Data and Computer Communications

Data Encoding

Encoding Techniques

- Digital data, digital signal
- Analog data, digital signal
- Digital data, analog signal
- Analog data, analog signal

Digital Data, Digital Signal

- Digital signal
  - Discrete, discontinuous voltage pulses
  - Each pulse is a signal element
  - Binary data encoded into signal elements

Terms (1)

- Unipolar
  - All signal elements have same sign
- Polar
  - One logic state represented by positive voltage the other by negative voltage
- Data rate
  - Rate of data transmission in bits per second
- Duration or length of a bit
  - Time taken for transmitter to emit the bit

Terms (2)

- Modulation rate
  - Rate at which the signal level changes
  - Measured in baud = signal elements per second
- Mark and Space
  - Binary 1 and Binary 0 respectively

Interpreting Signals

- Need to know
  - Timing of bits - when they start and end
  - Signal levels
- Factors affecting successful interpreting of signals
  - Signal to noise ratio
  - Data rate
  - Bandwidth

Comparison of Encoding Schemes (1)

- Signal Spectrum
  - Lack of high frequencies reduces required bandwidth
  - Lack of dc component allows ac coupling via transformer, providing isolation
  - Concentrate power in the middle of the bandwidth
- Clocking
  - Synchronizing transmitter and receiver
  - External clock
  - Sync mechanism based on signal

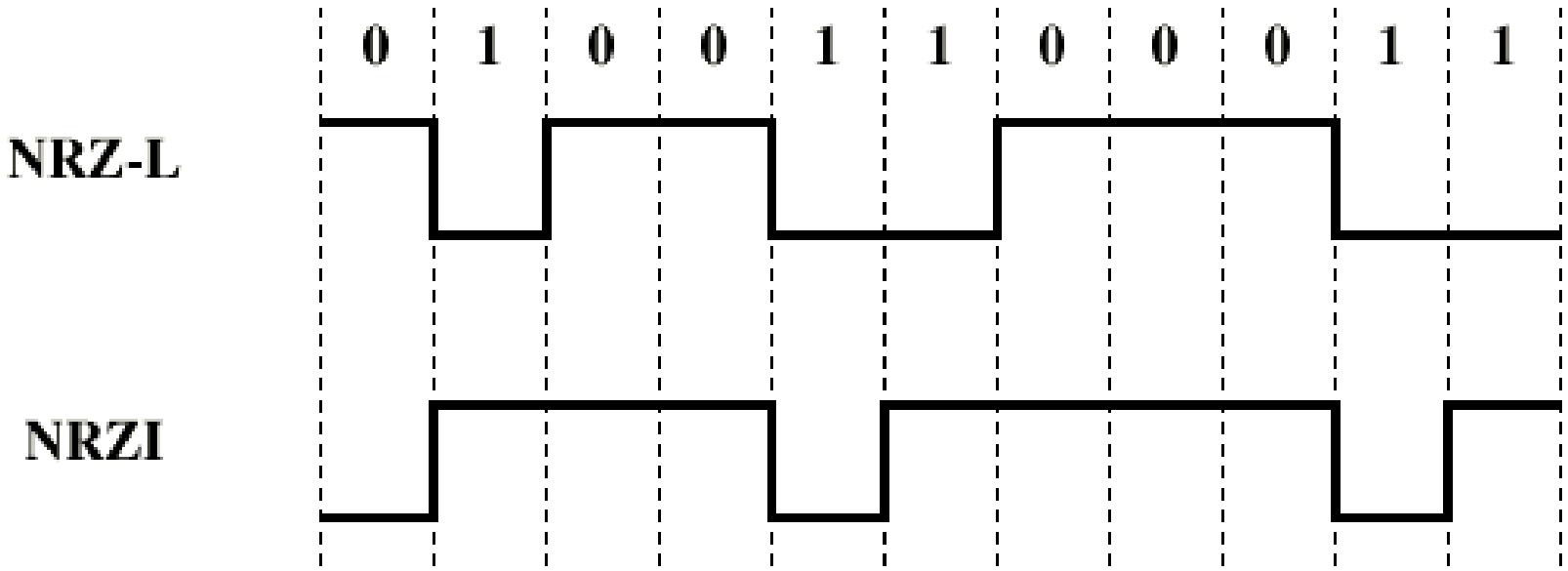
Comparison of Encoding Schemes (2)

