Data Communications

Pokhara University

Data Communication (3 – 1 - 2)

Evaluation:

	Theory	Practical	Total
Sessional	30	20	50
Final	50	-	50
Total	80	20	100

Course Objectives:

1 To Appreciate the concept of Data Communication.
2 To understand the basics of communication signals.
3 To understand the requirements to get two computers exchange data.
4 To understand the basics of switching and networking.

Course Contents:

1. **Introduction** **2 hrs**
   1.1 Evolution of Data Communication systems
   1.2 Analog and Digital Data Transmission, Data Communication Terminology
   1.3 Standards Organizations, Applications.

2. **Data Transmission** **3 hrs**
   2.1 Parallel and Serial Transmission
   2.2 Line Configuration, Synchronous/Asynchronous Communication
   2.3 Bit Rate/ Baud rate, Transmission Channel, RS-232C and RS-449 Interface Standards

3. **Signals and Systems** **5 hrs**
   3.1 Signals and their classification: Periodic and non-periodic signals; Deterministic andRandom signals; Energy and Power signals; Continuous and Discrete time signals
   3.2 Continuous and Discrete time system
   3.3 Basic system properties: Linearity, Causality, Stability and Time Invariance LTI System

4. **Analysis of Signals and System's response** **6 hrs**
   4.1 Unit Step function and Impulse function, Impulse response
   4.2 Fourier series representation: Continuous time Fourier series and Discrete time Fourier series
   4.3 Fourier Transform: Continuous and Discrete time Fourier transform

5. **Overview of Data Communication Networking:** **3 hrs**
   5.1 Network Types, Topology
   5.2 OSI layers and Functions, TCP/IP layer, Local Area Networks (LAN) Architecture, LLC/MAC & Routing
   5.3 IEEE Standards, Ethernet (CSMA/CD), Wide Area Networks (WAN): X.25, Frame Relay, ATM

6. **Transmission Media** **5 hrs**
   6.1 Electromagnetic Spectrum for Telecommunication

6.2 Type of Propagation
6.3 Guided Transmission Media: Twisted–Pair Cable, Co-axial Cable, Optical Fiber. Characteristicsof Unguided Communication Bands, Antennas
6.4 Unguided Transmission Media: Terrestrial Microwave, Satellite Communication, VSAT, and Cellular Telephony

7. Impairments, Error handling and Compression Techniques **4 hrs**

7.1 Attenuation & Distortion, Delay Distortion, Noise & Types, interference, crosstalk
7.2 Types of error & its Detection and Correction Methods
7.3 Types of data Compression Techniques

8. Data Link Control and Protocol **3 hrs**

8.1 Flow Control: Stop - & - Wait, Sliding Window, Error Control: Automatic Repeat Request (ARQ), Stop–andWait ARQ, Sliding Window (ARQ)
8.2 Asynchronous &Synchronous Protocols and its types

9. Multiplexing & Switching **5 hrs**

9.1 Multiplexing types and Application
9.2 Multiplexing Vs Non-Multiplexing
9.3 The Telephone System: Analog services and its Hierarchy
9.4 Digital services and Hierarchy Circuit Switching, Packet Switching, Message Switching, and Private Branch Exchange

10. Data Encoding & Modulation **9 hrs**

10.1 Encoding Vs Modulation
10.2 Encoding of Digital Data as Digital Signals & its Techniques, Amplitude, Frequency, and Phase Shift Keying. Pulse Code and Delta Modulation. Analog Modulation (Amplitude, Frequency, and Phase Modulation)
10.3 Multilevel Modulation, Differential PSK, QPSK Modem, Higher-Data Rate Modems

Laboratory:

(The ability to complete the lab projects will depend on the facilities, availability of components, and time allocated to lab work. These projects are representative of the theory: Simulated USING MATLAB/other programming languages).

1. Signal Analysis using MATLAB (Maximum 3-Labs)
2. Analysis of Signal response using simple filters
3. Simulated simple PCM coder that converts samples into a digital code.
4. Amplitude Modulation and Demodulation.
5. Frequency Modulation and Demodulation.
6. Simulated Error Control Coding techniques.

Text Book:

William Stallings, Data and Computer Communications, fifth education.

References:

1. U. D. Black, Data Communications and Distributed Networks Behrouz Forouzan, Introduction to Data Communications and Networking.
2. Oppeheim, Signals and Systems

Unit1: Introduction

Data Communication

- Data communication is the processing and the transport of digital data over connections between computers and/or other devices (generally over large distances)
- Data communication comprises two topical areas:
  - Computer Networks
    - How to connect several computers?
    - Which media can be used for data transport?
    - How to represent digital data on the medium?
    - How to coordinate the access of several computers to the medium?
  - Communication Protocols (Internet Technology)
    - Design of uniform data units for transfer
    - How to achieve a reliable and efficient transfer?

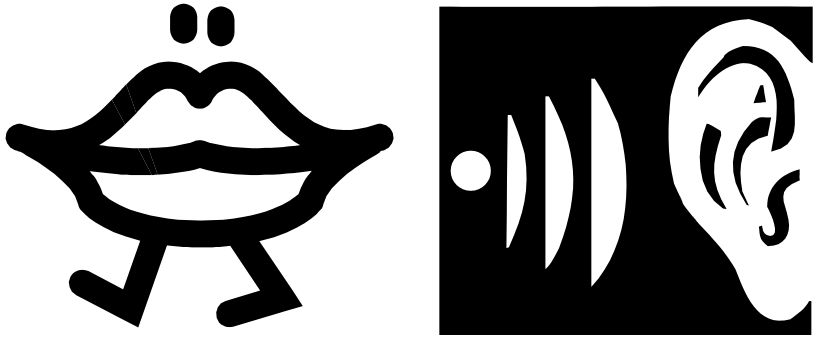
Data Communication Vs Networking

- **Data communications** deals with the transmission of signals in a reliable and efficient manner.

- **Networking** deals with the technology and architecture of the communications networks used to interconnect communicating devices.

- *The fundamental problem of communication is that of* reproducing at one point either exactly or approximately a message selected at another point
  - *The Mathematical Theory of Communication*, Claude Shannon

Human Communications

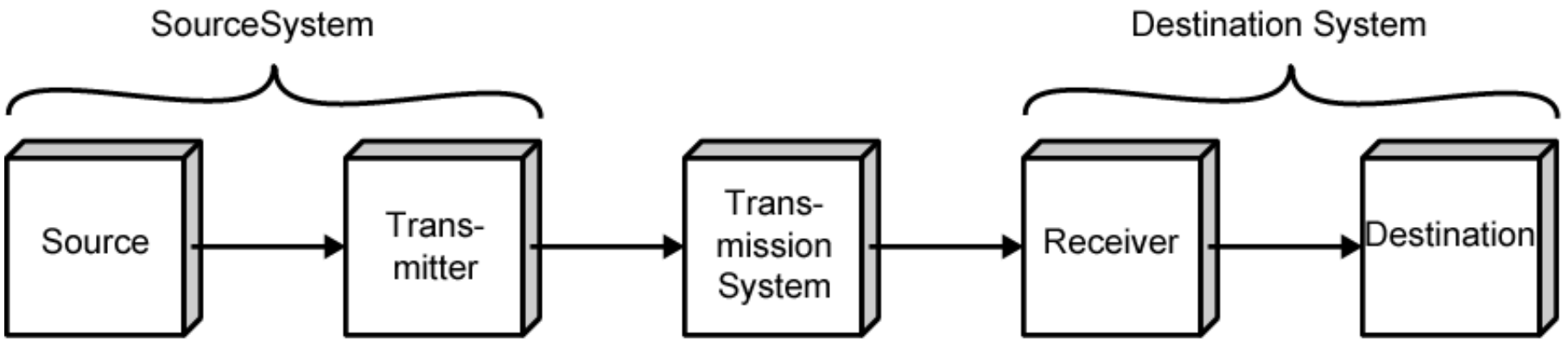


- A transmitter: mouth
- A receiver: ear
- The media: air
  - Question: Can you talk at outer space?
- The protocol: a common human language
  - Question: why do we learn English?

