

Data Communications

05 – Signal Encoding Techniques

Signal Encoding Techniques

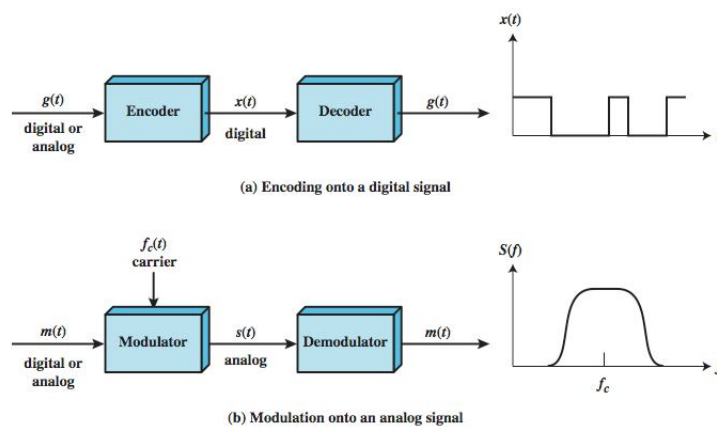
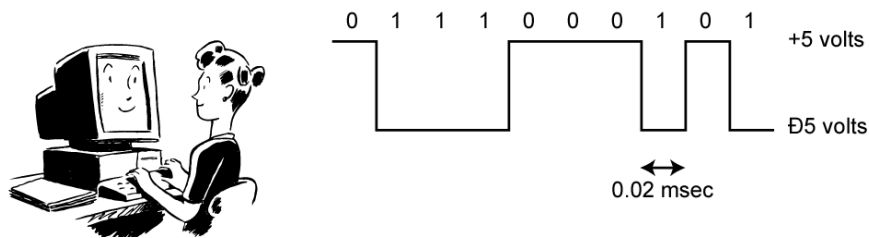


Figure 5.1 Encoding and Modulation Techniques

Digital Data, Digital Signal

- Digital signal
 - discrete, discontinuous voltage pulses
 - each pulse is a signal element
 - binary data encoded into signal elements



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Some Terms

- unipolar
- polar
- data rate
- duration or length of a bit
- modulation rate
- mark and space

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Interpreting Signals

- need to know
 - timing of bits - when they start and end
 - signal levels
- factors affecting signal interpretation
 - signal to noise ratio
 - data rate
 - bandwidth
 - encoding scheme

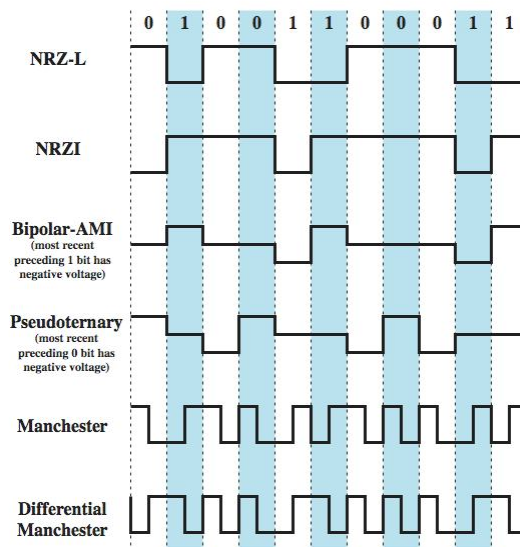
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Comparison of Encoding Schemes

- signal spectrum
- clocking
- error detection
- signal interference and noise immunity
- cost and complexity

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Encoding Schemes



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Nonreturn to Zero-Level (NRZ-L)

- two different voltages for 0 and 1 bits
- voltage constant during bit interval
 - no transition i.e. no return to zero voltage
 - such as absence of voltage for zero, constant positive voltage for one
 - more often, negative voltage for one value and positive for the other

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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 binary 1
 - no transition denotes binary 0
- example of differential encoding since have
 - data represented by changes rather than levels
 - more reliable detection of transition rather than level
 - easy to lose sense of polarity

