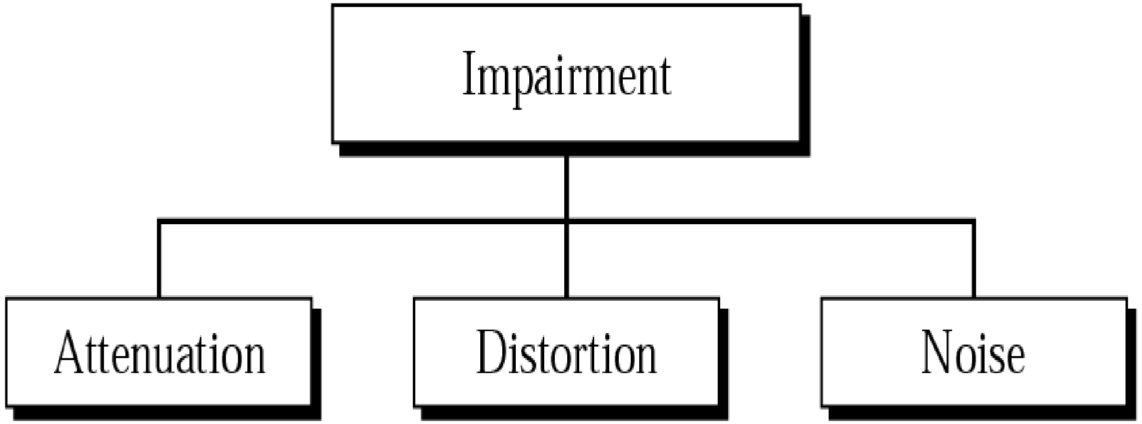
Transmission Impairments

- Signals travel through transmission media, which are not perfect.
- The imperfection causes signal impairment.
- This means that the signal at the beginning of the medium is not the same as the signal at the end of the medium.
- What is sent is not what is received.
- Consequences:
  - For analog signals: degradation of signal quality
  - For digital signals: bit errors

- Three causes of impairment are attenuation, distortion, and noise.



