10EC61

# DIGITAL COMMUNICATION

## TEXT BOOK:

- **Digital communications**, Simon Haykin, John Wiley, 2003.

## REFERENCE BOOKS:

- **Digital and analog communication systems & An introduction to Analog and Digital Communication**, K. Sam Shanmugam, John Wiley, 1996. 2.Simon Haykin, John Wiley, 2003
- **Digital communications** - Bernard Sklar: Pearson education 2007

## UNIT 1

OUTLINE

- Introduction and basic signal processing operations in digital communication.
- Sampling Principles: Sampling Theorem, Quadrature sampling of Band pass signal, Practical aspects of sampling and signal recovery.

## COMMUNICATION SYSTEM

- The purpose : to transmit some signal which is generated by a source to a destination through a media or channel.
- *source* is generating some electrical signal which is
  - possibly captured from some real life image or audio.
  - Or a signal generated by a transducer
- The signal needs to be transmitted to a *destination* through a media which is technically called the *channel*.
- So, we have a source, a destination and a channel.

## EXAMPLE 1: RADIO

- Source : Microphone
- Destination : Speakers in the Rx
- Channel/Media : Free Space

## EXAMPLE 2: TELEVISION

- Source :
- Destination :
- Channel/Media :

## EXAMPLE 2: TELEVISION

- Source : Video Camera and Microphone
- Destination : Picture tubes or LCD's and Speakers in the Rx Television.
- Channel/Media : Free Space/ Coaxial Cables

## EXAMPLE 3: TELEPHONE

- Source :
- Destination :
- Channel/Media :

## EXAMPLE 3: TELEPHONE

- Source : the microphone in a phone
- Destination : the speaker in another phone set
- Channel/Media : wire line, the twisted pair wires.

## EXAMPLE 4: CELLULAR MOBILE PHONE

- Source :
- Destination :
- Channel/Media :

## EXAMPLE 4: CELLULAR MOBILE PHONE

- Source : the microphone in a phone
- Destination : the speaker in another phone set
- Channel/Media : Space, OFC

## EXAMPLE 5: STORAGE CHANNELS

- Channel/Media : CD, DVD, Blueray, Magnetic Tape, Magnetic Disk etc.

## SOURCE

- Digital Communication: Data to be transmitted is in digital form
- But the source can be *digital* or *analog*

## ADVANTAGES OF DIGITAL COMMUNICATION

1. Immunity to transmission noise and interference
2. Digital circuits are less subjected to distortion and interference
3. Error detecting and Error correcting codes improve the system performance by reducing the probability of error.
4. Multiplexing of signal is easier with digital signals
5. Regeneration of coded signals along the transmission path is possible

## ADVANTAGES OF DIGITAL COMMUNICATION…

6. Provides security and privacy to the data transmitted (encryption)
7. Transmission rate can be changed easily
8. Digital storage is cheaper and flexible
9. Can use common format for encoding different kinds of message signals
10. Signal jamming can be avoided by using spread spectrum technique
11. The Hardware implementation is more flexible than analog hardware because of the use of microprocessors, VLSI chips etc.

## PULSE DEGRADATION AND REGENERATION

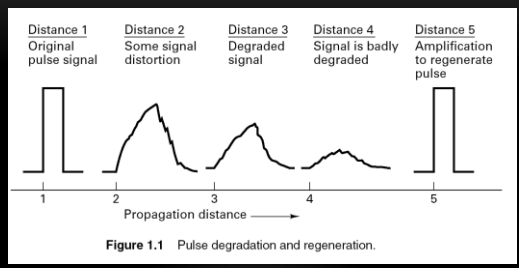



**Figure 1.1** Pulse degradation and regeneration.

## DISADVANTAGES OF DIGITAL COMMUNICATION

1. Requires larger transmission bandwidth
2. Requires synchronization of transmitter and receiver
3. System complexity is more compared to analog communication systems
4. Requires A/D conversions at high rate
5. Nongraceful degradation

## DIGITAL SIGNAL NOMENCLATURE

- **Baud Rate**
  - Refers to the rate at which the signaling elements are transmitted, i.e. number of signaling elements per second.
- **Bit Error Rate**
  - The probability that one of the bits is in error or simply the probability of error

