Chapter 1: Communication System

An Introduction

Communications

- **Communications**

  Transfer of information from one place to another.

  Should be efficient, reliable and secured.

  "A communication system is a process of **conveying information** from a source to a destination"

- **Communication system**

  Components/subsystems act together to accomplish information transfer/exchange

  "An electronic communication system is transferring information using an electrical field as a **mean of signal**"

Requirements

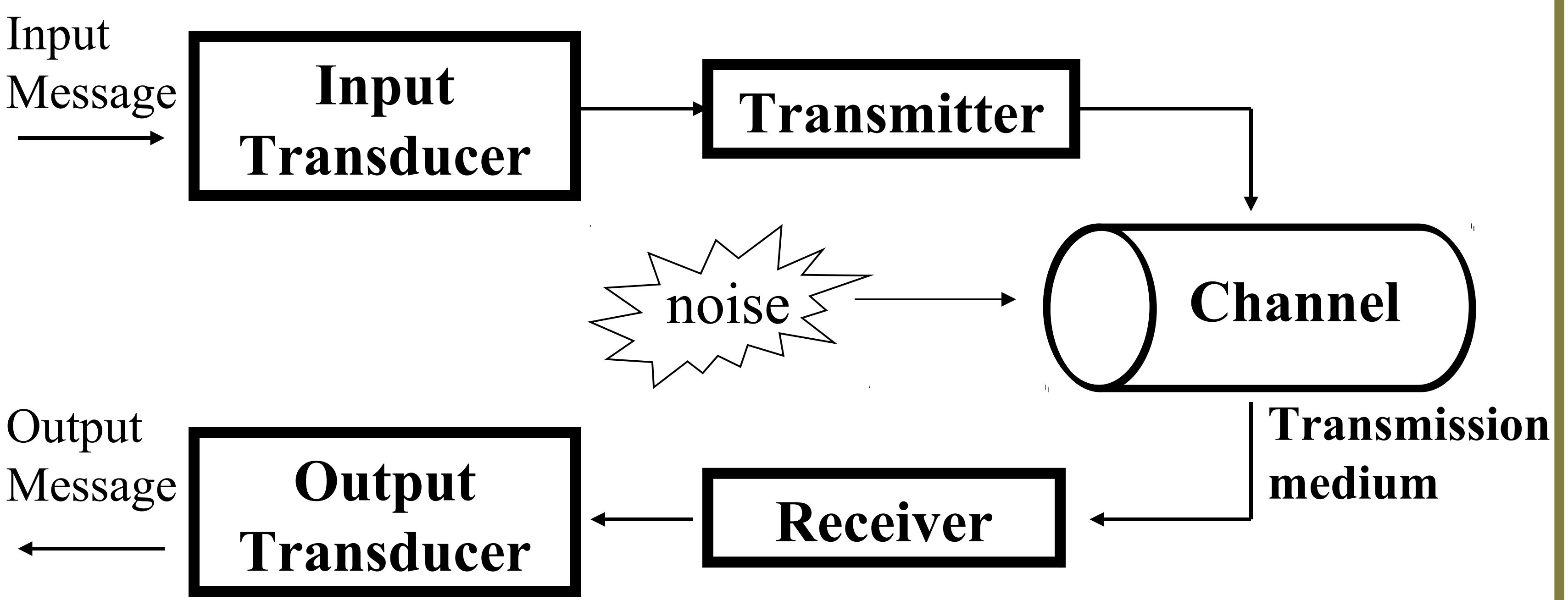
- **Rate of information transfer**
  - The rate of information transfer is defined as the amount of information that must be communicated from source to destination.
  - It will determined the physical form and technique used to transmit and receive information and therefore determines the way system is designed and constructed
- **Purity of signal received**
  - The received signal must be the same as the transmitted signal

Requirements

- **Simplicity of the system**
  - Any communication system must be convenient in order to be effective and efficient and easy to use

- **Reliability**
  - Users must be able to depend on a communication system. It must work when needed and transmit and receive information without errors or with an acceptable error.

Elements of Communication system



Elements of Communication system

- **Input Transducer**

  To **convert the message** to a form suitable for the particular type of communication system.

  Eg: Speech waves are converted to voltage variation by a microphone.

