Signals, Encoding and Modulation

Sulochana Sooriyaarachchi
Gihan Dias

CS2032 – Principles of Computer Communication

2012 Batch – July 2014

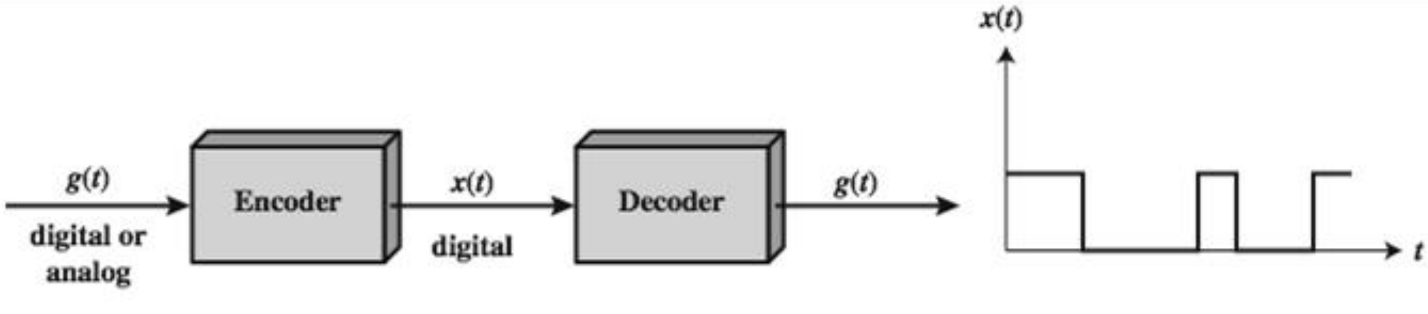
Outcomes

- After successful completion of this lesson you will be able to:
- Identify and compare different techniques for encoding data into signals

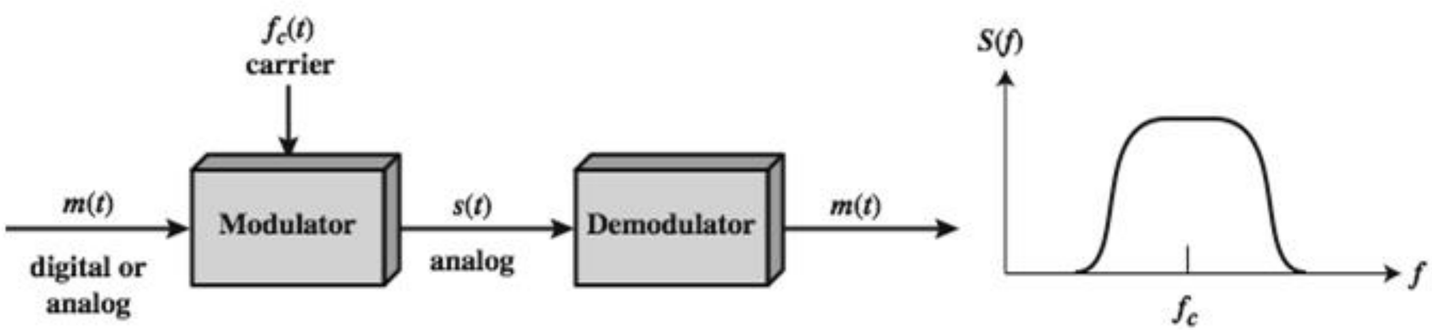
Encoding and Modulation

- Encoding takes a digital or an analog signal and converts it to a form suitable for sending on a wire or a fibre
- Baseband
- Modulation takes a digital or an analog signal and modifies a *carrier* signal with it
- Passband

Encoding and Modulation



(a) Encoding onto a digital signal



(b) Modulation onto an analog signal

Forms of Encoding and Modulation

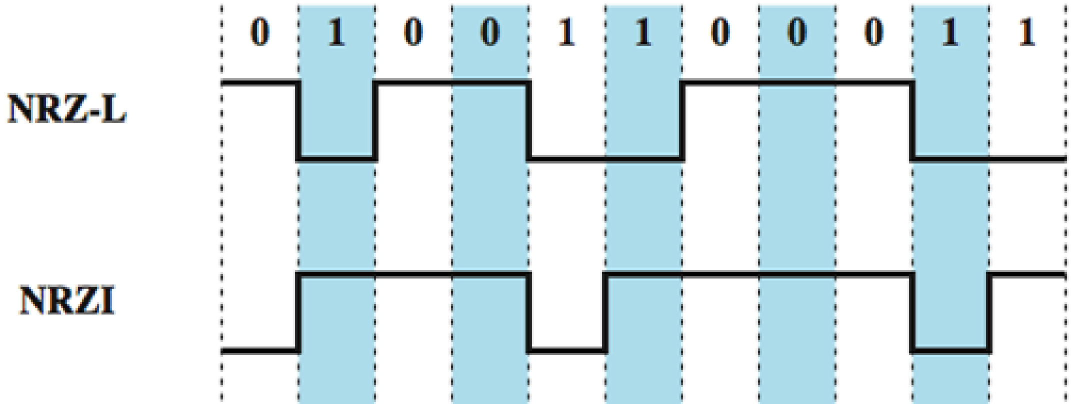
- Digital Data, Digital Baseband Signal
  - e.g. Computer file sent on a Network cable
- Digital Data, Analog Carrier Signal
  - e.g. a computer file sent on a wireless network
- Analog Data, Digital Data
  - e.g. sound stored on computer
  - can then be transmitted on a baseband or carrier signal
- Analog Data, Analog Carrier Signal
  - e.g. sound transmitted on FM radio

