Communication Systems

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Overview

Communication History

Visual Era

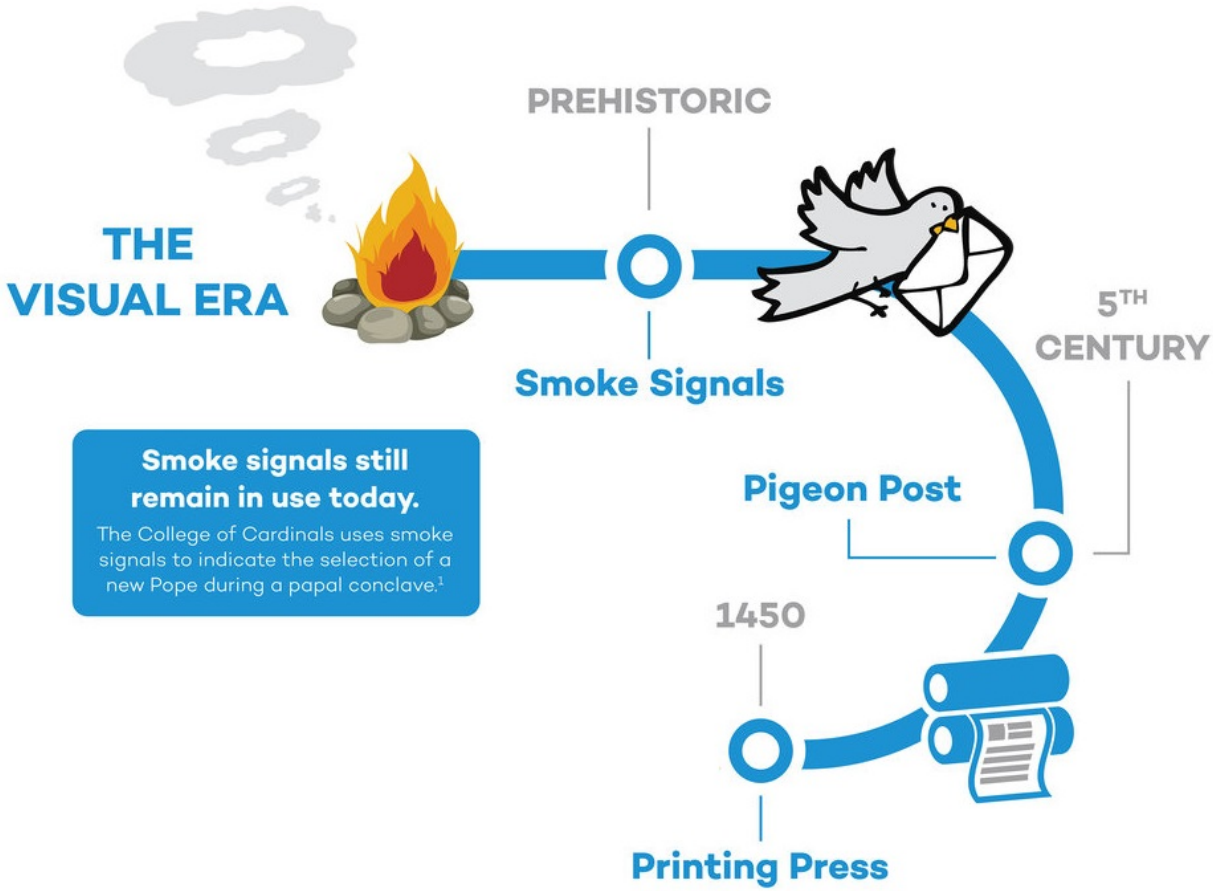


Figure: Visual era.