## CHANNEL

- Channel is a medium through which electrical signal is sent from on place to another

**CHARACTERISTICS OR PARAMETERS OF CHANNELS**

Selection of channel for digital communication is based on

- Bandwidth
- Power
- Amplitude and phase requirement at the o/p
- Linear and non-linear characteristics requirement.
- Effect of external interference on the channel

## CHANNEL…

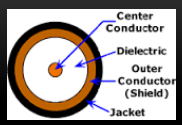
- Five channels are considered in digital communication:
  i. Telephone Channels
  ii. Coaxial Cables
  iii. Optical Fibers
  iv. Microwave Radio
  v. Satellite Channels

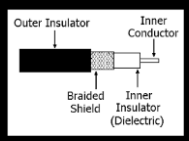
## TELEPHONE CHANNELS

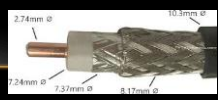
- Designed to provide voice grade communication.
  - Also good for data communication over long distances.
- The channel has a band-pass characteristic occupying the frequency range 300Hz to 3400hz, a high SNR of about 30db, and approximately linear response.
- Transmission rates upto16.8 kilobits per second have been achieved over the telephone lines.
- Used for long distance communication
- Media used: open wire cables, OFC, Microwave and satellites.

## COAXIAL CABLE

- The coaxial cable consists of a single wire conductor centered inside an outer conductor, which is insulated from each other by a dielectric.
- Two main advantages of the coaxial cable:
  1. wide bandwidth
  2. low external interference.
- Disadvantage:
  - Closely spaced repeaters are required.
- With repeaters spaced at 1km intervals the data rates of 274 megabits per second have been achieved.

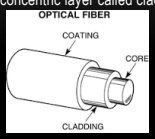


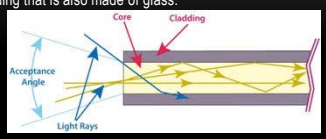




## OPTICAL FIBERS (OFC)

- An optical fiber consists of a very fine inner core made of silica glass, surrounded by a concentric layer called cladding that is also made of glass.

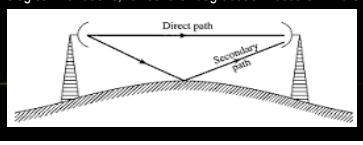


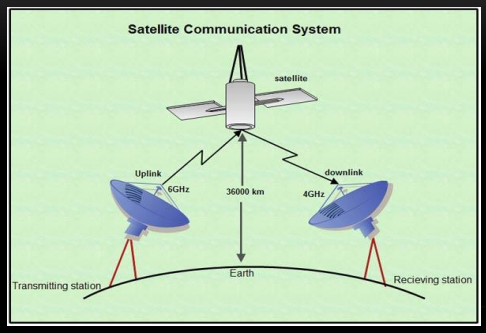

- The refractive index of the glass in the core is slightly higher than refractive index of the glass in the cladding.
- Works on the principal of Total Internal Reflection
- Free from external electrical interference
- Maximum repeater spacing : 100+ kms
- Speed- 270+ Gbps per channel (370 channels, 101 Tbit/s effective speed)

## MICROWAVE RADIO

- Operates on the line-of-sight (LOS) link, consists basically of a transmitter and a receiver that are equipped with antennas.
- The antennas are placed on towers at sufficient height to have the transmitter and receiver in line-of-sight of each other.
- Operating frequency range :1 to 30 GHz, Maximum transmission rate :7500 Mbps
- Under normal atmospheric conditions, a microwave radio channel is very reliable and provides path for high-speed digital transmission.
- Major problem- Multipath reception: due to the phase shift between the path, received signal strength increases or decreases, resulting in fading.
- During meteorological variations, a severe degradation occurs in the system performance.