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NRZ Pros & Cons

- Pros
 - easy to engineer
 - make good use of bandwidth
- Cons
 - dc component
 - lack of synchronization capability
- used for magnetic recording
- not often used for signal transmission

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Multilevel Binary Bipolar-AMI

- Use more than two levels
- Bipolar-AMI
 - zero represented by no line signal
 - one represented by positive or negative pulse
 - one pulses alternate in polarity
 - no loss of sync if a long string of ones
 - long runs of zeros still a problem
 - no net dc component
 - lower bandwidth
 - easy error detection

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Multilevel Binary Pseudoternary

- one represented by absence of line signal
- zero represented by alternating positive and negative
- no advantage or disadvantage over bipolar-AMI
- each used in some applications

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Multilevel Binary Issues

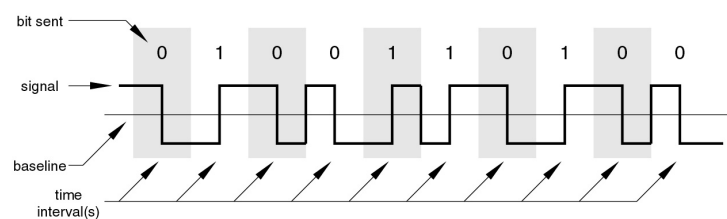
- synchronization with long runs of 0's or 1's
 - can insert additional bits, cf ISDN
 - scramble data (later)
- not as efficient as NRZ
 - each signal element only represents one bit
 - receiver distinguishes between three levels: +A, -A, 0
 - a 3 level system could represent $\log_2 3 = 1.58$ bits
 - requires approx. 3dB more signal power for same probability of bit error

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Manchester Encoding

- has transition in middle of each bit period
- transition serves as clock and data
- low to high represents one
- high to low represents zero
- used by IEEE 802.

Manchester Encoding

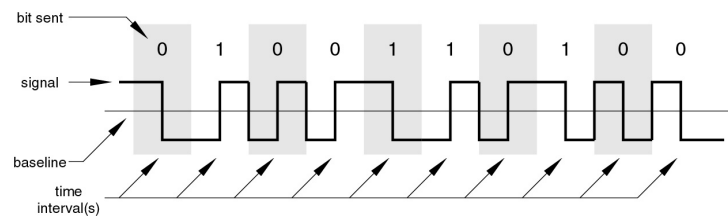


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Differential Manchester Encoding

- midbit transition is clocking only
- transition at start of bit period representing 0
- no transition at start of bit period representing 1
 - this is a differential encoding scheme
- used by IEEE 802.5

Differential Manchester Encoding



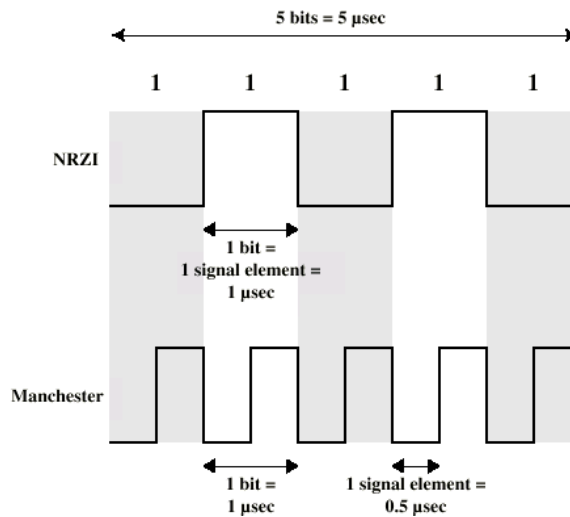
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Biphase Pros and Cons

- Con
 - at least one transition per bit time and possibly two
 - maximum modulation rate is twice NRZ
 - requires more bandwidth
- Pros
 - synchronization on mid bit transition (self clocking)
 - has no dc component
 - has error detection

