

Data Communications

Transmission Impairments

Data Rate Limits

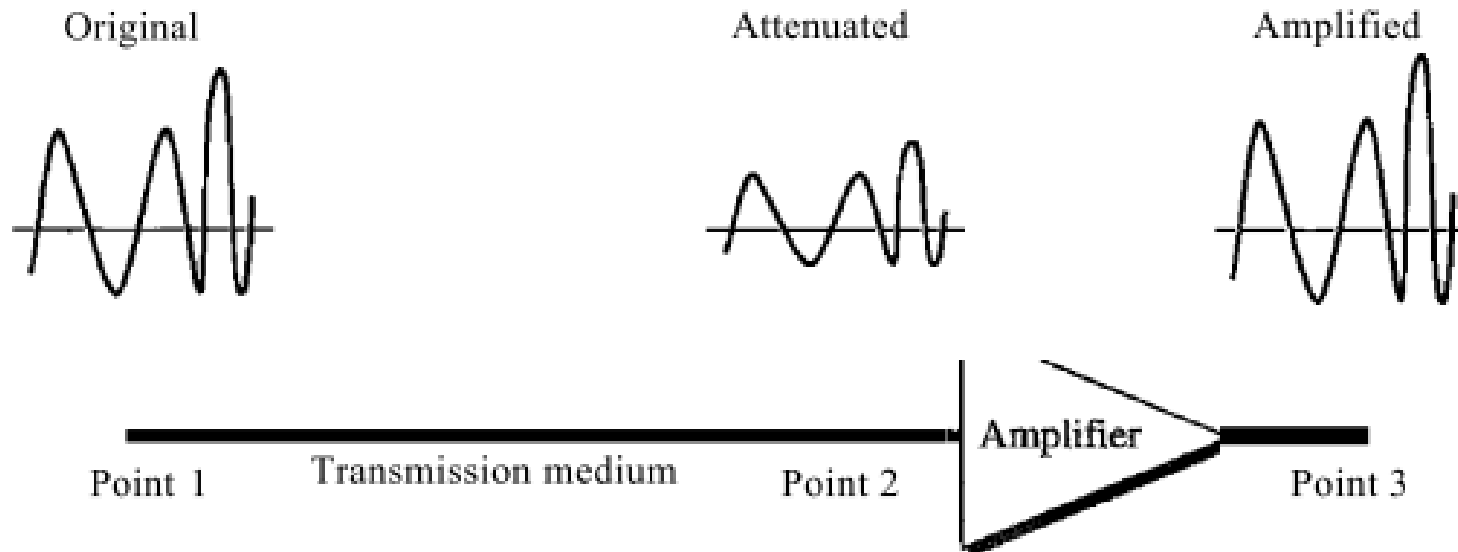
TRANSMISSION IMPAIRMENT

- Signals travel through transmission media, which are not perfect. The imperfection causes signal impairment.
- Three causes of impairment are attenuation, distortion, and noise

Attenuation

- Attenuation means a loss of energy. When a signal, simple or composite, travels through a medium, it loses some of its energy in overcoming the resistance of the medium.
- To compensate for this loss, amplifiers are used to amplify the signal

Attenuation



Decibel

- To show that a signal has lost or gained strength, we use the unit of the decibel.
- The decibel (dB) measures the relative strengths of two signals or one signal at two different points.
- Note that the decibel is negative if a signal is attenuated and positive if a signal is amplified.

