

CS25010

Basic Terminology and  
Concepts of Computer  
Communications - Part Two

David Price and Friends  
Computer Science

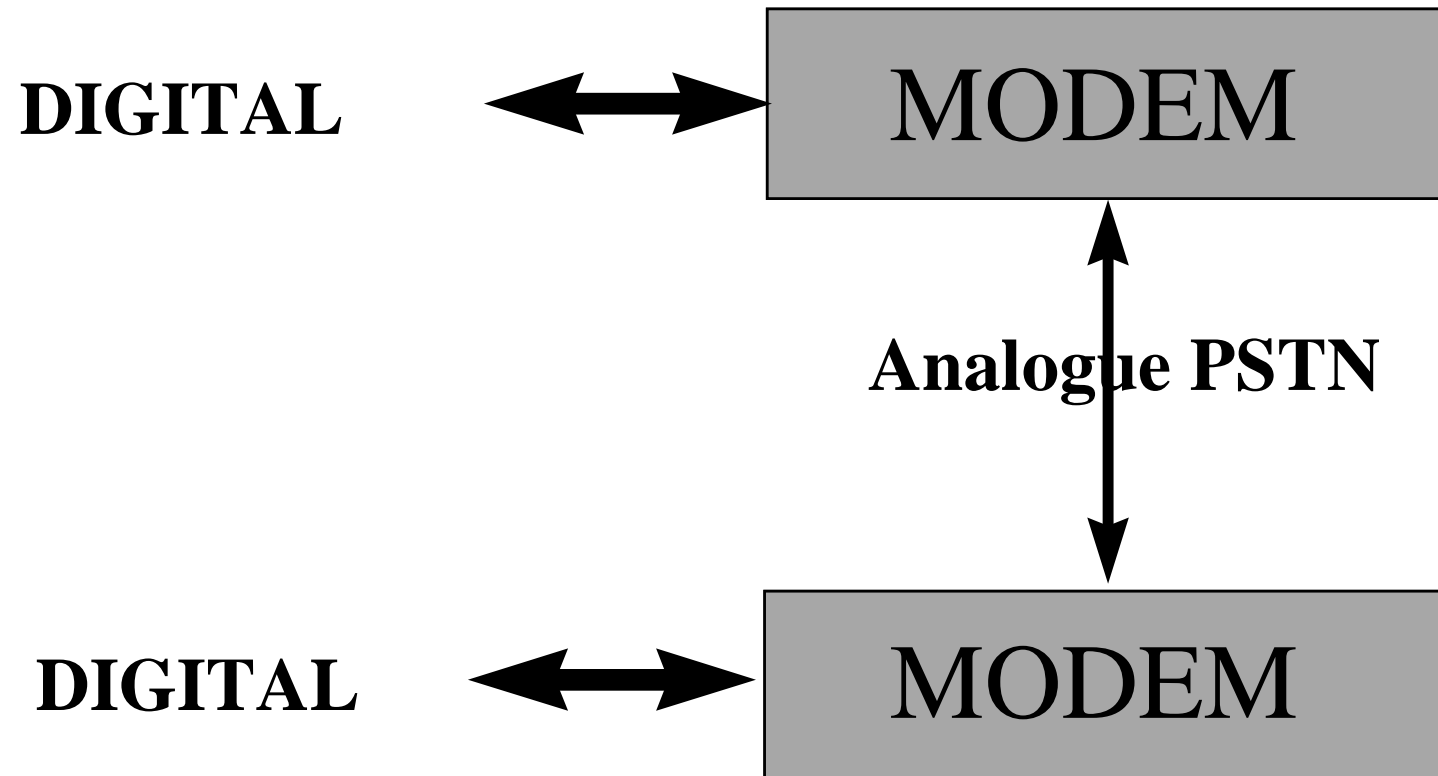
# Publicly Available Networks

- **PSTN - Public Switched Telephone Network**
  - Originally full analogue dial-up network for voice
- **PSS (GNS) - Public Data Networks**
  - packet switched data network (circuit networks also exist)
- **Leased Lines**
  - hired 24 hours/day - analogue and digital
- **ISDN - Integrated Digital Services Network**
  - fully digitally dial-up network

# PSTN - Public Switched Telephone Network

- Designed to carry the human voice
- frequencies for 20Hz to 20kHz present in voice but.....
- intelligibility o.k. if low frequencies and frequencies much above 3kHz lost
- PSTN typically has limits at about 300/400 Hz and above 3400/3500 Hz
- MODEMs must operate within these limits