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Modulation Rate



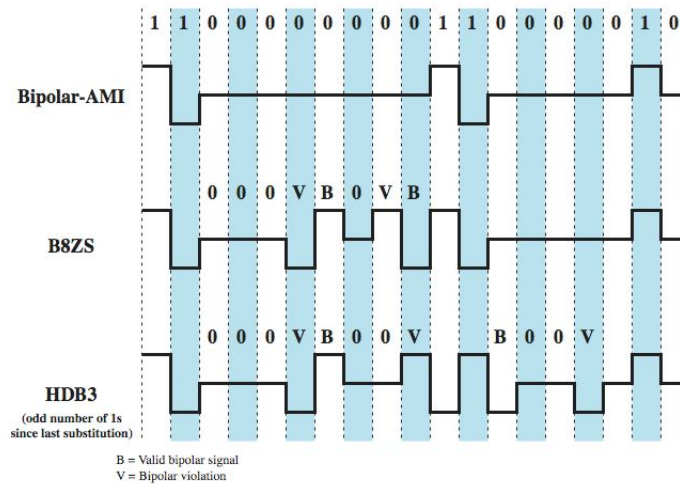
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Scrambling

- use scrambling to replace sequences that would produce constant voltage
- these filling sequences must
 - produce enough transitions to sync
 - be recognized by receiver & replaced with original
 - be same length as original
- design goals
 - have no dc component
 - have no long sequences of zero level line signal
 - have no reduction in data rate
 - give error detection capability

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B8ZS and HDB3

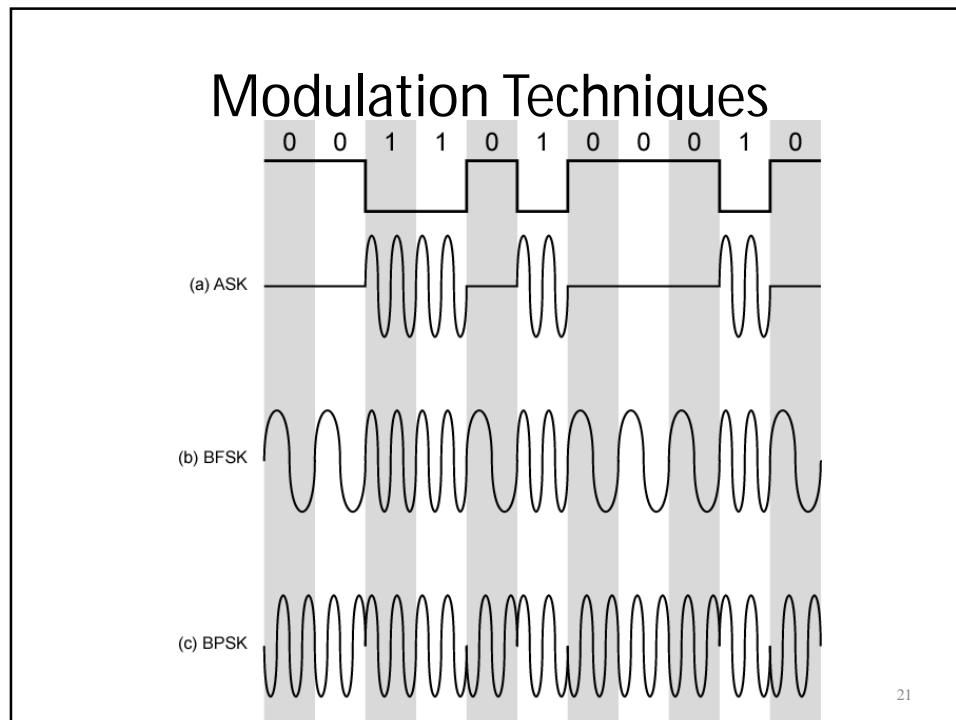


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Digital Data, Analog Signal

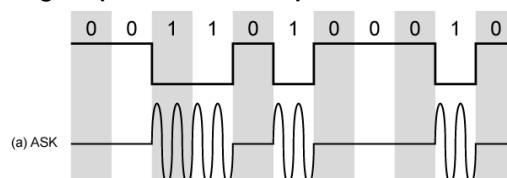
- main use is public telephone system
 - has freq range of 300Hz to 3400Hz
 - use modem (modulator-demodulator)
- encoding techniques
 - Amplitude shift keying (ASK)
 - Frequency shift keying (FSK)
 - Phase shift keying (PK)

