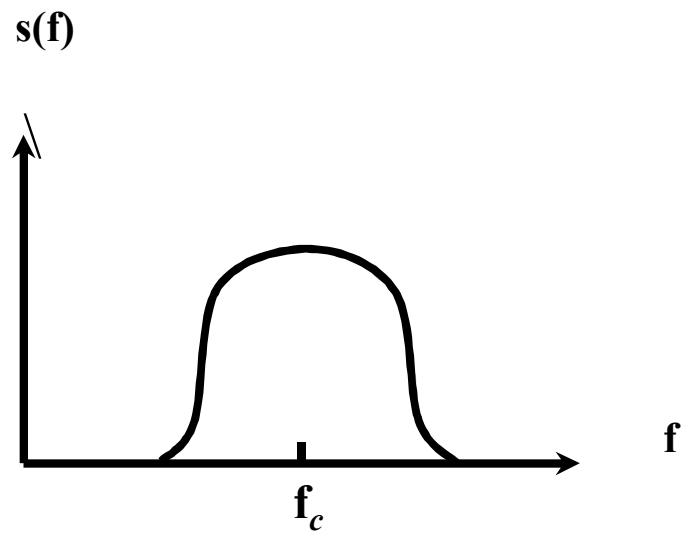
Digital Data / Analogue Signals

- The *carrier signal* ($\mathbf{f_c}$) has three characteristics that can be modulated:
  - Amplitude
  - Frequency
  - Phase



- The spectrum of the resultant *bandlimited* modulated signal is typically centred on $\mathbf{f_c}$

