmit more bits per symbol. However the points are closer together and they are therefore more susceptible to noise and data errors.
- To provide an example of how QAM operates, the table below provides the bit sequences, and the associated amplitude and phase states. From this it can be seen that a continuous bit stream may be grouped into threes and represented as a sequence of eight permissible states.

Why QAM called combined ASK AND PSK

- Quadrature Amplitude Modulation uses the phase and amplitude of the carrier signal to encode data. QAM finds widespread use in current and emerging wireless standards, including Wi-Fi, Digital Video Broadcast (DVB), WiMAX, IEEE 802.11n, and HSDPA/HSUPA.
- The QAM modulation scheme encodes data by varying both amplitude and phase of the carrier signal. Thus, it is sometimes viewed as a combination of ASK and PSK modulation. A more fundamental way of viewing QAM thought is that it encodes data by varying the amplitude of two carrier signals that are in-quadrature (phase difference of 90). Hence the name "quadrature-amplitude modulation". We will now leverage our understanding of IQ data to understand this idea. As we have seen, a modulated carrier signal can be expressed in terms of it's IQ components as:

$$A_c Cos\,(2\pi f_c t + \phi) = ICos(2\pi f_c t) - QSin(2\pi f_c t)$$

where $I = A_c Cos(\phi)$ and $Q = A_c Sin(\phi)$

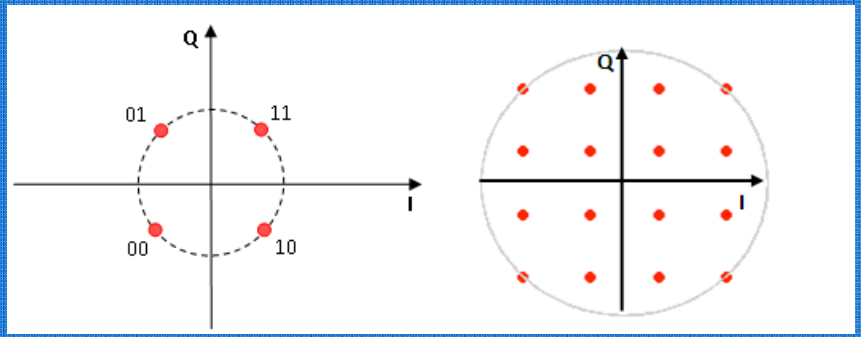
where and are the amplitudes of the in-phase and quadrature-phase components respectively. Thus, we can change the amplitude () and phase ()of the carrier signal by varying the I and Q values.

Constellation diagrams for QAM

- The constellation diagrams show the different positions for the states within different forms of QAM, quadrature amplitude modulation. As the order of the modulation increases, so does the number of points on the QAM constellation diagram.
- The diagrams below show constellation diagrams for a variety of formats of modulation:

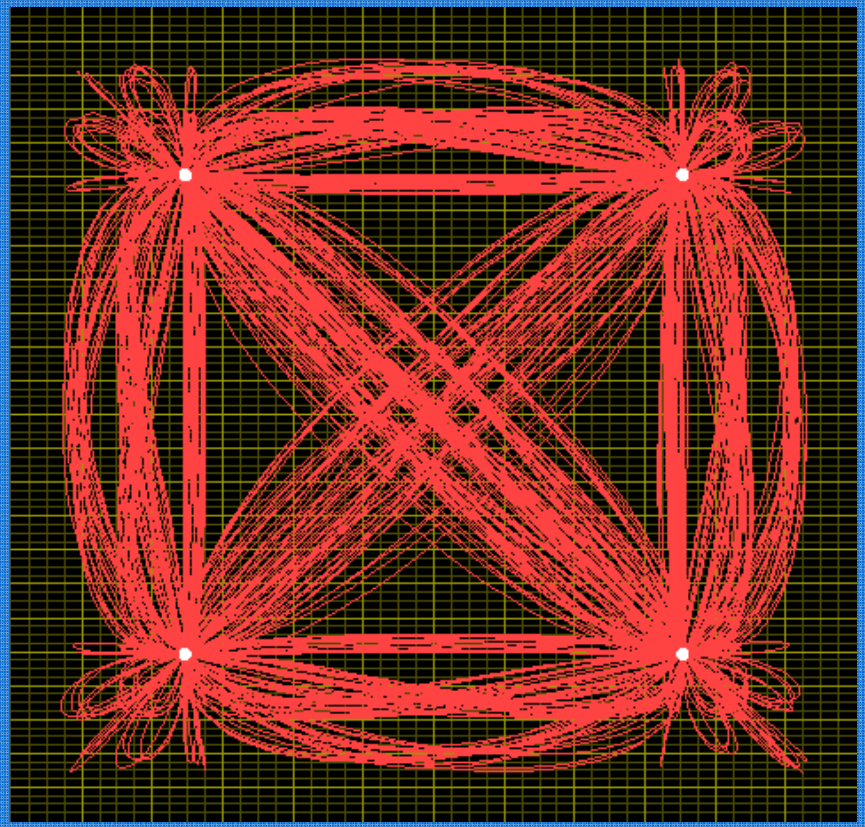
Constellation diagrams for QAM

- Let's look at the time-domain representation of QAM signals. Taking 4-QAM as an example, suppose we wish to transmit the bitstream 100111. We map these to 4 QAM symbols representing 10, 01, 11. The resulting time-domain waveform for this bitstream is shown in Figure 53. Each symbol is represented by National Instruments RF & Communications Handbook, Page 62 16/08/2007 19:00:35, Copyright © 2007 National Instruments Corporation
- one period of the sine wave and has a unique phase shift. In this respect, 4-QAM might be considered a special case of QAM where the amplitude is the same for all symbols.



Constellation diagrams for QAM

- The constellation plot in this Figure shows the phase and amplitude transitions of the carrier signal. The raw IQ data is represented by the red trance with the white dots representing those samples of IQ data that occur on symbol clock periods and that are mapped back to digital bit patterns based on the 4-QAM symbol map. We note that the transitions go through the origin. This causes abrupt amplitude variations between consecutive symbols and causes noise to be injected in the transmitted symbol due to the amplifier turning off and back on abruptly. This problem can be fixed by using offset-QAM. Refer to the offset-PSK modulation scheme discussed earlier for more details.



Conclusion

- Quadrature Amplitude Modulation is an important modulation scheme with many practical applications, including current and future wireless technologies. Some examples of communication systems that use QAM are Wi-Fi, cable modems, Digital Video Broadcast (DVB) and WiMAX.