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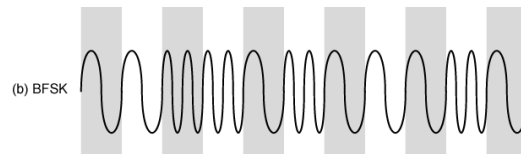
Amplitude Shift Keying

- encode 0/1 by different carrier amplitudes
 - usually have one amplitude zero
- susceptible to sudden gain changes
- inefficient
- used for
 - up to 1200bps on voice grade lines
 - very high speeds over optical fiber



Binary Frequency Shift Keying

- most common is binary FSK (BFSK)
- two binary values represented by two different frequencies (near carrier)
- less susceptible to error than ASK
- used for
 - up to 1200bps on voice grade lines
 - high frequency radio
 - even higher frequency on LANs using co-ax



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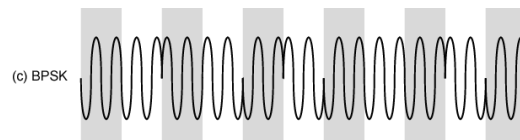
Multiple FSK

- each signalling element represents more than one bit
- more than two frequencies used
- more bandwidth efficient
- more prone to error

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Phase Shift Keying

- phase of carrier signal is shifted to represent data
- binary PSK
 - two phases represent two binary digits
- differential PSK
 - phase shifted relative to previous transmission rather than some reference signal



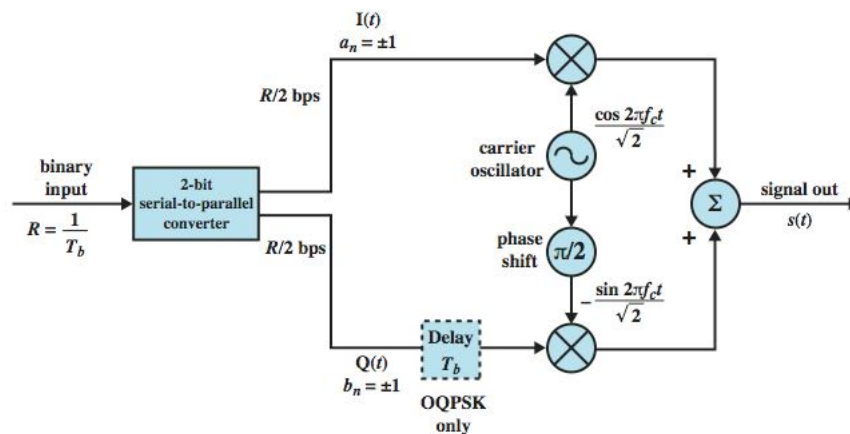
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Quadrature PSK

- get more efficient use if each signal element represents more than one bit
 - eg. shifts of $\pi/2$ (90°)
 - each element represents two bits
 - split input data stream in two & modulate onto carrier & phase shifted carrier
- can use 8 phase angles & more than one amplitude
 - 9600bps modem uses 12 angles, four of which have two amplitudes

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QPSK and OQPSK Modulators



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Performance of Digital to Analog Modulation Schemes

- bandwidth
 - ASK/PSK bandwidth directly relates to bit rate
 - multilevel PSK gives significant improvements
- in presence of noise:
 - bit error rate of PSK and QPSK are about 3dB superior to ASK and FSK
 - for MFSK & MPSK have tradeoff between bandwidth efficiency and error performance

