Carrying Out God's
Dominion Through IoT

CALVIN
INSTITUTE OF TECHNOLOGY

Computer Networks

(IEE 3112 & IBDA2022 – Jaringan Komputer)

Lecture #06 -- PHYSICAL Layer

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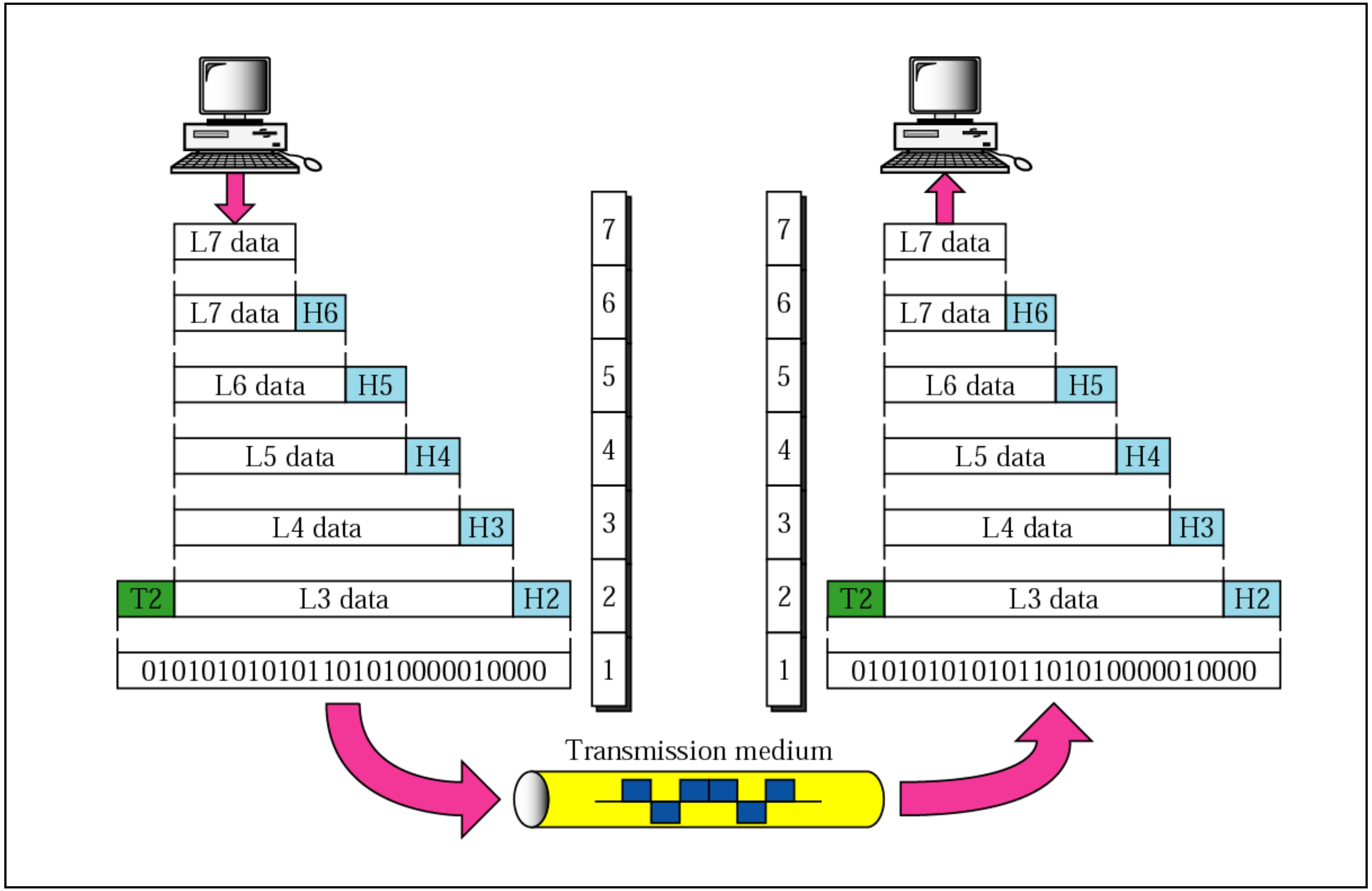
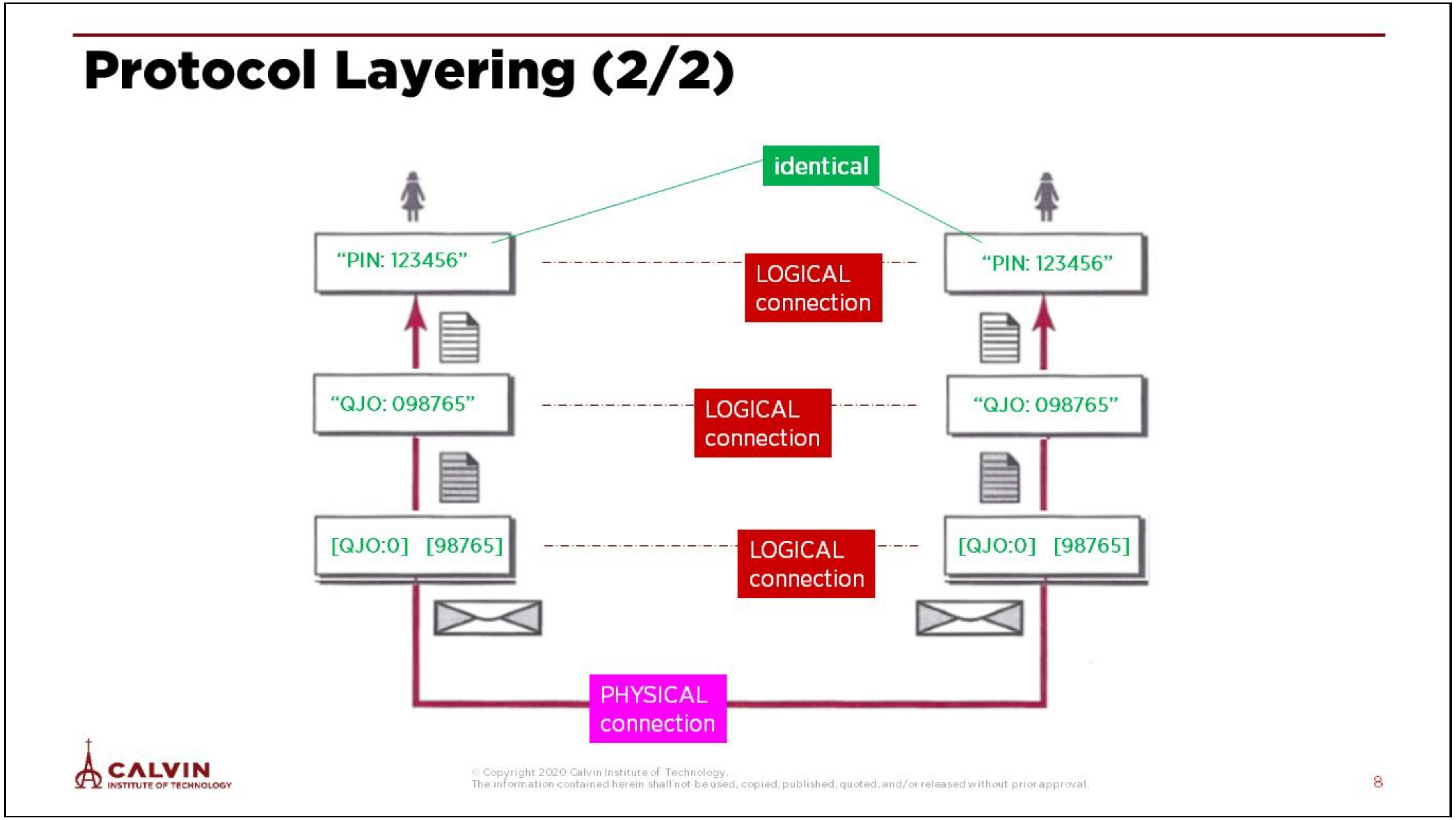
@eaFEB25

