IT301: Data Communication & Computer Network(DCCN)

Class: B. Tech (CS) Sec A
Semester : V
Teacher: Dr. Amritanjali

Week 3

Syllabus

Module I

- **Data Communications and Networking**: Overview A Communications Model, Data Communications, Data Communication Networking, The Need for Protocol Architecture, A Simple Protocol Architecture, OSI, The TCP/IP Protocol Architecture, Data Transmission Concepts and Terminology, Analog and Digital Data Transmission, Transmission Impairments, Channel Capacity. (8L)

Module II

- **Transmission Media and Signal Encoding Techniques:** Guided Transmission Media, Wireless Transmission, Wireless Propagation, Line-of-Sight Transmission. Digital Data Digital Signals, Digital Data Analog Signals, Analog Data Digital Signals, Analog Data Analog Signals. (8L)

Module III

- **Digital Data Communication Techniques and Data Link Control:** Asynchronous and Synchronous Transmission, Types of Errors, Error Detection, Error Correction, Line Configurations, Interfacing, Flow Control, Error Control, High-Level Data Link Control (HDLC). (8L)

Module IV

- Multiplexing, Circuit Switching and Packet Switching Multiplexing Frequency Division Multiplexing, Synchronous Time Division Multiplexing, Statistical Time Division Multiplexing, Switching Networks, Circuit-Switching Networks, Circuit-Switching Concepts, Control Signaling, Soft switch Architecture, Packet-Switching Principles, X.25, and Frame Relay. (8L)

Module V

- Asynchronous Transfer Model Protocol Architecture, ATM Logical Connections, ATM Cells, Transmission of ATM Cells, ATM Service Categories, ATM Adaptation Layer. Routing in Switched Networks Routing in Circuit-Switching Networks, Routing in Packet-Switching Networks, Least-Cost Algorithms. (8L)

Text Book: Stallings W., Data and Computer Communications, 10th Edn., Pearson Education, PHI, New Delhi, 2014.(T1)

Reference Book: Forouzan B. A., Data Communications and Networking, 5thEdn. TMH, New Delhi, 2017.(R1)

Data Transmission

Basic Concepts

- **Transmission Medium**

  Guided- Waves are guided along a physical path

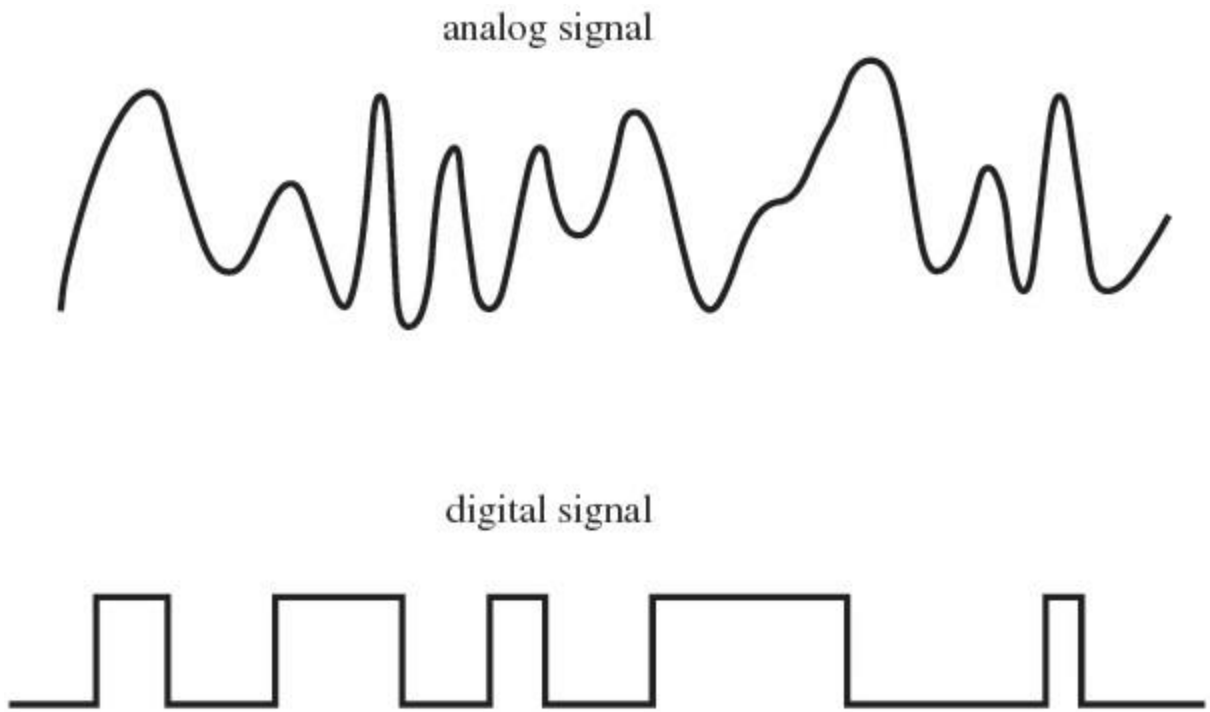
  Unguided- Provides means for transmitting waves, but do not guide them

- **Signals**

  Analog- Signal intensity varies smoothly with time

  Digital- Signal intensity maintains a constant level for some period of time and then abruptly changes to another constant level