A Communications Model

- What is the purpose of communications?
  - **Exchange of information between two parties**
- Key elements
  - Source: Generates data to be transmitted. E.g., telephones, PCs.
    - Transmitter: A transmitter transforms and encodes the information in such a way as to produce electromagnetic signals that can be transmitted across some sort of transmission system.
  - Transmission System
    - It can be a single transmission line or a complex network connecting source and destination.
  - Destination: Takes incoming data from the receiver
    - Receiver: The receiver accepts the signal from the transmission system and converts it into a form that can be handled by the destination device.

Simplified Communications Model



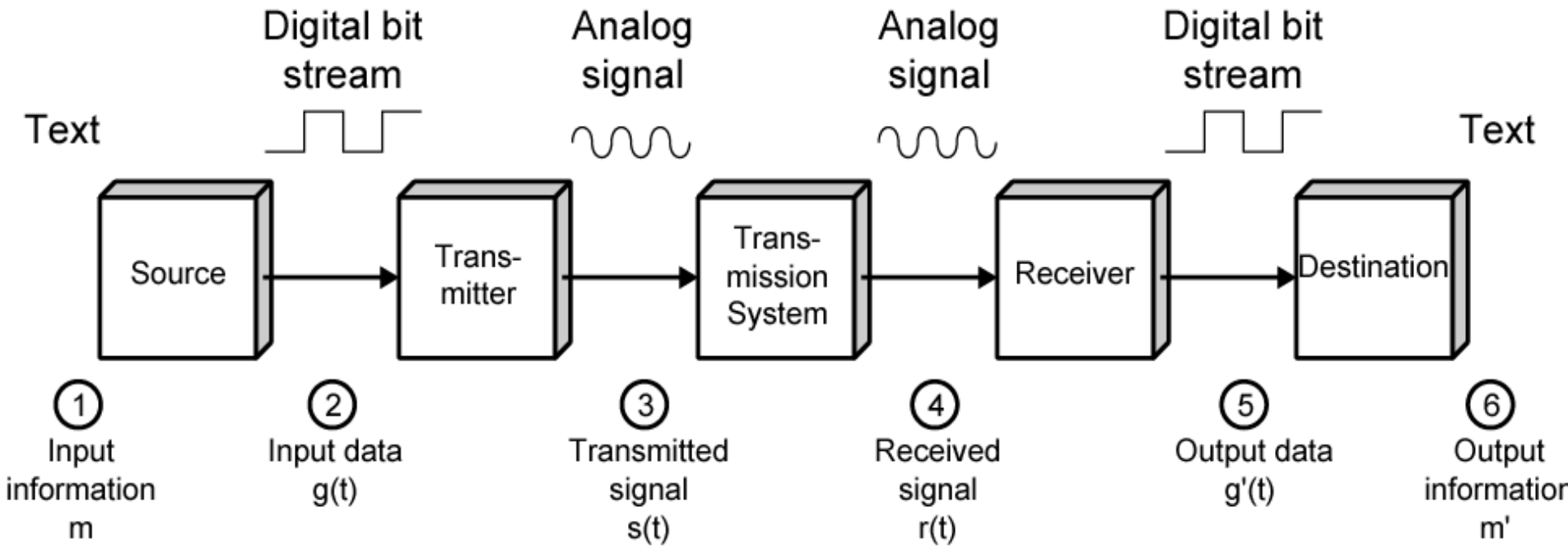
(a) General block diagram

(b) Example

Simplified Data Communications Model

Assume the source and destination are PCs.

The source wishes to send a message ***m*** to the destination.



Transmission of Information

- One basic choice facing a business user is the selection of transmission medium.
  - Within the business premise
    - Completely up to the business
  - Long-distance communications
    - Up to the long-distance carrier
  - New technologies
    - Optical fiber transmission
    - Wireless transmission
- How to improve the efficiency of the use of network facilities?
  - Multiplexing and compression

Evolution of Data Communication

- Sharing resources saves costs:
  - By communication, one can access resources of other parties this reduces the costs (compared to buying own resources)
  - Several institutions can share expensive resources which cannot by completely utilized by a single institution
  - Needed:
    - Efficient mechanisms for data exchange between components of a distributed systems
    - Mechanisms for efficient interaction
  - The driving power for the enormous increasing significance of data communication:
    - Decreasing costs for hardware...
    - while the computing power increases.
  - Interaction of several communication partners: usually Client/Server principle
    - Server: Program (process) which offers a service over a network. Servers receive requests and return a result to the inquiring party.
    - Client: Program (process) which uses a service offered by a server

What are the trends?

- Three forces are driving the ***evolution of data communications*** and networking

1. Growth of communication traffic
   - Voice traffic
     - telephone
   - Data traffic
     - Internet access, video conferencing
   - Challenges (to the network service providers):
     - how to maximize the capacity and minimize the cost?
2. Development of new services
   - Refer to the figure on the next page
3. Advances in technology
   - Faster and cheaper computing and communications
   - Networks are more intelligent: quality of service (QoS)
   - Internet, Web, intranets, extranets, etc.
   - Pervasive computing/ubiquitous computing

Contemporary Data Comms

- trends
  - traffic growth at a high & steady rate
  - development of new services
  - advances in technology
- significant change in requirements
  - emergence of high-speed LANs
  - corporate WAN needs
  - digital electronics

Data Communications History

- 1838: Samuel Morse & Alfred Veil Invent Morse Code Telegraph System
- 1876: Alexander Graham Bell invented Telephone
- 1910: Howard Krum developed Start/Stop Synchronization
- 1930: Development of ASCII Transmission Code
- 1945: Allied Governments develop the First Large Computer
- 1950: IBM releases its first computer IBM 710
- 1960: IBM releases the First Commercial Computer IBM 360

Main Contributors of Data Comm.