Wired Era

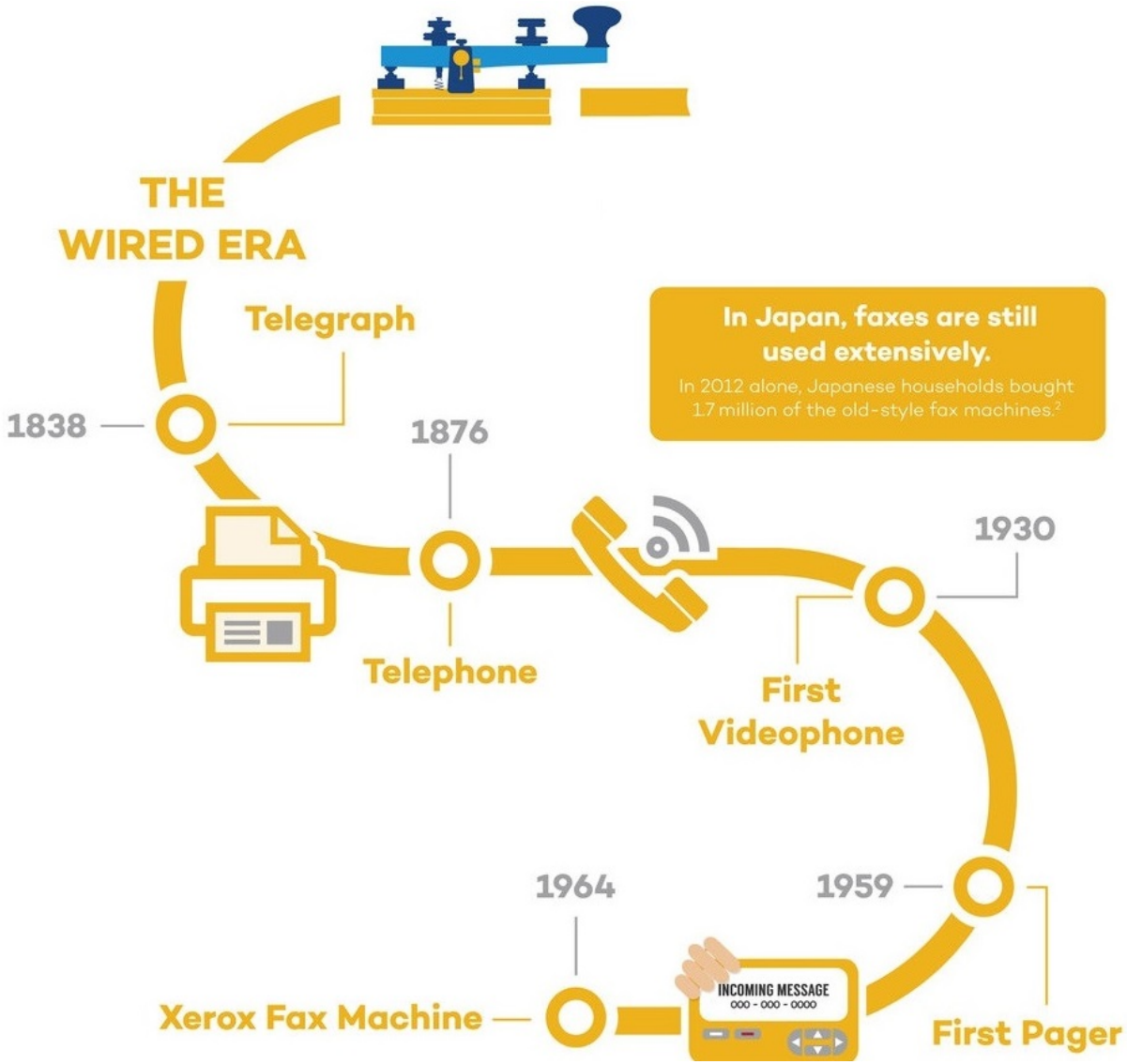


Figure: Wired Era.

Wireless Era

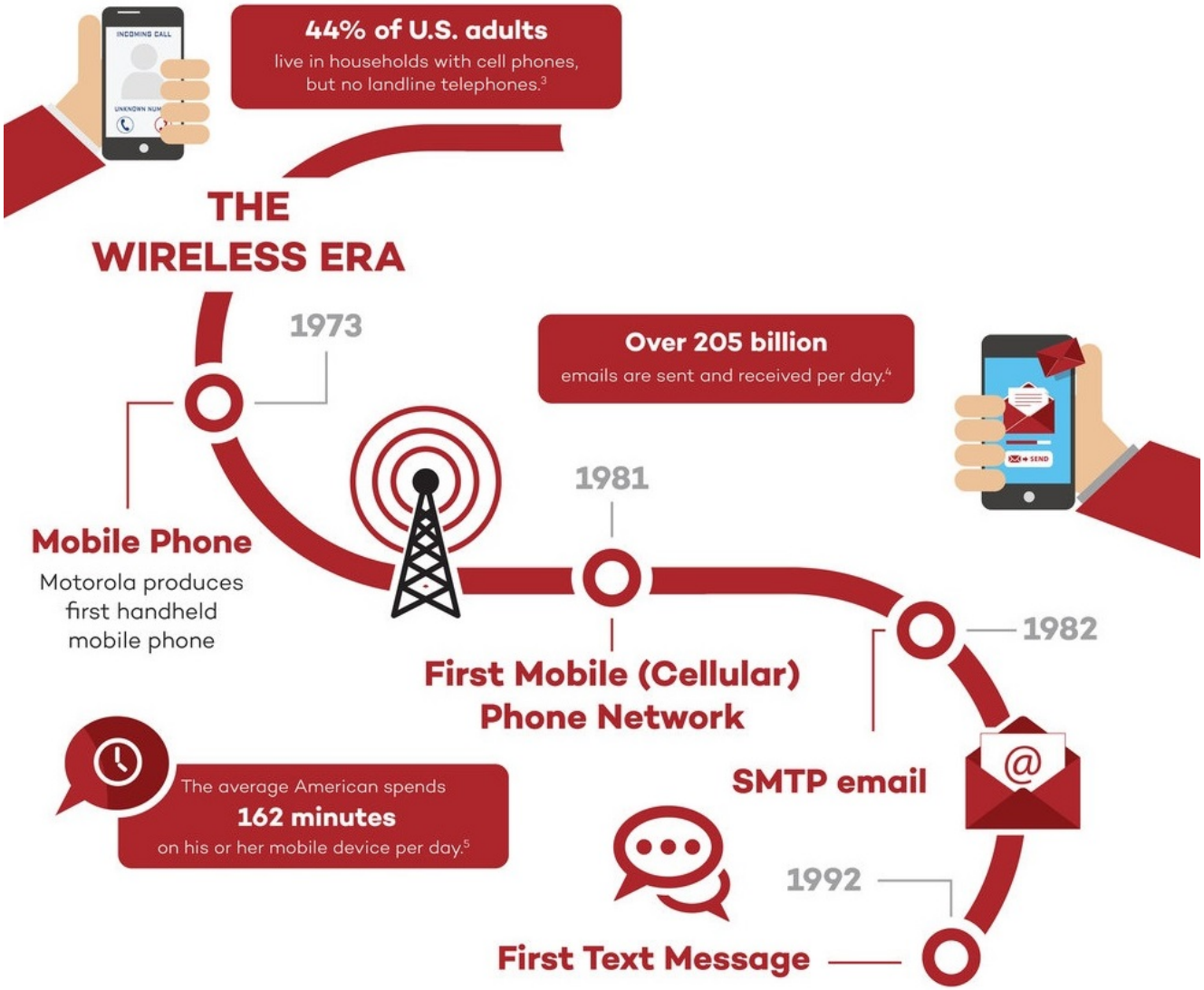


Figure: Wireless Era.