Analog and Digital Signals

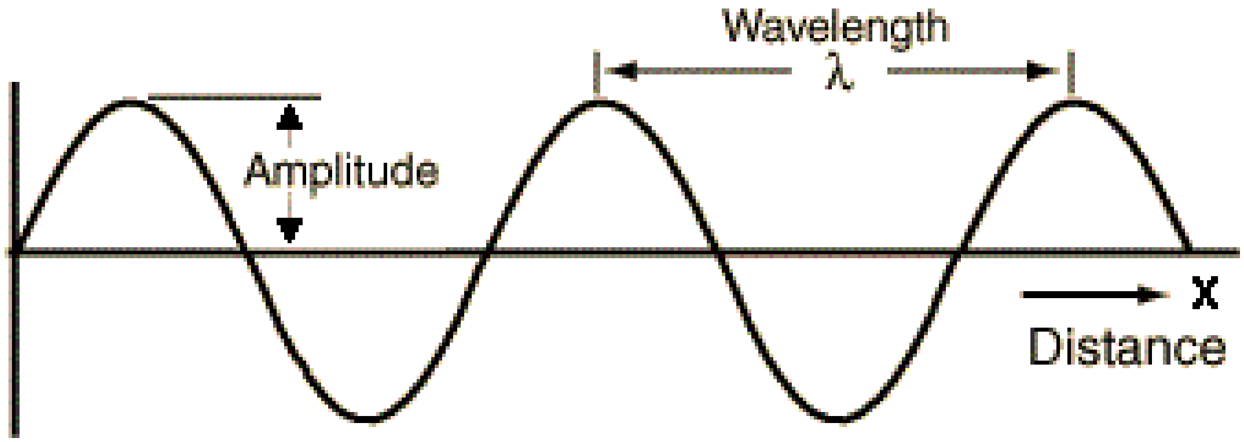


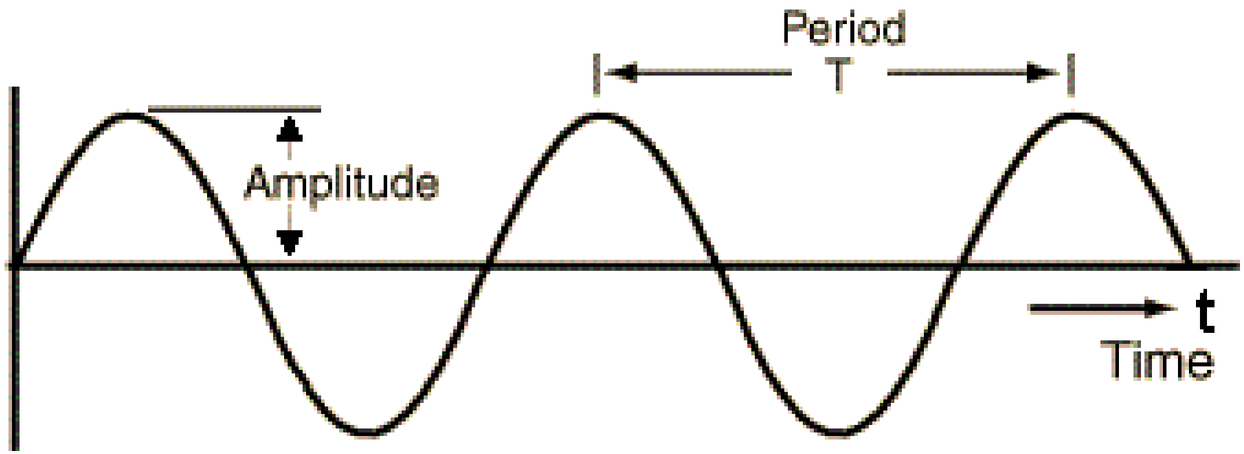
Periodic Signals

- **Periodic Signal**
  - Same signal pattern repeats over time
  - $s(t+T) = s(t) \qquad -\infty < t < +\infty$
- **Peak Amplitude**
  - Maximum value or the strength of the signal over time
  - Measured in volts
- **Frequency**
  - Rate at which signal repeats
  - Measured hertz

- **Time Period**
  - Amount of time it takes for one repetition
- **Phase**
  - Relative position in time within a single period of the signal
- **Wavelength**
  - Distance occupied by a single cycle

Examples


Wavelength
λ
Amplitude
x
Distance


Period
T
Amplitude
t
Time

- An electromagnetic wave consists many frequencies
- Spectrum- Range of frequencies that it contains
- Absolute Bandwidth- Width of the spectrum
- Effective Bandwidth- Band of frequencies with most of the signal energy
- DC Component- a component of zero frequency