- **Transmitter**

  Processes the input signal → to produce a transmitted signal that suited the characteristic of **transmission channel**.

  eg: modulation, coding

  Other functions performed:

  Amplification, filtering

Elements of Communication system

- **Channel (Transmission medium)**

  A medium that bridges the distance from source to destination.

  eg: Atmosphere (free space), coaxial cable, fiber optic, waveguide

  Signal undergoes degradation from noise, interference and distortion.

- Transmission systems can be evaluated according to five (5) main criteria:

  → Capacity → Performance
  → Distance → Security
  → Cost which include installation, operation and maintenance

Elements of Communication system

The two main categories of channel commonly used are:

- **Line (conducted media)**
  - The channel is made up metallic cable (such as coaxial cable, twisted pair, parallel wires, and others) or fibre optic cable.

- **Free space or radiated media**
  - This is the medium where the transmission of signal is carried out by the propagation of electromagnet wave.
  - The main applications are in radio broadcasting, microwaves and satellites transmission systems.

Elements of Communication system

- **Loses in medium of transmission**
  - However, each medium introduces losses termed as attenuation, distortion and adds noise to some degree to the transmitted signal. The amount of attenuation, distortion and noise depends on the type of transmission medium used.
  - There is normally no signal processing in the transmission medium, it is just the medium where the transmitter is connected to the receiver.

Elements of Communication system

- **Receiver**

  To **extract the desired signal** from the output channel and to convert it to a form suitable for the output transducer.

  eg: Demodulation, decoding

  Other functions performed:

  Amplification, filtering.

- **Output Transducer**

  Converts the electrical signal at its input into a form desired by the system used.

  Eg: Loudspeaker, PC and tape-recorders.

Losses in Communication System

Various unwanted undesirable effect crop up in transmissions

- **Attenuation**
  - Reduces signal strength at the receiver
- **Distortion**
  - Waveform perturbation caused by imperfect response of the system to the desired signal itself
  - Equalizer can be used to reduced the effect
- **Interference**
  - Contamination by extraneous signals from human sources

Losses in Communication System

- **Noise**
  - Random and unpredictable electrical signals from internal or external to the system
  - The term SNR (signal to noise ratio) is used to measure performance (noise) relative to an information analog signal
  - The term BER (Bit Error Rate) is used in digital system to measure the deterioration of the signal

Analog vs. Digital

The signal can be analog or digital message:

- **Analog**
  - Continuous Variation
    - Assumes the total range of frequencies/time
  - All information is transmitted.

- **Digital**
  - Takes samples
    - non-continuous stream of on/off pulses
  - Translates to 1s and 0s

Analog Vs Digital
(Advantages and Disadvantages)

Digital CS

Advantages:

- Inexpensive
- Privacy preserved (Data encrypt.)
- Can merge different data
- Error correction

Disadvantages:

- Larger bandwidth
- Synchronization problem is relatively difficult.

Analog CS

Disadvantages:

- Expensive
- No privacy preserved
- Cannot merge different data
- No error correction capability

Advantages:

- Smaller bandwidth
- Synchronization problem is relatively easier.