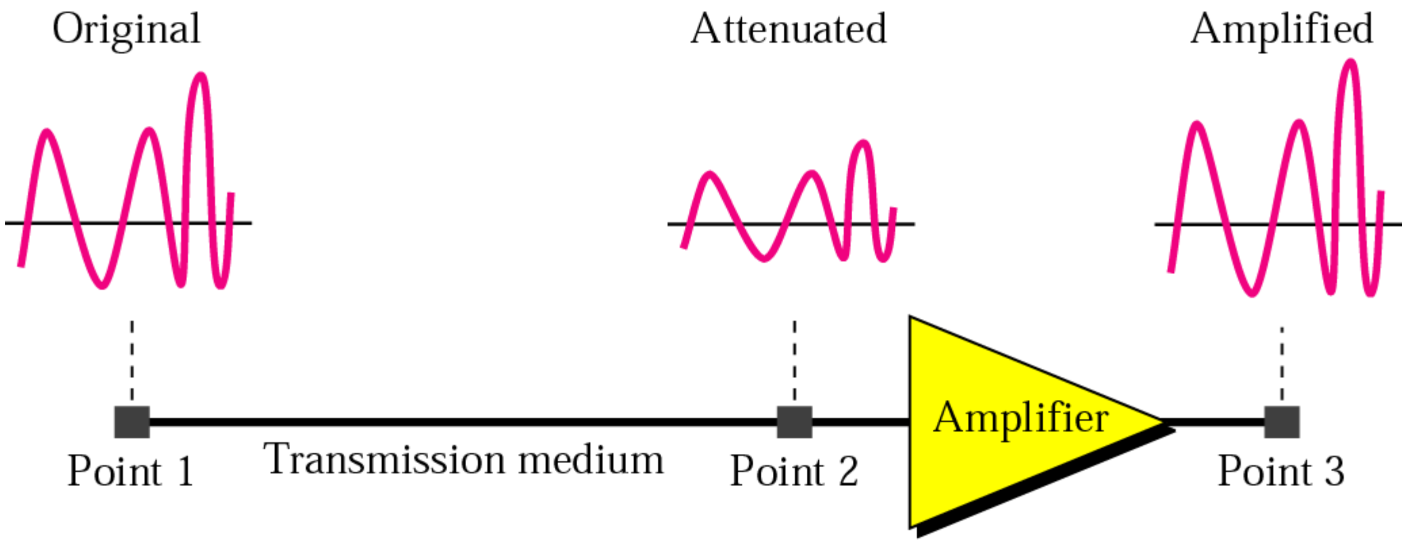
Attenuation

- Attenuation means a loss of energy. Signal strength falls off with distance.
- When a signal, simple or composite, travels through a medium, it loses some of its energy in overcoming the resistance of the medium. That is why a wire carrying electric signals gets warm, if not hot, after a while.
- Some of the electrical energy in the signal is converted to heat.
- Depends on medium
  - For guided media, the attenuation is generally exponential and thus is typically expressed as a constant number of decibels per unit distance.
  - For unguided media, attenuation is a more complex function of distance and the makeup of the atmosphere.

A received signal must have sufficient strength so that the electronic circuitry in the receiver can detect the signal.

- The signal must maintain a level sufficiently higher than noise to be received without error.
- These two problems are dealt with by the use of amplifiers or repeaters.

- Figure shows the effect of attenuation and amplification.



Decibel

To show that a signal has lost or gained strength, engineers use the unit of the decibel.

- The decibel (dB) measures the relative strengths of two signals or one signal at two different points.

$$A_{db} = 10 \log_{10} \frac{P_2}{P_1}$$

- Variables P1 and P2 are the powers of a signal at points 1 and 2, respectively.
- The decibel is negative if a signal is attenuated and positive if a signal is amplified.
- Decibel in terms of voltage instead of power.
- Power is proportional to the square of the voltage

the formula is

$$A_{db} = 20 \log_{10} \frac{V_2}{V_1}$$

- Imagine a signal travels through a transmission medium and its power is reduced to half.
- This means that P2 = 1/2P1.
- In this case, the attenuation (loss of power) can be calculated as
- $10 \log_{10} (P2/P1) = 10 \log_{10} 0.5P1/P1)$

$$= 10 \log_{10} (0.5)$$

$$= 10(–0.3)$$

$$= –3 \text{ dB}$$

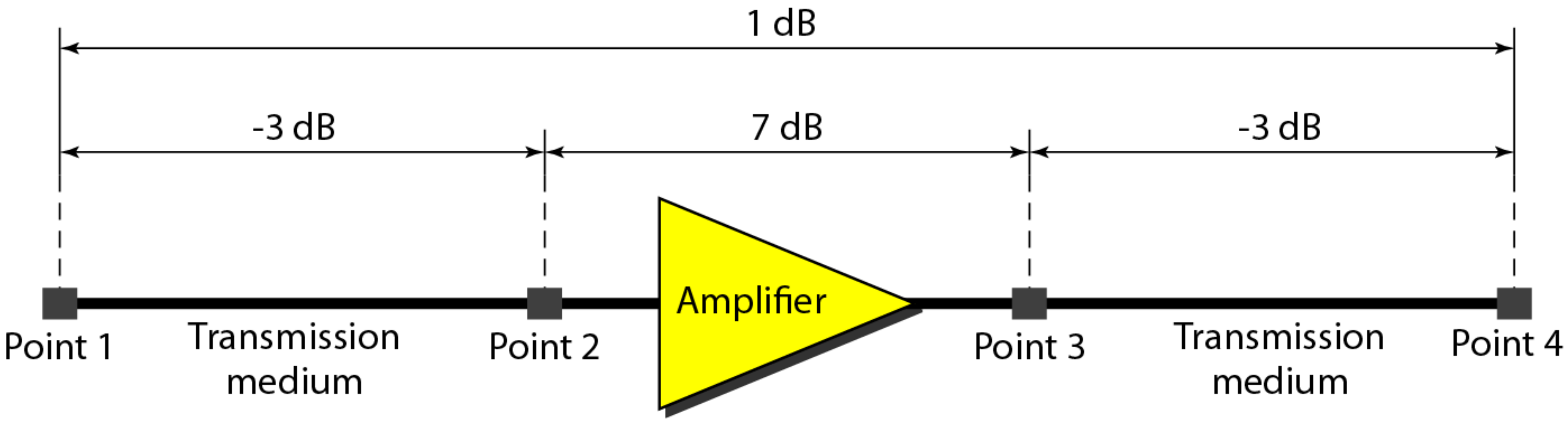
A loss of 3 dB (–3 dB) is equivalent to losing one-half the power.