DC Component

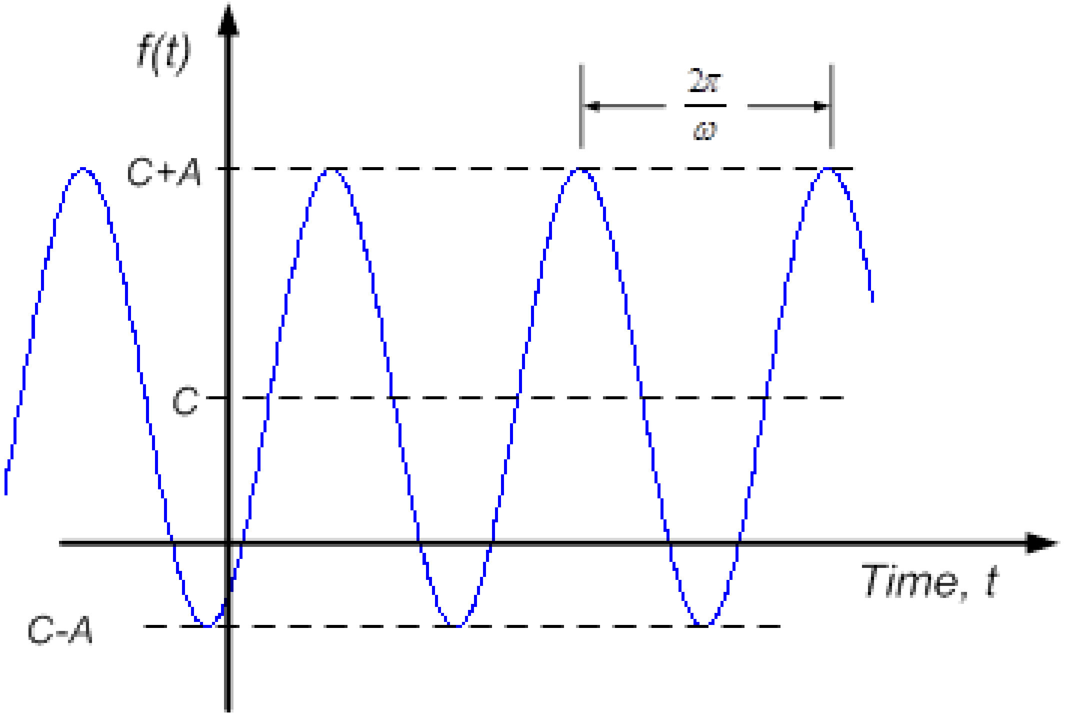


Image Source;
https://learn.digilentinc.com/

Analog Transmission

- Means of transmitting analog signals
- Carries analog or digital data
- Signals become weak after a certain distance
- Amplifiers are used to increase signal energy
- Amplifiers boosts noise component also
- Cascaded amplifiers distorts the signal, which causes bit errors for digital data

Digital Transmission

- Assumes digital data
- Signal gets attenuated with distance
- Repeaters are used to increase transmission range
- Repeaters recovers bit patterns and retransmit the signal, removing noise from the signal
- This is the preferred method of transmission

Factors Favoring Digital Transmission

- Digital Technology
  - A continuous drop in the digital equipments
- Data Integrity
  - Data integrity can be preserved over long distances on even low quality lines
- Capacity Utilization
  - Transmission capacity of high bandwidth links can be utilized easily at low cost with time division multiplexing

- Security and Privacy
  – Encryption techniques can be readily applied to binary data
- Integration
  – Both analog and digital data are represented uniformly as binary data and transmitted through digital signals using same techniques

Transmission Impairments

Impairments caused during the transmission of signals

- Attenuation
- Distortion
- Noise

Attenuation

- Loss of energy due to resistance imposed by the medium as a result signal strength reduces with distance
- It is measured in decibles (dB)
- It is measured by finding the relative strengths of the signal at different points of time
- Attenuation = $10\log_{10}(P2/P1)$
- P2- Power at the receiver side
- P1- Power at the sender side

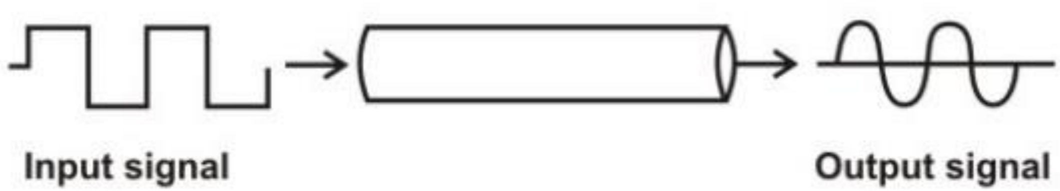
Attenuation

Problems caused due to distortion

- If the strength of the signal is very low, the signal cannot be detected and interpreted properly at the receiving end.

Attenuation Distortion

- Attenuation of all frequency components is not same.
- Some frequencies are passed without attenuation, some are weakened and some are blocked.
- This dependence of attenuation of a channel on the frequency of a signal leads to signal distortion



Delay Distortion

- The velocity of propagation of different frequency components of a signal are different in guided media.
- The velocity of propagation has been found to be maximum near the center frequency and lower on both sides of the edges of the frequency band.
- As a result different components arrive at different time.
- In case of digital signals, this problem leads to inter symbol interference, which restricts the maximum bit rate of transmission through a particular transmission medium.

Noise

- Any unwanted signals that are inserted somewhere between transmission and reception.

Four categories

- Thermal noise
- Intermodulation noise
- Crosstalk
- Impulse noise

Thermal Noise

- Arises from random electron motion with increase in temperature
- Also called as White Noise as it is distributed across entire spectrum
- Every equipment element and the transmission medium contribute thermal noise to a communication system
- It places an upper bound on communication systems performance.
- Thermal noise in a bandwidth of B Hz is :

$$N_o = kTB \text{ watts}$$

- k- Boltzman's constant = $1.38\ 10^{-23}$ J/K
- T- Temperature in Kelvin

Intermodulation Noise

- Intermodulation noise is produced when there is some nonlinearity in the transmitter, receiver, or intervening transmission system.
- For example, two signals f1 and f2 will generate signals of frequencies (f1 + f2) and (f1 - f2),
- The derived signals interfere with the signals of the same frequencies sent by the transmitter.

Cross Talk

- Crosstalk refers to unwanted coupling between signal paths.
- Signal carrying wires generate electromagnetic radiation, which is induced on other conductors because of close proximity of the conductors
- Example: hear another conversation when using the telephone

