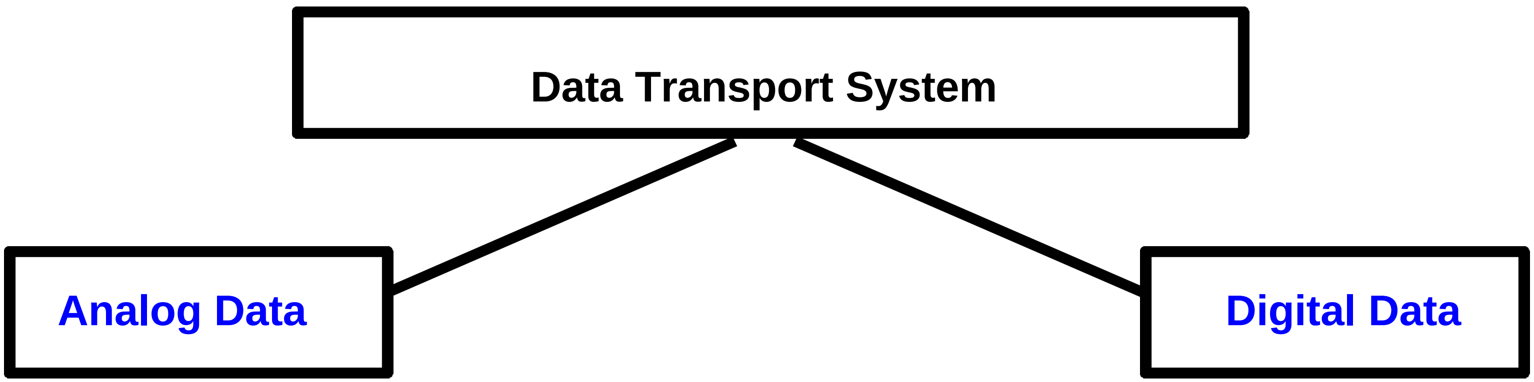
ANALOG VS DIGITAL

BASICS OF DATA COMMUNICATIONS

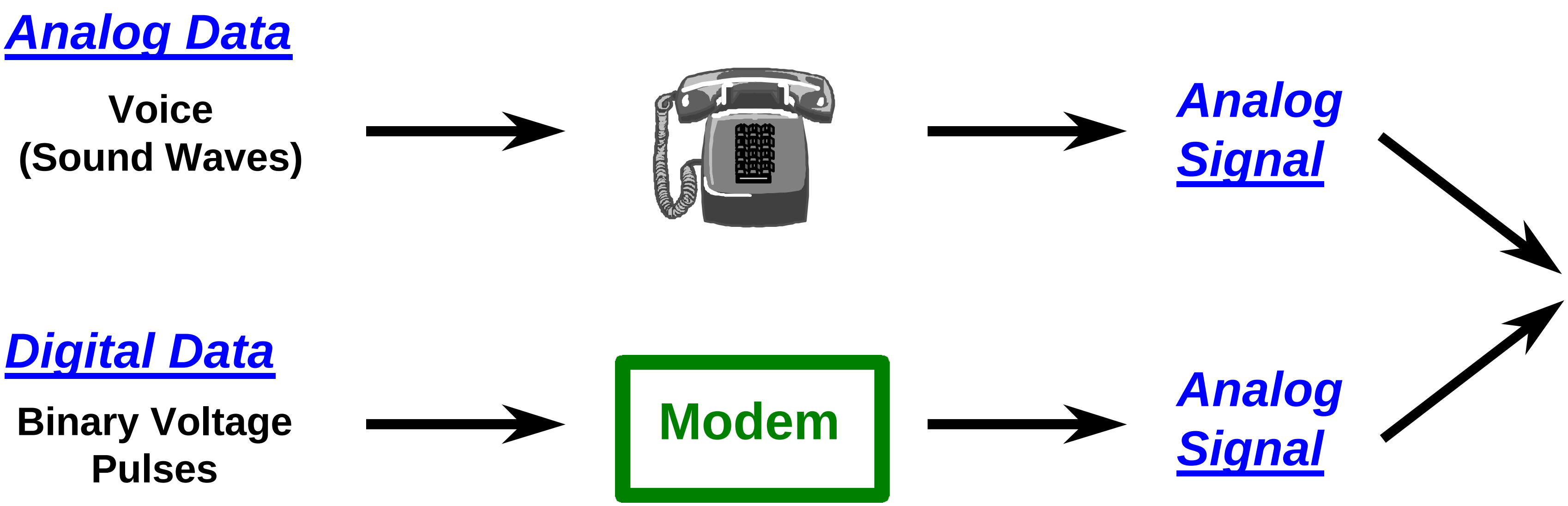


The transport of data through a telecommunications network can be classified into two overall transport techniques:

- ***Analog Data*** **- Data modulated or changed to conform to a voice transmission format.**
- ***Digital Data*** **- Data transported in a digital or discrete line code format.**

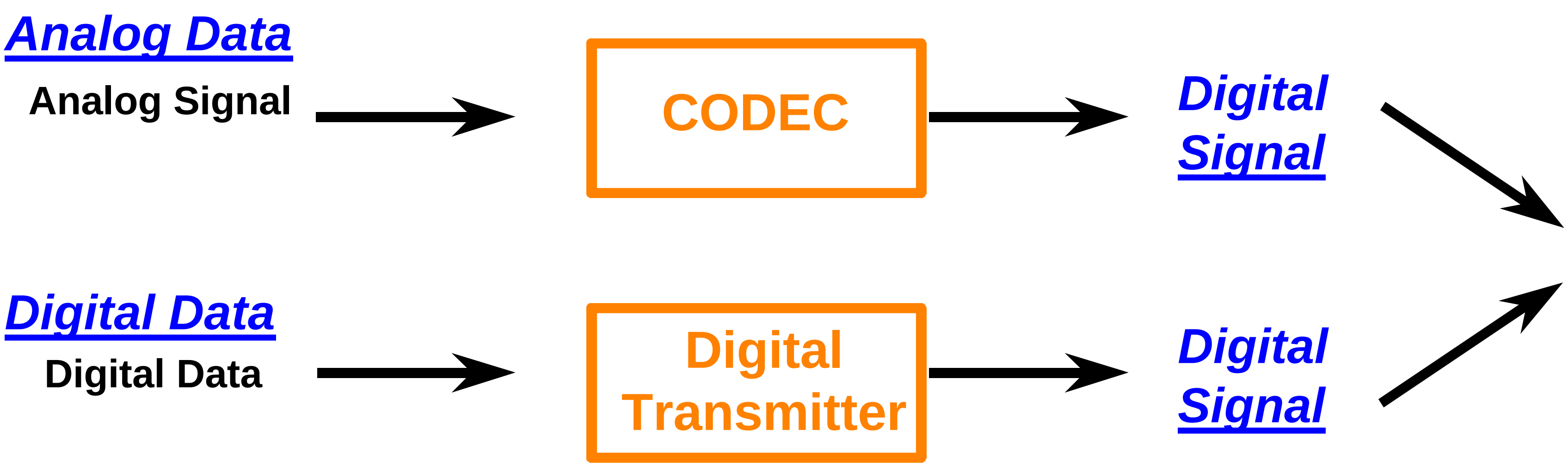
ANALOG SIGNALING OF ANALOG DATA AND DIGITAL DATA

Analog Signals **- Data represented with continuously varying Electromagnetic Wave**