Digital Data,
Digital Baseband Signal

Data bits encoded into voltage pulses

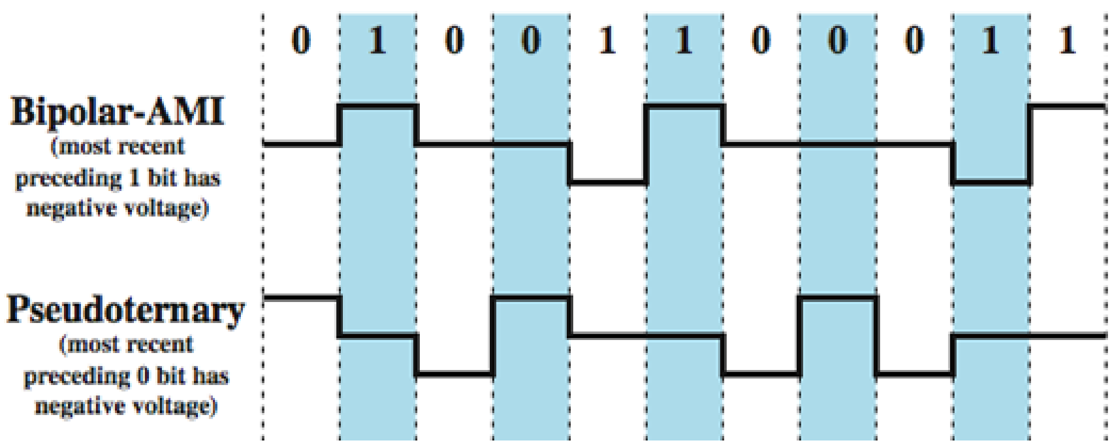
NRZ

- **N**o**R**eturn to **Z**ero-**L**evel (NRZ-L)
- Presence (0) or absence (1) of**voltage**
- **N**o**R**eturn to **Z**ero, **I**nvert on ones (NRZI)
- Presence (1) or absence (0) of a **transition**
- A differential encoding



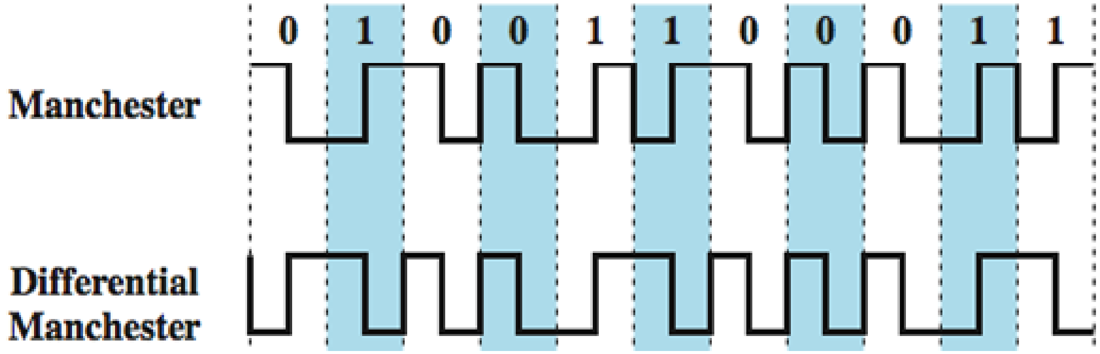
Multilevel Binary

- Uses more than 2 signal levels
- Bipolar AMI
  - No signal (0), positive pulse (1) and negative pulse (1)
- Pseudoternary
  - No signal (1), positive pulse (0) and negative pulse (0)

