Introduction to Communication Systems

- Communication is the process of exchanging information
- People communicate to convey their ideas, thoghts, etc.
- Two barriers: Distance and Language
- Some early communication methods: Smoke, drumbeats, horn, flags
- Human communication took a deep leap in the late ninteeth century: Electricity and its applications
- Telegraph: 1844
- Telephone: 1876
- Radio: 1887 -invented, 1895- demonstrated
- We cant think about a world without telephone, radio, tv, email, computer networks etc

Introduction

- The communication system exist to convey a message
- Information is what we conveyed or what we intended to convey
- The amount of information is measured in bits
- Unless the message arriving from the information source is electrical in nature, it will be unsuitable for immediate transmission
- Even then a lot of work must be done to make such a message suitable
- All these works are done by a transmitter

Communication Systems

- For any electronic communication system basicaly three elements are there:
  - Transmitter
  - Communication medium/channel
  - Receiver
- Message or information/intelligence signal is produced by human being or some computer is fed to the tansmitter, which is transmitted over the channel
- Message is picked by receiver and relayed to some other computer/ human being
- The message is affected by noise in the channel
- Noise: any phenomenon that degrades or interferes with the transmitted information.

Communication Systems

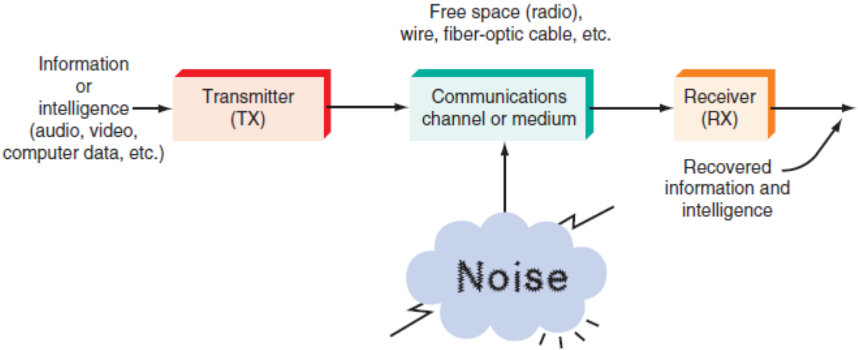

Figure: General model of all communication systems

Transmitter

- First step in sending a message is to convert it into electronic form suitable for transmission
- Transducers are used for these conversion
- Microphone translate voice into electronic audio
- Camera: translate to video
- Transmitter is not a single element
- Typically consists of: oscillators, amplifiers, tuned circuits and filters, modulators, frequency mixers, frequency synthesizers, and other circuits

Communication Channel

- The communication channel is the medium by which the electronic signal is sent from one place to another
- Channel is often used to the frequency range allocated to a particular service or transmission
- Many types of communication mediums such as: wired conductor, fiber optic cables, free-space
- Wired conductor: Pair of wires, coaxial cable, twisted pair
- Optical fiber: Today's main communication channel
- Free-Space: Wireless, radio
- Other types of media: sonar, earth, power lines etc.

Receivers

- A receiver is a collection of electronic components and circuits that accepts the transmitted message from the channel and converts it back to a form understandable by humans
- Receivers contain amplifiers, oscillators, mixers, tuned circuits and filters, and a demodulator or detector that recovers the original intelligence signal from the modulated carrier

Noise

- It is inevitable that the signal will deteriorate during the process of transmission and reception of some distrotion in the system or because of the introduction of noise
- Noise is unwanted energy, usually random character, present in a transmission system due to variety of causes
- Since noise will be received together with the signal, it places a limitation on the transmission system as a whole
- When noise is severe it may mask the given signal so much that the signal becomes unintelligible and therefore useless
- Noise may interfere with signal at any point in a communication system, but it will have its greatest effect when the signal is weakest

Distortion

- Anything that a channel does to a signal other than delaying it or multiplying with a constant is considered to be a distortion
- The channel can be expressed by the following transfer function

$$H(f) = A(f) \exp^{-j\theta(f)} \tag{1}$$

The amplitude factor is $A(f)$ and the phase factor is $\theta(f)$

- If A(f) is not constant we have amplitude distortion
- If $\theta(f)$ is not constant we have phase distortion