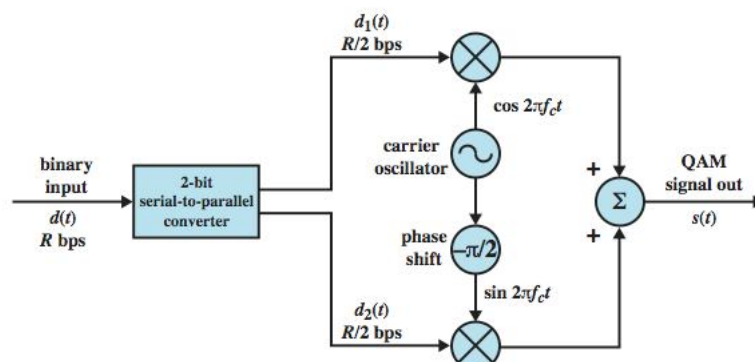
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Quadrature Amplitude Modulation

- QAM used on asymmetric digital subscriber line (ADSL) and some wireless
- combination of ASK and PSK
- logical extension of QPSK
- send two different signals simultaneously on same carrier frequency
 - use two copies of carrier, one shifted 90°
 - each carrier is ASK modulated
 - two independent signals over same medium
 - demodulate and combine for original binary output

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QAM Modulator



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QAM Variants

- two level ASK
 - each of two streams in one of two states
 - four state system
 - essentially QPSK
- four level ASK
 - combined stream in one of 16 states
- have 64 and 256 state systems
- improved data rate for given bandwidth
 - but increased potential error rate

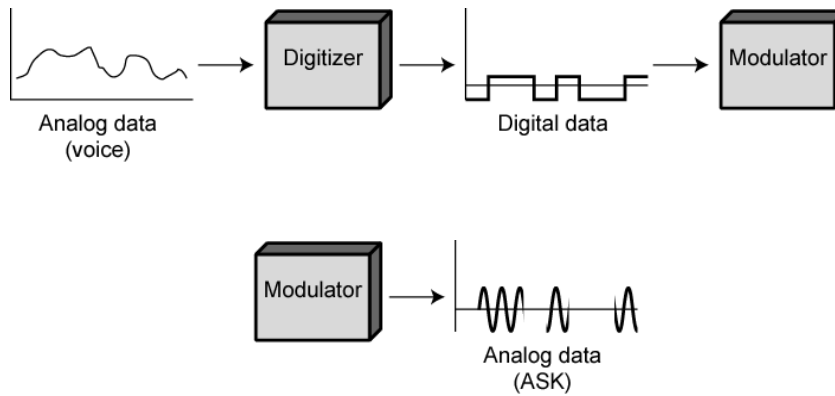
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Analog Data, Digital Signal

- digitization is conversion of analog data into digital data which can then:
 - be transmitted using NRZ-L
 - be transmitted using code other than NRZ-L
 - be converted to analog signal
- analog to digital conversion done using a codec
 - pulse code modulation
 - delta modulation

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Digitizing Analog Data



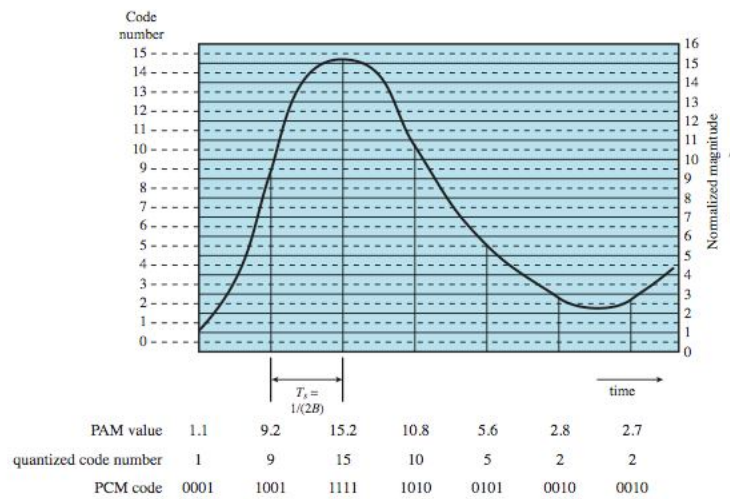
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Pulse Code Modulation (PCM)