- A signal travels through an amplifier, and its power is increased 10 times. This means that P2 = 10P1 . In this case, the amplification (gain of power) can be calculated as

$$10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} \frac{10P_1}{P_1}$$

$$= 10 \log_{10} 10 = 10(1) = 10 \text{ dB}$$

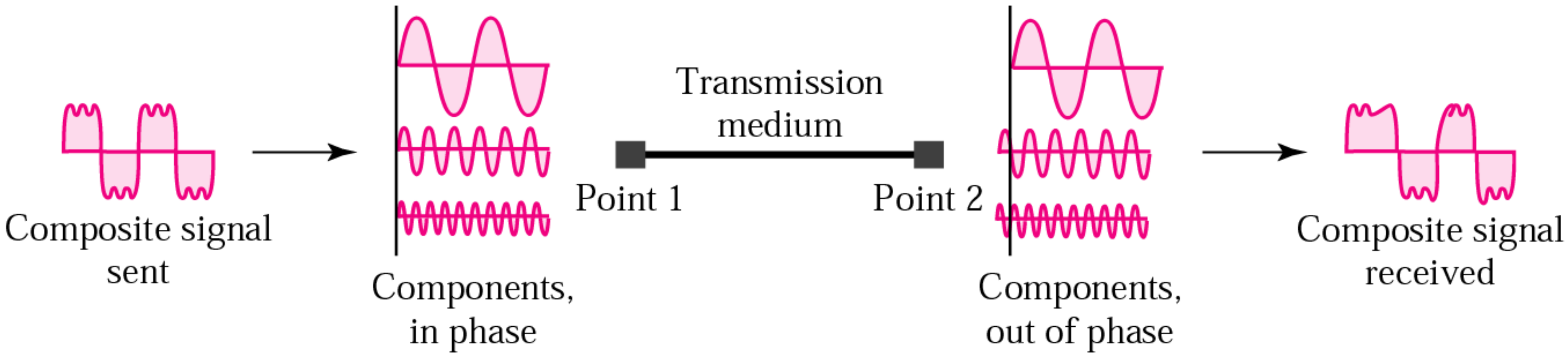
- One reason that engineers use the decibel to measure the changes in the strength of a signal is that decibel numbers can be added (or subtracted) when we are measuring several points (cascading) instead of just two.
- In Figure a signal travels from point 1 to point 4. The signal is attenuated by the time it reaches point 2. Between points 2 and 3, the signal is amplified. Again, between points 3 and 4, the signal is attenuated. We can find the resultant decibel value for the signal just by adding the decibel measurements between each set of points.


1 dB
-3 dB
7 dB
-3 dB
Amplifier
Point 1
Transmission medium
Point 2
Point 3
Transmission medium
Point 4

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 through a medium and therefore, its own delay in arriving at the final destination.
- Differences in delay may create a difference in phase if the delay is not exactly the same as the period duration.
- In other words, signal components at the receiver have phases different from what they had at the sender.
- The shape of the composite signal is therefore not the same.

Figure shows the effect of distortion on a composite signal.



- **Attenuation Distortion**

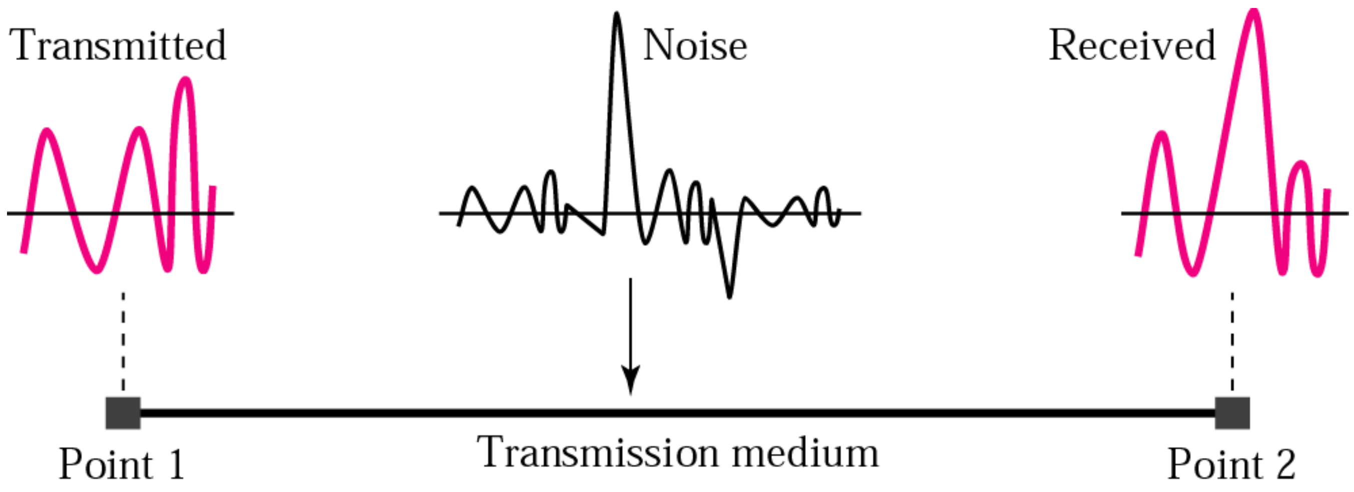
- Attenuation is often an increasing function of frequency. This leads to attenuation distortion: some frequency components are attenuated more than other frequency components.
- Attenuation distortion is particularly noticeable for analog signals: the attenuation varies as a function of frequency, therefore the received signal is distorted, reducing intelligibility.