REVIEW

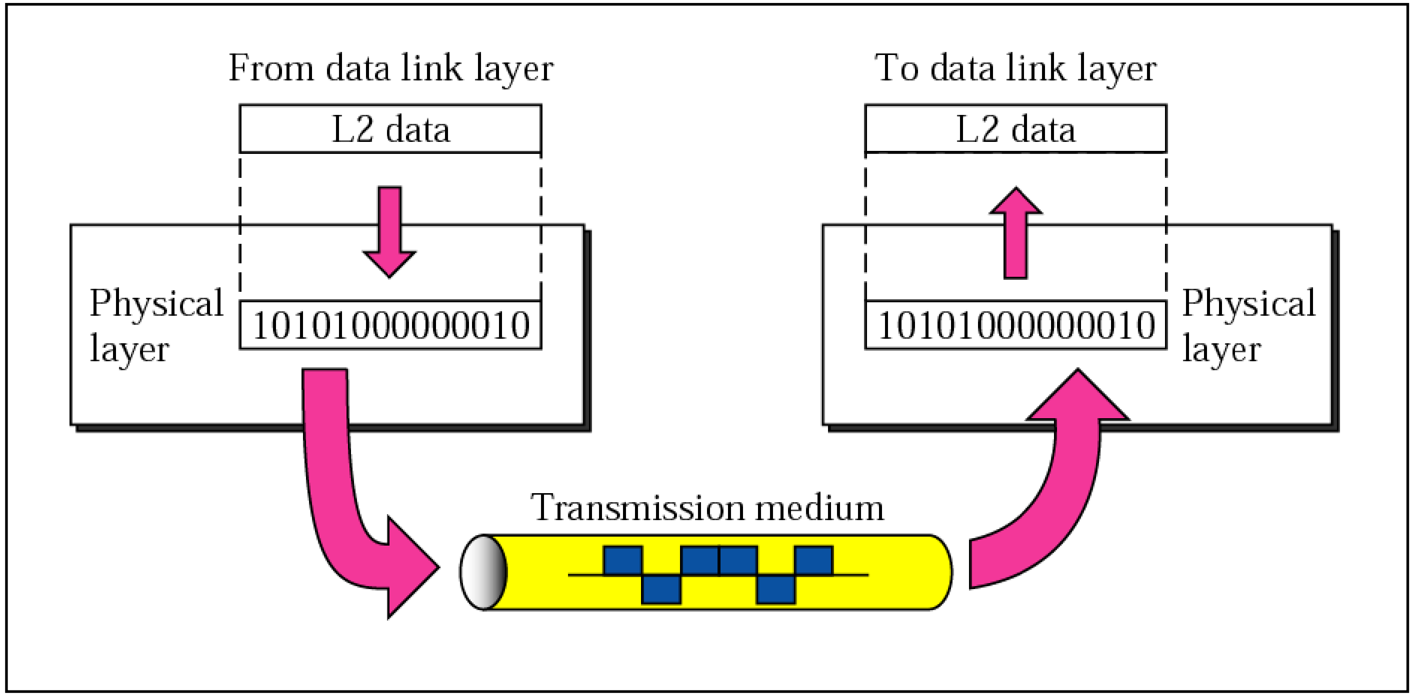
Review (1/3): Data Communication

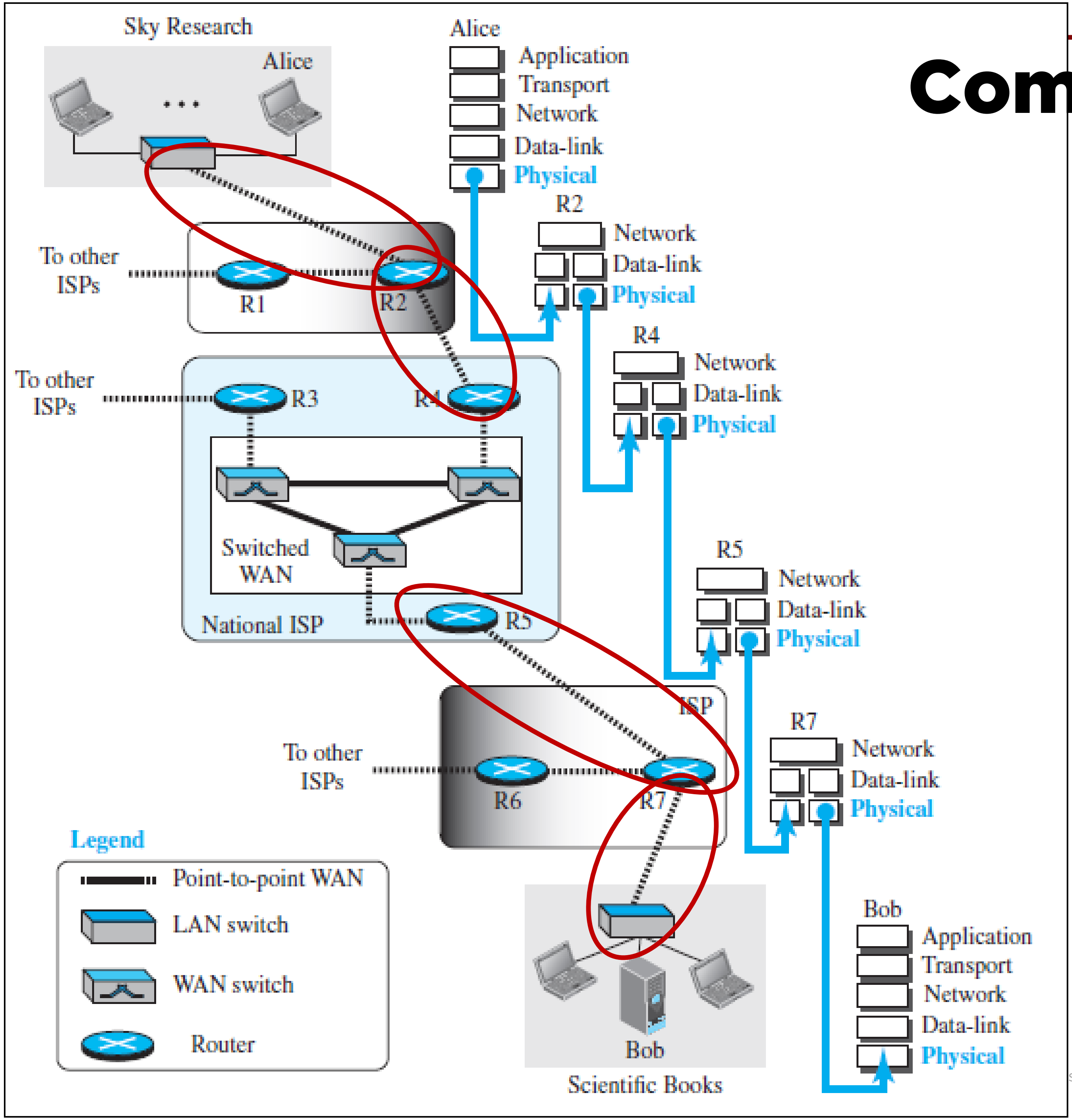


Review (2/3): Physical/Logical Connection



Review (3/3): PHYSICAL Layer





Comm. at Physical Layer

- Communication at application, transport, network, or data-link is logical; communication at the physical layer is physical.

- We have host-to-router, router-to-router, and router-to-host communications.

- Alice and Bob need to exchange data, but communication at the Physical Layer means also exchanging signals.
  - Data need to be transmitted and received, but the media have to change data to signals.

DATA & SIGNAL

Data

- ❑ Data can be categorized as analog and digital.

- ❑ The term analog refers to information that takes continuous values, while digital refers to information that has discrete states / values.