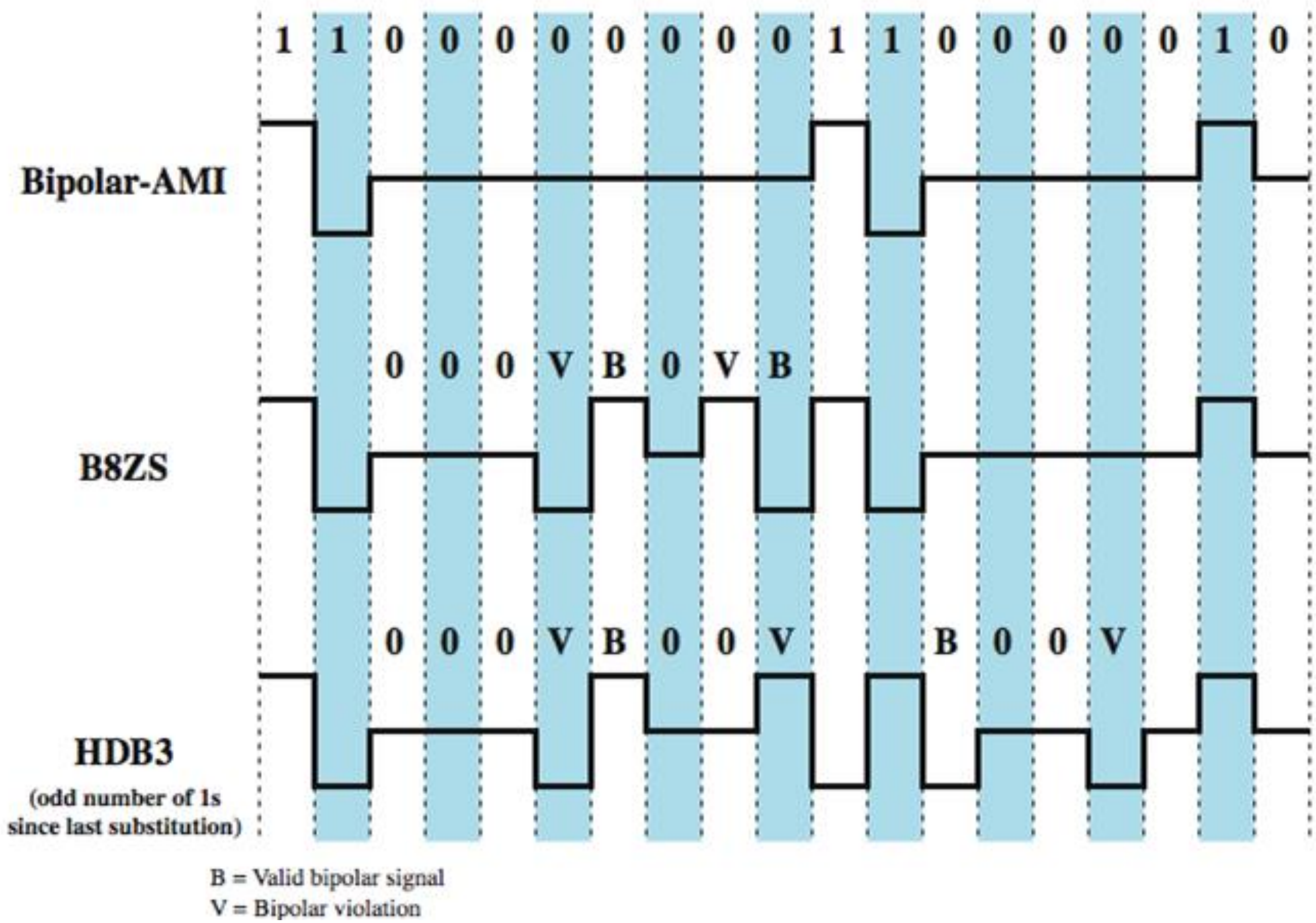


Biphase

- Transition at the middle of bit period as clocking
- Manchester
  - Midbittransition for both clocking and data
  - Low-to-high (1), high-to-low (0)
- Differential Manchester
  - Midbittransition only for clocking
  - Transition at beginning of bit period(0), no transition at the beginning of bit period(1)



Scrambling schemes



Scrambling schemes(2)

- **B**ipolar with **8-Z**eros **S**ubstitution (B8ZS)
- Replace octets of all zeros with **000+-0-+** if the last pulse preceding the octet is positive
- Replace octets of all zeros with **000-+0+-** if the last pulse preceding the octet is negative
- **H**igh-**D**ensity **B**ipolar **3**-zeros (HDB3)
- Replace strings of 4 zeros

Polarity of preceding pulse	**odd**	**even**
-	000-	+00+
+	000+	-00-

Desired Characteristics of Signal

- No dc component
- As many transitions as possible for synchronization
- Noticeable difference in signal levels
- Manageable range of frequency components to reconstruct the signal after transmission

Comparison

- NRZ-L: difficult to synchronize sender and receiver
  - E.g. bit string of all ones or all zeros
- NRZ-I: synchronization still is problematic
  - E.g. bit string of all zeros
- NRZ is simple and low cost to implement
- Multilevel Binary: cancels off dc component as much as possible by alternating sign of voltage levels
- Manchester and Differential Manchester: clocking information is embedded in the signal itself

Digital Data, Analog Signal

e.g. 1) To produce analog signal of voice frequency range, to transmit over telephone network

2) to transmit digital data on an radio freq. carrier

Operates on one or more of

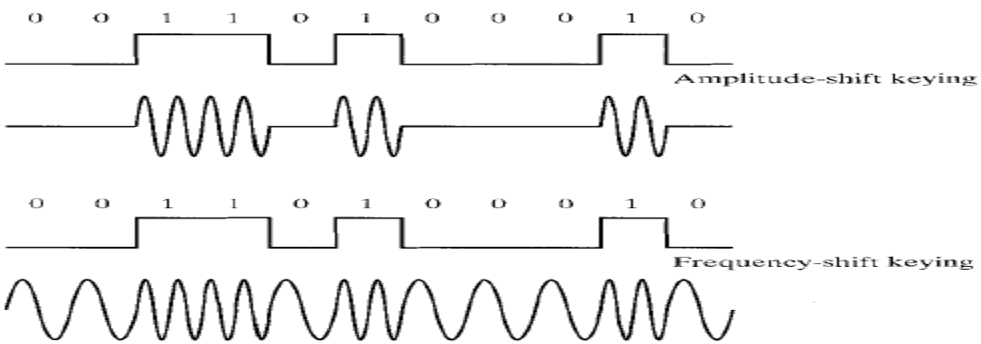
- Amplitude,
- Frequency and
- Phase

of the carrier signal

Amplitude Shift Keying (ASK)

- Two amplitudes to represent two binary values

$$s(t) = \begin{cases} A\cos(2\pi f_c t) & \text{binary } 1 \\ 0 & \text{binary } 0 \end{cases}$$



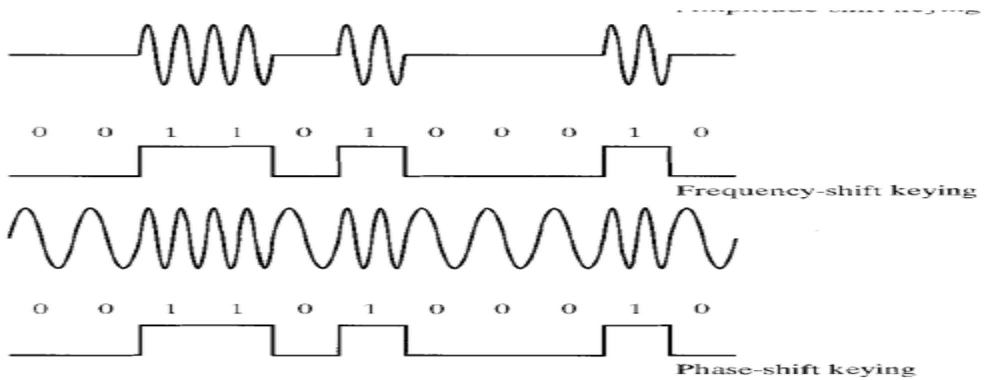
- Multiple amplitudes for representing multiple bits

$$s(t) = \begin{cases} A_1\cos(2\pi ft) & 00 \\ A_2\cos(2\pi ft) & 01 \\ A_3\cos(2\pi ft) & 10 \\ A_4\cos(2\pi ft) & 11 \end{cases}$$

Frequency Shift Keying (FSK)

- Two frequencies to represent two binary values (BFSK)

$$s(t) = \begin{cases} A\cos(2\pi f_1 t) & \text{binary } 1 \\ A\cos(2\pi f_2 t) & \text{binary } 0 \end{cases}$$



