Data Communications

Transmission Impairments

Data Rate Limits

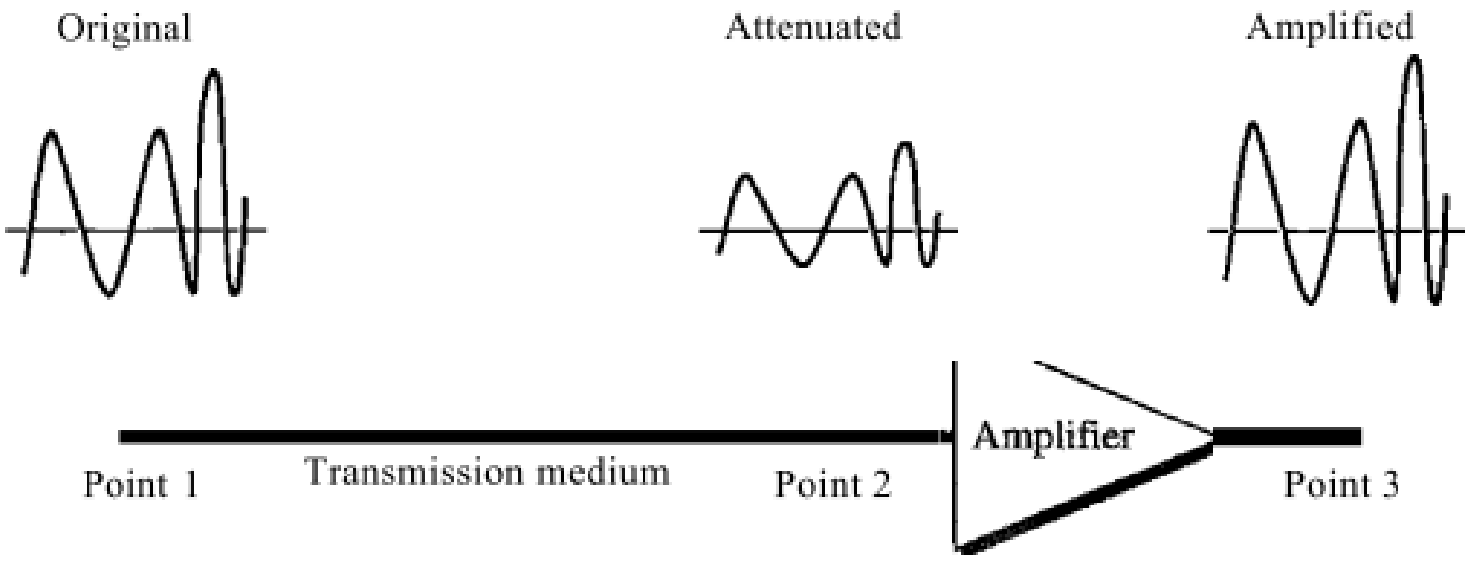
TRANSMISSION IMPAIRMENT

- 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.

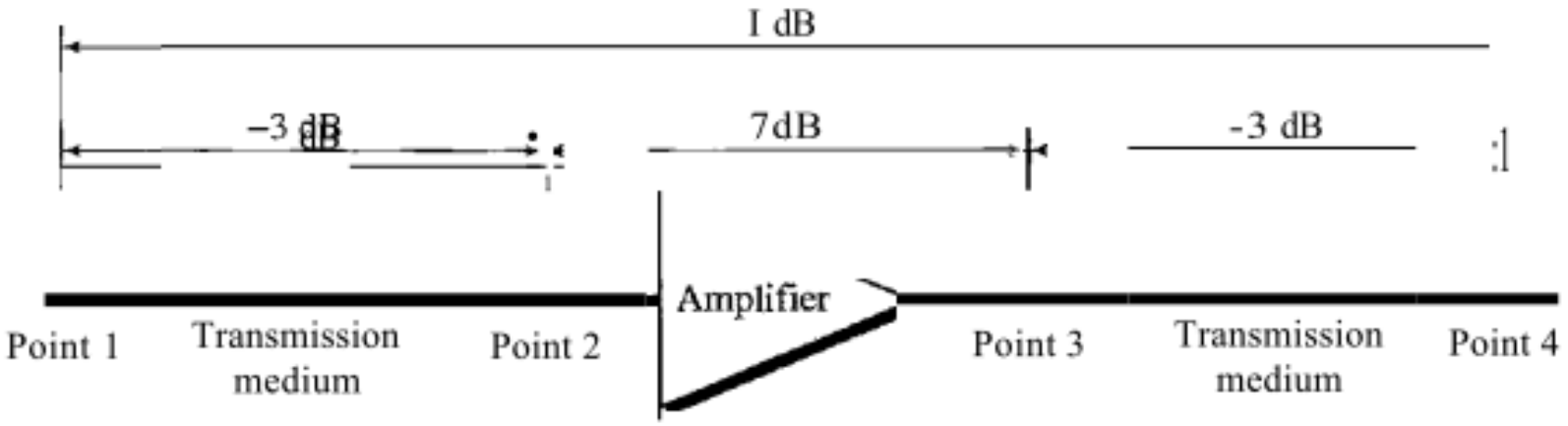
Computing Attenuation

- 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 P2= P1/2 In this case, the attenuation (loss of power) can be calculated as:
- Att. = $10\text{Log}_{10}([P1/2]/P1) = 10(-0.3) = -3\text{dB}$