Baseband vrs Modulated Signal

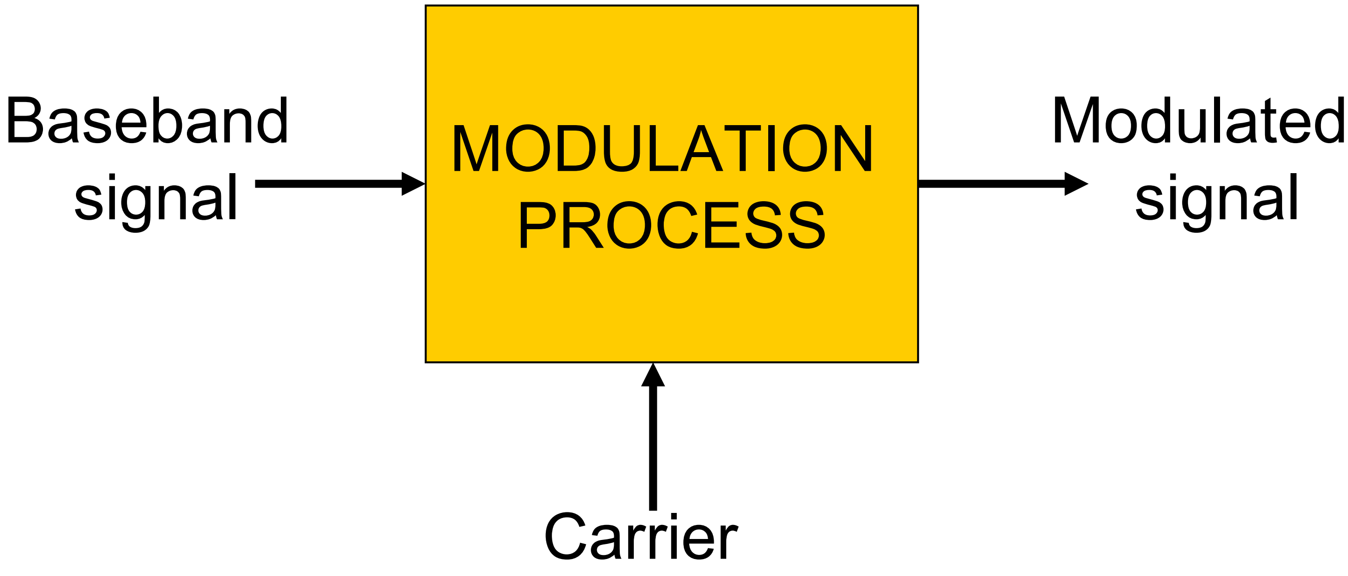
- **Baseband Signal**
  - Base band signal is the modulating signal/**original information** signal either in a digital or analog form (intelligent/message) in communication system

    Example: voice signal (300Hz – 3400Hz)

  - Transmission of original information whether analog or digital, directly into transmission medium is called **baseband transmission.**

- **Modulated Signal**
  - Modulated signal is baseband signal which its original frequency is **shifted to higher frequency** to facilitate transmission purposes

Block Diagram of Modulation Process



Baseband Transmission

- The need of baseband transmission:
  - The concepts and parameter of baseband transmission are used in modulated transmission
  - Performance of baseband transmission is used as the standard for comparing modulation techniques
- Baseband signal is not suitable for long distance communication because:
  - Hardware limitation (eg: requires very long antenna)
  - Interference with other waves

Modulation

- **Modulation –**

  Process of changing baseband signals to **facilitate** the transmission medium

- **Process of modulation**

  - Frequency translation such as AM, FM, PM etc
  - Sampling and coding such as PAM, PCM etc
  - Keying such as ASK, FSK etc

Modulation

- Types of modulation :
  - Analogue modulations are frequency translation method caused by changing the appropriate quantity in a carrier signal
  - Digital modulation is the result of changing analogue signal into binary ones by sampling and coding
  - Keying modulations are digital signals subsequently modulated by the frequency modulation by using one or other analogue method

Why Modulate?

- Reduce noise and interference
  - By using proper frequency where noise and interference are at minimum
  - Increasing power is costly and may damage equipment
- Frequency Assignment
  - For TV and radio broadcasting, each station has a different assigned carrier
- Multiplexing
  - Combining several signals for simultaneous transmission on one channel by placing each signal on different carrier frequency

Electromagnetic Frequency Spectrum

- The electromagnetic frequency spectrum is divided into
  - subsections, or bands, with each band having a different name and boundary
- The International Telecommunications Union (ITU) is an international agency in control of allocating frequencies and services within the overall frequency spectrum

Electromagnetic Frequency Spectrum

- In the United State, the Federal Communications Commission (FCC) assigns frequencies and communications services for free space radio propagation