- **Phase distortion**
- Delay distortion occurs because the velocity of propagation of a signal through a guided medium varies with frequency. Various frequency components of a signal will arrive at the receiver at different times, resulting in phase shifts between the different frequencies.
- Delay distortion is particularly critical for digital data
  Some of the signal components of one bit position will spill over into other bit positions, causing intersymbol interference, which is a major limitation to maximum bit rate over a transmission channel.

Noise

- Noise is another cause of impairment.
- For any data transmission event, the received signal will consist of the transmitted signal, modified by the various distortions imposed by the transmission system, plus additional unwanted signals that are inserted somewhere between transmission and reception.
- The undesired signals are referred to as noise, which is the major limiting factor in communications system performance.

Figure shows the effect of noise on a signal.



Categories of noise that corrupt the signal **:**

- Thermal noise
- Intermodulation noise
- Induced noise
- Crosstalk
- Impulse noise

Thermal noise (or white noise)

- Thermal noise is the random motion of electrons in a wire which creates an extra signal not originally sent by the transmitter. (Due to thermal agitation of electrons)
- It is present in all electronic devices and transmission media, and is a function of temperature.
- Cannot be eliminated, and therefore places an upper bound on communications system performance.

Intermodulation noise

- When signals at different frequencies share the same transmission medium, the result may be intermodulation noise.
- Signals at a frequency that is the sum or difference of original frequencies or multiples of those frequencies will be produced. E.g., the mixing of signals at f1 and f2 might produce energy at frequency f1 + f2. This derived signal could interfere with an intended signal at the frequency f1 + f2.

- **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.
- It is an unwanted coupling between signal paths. It can occur by electrical coupling between nearby twisted pairs. Typically, crosstalk is of the same order of magnitude as, or less than, thermal noise.

- **Impulse noise** is non-continuous, consisting of irregular pulses or noise spikes of short duration and of relatively high amplitude.
- It is a spike (a signal with high energy in a very short time)
- It is generated from a variety of cause, e.g., external electromagnetic disturbances such as lightning.
- It is generally only a minor annoyance for analog data.
- But it is the primary source of error in digital data communication.

LEVEL

- Level means Signal Magnitude, level could be comparative. The output of an amplifier is 20 dB higher than the input. In telephony it is measured in dBm (decibel referenced to 1 mW), in wireless system it is dBW (decibel referenced to 12 watts), in video systems the unit measure is voltage
- In telecommunication network, if level is too high, amplifiers become overloaded and other types distortion can occur. If the level are too low, customer satisfaction may suffer with a degrades loudness rating.
- System level is important parameter for engineering telecommunication system.
- dBm = dBm0 + dBr Where, dBr – decibels “reference”

Signal to Noise Ratio (SNR)