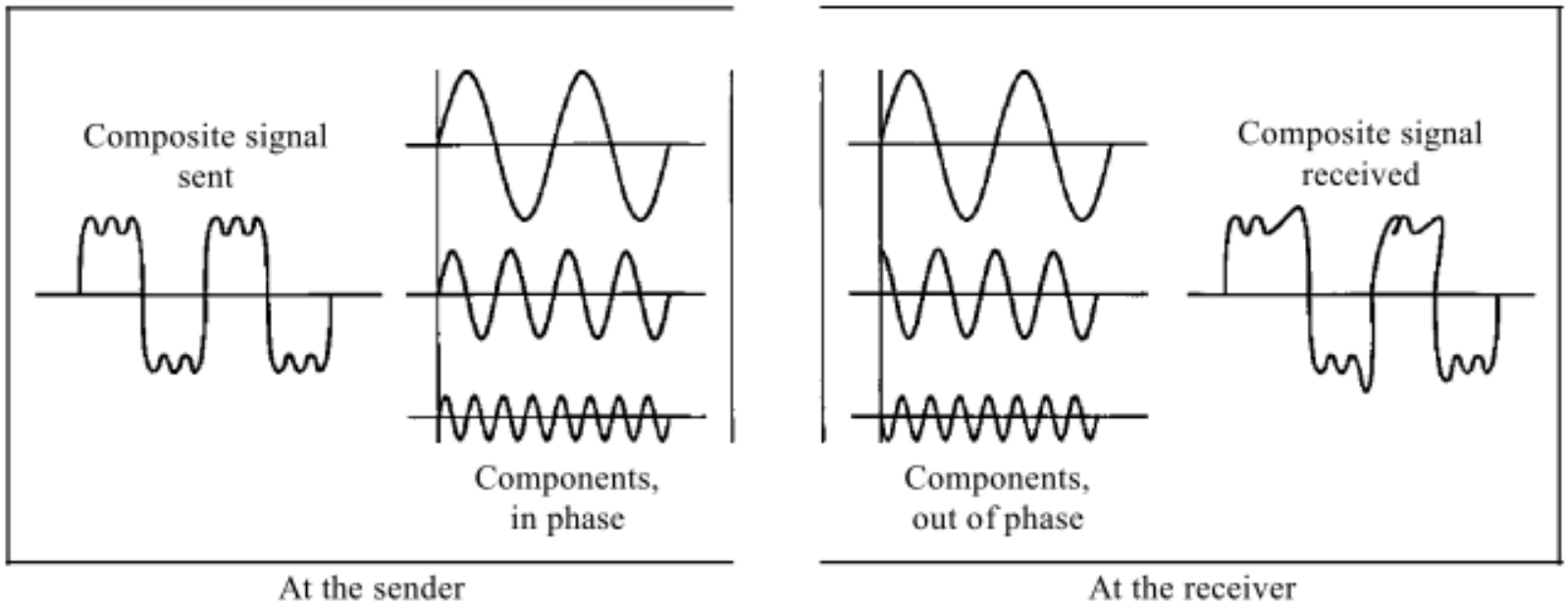
Cascading Attenuation/Amplification



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

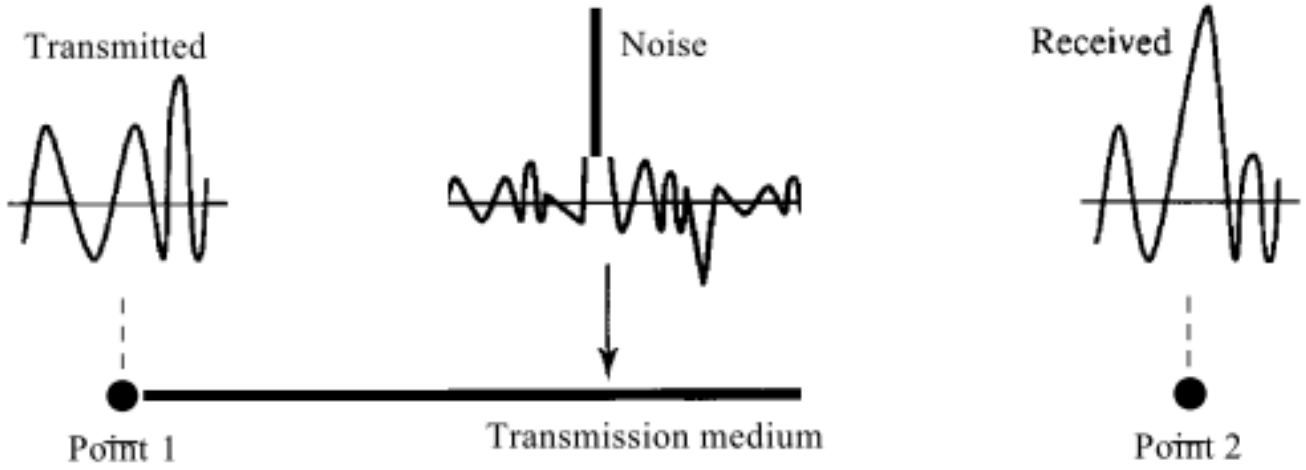
Distortion


Composite signal sent
Components, in phase
At the sender
Components, out of phase
Composite signal received
At the receiver

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.

