Communication Systems

Mohammad Hadi

mohammad.hadi@sharif.edu

@MohammadHadiDastgerdi

Spring 2021

Overview

History of Communication

History

- Early communication was based on fire and horn. Location and time are communicated by fire and horn, respectively.

Figure: Fire.

History

- In the 5th century, letters could be sent by using pigeon's homing abilities.

Figure: Pigeon.

History

- Newspapers were used starting in the 1800s to provide mass communication through printed text distributed throughout a town.

Figure: Newspaper.

History

- The telegraph became popular in 1838. Twenty years later, the Trans-Atlantic telegraph provided communication between America and Europe. The first message sent by this method was: "Europe and America are united by telegraphy. Glory to God in the highest; on Earth, peace and good will toward men.".

Figure: Telegraph.

History

- Signal lamps used light to communicate via Morse code beginning in 1867.

Figure: Lantern.

- In 1876, Alexander Graham Bell invented the telephone.

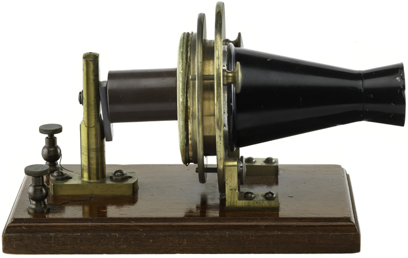

Figure: Telephone.

History

- In 1901, Marconi built a station near South Wellfleet, Massachusetts that sent a wireless message of greetings from United States President Theodore Roosevelt to King Edward VII of the United Kingdom.

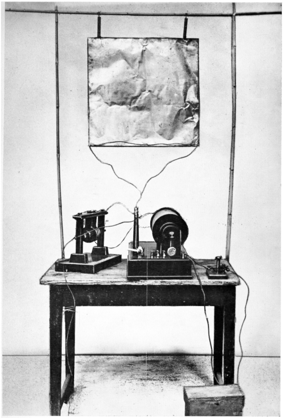

Figure: Radiotelegraphy.

- Transcontinental telephone calling allowed people to call others overseas beginning in 1914.

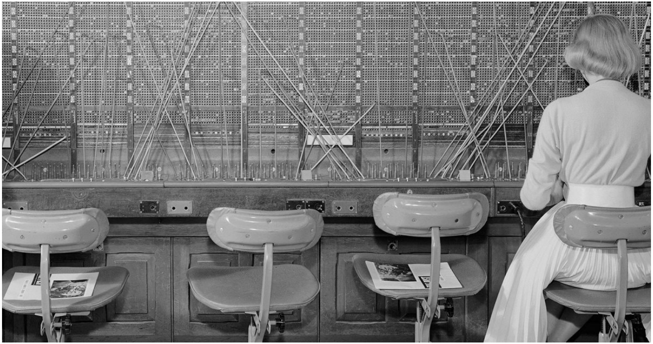

Figure: Transcontinental Telephone.

History

- The first television was made in 1927, but it took decades before families in America could watch their own.

Figure: Television.

- In 1957, Sputnik was launched into earth orbit. The first communication satellite was Echo I launched in 1960. In 1962, Telstar I, the first active communication satellite was deployed into orbit. .

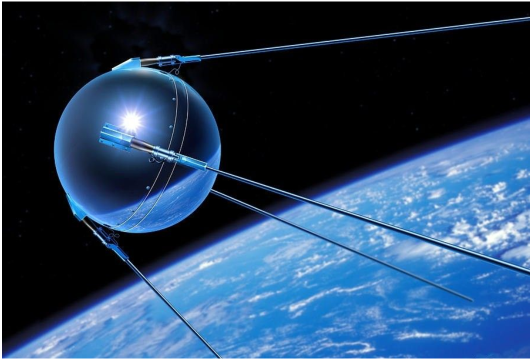

Figure: Satellite.

History

- The first wide area network (WAN) came in 1965 and ARPANET was used to connect four universities in 1969.