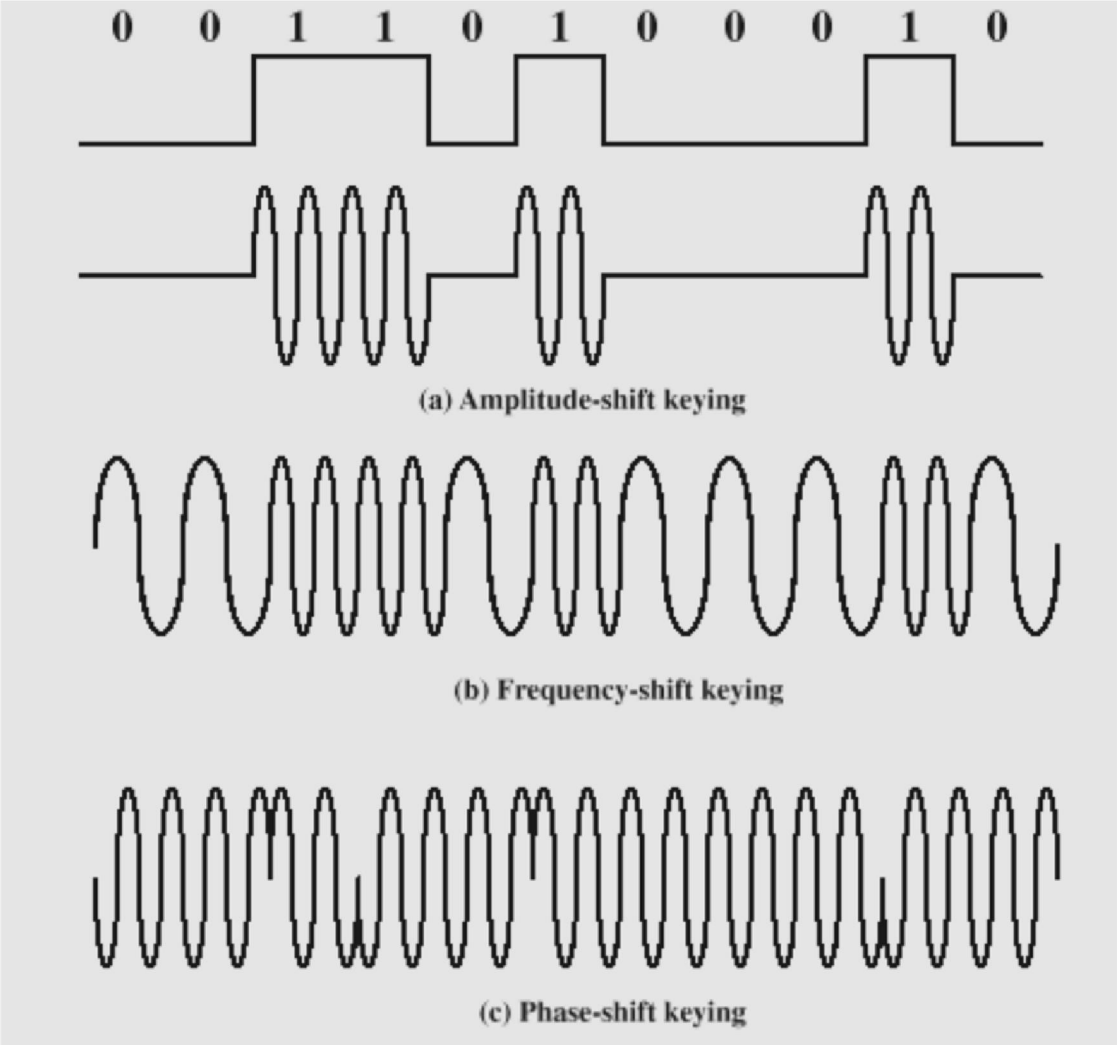
Digital Data / Analogue Signals

- Most common application:
  - The transmission of digital data across the *Plain old Telephone System (PoTS)*
  - PoTS was designed for transmission of analogue voice
- Requires a *Modulator/Demodulator* (modem):
  - A device used to encode *digital data* onto an *analogue signal* and vice versa
- The resultant analogue signal is in the *voice*-frequency range