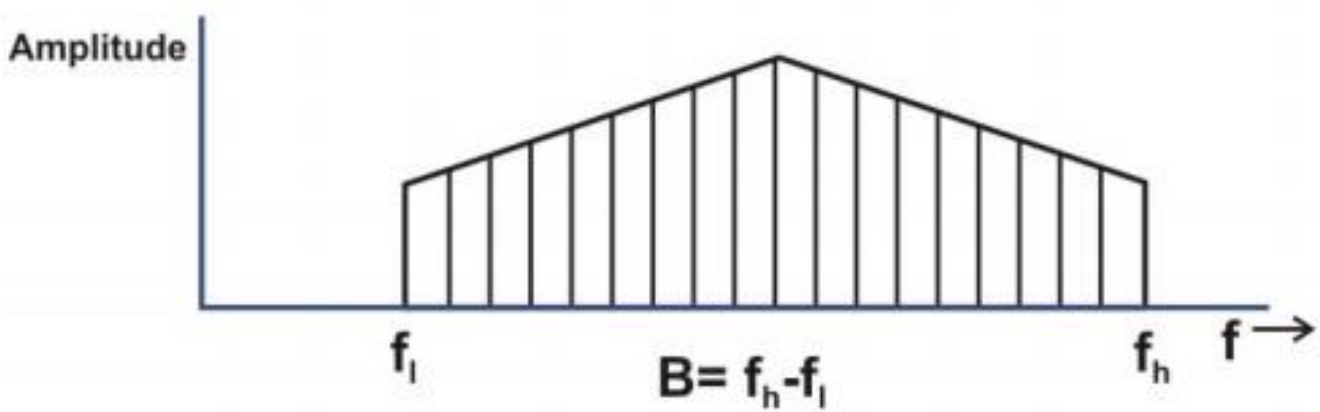
Impulse Noise

- Impulse noise is non-continuous
- Irregular pulses or noise spikes of short duration of relatively high amplitude
- Generated from a variety of causes, including external electromagnetic disturbances such as lightning, spark due to loose contact in electric circuits, etc.
- Primary source of error in digital data communication causing burst errors
- A sharp spike of energy of 0.01 seconds duration can destroy 50 bits of data being transmitted at 4800 bps

Bandwidth and Channel Capacity

Bandwidth

- Bandwidth refers to the range of frequencies that a medium can pass without a loss of one-half of the power (-3dB) contained in the signal.
- Bandwidth of a medium decides the quality of the signal at the other end.



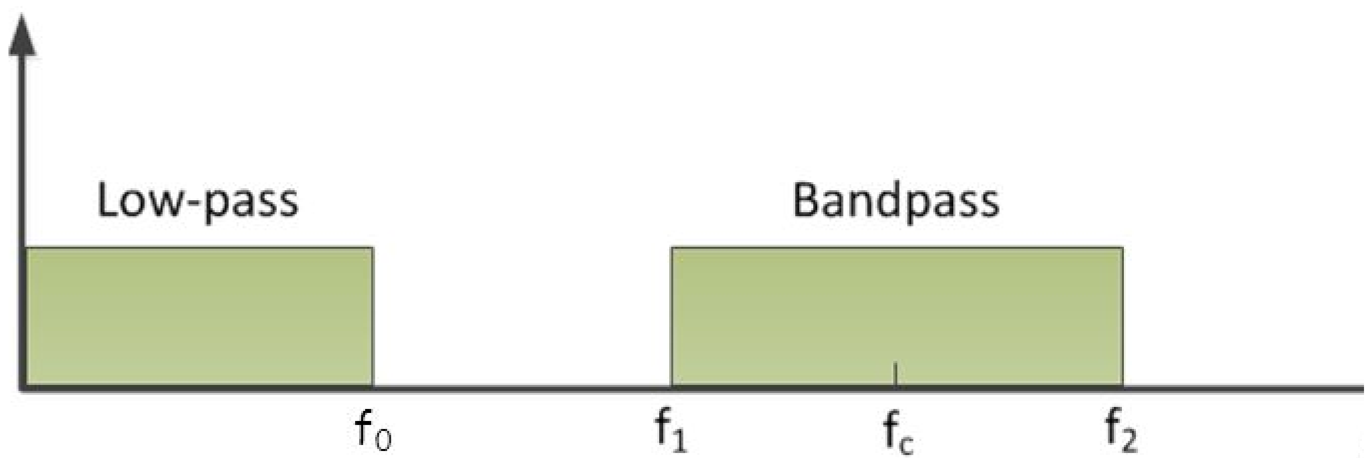
Low Pass Channels

Low frequency components can pass the channel

High frequency components are blocked

Bandpass Channel

Frequency components in the range [f1, f2] pass through the channel



Channel capacity

- **Channel capacity** is the maximum rate at which data can be transmitted over a given communication path or channel, under given conditions

  Data Rate or Bit Rate-

- The rate in bits per second (bps) at which data can be communicated

  Buad Rate or Signaling rate- Number of signal elements

  (voltage levels) transmitted per second

- In binary signaling with 2 signal levels,

  Bit Rate = Baud Rate

- In multilevel signaling with M signal levels,

  Bit Rate = Baud Rate x $\log_2 M$

Nyquist Bandwidth

- For a given bandwidth B, maximum signaling rate or baud rate achievable is equal to the double of the channel bandwidth

  Baud Rate $\leq$ 2B

- Using Nyquist formulation, Channel Capacity is calculated as follows-

  C = Max Baud Rate x $\log_2 M = 2B \log_2 m$ bits/sec

  B is the bandwidth of the channel in Hz

  M is the number of signal levels used in the signal

- If M=2, C = 2B = Max Baud Rate
- Value of M is limited by the noise and other impairments

Let us consider the telephone channel having bandwidth B = 4 kHz. Assuming there is no noise, determine channel capacity for the following encoding levels: (i) 2, and (ii) 128.

Ans:

(i) $C = 2B = 2 \times 4000 = 8$ Kbits/s

(ii) $C = 2 \times 4000 \times \log_2 128 = 8000 \times 7 = 56$ Kbits/s

Shannon Capacity Formula

- In the presence of white noise, Shannon capacity formula gives the maximum data rate capacity

  $C = B \log_2 (1 + SNR)$,

  SNR (Signal to Noise Ratio) = S/N

- S and N are the signal and noise power, respectively, at the output of the channel.
- This theorem gives an upper bound of the data rate which can be reliably transmitted over a thermal-noise limited channel

Example

- Suppose we have a channel of 3000 Hz bandwidth, we need an S/N ratio (i.e. signal to noise ration, SNR) of 30 dB to have an acceptable bit-error rate. Find the maximum data rate?