- Transmission Technology
- Packet Switching Technology
- Internet
  - 1967: ARPANET by Advanced Research Project Agency (ARPA) of U.S.
  - 1975: TCP/IP protocol
- LAN Technology
  - Ethernet & IEEE 802 Networks
- WAN
  - 1976: ISO releases High-Level Data Link Control (HDLC) & Consultative Committee for International Telephony and Telegraphy (CCITT) releases X.25 (PSPDN)

Voice and Data

- In 70's & 80's main thrust in Wide Area Networking (WAN) was to put Data on Voice Circuits using Modem & on ISDN lines
- In 90's the trend is reverse. Major Efforts were on putting Voice Over Data using:
  - Voice Over Frame Relay
  - Voice Over Internet
  - Voice Over ATM etc

Transmission Terminology

- data transmission occurs between a transmitter & receiver via some medium
- guided medium
  - eg. twisted pair, coaxial cable, optical fiber
- unguided / wireless medium
  - eg. air, water, vacuum

Transmission Terminology

- direct link
  - no intermediate devices
- point-to-point
  - direct link
  - only 2 devices share link
- multi-point
  - more than two devices share the link

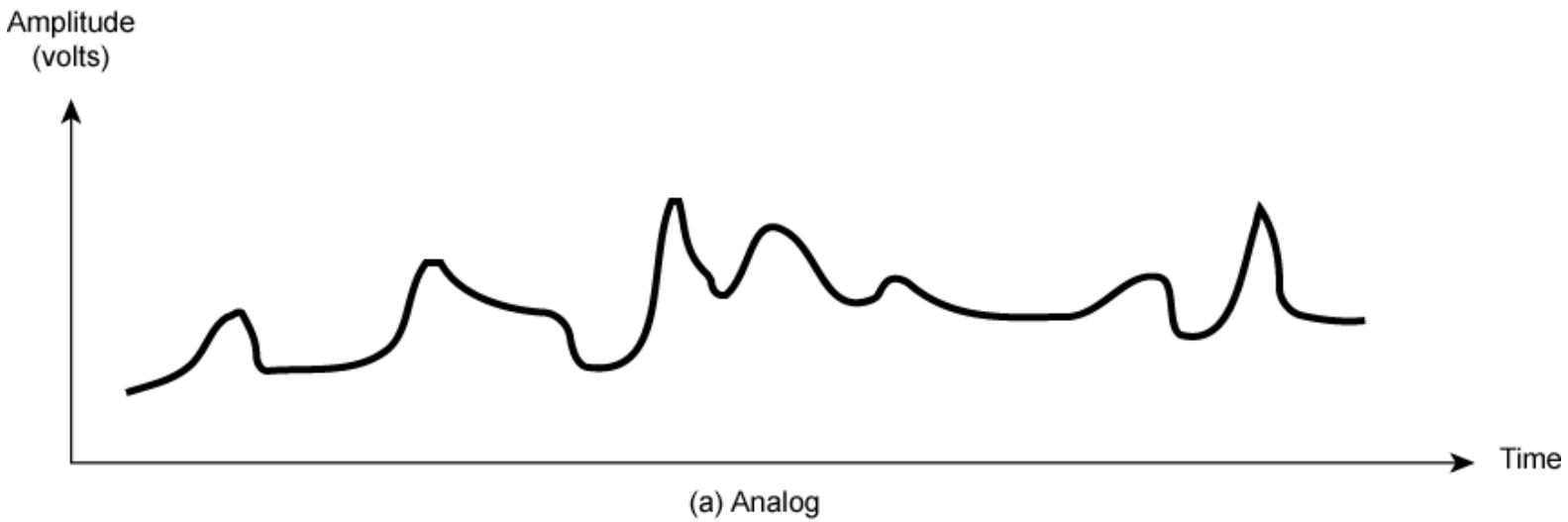
Transmission Terminology

- simplex
  - one direction
    - eg. television
- half duplex
  - either direction, but only one way at a time
    - eg. police radio
- full duplex
  - both directions at the same time
    - eg. telephone

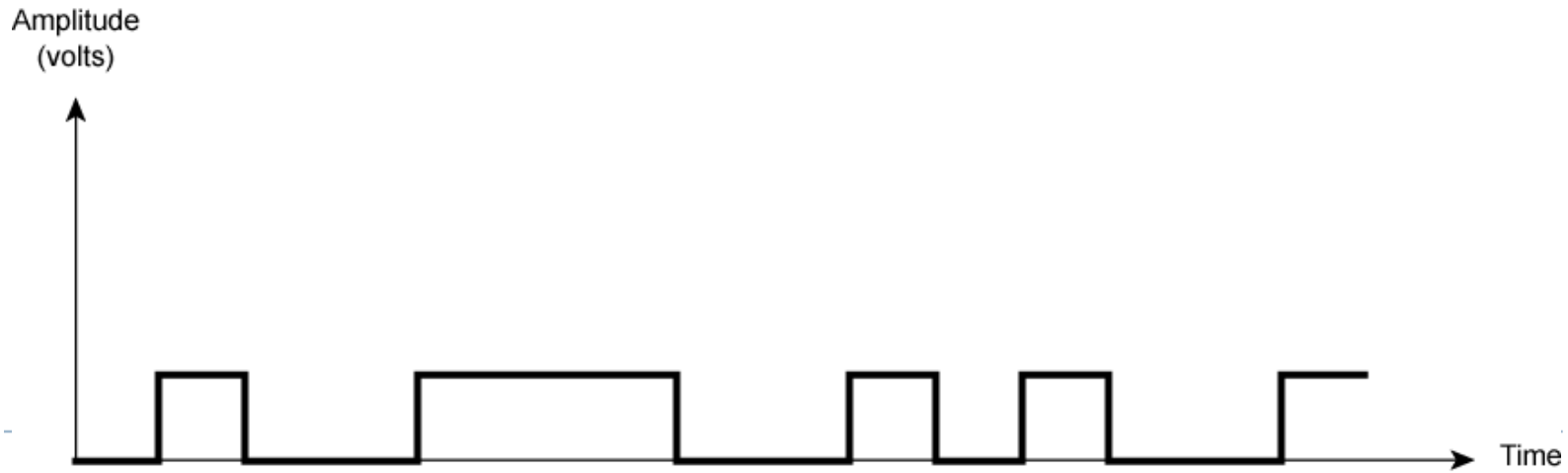
Frequency, Spectrum and Bandwidth

- time domain concepts
  - analog signal
    - various in a smooth way over time
  - digital signal
    - maintains a constant level then changes to another constant level
  - periodic signal
    - pattern repeated over time
  - aperiodic signal
    - pattern not repeated over time