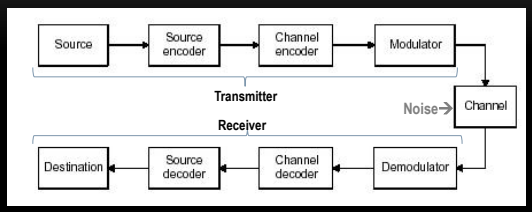
## SATELLITE CHANNEL




## SATELLITE CHANNEL

- A Satellite channel consists of :
  - *a satellite in geostationary orbit (can be other orbits also)*
  - *an uplink from ground station, and*
  - *a down link to another ground station*
- Both link operate at microwave frequencies, with uplink frequency higher than the down link frequency.
- In general, Satellite can be viewed as repeater in the sky.
- It permits communication over long distances at higher bandwidths and relatively low cost.
- Max area covered: 1/3 of the earth surface.

## ELEMENTS OF DIGITAL COMMUNICATION SYSTEM




- Fig: Functional elements of a digital communication system.

Three main Blocks:
1. Transmitter
2. Communication Channel
3. Receiver

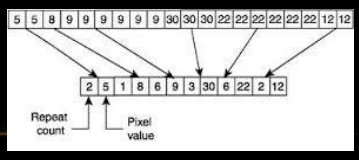
## ELEMENTS OF DIGITAL COMMUNICATION SYSTEM…

- Source of Information: 1. Analog Information Sources.
  2. Digital Information Sources.
- Analog Information Sources → Microphone actuated by a speech, TV Camera scanning a scene, continuous amplitude signals.
- Digital Information Sources → These are teletype or the numerical output of computer which consists of a sequence of discrete symbols or letters.
- An Analog information is transformed into a discrete information through the process of sampling and quantizing.

## ELEMENTS OF DIGITAL COMMUNICATION SYSTEM…

### SOURCE ENCODER / DECODER:

- Source signal consists of lots of redundancy which when transmitted as it is results in 'improper utilization of bandwidth.
- Aim of the source coding is to remove the redundancy in the transmitting information, so that bandwidth required for transmission is minimized.
- Ex: Runlength coding.

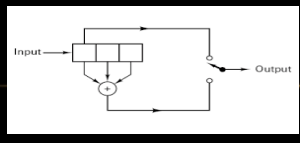



## ELEMENTS OF DIGITAL COMMUNICATION SYSTEM…

### CHANNEL ENCODER / DECODER:

- Is used to reduce channel noise effect
- Channel coding is the process of adding *controlled redundancy* to the data to be transmitted to detect and/or correct the errors caused by the channel noise at the receiver
- But adding redundancy increases bit rate and hence increases bandwidth
- Detector detects the errors in the received data and corrects it.
- The important parameters : Method of coding, efficiency, error control capabilities and complexity of the circuit.

Examples: error correcting codes like linear block codes, cyclic codes, convolution codes



## ELEMENTS OF DIGITAL COMMUNICATION SYSTEM…

**MODULATOR:**

- The Modulator converts the input bit stream into an electrical waveform suitable for transmission over the communication channel.
- Modulator can be effectively used to-
  - ✓ *minimize the effects of channel noise*
  - ✓ *match the frequency spectrum of transmitted signal with channel characteristics*
  - ✓ *provide the capability to multiplex many signals.*
- e.g.: ASK, PSK, FSK etc.

**DEMODULATOR:**

- The extraction of the message from the information bearing waveform produced by the modulation is accomplished by the demodulator.
- The output of the demodulator is bit stream.

## ELEMENTS OF DIGITAL COMMUNICATION SYSTEM…

**Communication Channel:**

- The Channel provides the electrical connection between the source and destination.
- The different channels are: *Pair of wires, Coaxial cable, Optical fibre, Radio channel, Satellite channel or combination of any of these.*
- The communication channels have only finite Bandwidth, non-ideal frequency response, the signal often suffers amplitude and phase distortion as it travels over the channel.
- Also, the signal power decreases due to the attenuation of the channel.
- The signal is corrupted by unwanted, unpredictable electrical signals referred to as noise.
- The important parameters of the channel are Signal to Noise power Ratio (SNR), usable bandwidth, amplitude and phase response and the statistical properties of noise.