IP Cloud Era

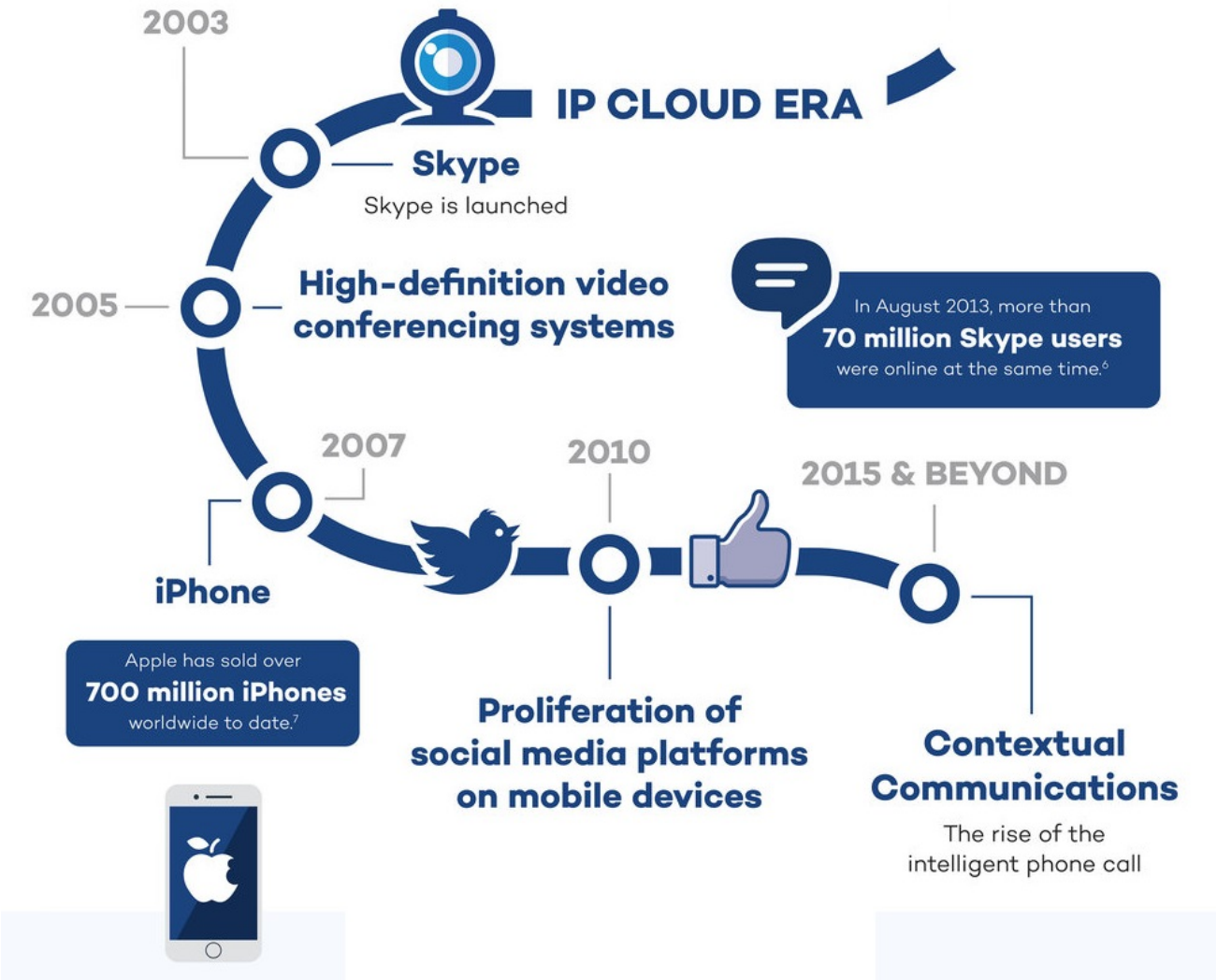


Figure: IP cloud Era.

Communication Systems

Communication Systems

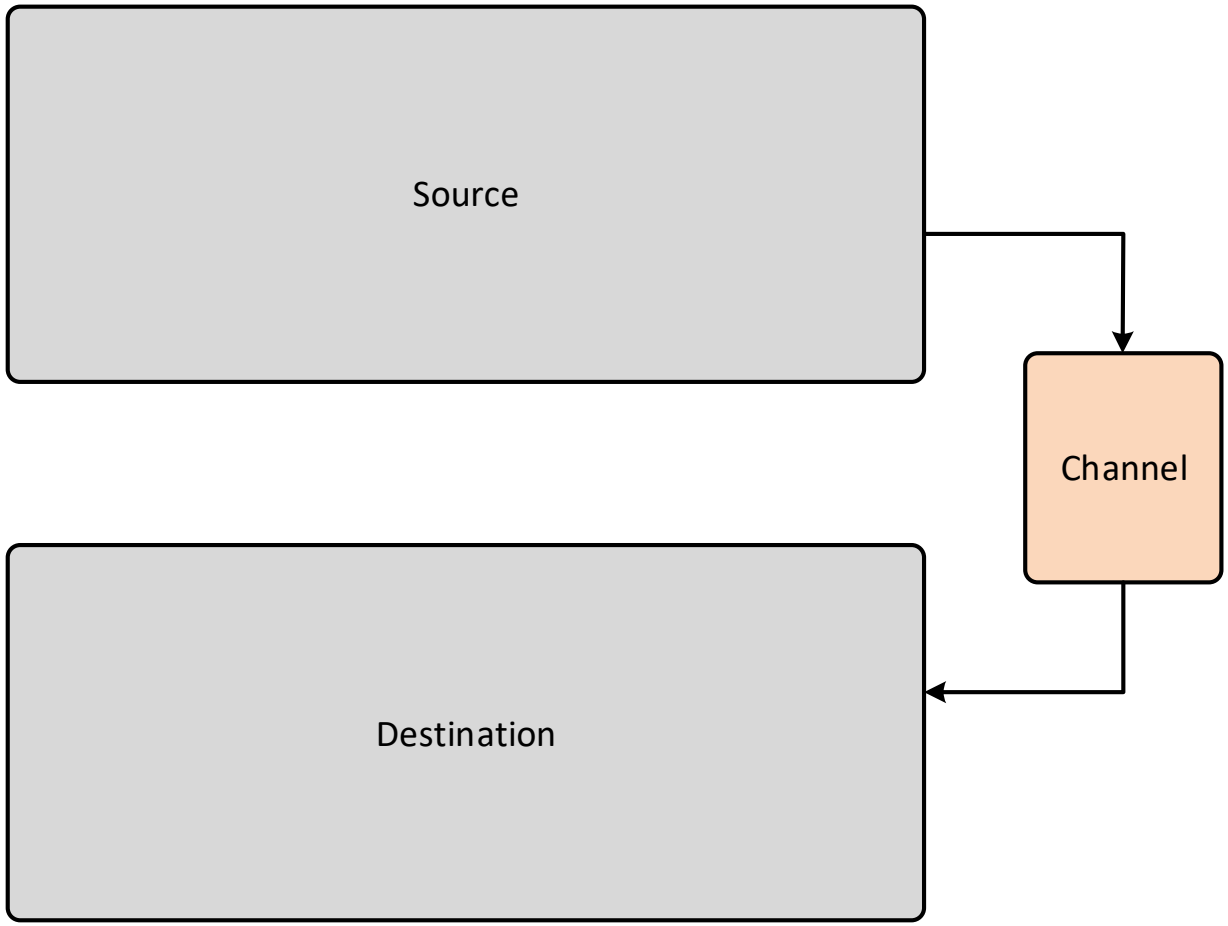


Figure: Abstract diagram of a communication system.