Transceivers

- Most electronic communication system is two-way, i.e, both transmitter and receiver are present at both the locations as a single unit and is generally known as transceivers

Types of Communication Systems

- One-Way (Simplex) or Two-Way (Duplex... Half duplex and Full duplex)
- Analog and Digital
- Baseband and Passband communication
- Simplex: Radio or TV broadcasting, controlling a toy car

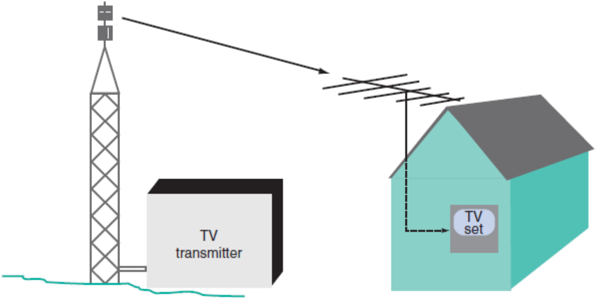

Figure: TV broadcasting

Types of Communication Systems

- Full duplex: Bulk of the electronic communication systems are full duplex
- Simultaneous two way communication
- Telephone: talk and listen simultaneously

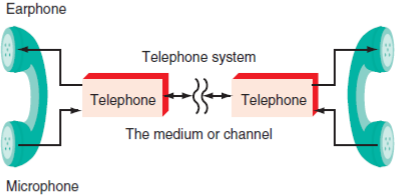

Figure: Full duplex

Types of Communication Systems

- The form of two-way communication in which only one party transmits at a time is known as half duplex communication
- Here communication is two way, but direction alternate
- Most radio transmissions, such as those used in the military, fire, police, aircraft, marine, and other services, are half duplex communication

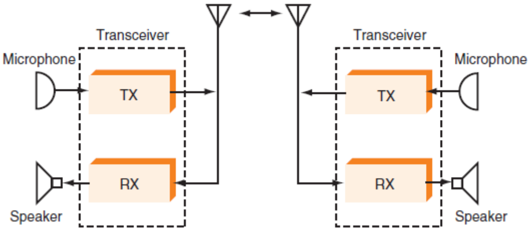

Figure: Full duplex

Types of Communication Systems

- Analog Signals: An analog signal is a smoothly and continuously varying voltage or current. Some typical analog signals

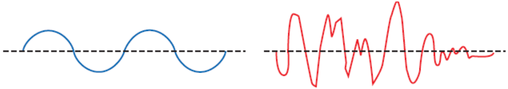

Figure: Analog signal: single tone and multitone

- Digital Signals: Digital signals in contrast to analog signals, do not vary continuously, but change in steps or in discrete increments

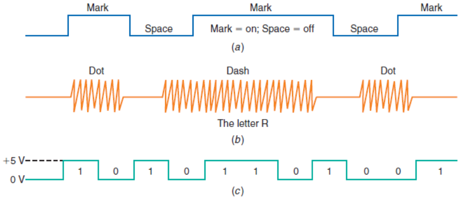

Figure: Digital signals

Modulation and Multiplexing

- Modulation and multiplexing are electronic techniques for transmitting information efficiently from one place to another
- Modulation makes the information signal more compatible with the medium
- Multiplexing allows more than one signal to be transmitted concurrently over a single medium

Modulation

- Modulation is a process that causes a shift in the range of frequencies in a signal
- Communication that uses modulation is carrier communication or pass band communication
- Communication that does not uses modulation is baseband communication
- Signals which contains significant amount of low frequency components is known as baseband signal i.e., the signals produced by a source or the output of a transducer
- In baseband communication, baseband signals are transmitted without modulation
- They can be transmitted over a pair of wires, coaxial cables, or optical fibers
- Communication that uses modulation to shift the frequency spectrum of a signal is known as carrier communication

Need of Modulation

- For efficient transmission it was found that the antenna dimensions had to be of the same order of magnitude as the wavelength of the signal being transmitted
- For efficient radiation and reception the transmitting and receiving antennas would have to have lengths comparable to a quarter-wavelength of the frequency used
- All sound is concentrated within the range from 20 Hz to 20kHz, so that all signals from the different sources would be hopelessly and inseparably mixed up
- Multiplexing–more signals can be transmitted
- Compatability with the medium/channel