Analogue & Digital Signals

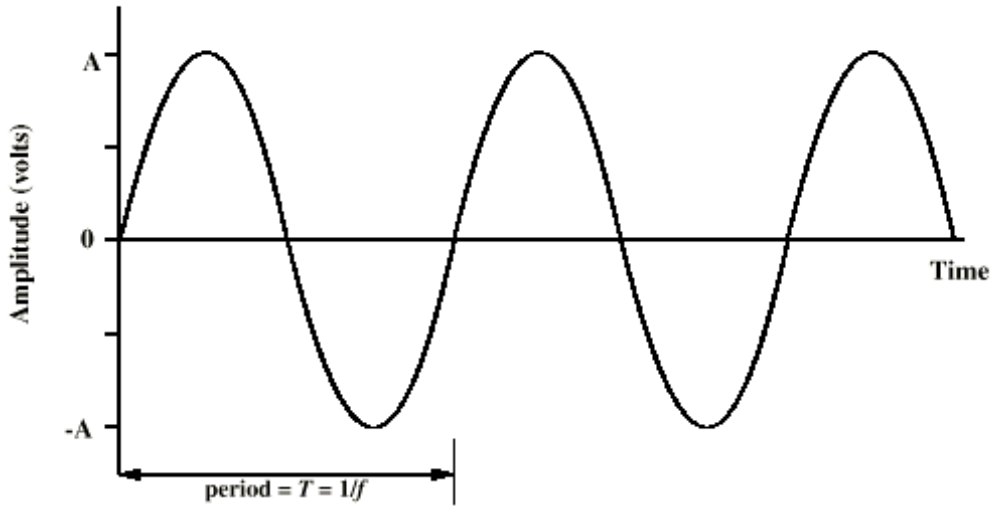


(a) Analog

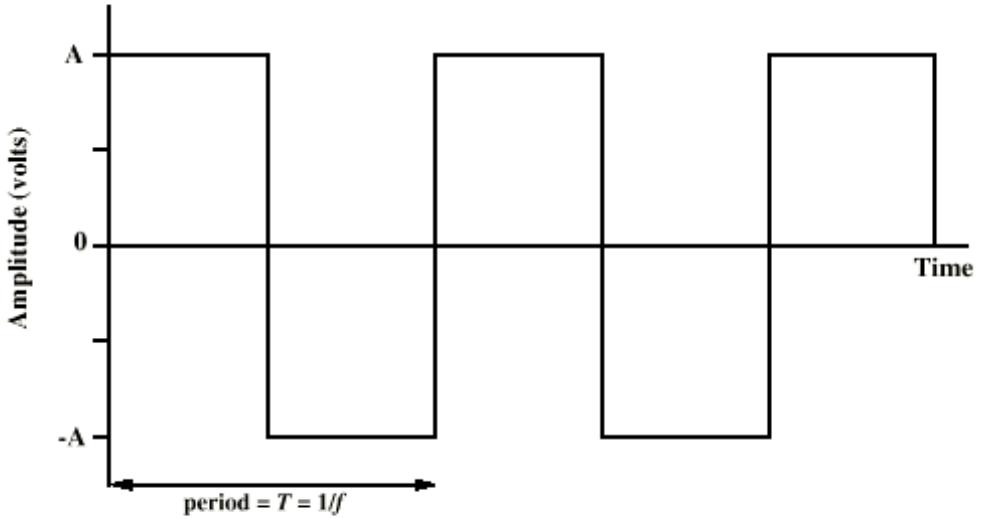


(b) Digital

Periodic Signals



(a) Sine wave



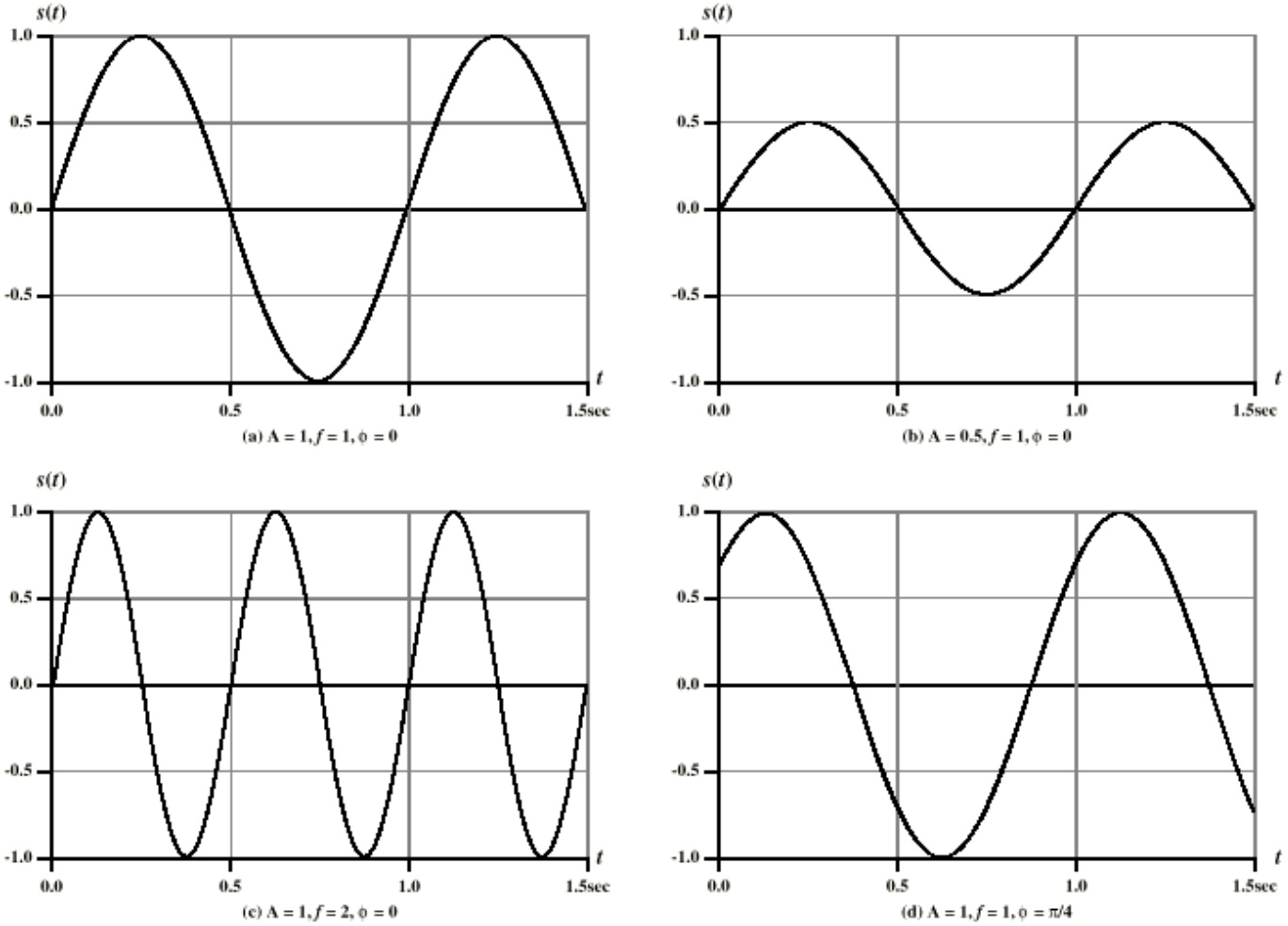
(b) Square wave

Sine Wave

- peak amplitude (A)
  - maximum strength of signal
  - volts
- frequency (f)
  - rate of change of signal
  - Hertz (Hz) or cycles per second
  - period = time for one repetition (T)
  - $T = 1/f$
- phase (ϕ)
  - relative position in time

Varying Sine Waves

$s(t) = A \sin(2\pi ft + \Phi)$



Wavelength (λ)

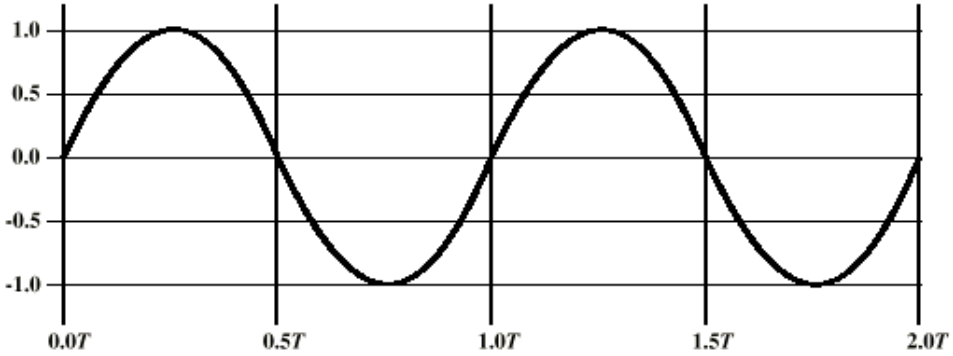
- is distance occupied by one cycle
- between two points of corresponding phase in two consecutive cycles
- assuming signal velocity *v* have $\lambda = vT$
- or equivalently $\lambda f = v$
- especially when *v*=c
  - $c = 3*10^8\ ms^{-1}$ (speed of light in free space)

