Lecture (5)
" Data Communication”

Transmission

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BANDWIDTH AND BITRATE

- **Bandwidth:**

  The maximum possible data transfer rate.

- **Bit Rate :**

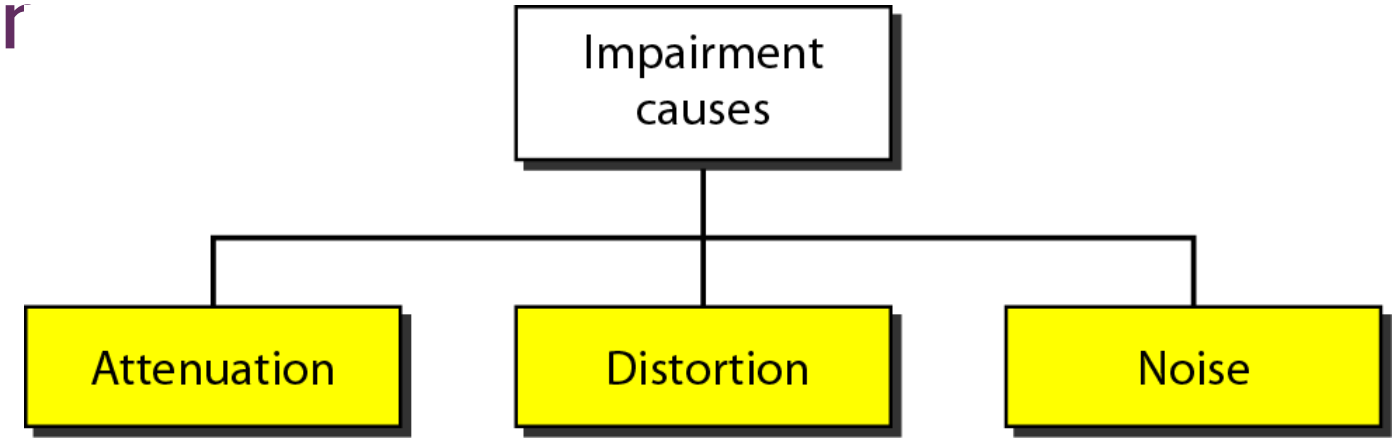
  Number of bits transmitted per second.

FACTORS AFFECTING BANDWIDTH AND BITRATE

- **Network Congestion**:
  - High traffic can reduce effective bandwidth and bitrate.
- **Latency**:
  - Delays in transmission can affect the perceived bitrate.
- **Protocol Overhead**:
  - Additional data used for communication can reduce effective bitrate.
- **Medium Quality**:
  - The quality of the transmission medium (cables,wireless) impacts both bandwidth and bitrate.

DEFINITION OF TRANSMISSION IMPAIRMENT

- **What isTransmission Impairment?**
- Degradation of a signal as it travels through a transmission medium.
- **Impact:** Can lead to loss of data integrity and quality of communicatior