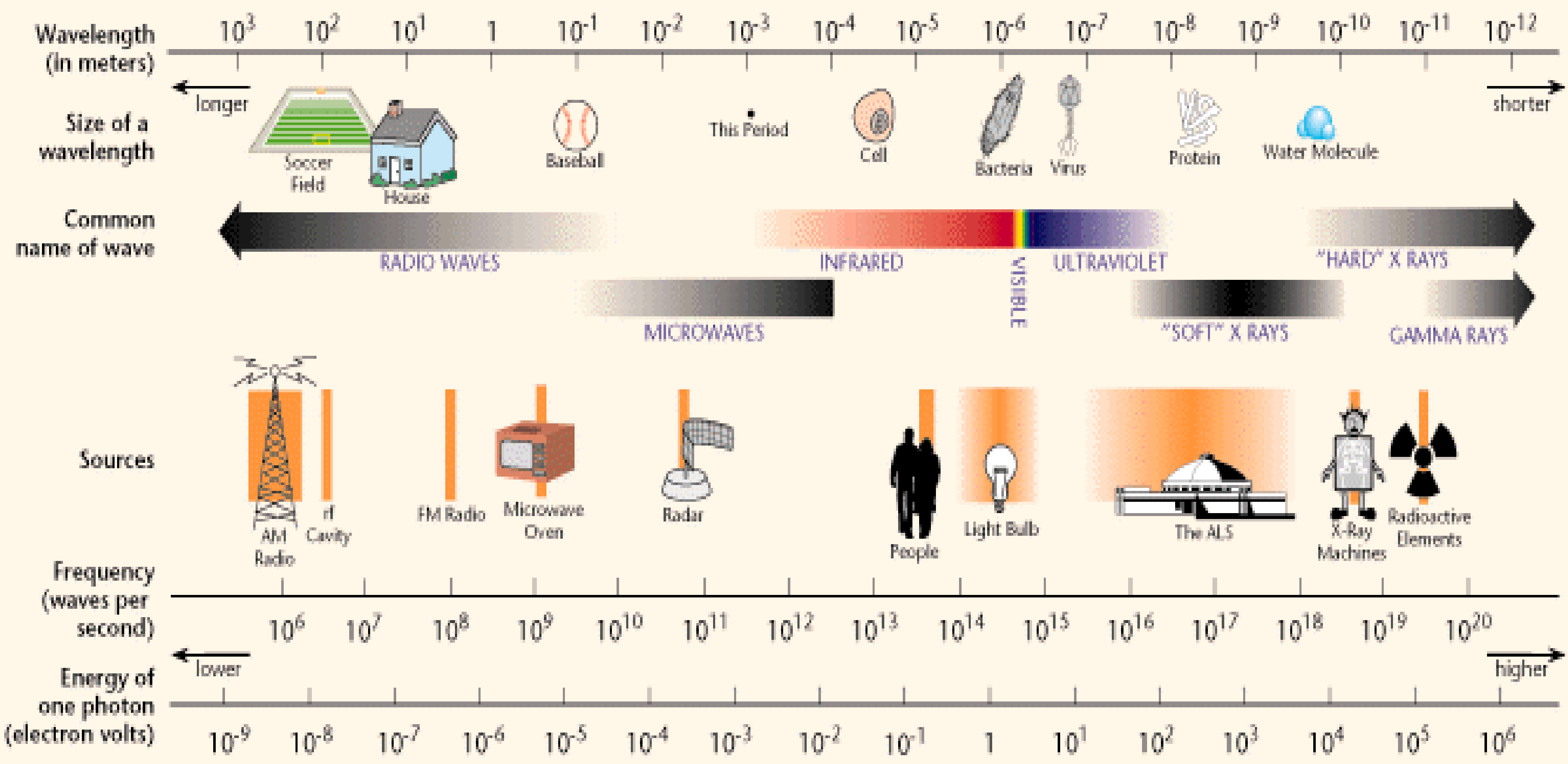
Speed of electromagnetic wave = speed of light, $c = 3.0 \times 10^8$ ms^{-1}

f = freq

λ = wavelength

$$c = f\lambda$$

THE ELECTROMAGNETIC SPECTRUM



Frequency allocation

- If the transmission channel is the atmosphere,
  interference and propagation are strongly dependent on the transmission frequency

- On international basis, frequency assignment and technical standards are set by the ITU

- There are three main sector that provides frequency assignment and is concerned with the efficient use of radio frequency spectrum
  - **ITU(R)**
  - **ITU(T)**
  - **ITU(D)**

Frequency Bands

3 – 30 kHz	VLF (very low freq)	Ground wave
30 – 300 kHz	LF (low freq)	Ground wave
300 – 3000 kHz	MF (medium freq)	Ground wave/sky wave
3 – 30 MHz	HF (high freq)	Sky wave (Ionospheric)
30 – 300 MHz	VHF (very high freq)	Space wave (LOS)
300 – 3000 MHz	UHF (ultrahigh freq)	Space wave (LOS)
3 – 30 GHz	SHF (superhigh freq)	LOS/Satellite
30 – 300 GHz	EHF (Extremely high freq)	LOS/Satellite