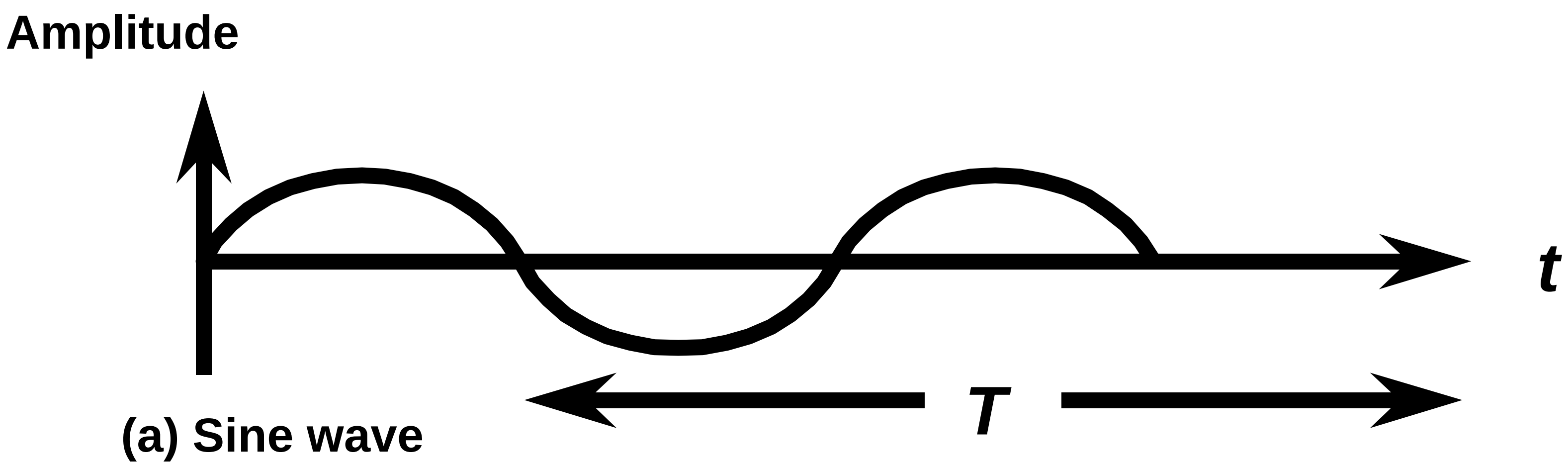


DIGITAL SIGNALING OF ANALOG DATA AND DIGITAL DATA

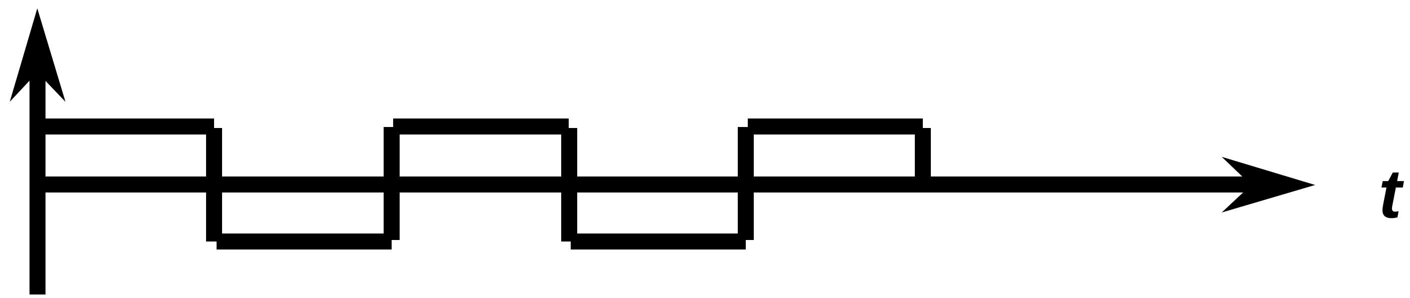
Digital Signals **- Data represented with a sequence of voltage pulses**



EXAMPLES OF PERIODIC SIGNALS



(a) Sine wave



(b) Square wave

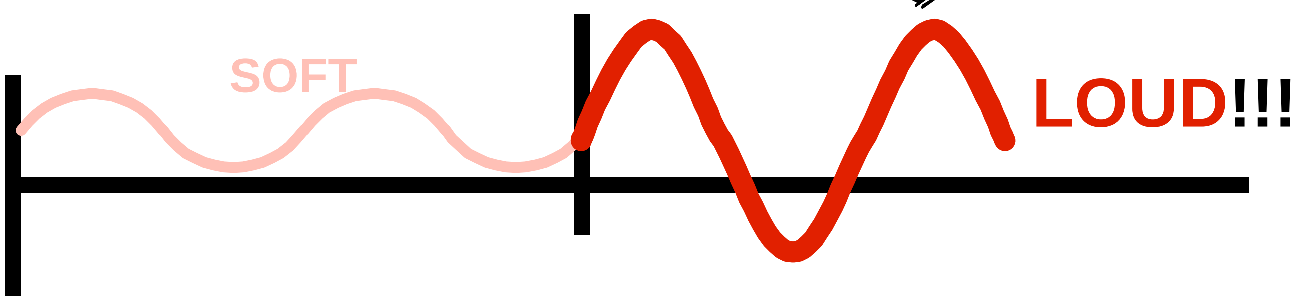
CHARACTERISTICS OF AN ANALOG SIGNAL

- ***ANALOG*** **- means that the signal is continuous rather than either on or off.**
- **Both sound and light are analog signals spread over a wide range of frequencies.**
- **Amplitude, frequency, and phase are characteristics of an analog signal.**

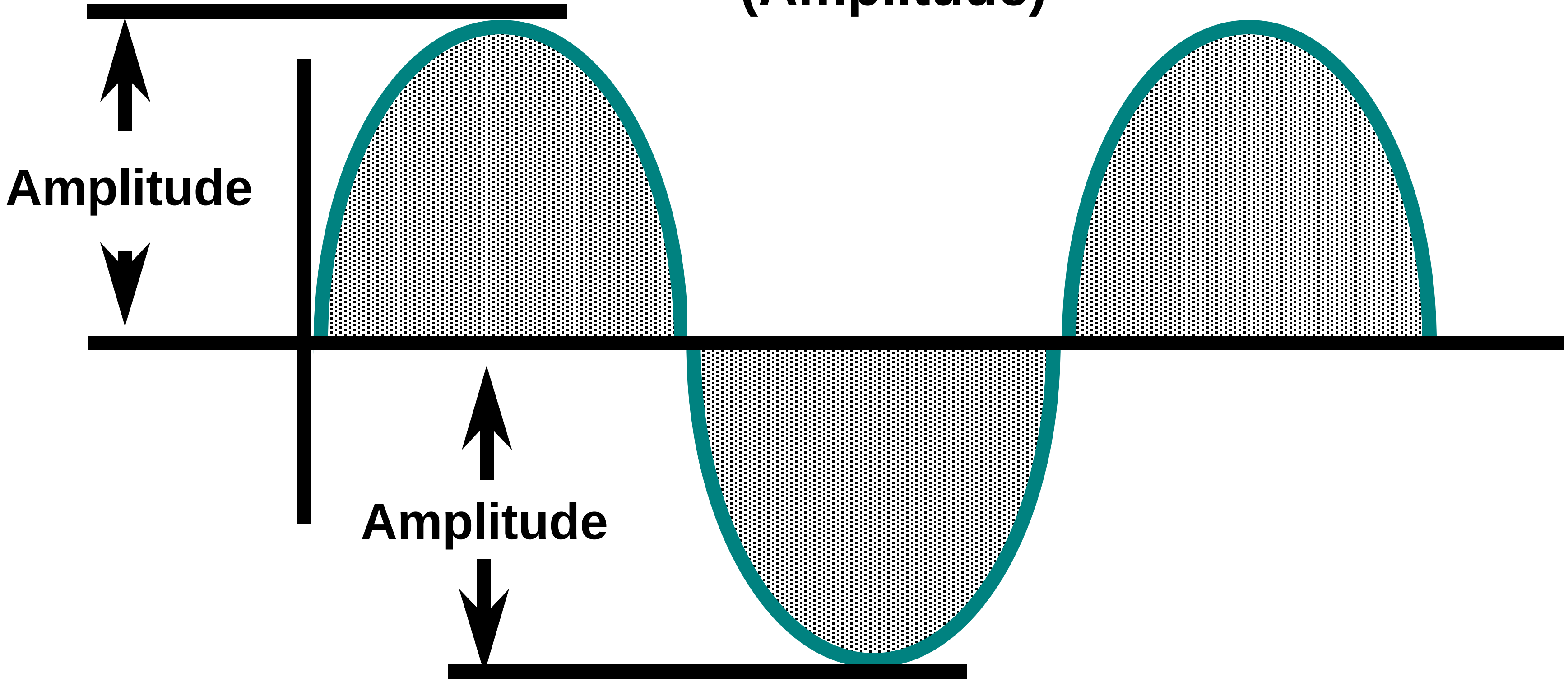
The amplitude of the wave is a measure of the loudness of the sound:

The **Greater** the **Amplitude**

The **Louder** the **Sound!!!**



SINE WAVE PROPERTIES
(Amplitude)

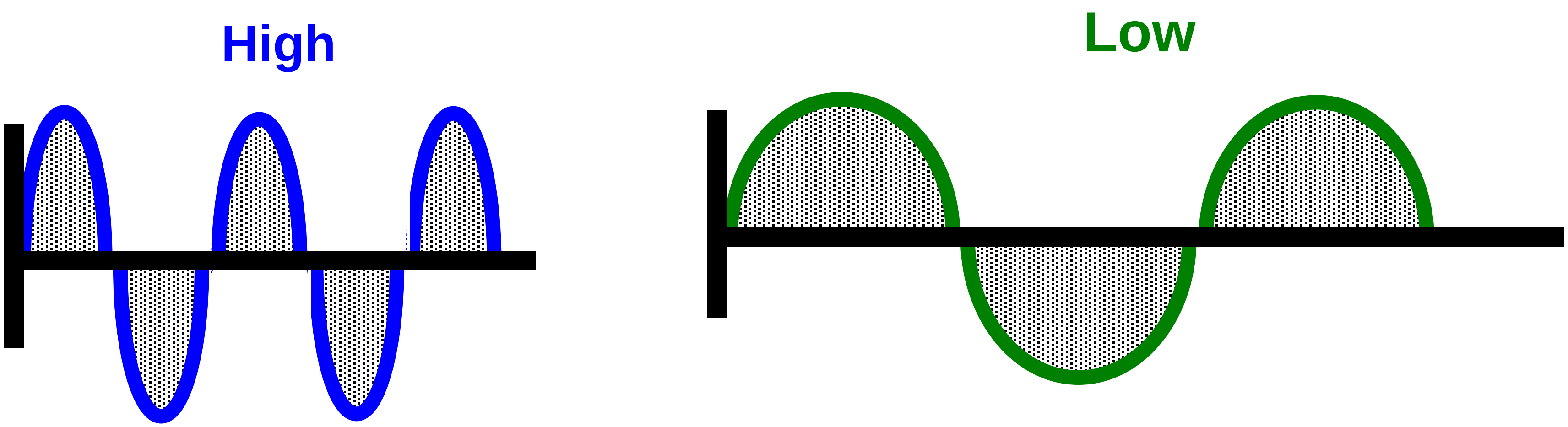


Modifiable via Adjustment to <u>Voltage Level</u>

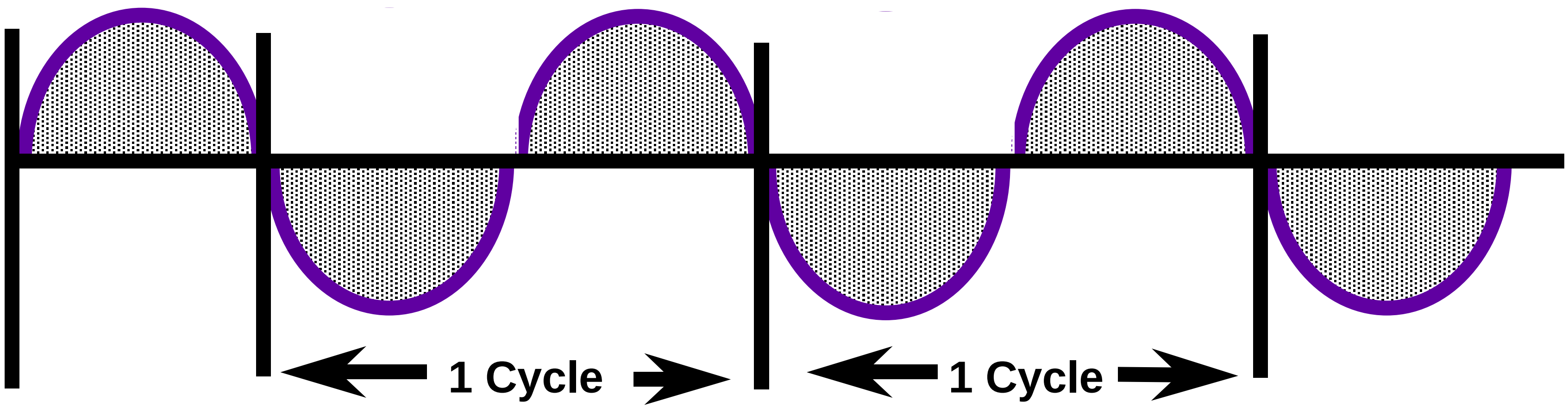
SINE WAVE PROPERTIES
(Frequency)

The frequency (f) of a periodic signal is defined as the number of cycles passing any given point per second.

It is customary to express the frequency in hertz (Hz), meaning vibrations per second or cycles per second. The shorter the wavelength, the higher the frequency, or the pitch of the sound.

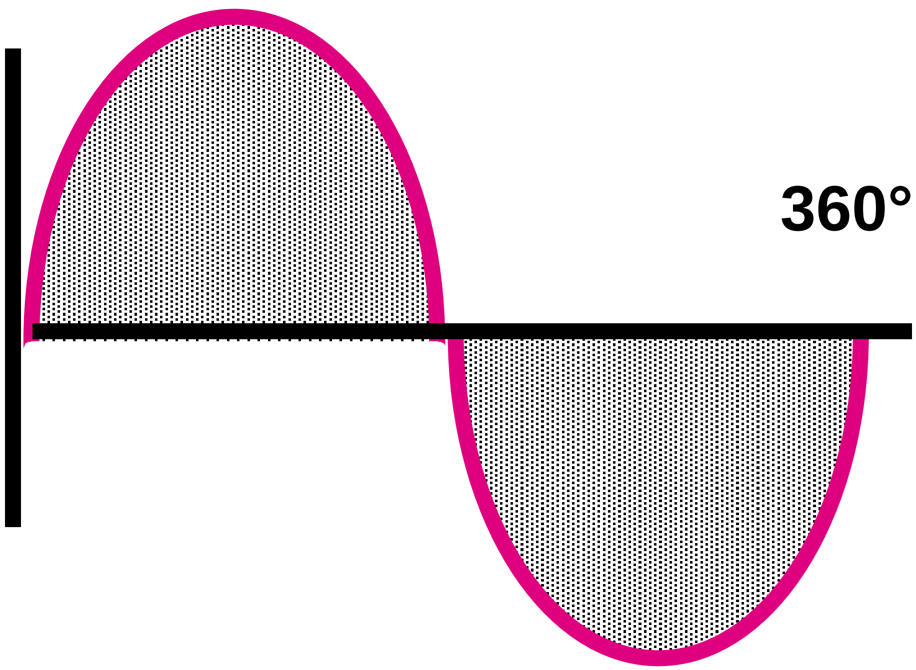


SINE WAVE PROPERTIES (FREQUENCY)