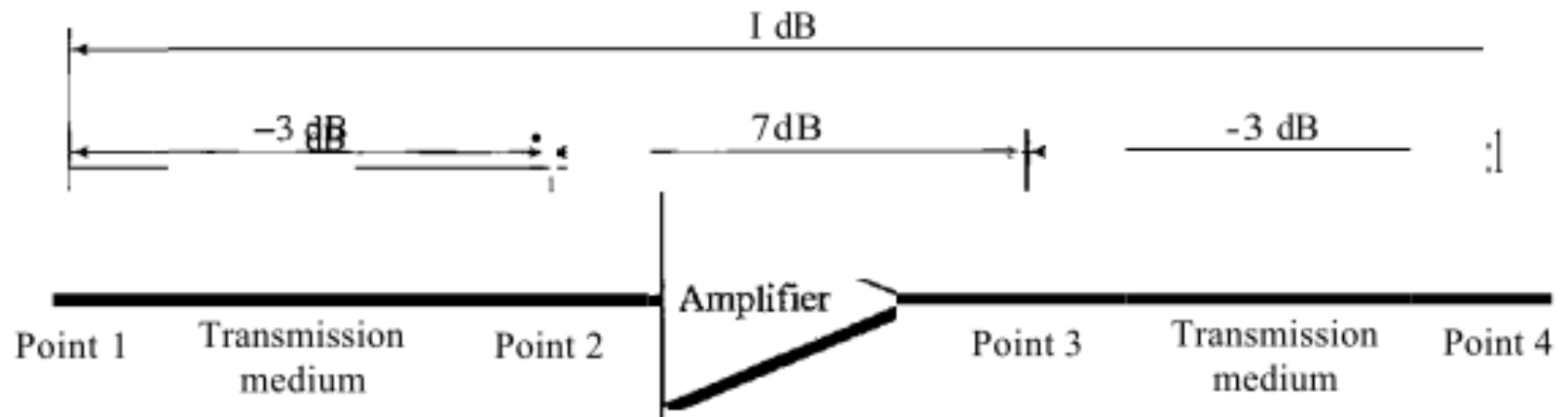
Computing Attenuation

- Attenuation = $10\text{Log}_{10} (P_2/P_1)$
- P_2 is the power of the received signal
- P_1 is the power of the transmitted signal

Example

- Suppose a signal travels through a transmission medium and its power is reduced to one-half.
- This means that $P_2 = P_1/2$ In this case, the attenuation (loss of power) can be calculated as:
- $\text{Att.} = 10\text{Log}_{10}([P_1/2]/P_1) = 10(-0.3) = -3\text{dB}$