Frequency Domain Concepts

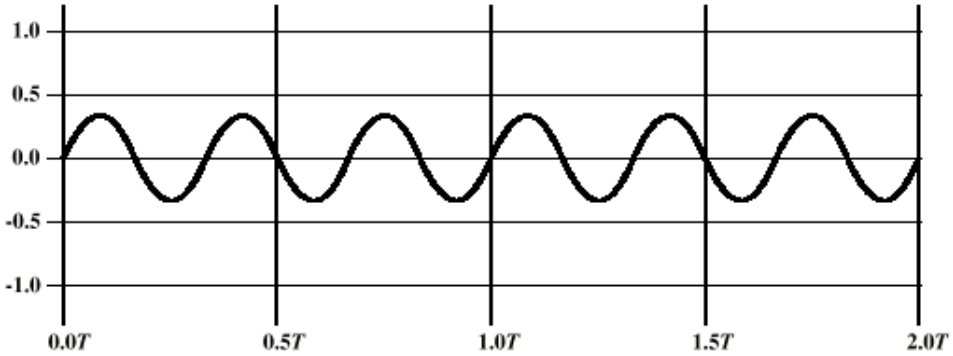
- signal are made up of many frequencies
- components are sine waves
- Fourier analysis can shown that any signal is made up of component sine waves
- can plot frequency domain functions

Addition of Frequency Components (T=1/f)

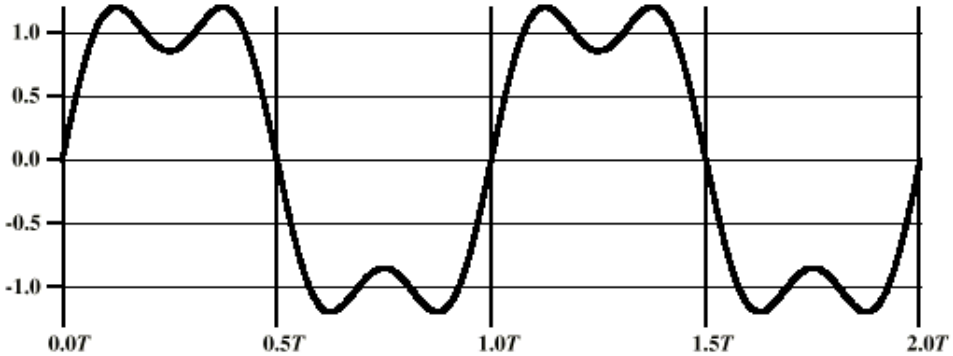
- c is sum of *f* & *3f*



(a) sin (2 *ft*)



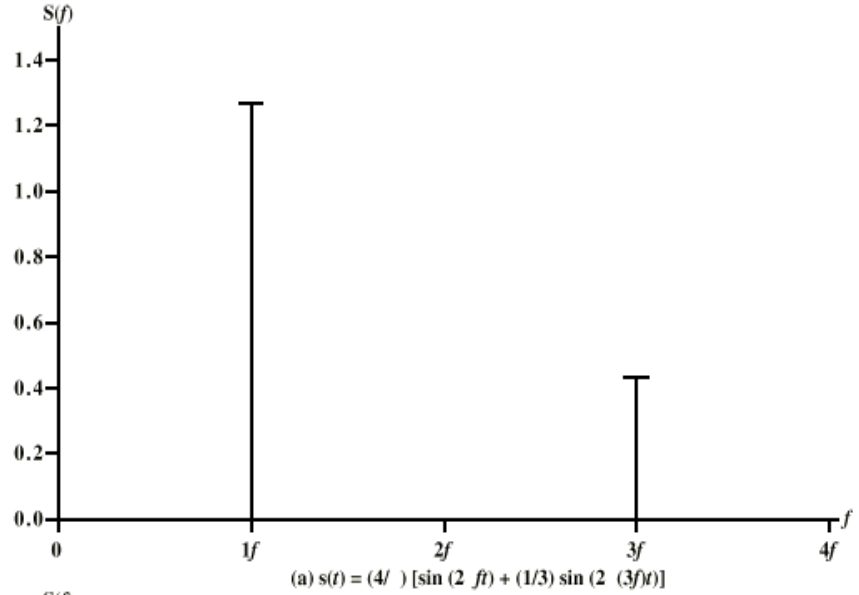
(b) (1/3) sin (2 (3*f*)*t*)



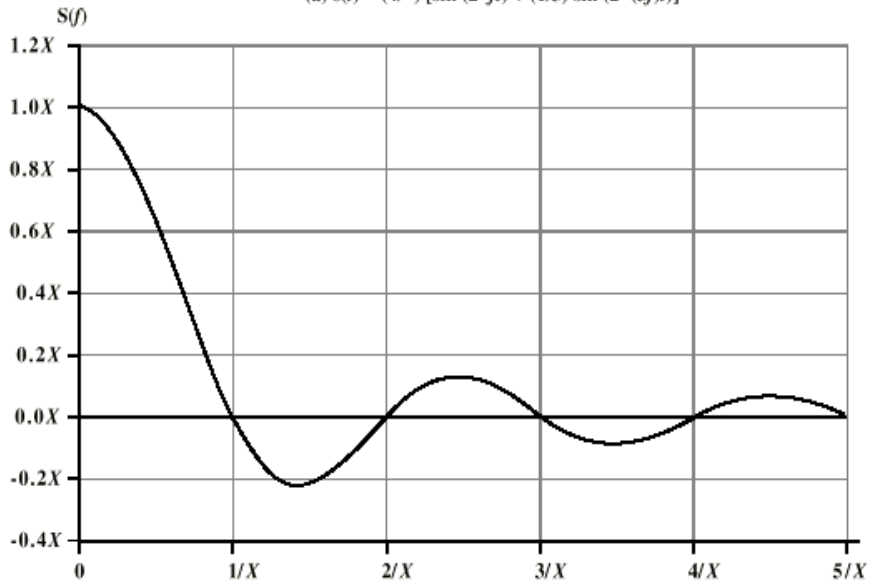
(c) (4/) [sin (2 *ft*) + (1/3) sin (2 (3*f*)*t*)]

Frequency Domain Representations

- freq domain func of Fig 3.4c
- freq domain func of single square pulse



(a) s(t) = (4/) [sin (2 ft) + (1/3) sin (2 (3f)t)]



(b) s(t) = 1 – X/2 t X/2

Spectrum & Bandwidth

- spectrum
  - range of frequencies contained in signal
- absolute bandwidth
  - width of spectrum
- effective bandwidth
  - often just *bandwidth*
  - narrow band of frequencies containing most energy
- DC Component
  - component of zero frequency