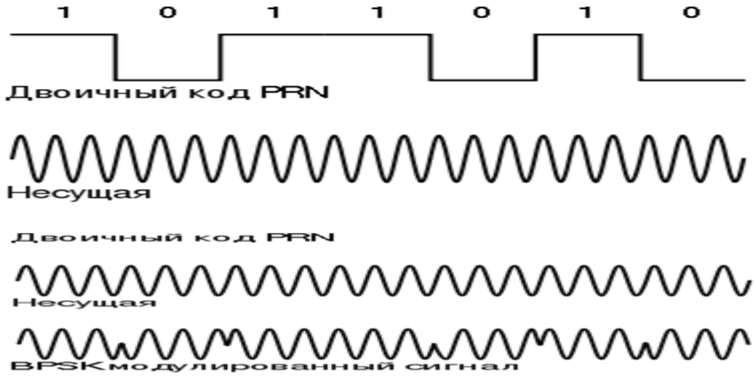
- Multiple frequencies to represent multiple bits at a time (MFSK)

$$s(t) = \begin{cases} A\cos(2\pi f_1 t) & 00 \\ A\cos(2\pi f_2 t) & 01 \\ A\cos(2\pi f_3 t) & 10 \\ A\cos(2\pi f_4 t) & 11 \end{cases}$$

Phase Shift Keying (PSK)

- Two phases to represent two binary values (BPSK)

$$s(t) = \begin{cases} A\cos(2\pi f_c t) & \text{binary 1} \\ A\cos(2\pi f_c t + \pi) & \text{binary 0} \end{cases}$$



- Multiple phases to represent multiple bits

$$s(t) = \begin{cases} A\cos(2\pi f_c t + 45^0) & 00 \\ A\cos(2\pi f_c t + 135^0) & 01 \\ A\cos(2\pi f_c t + 225^0) & 10 \\ A\cos(2\pi f_c t + 315^0) & 11 \end{cases}$$

Analysis of A/F/PSK

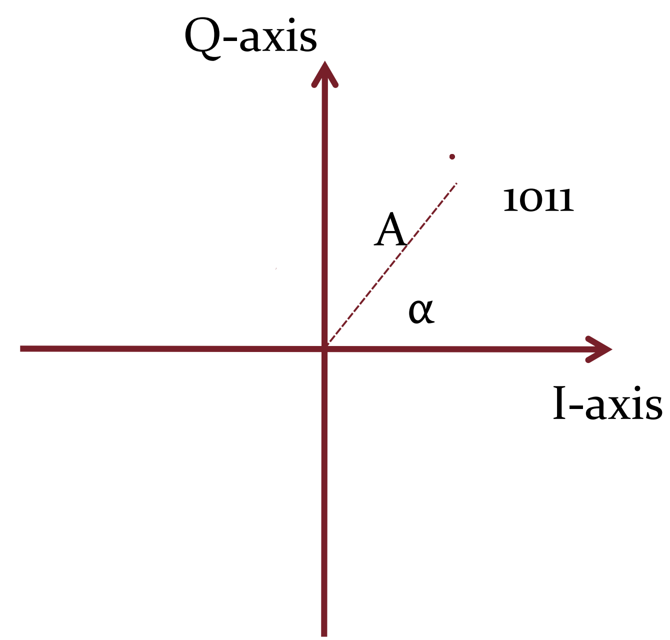
- One amplitude/frequency/phase per single bit gives a data rate equals to baud rate
- Higher data rates
  - Representing multiple bits with a single amplitude/frequency/phase
  - n bits per amplitude/frequency/phase→ assign 2^n amplitudes/frequencies/phases for combinations
- More different signals → More bits per baud
  - Combine amplitude, frequency and phase shifts
- Signals are represented in *constellation diagram*

Constellation Diagram

- Amplitude (A) and phase shifts (α) of a given sinusoidal signal is plotted with dots

$$s(t) = \{A_n \mathrm{Sin}(2\pi f_c + \alpha)$$

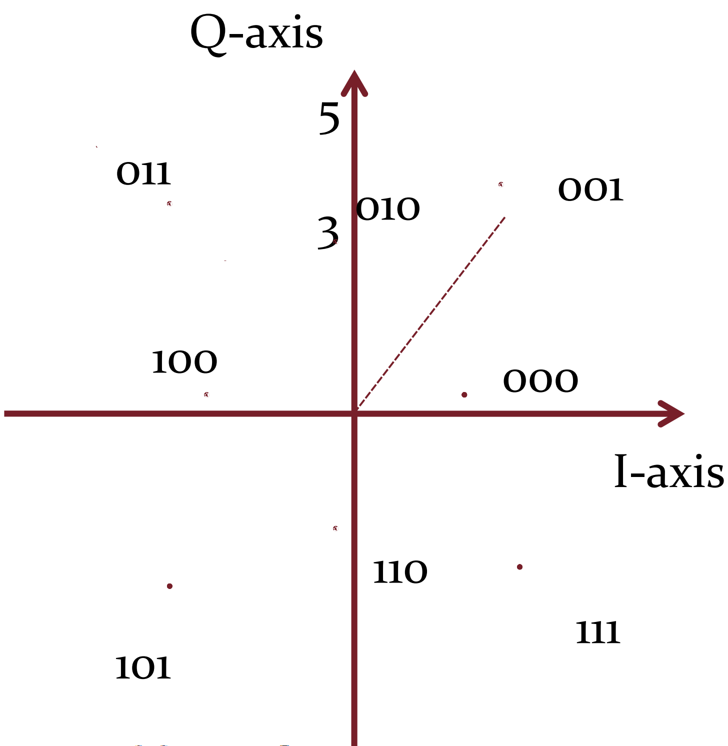
- Each dot interprets a bit string
- I: In-phase axis, Q:Quadratureaxis



QuadratureAmplitude Modulation (QAM)