International Telecommunications Union (ITU) Band Designation

Frequency Bands

Frequency Bands	Letter Designation
1.0 – 2.0 GHz	L
2.0 – 4.0 GHz	S
4.0 – 8.0 GHz	C
8.0 – 12.0 GHz	X
12.0 – 18.0 GHz	Ku
18.0 – 27.0 GHz	K
27.0 – 40.0 GHz	Ka
26.5 – 40.0 GHz	R

Federal Communications Commission (FCC) Emission Classifications

Frequency Bands

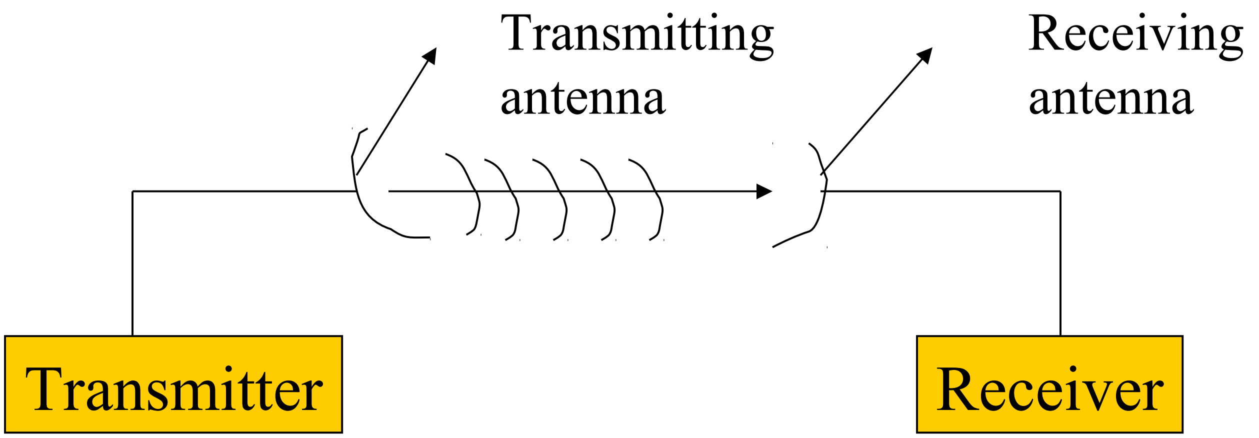
Frequency Bands	Letter Designation	Uses
33.0 – 50 GHz	Q	Radar/satellite comm
40.0 – 75.0 GHz	V	Radar/satellite comm
75.0 – 110 GHz	W	Radar/satellite comm
10^3 – 10^7GHz	Infrared, visible light and ultra violet	Optical communication

Federal Communications Commission (FCC) Emission Classifications

Radio Communication System

- It is wireless communication system
- The information is being carried by the electromagnetic waves, which is propagated in free space
- Electromagnetic waves are waves that travel at the speed of light and made up of an electrical field and magnetic field at right angles to one another and to the direction of propagation

Radio Communication System



Block diagram of a radio communication system

Propagation Waves

There are three main type of propagations:

- **Ground wave propagation**
  - Dominants mode for frequencies **below 2 MHz**
  - The movement tend to follow the contour of the earth with large antenna size
- **Sky-wave propagation**
  - Dominants mode for frequencies between 2 – 30 MHz range
  - Coverage is obtained by reflection the wave at ionosphere and at the earth boundaries
  - This is because the index **refractions of the ionosphere** varies with the altitude as the ionization density changes