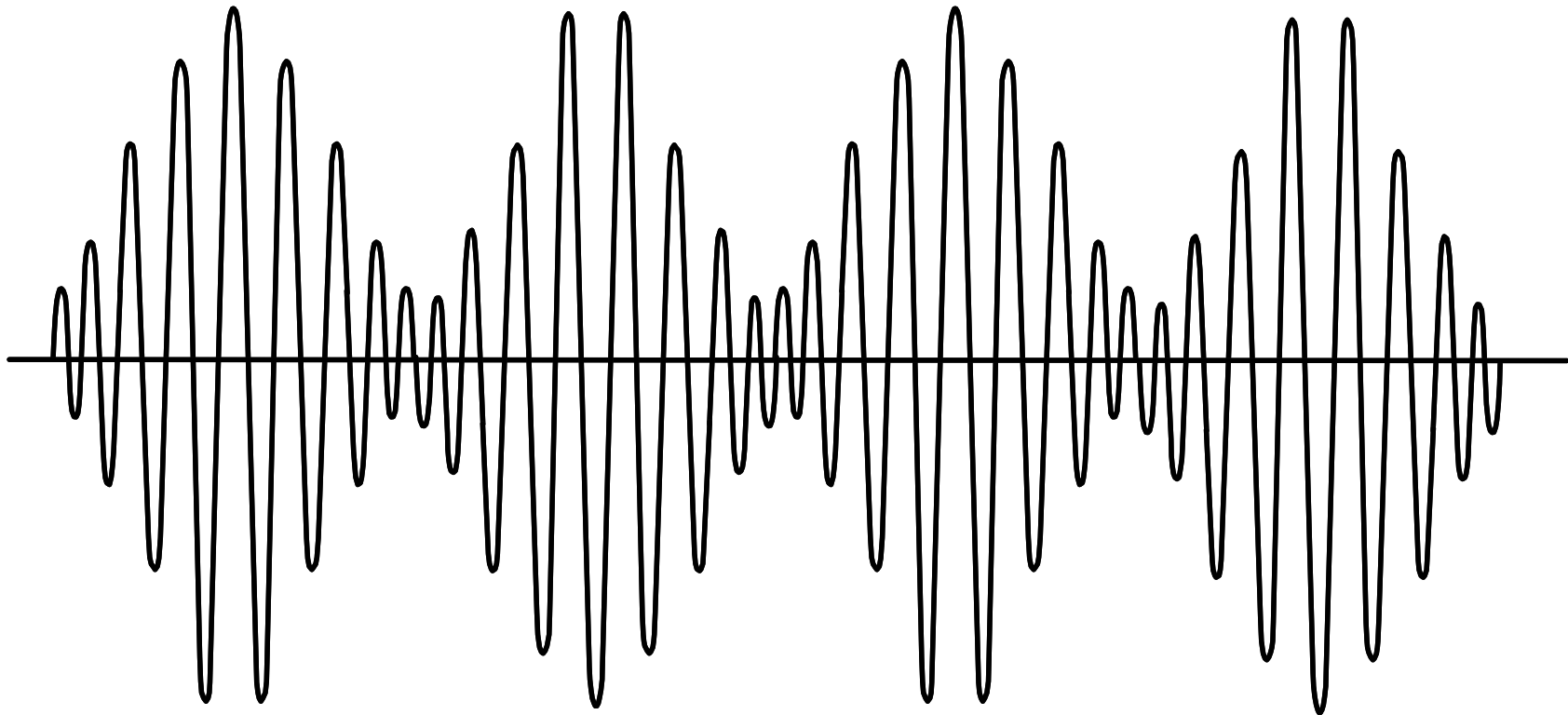
# MODEMs



# Modulation Methods

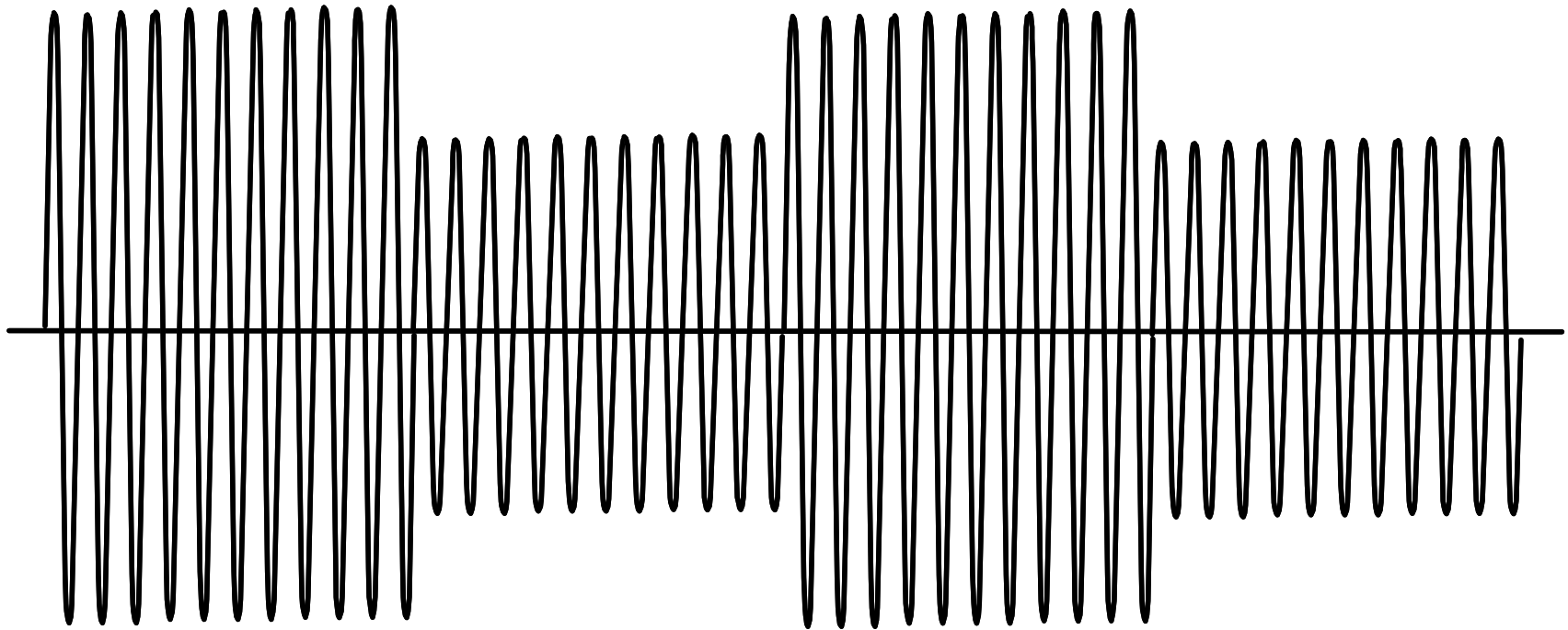
- Amplitude Modulation
- Frequency Modulation
- Phase Modulation