- Combination of Amplitude and Phase Shifts

- E.g. a set of signals is given in Figure 1



$$s(t) = \{A_n \mathrm{Sin}(2\pi f_c + \alpha)$$

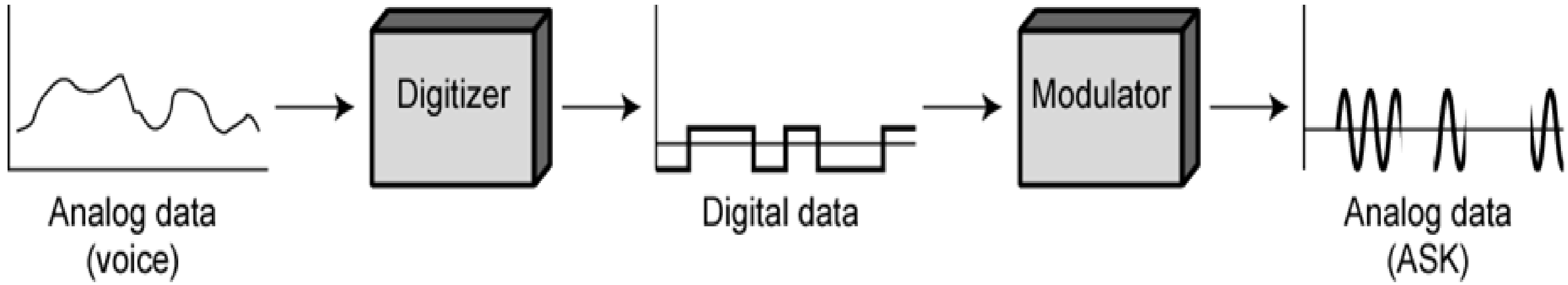
Figure 1: constellation diagram

Analog Data, Digital Data

The Digital Data may then be transmitted on a baseband or

Introduction

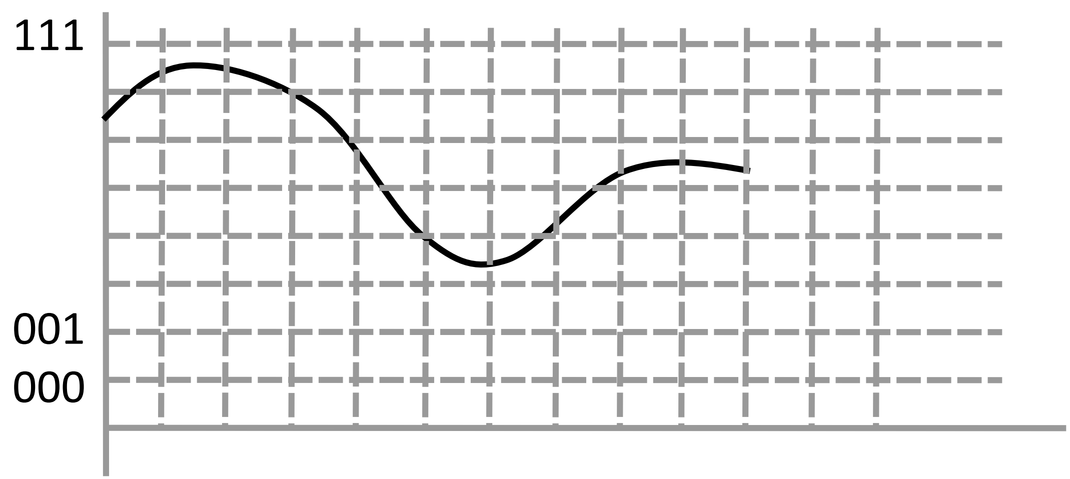
- Converting analog data to digital data (digitization)



- **Codec:**converts analog data into digital form and recovers the original analog data from digital signal
- Techniques used in codec
  - Pulse Code Modulation (PCM)
  - Delta Modulation (DM)

PCM – How to

- Divide the amplitude range into 2^n levels
- Assign each amplitude level a bit pattern of n bits
- Sample the analog signal periodically
- Approximate the amplitude of each sample to the most closely matching level



