Chapter 3

Data and Signals

3-4 TRANSMISSION IMPAIRMENT

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

Topics discussed in this section:

- **Attenuation**
- **Distortion**
- **Noise**

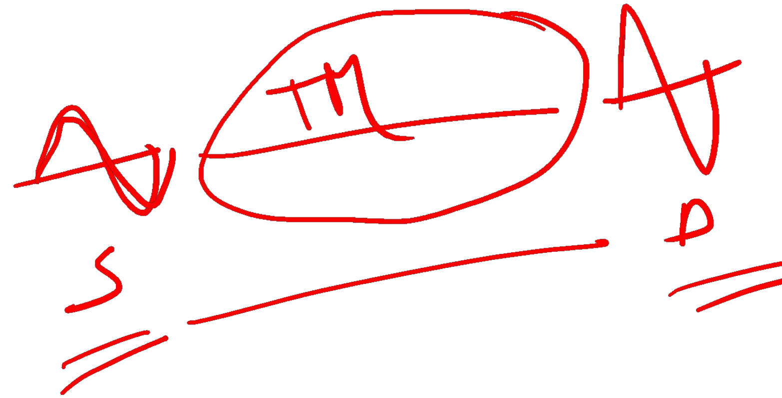
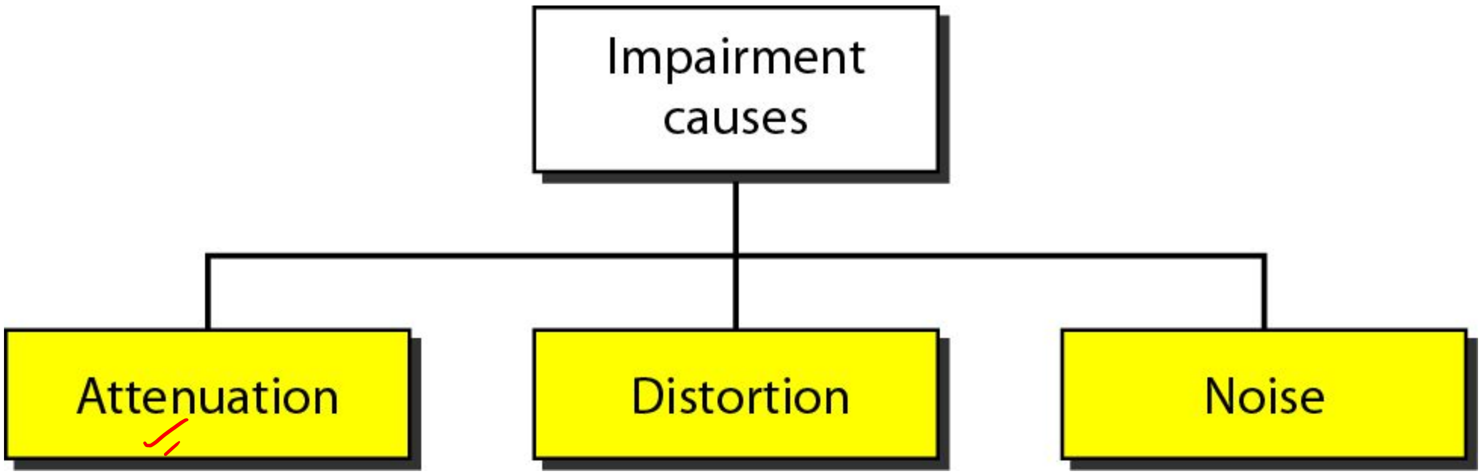


Figure 3.25 *Causes of impairment*



3.4

Attenuation

- Means loss of energy -> weaker signal
- When a signal travels through a medium it loses energy overcoming the resistance of the medium
- Amplifiers are used to compensate for this loss of energy by amplifying the signal.