- Error detection
  - Can be built in to signal encoding
- Signal interference and noise immunity
  - Some codes are better than others
- Cost and complexity
  - Higher signal rate (& thus data rate) lead to higher costs
  - Some codes require signal rate greater than data rate

Nonreturn to Zero Inverted

- Nonreturn to zero inverted on ones
- Constant voltage pulse for duration of bit
- Data encoded as presence or absence of signal transition at beginning of bit time
- Transition (low to high or high to low) denotes a binary 1
- No transition denotes binary 0
- An example of differential encoding

NRZ



Differential Encoding

- Data represented by changes rather than levels
- More reliable detection of transition rather than level
- In complex transmission layouts it is easy to lose sense of polarity

Modulation Rate

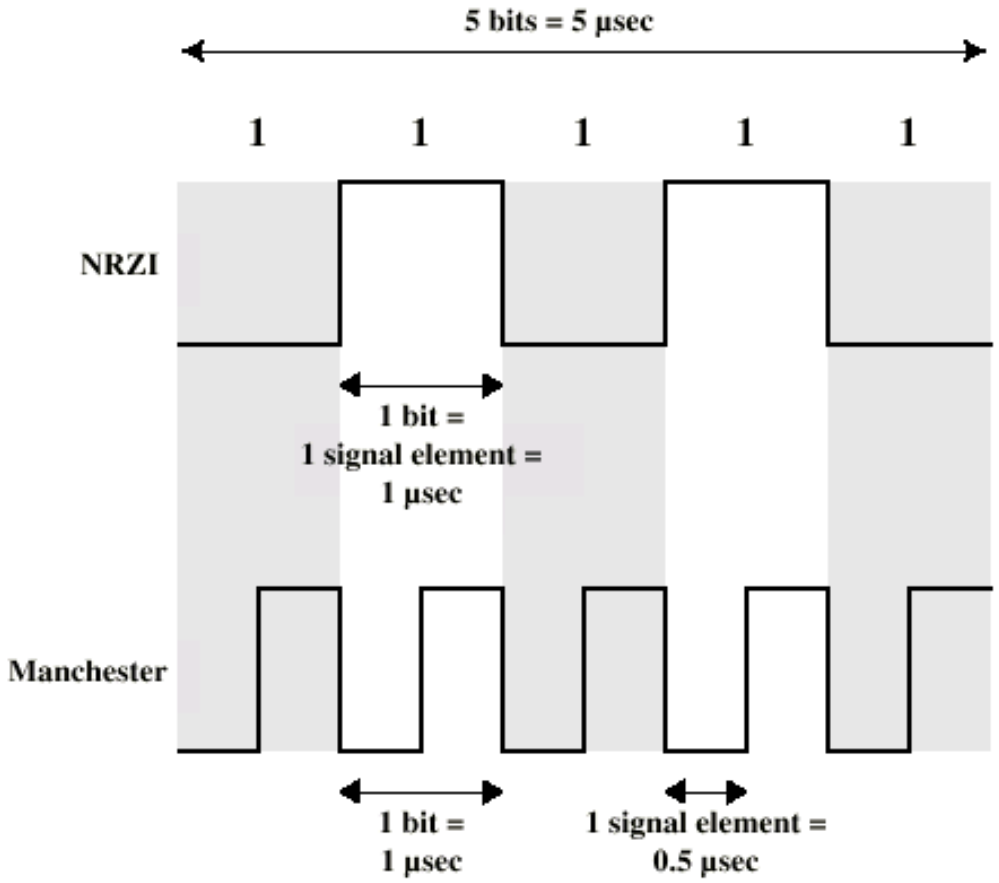
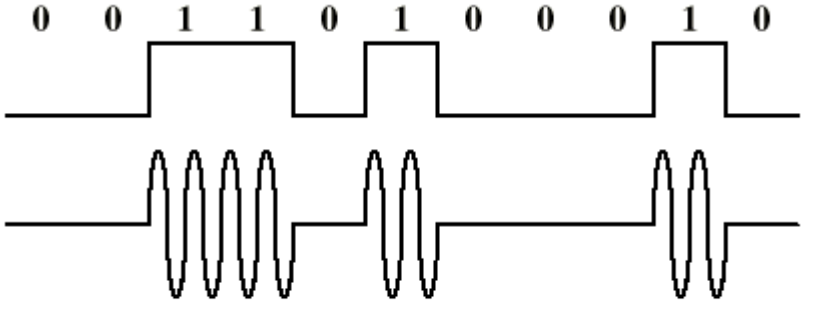