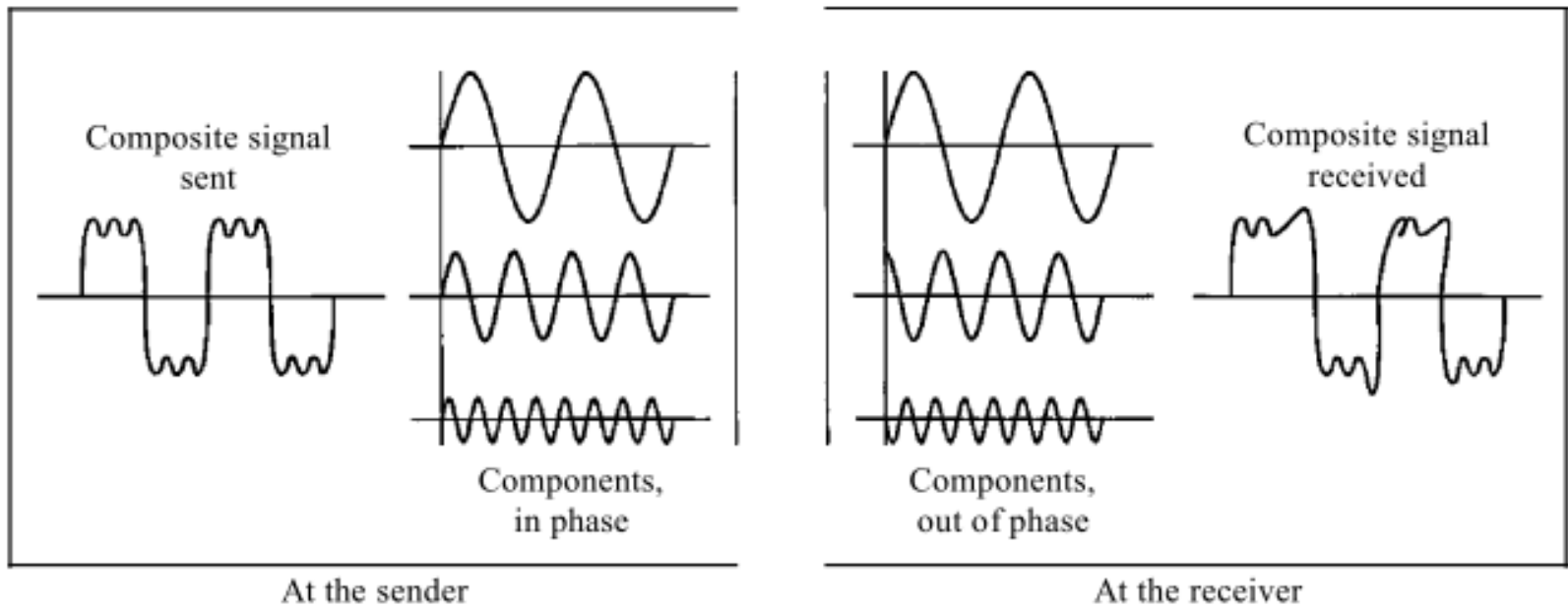
Cascading Attenuation/Amplification



Distortion

- Distortion means that the signal changes its form or shape.
- Distortion can occur in a composite signal made of different frequencies.
- Each signal component has its own propagation speed

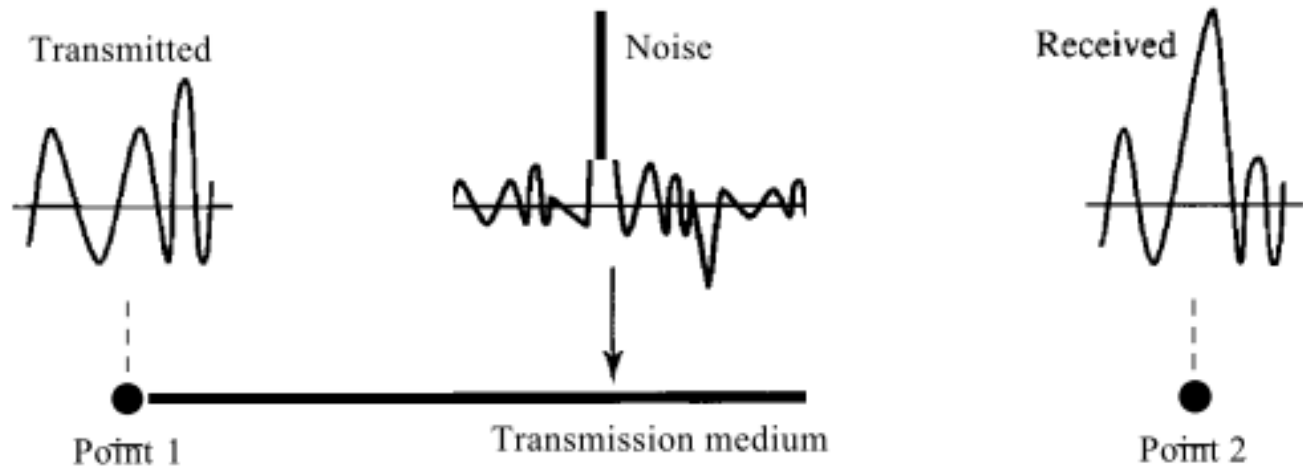
Distortion



Noise

- Several types of noise, such as thermal noise, induced noise, crosstalk, and impulse noise, may corrupt the signal.
- Thermal noise is the random motion of electrons in a wire which creates an extra signal not originally sent by the transmitter.
- Induced noise comes from sources such as motors and appliances. These devices act as a sending antenna, and the transmission medium acts as the receiving antenna.
- Crosstalk is the effect of one wire on the other. One wire acts as a sending antenna and the other as the receiving antenna.
- Impulse noise is a spike that comes from power lines, lightning, and so on.