# Amplitude Modulation



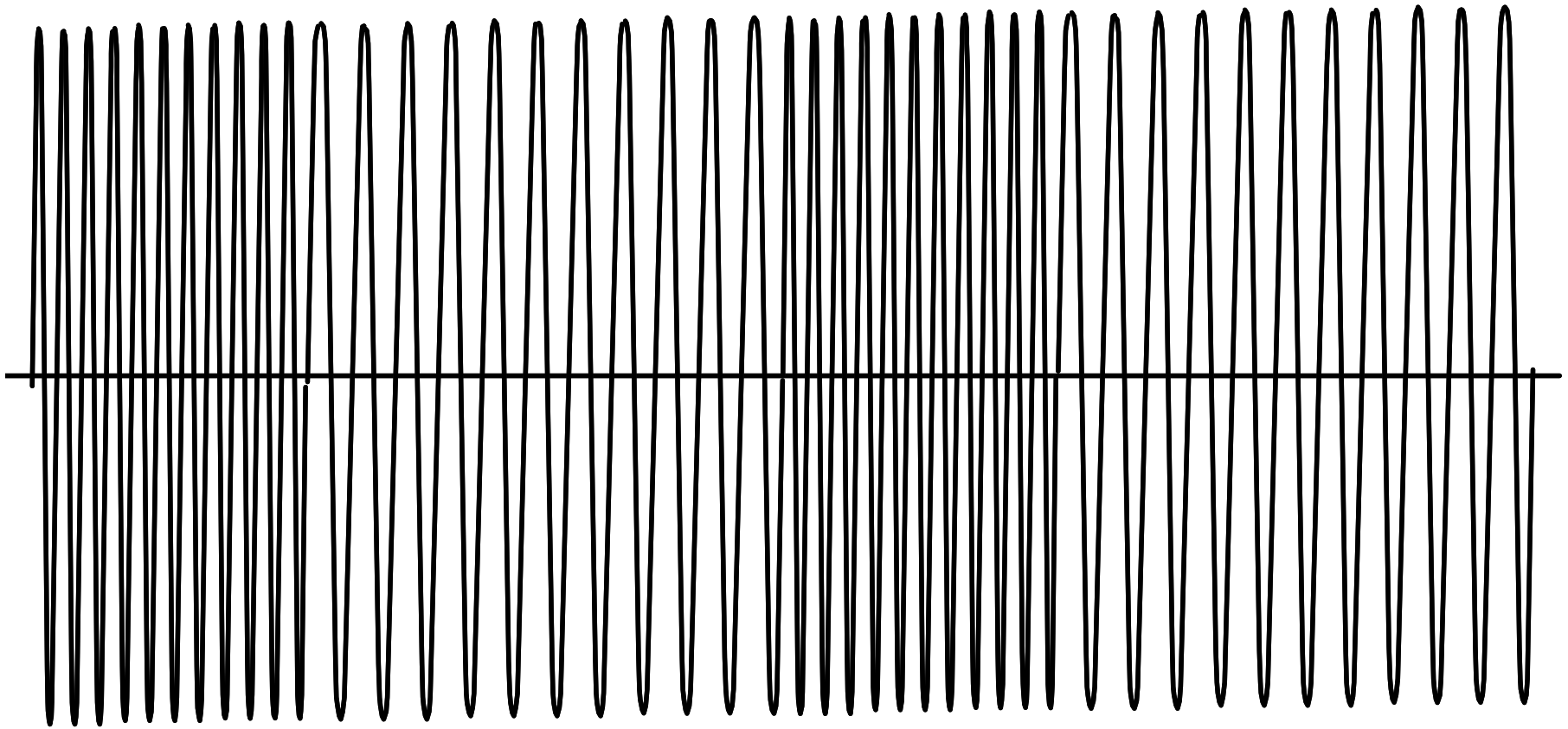
**Analogue Carrier modulated by Analogue Data**