Measurement of Attenuation

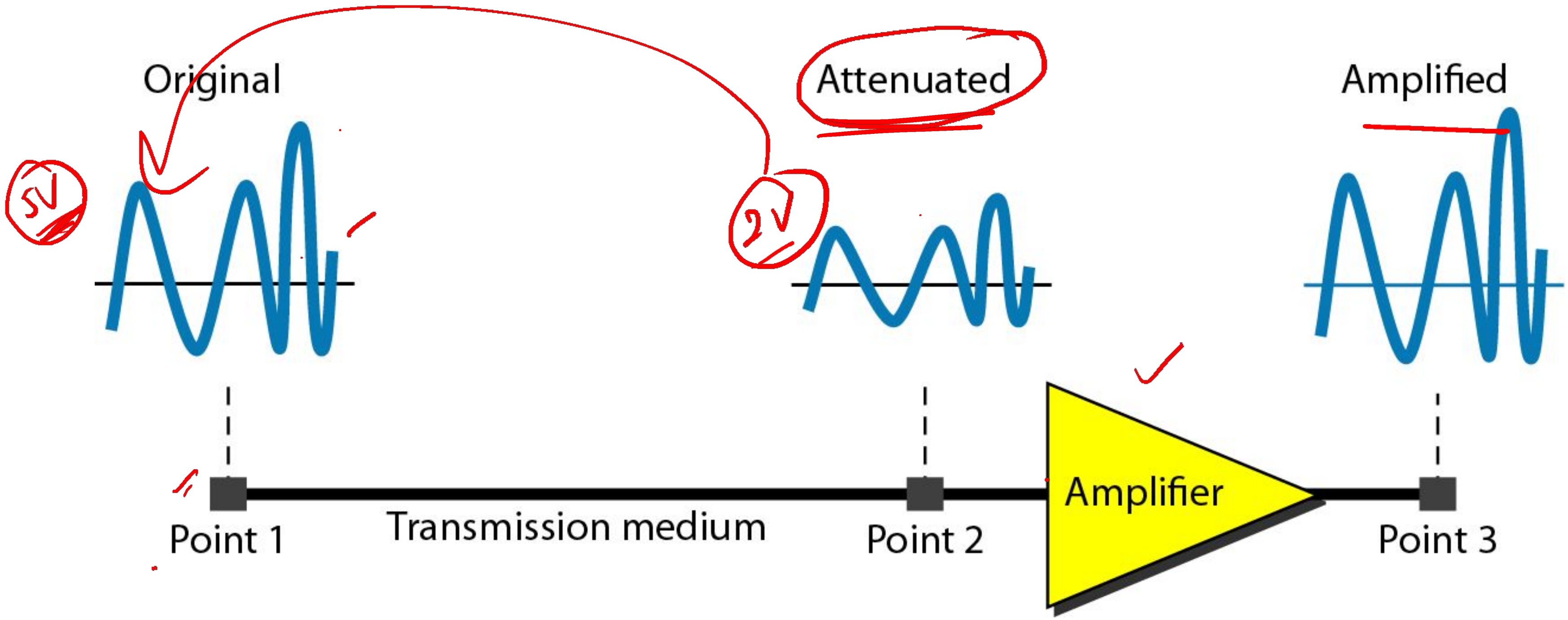
- To show the loss or gain of energy the unit "decibel" is used.

$$dB = 10\log_{10} P_2/P_1$$

P_1 - input signal

P_2 - output signal

Figure 3.26 *Attenuation*



Example 3.26

$P_2 = 1/2 P_1$

Suppose a signal travels through a transmission medium and its power is reduced to one-half. This means that P_2 is (1/2)P_1. In this case, the attenuation (loss of power) can be calculated as

$$10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} \frac{0.5 P_1}{P_1} = 10 \log_{10} 0.5 = 10(-0.3) = -3 \text{ dB}$$

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

Example 3.27

A signal travels through an amplifier, and its power is increased 10 times. This means that $P_2 = 10P_1$. In this case, the amplification (gain of power) can be calculated as