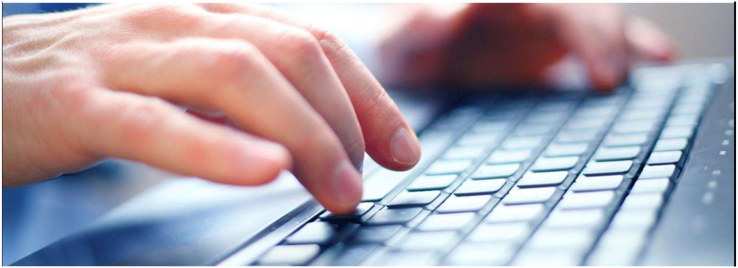

Figure: Computer Networks.

History

- The first smartphone invented in 1973 by Motorola.

Figure: Smart Phone.

History

- In the late 70s, fiber optical telecommunications were introduced. This helped to speed up communications with better connections and less issues.

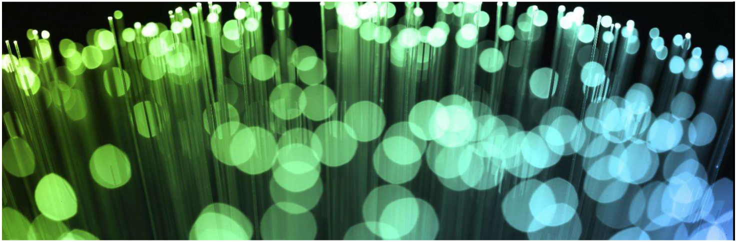

Figure: Optical Fiber.

History

- SMTP email became available in 1981.

Figure: Email.

History

- Instant messaging became popular in the mid-1990s.

Figure: Instant Messaging.

History

- Social media has became a very popular way to communicate with friends, family, and business partners today.

Figure: Social Media.

History

- Today's, mobile apps are widely used with smartphones to connect visually and audibly.

Figure: Mobile Applications.

Communication Systems

Communication Systems

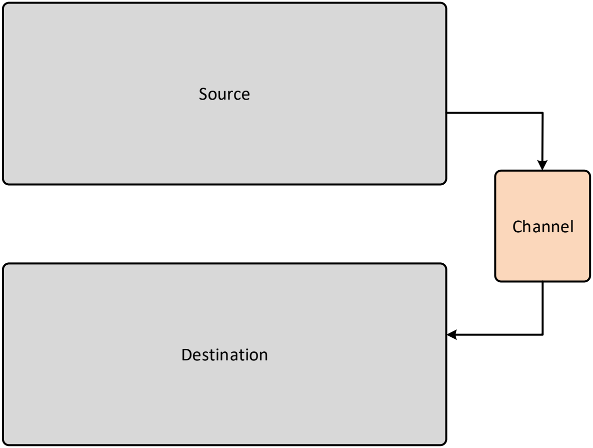

Figure: Abstract diagram of a communication system.

Channel

- Channel is the physical medium that is used to send a signal from the source to the destination.
- Channel has two important limitations
  1. Physical impairments
     1. Attenuation
     2. Noise
     3. Distortion
     4. Delay
     5. Jitter
  2. Working constraints
     1. Available bandwidth
     2. Central Frequency
     3. Injected power

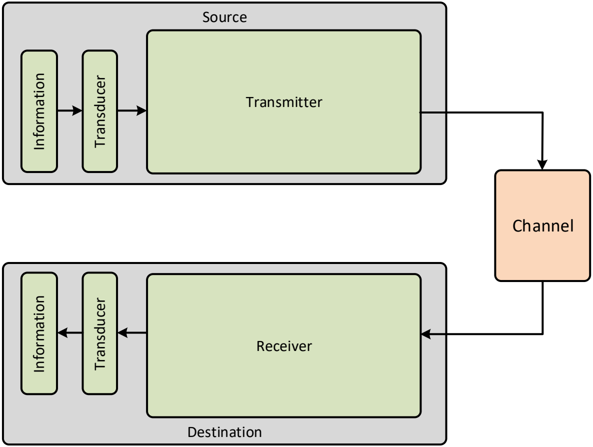

Figure: Functional diagram of a communication system.

