Review of Data and Signals Digital Modulations PCM

Review Questions

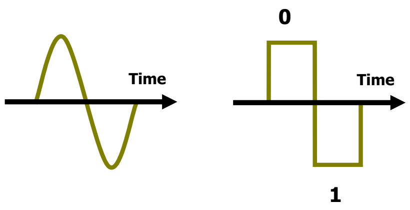
- What is data?
- What is information?
- What is signal?
- What are amplitude, frequency, phase?
- What is the difference between signaling rate (baud rate) and data rate?

Introduction

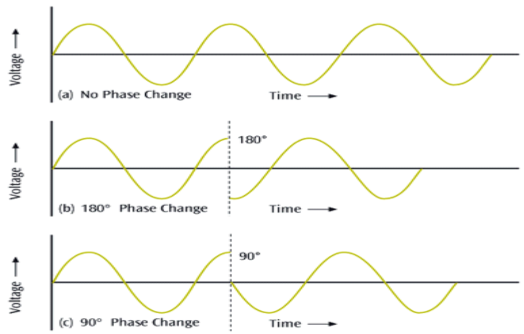
- Data are entities that convey meaning
- Signals are the electric or electromagnetic encoding of data
- Computer networks and data/voice communication systems transmit signals
- Data and signals can be analog or digital

Waveforms

Analog **Digital**



Phase (I)



Phase (II)

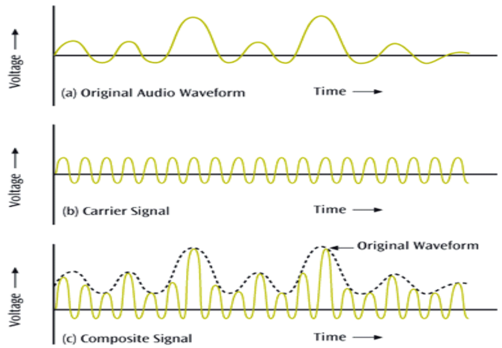
- The phase of a signal is the position of the waveform relative to a given moment of time or relative to time zero.
- A change in phase can be any number of angles between 0 and 360 degrees.
- Phase changes often occur on common angles, such as 45, 90, 135, etc.

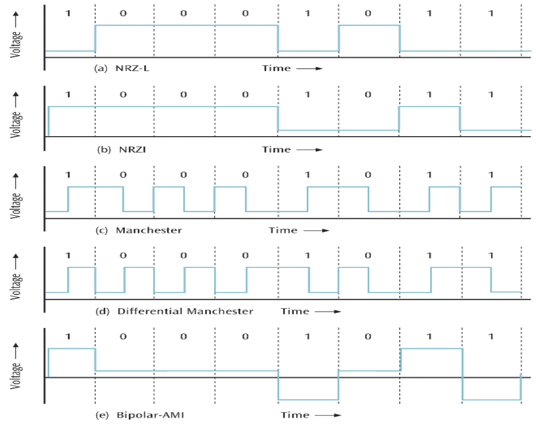
Data to Signal

Signal

Data	Digital (Signal)	Analog (Signal)
Digital	NRZ-L NRZ-I Manchester Differential Manchester Bipolar-AMI	Amplitude modulation Frequency modulation Phase modulation Spread spectrum technology
Analog	Pulse code modulation Delta modulation	Modulate data onto different frequencies

Analog data-analog signals





NRZ-L

- Digital 1s are represented as one voltage (amplitude), while digital 0s are represented as another:
  - Cheap to implement
  - Check for voltage of each bit
  - A long series of 1s or 0s produces a flat, unchanging voltage level (produces synchronization problems)

NRZI

- Digital 1s are represented by a voltage change (high-to-low, or low-to-high), while 0s are represented as a continuation of the same voltage level:
  - Even cheaper to implement (only check for changes)
  - A long series of 0s produces a flat, unchanging voltage level

Manchester encoding

- Digital 1s are represented by a midway voltage change from low to high, while 0s are represented as midway voltage changes from high to low
  - Hardware has to work twice as fast to detect changes
  - Baud rate (number of signal changes) is twice bits per second rate

