Modulation Coding Schemes

DD Owned by David Cherney DISH •••
Last updated: Jul 03, 2023 • Initializing...

Contents

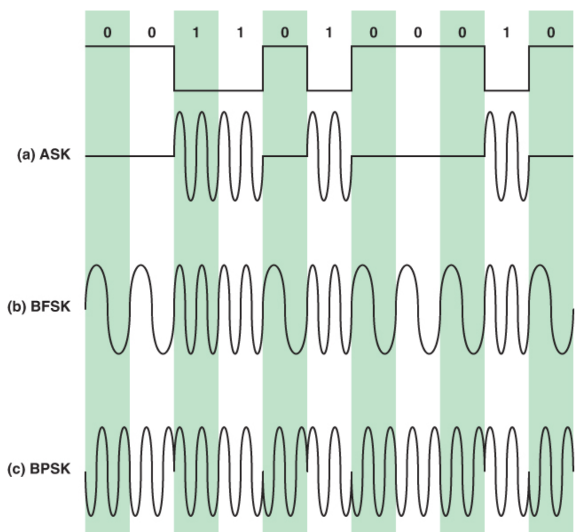
A constant frequency signal is called a carrier signal. Modulation is the process of changing between carrier signals in a way that is interpretable as transmitting information.

There are several ways of modulating, listed below.

- amplitude
- frequency
- phase

Definition: A modulation coding scheme is a scheme for encoding symbols using modulation.

The diagram below shows examples of modulation coding schemes (MCS) of each of these types for binary symbols 0 and 1.



- In amplitude shift keying an amplitude (ASK) a zero amplitude carrier is interpreted as a 0 while a non-zero (above threshold) amplitude is interpreted as 1.
- In binary frequency shift keying (BFSK) modulation is between two frequencies, the lower frequency is interpreted as a 0 while the higher frequency is interpreted as a 1.
- In binary *phase* shift keying (PBSK) a wave that begins the time interval decreasing and ends increasing is 0 while a sinusoidal wave of the same frequency that starts a time interval increasing and ends the time interval decreasing is 1 The two variations of the wave differ by a phase of π radians.

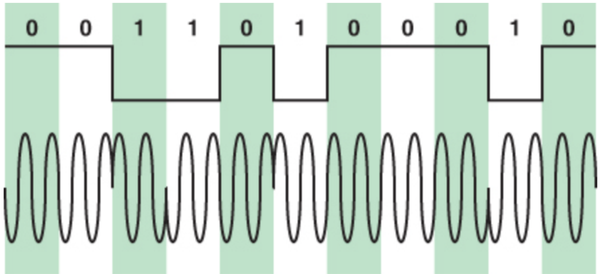
Modulation Terminology

Definition: The period of change in a MCS is the slot duration.

Definition: The frequency of change in a MCS is the rate of transmission.

The slot duration is denote T_b. The rate of transmission is thus $R=1/T_b$. In both 4G and 5G the slot duration T_b=1 ms so R=1 kHz.

There are many modulation coding schemes. As an example of a variation, in differential phase shift keying (DPSK) it is not the phase that signals 0 or 1, but rather it is the change or lack of change from one phase to another that signals 0 or 1, as shown below. DSPK has slightly better performance than BPSK.



Differential phase shift keying

Another example of a variation is in the 3GPP specifications for 5G and is called π/2 phase shift keying. It uses a phase difference of π just like BPSK, but staggers the phases differently. The MCS called π/2-PSK has slightly better performance than BPSK.

- BPSK uses the signal
  - $S \propto \sin(2\pi f t)$ for 0
  - $S \propto \sin(2\pi f t + \pi)$ for 1
- π/2-BPSK uses the signal
  - $S \propto \sin(2\pi f t - \pi/2)$ for 0
  - $S \propto \sin(2\pi f t + \pi/2)$ for 1

Multilevel Modulation

There are modulation techniques with more "levels" than the 2 in binary or 4 in quadrature. The number of levels L is related to the number of symbols M as $L=\log_2(M)$.

- Phase modulation coding schemes with multiple levels are called multilevel phase shift keyings (MPSKs).
- Amplitude modulation coding schemes with multiple levels are called multilevel amplitude shift keyings (MASKs).

Quadrature Modulation

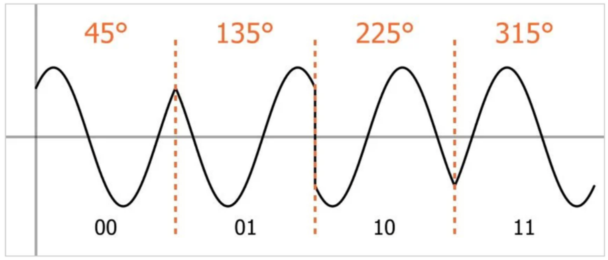
In all of the examples above only two symbols were transmitted, 0 and 1. There are also modulation techniques that allows more than 2 symbols.

QPSK

One example is quadrature phase shift keying (QPSK), in which there are 4 different phases that might be transmitted in a time window. The amplitude and the frequency f stay the same for all four options, as delineated below.