Transceiver

- The information is generated randomly in the source.
- The source transducer converts the information to a signal, which can be fed to the transmitter.
- The transmitter transforms its input signal into a signal, which can effectively cope with the channel limitations.
- The receiver extracts its output signal from the signal polluted by the undesirable effects of the channel.
- The destination transducer converts the extracted signal to a desirable information.
- The information may have a different format in the destination.

Electrical Communication Systems

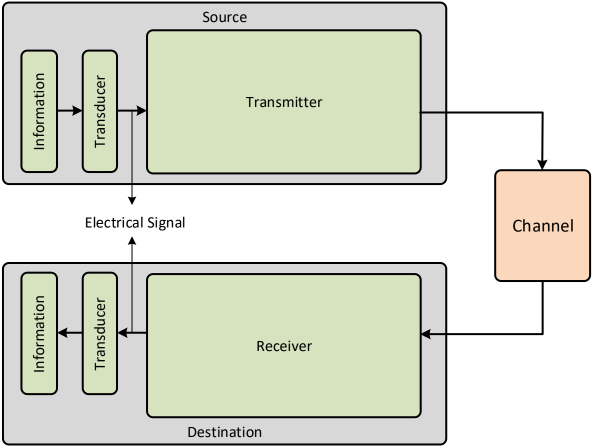

Figure: Functional diagram of an electrical communication system.

Analog Communication Systems

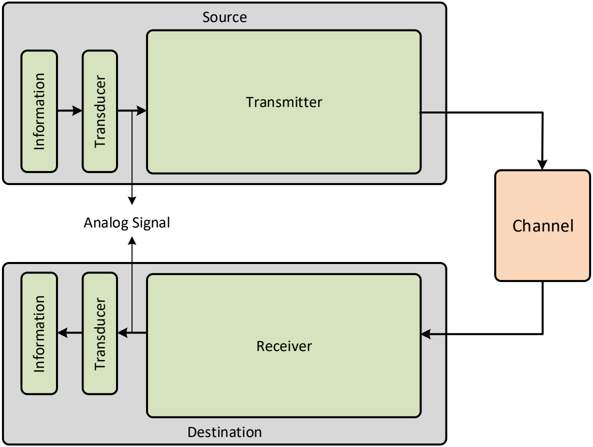

Figure: Functional diagram of an analog communication system.

Digital Communication Systems

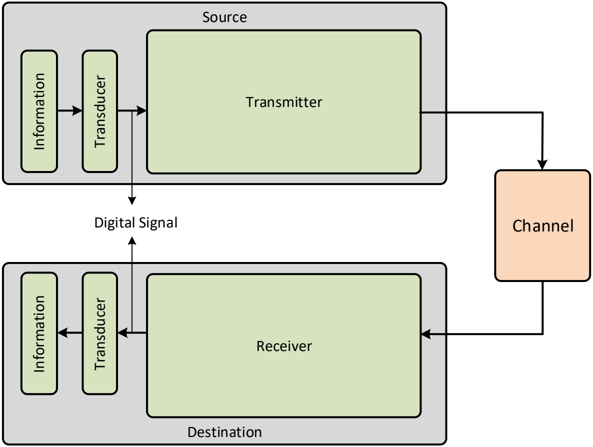

Figure: Functional diagram of a digital communication system.

Analog and Digital Electrical Communication System

The input signal to the transmitter or the output signal from the receiver is

- electrical in an electrical communication system.
- analog in an analog communication system.
- digital in a digital communication system.

