DIGITAL COMMUNICATION

The techniques used to modulate digital information so that it can be transmitted via microwave, satellite or down a cable pair are different to that of analogue transmission. The data transmitted via satellite or microwave is transmitted as an analogue signal. The techniques used to transmit analogue signals are used to transmit digital signals. The problem is to convert the digital signals to a form that can be treated as an analogue signal that is then in the appropriate form to either be transmitted down a twisted cable pair or applied to the RF stage where is modulated to a frequency that can be transmitted via microwave or satellite.

The equipment that is used to convert digital signals into analogue format is a modem. The word modem is made up of the words “modulator” and “demodulator”.

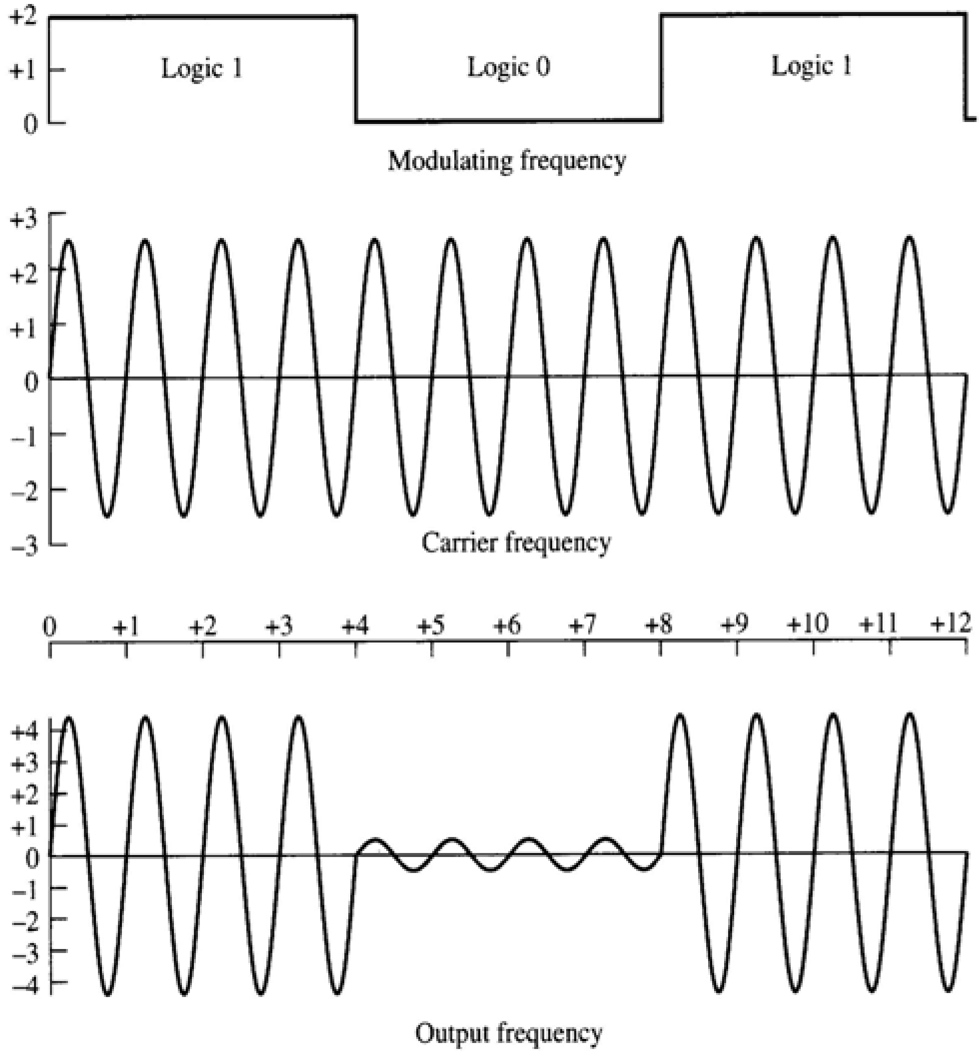
A modem accepts a serial data stream and converts it into an analogue format that matches the transmission medium.