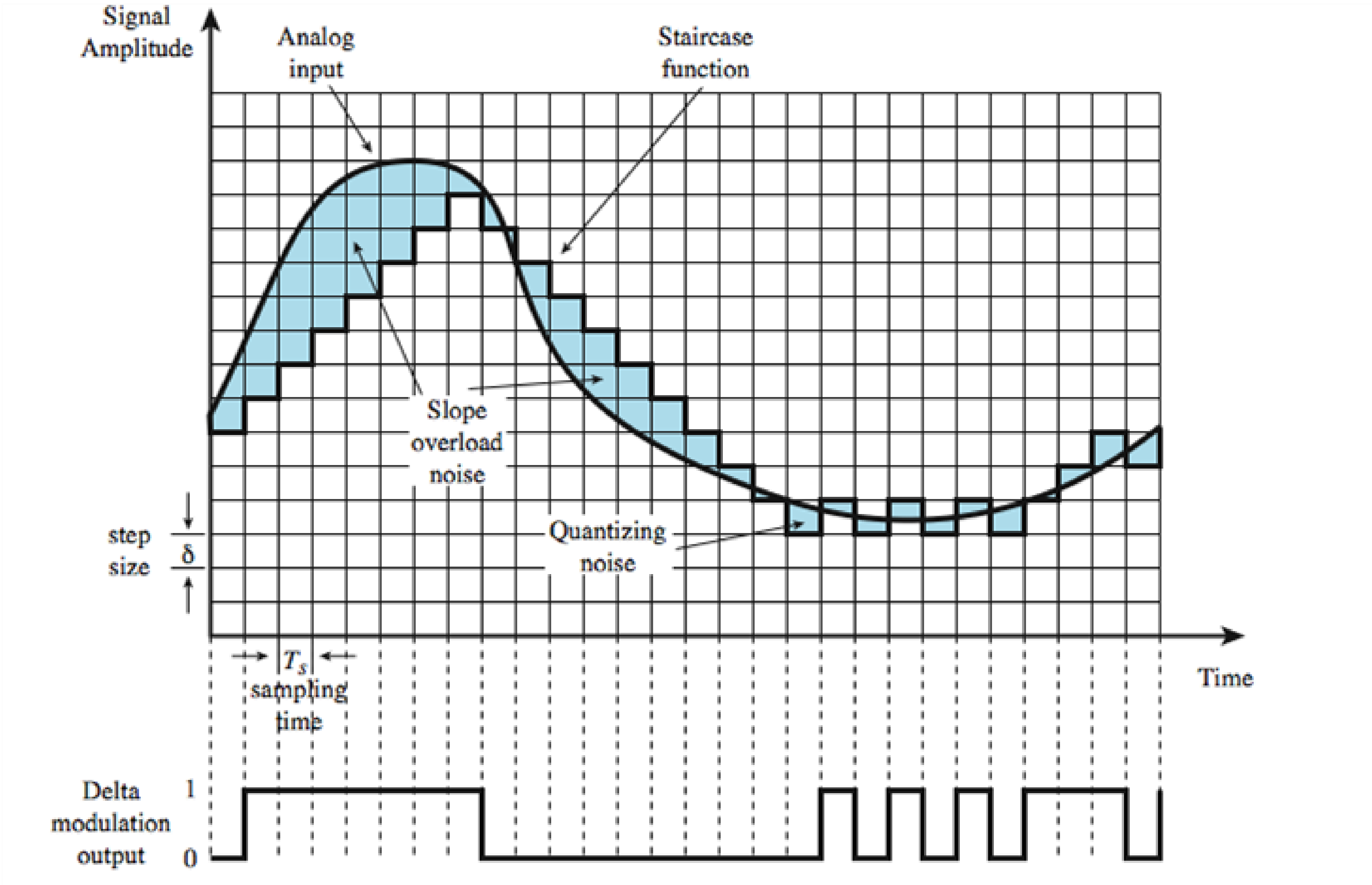
Analysis of PCM

- Accuracy of reconstructed signal
- Sampling rate?
- Number of amplitude levels?

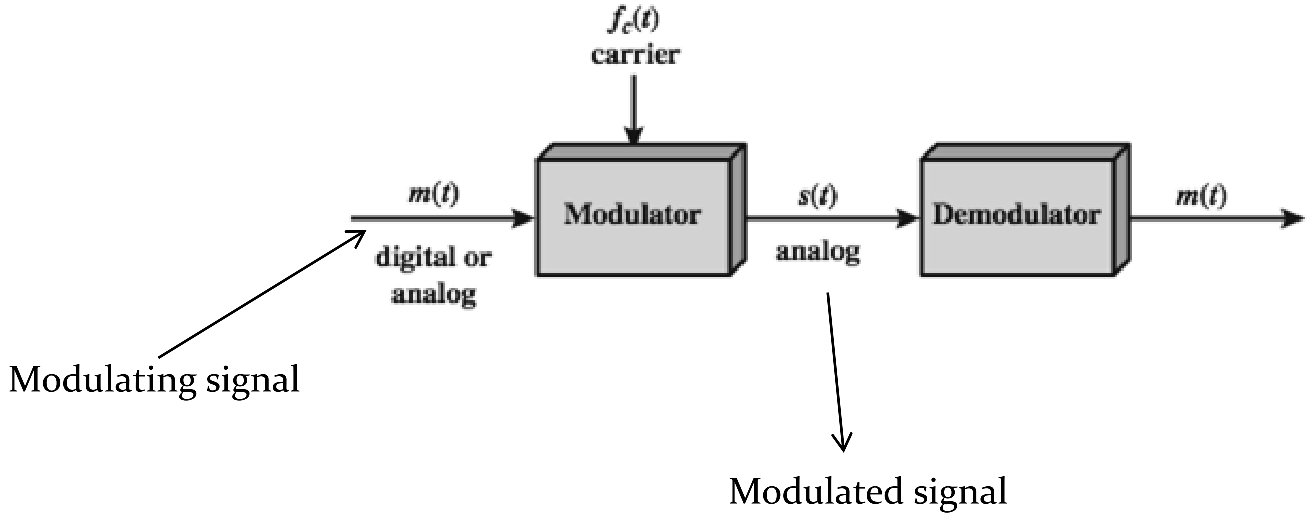
Delta Modulation (DM)

- 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
- can encode each sample as single bit (1 for up or 0 for down)

DM …continued



Analog Data, Analog Signal



Introduction

- Moving a signal from its baseband to a different frequency band (Modulation)
- Data is modulated on to a *carrier* wave
- Principal techniques:
  - Amplitude Modulation (AM)
  - Angle Modulation
    - Frequency Modulation (FM)
    - Phase Modulation (PM)

Amplitude Modulation (AM)

$$A(t) = A_c[1 + \mu\, m(t)]$$

where A(t) is the amplitude of the modulated signal, A_c is the amplitude of the carrier signal μ is the modulation index