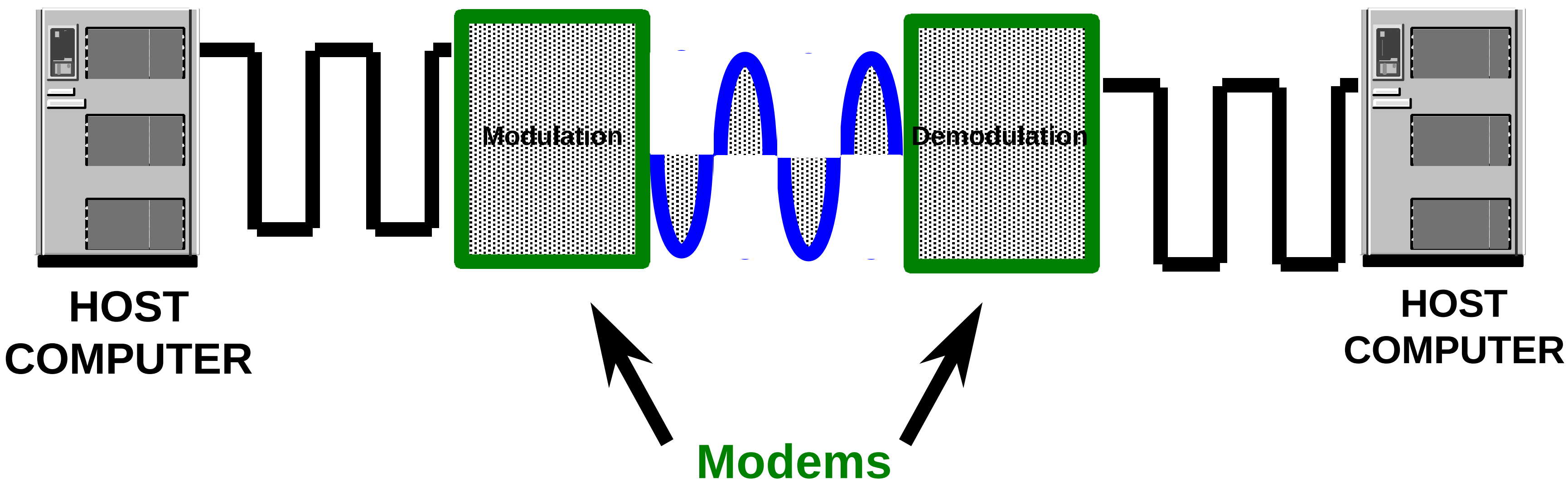
One cycle per second = one Hertz (Hz)
Cycle = One wavelength

SINE WAVE PROPERTIES (PHASE)



Phase is the relative position within a cycle.

Use of Modems in Data Transmission

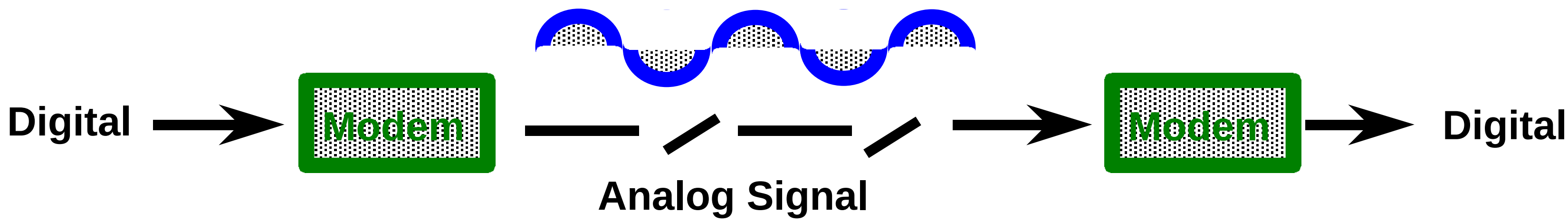


MODULATION OF ANALOG SIGNALS

- **Use a signal appropriate to the channel:**
  "Carrier" (for telephone signal in 300-3400 Hz range)
  Add data to it - "Modulate" the signal

Convert: Digital to Analog >>>>> Modulation
Analog to Digital >>>>> Demodulation

Function performed via modem (Modulator/Demodulator)



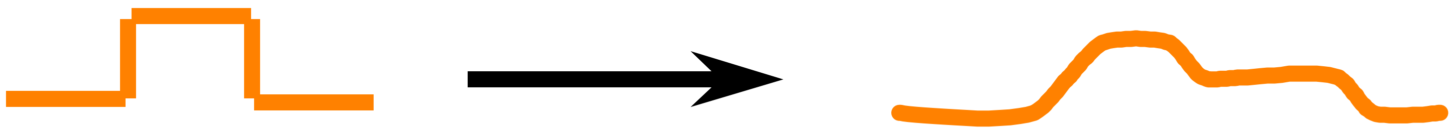
Modulation Techniques

- **Amplitude Modulation (AM)**
- **Frequency Modulation (FM)**
- **Phase Modulation (PM)**

DIGITAL vs. ANALOG TRANSMISSION

Problems with Digital (Baseband) Transmission

- **Long distances - deterioration due to capacitance, resistance, and noise.**



Need frequent repeaters (every 300M - 2KM) to regenerate the signal.
Regenerated signal = original

- **Accommodate the channel - Fit within the bandwidth of the channel (e.g., telephone system 300-3400Hz).**

Problems with Analog Transmission

- **Signal to noise ratio - Better over long distances but amplifiers cannot clean up signal in analog form.**

Use Digital over short distances or with repeaters, use Analog where it is needed to fit the channel.

Digital vs. Analog Transmission

- Digital signals can be transmitted in a manner that largely overcomes the problems of noise.
- With digital transmission each repeater regenerates the on/off pulses.
- Fresh, new, clean pulses with the noise removed are reconstructed and sent on to the next repeater where the reconstruction process is performed again.
- Another advantage of digital transmission is the digital signals are already in an appropriate form for computer processing.

Digital vs. Analog Transmission *(continued)*

- **A disadvantage of digital transmission is that the original analog signal can never be reproduced exactly because the input analog signal must be quantized. That is, it must be represented by a limited set of specific discrete values.**

Digital vs. Analog Transmission *(continued)*

- **Analog information such as a human voice needs to be converted to digital form before it can be transmitted over a digital channel.**

  This conversion is performed by a device called a CODEC (from Coder/Decoder).

  Any analog data- - sound, heat, light, TV pictures, color photographs - - can be digitized into a bit stream and transmitted over a digital channel.

  The most common technique used today to transmit analog signals in digital form is called pulse code modulation (PCM).

ANALOG AND DIGITAL SIGNALING
OF ANALOG AND DIGITAL DATA

Analog Signals **- Represent data with continuously varying**

electromagnetic wave.