Solution

$SNR_{dB} = 10\log_{10}(SNR)$

$10 \log_{10} (SNR) = 30$

SNR = 10^3 = 1000

$C = B \log_2(1 + SNR)$

$= 3000 \times \log_2 (1+1000) \approx 30{,}000$ bps

Combining Nyquist and Shannon Formulations

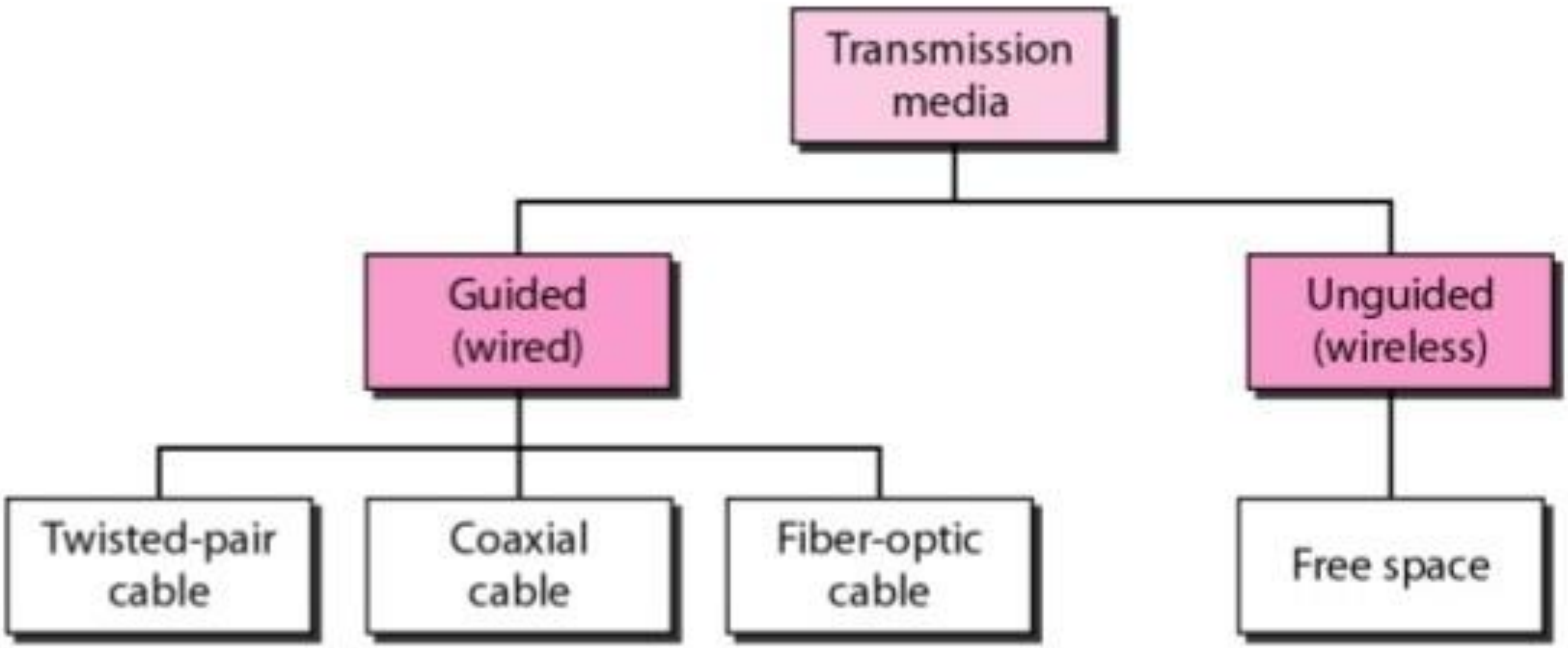
- Using Shannon Formula, we can find the maximum achievable bit rate for a given signal to noise ratio and bandwidth.
- Then, by applying Nyquist formula, we can find the signalling levels required to achieve the bit rate computed from Shannon's formula.

Module II

Transmission Medium

- A transmission medium can be broadly defined as anything that can carry information from a source to a destination
- It can be free space, metallic cable, or fiber-optic cable
- The information is contained in a signal
- These signals are transmitted from one device to another in the form of electromagnetic energy, which is propagated through transmission media

Classes of transmission media



Guided Media

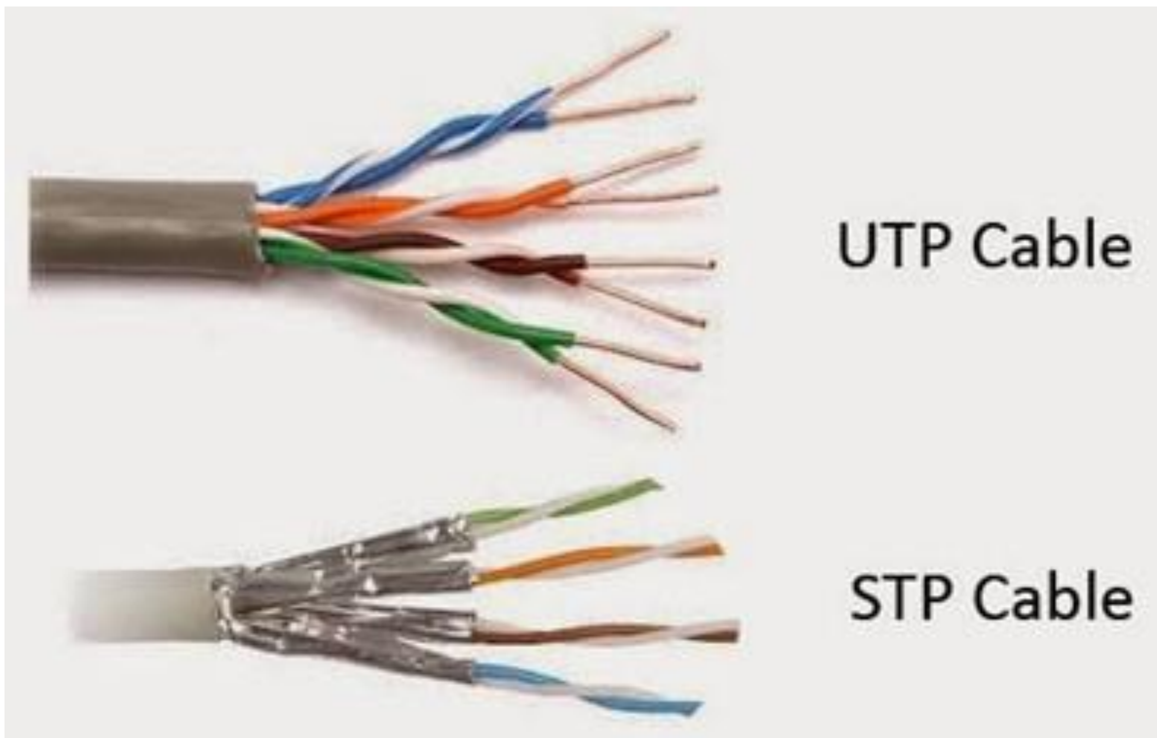
- Guided media, which are those that provide a conduit from one device to another
- Include twisted-pair cable, coaxial cable, and fiber-optic cable
- A signal is directed and contained by the physical limits of the medium
- Twisted-pair and coaxial cable use metallic (copper) conductors that transport signals in the form of electric current