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. Noise
     2. Attenuation
     3. Delay
     4. Distortion
     5. Fading
  2. Working constraints
     1. Available bandwidth
     2. Central Frequency
     3. Injected power
     4. Usage time

Communication Systems

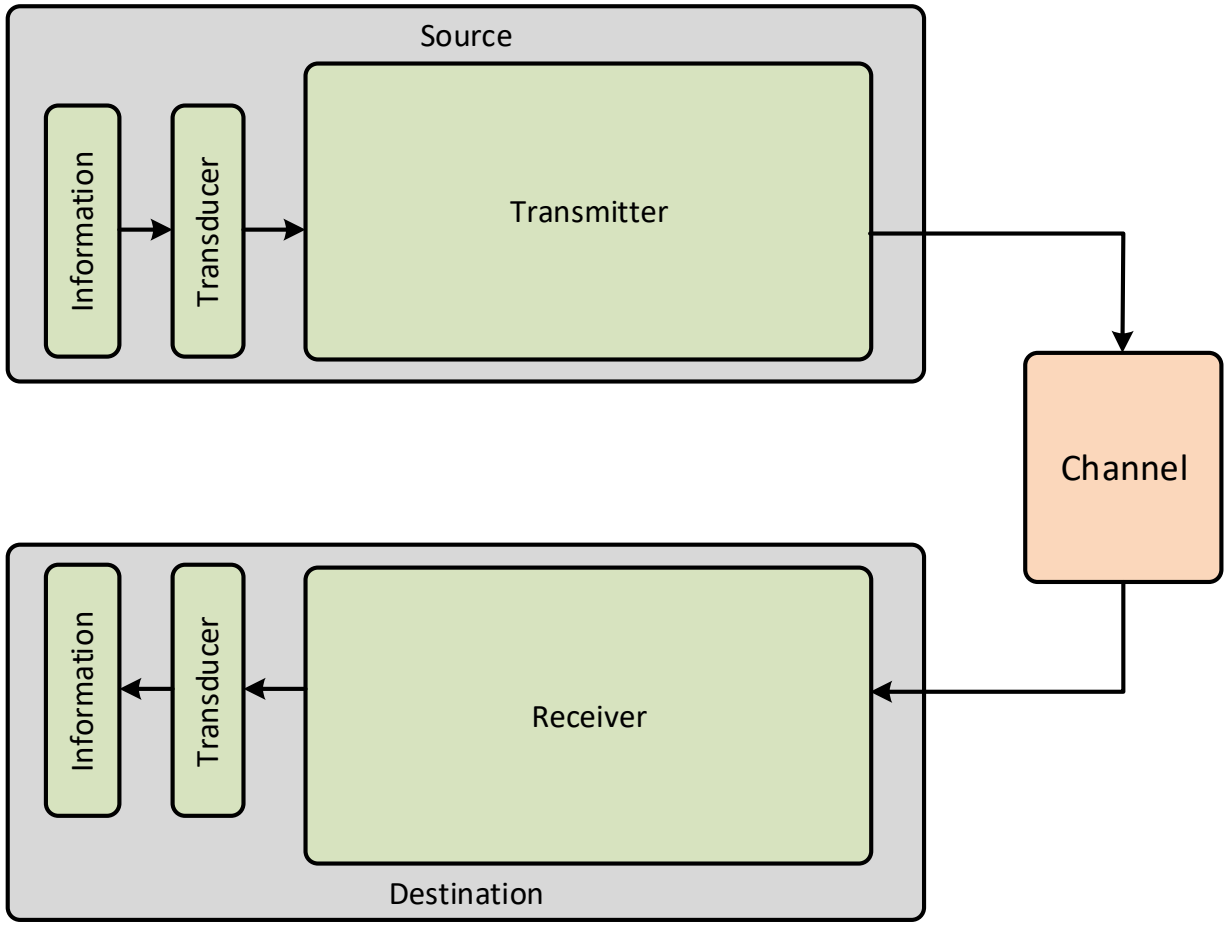


Figure: Functional diagram of a communication system.