Analog Data

Voice
(Sound Waves)

↔

↔ ***Analog Signal***

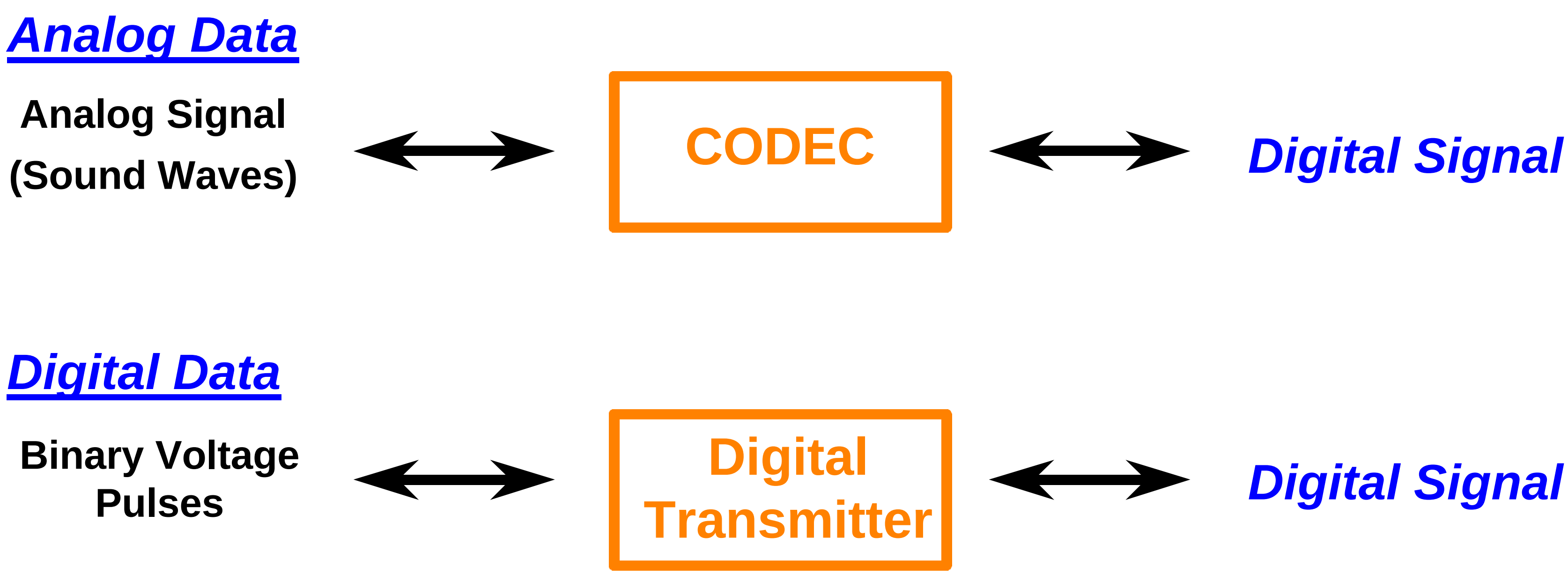
Digital Data

Binary Voltage
Pulses

↔ **Modem** ↔ ***Analog Signal***

ANALOG AND DIGITAL SIGNALING
OF ANALOG AND DIGITAL DATA

Digital Signals **- Represent data with sequence of voltage pulses.**



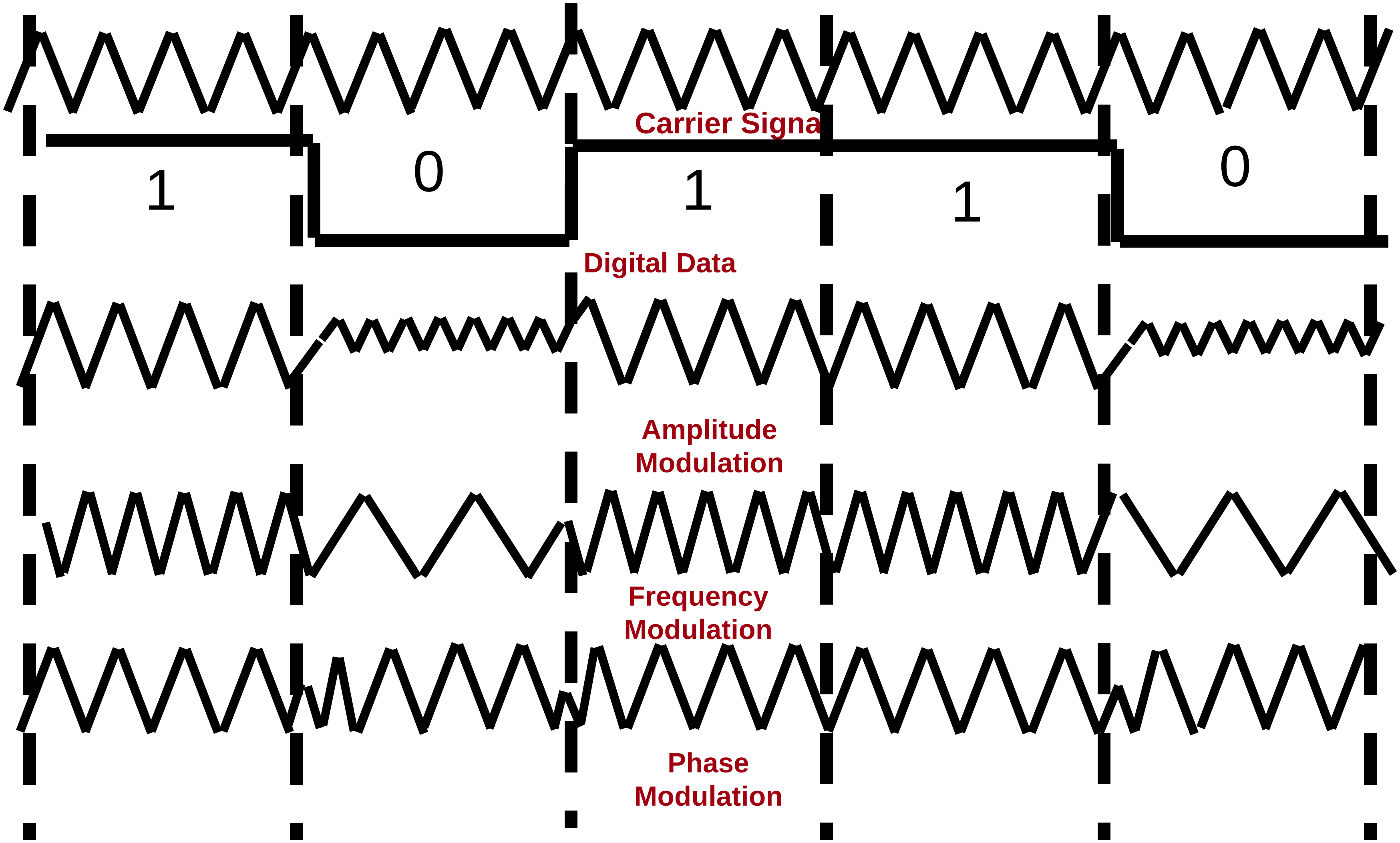
Why has the use of Analog Transmission dropped while Digital Transmission increased?

– ***Digital Technology:*** **The advent of large scale integration (LSI) and very large scale integration (VLSI) technology have caused a drop in cost. Analog transmission has not shown a similar drop.**
Data Integrity: **With the use of repeaters rather than amplifiers, the effects of noise and other signal impairments are not cumulative. Thus we can transmit longer distances and over less expensive lines while maintaining the data integrity.**
Capacity Utilization: **It has become very economical to build transmission links of very high bandwidth, including satellite and fiber optics. The high degree of multiplexing needed to utilize this capacity is more easily achieved with digital rather than analog techniques.**
Security and Privacy: **Encryption techniques can be readily applied to digital data and analog data that have been digitized.**
Integration: **By treating both digital and analog data digitally, both signals have the same form and can be treated economically.**