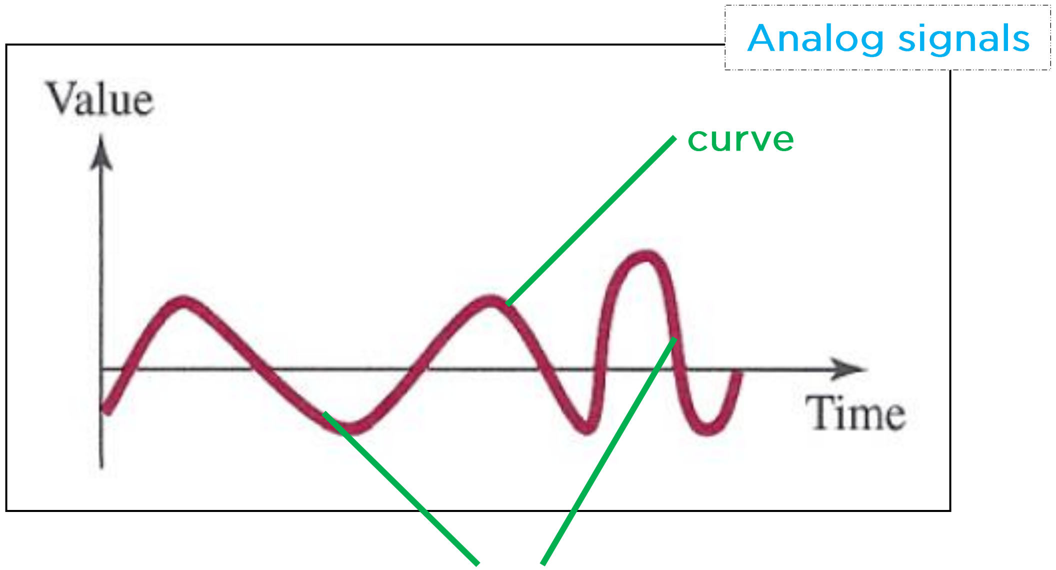
NOW . . .

- ❑ One of the big ideas behind today's technology world is that much of the world's natural phenomena (analog) can be translated into digital data.
- ❑ New technologies may "blur" the line between analog data and digital data. However, the essential nature of analog data will always be the standard on which digital conversions are based.
- ❑ Digital data is powerful enough to simulate and render analog data, BUT it is extremely limited in its ability to comprehensively recreate analog data!

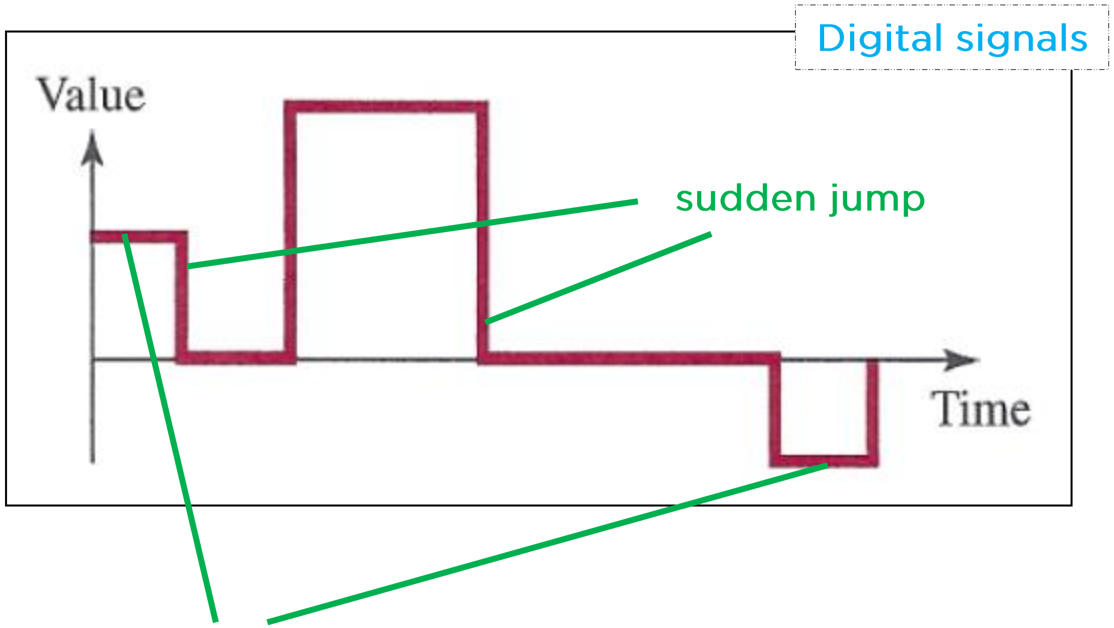
Signals

- To transfer data electronically, it must first be converted into electromagnetic signals, thus SIGNALS is used to transfer DATA from one party to another.

