Communication Channels

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Overview

Communication Channels

Channel Type

1. Ideal channel
2. Attenuation channel
3. Distortion-less channel
4. Linear filter channel
5. Additive white Gaussian noise channel
6. Linear filter additive white Gaussian noise channel
7. Linear filter additive colored Gaussian noise channel
8. Nonlinear channel

Ideal Channel

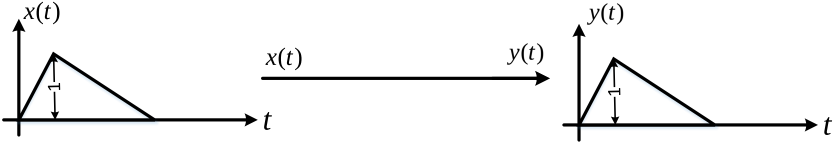


Figure: Ideal channel.

$$y(t) = x(t)$$

Attenuation Channel

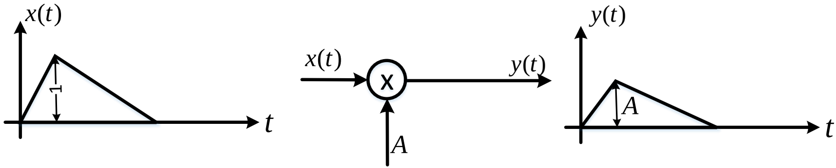


Figure: Attenuation channel.

$$y(t) = Ax(t)$$

Distortion-less Channel

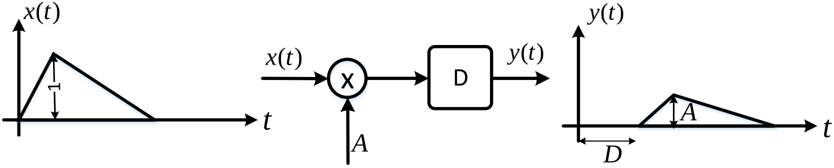


Figure: Distortion-less channel.

$$y(t) = Ax(t - D)$$

Linear Filter Channel

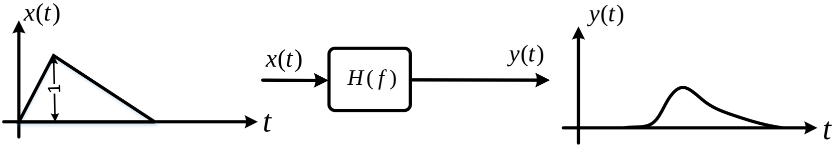


Figure: Linear filter channel.

$$y(t) = x(t) * h(t)$$

AWGN Channel

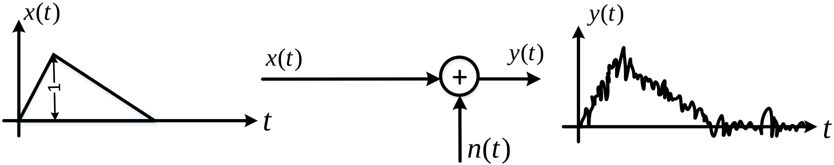


Figure: Additive white Gaussian noise channel.

$$y(t) = x(t) + n(t)$$

Linear filter AWGN Channel

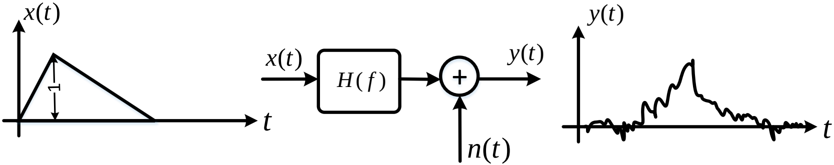


Figure: Linear filter additive white Gaussian noise channel.