There are many different modulation techniques that can be utilised in a modem. These techniques are:

- Amplitude shift key modulation (ASK)
- Frequency shift key modulation (FSK)
- Binary-phase shift key modulation (BPSK)
- Quadrature-phase shift key modulation (QPSK)
- Quadrature amplitude modulation (QAM)

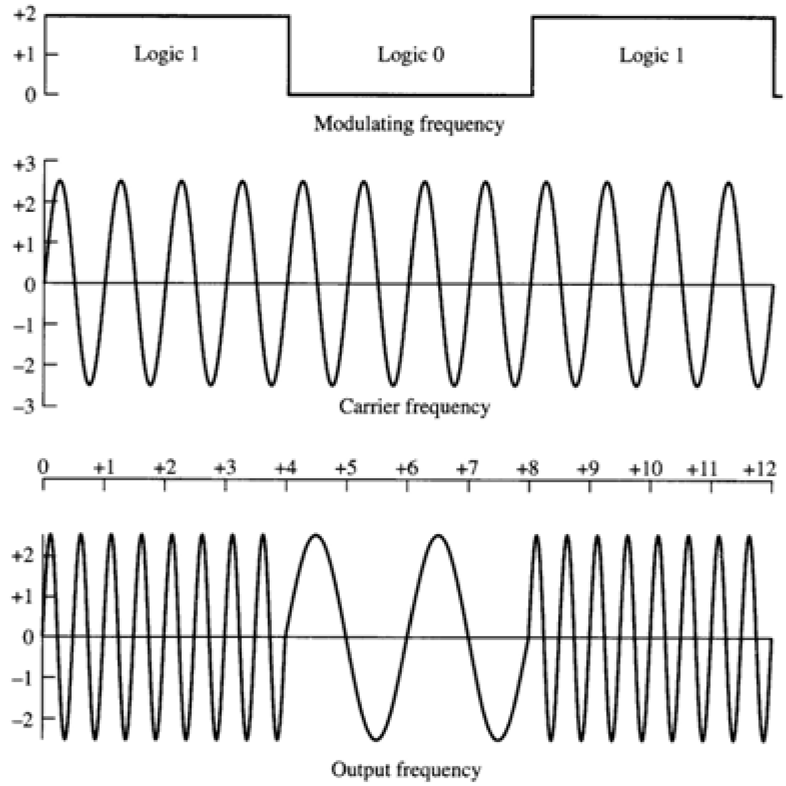
Amplitude Shift Key Modulation

In this method the amplitude of the carrier assumes one of the two amplitudes dependent on the logic states of the input bit stream. A typical output waveform of an ASK modulator is shown in the figure below. The frequency components are the USB and LSB with a residual carrier frequency. The low amplitude carrier is allowed to be transmitted to ensure that at the receiver the logic 1 and logic 0 conditions can be recognised uniquely.



Frequency Shift Key Modulation

In this method the frequency of the carrier is changed to two different frequencies depending on the logic state of the input bit stream. The typical output waveform of an FSK is shown below. Notice that a logic high causes the centre frequency to increase to a maximum and a logic low causes the centre frequency to decrease to a minimum.



Phase Shift Key Modulation

With this method the phase of the carrier changes between different phases determined by the logic states of the input bit stream.

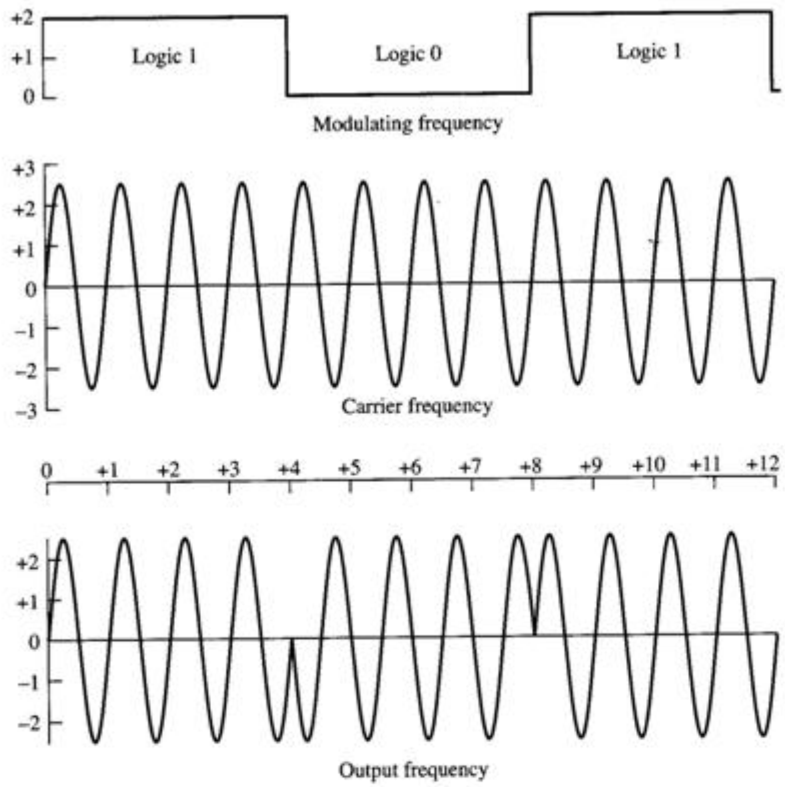
There are several different types of phase shift key (PSK) modulators.