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

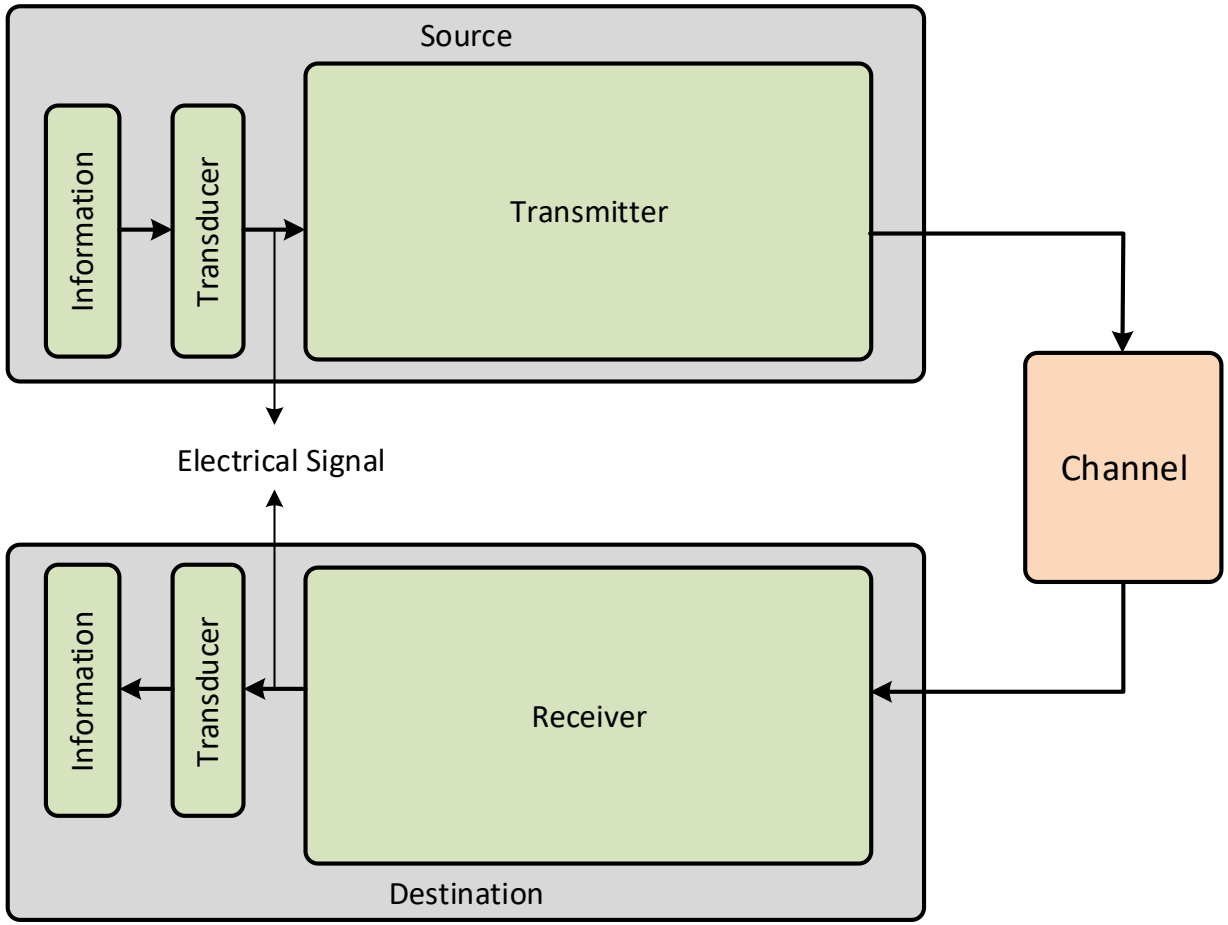


Figure: Functional diagram of an electrical communication system.

Analog Communication Systems

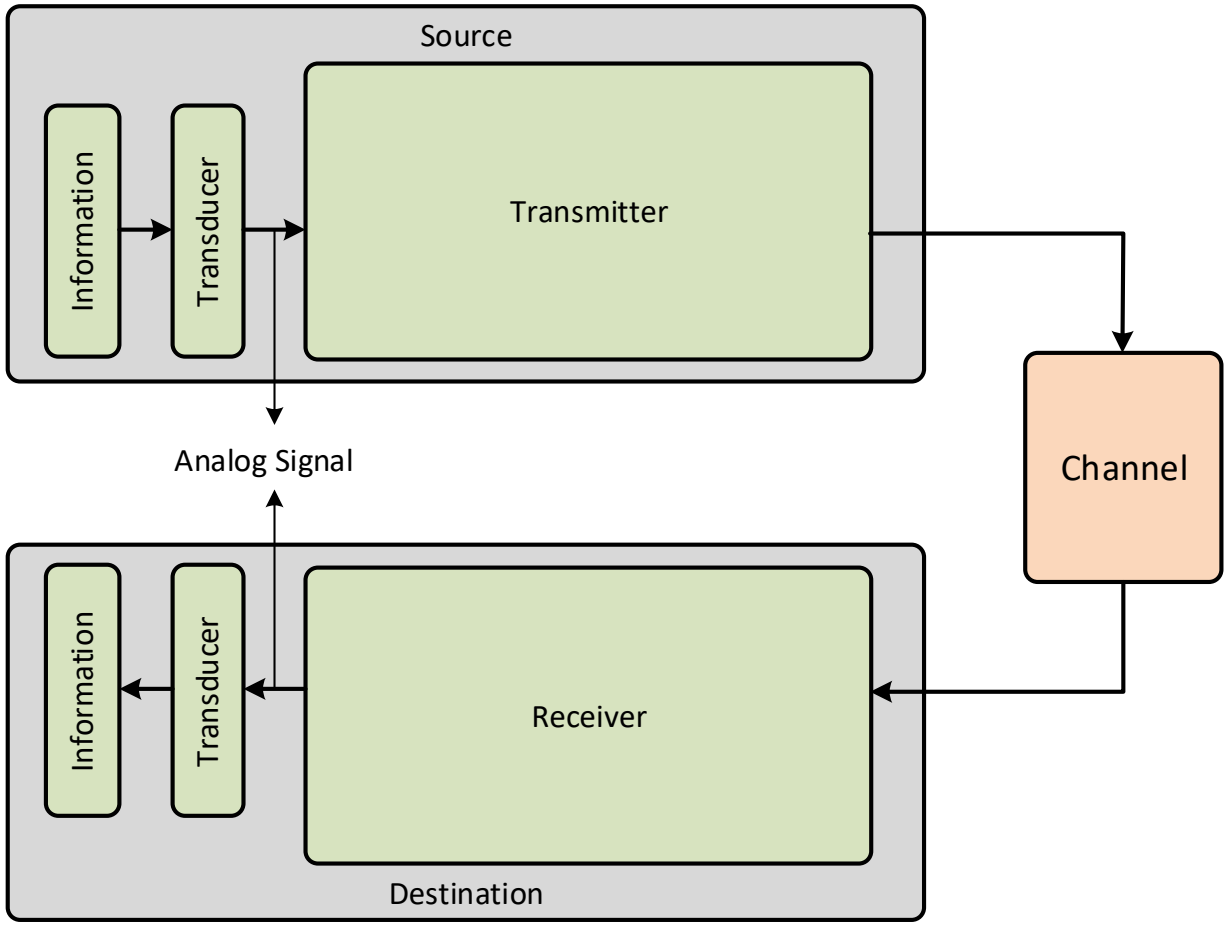


Figure: Functional diagram of an analog communication system.