$$y(t) = x(t) * h(t) + n(t)$$

Linear Filter Additive Colored Gaussian Noise Channel

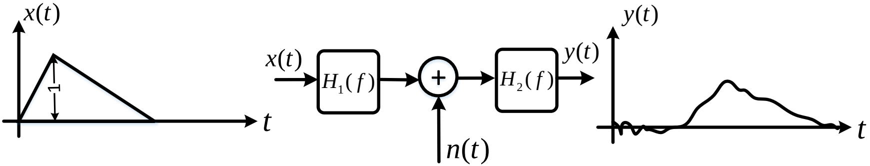


Figure: Linear filter additive colored Gaussian noise channel.

$$y(t) = \left[x(t) * h_1(t) + n(t)\right] * h_2(t) = x(t) * h_1(t) * h_2(t) + n(t) * h_2(t)$$

Nonlinear Noisy Channel

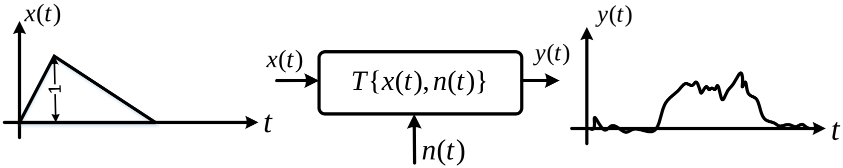


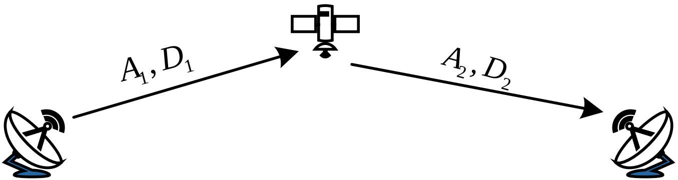
Figure: Nonlinear noisy channel.

$$y(t) = T\{x(t), n(t)\}$$

Channel Modeling

Example (Satellite channel)

A geostationary satellite at 36000-km orbit with uplink and downlink frequencies $f_1 = 6$ GHz and $f_2 = 4$ GHz communicates through two distortionless channels with delays $D_1 = D_2 = 120$ ms and free space losses $A_1 = -199.1$ dB and $A_2 = -195.6$ dB.



$$D_1 = D_2 = \frac{l}{c} = \frac{36000}{300000} = 0.12 \text{ s} = 120 \text{ ms}$$

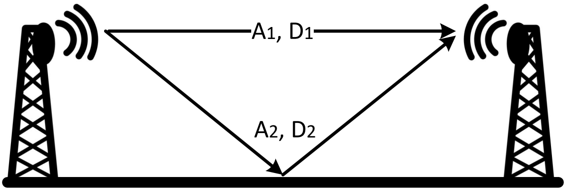
$$A_1^2 = (\frac{c}{4\pi f_1 l})^2 = (\frac{300000}{4\pi \times 6 \times 10^9 \times 36000})^2 = 1.22\times 10^{-20} \equiv 10\log_{10}(1.22\times 10^{-20}) = -199.1 \text{ dB}$$

$$A_2^2 = (\frac{c}{4\pi f_2 l})^2 = (\frac{300000}{4\pi \times 4 \times 10^9 \times 36000})^2 = 2.75\times 10^{-20} \equiv 10\log_{10}(2.75\times 10^{-20}) = -195.6 \text{ dB}$$

Linear Filter Channel

Example (Point-to-point microwave radio channel)

A point-to-point microwave radio channel can be modeled as a linear filter channel with the frequency response $H(f) = A_1 e^{-j2\pi f D_1}(1 + Ae^{-j2\pi f D})$, where $A = A_2/A_1 < 1$ and $D = D_2 - D_1 \geq 0$.



$$y(t) = A_1 x(t - D_1) + A_2 x(t - D_2)$$

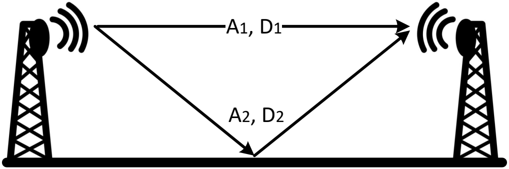
$$y(t) = x(t) * \left[A_1\delta(t - D_1) + A_2\delta(t - D_2)\right] = x(t) * h(t) \Rightarrow h(t) = A_1\delta(t - D_1) + A_2\delta(t - D_2)$$

$$Y(f) = \left[A_1 e^{-j2\pi f D_1} + A_2 e^{-j2\pi f D_2}\right] X(f) \Rightarrow H(f) = A_1 e^{-j2\pi f D_1}(1 + Ae^{-j2\pi f D})$$