- The signal-to-noise ratio is defined as

$$\text{SNR} = \frac{\text{Average signal power}}{\text{Average noise power}}$$

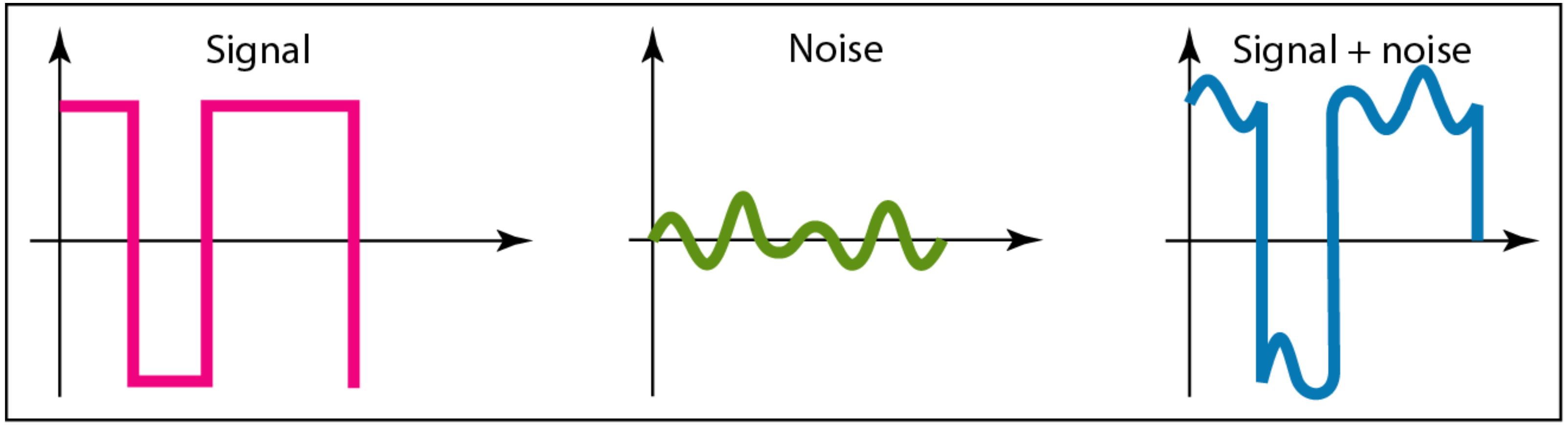
- We need to consider the average signal power and the average noise power because these may change with time.
- SNR is actually the ratio of what is wanted (signal) to what is not wanted (noise).
- A high SNR means the signal is less corrupted by noise; a low SNR means the signal is more corrupted by noise.
- Because SNR is the ratio of two powers, it is often described in decibel units,
- SNR dB, is defined as

$$\text{SNR}_{db} = 10 \log_{10} \text{SNR}$$

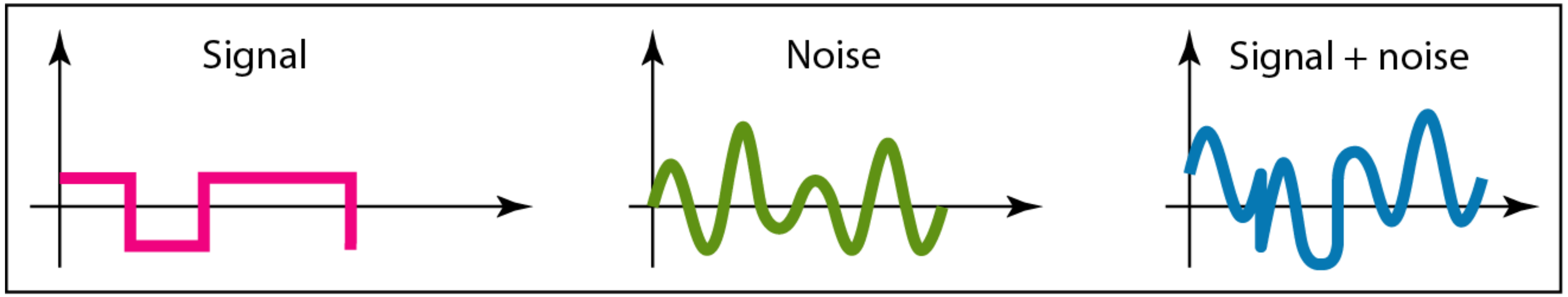
Signal to Noise Ratio (SNR)

- SNR ratio expresses in decibel the amount by which a signal level exceeds the noise within a specified bandwidth.
- The types of material to be transmitted, minimum SNR to satisfy the customer and make the receiving instrument function within certain specified criteria.
- **The following SNR with the corresponding and instrument** voice : 40 dB based on customer satisfaction voice : 45 dB
- data : ~ 15 dB, based on a specified error rate and modulation type.
- (S/N)dB = level (signal in dBm) – level (noise in dBm)

Two cases of SNR: a high SNR and a low SNR



a. Large SNR



b. Small SNR

- 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.