Figure 5.5 A Stream of Binary Ones at 1 Mbps

Digital Data, Analog Signal

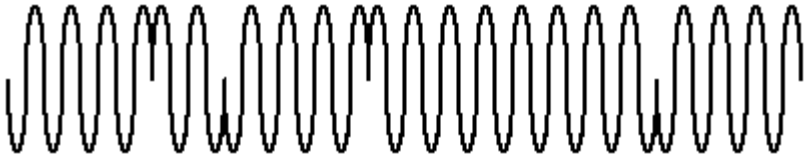
- Public telephone system
  - 300Hz to 3400Hz
  - Use modem (modulator-demodulator)
- Amplitude shift keying (ASK)
- Frequency shift keying (FSK)
- Phase shift keying (PK)

Modulation Techniques



(a) Amplitude-shift keying

(b) Frequency-shift keying



(c) Phase-shift keying

Amplitude Shift Keying

- Values represented by different amplitudes of carrier
- Usually, one amplitude is zero
  - i.e. presence and absence of carrier is used
- Susceptible to sudden gain changes
- Inefficient
- Up to 1200bps on voice grade lines
- Used over optical fiber

Frequency Shift Keying

- Values represented by different frequencies (near carrier)
- Less susceptible to error than ASK
- Up to 1200bps on voice grade lines
- High frequency radio
- Even higher frequency on LANs using co-ax