- Two-phase (2 PSK)
- Four-phase (4 PSK)
- Eight-phase (8 PSK)
- Sixteen-phase (16 PSK)
- Sixteen-quadrature amplitude (16 QAM)

The 16 QAM is a composite modulator consisting of amplitude modulation and phase modulation. The 2 PSK, 4 PSK, 8 PSK and 16 PSK modulators are generally referred to as binary phase shift key (BPSK) modulators and the QAM modulators are referred to as quadrature phase shift key (QPSK) modulators.

Two-Phase Shift Key Modulation

In this modulator the carrier assumes one of two phases. A logic 1 produces no phase change and a logic 0 produces a 180° phase change. The output waveform for this modulator is shown below.



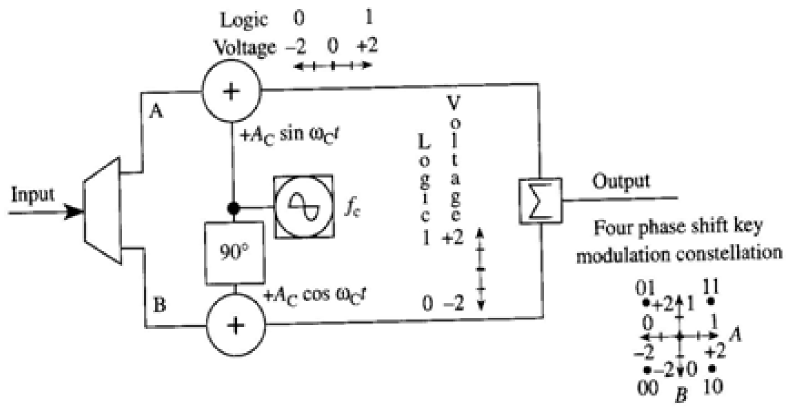
Four-Phase Shift Key Modulation

With 4 PSK, 2 bits are processed to produce a single phase change. In this case each symbol consists of 2 bits, which are referred to as a dibit. The actual phases that are produced by a 4 PSK modulator are shown in the table below.

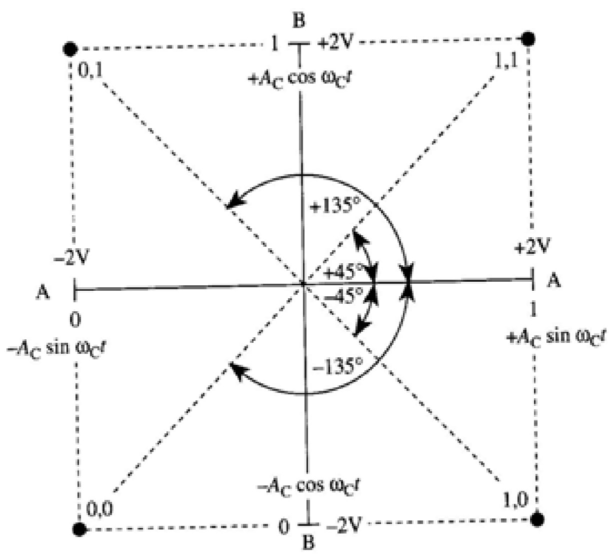
Dibit	Phase Change
00	+225°/-135°
01	+135°/-225°
10	+315°/-45°
11	+45°/-315°

Figure 8: PSK Table

Because the output bit rate is less than the input bit rate, this results in a smaller bandwidth. A typical 4 PSK circuit and the constellation is shown below.



(a)



(b)

Eight-Phase Shift Key Modulation

With this modulator 3 bits are processed to produce a single phase change. This means that each symbol consists of 3 bits.