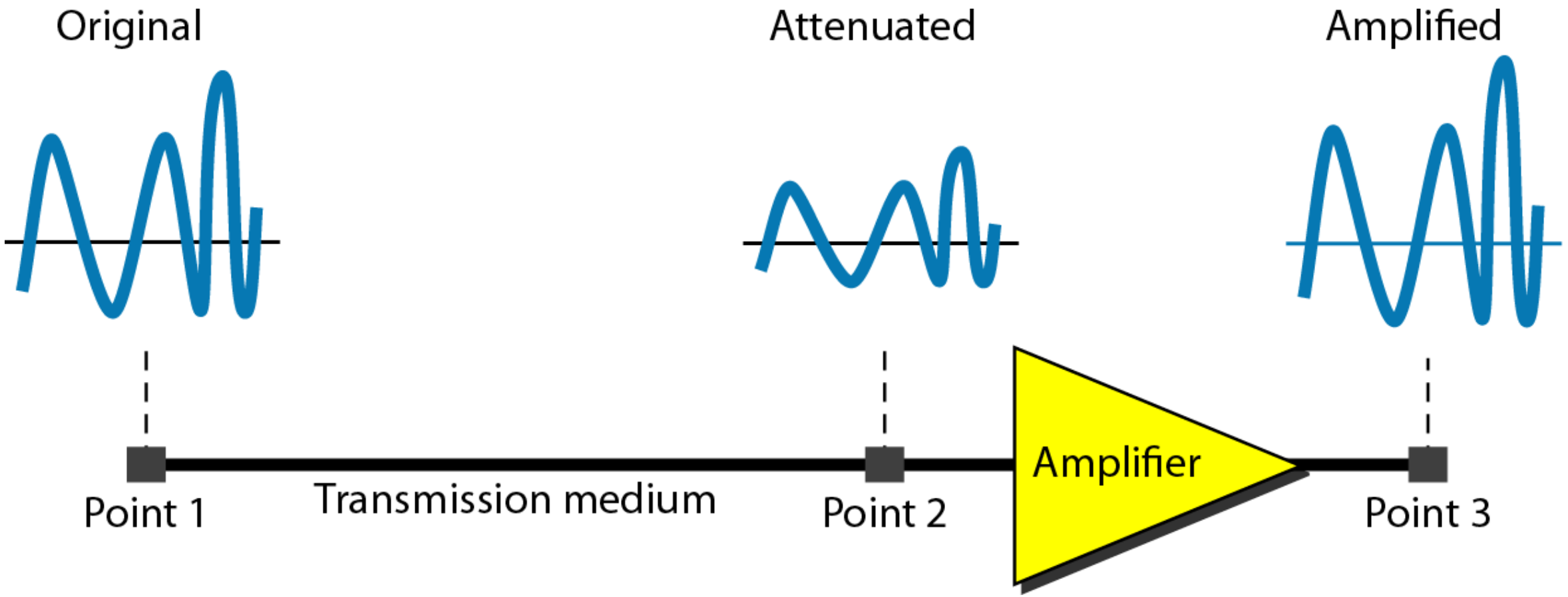
CAUSES OF TRANSMISSION IMPAIRMENT

- **Types of Impairments:**
  - **Attenuation:** Reduction in signal strength over distance.
  - **Noise:** Unwanted electrical signals that distort the original signal.
  - **Distortion:** Alteration of the waveform of the signal.
- **Example:**
  - A voice call may become affected due to these impairments.

ATTENUATION

- **Definition:**
  - The loss of signal strength as it travels through a medium.
- **Factors Influencing Attenuation:**
  - Distance, medium type (copper, fiber optics), frequency of the signal.
- **Example:**
  - A long-distance telephone call may have reduced audio quality due to attenuation.

ATTENUATION



Attenuation can be expressed in decibels (dB) using the formula:

$$\text{Attenuation (dB)} = 10 \log_{10} \left(\frac{P_1}{P_2} \right)$$

ATTENUATION EXAMPLE

Suppose a signal travels through a transmission medium and its power is reduced to one-half. This means that P_2 is (1/2)P1. In this case, the attenuation (loss of power) can be calculated as

ATTENUATION EXAMPLE

Given that $P_2 = \frac{1}{2}P_1$, we can substitute this into the formula:

$$\text{Attenuation (dB)} = 10 \log_{10} \left(\frac{P_1}{\frac{1}{2}P_1} \right) = 10 \log_{10}(2)$$

Now, we can calculate $\log_{10}(2)$:

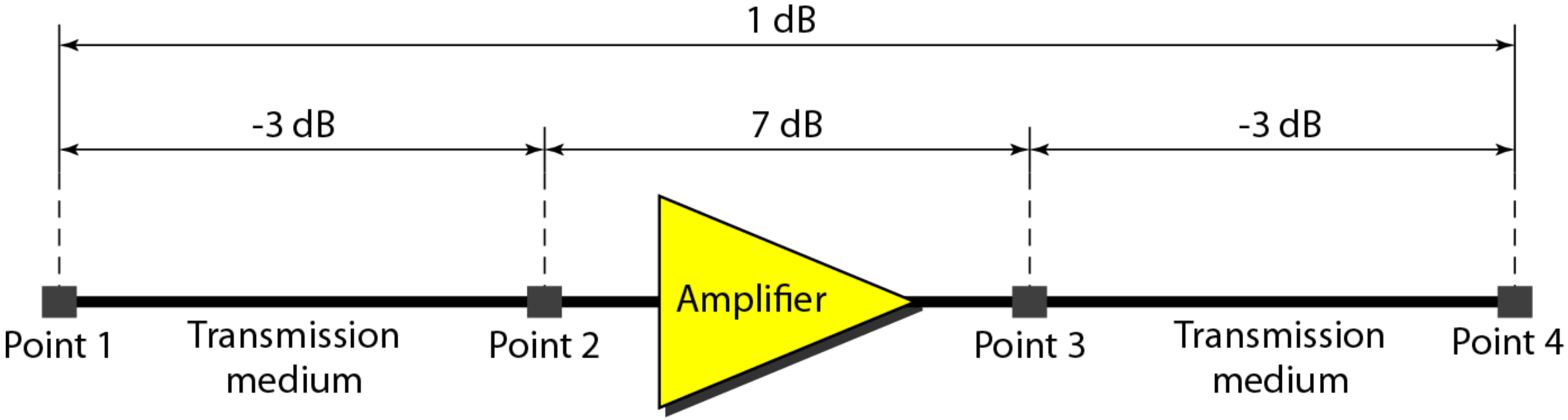
$$\log_{10}(2) \approx 0.3010$$

Substituting this value back:

$$\text{Attenuation (dB)} = 10 \times 0.3010 = 3.010 \, \text{dB}$$

Result:

The attenuation (loss of power) is approximately **3.01 dB**.



a signal travels from point 1 to point 4. In this case, the decibel value can be calculated

$$dB = -3 + 7 - 3 = +1$$

Sometimes the decibel is used to measure signal power in milliwatts. In this case, it is referred to as dB_m and is calculated as $dB_m = 10 \log 10 P_m$, where P_m is the power in milliwatts.

Example: Calculate the power of a signal with $dB_m = -30$?

To convert from dBm to milliwatts (mW), you can use the formula:

$$P_m = 10^{\frac{dBm}{10}}$$

Given $dBm = -30$:

$$P_m = 10^{\frac{-30}{10}} = 10^{-3}$$

Now, converting 10^{-3} to milliwatts:

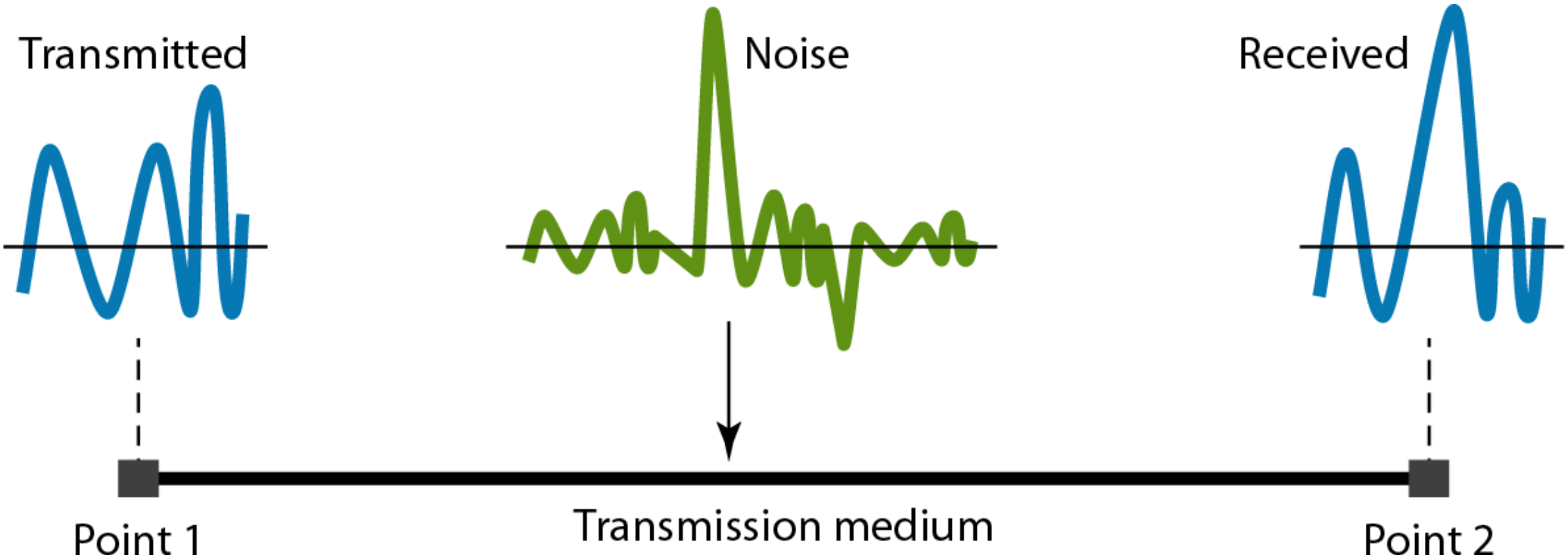
$$P_m = 0.001\,\mathrm{mW}$$

Result:

The power of the signal is **1 µW** (micro-watt).