- sampling theorem:
 - “If a signal is sampled at regular intervals at a rate higher than twice the highest signal frequency, the samples contain all information in original signal”
 - eg. 4000Hz voice data, requires 8000 sample per sec
- strictly have analog samples
 - Pulse Amplitude Modulation (PAM)
- so assign each a digital value

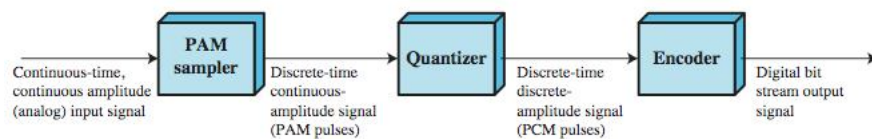
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PCM Example



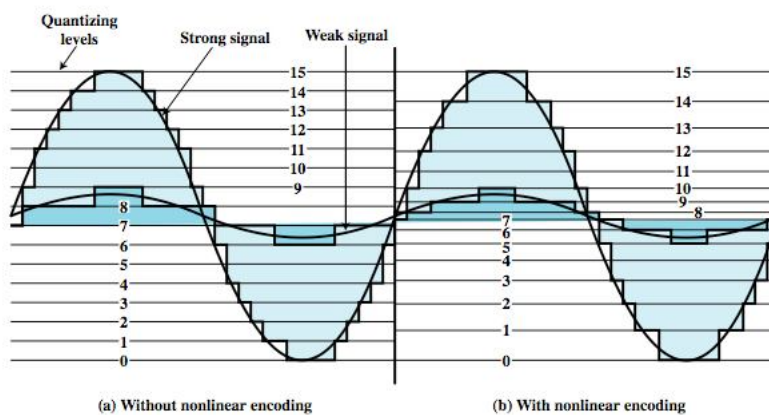
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PCM Block Diagram



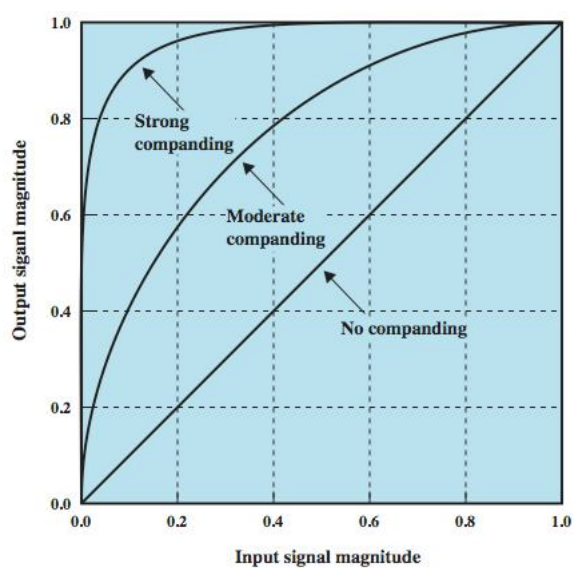
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Non-Linear Coding