Differential Manchester

- Digital 0s are represented by a voltage change (high-to-low, or low-to-high) at the beginning of the bit as well as a midway voltage change, while 1s are represented as a continuation of the same voltage level at the beginning, followed by a midway voltage change

Bipolar-AMI

- Three voltage level
  - 0 transmitted as 0 voltage
  - 1 transmitted as either +1 or –1 voltage
    - Alternating between the two
- Disadvantages
  - Long string of 0s
  - Hardware capable to recognize + & - voltages

4B/5B Digital Encoding

- Encoding technique that converts four bits of data into five-bit quantities.
  - The five-bit quantities are unique in that no five-bit code has more than 2 consecutive zeroes.
  - The five-bit code is then transmitted using an NRZ-I encoded signal.

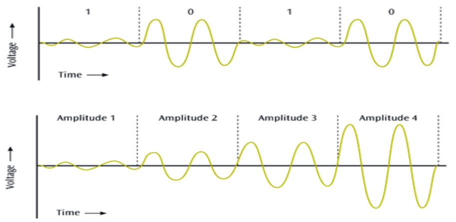
Valid Data Symbols

Original 4-bit data	New 5-bit code
0000	11110
0001	01001
0010	10100
0011	10101
0100	01010
0101	01011
0110	01110
0111	01111
1000	10010
1001	10011
1010	10110
1011	10111
1100	11010
1101	11011
1110	11100
1111	11101

Invalid codes
00001
00010
00011
01000
10000

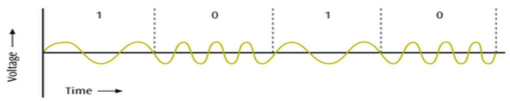
Amplitude Shift Keying : ASK

- One amplitude encodes a 0 while another amplitude encodes a 1 (amplitude modulation).



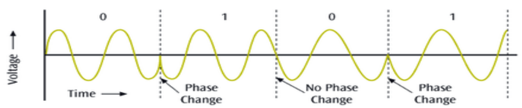
Frequency Shift Keying : FSK

- One frequency encodes a 0 while another frequency encodes a 1 (frequency modulation).



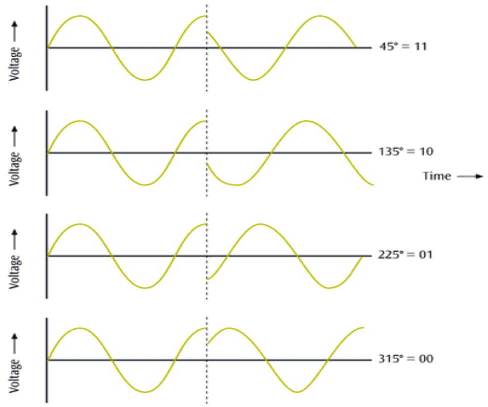
Phase Shift Keying : PSK

- One phase change encodes a 0 while another phase change encodes a 1 (phase modulation).



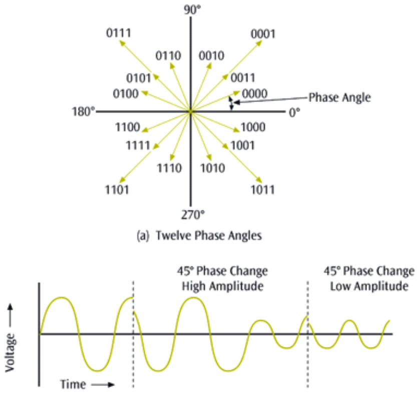
Quadrature phase modulation

- Four different phase angles are used, namely:
  - 45 degrees
  - 135 degrees
  - 225 degrees
  - 315 degrees



Quadrature Amplitude Modulation

- In this technology, 12 different phases are combined with two different amplitudes.
- Since only 4 phase angles have 2 different amplitudes, there are a total of 16 combinations.
- With 16 signal combinations, each baud equals 4 bits of information.



(a) Twelve Phase Angles

(b) A phase change with two amplitudes

How do you send more data

- Manipulate one or more of the main three properties (amplitude, frequency, or phase) to denote multiple bits
  - The most common (because it's cheaper) is amplitude, or frequency
- Baud rate vs. Bit rate, putting more bits in a baud
- Shannon's Law allows you to calculate the maximum data transfer rate (p56):
  - S(f) = f . log2(1 + W / N) bps

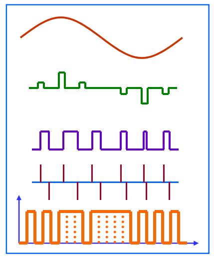
$$C = W \log(1 + \frac{S}{N})$$

PULSE MODULATION

The process of transmitting signals in the form of pulses (discontinuous signals) by using special techniques.