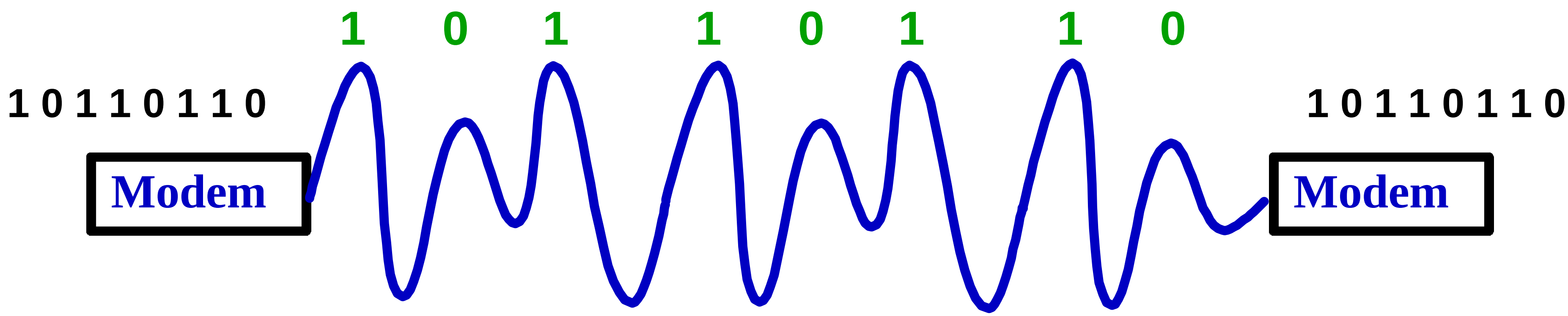
BASIC MODULATION TECHNIQUES

- **Transmission of information represented in binary form over an analog channel requires a process called modulation.**
- **When no information is being passed, a steady alternating current of constant amplitude and frequency called a carrier signal is present.**
- **Some characteristics of the carrier current must be altered to represent bits of information.**

SIGNAL MODULATION

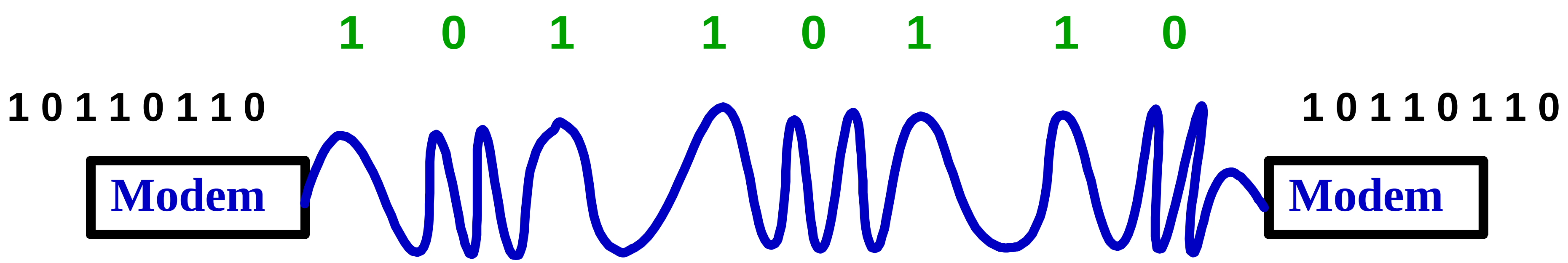


BASIC MODULATION TECHNIQUES



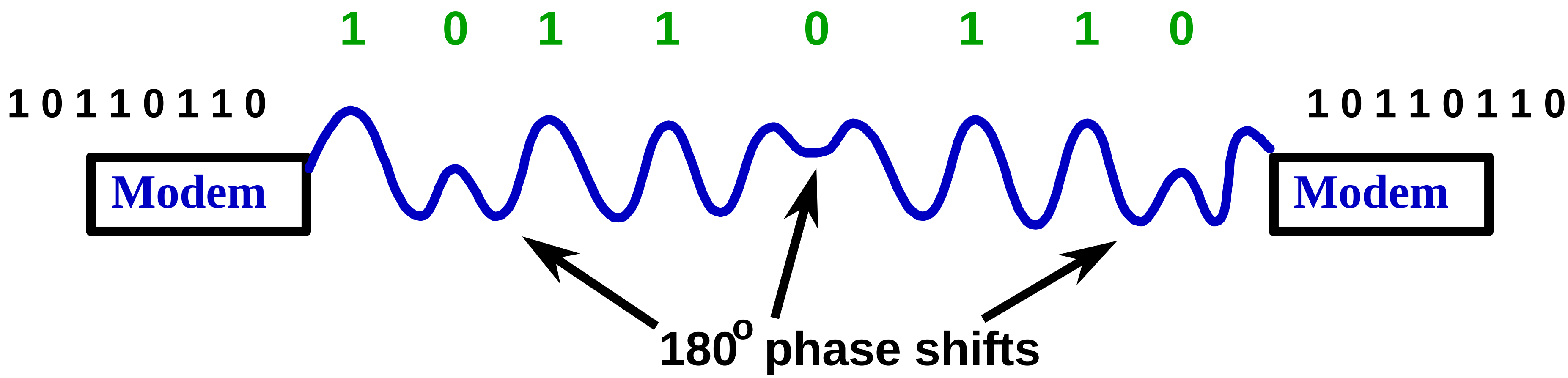
- ***AMPLITUDE*** **modulation (AM) converts digital data to analog signals using a single frequency carrier signal. A high amplitude wave denotes a binary 1 and a low amplitude wave denotes a binary 0.**

BASIC MODULATION TECHNIQUES



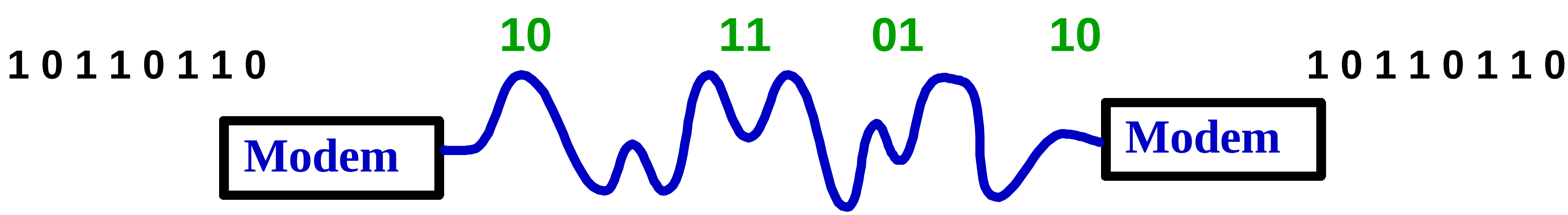
- ***FREQUENCY*** **shift keying (FSK) uses a constant amplitude carrier signal and two frequencies to distinguish between 1 and 0.**

BASIC MODULATION TECHNIQUES



- ***PHASE*** **shift keying (PSK) uses a phase shift at transition points in the carrier frequency to represent 1 or 0.**

BASIC MODULATION TECHNIQUES



- ***DIFFERENTIAL*** **phase shift keying (DPSK) uses different phase shifts to represent four possible combinations of 0 and 1 bits. In the example, 45 degrees represents 00, 135 degrees stands for 01, 225 degrees for 11, and 315 degrees for 10. The pairs of bits are called dibits.**

THE PROCESS OF CHANGING THE CARRIER SIGNAL IS CALLED ***MODULATION***

- **The number of carrier signal changes per second is called the *Line Signaling Rate* and is measured in *Baud*. Thus, 2400 baud means 2400 carrier signal changes per second.**
- **The communications equipment in which modulation is performed is called a *Modem* (MOdulate/DEModulate).**
- **There are four common modulation techniques:**
  - **Amplitude**
  - **Phase shift keying**
  - **Frequency shift keying**
  - **Differential phase shift keying**

AMPLITUDE MODULATION (*AM*):

- **Varies the amplitude of the signal to transmit information.**

- **A constant frequency is used with a high amplitude wave representing 1 and a low amplitude wave representing 0.**

- **Use of four amplitude levels allows four combinations of two bits (00, 10, 01, 11) to be sent with a single change in signal.**

- **Amplitude Modulation is seldom used without other forms of modulation because the signals it produces are susceptible to noise, and it takes a long time (relative to other modulation techniques) to sample the**

FREQUENCY SHIFT KEYING MODULATION (*FSK*)

- **A constant amplitude signal is modulated between two frequencies to represent 0 and 1.**
- ***FSK* modulation is less affected by noise on the transmission lines than is amplitude modulation.**

PHASE SHIFT KEYING (*PSK*)