FSK on Voice Grade Line

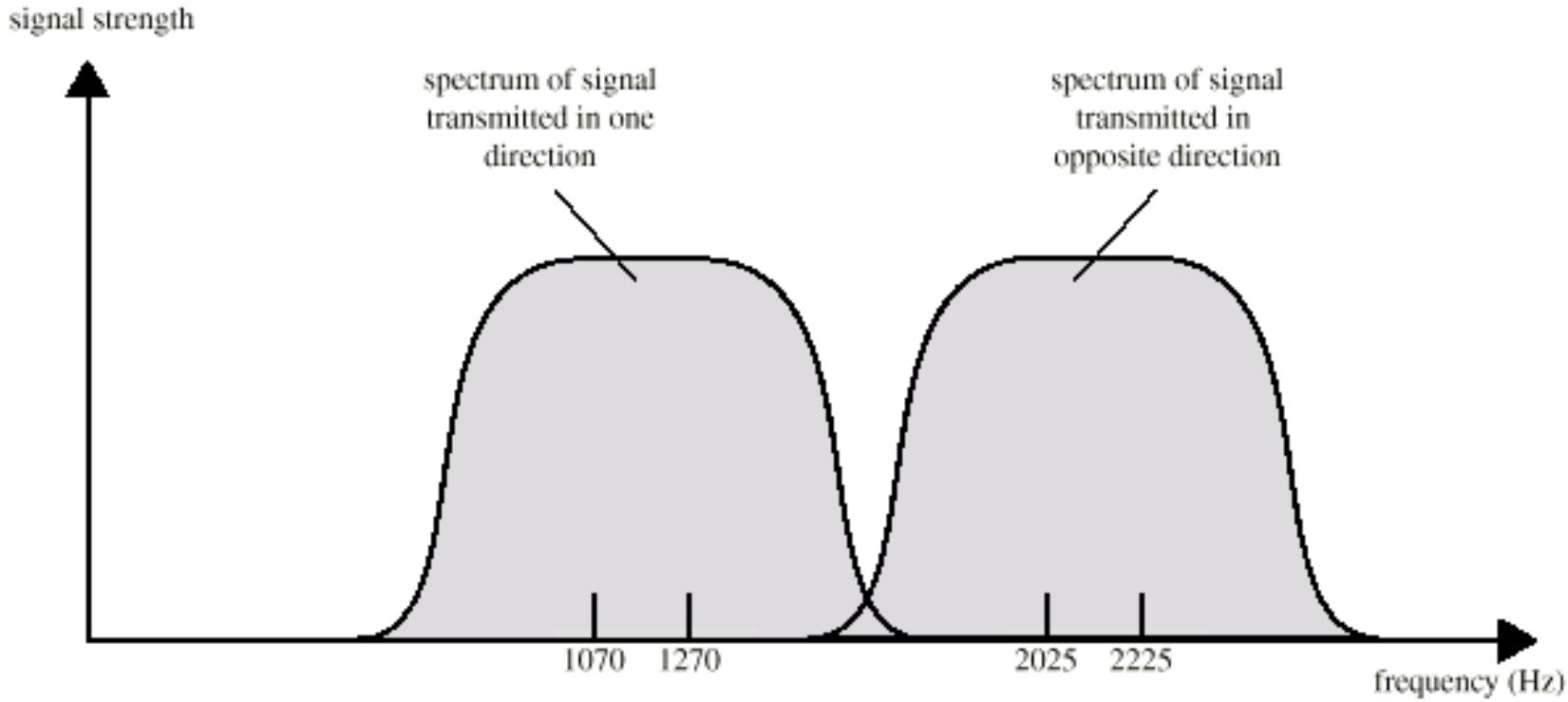


Figure 5.8 Full-Duplex FSK Transmission on a Voice-Grade Line

Phase Shift Keying

- Phase of carrier signal is shifted to represent data
- Differential PSK
  - Phase shifted relative to previous transmission rather than some reference signal

Quadrature PSK

- More efficient use by each signal element representing more than one bit
  - e.g. shifts of $\pi/2$ (90^o)
  - Each element represents two bits
  - Can use 8 phase angles and have more than one amplitude
  - 9600bps modem use 12 angles , four of which have two amplitudes

Performance of Digital to Analog Modulation Schemes

- Bandwidth
  - ASK and PSK bandwidth directly related to bit rate
  - FSK bandwidth related to data rate for lower frequencies, but to offset of modulated frequency from carrier at high frequencies
  - (See Stallings for math)
- In the presence of noise, bit error rate of PSK and QPSK are about 3dB superior to ASK and FSK

Analog Data, Digital Signal

- Digitization
  - Conversion of analog data into digital data
  - Digital data can then be transmitted using NRZ-L
  - Digital data can then be transmitted using code other than NRZ-L
  - Digital data can then be converted to analog signal
  - Analog to digital conversion done using a codec
  - Pulse code modulation
  - Delta modulation

Pulse Code Modulation(PCM) (1)

- If a signal is sampled at regular intervals at a rate higher than twice the highest signal frequency, the samples contain all the information of the original signal
  - (Proof - Stallings appendix 4A)
- Voice data limited to below 4000Hz
- Require 8000 sample per second
- Analog samples (Pulse Amplitude Modulation, PAM)
- Each sample assigned digital value

Pulse Code Modulation(PCM) (2)

- 4 bit system gives 16 levels
- Quantized
  - Quantizing error or noise
  - Approximations mean it is impossible to recover original exactly
- 8 bit sample gives 256 levels
- Quality comparable with analog transmission
- 8000 samples per second of 8 bits each gives 64kbps