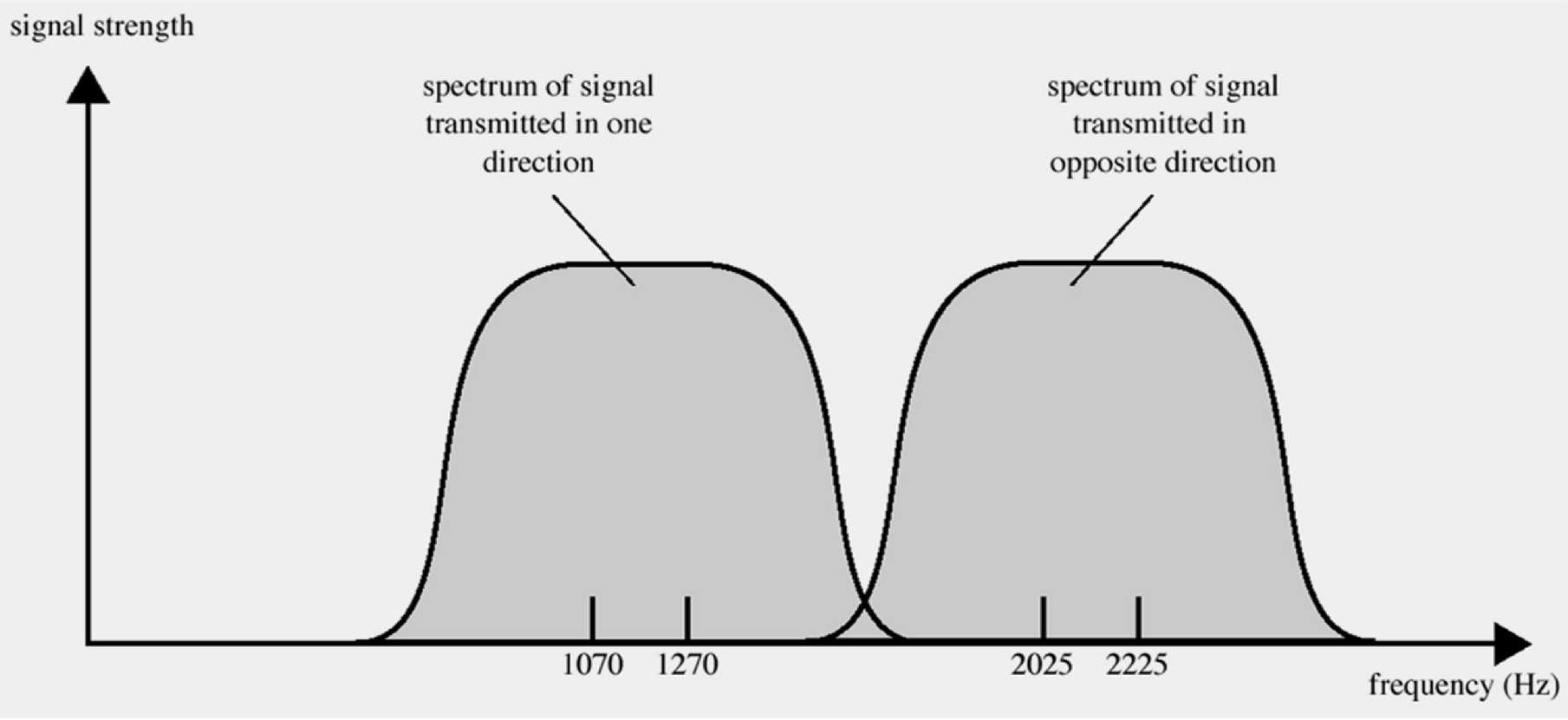
Digital Data / Analogue Signals

- Three modulation techniques exist
  - Amplitude shift keying
    - This involves representing *data* using two or more different *amplitudes* e.g. A_1, A_2 etc.
  - Frequency shift keying
    - This involves representing *data* using two or more different *frequencies* e.g. f_1, f_2 etc.
  - Phase shift keying
    - This involves representing *data* using two or more different phase shifts e.g. π, $\pi/4$ etc.
  - See examples in class of all three techniques

Example Analogue Signals



Full Duplex FSK signal

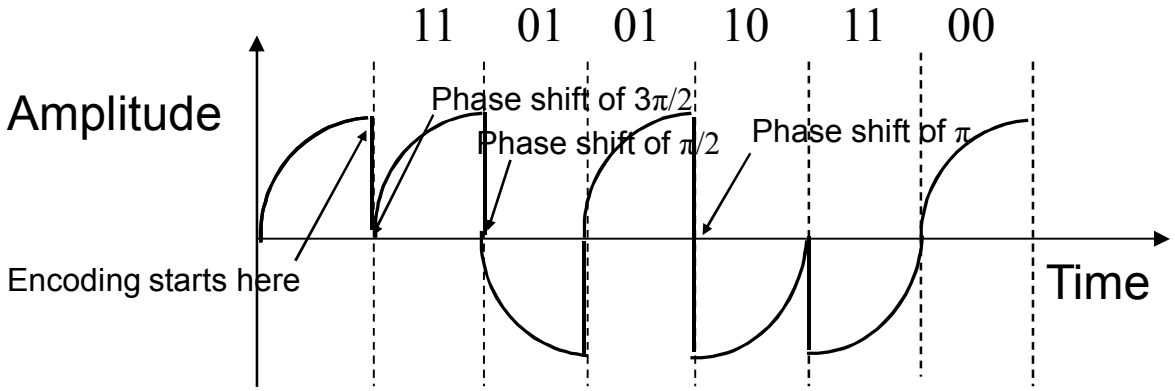


Example QPSK Waveform

- Consider the following bit stream: **110101101100**
- Quadrature PSK uses a phase shift of magnitude π/2 to encode the data. This allows for four possible states i.e. 2-bits per signal element.

Example QPSK Waveform

- Sample rules to encode each *two-bit* quantity might be as follows:
  - No phase shift implies 00
  - Phase shift of π/2 implies 01
  - Phase shift of 2π/2 or π implies 10
  - Phase shift of 3π/2 implies 11



Digital Data / Analogue Signals

- 9600 bps modem uses combination of *phase* and *amplitude* modulation
- 12 phase angles of 30 degrees each (π/6)
- Four of the phases have two amplitude levels giving 16 signal levels
- How many states can be represented?

Modulation Rate V Bit Rate Revisited

- Previously we saw that the relationship between data rate and mod. rate is given by:

$$\mathbf{D = R/b}$$

D = Mod. Rate, R = Data Rate and b = bits per sig. element

- It can also be expressed as:

$$\mathbf{D = R/\log_2 L}$$

D and R are as above and L = # levels per signal element

- The BW of a Transmission System can be *optimised* by using complex encoding techniques