Propagation Waves

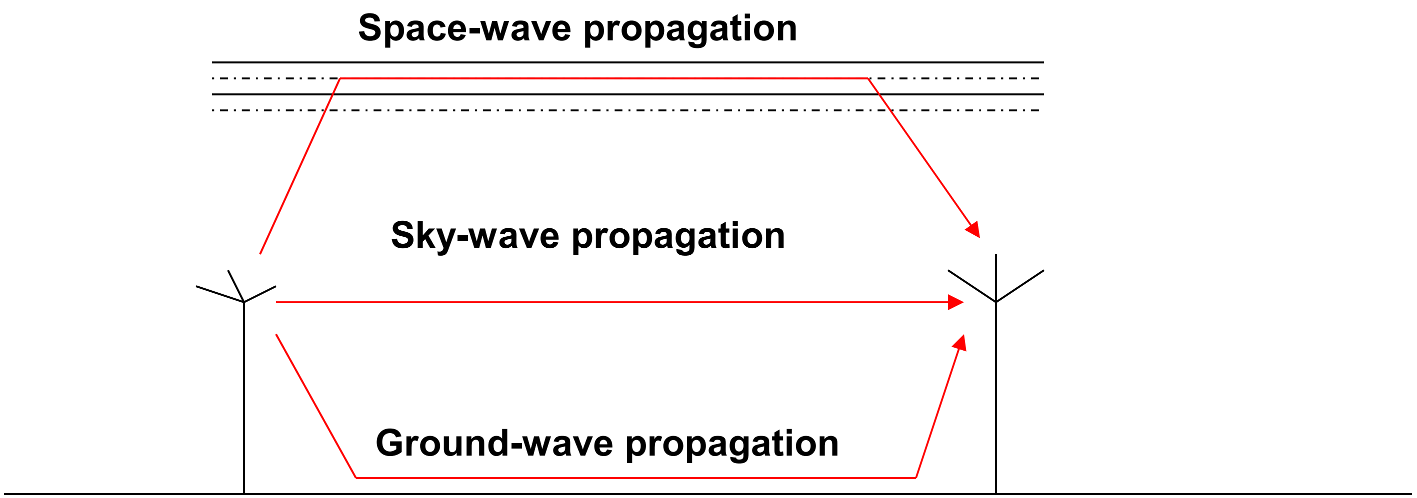
- There are areas of **no coverage along the earth surface** between transmitting and receiving antenna
- The angle of reflection and the loss of signal depend on the **frequency, time, season, activities** of the sun etc

- **Space wave propagation (LOS)**
  - Dominants mode for frequencies above **30 MHz** where in propagates in straight line
  - No refraction and can almost propagates through ionosphere

Propagation Waves

- But the signal path has to be above horizon to avoid blocking leading antenna to be placed on tall towers
- The distance to radio horizon is

$$d = \sqrt{2h} \quad \text{miles}$$



Propagation Waves

- The three waves propagation methods:
  - Ground wave propagation
  - Sky wave propagation
  - Space wave propagation