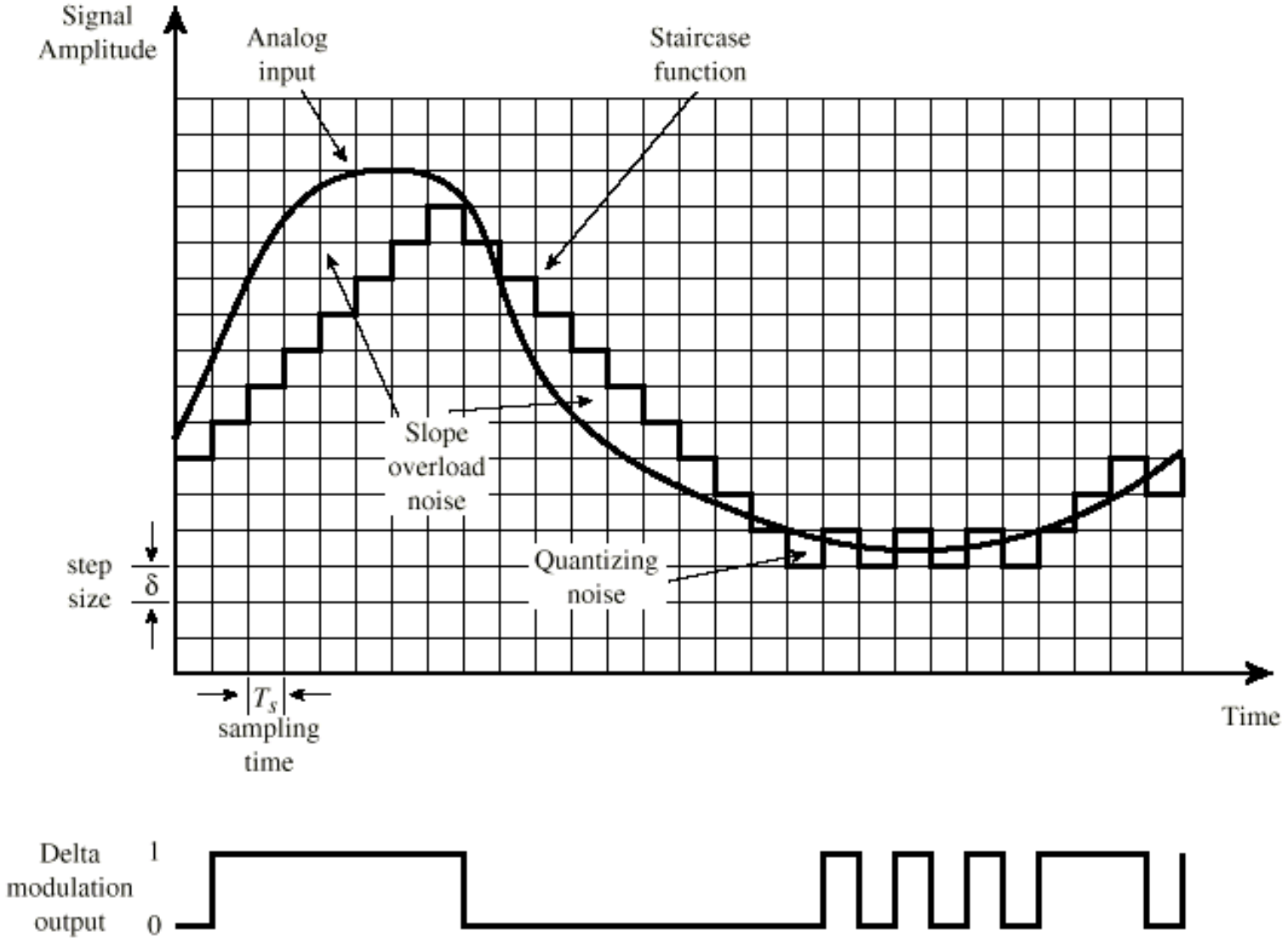
Nonlinear Encoding

- Quantization levels not evenly spaced
- Reduces overall signal distortion
- Can also be done by companding