- $A\sin(2\pi f t + \pi/4)$ transmits 00

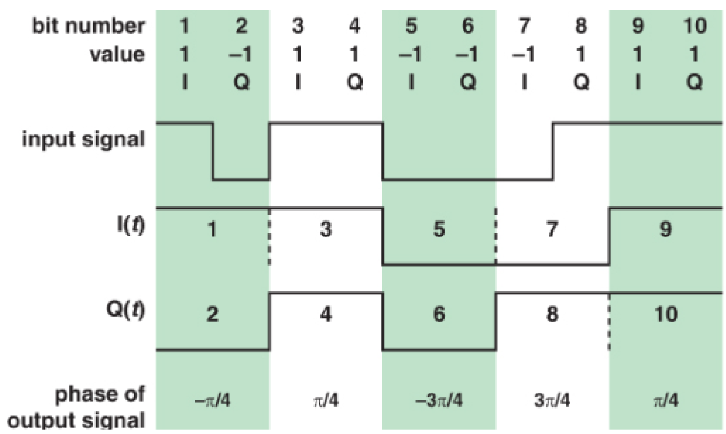
- Asin(2π f t + 3π/4) transmits 01
- Asin(2π f t + 5π/4) transmits 10
- Asin(2π f t + 7π/4) transmits 11



Some manipulation with trigonometric identities allows combining the 4 pieces of the piecewise defined function into the single function

$[I(t) \cos(2\pi f t) - Q(t) \sin(2\pi f t)] / \sqrt{2}$

where I and Q are either -1 or 1 depending on time, and that time variation transmits the information; I=-1 and Q=1 for transmitting the symbol 01, et cetera.



Note that QPSK occasionally requires that the phase shift by 3π/2. A physical device must try to create this phase shift instantly, but of course only approximates the phase shift with a continuous process. There is a variation called offset QPSK that requires at most a phase shift of π/2, making approximations to instant phase shifts slightly better. Let me know if you want more detail on this modulation technique.

QAM

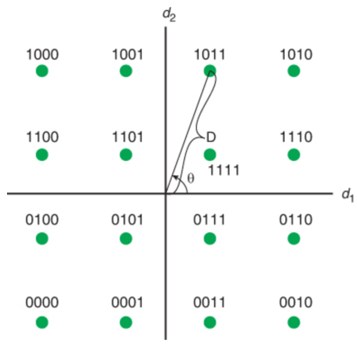
Quadrature amplitude modulation (QAM) is similar to QPSK:

- QPSK has signal $S \propto I(t) \cos(2\pi f t) - Q(t) \sin(2\pi f t)$
- QAM has signal $S \propto d_1(t) \cos(2\pi f t) + d_2(t) \sin(2\pi f t)$

where the amplitudes of the terms d_1 and d_2 vary in time between 0 and 1. The reader fluent in trigonometry will see that this amplitude modulation is interpretable as phase modulation. Indeed, the only difference between QPSK and QAM is interpretation as phase modulation or amplitude modulation.

16-QAM

Consider the signal $S \propto d_1(t) \cos(2\pi f t) + d_2(t) \sin(2\pi f t)$. Allowing the amplitudes of the sine and cosine terms to take on 4 values each allows for 16 symbols, each symbol being 4 binary characters.

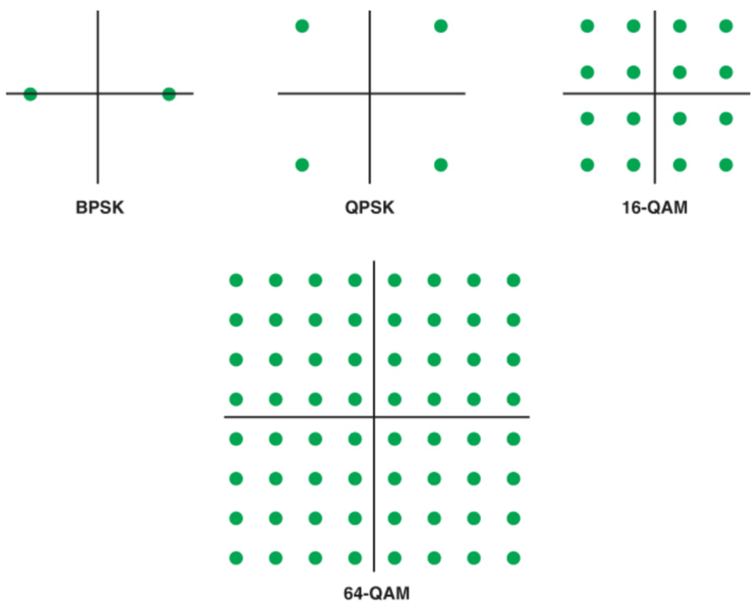


The 16-QAM constellation shows how 16 four bit characters are encoded.

Of course, the name 16-QAM is a misnomer; BFSK has 2 characters, and QAM has 4 characters, and so the name of the amplitude modulation coding scheme with 16 characters with should be hexadecimal amplitude modulation. One can only guess why the name 16-QAM stuck. It might have to do with the infinite tower of amplitude modulation coding schemes possible.

AMK Constellations

The constellation diagram for 16-QAM is one from an infinite series of possible amplitude modulation coding schemes.



You can imagine 128-QAM, 512-QAM, 1024-QAM, 2048-QAM and 4096-QAM. The analog systems for generating the physical signals are constantly in development.

Base Band Units

Digital signals are converted into analog radio signals by modulation. Let's discuss exactly where in the system this is done.

Definition: The base band of a digital signal is the frequency range originally used to encode a digital signal into analog signal.

However, this base band signal is converted into a different collection of frequencies right before transmission. The collection of equipment that does this secondary conversion is called a base band unit (BBU). The BBU has components in the CU, the DU and in the radio head.