## SAMPLING

- Sampling is the process of converting continuous-time signal to a discrete-time signal.
  - A common example is the conversion of a sound wave (a continuous/analog signal) to a sequence of samples (a discrete-time signal).
- Two types of sampling:
  1. Ideal Sampling (or Impulse sampling or instantaneous sampling)
  2. Practical Sampling
     - i. *Natural Sampling (or Chopper Sampling)*
     - ii. *Flat Top Sampling (or Sample and Hold Sampling)*

## ALIASING

- Aliasing can be referred to as "the phenomenon of a high-frequency component in the spectrum of a signal, taking on the identity of a low-frequency component in the spectrum of its sampled version."
- The corrective measures taken to reduce the effect of Aliasing are –
  - In the transmitter section of PCM, a **low pass anti-aliasing filter** is employed, before the sampler, to eliminate the high frequency components, which are unwanted.
  - The signal which is sampled after filtering, is sampled at a rate slightly higher than the Nyquist rate.
- This choice of having the sampling rate higher than Nyquist rate, also helps in the easier design of the **reconstruction filter** at the receiver.

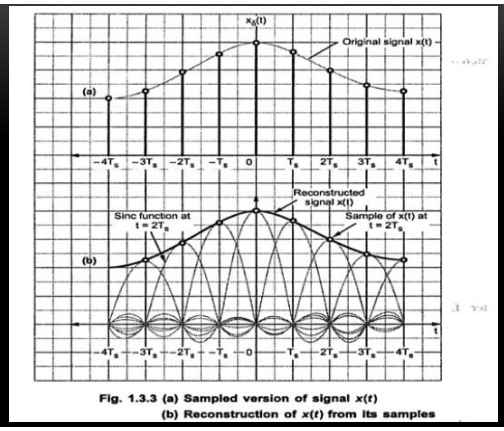



Fig. 1.3.3 (a) Sampled version of signal $x(t)$
(b) Reconstruction of $x(t)$ from its samples

## NATURAL SAMPLING

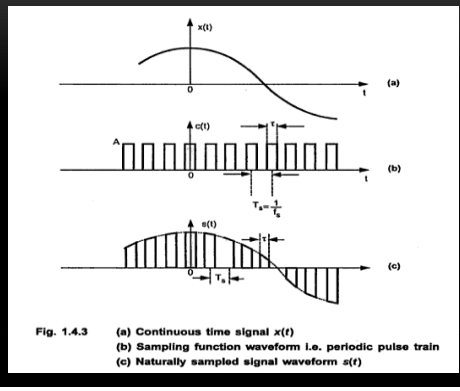



Fig. 1.4.3 (a) Continuous time signal $x(t)$
(b) Sampling function waveform i.e. periodic pulse train
(c) Naturally sampled signal waveform $s(t)$

## NATURAL SAMPLING

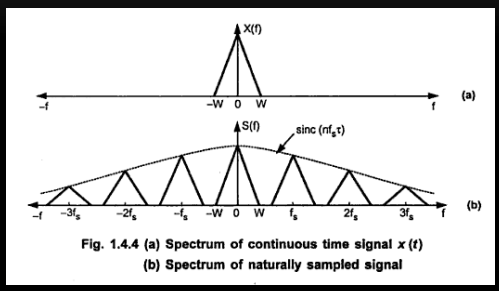
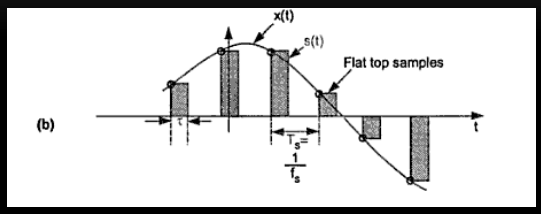
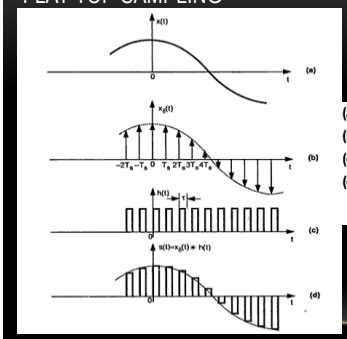