# Amplitude Shift Keying



**Analogue Carrier modulated by Digital Data**  
**Carrier frequency fixed, two amplitudes**

# Frequency Shift Keying



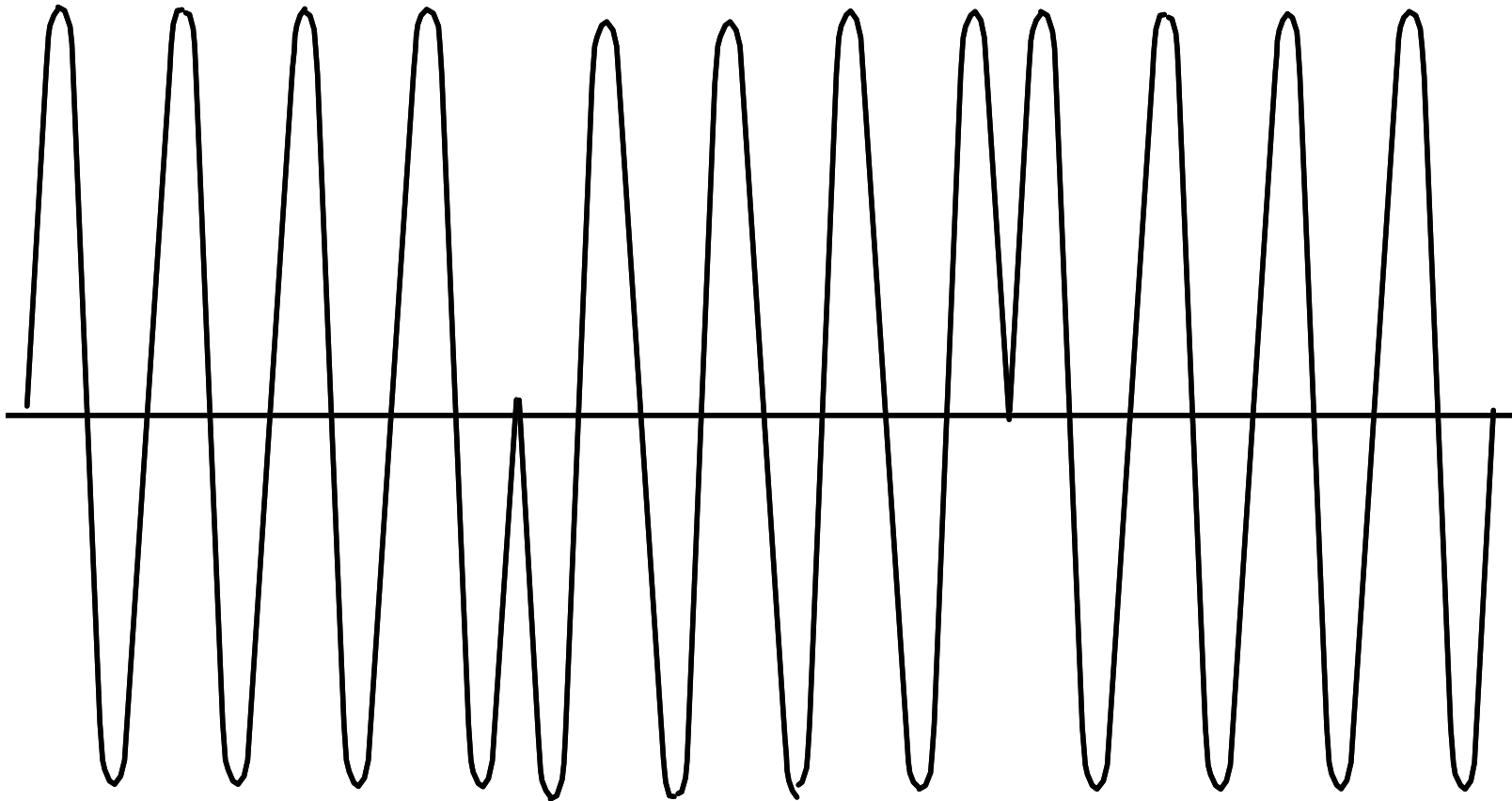
**modulated by Digital Data two frequencies used**



# CCITT V21 Modem Standard

|           |       | Frequency | Centre |
|-----------|-------|-----------|--------|
| Originate | MARK  | 980       | 1080   |
| End       | SPACE | 1180      |        |
|           |       |           |        |
| Answer    | MARK  | 1650      | 1750   |
| End       | SPACE | 1850      |        |
|           |       |           |        |