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Companding



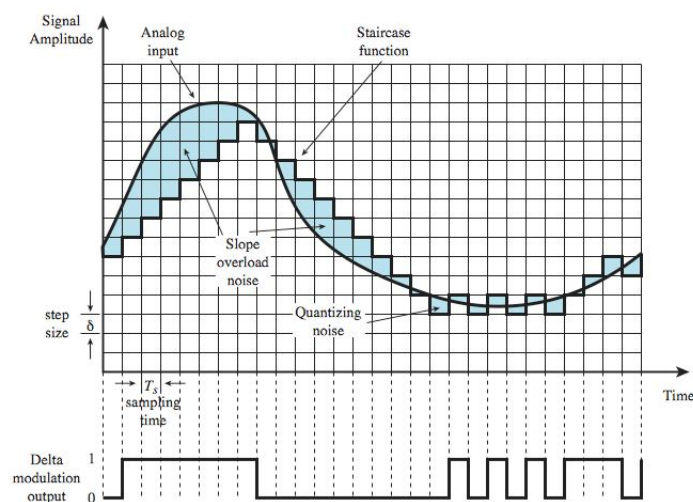
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Delta Modulation

- analog input is approximated by a staircase function
 - can move up or down one level (δ) at each sample interval
- has binary behavior
 - since function only moves up or down at each sample interval
 - hence can encode each sample as single bit
 - 1 for up or 0 for down

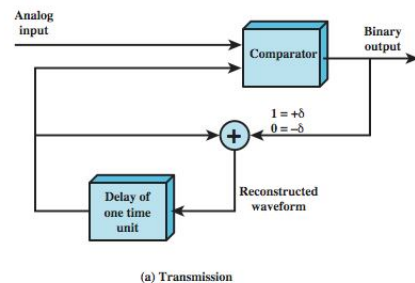
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Delta Modulation Example

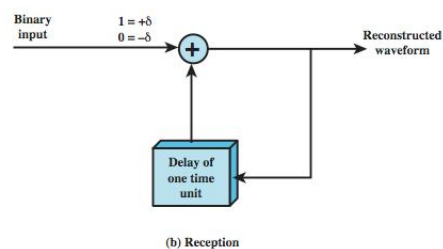


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Delta Modulation Operation



(a) Transmission



(b) Reception

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PCM verses Delta Modulation

- DM has simplicity compared to PCM
- but has worse SNR
- issue of bandwidth used
 - eg. for good voice reproduction with PCM
 - want 128 levels (7 bit) & voice bandwidth 4khz
 - need $8000 \times 7 = 56\text{kbps}$
- data compression can improve on this
- still growing demand for digital signals
 - use of repeaters, TDM, efficient switching
- PCM preferred to DM for analog signals

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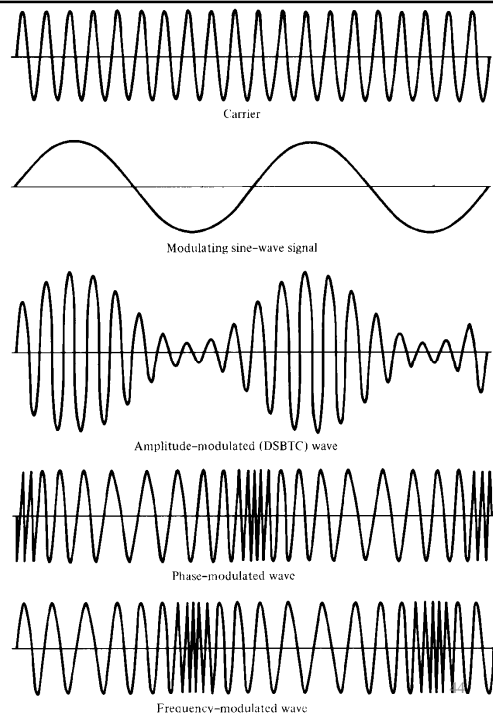
Analog Data, Analog Signals

- modulate carrier frequency with analog data
- why modulate analog signals?
 - higher frequency can give more efficient transmission
 - permits frequency division multiplexing (chapter 8)
- types of modulation
 - Amplitude
 - Frequency
 - Phase

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Analog Modulation Techniques

- Amplitude Modulation
- Frequency Modulation
- Phase Modulation



Summary

- looked at signal encoding techniques
 - digital data, digital signal
 - analog data, digital signal
 - digital data, analog signal
 - analog data, analog signal

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