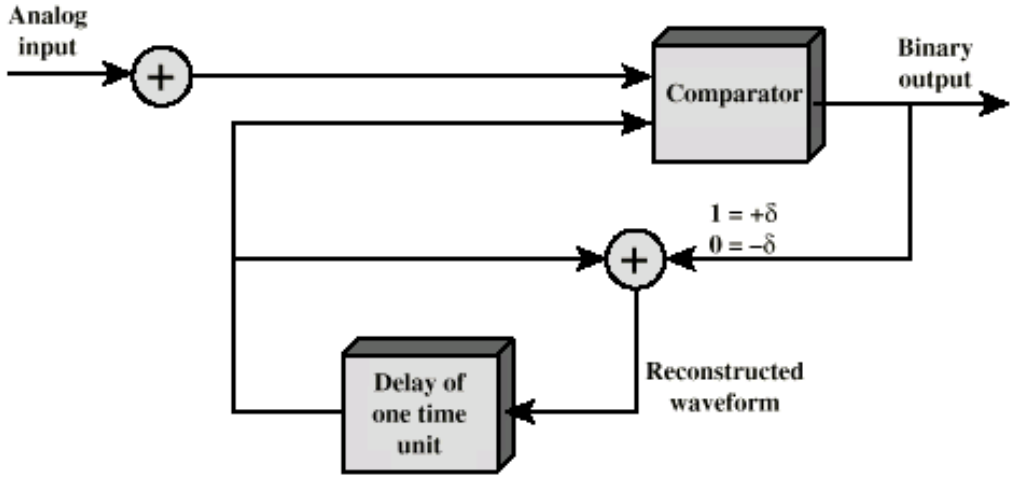
Delta Modulation

- Analog input is approximated by a staircase function
- Move up or down one level (δ) at each sample interval
- Binary behavior
  - Function moves up or down at each sample interval

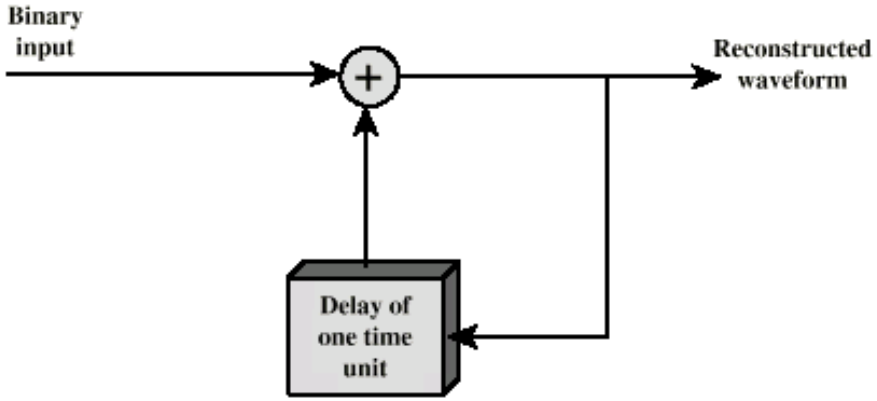
Delta Modulation - example



Delta Modulation - Operation



(a) Transmission



(b) Reception

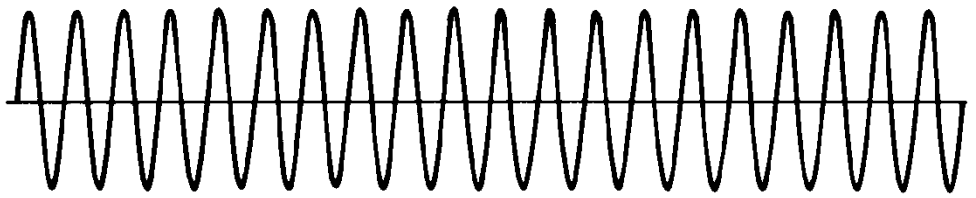
Delta Modulation - Performance

- Good voice reproduction
  - PCM - 128 levels (7 bit)
  - Voice bandwidth 4khz
  - Should be 8000 x 7 = 56kbps for PCM
- Data compression can improve on this
  - e.g. Interframe coding techniques for video