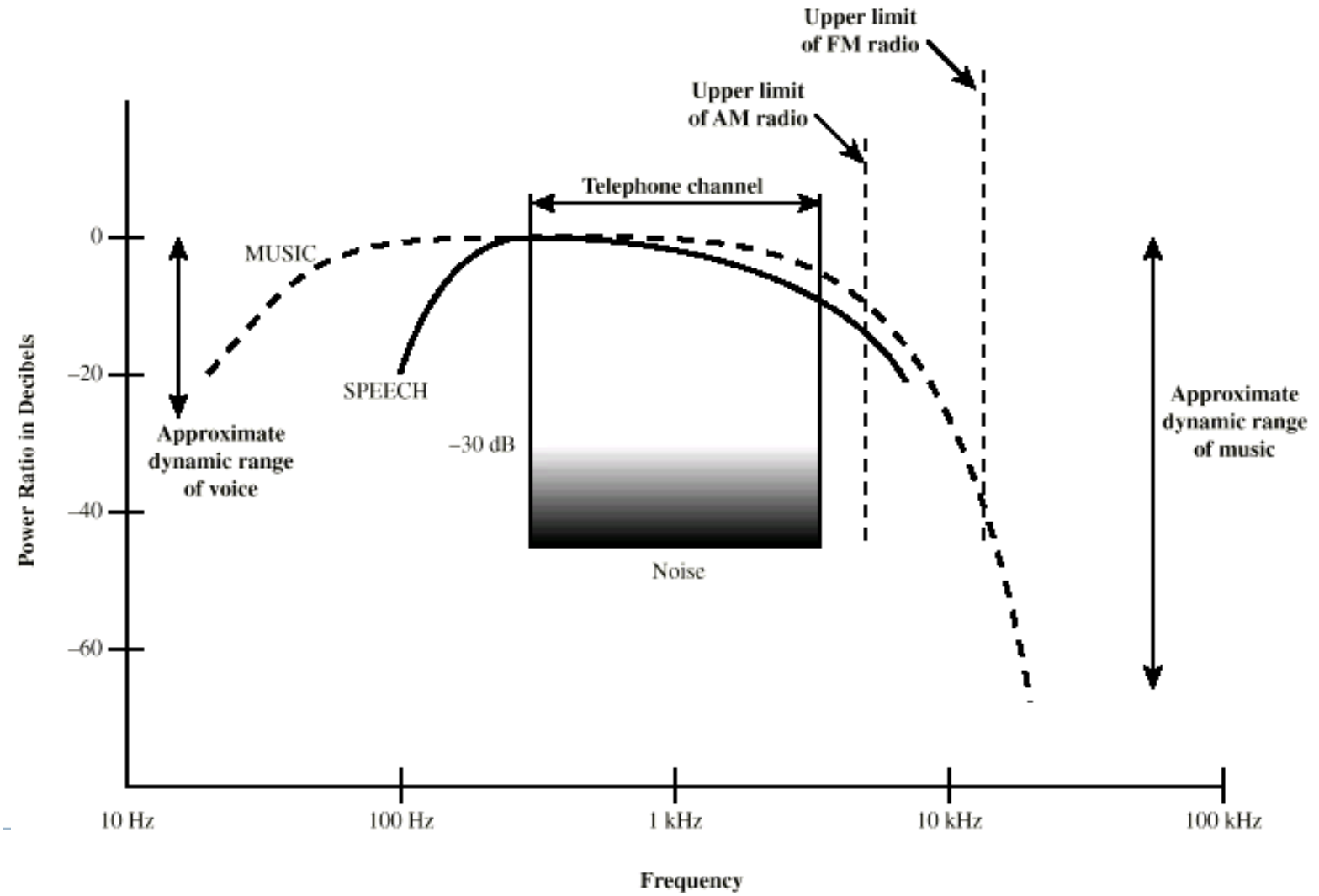
Data Rate and Bandwidth

- any transmission system has a limited band of frequencies
- this limits the data rate that can be carried
- square have infinite components and hence bandwidth
- but most energy in first few components
- limited bandwidth increases distortion
- have a direct relationship between data rate & bandwidth

Analog and Digital Data Transmission

- data
  - entities that convey meaning
- signals & signalling
  - electric or electromagnetic representations of data, physically propagates along medium
- transmission
  - communication of data by propagation and processing of signals

Acoustic Spectrum (Analog)



Audio Signals

- freq range 20Hz-20kHz (speech 100Hz-7kHz)
- easily converted into electromagnetic signals
- varying volume converted to varying voltage
- can limit frequency range for voice channel to 300-3400Hz

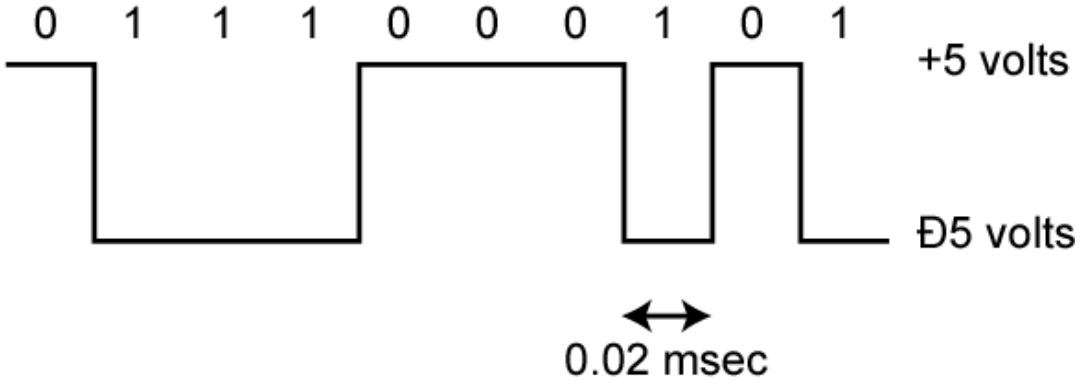
In this graph of a typical analog signal, the variations in amplitude and frequency convey the gradations of loudness and pitch in speech or music. Similar signals are used to transmit television pictures, but at much higher frequencies.

Video Signals

- USA - 483 lines per frame, at frames per sec
  - have 525 lines but 42 lost during vertical retrace
- 525 lines x 30 scans = 15750 lines per sec
  - 63.5μs per line
  - 11μs for retrace, so 52.5 μs per video line
- max frequency if line alternates black and white
- horizontal resolution is about 450 lines giving 225 cycles of wave in 52.5 μs
- max frequency of 4.2MHz