Twisted Pairs

- A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together
- One of the wires is used to carry signals to the receiver, and the other is used only as a ground reference
- Twisting makes it probable that both wires are equally affected by external influences (noise or crosstalk)
- As the receiver calculates the difference between the two, the unwanted signals are mostly canceled out
- A twisted-pair cable can pass a wide range of frequencies
- However, with increasing frequency, the attenuation sharply increases with frequencies above 100 kHz
- They can be used for both analog and digital communication.

Twisted Pairs

UTP- Unshielded Twisted Pair
STP- Shielded Twisted Pair



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Performance

Advantages

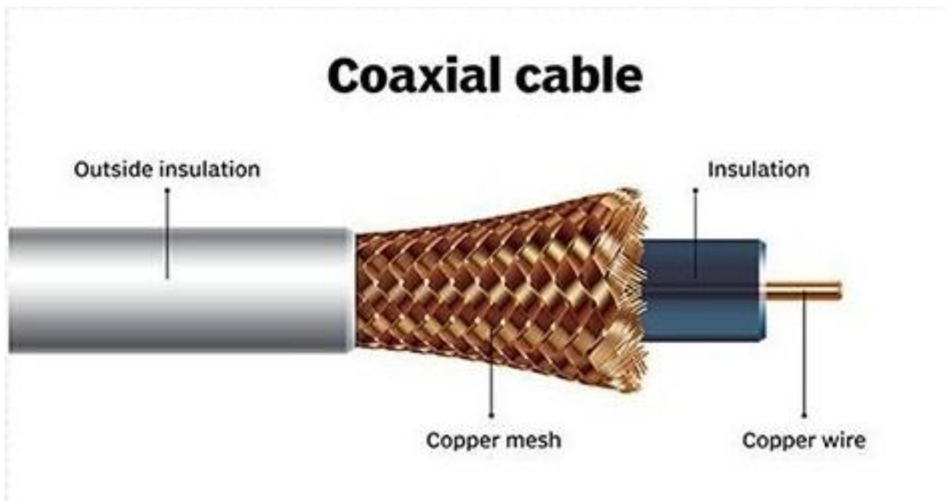
- Inexpensive and readily available
- Flexible, light weight, easy to install

Disadvantages

- Susceptibility to interference and noise
- Attenuation problem, repeaters needed every 2-3 km
- Relatively low bandwidth (100 MHz)

Coaxial Cable

- Coaxial cable has a central core conductor of solid or stranded wire (usually copper) enclosed in an insulating sheath
- This is encased in an outer conductor
- The outer metallic wrapping serves both as a shield against noise and as the second conductor
- This outer conductor is also enclosed in an insulating sheath and the whole cable is protected by a plastic cover
- Can be used for both analog and digital signaling



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Performance

Advantages

- higher bandwidth 400 to 600 Mhz
- can be easily tapped
- much less susceptible to interference than twisted pair