- Similar to data, SIGNAL can be either analog or digital in nature.



The curve representing the analog signal passes through an infinite number of points.



Limited level of values

Note
The simplest form of digital signals has value as “1” and “0”.

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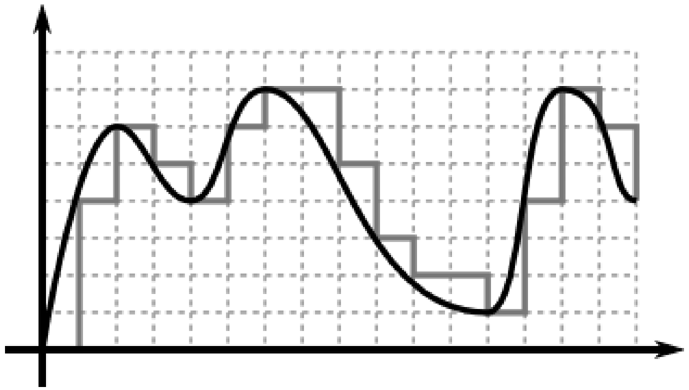
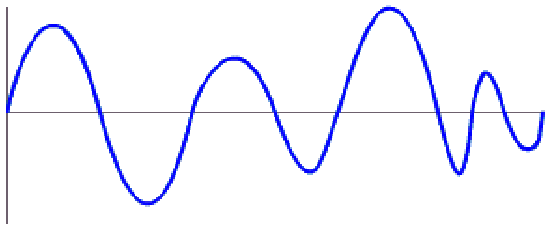
Periodic & Non-periodic

- Both analog and digital signals can take one of two forms: periodic or non-periodic.

- A periodic signal completes and repeats a pattern within a measurable time frame, called a period. The completion of one full pattern is called a cycle.

- A non-periodic signal changes without exhibiting a pattern or cycle that repeats over time.





Note:
In data communications, we commonly use *periodic analog signals* and *non-periodic digital signals*.

ANALOG SIGNAL
(sine)

Sine Wave (1/3)

- Sine wave is the most simple (and fundamental) analog signals; while a so-called composite analog signal consists of multiple sine waves.

- In basic math form, it is a function of time (t), and described as:

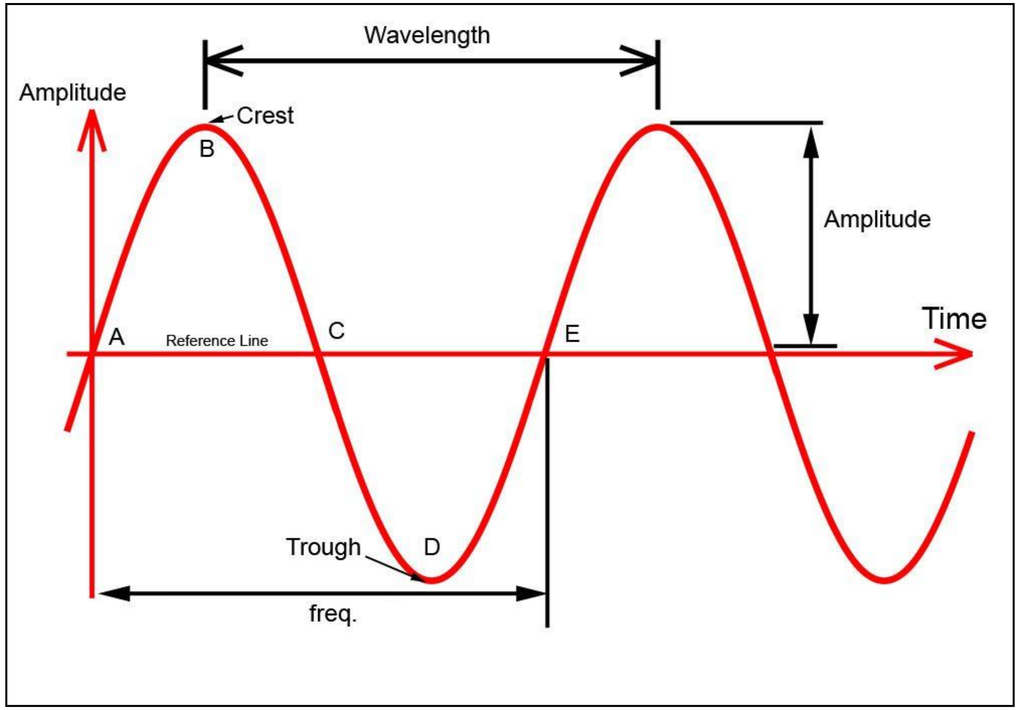
$$\boxed{y(t) = A\sin(2\pi f t + \theta)}$$