Digital Communication Systems

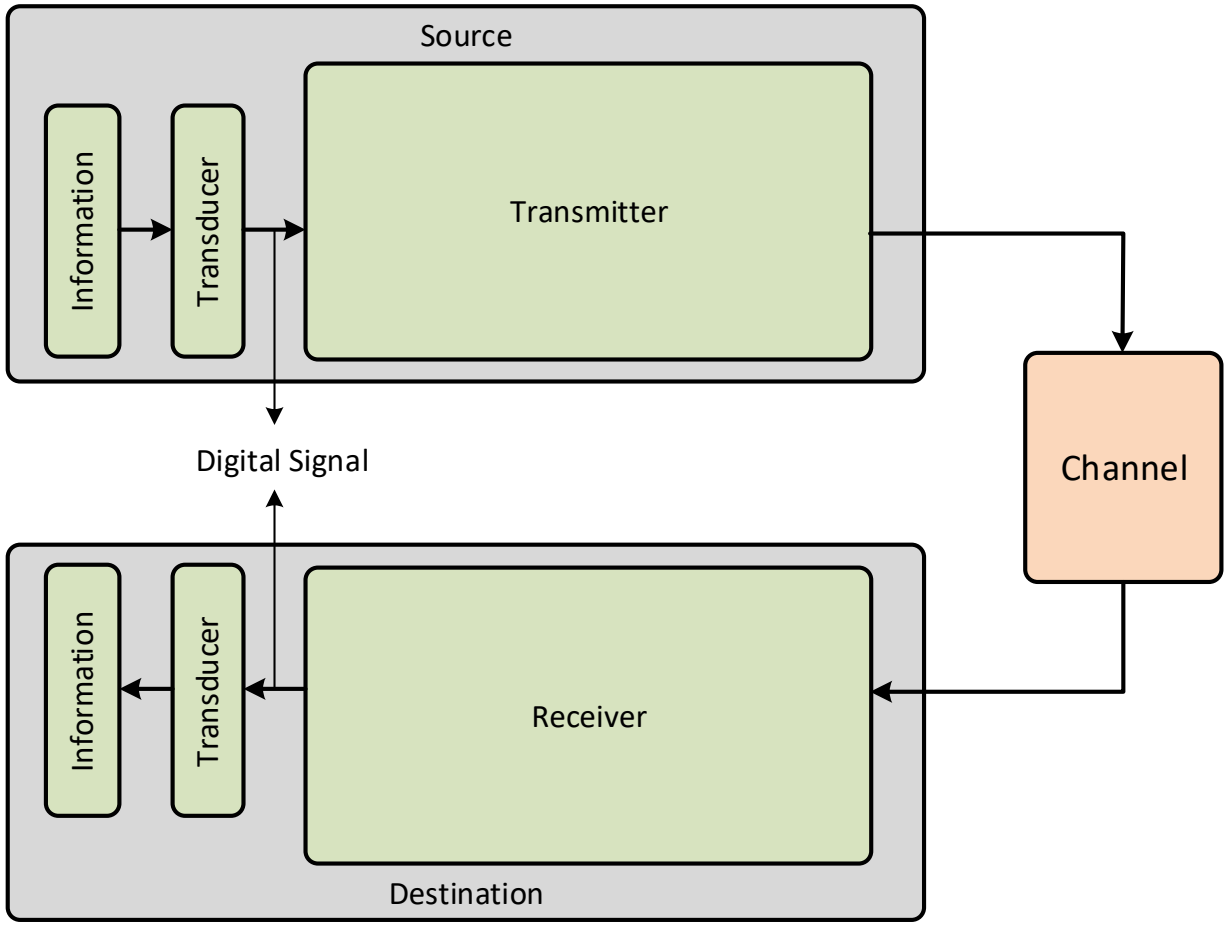


Figure: Functional diagram of a digital communication system.

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

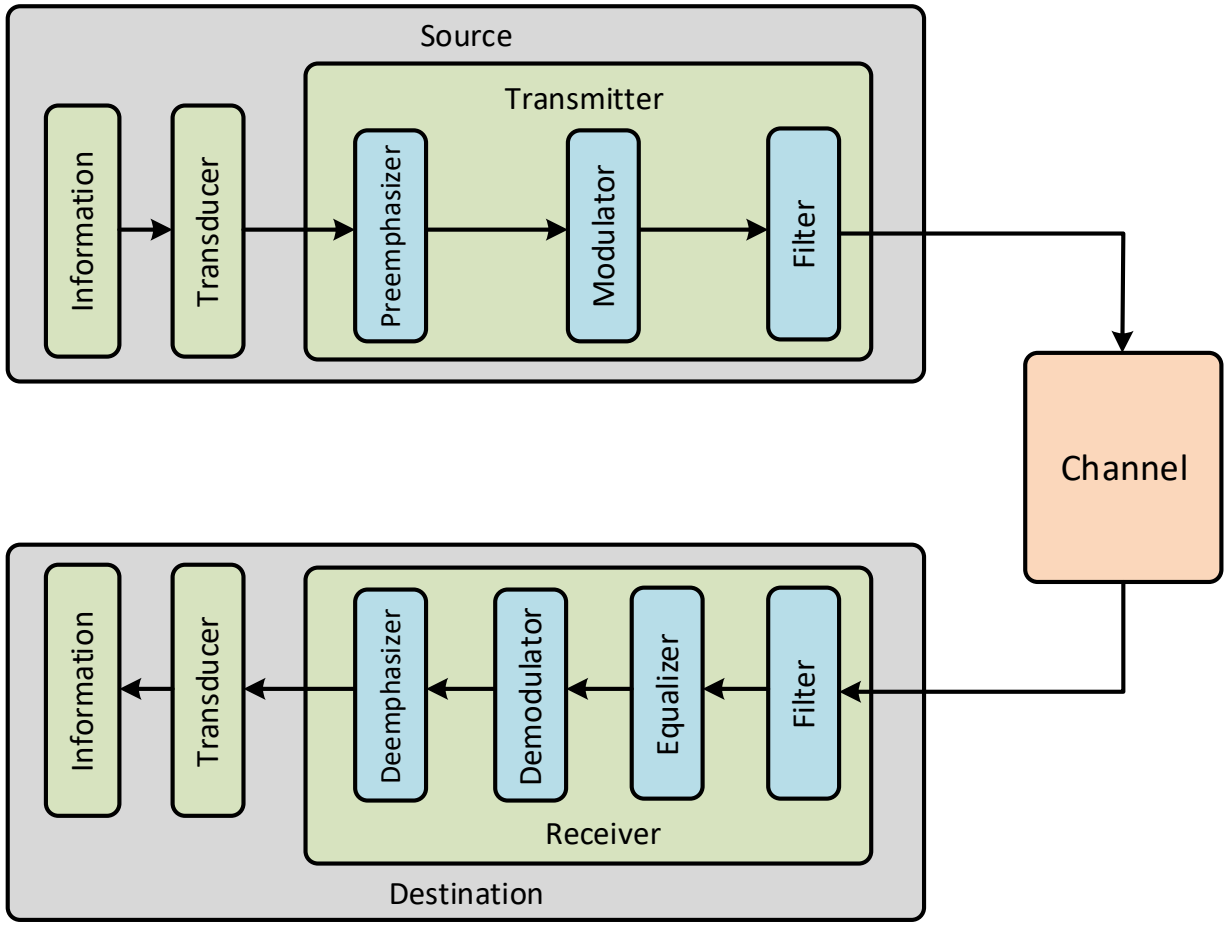


Figure: Detailed diagram of an analog communication system.