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

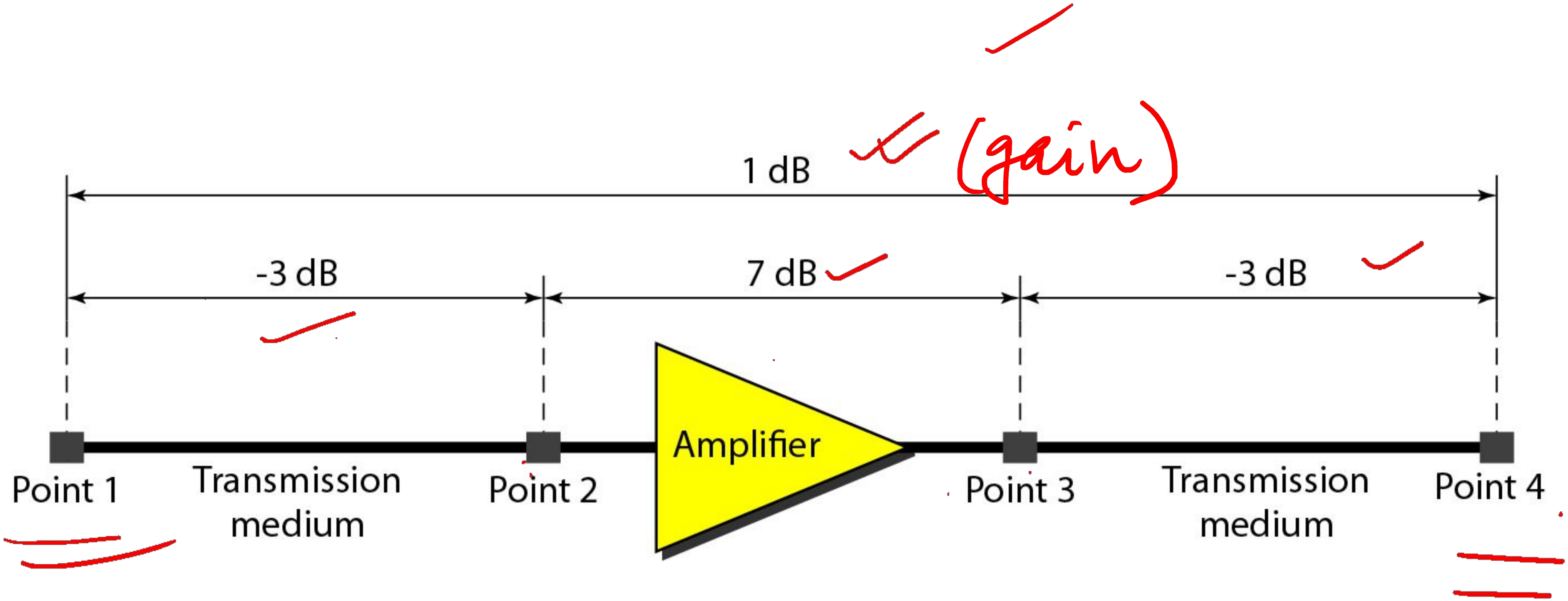
$$= 10 \log_{10} 10 = 10(1) = 10 \text{ dB}$$

Example 3.28

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

$$\boxed{\mathrm{dB} = -3 + 7 - 3 = +1}$$

Figure 3.27 *Decibels for Example 3.28*



Example 3.29

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 log10 P$_m$, where P$_m$ is the power in milliwatts. Calculate the power of a signal with dB$_m$ = −30.

$10\log_{10} P_m = -30$

$\log_{10} P_m = -3$

$P_m = 10^{-3}$ mW

Solution

We can calculate the power in the signal as

$$\mathrm{dB_m} = 10\log_{10} P_m = -30$$

$$\log_{10} P_m = -3 \qquad P_m = 10^{-3}\ \mathrm{mW}$$

Example 3.30

1 km → −0.3 dB → −1.5 dB
5 km → −0.3×5 → −1.5
$10 \log_{10} \frac{P_2}{P_1} = -1.5$
$\log_{10} \frac{P_2}{P_1} = -0.15$
$\frac{P_2}{P_1} = 10^{-0.15}$
$\frac{P_2}{P_1} = 0.71$

The loss in a cable is usually defined in decibels per kilometer (dB/km). If the signal at the beginning of a cable with −0.3 dB/km has a power of 2 mW, what is the power of the signal at 5 km?