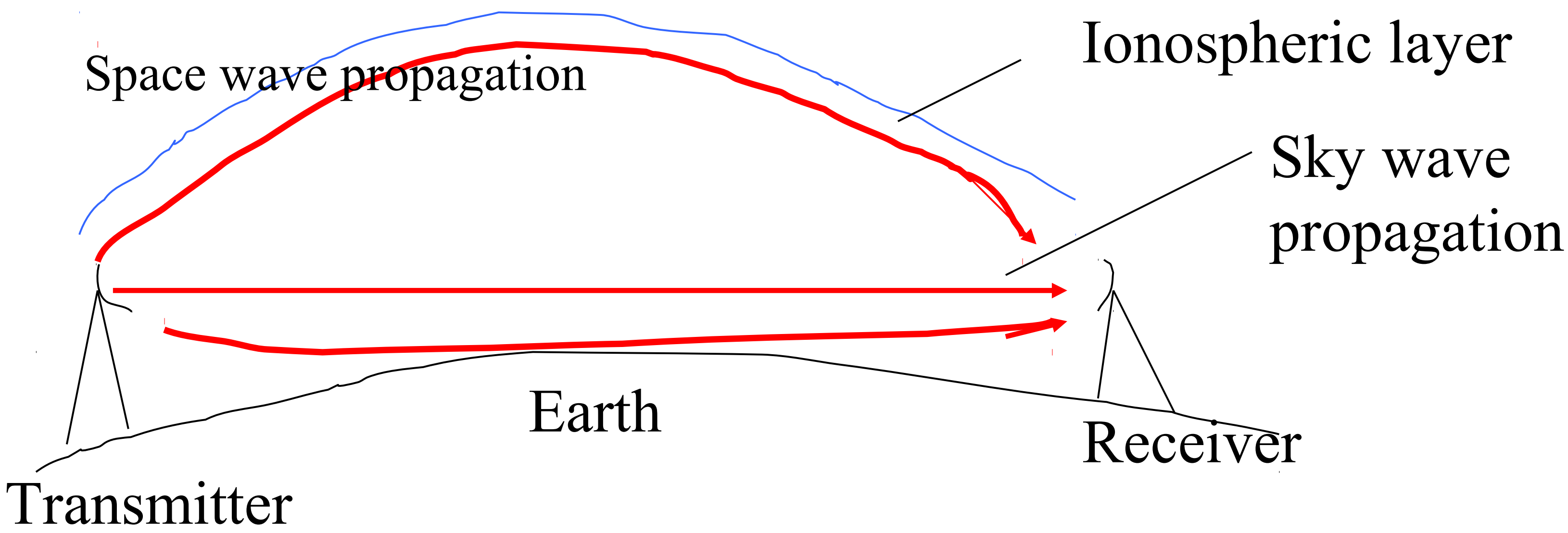


Fig: Radio wave propagation methods

Propagation Waves

- **Ground (surface) wave**
  - Wave that progress along the surface the earth
  - It follows the curvature of the earth

- **Sky wave propagation**
  - Sky waves are those waves that radiated towards ionosphere. By a process of refraction and reflection, the receiver on the earth will receive the signal. The various layers of the ionosphere have specific effects on the propagation of radio waves

Propagation Waves

- Space wave
  - The wave is propagated in a straight line
  - space wave is limited in their propagation by the curvature of the earth
  - sometimes it is called direct wave or line-of-sight (LOS)
  - The radio horizon of the antenna is the distance between the transmitter and receiver and is denoted by d,

    where

$$\mathrm{d} \approx \mathrm{d_t} + \mathrm{d_r} \qquad \text{in km}$$

$$\text{and} \qquad \mathrm{d_t} = 4\sqrt{h_t} \qquad \text{and} \qquad \mathrm{d_r} = 4\sqrt{\mathrm{h_r}}$$

Propagation Waves

- d_t = radio horizon of the transmitting antenna, in km
- h_t= height of transmitting antenna, in m
- d_r= radio horizon of the receiving antenna, in km
- h_r= height of receiver antenna, in m

LOS propagation

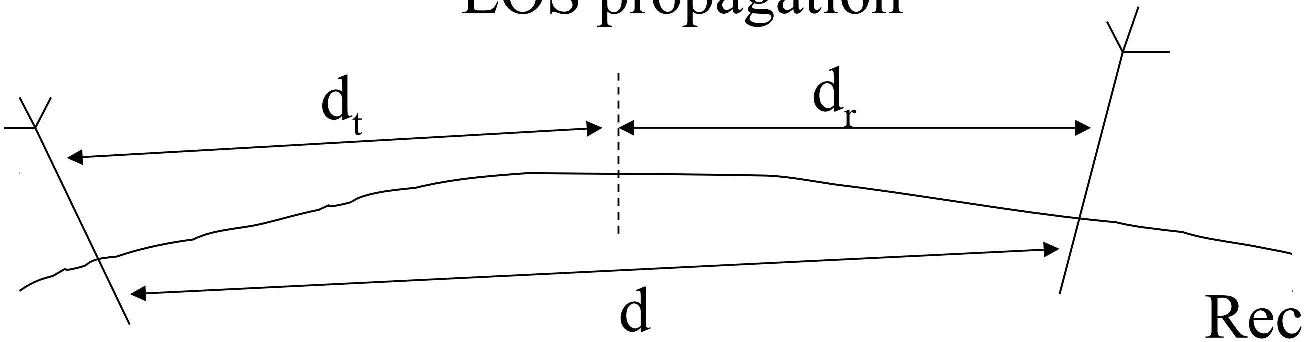
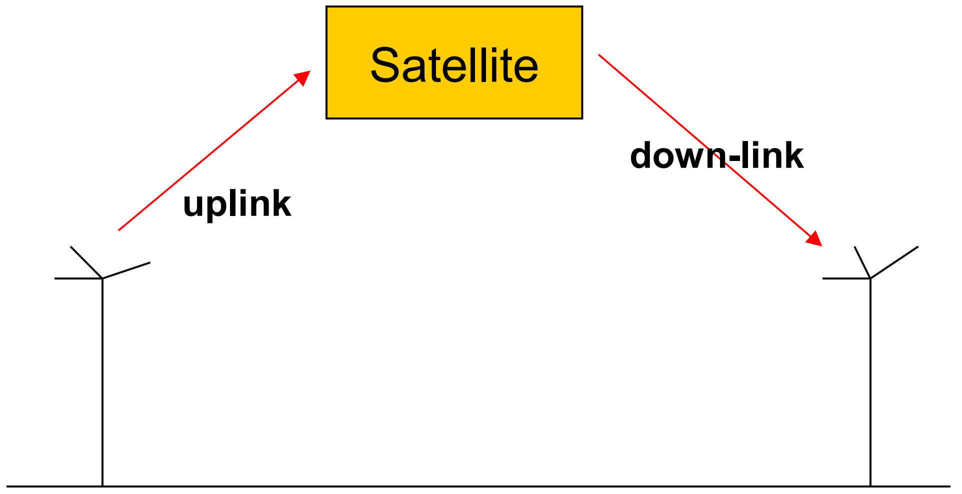