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

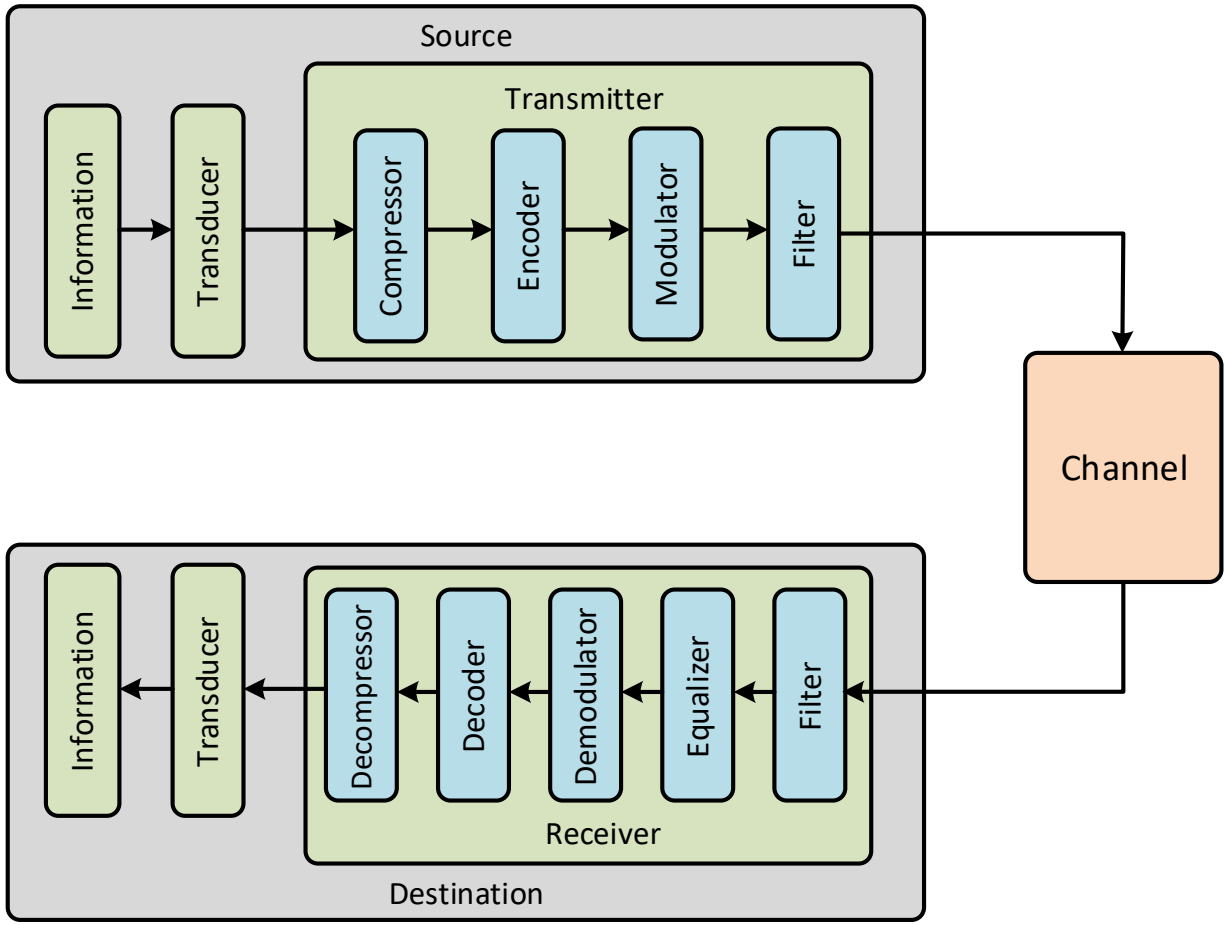


Figure: Detailed diagram of a digital communication system.

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

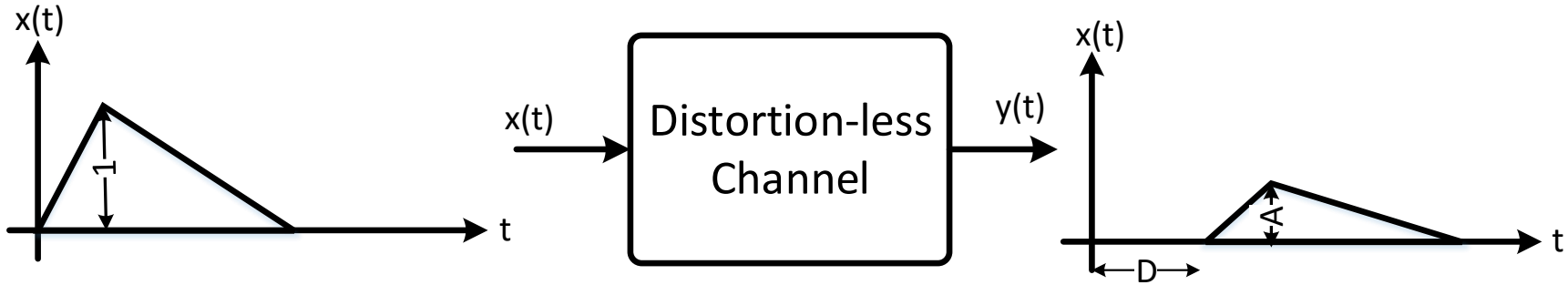
Modeling, Analysis, and Design

Roughly,

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

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.