NOISE

- **Types of Noise:**
  - **Thermal Noise:** Caused by the random motion of electrons in a conductor.
  - **Interference:** Signals from other electronic devices or environmental factors.
  - **Crosstalk:** Unwanted transfer of signals between communication channels.
- **Example:**
  - Radio static due to atmospheric noise interfering with the transmission.


Transmitted
Noise
Received
Point 1
Transmission medium
Point 2

SIGNAL-TO-NOISE RATIO (SNR)AND SNR IN DECIBELS

To calculate the Signal-to-Noise Ratio (SNR) and SNR in decibels (SNRdB), you can use the following formulas:

1. **SNR** is given by the ratio of the signal power (P_s) to the noise power (P_n):

$$\text{SNR} = \frac{P_s}{P_n}$$

2. **SNR in dB** is calculated using:

$$\text{SNRdB} = 10 \log_{10} \left(\frac{P_s}{P_n} \right)$$

The power of a signal is 10 mW and the power of the noise is 1 μW; what are the values of SNR and SNR_{dB} ?

Solution:

The values of SNR and SNRdB can be calculated as follows:

Given:

- $P_s = 10\,\text{mW} = 10 \times 10^{-3}\,\text{W} = 0.01\,\text{W}$
- $P_n = 1\,\mu\text{W} = 1 \times 10^{-6}\,\text{W} = 0.000001\,\text{W}$

Step 1: Calculate SNR

$$\text{SNR} = \frac{0.01\,\text{W}}{0.000001\,\text{W}} = 10000$$

Step 2: Calculate SNRdB

$$\text{SNRdB} = 10\log_{10}(10000) = 10 \times 4 = 40\,\text{dB}$$

Results:

- **SNR** = 10,000
- **SNRdB** = 40 dB

The values of SNR and SNRdB for a noiseless channel are

$$\text{SNR} = \frac{\text{signal power}}{0} = \infty$$

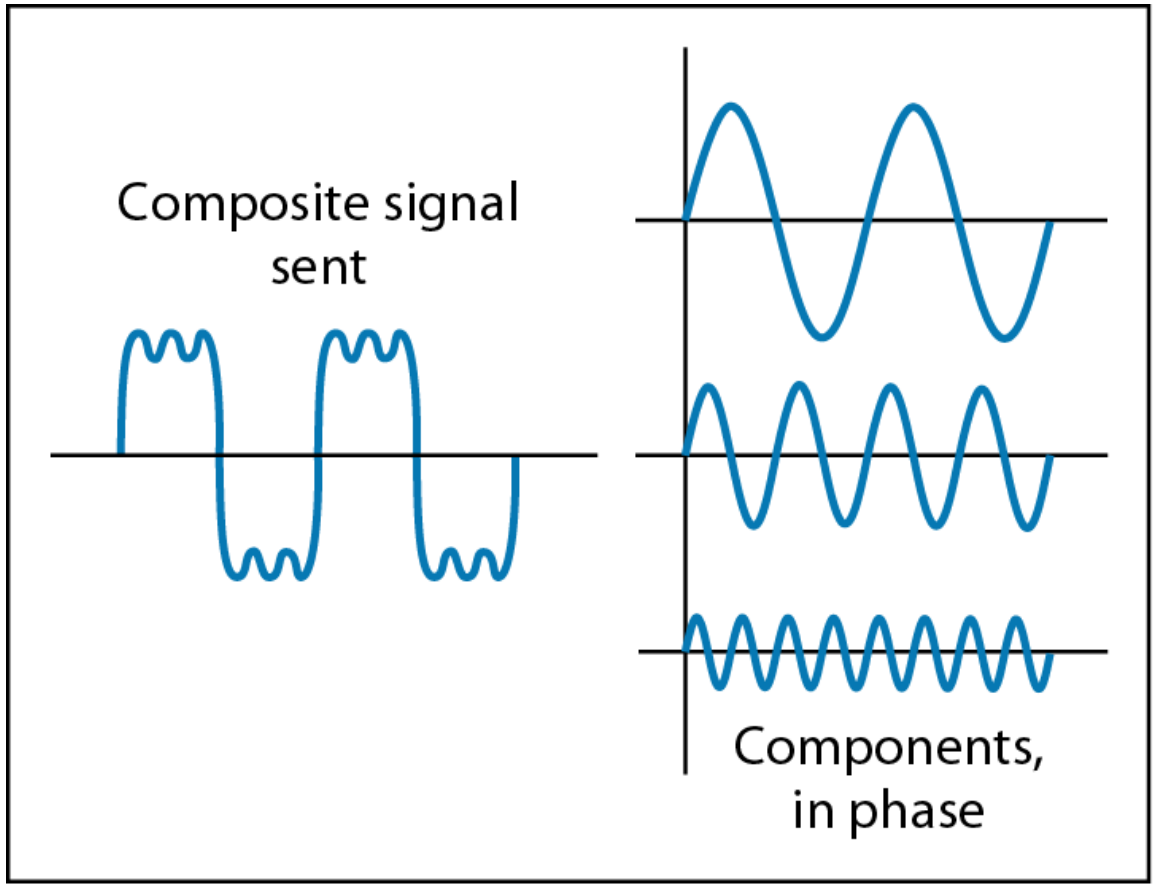
$$\text{SNR}_{\text{dB}} = 10 \log_{10} \infty = \infty$$