# Phase Shift Keying



**Carrier frequency fixed, but 180 degree  
phase changes occur**

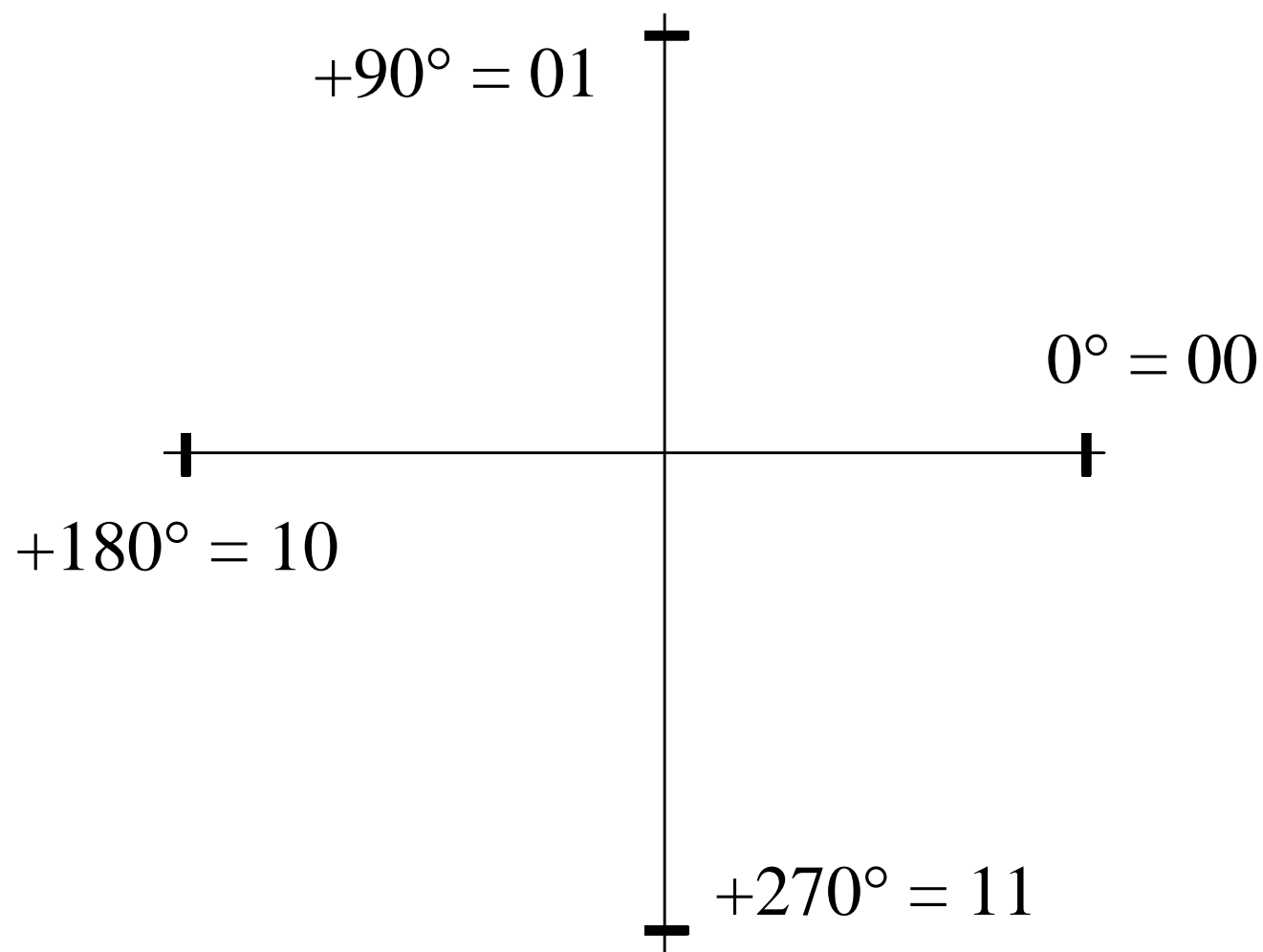
# Multiple Level Signalling

- One signal event does not have to represent a single binary digit