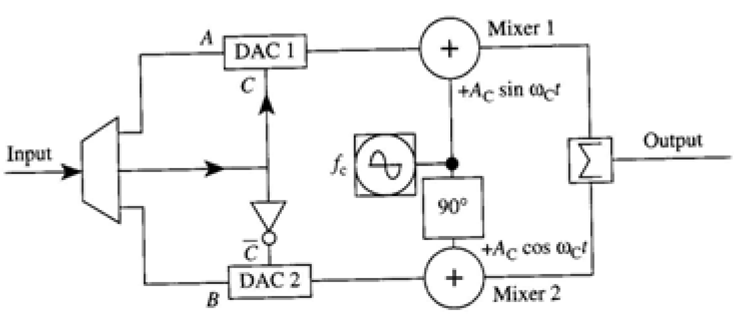


Figure 10: 8 PSK Modulator

Figure 10 above shows a typical circuit for the 8 PSK modulator. With this modulator bit A controls the output polarity of the first digital-to-analogue converter (DAC1). Bit B is used to control the output polarity of the second DAC 2 and bit C is used to control the output amplitude of both DACs.

A	Polarity	B	Polarity	C	Amplitude	$\bar{C}$	Amplitude
0	−	0	−	0	0.5	1	1.21
1	+	1	+	1	1.21	0	0.5

Figure 11: Digital to Analogue Conversion Condition for 8 PSK modulator

The conditions shown in the table above (Figure 11) produce the positions shown in table below (Figure 12) for all the different permutations.

$\bar{C}$	C	B	A	C	A	Polarity	Amplitude	$\bar{C}$	B	Polarity	Amplitude	Quad
1	0	0	0	0	0	−	0.5	1	0	−	1.21	3
1	0	0	1	0	1	+	0.5	1	0	−	1.21	4
1	0	1	0	0	0	−	0.5	1	1	+	1.21	2
1	0	1	1	0	1	+	0.5	1	1	+	1.21	1
0	1	0	0	1	0	−	1.21	0	0	−	0.5	3
0	1	0	1	1	1	+	1.21	0	0	−	0.5	4
0	1	1	0	1	0	−	1.21	0	1	+	0.5	2
0	1	1	1	1	1	+	1.21	0	1	+	0.5	1

Figure 12: Input permutations and Positions

The constellation diagram can be drawn according to the above table and is shown below.

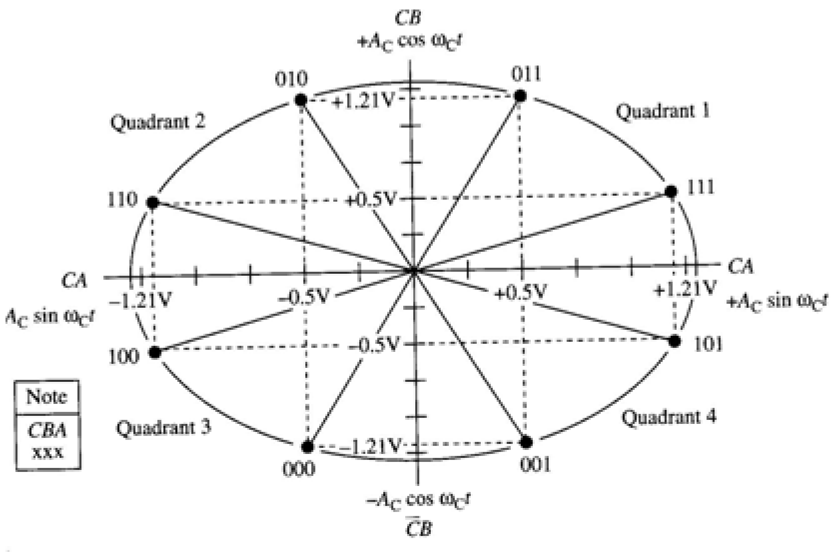


Figure 13: 16 PSK Constellation

<u>Sixteen-Phase Shift Key Modulation</u>

With this modulator 4 bits are processed to produce a single phase change. This means that each symbol consists of 4 bits. The constellation for this modulator scheme is shown below.