Analog Communication Systems

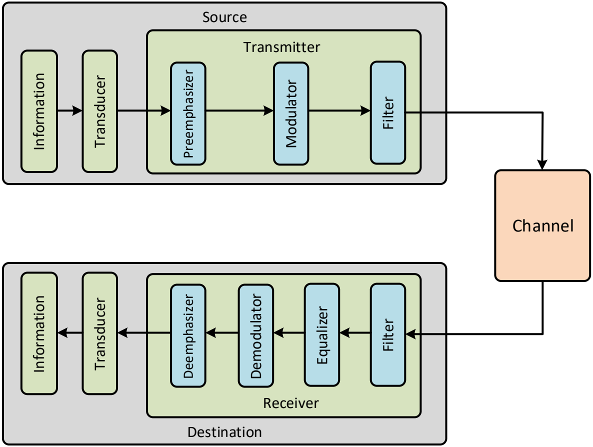

Figure: Detailed diagram of an analog communication system.

Analog Communication Systems

✓ The preemphasizer manipulates the signal to better cope with the physical impairments of the channel.

✓ The modulator manipulates the signal to better meet the working constraints of the channel.

✓ The filter manipulates the signal to better cope with the working constraints of the channel.

✓ The deeemphasizer, demodulator, and filter in the receiver are the inverse counterparts of their corresponding blocks in the transmitter.

✓ The equalizer mitigates the undesired effects imposed by the physical impairments of the channel.

Digital Communication Systems

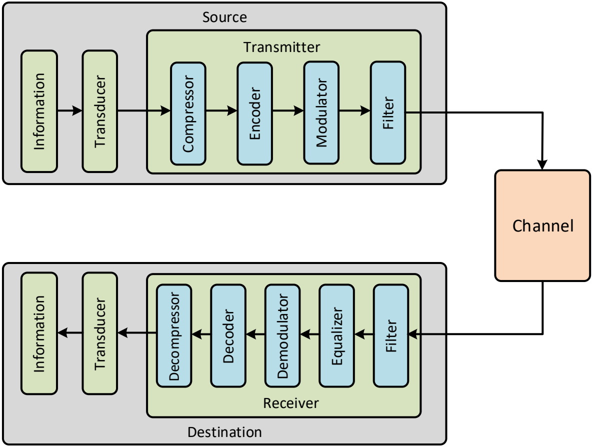

Figure: Detailed diagram of a digital communication system.

Digital Communication Systems

✓ The compressor removes the redundant data from the input information signal and helps to better meet the working constraint of the channel.

✓ The encoder adds a controllable amount of redundancy to the information signal to better cope with the physical impairments of the channel.

✓ The modulator manipulates the signal to better fit the working constraints of the channel.

✓ The filter manipulates the signal to better cope with the working constraints of the channel.

✓ The decompressor, decoder, demodulator, and filter in the receiver are the inverse counterparts of their corresponding blocks in the transmitter.

✓ The equalizer mitigates the undesired effects imposed by the physical impairments of the channel.

Modeling, Analysis, and Design

Modeling, Analysis, and Design

Roughly,

- ✓ In the modeling, the system transformation is determined.
- ✓ In the analysis, the system performance is determined.
- ✓ In the design, the system setting is determined.

Modeling

Example (Distortionless Channel)

The distortionless channel is modeled by a linear time-invariant system with the transfer function $H_c(f) = Ae^{-j2\pi ft}$, whose amplitude $A \leq 1$ is constant and whose phase $-2\pi fD$ is a linear function of f.

Figure: Distortionless channel.

$$y(t) = Ax(t-D) \Rightarrow Y(f) = Ae^{-j2\pi fD}X(f)$$

$$\Rightarrow H_c(f) = \frac{Y(f)}{X(f)} = Ae^{-j2\pi fD}$$

Example (Point-to-point Microwave Radio Channel)

A point-to-point microwave radio channel can be modeled by a linear time-invariant system with the transfer function $H_c(f) = A_1 e^{-j2\pi f D_1}(1 + Ae^{-j2\pi f D})$, where $A = A_2/A_1 < 1$ and $D = D_2 - D_1 \geq 0$.