- Therefore one signal event might provide  $> 1$  bit of data
- (**bit** means binary digit)

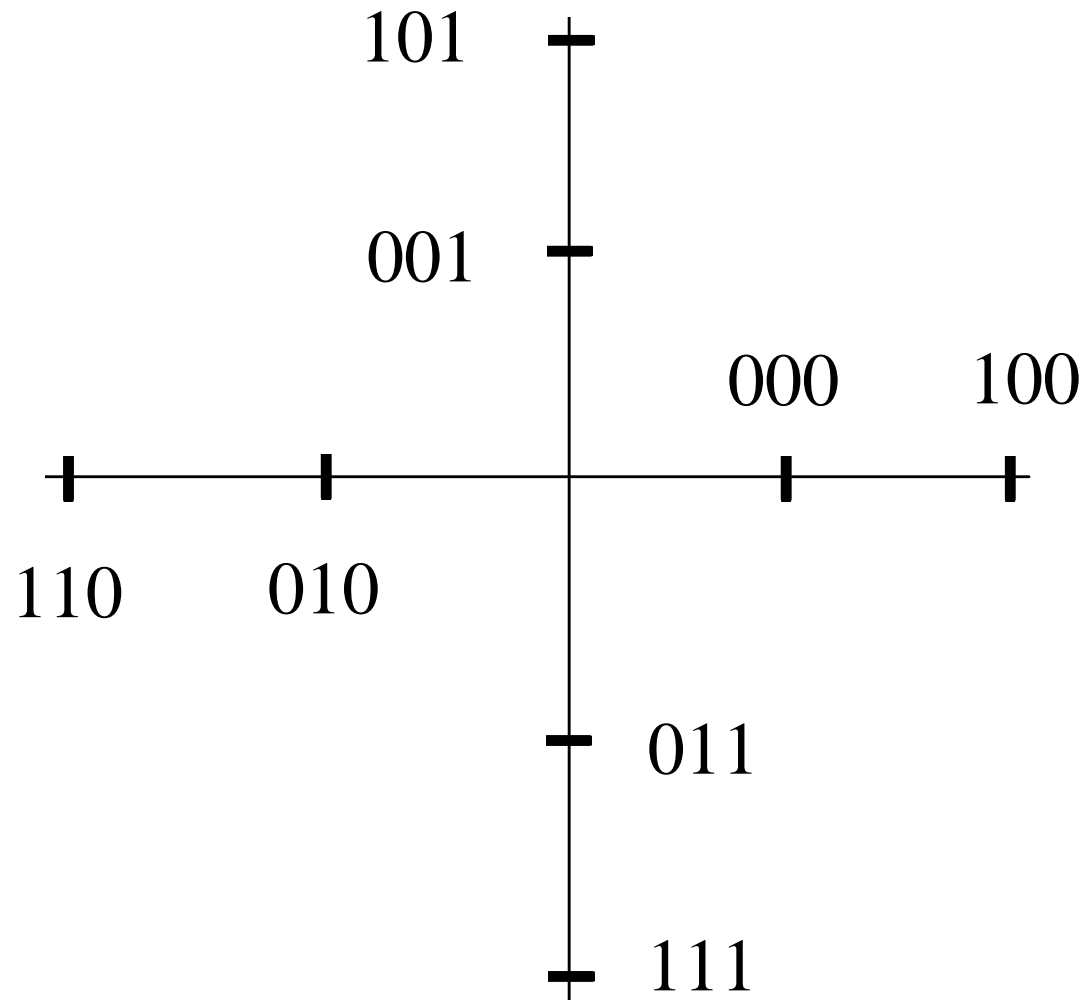
# BELL 201C Modem Standard (USA)