**Fig. 1.4.4 (a) Spectrum of continuous time signal $x(t)$**
**(b) Spectrum of naturally sampled signal**

## FLAT TOP SAMPLING



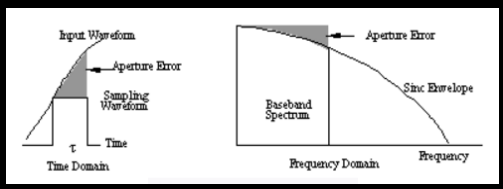

## FLAT TOP SAMPLING



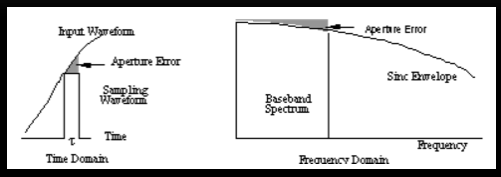

**(a) Baseband signal $x(t)$**
**(b) Instantaneously sampled signal $x_\delta(t)$**
**(c) Constant pulse width function $h(t)$**
**(d) Flat top sampled signal $s(t)$ obtained through convolution of $h(t)$ and $x_\delta(t)$**

## APERTURE EFFECT/ERROR

- Distortion introduced by flat topped sampling, causes loss of high frequency information.
- This is because the input signal may be changing while the sampled value is held constant.
- This error can be readily observed in both the time and frequency domains.




## APERTURE EFFECT/ERROR….




- This error or noise can be reduced by reducing the aperture width.
- by reducing the sampling window to very near zero, this form of distortion could be essentially eliminated.

## APERTURE EFFECT

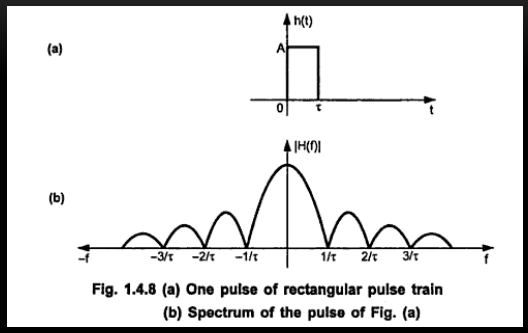



**Fig. 1.4.8 (a) One pulse of rectangular pulse train**
**(b) Spectrum of the pulse of Fig. (a)**

## COMPENSATION FOR APERTURE EFFECT

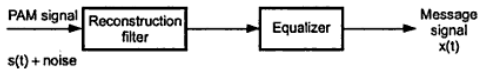
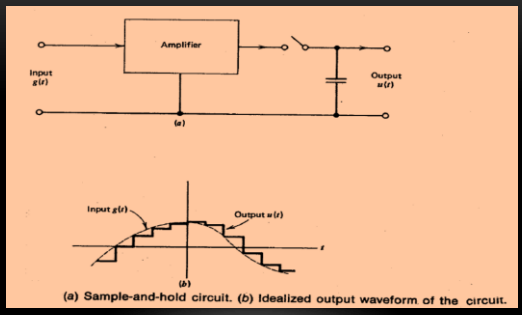



**Fig. 1.4.9 Recovering $x(t)$**

## SAMPLE AND HOLD CIRCUIT FOR SIGNAL RECOVERY



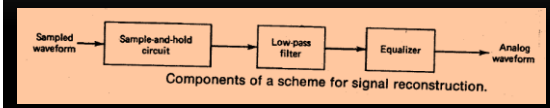

(a) Sample-and-hold circuit. (b) Idealized output waveform of the circuit.

## SAMPLE AND HOLD CIRCUIT FOR SIGNAL RECOVERY…

- In natural sampling and flat-top sampling, signal power at the o/p of low pass reconstruction filter in the receiver is small.
  - To overcome this, sample & hold circuit is used
- It consist of an amplifier of unity gain & low o/p impedance, a switch and a capacitor.
- The switch is time to close only for the small duration 'T' of each sampling pulse.
  - the capacitor charges up to a voltage level equal to that of the i/p sample.
- When the switch is open, capacitor retains its voltage level till the next closure of switch.
- Thus S&H circuit produces an o/p waveform that represent a staircase interpolation of the original analog signal.

## SAMPLE AND HOLD CIRCUIT FOR SIGNAL RECOVERY

- Reconstruction




Components of a scheme for signal reconstruction.

- To recover the original signal g(t) without distortion, the o/p of S&H is passed through an LPF designed to remove the spectral components of U(f) at multiples of sampling rate $f_s$ and an equalizer whose amplitude response is equal to (1/|H(f)|)