Baseband Transmission

- Before it can be transmitted, the information or intelligence must be converted to an electronic signal compatible with the medium
- The original information or intelligence signals are referred to as baseband signals.
- In a communication system, baseband information signals can be sent directly and unmodified over the medium or can be used to modulate a carrier for transmission over the medium
- Putting the original voice, video, or digital signals directly into the medium is referred to as baseband transmission
- In many instances, baseband signals are incompatible with the medium
- The baseband information signal, be it audio, video, or data, is normally used to modulate a high-frequency signal called a carrier

Baseband Transmission

- The higher- frequency carriers radiate into space more efficiently than the baseband signals themselves
- Such wireless signals consist of both electric and magnetic fields
- These electromagnetic signals, which are able to travel through space for long distances, are also referred to as radio-frequency (RF) waves, or just radio waves

Broadband Transmission

- Modulation is the process of changing the characteristics of a high frequency signal (carrier) by a low frequency signal (message)
- The information or intelligence to be sent is said to be impressed upon the carrier
- The carrier is fed to a circuit called a modulator along with the baseband intelligence signal
- The intelligence signal changes the carrier in a unique way
- The modulated carrier is amplified and sent to the antenna for transmission. This process is called broadband transmission.

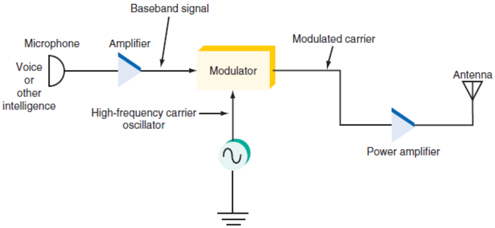

Figure: Broadband Transmission

Modulation

- Consider the sine wave $v = V_p \sin(\omega t + \theta)$
- $Vp =$ Peak value of the sine wave
- $\omega =$ Angular frequency $= 2\pi f$
- $\theta =$ Phase angle
- $v =$ Instantaneous value of the sine wave

Modulation

- Characteristics of the sine wave can be changed three ways:Amplitude, frequency, phase
- Amplitude modulation: Changing V_p
- Frequency modulation: Changing ω
- Phase modulation: Changing θ
- Phase modulation produces frequency modulation: the PM signal is similar in appearance to a frequency-modulated carrier

Amplitude Modulation

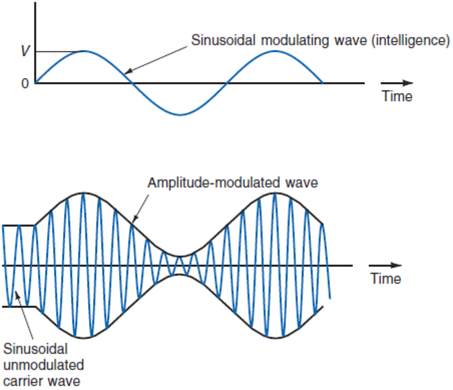

Figure: Amplitude Modulation

Frequency Modulation

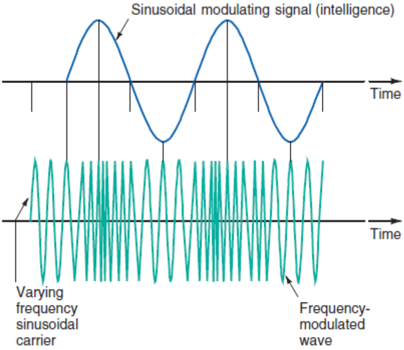

Figure: Frequency Modulation

Demodulation

- At the receiver, the carrier with the intelligence signal is amplified and then demodulated to extract the original baseband signal
- Another name for the demodulation process is detection

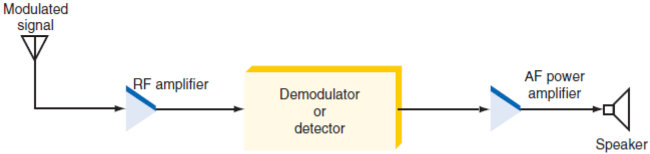

Figure: Demodulator

Multiplexing

- Multiplexing is the process of allowing two or more signals to share the same medium or channel
- A multiplexer converts the individual baseband signals to a composite signal that is used to modulate a carrier in the transmitter