Fig: Line of sight propagation

Satellite Communication

- Satellite employs LOS radio transmission over very long distance
- It offers brad coverage even across the ocean and can handle bulk of very long distance telecommunication



Historical Development

Year	Events
1844	Telegraph
1876	Telephone
1904	AM Radio
1923	Television
1936	FM Radio
1962	Satellite
1966	Optical links using laser and fiber optics
1972	Cellular Telephone

Historical Development

Year	Events
1975	First digital telephone switch
1975	Wideband communication system (cable TV etc)
1980	Compact disc is developed by Philip & Sony
1981	FCC adopts rules for commercial cellular telephone
1982	Internet is used to replace ARPANET
1985	Fax machines widely available in offices
1989	First SONET standard optical fiber products released
1990	WWW becomes part of the internet
1990-2000	Digital communication system (ISDN, BISDN, HDTV, handheld computers, digital cellular etc Global telecom system

Power Measurement (dB, dBm)

- The decibel (dB) is a transmission-measuring unit used to express gain and losses an electronic devices and circuits

- for describing relationship between signal and noise
  - dB → 1W
  - dBm → 1mW
  - example: 100W = $10 \log_{10} 100$ = 2dB

$$= 10 \log_{10} \frac{100}{1mW} = 50 \text{ dBm}$$

Power Measurement (dB, dBm)

- If two powers are expressed in the same unit (eg: watts or microwatts), their ratio is a dimensionless quantity that can be expressed in decibel form as follows:

$$dB = 10\log_{10}\left(\frac{P_1}{P_2}\right)$$

Where P_1 = power level 1 (watts)

P_2 = power level 2 (watts)

The dB value is the difference in dB between P1 and P2

Power Measurement (dB, dBm)

- When used in electronic circuits to measure a power gain or loss, that equation can rewritten as

$$\text{Gain}_{\,(dB)} = 10\log_{10}\left(\frac{P_{out}}{P_{in}}\right)$$

Where

Gain $_{(dB)}$ = power gain (dB)
P_{out} = output power level (watts)
P_{in} = input power level (watts)

$$\frac{P_{out}}{P_{in}} = \text{absolute power}$$

- (+) dB - power gain
  - output power is greater than input power
- (-) dB power loss
  - output power is less than input power

Examples

1. Convert the absolute power ratio of 200 to a power gain in dB

Solution:

Power gain, A_p (dB) $= 10 \log_{10} [200]$

$= 10(2.3)$

$= 23$ dB

2. Convert the power gain A_p = 23 dB to an absolute power ratio

Solution

Power gain, A_p (dB) $= 10 \log_{10} [Pout/Pin]$

$2.3 = \log_{10} [Pout/Pin]$

$[Pout/Pin] = \text{antilog } 2.3$

$= 200$

Examples

3. Convert a power level of 200mW to dBm

Solutuion:

$$dBm = 10 \log_{10} [200mW/1mW]$$

$$= 10(200)$$

$$= 23 \text{ dBm}$$

Limitation in a Communication System

There are two categories of limitations:

- Technological constraint
  - Equipment ability
  - Economy and cost factor
  - National and international law and agreement as well as standardization (such as ITU etc)
  - Interaction with existing system
- Physical constraint
  - Bandwidth
    - **The difference between the upper frequency and lower frequency of the signal or the equipment operation range**
  - Noise
    - **Any unwanted electrical energy present in the usable passband of a communication circuit**

Communication System Chart