- ***PSK*** **uses a phase shift at transition points in the carrier signal to represent 0's and 1's.**

- **Phase is the measure of relative time that the sine wave crosses through zero amplitude. Just at the time the carrier signal is crossing zero it is shifted one-half cycle. So instead of continuing to increase in positive value, the signal repeats the 0 to maximum negative value cycle.**

- ***PSK*** **is affected even less by noise than frequency shift keying (*FSK*) and is used for higher speed transmission above 2000 bps.**

DIFFERENTIAL PHASE SHIFT KEYING (*DPSK*)

- ***DPSK*** **uses different phase shifts to represent different combination of bits.**

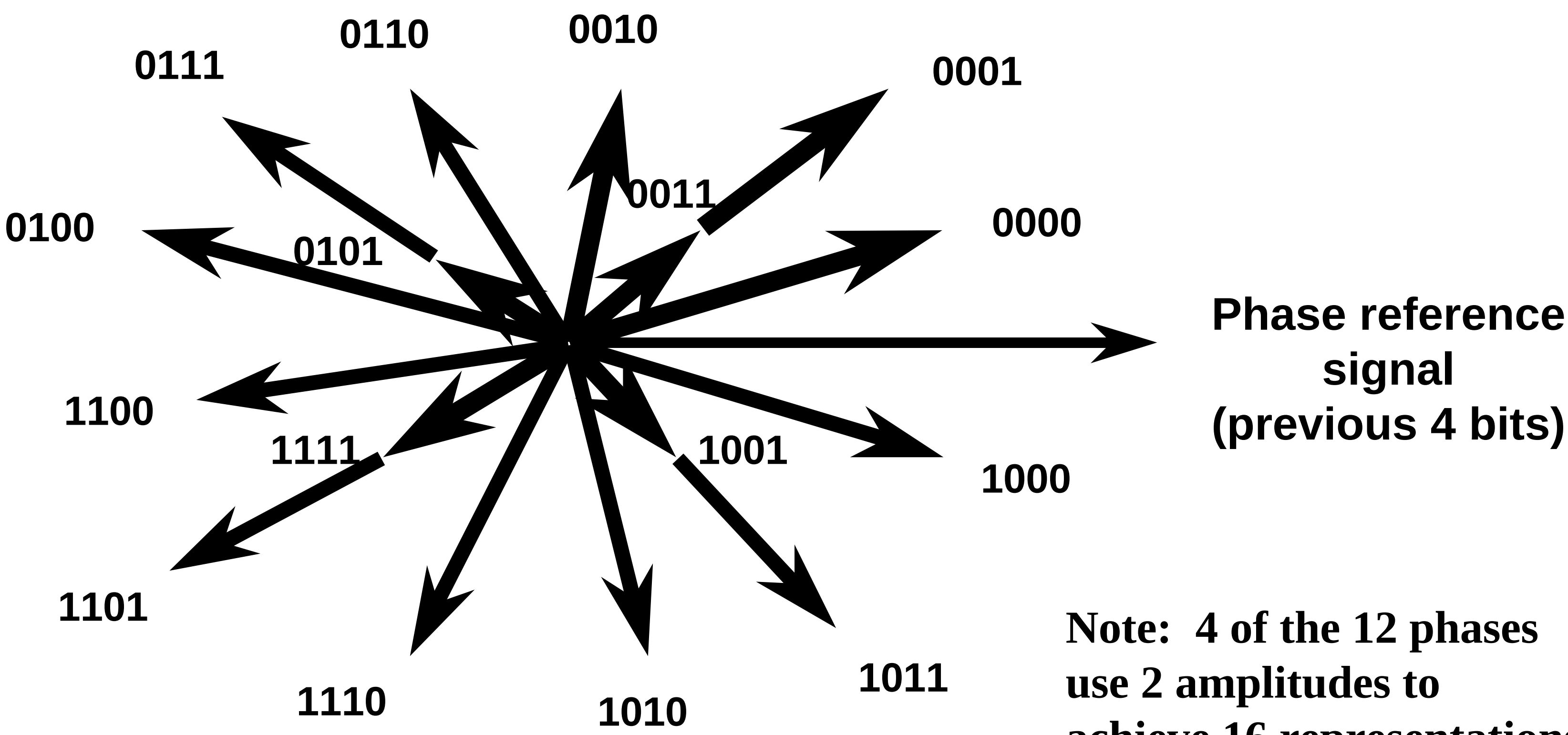
- **To represent the four dibits (00, 10, 11) four phase shifts are required.**

- **By sending dibits instead of single bits over the same carrier signal, *DPSK* modems can achieve higher transfer rates.**

COMBINATION MODULATION TECHNIQUES

- **High speed modems use combination modulation techniques to achieve high data transfer rates.**
- **For example, to transmit four bits per signal change, a combination of differential phase shift keying (*DPSK*) and amplitude modulation (*AM*) techniques can be used.**
- **Sixteen different signal states can be derived using a combination of 12 different phases and two amplitude levels.**
- **The line signaling rate for a 9600 bps modem using such a technique is 2400 baud, since each change in the signal represents four bits.**

PHASE AND AMPLITUDE STATES OF COMBINATION MODULATION TECHNIQUES



Note: 4 of the 12 phases use 2 amplitudes to achieve 16 representations.

<u>PAM</u> AND <u>PCM</u>

- **<u>Pulse Code Modulation</u> (*PCM*) is based on a sampling theorem.**

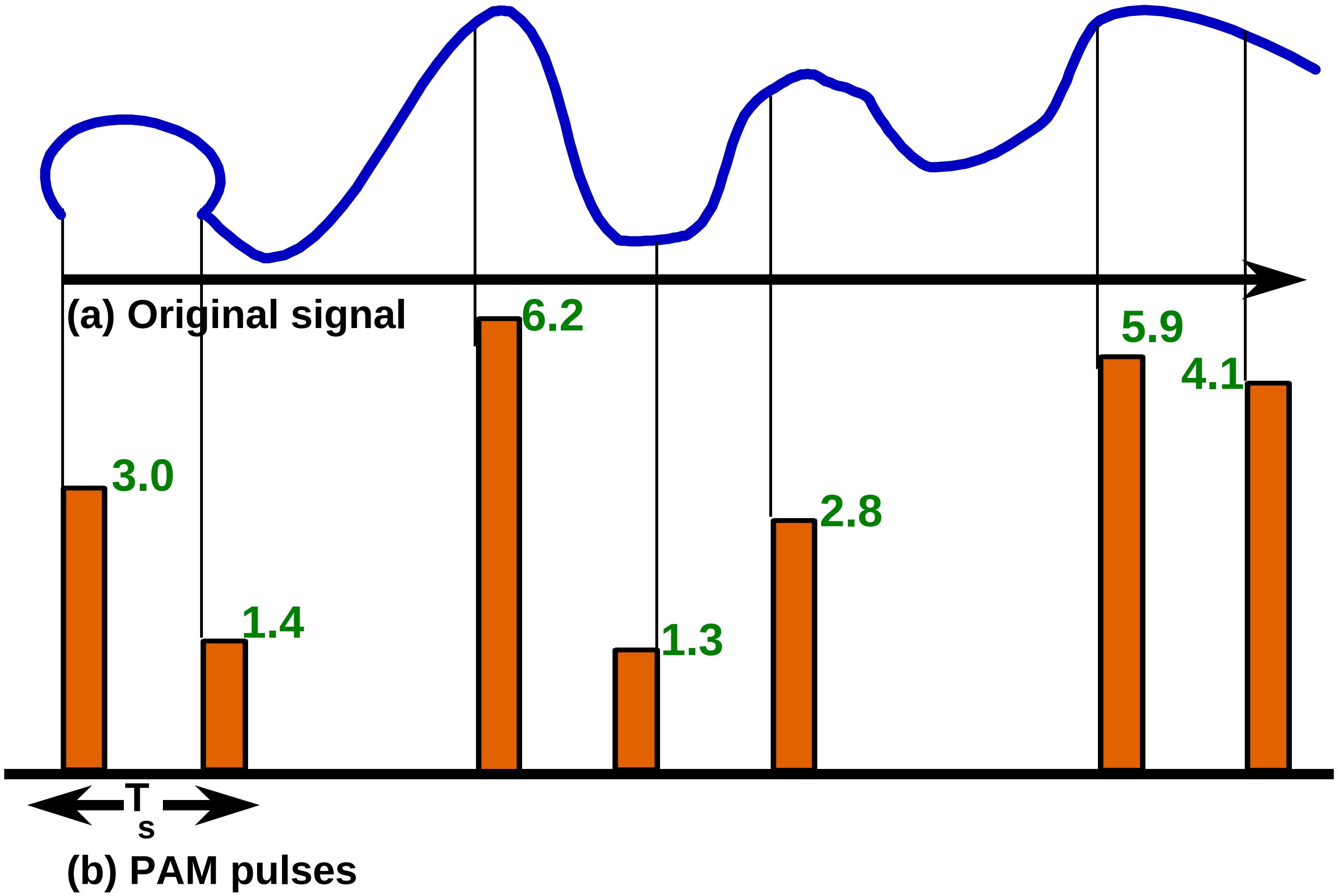
  If voice data are limited to frequencies below 4000Hz, 8000 analog samples per second would be sufficient to completely characterize the voice signal.