$P_1 = 2$ mW

d

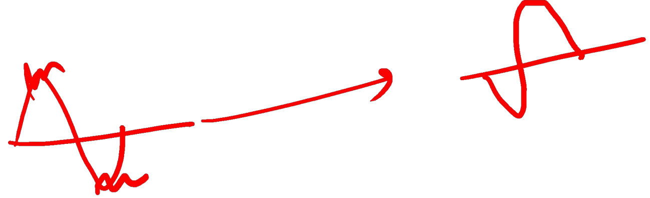
Solution

The loss in the cable in decibels is 5 × (−0.3) = −1.5 dB. We can calculate the power as

$$\text{dB} = 10 \log_{10} \frac{P_2}{P_1} = -1.5$$

$$\frac{P_2}{P_1} = 10^{-0.15} = 0.71$$

$$P_2 = 0.71 P_1 = 0.7 \times 2 = 1.4 \text{ mW}$$

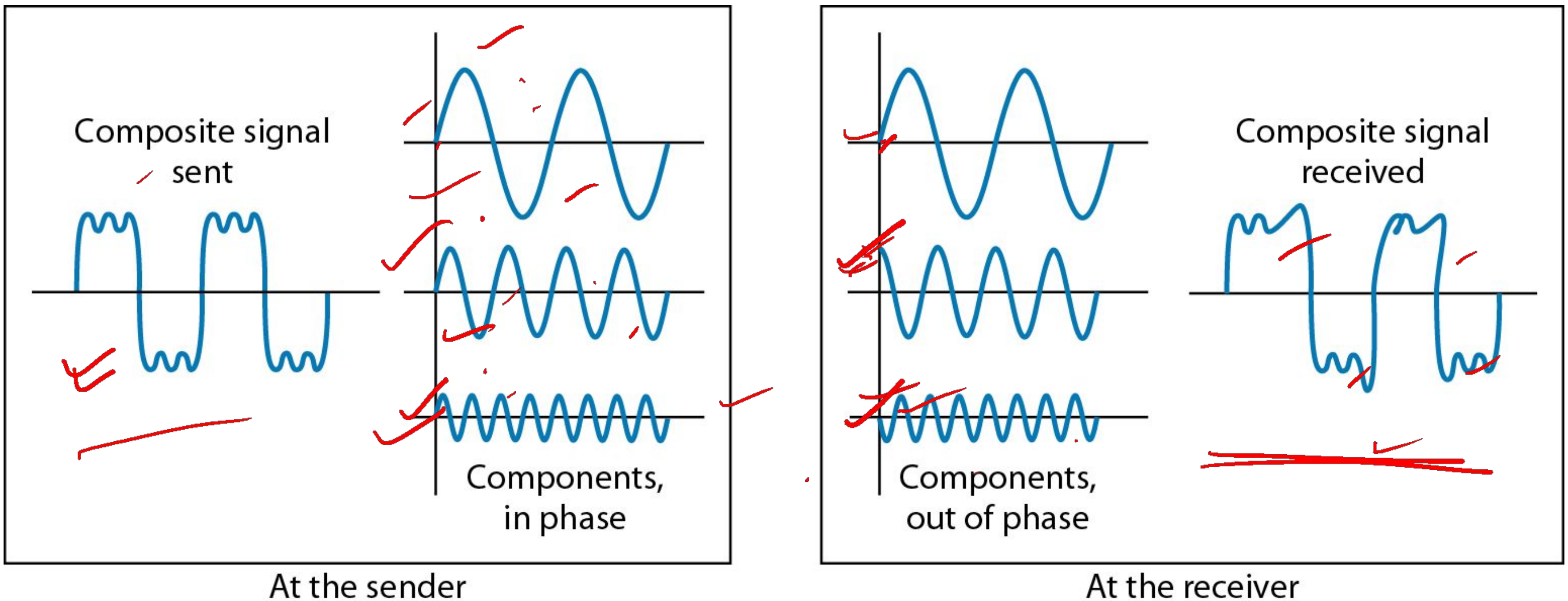


Distortion

Combo of various sine signals

- Means that the signal changes its form or shape
- Distortion occurs in composite signals
- Each frequency component has its own propagation speed traveling through a medium.
- The different components therefore arrive with different delays at the receiver.
- That means that the signals have different phases at the receiver than they did at the source.

