Modulation.

A key aspect of wireless communication is modulation. This is where a carrier signal which is going to be sent from the transmitter across the network is modified in some way to be able to send information in a more efficient manner. We will explain the basic concept of modulation, as well as looking at some methods used in digital communication to transmit data. The most well-known forms of modulation are frequency modulation (FM) and amplitude modulation (AM) which are used in radio broadcast. These work by taking a baseband signal, in the case of radio broadcast this will be audio signals, and varying the carrier signal’s frequency or amplitude proportionately to the baseband signal.

Let’s take a baseband audio signal , which is to be transmitted using a sinusoidal carrier signal , which has a frequency and an amplitude . If we assume to be a continuous sinusoid which has a frequency and an amplitude , which can be assumed to be limited to the range ±1. The result of combining these two waves in frequency modulation is given by   
where . represents the frequency deviation from the carrier signal frequency and is the sensitivity of the frequency modulator. This can be written in the general form

In this equation is the instantaneous frequency.

What this results in is a signal which varies its frequency around a carrier frequency , which results in a waveform like below. Notice as the values of the baseband signal rise, the frequency of the modulated signal increases. The result of this in the frequency domain is a peak at the carrier frequency with sidebands roughly contained to the deviation frequency.

The modulation index oigeinoagoiagoin

Frequency spectrum for modulated signals given by Bessel functionsn vaouvaovn

Demodulation ououbu

Digital data can also be sent in this manner using a process called amplitude-shift keying (ASK) or frequency-shift keying (FSK). As the information we are sending is usually a binary stream of data, we can assign values of amplitude or frequency to the symbols 1 and 0. The simplest form of ASK is on-off keying (OOK), where a 1 is represented by the presence of a signal for a determined length of time, and a 0 by no signal over that same time. Binary FSK (BFSK) works by transmitting binary information using a pair of discrete frequencies to transmit data where a 1 or zero is represented by frequencies of the carrier frequency plus and minus some frequency deviation. This can be achieved by using a single oscillator which means the phase of the generated sinusoids are continuous.

Gaussian FSK (GFSK) uses a Gaussian filter to smoother the transitions of the base data, which reduces sideband power, and therefore interference with neighbouring channels. This method’s smoother transitions increase the probability of intersymbol interference. GFSK is used in many areas of wireless communication, including Bluetooth.

Minimum-shift keying (MSK) is a form the FSK that uses a frequency deviation of 0.25 of the carrier frequency. This results in the high and low waveforms differing by half the carrier period. This has a particularly efficient spectral response compared to other forms of FSK. Gaussian MSK (GMSK) is similar to standard MSK, but again applies a Gaussian filter to the data stream before applying the frequency modulation. The deduces both sideband power, and results in narrower phase shift angles, but it requires higher power to reliably transmit data, compared to other methods. GMSK is used in GSM phone standard as well as the maritime navigation system AIS.

Audio FSK (AFSK) is a modulation technique which represents binary data by changes in pitch of audio data on the baseband signal and then modulated using conventional methods like FM for transmission.

Another method of modulation is to use phase-shift keying (PSK), which represents symbols using differences in phase. As with most modulation techniques, PSK required a demodulator designed specifically for the symbol set being used. Binary PSK (BPSK) uses 2 phases, separated by 180° representing binary 1 and 0.

Quadrature PSK (QPSK) represents 4 binary symbols using waveforms separated by 90° in phase. This can achieve the same data rate as BPSK but halves the bandwidth and maintains the same bit error rate (BER). However, this method uses twice the power and the implementation requires more complex transmitters and receivers.

Offset QPSK is a variant on QPSK, but processes the odd and even bits separately, so that the phase never changes by more than 90° at a time, which reduces amplitude fluctuations.

Combinations of all the above

QAM – Uses a combintation phase and amplitude

Chirp spread spectrum

Multiplexing

OFDM

Orthagonality