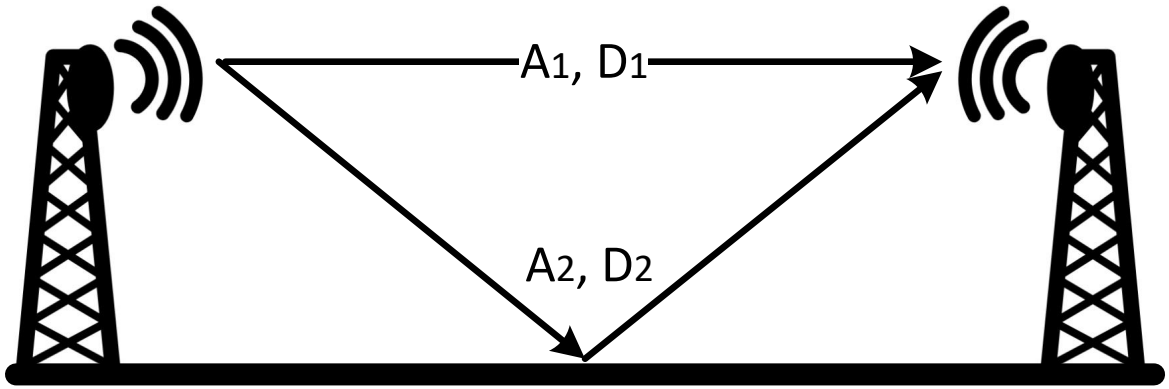
$$y(t) = Ax(t - D) \Rightarrow Y(f) = Ae^{-j2\pi fD}X(f)$$

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

Modeling

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 $H_c(f) = A_1 e^{-j2\pi fD_1}(1 + Ae^{-j2\pi fD})$, where $A = A_2/A_1 < 1$ and $D = D_2 - D_1 \geq 0$.



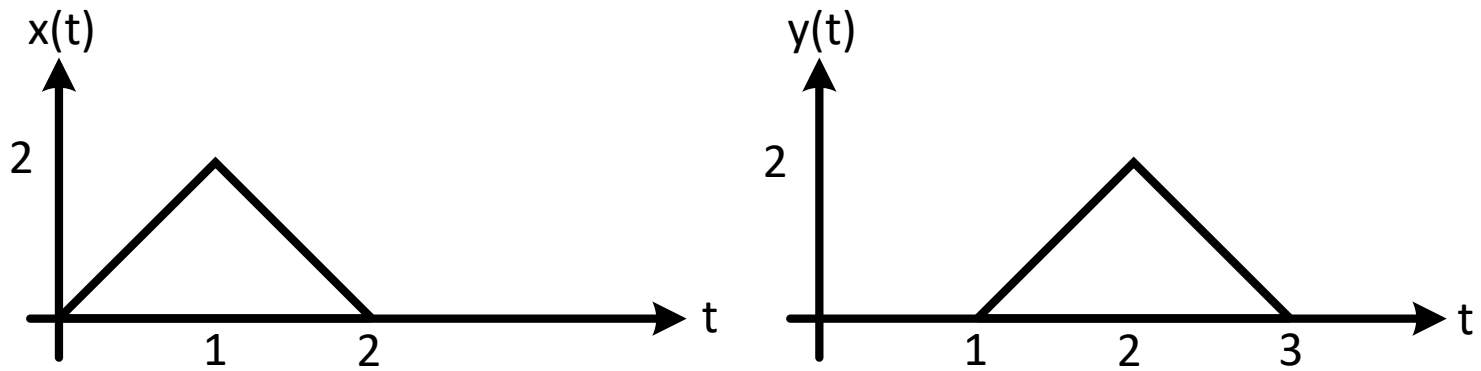
$$y(t) = A_1 x(t-D_1) + A_2 x(t-D_2) \Rightarrow Y(f) = \left[A_1 e^{-j2\pi fD_1} + A_2 e^{-j2\pi fD_2}\right] X(f)$$

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

Analysis

Example (Customized distortion-less channel)

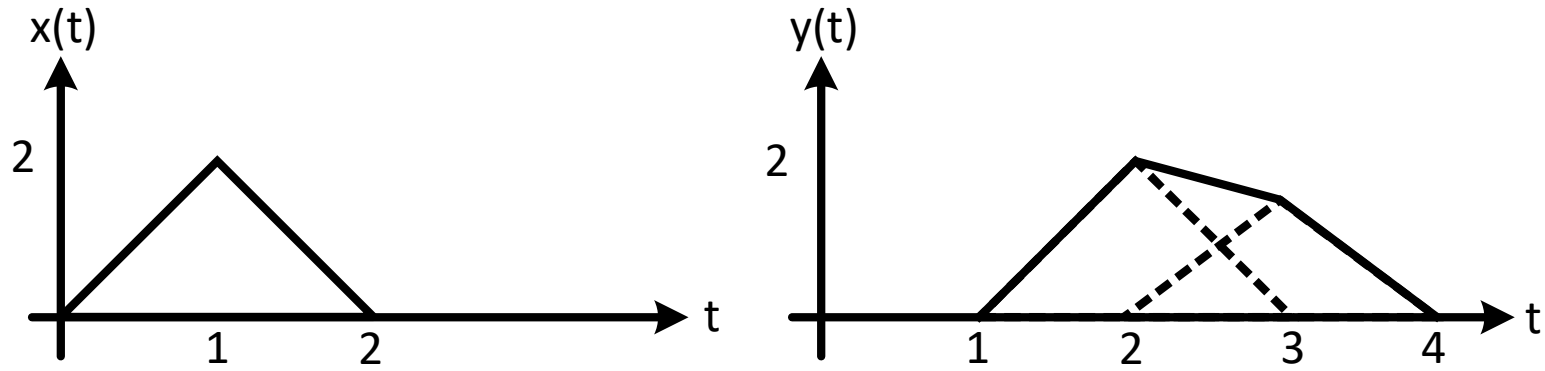
Passing $x(t)$ through the distortion-less channel with $A = 1$ and $D = 1$, the output $y(t) = x(t - 1)$ appears.



Analysis

Example (Customized point-to-point microwave radio channel)

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



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 $D = D_2 - D_1 \geq 0$.

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

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

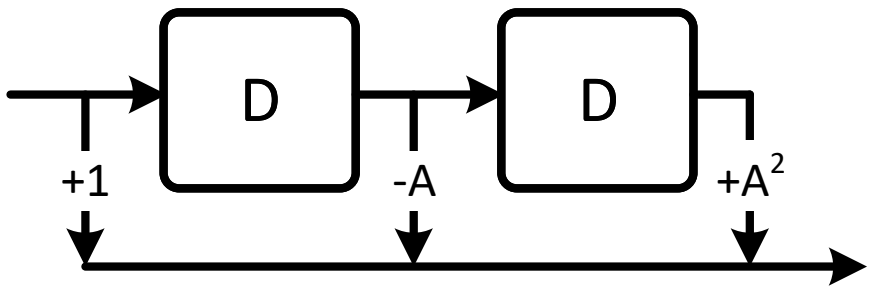
Design

Example (Point-to-point microwave radio channel equalizer)

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

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

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



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