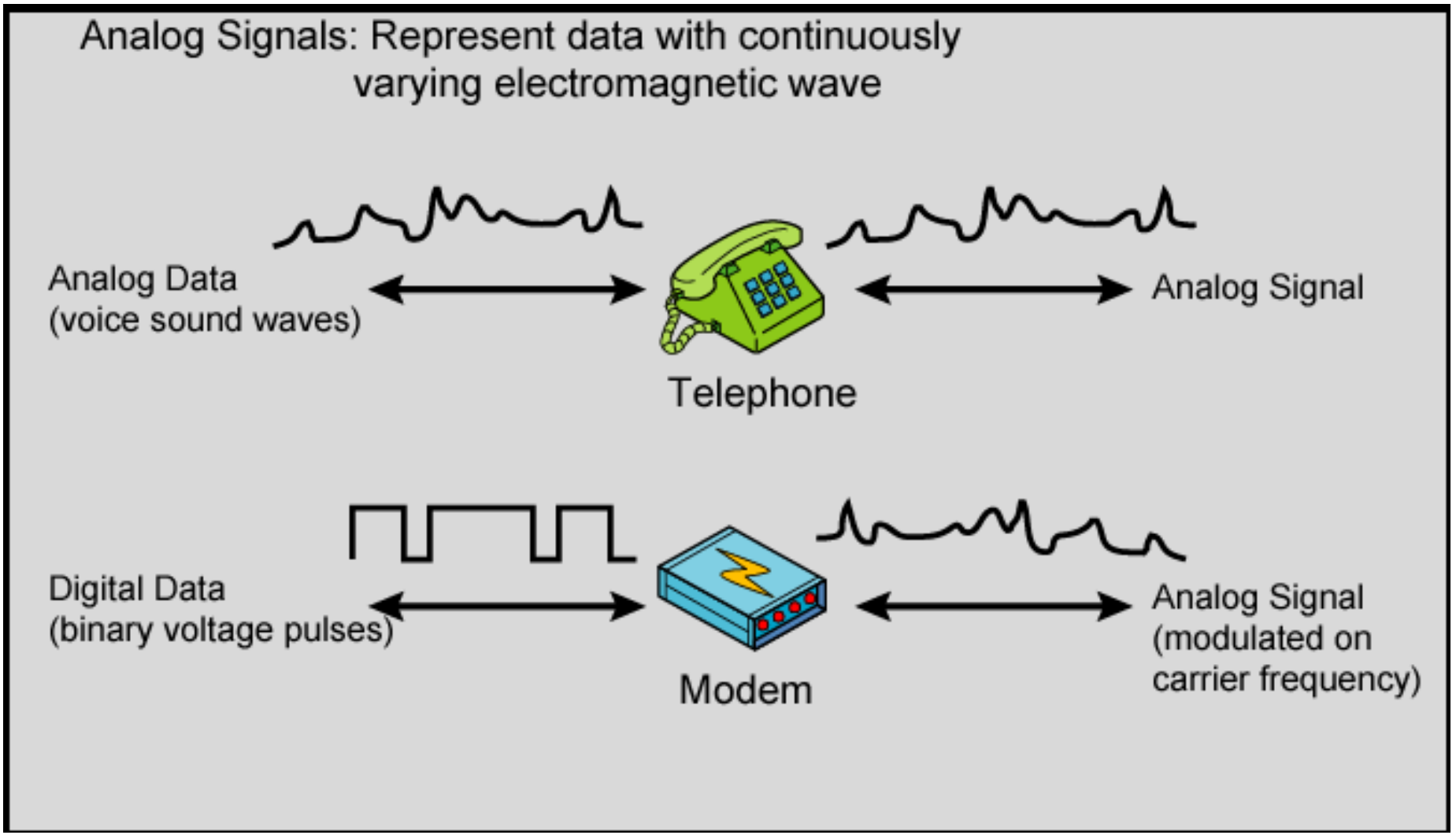
Digital Data

- as generated by computers etc.
- has two dc components
- bandwidth depends on data rate

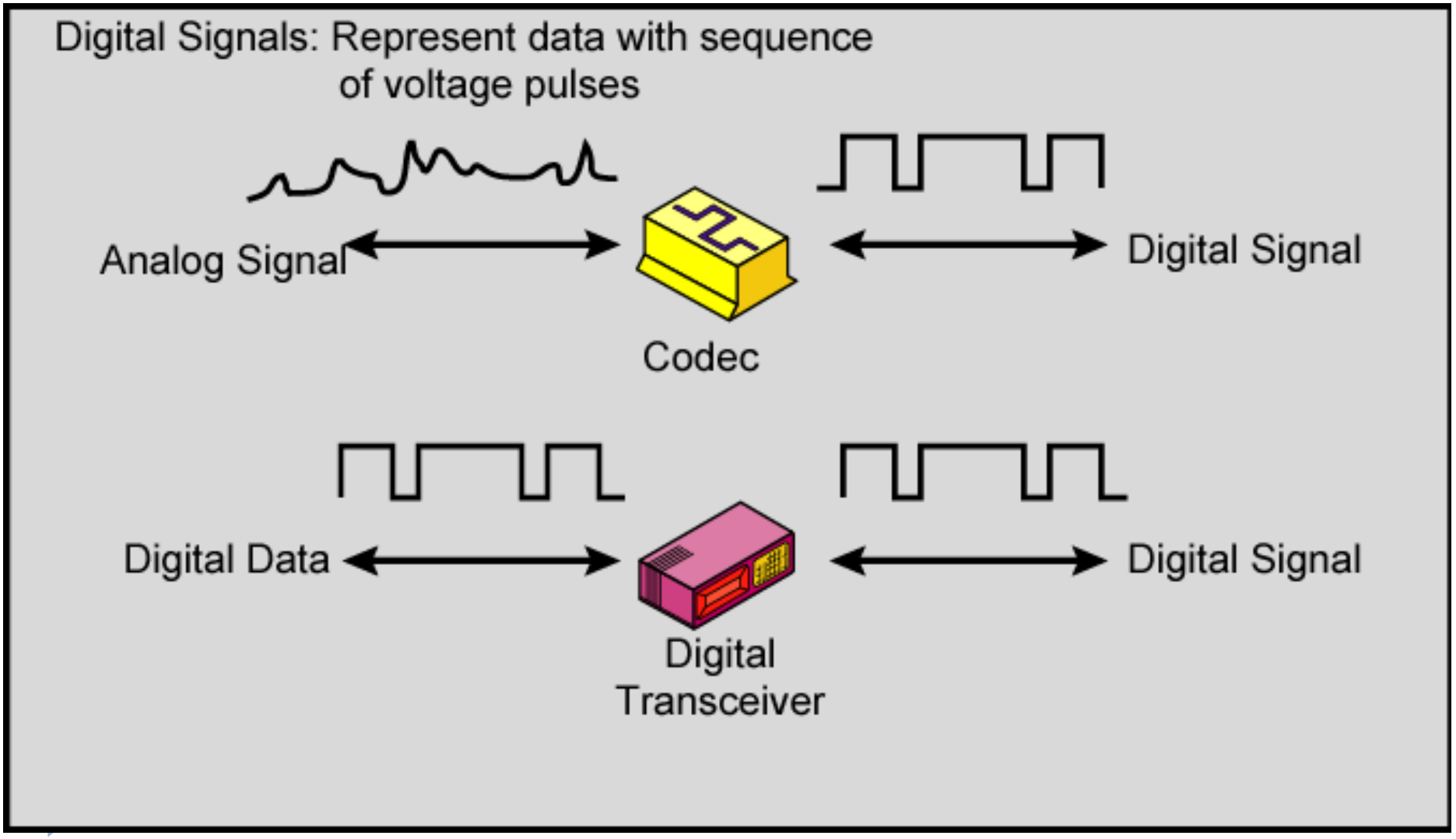


User input at a PC is converted into a stream of binary digits (1s and 0s). In this graph of a typical digital signal, binary one is represented by Ð5 volts and binary zero is represented by +5 volts. The signal for each bit has a duration of 0.02 msec, giving a data rate of 50,000 bits per second (50 kbps).