We can never achieve this ratio in real life; it is an ideal.

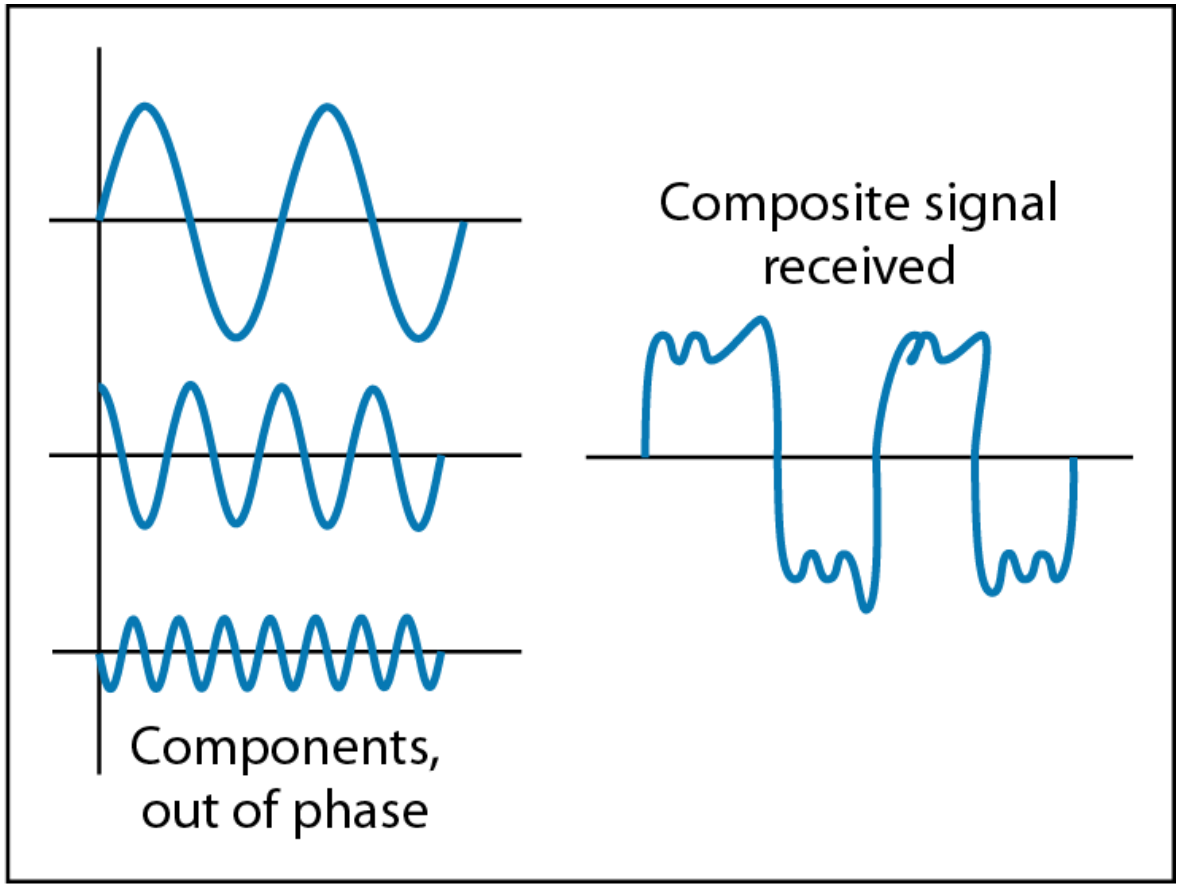
DISTORTION

- **Definition:**
  - Changes in the shape of the signal waveform during transmission.
- **Causes of Distortion:**
  - Variations in the transmission medium,different signal frequencies.
- **Example:**
  - A music signal may sound altered if higher frequencies are distorted.