Topics include:

- Pulse Amplitude Modulation
- Pulse Width Modulation
- Pulse Position Modulation
- Pulse Code Modulation



Pulse Modulation

Analog Pulse Modulation
- Pulse Amplitude (PAM)
- Pulse Width (PWM)
- Pulse Position (PPM)

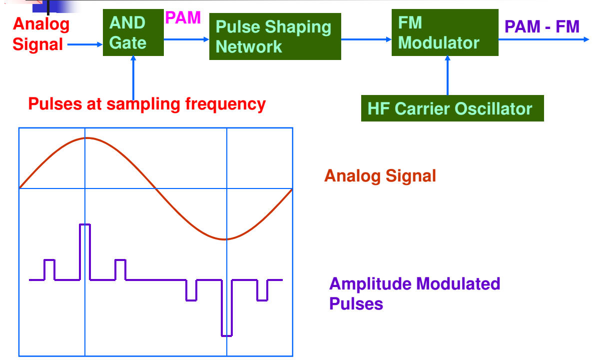
Digital Pulse Modulation
- Pulse Code (PCM)
- Delta (DM)

Pulse Amplitude Modulation (PAM):

* The signal is sampled at regular intervals such that each sample is proportional to the amplitude of the signal at that sampling instant. This technique is called "sampling".

* *For minimum distortion, the sampling rate should be more than twice the signal frequency.*

Pulse Amplitude Modulator



Pulse Code Modulation (PCM):

* Analog signal is converted into digital signal by using a digital code.
* Analog to digital converter employs two techniques:

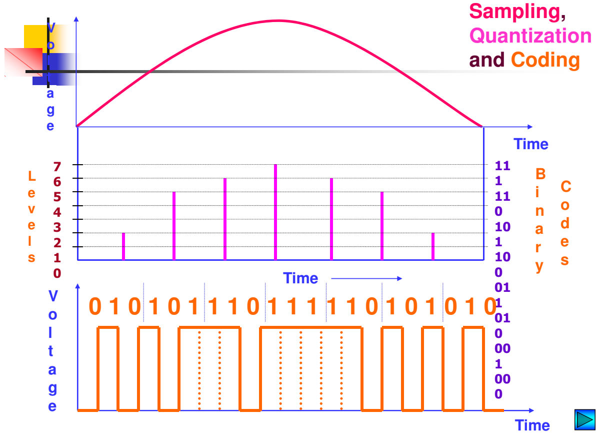
1. Sampling: The process of generating pulses of zero width and of amplitude equal to the instantaneous amplitude of the analog signal. The no. of pulses per second is called "sampling rate".

2. Quantization: The process of dividing the maximum value of the analog signal into a fixed no. of levels in order to convert the PAM into a Binary Code.
The levels obtained are called "quanization levels".

* A digital signal is described by its 'bit rate' whereas analog signal is described by its 'frequency range'.

* Bit rate = sampling rate x no. of bits / sample

Sampling, Quantization and Coding



Merits of Digital Communication:

1. Digital signals are very easy to receive. The receiver has to just detect whether the pulse is low or high.
2. AM & FM signals become corrupted over much short distances as compared to digital signals. In digital signals, the original signal can be reproduced accurately.
3. The signals lose power as they travel, which is called attenuation. When AM and FM signals are amplified, the noise also get amplified. But the digital signals can be cleaned up to restore the quality and amplified by the regenerators.
4. The noise may change the shape of the pulses but not the pattern of the pulses.
5. AM and FM signals can be received by any one by suitable receiver. But digital signals can be coded so that only the person, who is intended for, can receive them.
6. AM and FM transmitters are 'real time systems'. i.e. they can be received only at the time of transmission. But digital signals can be stored at the receiving end.
7. The digital signals can be stored, or used to produce a display on a computer monitor or converted back into analog signal to drive a loud speaker.