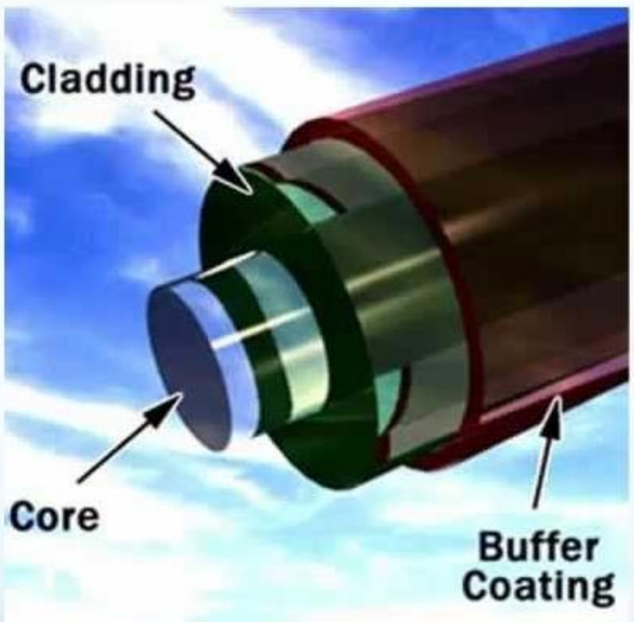
Disadvantages

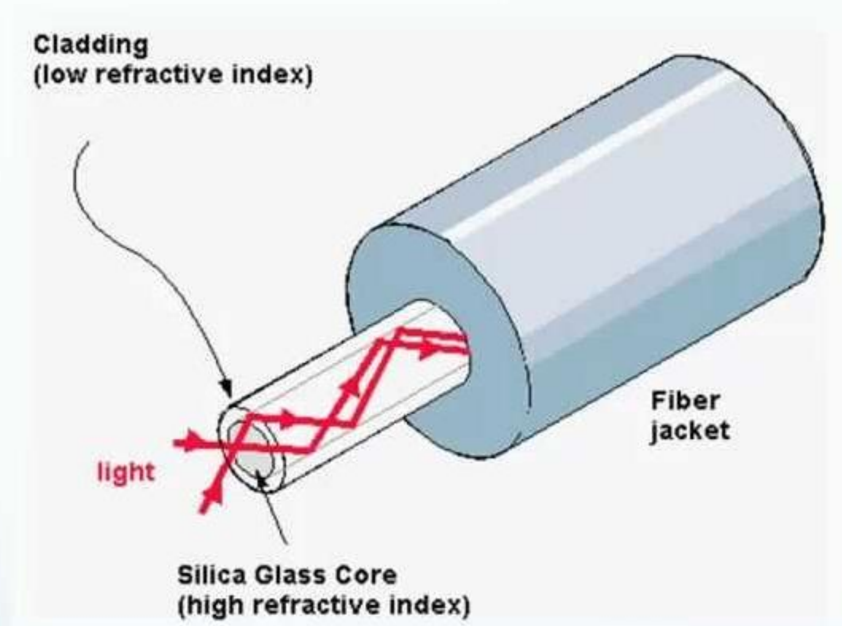
- high attenuation rate makes it expensive over long distance (repeaters required every 2-3 km)
- can be easily tapped
- bulky

Fiber Optic Cable

- Relatively new transmission medium used by telephone companies in place of long-distance trunk lines
- Also used by private companies in implementing local data networks
- Require a light source with injection laser diode (ILD) or light emitting diodes (LED)
- It consists of three concentric sections- jacket, cladding and core

Fiber Optic Cable





Transmission Modes

- Optical signal transmits a data encoded beam of light by means of total internal reflection

Single Mode Transmission

- Single transmission path
- Suitable for long distance communication

Multimode Transmission

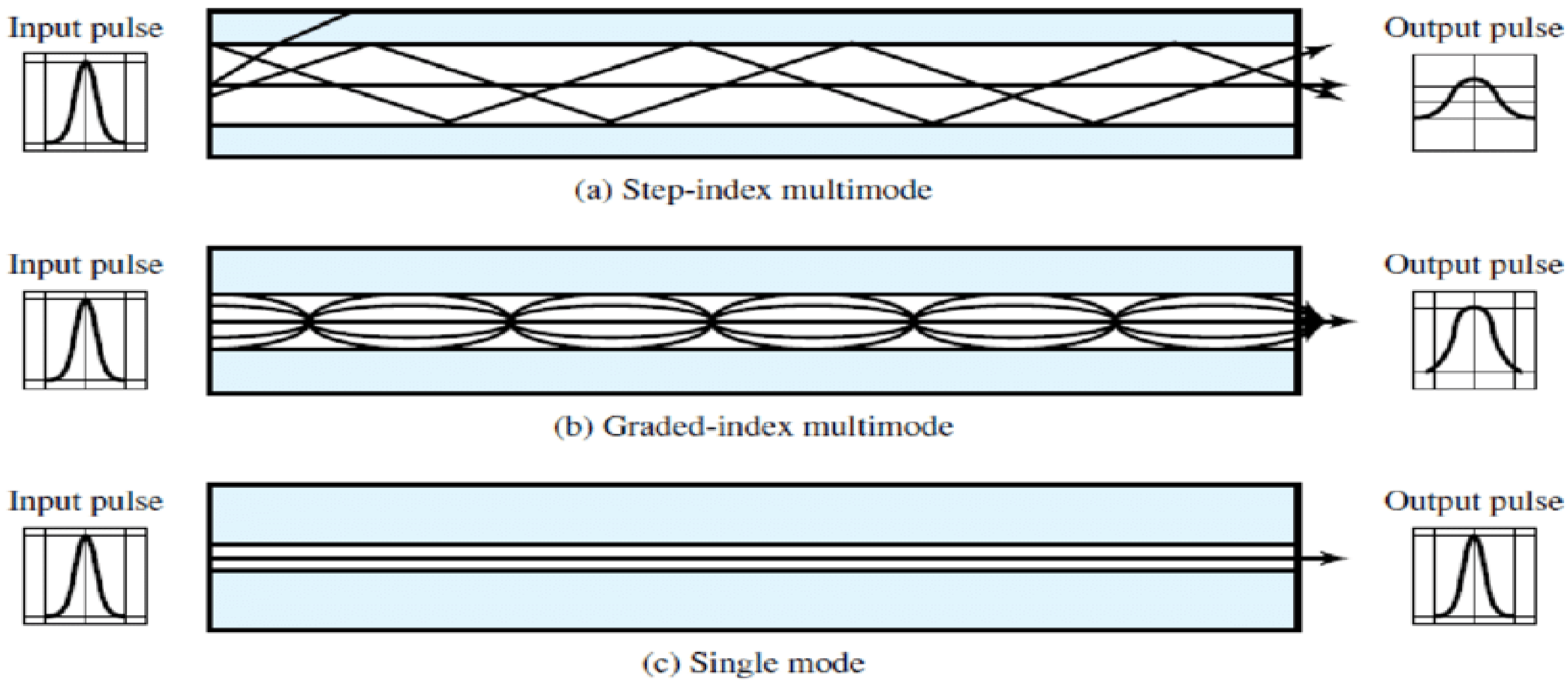
- Multiple propagation paths

1. Step Index Multimode

- Rays at shallow angles gets reflected and propagated
- Paths lengths are different
- Pulses get elongated, limiting the data rate

2. Graded Index Multimode

- Speed of rays is controlled by varying the refractive index of the core, highest at the centre
- Rays near the cladding travel slower than near the cladding
- Performance is intermediate between single mode and step index multimode



Fiber Optic Cable

Advantages

- greater capacity (hundreds of Gbps)
- smaller size and lighter weight
- lower attenuation
- immunity to environmental interference
- greater repeater spacing – 10s of km
- highly secure due to tap difficulty

Disadvantages

- expensive over short distance
- requires highly skilled installers
- adding additional nodes is difficult

Wireless Transmission

- Radio Frequency Transmission
- Microwave Transmission
- Infrared Transmission

Radio Frequency Transmission

- Frequency range from 30 MHz to 1 GHz
- Suitable for omnidirectional applications
- Penetrate through objects and travel long distances
- Performance depends on the wavelength, transmitter power, receiver quality, type, size and height of the antenna.