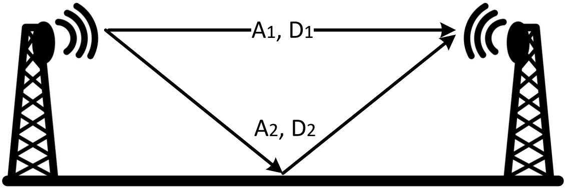

Figure: Point-to-point microwave radio channel.

$$y(t) = A_1 x(t-D_1) + A_2 x(t-D_2) \Rightarrow Y(f) = \left[A_1 e^{-j2\pi f D_1} + A_2 e^{-j2\pi f D_2}\right] X(f)$$

$$\Rightarrow H_c(f) = A_1 e^{-j2\pi f D_1}(1 + Ae^{-j2\pi f D})$$

Example (Customized Distortion-less Channel)

Passing $x(t)$ through the distortion-less channel with $A = 1$ and $D = 1$, the output $y(t)$ appears.

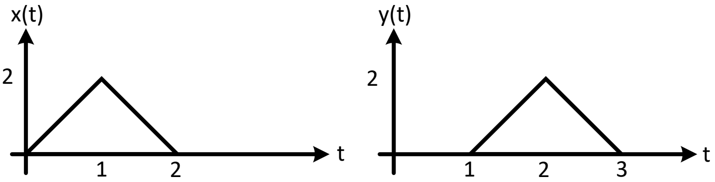

Figure: Input to and output from a distortion-less channel.

Example (Customized Point-to-point Microwave Radio Channel)

Passing $x(t)$ through the point-to-point microwave radio channel with $A_1 = 1$, $A_2 = 0.75$, $D_1 =$, and $D_2 = 2$, the output $y(t)$ appears.

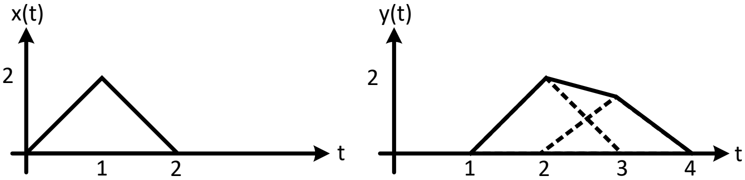

Figure: Input to and output from a point-to-point microwave radio channel.

Design

Example (Point-to-point Microwave Radio Channel Equalizer)

The distortion imposed by the point-to-point microwave radio channel can be equalized by a linear time-invariant system with the transfer function $H_e(f) = 1/(1 + Ae^{-j2\pi fD})$, where $A = A_2/A_1 < 1$ and $D = D_2 - D_1 \geq 0$.

$$H_c(f)H_e(f) = A_1 e^{-j2\pi fD_1}(1 + Ae^{-j2\pi fD})H_e(f) = A_1 e^{-j2\pi fD_1}$$

$$\Rightarrow H_e(f) = \frac{1}{1 + Ae^{-j2\pi fD}}$$

Design

Example (Point-to-point Microwave Radio Channel Equalizer)

For $A \ll 1$, the point-to-point microwave radio channel equalizer can be practically implemented by a tapped delay line structure.

$$|Ae^{-j2\pi fD}|<1 \Rightarrow H_e(f) = \frac{1}{1-\left[-Ae^{-j2\pi fD}\right]} = 1-Ae^{-j2\pi fD}+A^2e^{-j4\pi fD}+\cdots$$

$$A \ll 1 \Rightarrow H_e(f) = \frac{1}{1-\left[-Ae^{-j2\pi fD}\right]} \approx 1 - Ae^{-j2\pi fD} + A^2e^{-j4\pi fD}$$

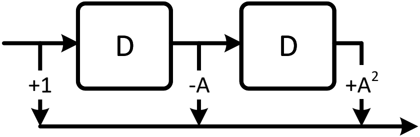

Figure: Tapped-delay line microwave radio channel equalizer.

The End