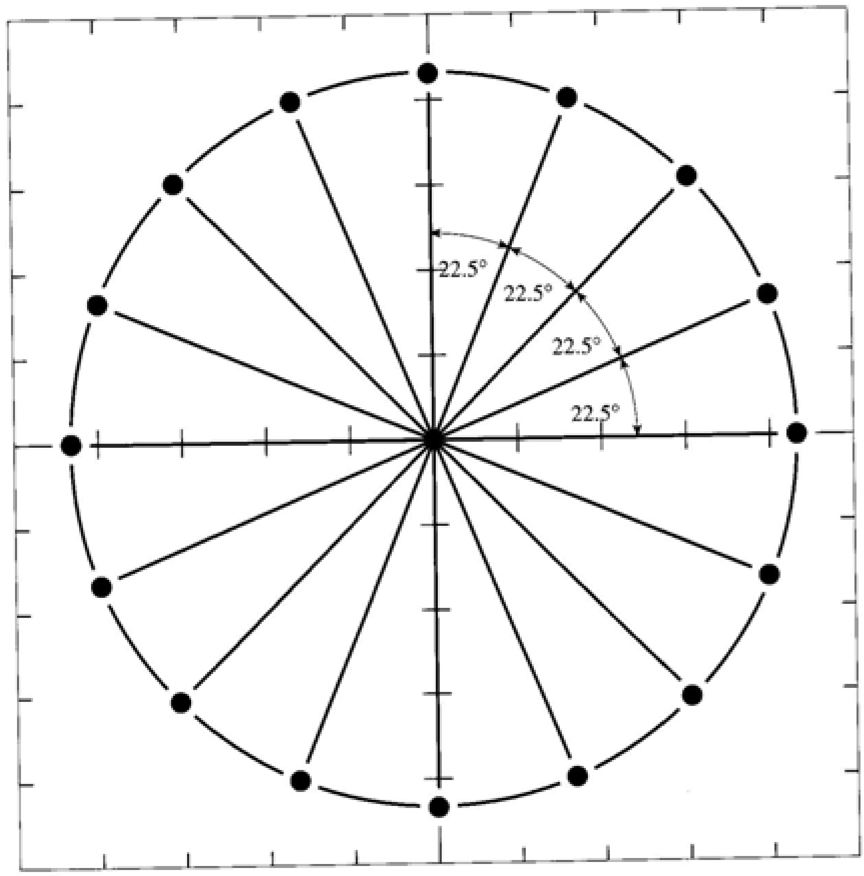


Figure 14: 16 PSK Modulation Constellation

<u>Sixteen-Quadrature Amplitude Modulation</u>

With this modulator, 4 bits are processed to produce a single vector. The resultant constellation consists of three different amplitudes distributed in 12 different phases as shown below.

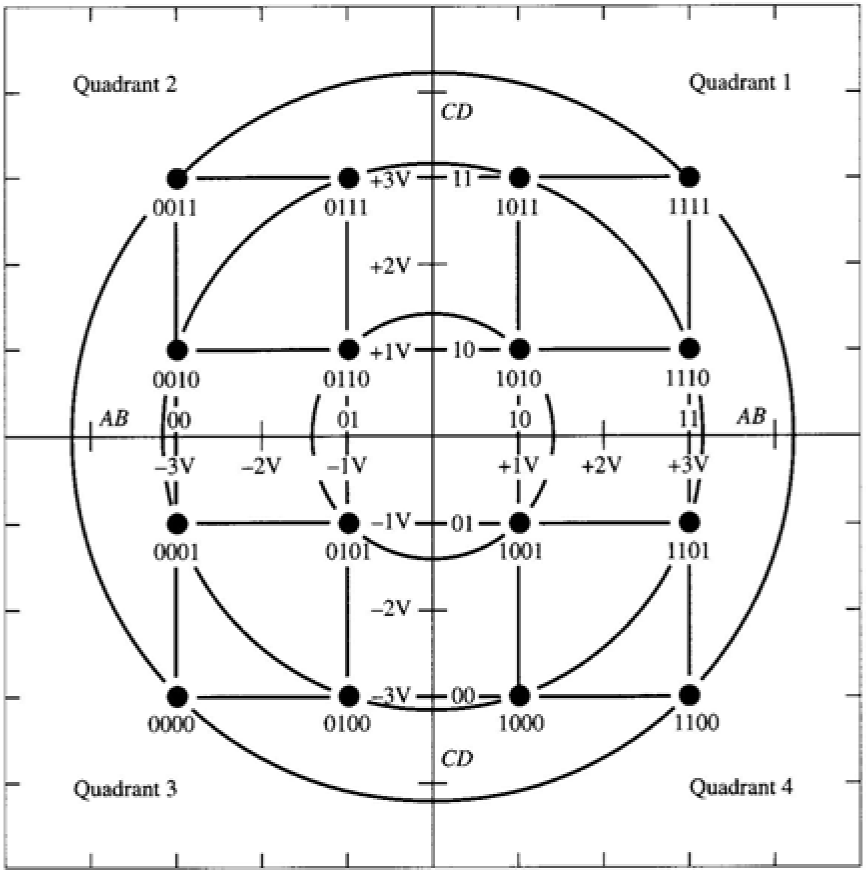


Figure 15: 16 QAM Constellation

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