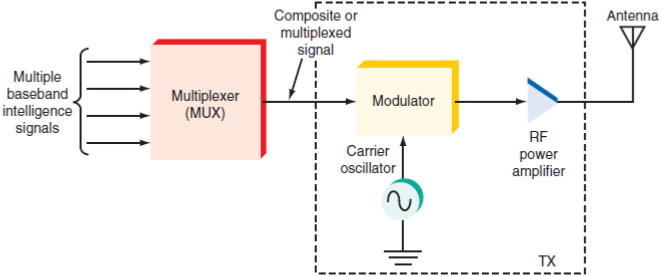

Figure: Multiplexing at the transmitter

Demultiplexer

- At the receiver, the composite signal is recovered at the demodulator, then sent to a demultiplexer where the individual baseband signals are regenerated

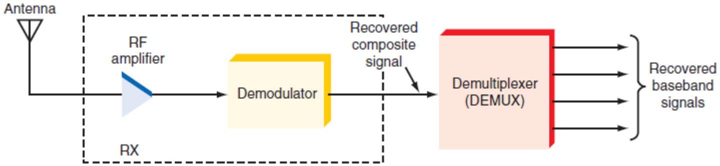

Figure: Demultiplexing at the receiver

- Frequency division multiplexing
- Time division multiplexing
- Code division multiplexing

Receiver Characteristics

- **Selectivity:** The selectivity of an AM receiver is defined as its ability to accept or select the desired band of frequency and reject all other unwanted frequencies which can be interfering signals
- The signal bandwidth should be narrow for better selectivity.
- Response of IF section, mixer and RF section considerably contribute towards selectivity
- **Sensitivity:** Sensitivity of a receiver is its ability to identify and amplify weak signals at the receiver output
- It is often defined in terms of voltage that must be applied to the input terminals of the receiver to produce a standard output power which is measured at the output terminals
- The higher value of receiver gain ensures smaller input signal necessary to produce the desired output power
- Thus a receiver with good sensitivity will detect minimum RF signal at the input and still produce utilizable demodulated signal

Receiver Characteristics

- Sensitivity is also known as receiver threshold
- It is expressed in microvolts or decibels
- Sensitivity of the receiver mostly depends on the gain of IF amplifier
- It can be improved by reducing the noise level and bandwidth of the receiver
- **Fidelity:** Fidelity of a receiver is its ability to reproduce the exact replica of the transmitted signals at the receiver output
- For better fidelity, the amplifier must pass high bandwidth signals to amplify the frequencies of the outermost sidebands, while for better selectivity the signal should have narrow bandwidth. Thus a trade off is made between selectivity and fidelity
- Low frequency response of IF amplifier determines fidelity at the lower modulating frequencies while high frequency response of the IF amplifier determines fidelity at the higher modulating frequencies

Receiver Characteristics

- **Double spotting:** Double spotting is a condition where the same desired signal is detected at two nearby points on the receiver tuning dial
- One point is the desired point while the other is called the spurious or image point
- It can be used to determine the IF of an unknown receiver
- Poor front-end selectivity and inadequate image frequency rejection leads to double spotting
- Double spotting is undesirable since the strong signal might mask and overpower the weak signal at the spurious point in the frequency spectrum
- Double spotting can be counter acted by improving the selectivity of RF amplifier and increasing the value of IF

Electromagnetic Spectrum

- Electromagnetic waves are signals that oscillate; i.e., the amplitudes of the electric and magnetic fields vary at a specific rate
- The field intensities fluctuate up and down, and the polarity reverses a given number of times per second
- The electromagnetic waves vary sinusoidally
- The range of electromagnetic signals encompassing all frequencies is referred to as the **electromagnetic spectrum**
- All electrical and electronic signals that radiate into free space fall into the electromagnetic spectrum
- The signals which propagates through cables are not considered as radio signals evenwhen the frequencies belongs to the electromagnetic spectrum