Analog Signals

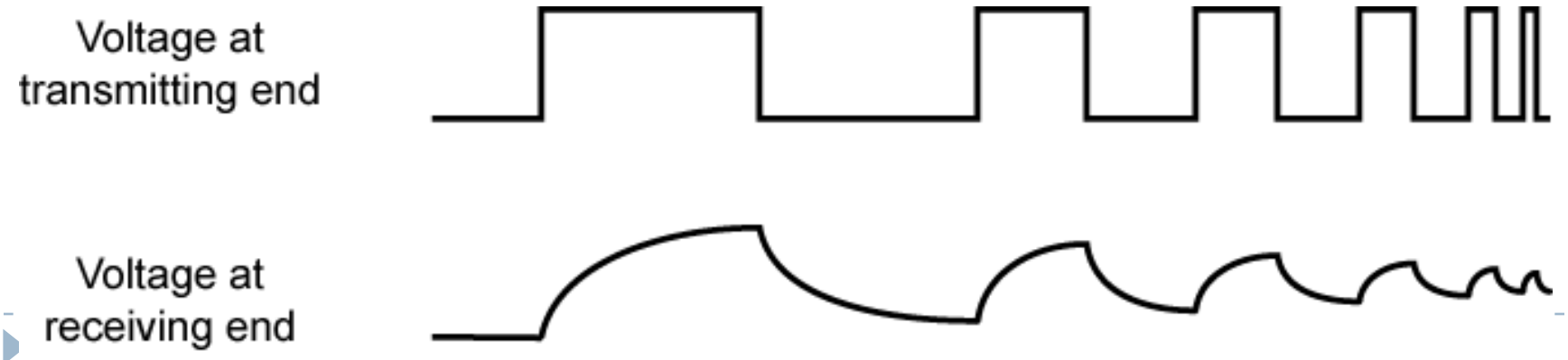


Digital Signals



Advantages & Disadvantages of Digital Signals

- cheaper
- less susceptible to noise
- but greater attenuation
- digital now preferred choice



Transmission Impairments

- signal received may differ from signal transmitted causing:
  - analog - degradation of signal quality
  - digital - bit errors
- most significant impairments are
  - attenuation and attenuation distortion
  - delay distortion
  - noise

Attenuation

- where signal strength falls off with distance
- depends on medium
- received signal strength must be:
  - strong enough to be detected
  - sufficiently higher than noise to receive without error
- so increase strength using amplifiers/repeaters
- is also an increasing function of frequency
- so equalize attenuation across band of frequencies used
  - eg. using loading coils or amplifiers

Delay Distortion

- only occurs in guided media
- propagation velocity varies with frequency
- hence various frequency components arrive at different times
- particularly critical for digital data
- since parts of one bit spill over into others
- causing intersymbol interference

Noise

- additional signals inserted between transmitter and receiver
- thermal
  - due to thermal agitation of electrons
  - uniformly distributed
  - white noise
- intermodulation
  - signals that are the sum and difference of original frequencies sharing a medium

Noise

- crosstalk
  - a signal from one line is picked up by another
- impulse
  - irregular pulses or spikes
    - eg. external electromagnetic interference
  - short duration
  - high amplitude
  - a minor annoyance for analog signals
  - but a major source of error in digital data
    - a noise spike could corrupt many bits

Channel Capacity

- max possible data rate on comms channel
- is a function of
  - data rate - in bits per second
  - bandwidth - in cycles per second or Hertz
  - noise - on comms link
  - error rate - of corrupted bits
- limitations due to physical properties
- want most efficient use of capacity

Shannon Capacity Formula

- consider relation of data rate, noise & error rate
  - faster data rate shortens each bit so bursts of noise affects more bits
  - given noise level, higher rates means higher errors
- Shannon developed formula relating these to signal to noise ratio (in decibels)
- $SNR_{db} = 10 \log_{10} (signal/noise)$
- Capacity $C = B \log_2(1+SNR)$
  - theoretical maximum capacity
  - get lower in practise

Nyquist Bandwidth

- consider noise free channels
- if rate of signal transmission is 2B then can carry signal with frequencies no greater than B
  - ie. given bandwidth B, highest signal rate is 2B
- for binary signals, 2B bps needs bandwidth B Hz
- can increase rate by using M signal levels
- Nyquist Formula is: $C = 2B \log_2 M$
- so increase rate by increasing signals
  - at cost of receiver complexity
  - limited by noise & other impairments

Standards Organizations for Data Communications

- An association of organizations, governments, manufacturers and users form the standards organizations and are responsible for developing, coordinating and maintaining the standards .
- The purpose is that all data communications equipment manufacturers and users comply with these standards.
- The primary standards organizations for data communication are:

International Standard Organization (ISO)

- ISO is the international organization for standardization on a wide range of subjects.
- It is comprised mainly of members from the standards committee of various governments throughout the world.
- It is even responsible for developing models which provides high level of system compatibility, quality enhancement, improved productivity and reduced costs. \
- The ISO is also responsible for endorsing and coordinating the work of the other standards organizations.

International Telecommunications Union-Telecommunication Sector (ITU-T)

- ITU-T is one of the four permanent parts of the International Telecommunications Union based in Geneva, Switzerland.
- It has developed three sets of specifications:
  - the *V series for modem interfacing and data transmission over telephone lines,*
  - *the X series for data transmission over public digital networks, email and directory services;*
  - *the I and Q series for Integrated Services Digital Network (ISDN) and its extension Broadband ISDN.*
- ITU-T membership consists of government authorities and representatives from many countries and it is the present standards organization for the United Nations.

Institute of Electrical and Electronics Engineers (IEEE)

- IEEE is an international professional organization founded in United States and is compromised of electronics, computer and communications engineers.
- It is currently the world's largest professional society with over 200,000 members.
- It develops communication and information processing standards with the underlying goal of advancing theory, creativity, and product quality in any field related to electrical engineering.

American National Standards Institute (ANSI)

- ANSI is the official standards agency for the United States and is the U.S voting representative for the ISO.
- ANSI is a completely private, non-profit organization comprised of equipment manufacturers and users of data processing equipment and services.
- ANSI membership is comprised of people form professional societies, industry associations, governmental and regulatory bodies, and consumer goods.

Electronics Industry Association (EIA)

- EIA is a non-profit U.S. trade association that establishes and recommends industrial standards.
- EIA activities include standards development, increasing public awareness, and lobbying and it is responsible for developing the RS (recommended standard) series of standards for data and communications.

Telecommunications Industry Association (TIA)

- TIA is the leading trade association in the communications and information technology industry.
- It facilitates business development opportunities through market development, trade promotion, trade shows, and standards development.
- It represents manufacturers of communications and information technology products and also facilitates the convergence of new communications networks

Internet Research Task Force (IRTF)

- The IRTF promotes research of importance to the evolution of the future Internet by creating focused, long-term and small research groups working on topics related to Internet protocols, applications, architecture and technology.

Internet Engineering Task Force (IETF)

- The IETF is a large international community of network designers, operators, vendors and researchers concerned with the evolution of the Internet architecture and smooth operation of the Internet.

Internet Architecture Board (IAB)

- IAB earlier known as Internet Activities Board is a committee created by ARPA (Advanced Research Projects Agency) so as to analyze the activities of ARPANET whose purpose is to accelerate the advancement of technologies useful for U.S military.
- IAB is a technical advisory group of the Internet Society and its responsibilities are:
  - Oversees the architecture protocols and procedures used by the Internet.
  - Manages the processes used to create Internet Standards and also serves as an appeal board for complaints regarding improper execution of standardization process.
  - Responsible for administration of the various Internet assigned numbers
  - Acts as a representative for Internet Society interest in liaison relationships with other organizations.
  - Acts as a source of advice and guidance to the board of trustees and officers of Internet Society concerning various aspects of internet and its technologies.