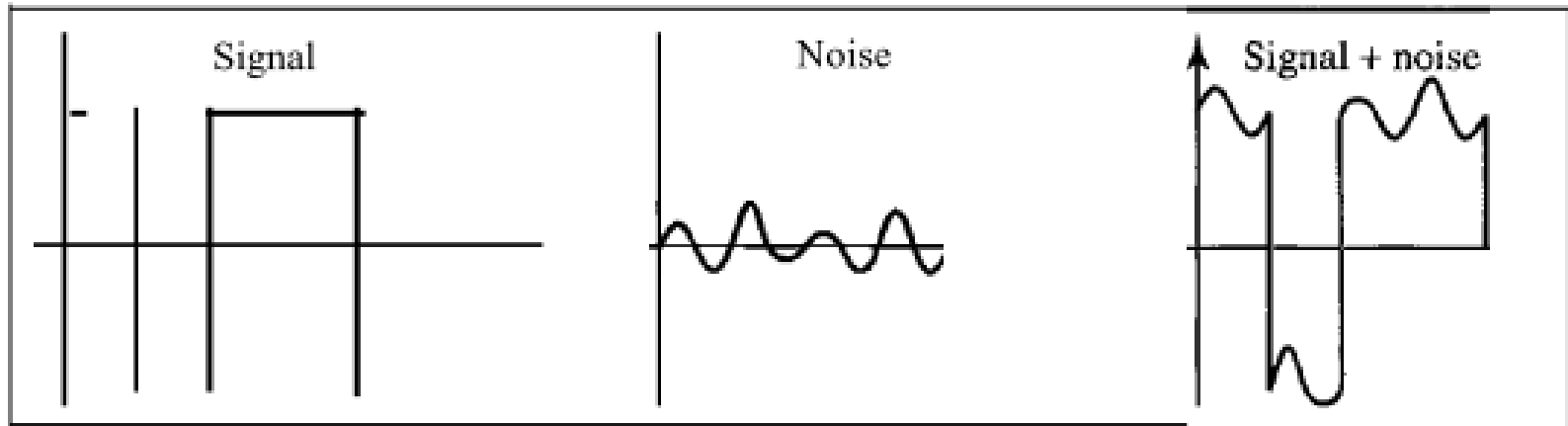
Noise



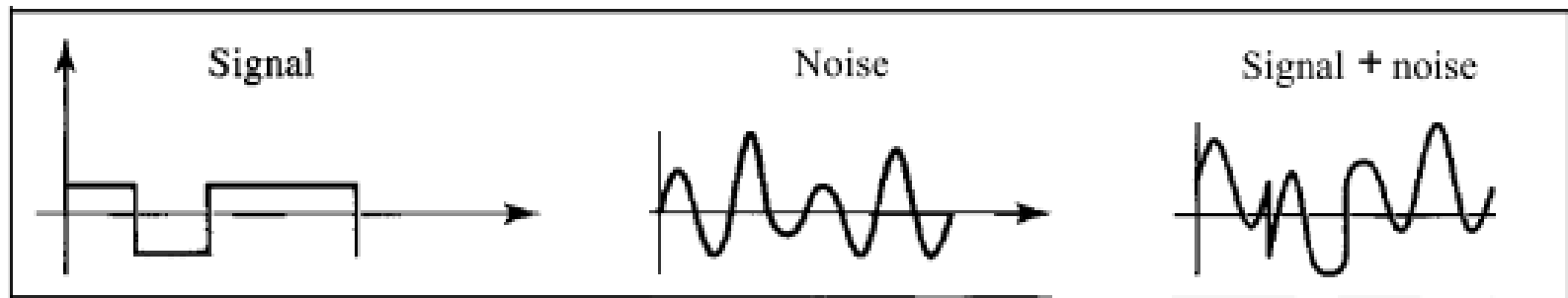
Signal-to-Noise Ratio (SNR)

- $SNR = 10\text{Log}_{10}(\text{Signal power}/\text{Noise Power})$
- the average signal power and the average noise power are considered because they may change with time.

Example



a. Large SNR



b. Small SNR

Example

- The power of a signal is 10 mW and the power of the noise is 1 μ W; what are the values of SNR

DATA RATE LIMITS

- Data rate defines the transmission rate in terms of bits sent per second
- Data rate depends on three factors:
 1. The bandwidth available
 2. The level of the signals we use
 3. The level of the noise

Noiseless Channel: Nyquist Bit Rate

- BitRate = $2 \times \text{bandwidth} \times \log_2 L$
- Increasing the levels of a signal may reduce the reliability of the system.

Noisy Channel: Shannon Capacity

- Capacity = bandwidth $\times \log_2 (1 + S/N)$
- S is signal power, N is noise power

Using Both Limits

- The Shannon capacity gives us the upper limit;
- The Nyquist formula tells us how many signal levels we need.