Electromagnetic Spectrum

- Electromagnetic spectrum with both frequency and wavelength

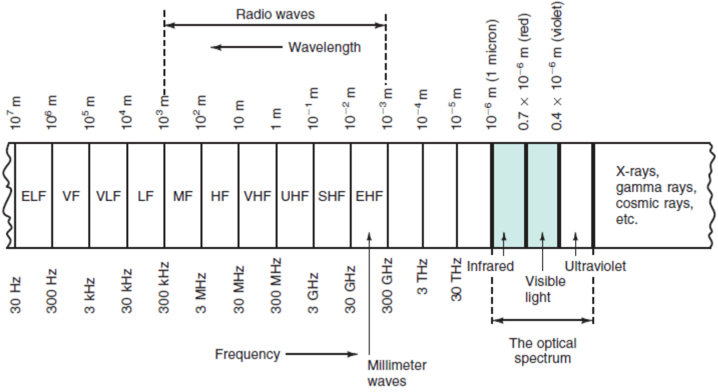

Figure: Electro magnetic spectrum

Frequency and Wavelength

- A given signal is located on the frequency spectrum according to its frequency and wavelength
- Frequency is the number of times a particular phenomenon occurs in a given period of time
- In electronics, frequency is the number of cycles of a repetitive wave that occurs in a given time period
- The unit of frequency is the hertz

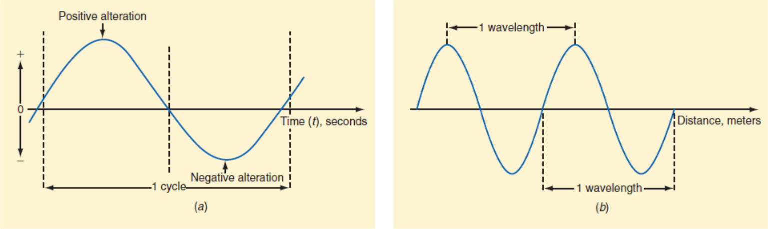

Figure: Frequency and wavelength

Frequency and Wavelength

- Wavelength is the distance occupied by one cycle of a wave, and it is usually expressed in meters
- Wavelength is measured between identical points on succeeding cycles of a wave
- If the signal is an electromagnetic wave, one wavelength is the distance that one cycle occupies in free space
- It is the distance between adjacent peaks or valleys of the electric and magnetic fields making up the wave
- Wavelength is also the distance traveled by an electromagnetic wave during the time of one cycle
- The wavelength of a signal, which is represented by the Greek letter λ (lambda)

Different Frequency Bands

- **Extremely Low Frequencies:** Extremely low frequencies (ELFs) are in the 30- to 300-Hz range. These include ac power line frequencies (50 and 60 Hz are common), as well as those frequencies in the low end of the human audio range
- **Voice Frequencies:**Voice frequencies (VFs) are in the range of 300 to 3000 Hz. This is the normal range of human speech
- **Very Low Frequencies:**Very low frequencies (VLFs) extend from 9 kHz to 30 kHz. Many musical instruments make sounds in this range as well as in the ELF and VF ranges. The VLF range is also used in some government and military communication.
- **Low Frequencies:**Low frequencies (LFs) are in the 30- to 300-kHz range. The primary communication services using this range are in aeronautical and marine navigation. Frequencies in this range are also used as subcarriers

Different Frequency Bands

- **Medium Frequencies:** Medium frequencies (MFs) are in the 300- to 3000-kHz (0.3- to 3.0-MHz) range. The major application of frequencies in this range is AM radio broadcasting (535 to 1605 kHz).
- **High Frequencies:** High frequencies (HFs) are in the 3- to 30-MHz range. These are the frequencies generally known as short waves. All kinds of simplex broadcasting and half duplex two-way radio communication take place in this range
- **Very High Frequencies:** Very high frequencies (VHFs) encompass the 30- to 300-MHz range. This popular frequency range is used by many services, including mobile radio, marine and aeronautical communication, FM radio broadcasting (88 to 108 MHz)
- **Ultrahigh Frequencies:**Ultrahigh frequencies (UHFs) encompass the 300- to 3000-MHz range. This, too, is a widely used portion of the frequency spectrum. Used for land mobile communication and services such as cellular telephones as well as for military communication