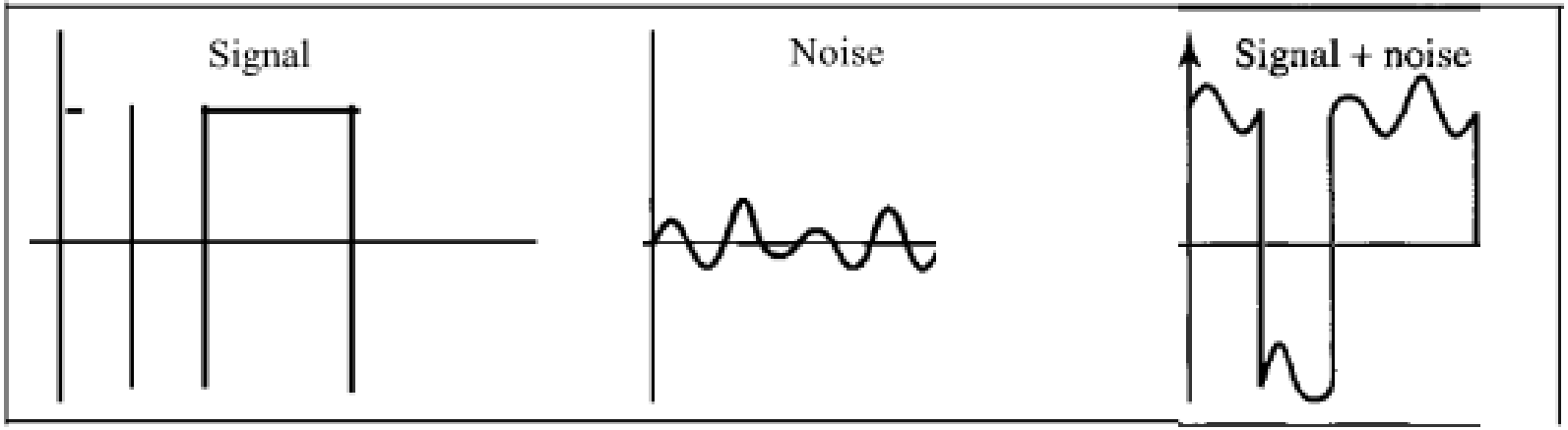
Noise


Transmitted
Noise
Received
Point 1
Transmission medium
Point 2

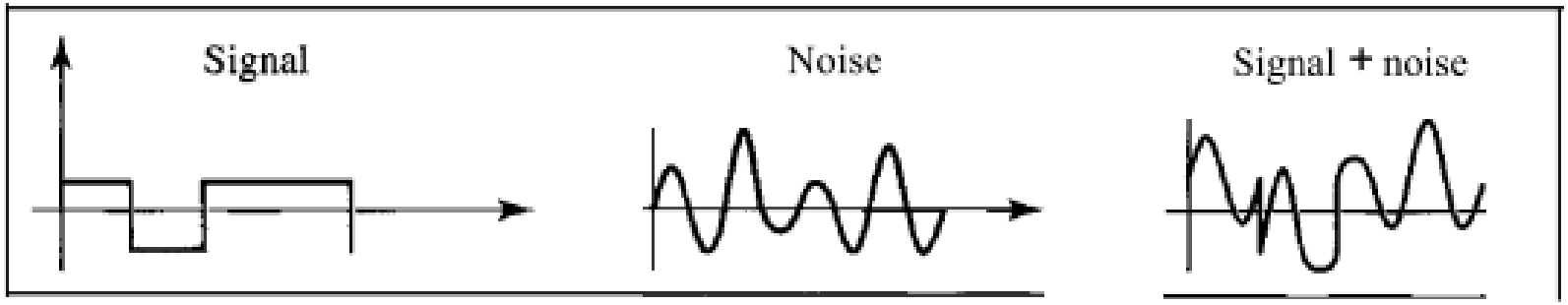
Signal-to-Noise Ratio (SNR)

- SNR = 10Log_{10}(Signal power/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 /μW;
- What is the value 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 x bandwidth x Log_2 L

- Increasing the levels of a signal may reduce the reliability of the system.

Noisy Channel: Shannon Capacity

- Capacity =bandwidth X $\log_2$ (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 can have.