DISTORTION



At the sender



At the receiver

EFFECTS OFTRANSMISSION IMPAIRMENT

- **Impact on Communication:**
  - Reduced clarity and quality of signals.
  - Increased error rates in data transmission.
- **Example:**
  - Data packets may be lost or corrupted,leading to retransmission in network communications.

REDUCING TRANSMISSION IMPAIRMENT

- **Techniques:**
  - **Amplification:** Boosting signal strength
  - **Shielding:** Protecting cables to reduce noise and interference.

  - **Example:**
  - Using fiber optic cables to minimize attenuation and improve data quality.

DATA RATE LIMITS

- A very important consideration in data communications is how fast we can send data, in bits per second, over a channel. Data rate depends on three factors:
- 1. The bandwidth available
- 2. The level of the signals we use
- 3. The quality of the channel (the level of noise)

- **Definition**:
  - A channel without any noise or interference,where the signal is transmitted perfectly.
- **Nyquist Bit Rate**:
  - Formula: $R = 2B \log_2(M)$
    - R: Maximum data rate (bps)
    - B: Bandwidth of the channel (Hz)
    - M: Number of discrete signal levels

Consider a noiseless channel with a bandwidth of 3000 Hz transmitting a signal with two signal levels.The maximum bit rate can be calculated as

To calculate the maximum bit rate of a noiseless channel, you can use the Nyquist formula:

$$R = 2B \log_2(L)$$

where:

- R is the maximum bit rate in bits per second (bps),
- B is the bandwidth of the channel in hertz (Hz),
- L is the number of signal levels.

Given:

- Bandwidth (B) = 3000 Hz,
- Number of signal levels (L) = 2.

Step 1: Calculate the maximum bit rate

$$R = 2 \times 3000 \times \log_2(2)$$

Since $\log_2(2) = 1$:

$$R = 2 \times 3000 \times 1 = 6000 \text{ bps}$$

Result:

The maximum bit rate is **6000 bps** (or 6 kbps).

Consider the same noiseless channel transmitting a signal with four signal levels (for each level, we send 2 bits). The maximum bit rate can be calculated as

Using the same Nyquist formula for the maximum bit rate in a noiseless channel:

$$R = 2B \log_2(L)$$

where:

- R is the maximum bit rate in bits per second (bps),
- B is the bandwidth of the channel in hertz (Hz),
- L is the number of signal levels.

Given:

- Bandwidth (B) = 3000 Hz,
- Number of signal levels (L) = 4.

Step 1: Calculate the maximum bit rate

$$R = 2 \times 3000 \times \log_2(4)$$

Since $\log_2(4) = 2$:

$$R = 2 \times 3000 \times 2 = 12000 \text{ bps}$$

Result:

The maximum bit rate is **12000 bps** (or 12 kbps).

- **Definition**:
  - A channel where noise can interfere with the signal,causing potential data loss or distortion.
    - Formula: $C = B \log_2(1 + \frac{S}{N})$
      - C: Channel capacity (bps)
      - B: Bandwidth of the channel (Hz)
      - S: Signal power
      - N: Noise power

PRACTICAL APPLICATION OF LIMITS

- **Nyquist Limit**:
  - Used in designing systems where noise is negligible (e.g., fiber optics).
- **Shannon Limit**:
  - Helps in determining the maximum capacity for systems like cellular networks, Wi-Fi, and satellite communications.

- Nyquist Example:
  - A channel with a bandwidth of 3 kHz and 2 signal levels would have a maximum data rate of:
    - $R = 2 \times 3000 \times \log_2(2) = 6000 \text{ bps}$
- Shannon Example:
  - A channel with a bandwidth of 3 kHz, signal power of 10 mW, and noise power of 1 mW:
    - $C = 3000 \log_2(1 + \frac{10}{1}) \approx 3000 \log_2(11) \approx 3000 \times 3.459 = 10377 \text{ bps}$

Thank you!