Channel Modeling

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

A noisy point-to-point microwave radio channel can be modeled as a linear filter additive white Gaussian noise channel with the impulse response $h(t) = A_1\delta(t - D_1) + A_2\delta(t - D_2)$ and additive white Gaussian noise process $n(t)$.



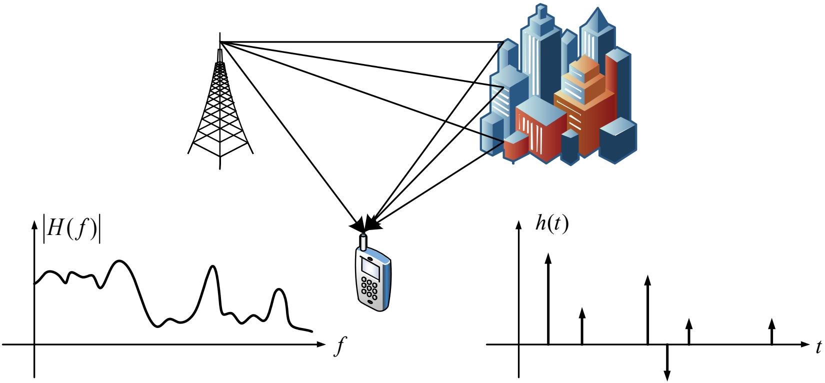
$$y(t) = A_1 x(t - D_1) + A_2 x(t - D_2) + n(t)$$

$$y(t) = x(t) * \left[A_1\delta(t - D_1) + A_2\delta(t - D_2)\right] + n(t) = x(t) * h(t) + n(t)$$

Channel Modeling

Example (Multipath radio channel)

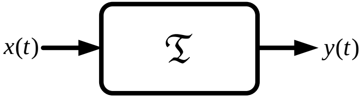
A multipath radio channel can be modeled as a linear filter channel with the impulse response $h(t) = \sum_{i=0}^{N} A_i \delta(t - D_i)$.



Channel Modeling

Example (Nonlinear channel)

A nonlinear channel is usually described by its Total Harmonic Distortion (THD).



$$x(t) = \cos(2\pi f_0 t)$$

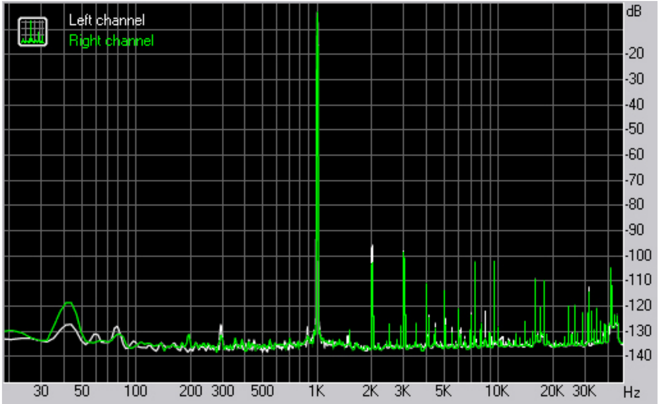
$$y(t) = B_0 + B_1 \cos(2\pi f_0 t) + B_2 \cos(2\pi 2 f_0 t) + B_3 \cos(2\pi 3 f_0 t) + \cdots$$

$$2HD = \frac{|B_2|}{|B_1|}, 3HD = \frac{|B_3|}{|B_1|}, 4HD = \frac{|B_4|}{|B_1|}, \cdots$$

$$\text{THD} = \sqrt{\frac{\sum_{i=2}^{\infty} B_i^2}{B_1^2}}$$

Example (Nonlinear channel)

The THD of a high-quality audio amplifier is around 0.005%.



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