  These samples are represented as narrow pulses whose amplitude is proportional to the value of the original signal.

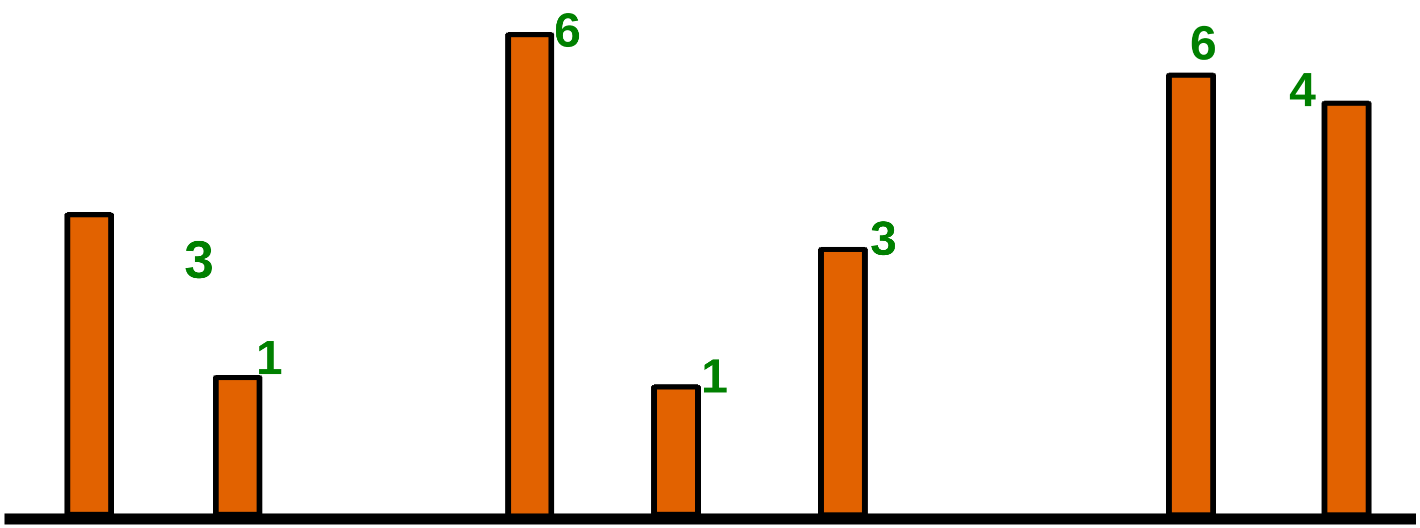
  This process is known as <u>Pulse Amplitude Modulation</u> (*PAM*)

  To produce *PCM* data, the *PAM* samples are quantized. That is, the amplitude of each *PAM* pulse is approximated by a N-bit integer, in the example, N = 3. The 8 = 23 levels are available for approximating the *PAM* pulses.**

PULSE CODE MODULATION



PULSE CODE MODULATION



(c) PCM pulses

011001110001011110100

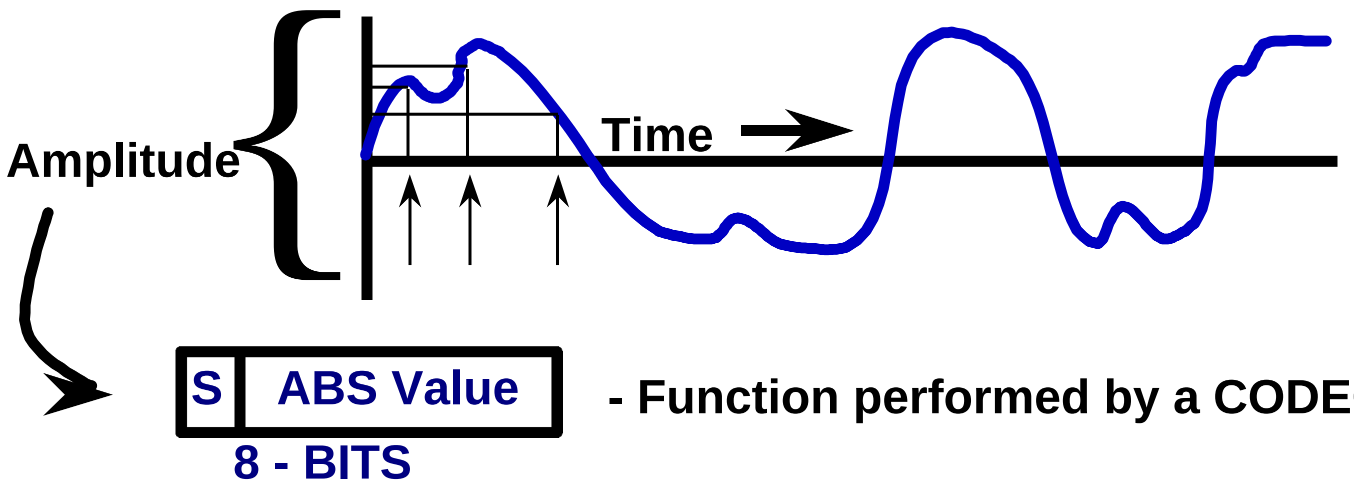
(d) PCM output

DIGITAL VOICE TRANSMISSION

- **Analog to digital voice encoding:**
  - **PCM most popular - used by telephone carriers.**
- **8 bit samples at 8 Khz rate - 64Kbps digital bit stream per voice call:**
  - **Analog signal is band limited: 300-3400 Hz.**
  - **Sample at 2X highest frequency: 8000 samples/sec.**

DIGITAL VOICE TRANSMISSION

- **Each 8-bit sample represents signal amplitude:**



- Function performed by a CODEC chip.

DATA ENCODING

Difference between Analog and Digital Data and Analog and Digital Signals.

- **Digital Data, Digital Signals**
  - **NRZ**
  - **RZ**
  - **Biphase**
  - **Delay Modulation**
  - **Multilevel Binary**
- **Digital Data, Analog Signals**
  - **Encoding Techniques**
    - **ASK**
    - **FSK**
    - **PSK**
- **Analog Data, Digital Signals**
  - **PAM**
  - **PCM**
  - **Delta Modulation (*DM*)**
- **Analog Data, Analog Signals**
  - **Amplitude Modulation**
  - **Angle Modulation**
  - **FM**
  - **PM**