Wireless Transmissions

Microwave Transmission

- Frequency range from 1 GHz – 40 GHz
- Directional beams suitable for point to point communication
- Suitable for long distance communication
- Does not penetrate through buildings
- Affected by bad weather

Infrared Transmission

- Frequency range from 300 GHz- 200 THz
- Do not pass through solid objects
- Useful for local communication

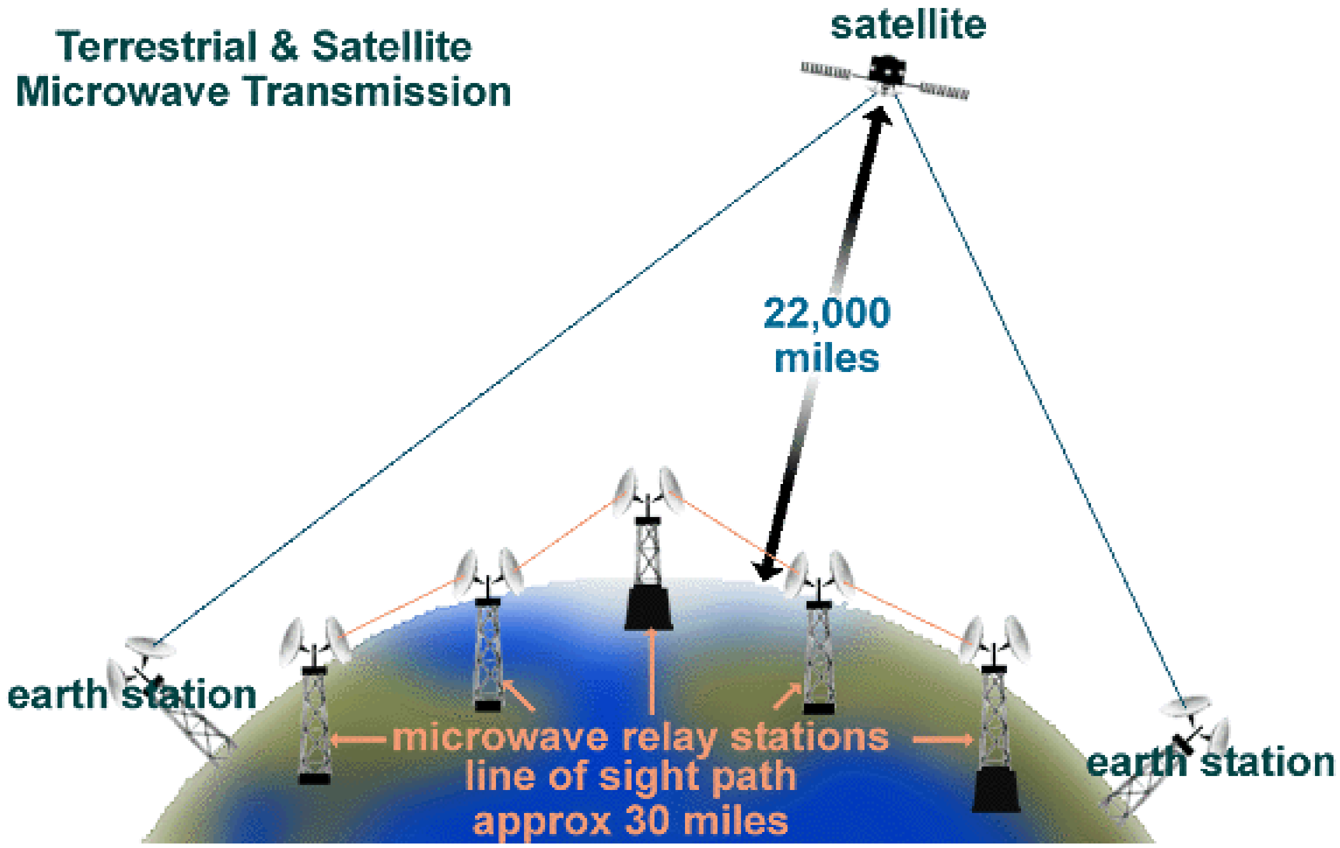
Terrestrial Microwave

- Parabolic dish of 3 m diameter is commonly used
- Requires line of sight transmission to the receiving antenna
- Located at substantial heights
- Long-haul telecommunication service, cellular service, TV signals to local CATV installations
- Loss due to attenuation varies as the square of distance

$$L = 10 \log(4\pi d/\lambda)^2 \text{ dB}$$

Satellite Microwave

- Satellite is used as microwave relay station
- Links two or more ground-based microwave transmitter/receiver
- Receives signals on one frequency band, amplifies or repeats the signal on another frequency
- Satellite can operate on multiple frequency bands called transponder channels
- Used for television distribution, long distance telecommunication, GPS
- Suffers from propagation delay of about a quarter of second for transmissions from one earth station to another
- Requires error and flow control mechanisms
- Inherently broadcast mechanism



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Broadcast Radio

- Omnidirectional transmission
- Does not require dish shape antenna
- Precise alignment of antenna not required
- Relatively less attenuation with distance
- Less sensitive to attenuation from rainfall
- Suffers from multipath interference