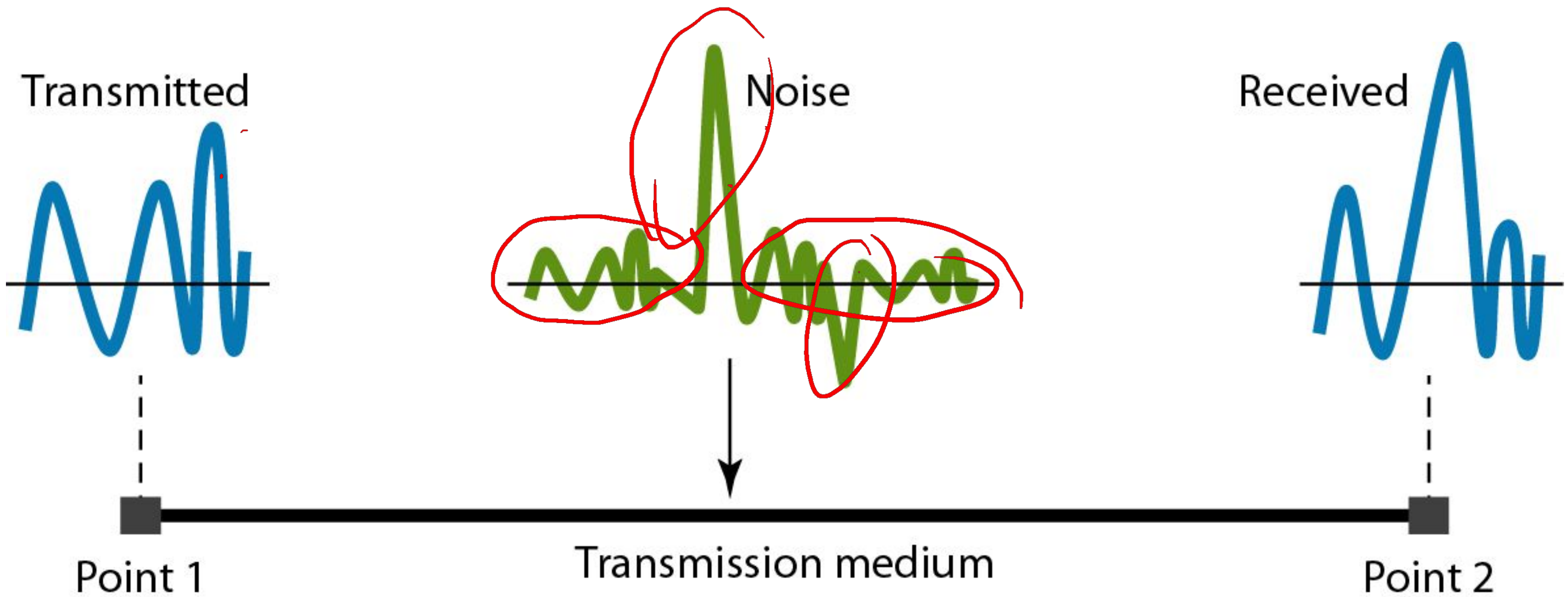
Figure 3.28 *Distortion*



Noise

- There are different types of noise
  - Thermal - random noise of electrons in the wire creates an extra signal
  - Induced - from motors and appliances, devices act are transmitter antenna and medium as receiving antenna.
  - Crosstalk - same as above but between two wires.
  - Impulse - Spikes that result from power lines, lighning, etc.

Figure 3.29 *Noise*



Signal to Noise Ratio (SNR)

- To measure the quality of a system the SNR is often used. It indicates the strength of the signal wrt the noise power in the system.
- It is the ratio between two powers.
- It is usually given in dB and referred to as $SNR_{dB.}$

$$SNR = \frac{P_S}{P_N}$$

Example 3.31

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 SNR$_{dB}$ can be calculated as follows:

$$\mathrm{SNR} = \frac{10{,}000\ \mu\mathrm{W}}{1\ \mathrm{mW}} = 10{,}000$$

$$\mathrm{SNR_{dB}} = 10 \log_{10} 10{,}000 = 10 \log_{10} 10^4 = 40 \text{ dB}$$

$$\frac{10\times10^{-3}\ \mathrm{W}}{1\times10^{-6}}$$

$$10\times10^{6}\times10^{-3}$$

$$10 \log_{10} (10\times10^{3})$$

$$40$$

Example 3.32

$SNR = \frac{S}{N} = \frac{S}{0} = \infty$

The values of SNR and SNR$_{dB}$ for a noiseless channel are

$SNR = \frac{S}{N} = \frac{S}{0}$

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

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

$= \infty$

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

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

Figure 3.30 *Two cases of SNR: a high SNR and a low SNR*