Different Frequency Bands

- **Microwaves and SHFs:** Frequencies between the 1000-MHz (1-GHz) and 30-GHz range are called microwaves. Microwave ovens usually operate at 2.45 GHz. Superhigh frequencies (SHFs) are in the 3- to 30-GHz range. These microwave frequencies are widely used for satellite communication and radar. Wireless local-area networks (LANs) and many cellular telephone systems also occupy this region
- **Extremely High Frequencies:** Extremely high frequencies (EHFs) extend from 30 to 300 GHz. Electromagnetic signals with frequencies higher than 30 GHz are referred to as millimeter waves. Equipment used to generate and receive signals in this range is extremely complex and expensive, but there is growing use of this range for satellite communication telephony, computer data, short-haul cellular networks, and some specialized radar.

Different Frequency Bands

- **Frequencies Between 300 GHz and the Optical Spectrum:** This portion of the spectrum is virtually uninhabited. It is a cross between RF and optical. Lack of hardware and components limits its use.
- **Optical spectrum:** Right above the millimeter wave region is what is called the optical spectrum, the region occupied by light waves. There are three different types of light waves: infrared, visible, and ultraviolet
- **Infrared:** The infrared region is sandwiched between the highest radio frequencies (i.e., millimeter waves) and the visible portion of the electromagnetic spectrum. Infrared occupies the range between approximately 0.1 millimeter (mm) and 700 nanometers (nm), or 100 to 0.7 micrometer (μm)
- Infrared radiation is generally associated with heat. Infrared is produced by light-bulbs, our bodies, and any physical equipment that generates heat.

Different Frequency Bands

- **Visible Spectrum:** Just above the infrared region is the visible spectrum we ordinarily refer to as light. Light is a special type of electromagnetic radiation that has a wavelength in the 0.4- to 0.8-μm range (400 to 800 nm).
- **Ultraviolet:** Ultraviolet light (UV) covers the range from about 4 to 400 nm. Ultraviolet generated by the sun is what causes sunburn
- Beyond the visible region are the X-rays, gamma rays, and cosmic rays. These are all forms of electromagnetic radiation, but they do not figure into communication systems

Bandwidth

- Bandwidth (BW) is that portion of the electromagnetic spectrum occupied by a signal
- It is also the frequency range over which a receiver or other electronic circuit operates
- More specifically, bandwidth is the difference between the upper and lower frequency limits of the signal or the equipment operation range
- The upper frequency is f_2 and the lower frequency is f_1, then,

$$BW = f_2 - f_1 \tag{2}$$

- Thus the term bandwidth refers to the range of frequencies that contain the information

Channel Bandwidth

- The term channel bandwidth refers to the range of frequencies required to transmit the desired information
- When information is modulated onto a carrier somewhere in the electromagnetic spectrum, the resulting signal occupies a small portion of the spectrum surrounding the carrier frequency
- The modulation process causes other signals, called sidebands, to be generated at frequencies above and below the carrier frequency by an amount equal to the modulating frequency
- For example, in AM broadcasting, audio signals up to 5 kHz can be transmitted. If the carrier frequency is 1000 kHz, or 1 MHz, and the modulating frequency is 5 kHz, sidebands will be produced at 1000 - 5 = 995 kHz and at 1000+ 5=1005 kHz.
- The bandwidth of the AM signal described above is the difference between the highest and lowest transmitting frequencies: BW = 1005 kHz - 995 kHz =10 kHz. In this case, the channel bandwidth is 10 kHz.

Primary Communication Resourses

- Two primary resourses: Channel bandwidth and transmitted power
- Transmitted power is the average power of transmitted signal
- General system design objective is to use these two resourses as efficiently as possible
- In most of the systems one resourse is considered as more important than the other
- So there is **power limited** and **bandlimited** channels present
- Sourse of noise may be internal or external
- A quantitative way to accountfor the effect of noise is to introduce signal to noise ratio
- Ratio of average signal power to the average noise power , both being measured at the same point

Sources of Information

- Four important sourses of information: Speech, music, pictures, computer data
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References

- Principles of Electronic Communication Systems: Louis E. Frenzel Jr., 4th edn
- Electronic Communication Systems: Kennedy and Davis
- Communication Systems: Simon Haykin