$$f_c(t) = A_c \cos(\omega_c t)$$

$$s(t) = A_c[1 + \mu\, m(t)] \cos(\omega_c t)$$

$$s(t) = A_c \cos(\omega_c t) + \mu\, A_c m(t) \cos(\omega_c t)$$

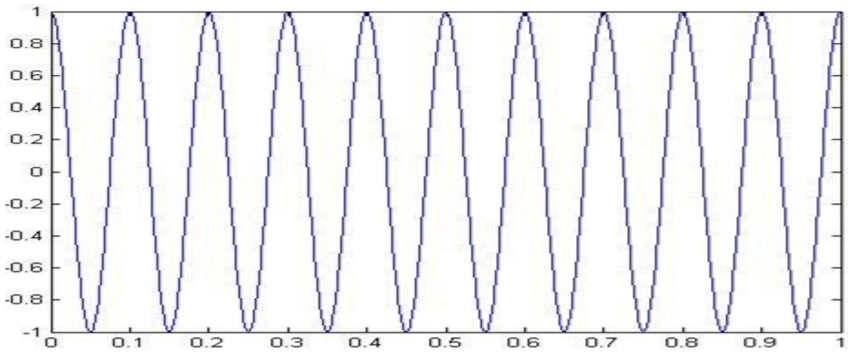
$$m(t)$$

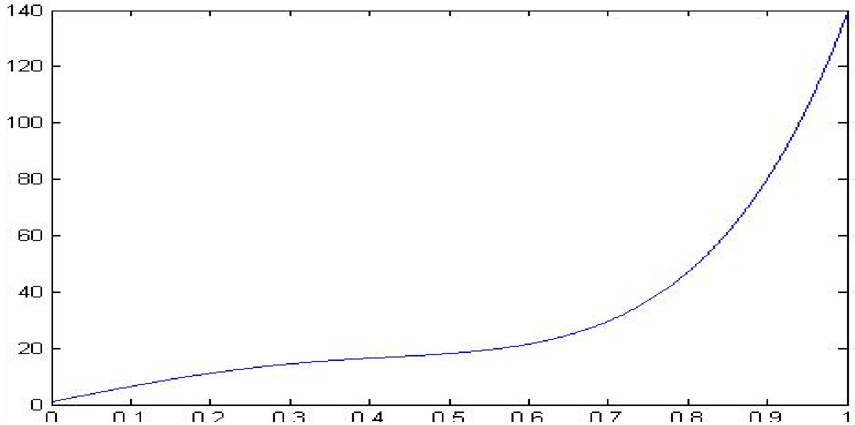
Carrier component

Acknowledgement: Prof. Dileeka Dias

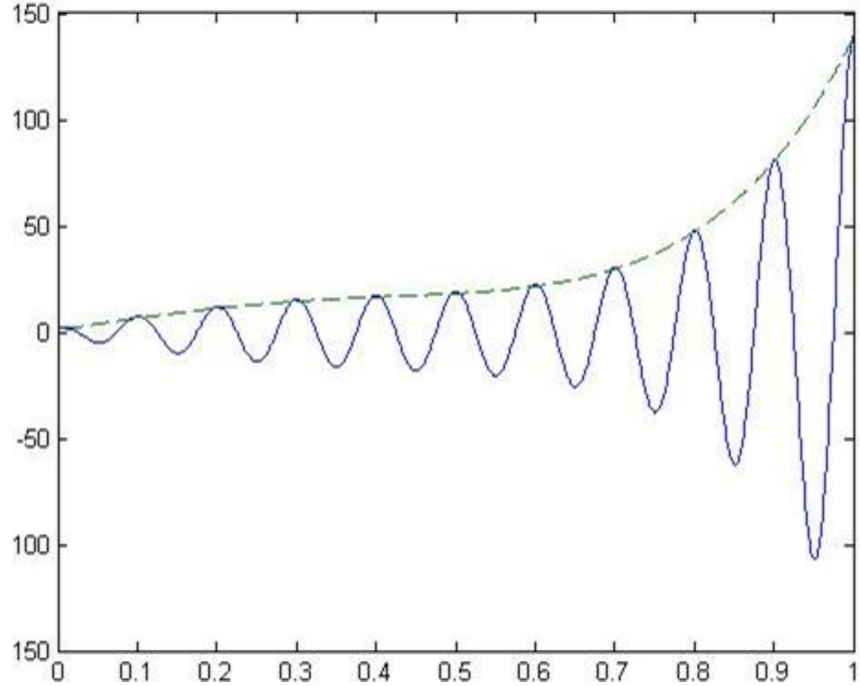
Example

Carrier signal





Modulating signal



Modulated signal

Angle Modulation

$$s(t) = A_c \cos(\omega_c t + \theta(t))$$ Modulated Signal