| <b>Data</b> |  | <b>Phase Shift</b> |
|-------------|--|--------------------|
| <b>00</b>   |  | <b>45 degrees</b>  |
| <b>01</b>   |  | <b>135 degrees</b> |
| <b>10</b>   |  | <b>225 degrees</b> |
| <b>11</b>   |  | <b>315 degrees</b> |

# Another Example



# Hybrid - Amplitude Modulated Phase Shift Keying



# Baud Rate v Data Rate

- Baud Rate
  - The number of signalling events per second.
  - The number of times per second that a data transmission channel changes state
- Data Rate
  - The number of data bits transmitted per second
- IF & only IF
  - each signalling event gives 1 BIT of information  
then Baud Rate == Data Rate

# Remember Earlier Examples...

- Phase Modulation with 4 different phase changes then each signalling event gives 2 bits of data and so...
- Data Rate == 2 \* Baud Rate
- Phase / Amplitude hybrid had 4 different phase changes and 2 amplitudes and so...
- Data Rate == 3 \* Baud Rate



# Maximum Data Rates

- Information Theory lectures come later but...
- Two limits, calculated by Nyquist and Shannon/Hartley provide some real hard limits and what can be achieved via communications channels including the PSTN

# Nyquist

- Ignoring noise, the maximum data rate =  $C$  on a channel with a bandwidth  $B$  and with  $M$  levels per signalling element then ...

$$C = 2 * B \log_2 M$$

Phase Modulation (0,90,180,270)

$$C = 2 * B \log_2 M$$

$$B = 3000$$

$$M = 4$$

$$C = 2 * 3000 \log_2(4)$$

$$= 6000 * 2$$

$$= 12000 \text{ bps}$$

# Shannon and Hartley

- B = Bandwidth
- S = signal power      N = noise power
- SNR = signal-to-noise ratio in decibels (dB)

$$SNR = 10 \log_{10} \left( \frac{S}{N} \right)$$

THEN

$$C = B \log_2 \left( 1 + \frac{S}{N} \right) bps$$

# Typical values for PSTN

$$B = 3000$$

$$SNR = 20dB$$

$$SNR = 20 = 10\log_{10}\left(\frac{S}{N}\right)$$

$$\therefore \frac{S}{N} = 10^{\left(\frac{20}{10}\right)} = 10^2 = 100$$

$$\therefore C = 3000\log_2(1 + 100) = 19963bps$$

# Multiple Channels over Media

- Multiplexing versus Concentrating
- Multiplexer
  - Combines multiple channels in a transparent way
- Concentrator
  - Combines but processes data too, code compression takes place.

# Frequency v Time v Statistical Time Multiplexing

- Frequency
  - Bandwidth of media split into different frequency bands used for different channels
- Time
  - Whole bandwidth allocated to one channel for a small time slot then to another channel- fixed width time slots
- Statistical Time
  - Like `time' but with variable time slots, allows for busy and quiet channels.