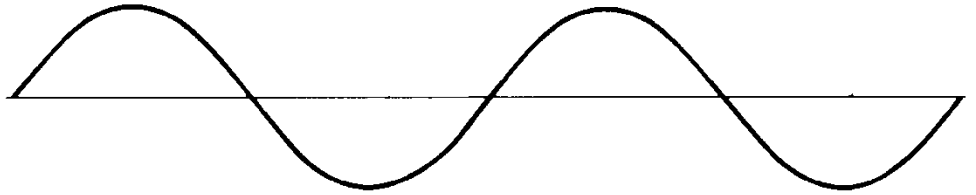
Analog Data, Analog Signals

- Why modulate analog signals?
  - Higher frequency can give more efficient transmission
  - Permits frequency division multiplexing (chapter 8)
- Types of modulation
  - Amplitude
  - Frequency
  - Phase

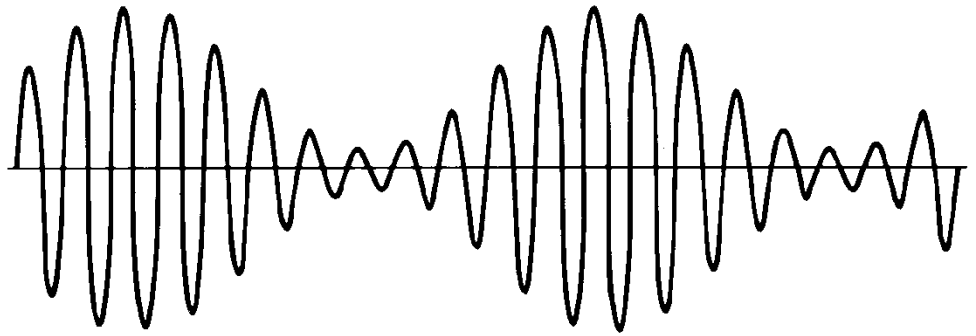
Analog Modulation



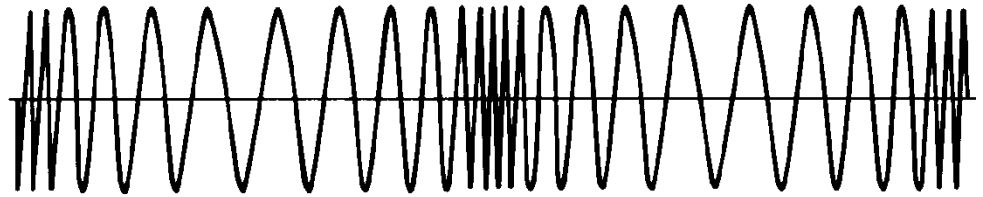
Carrier



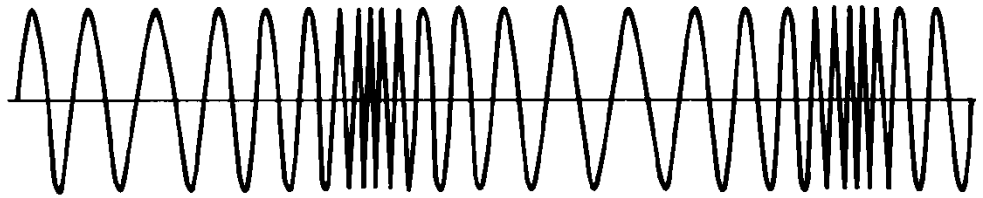
Modulating sine-wave signal



Amplitude-modulated (DSBTC) wave



Phase-modulated wave



Frequency-modulated wave

Spread Spectrum

- Analog or digital data
- Analog signal
- Spread data over wide bandwidth
- Makes jamming and interception harder
- Frequency hoping
  - Signal broadcast over seemingly random series of frequencies
- Direct Sequence
  - Each bit is represented by multiple bits in transmitted signal
  - Chipping code