For Phase Modulation

$$\theta(t) = \Delta_p m(t)$$

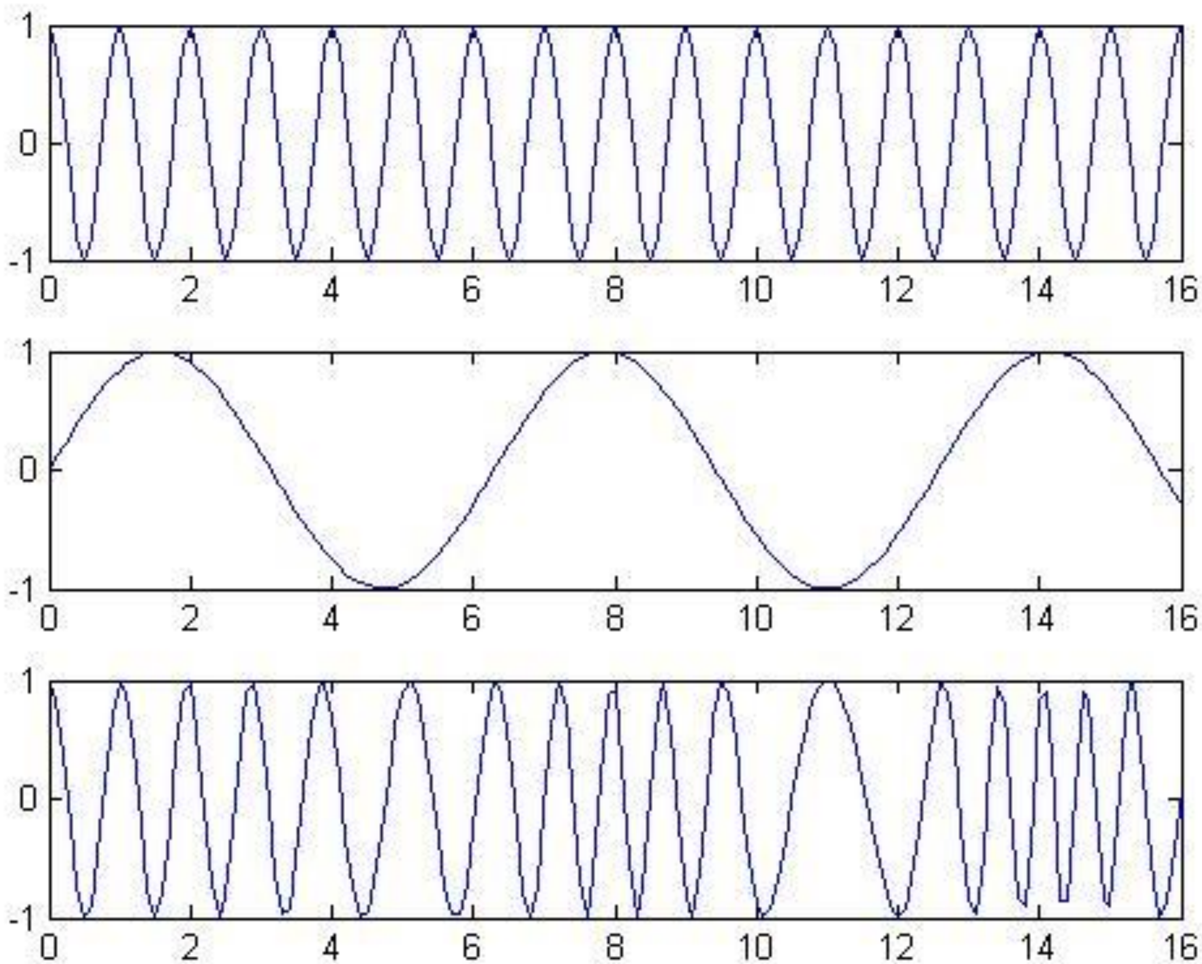
For Frequency Modulation

$$\theta(t) = 2\pi\, \Delta_f \int_{-\infty}^{t} m(\tau)\, d\tau$$

Modulation index is the change of modulated variable with respect to the modulatin

Acknowledgement: Prof. Dileeka Dias

Frequency Modulation (FM)

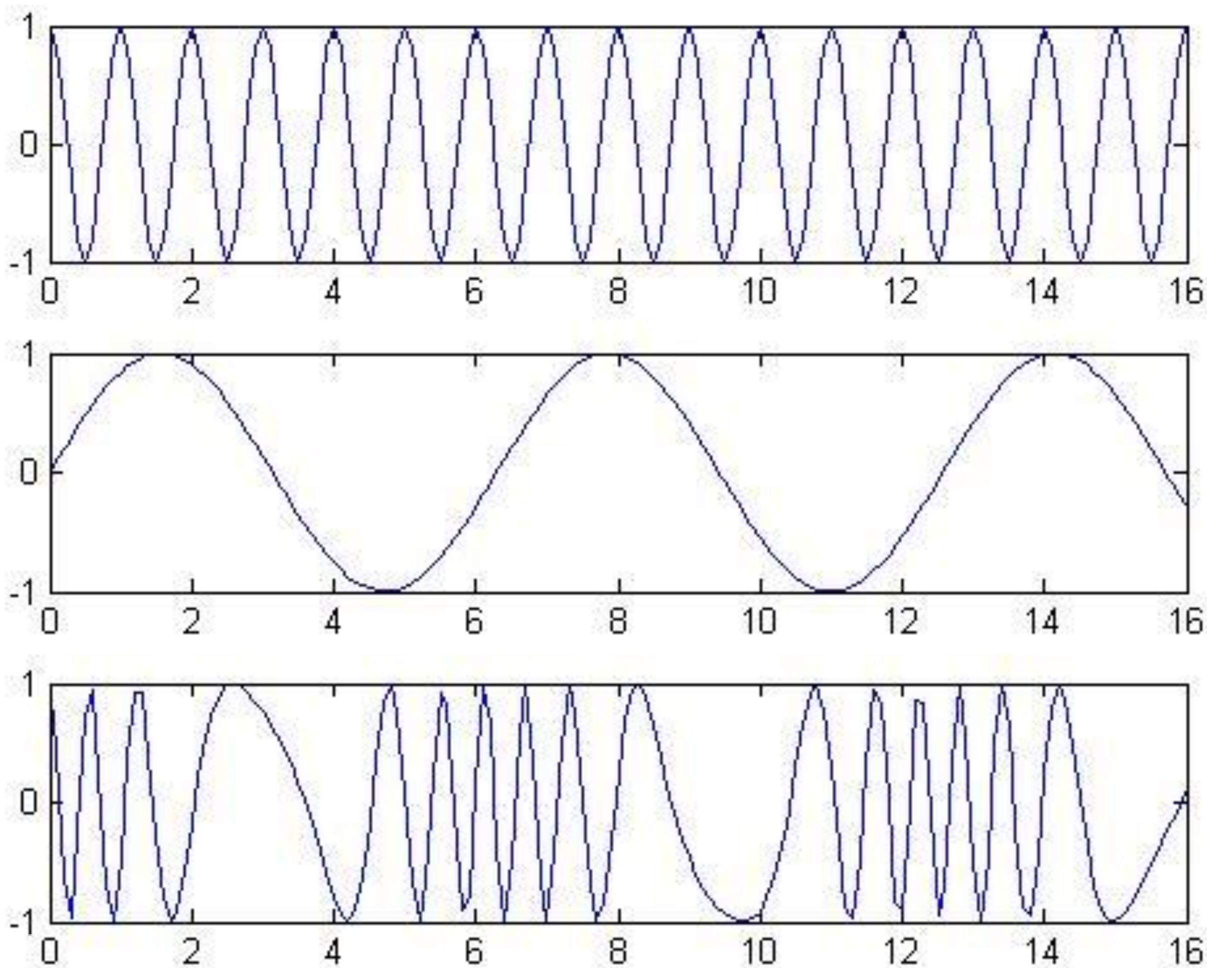


Carrier

Modulating signal

Modulated signal

Phase Modulation (PM)



Carrier

Modulating signal

Modulated signal

Thank you