AMPLITUDE

FREQUENCY (Hz)

PHASE (rad)

- A sine wave is fully described by three parameters, so called the **amplitude**, the **frequency**, and the **phase**.



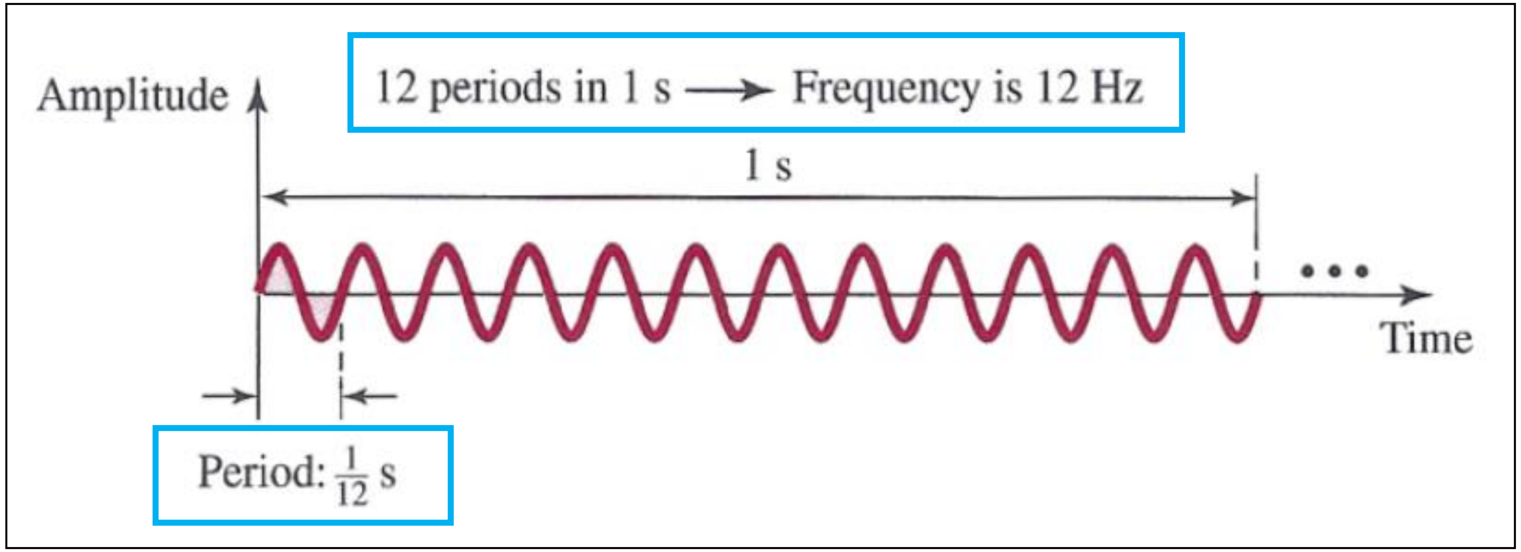
Sine Wave (2/3)

Amplitude

The peak amplitude of a signal is the absolute value of its highest intensity, proportional to the energy it carries.

Frequency & Period

The amount of time a signal needs to complete *one* cycle is called *one* ***period***, while ***frequency*** refers to the number of periods in *one* second.



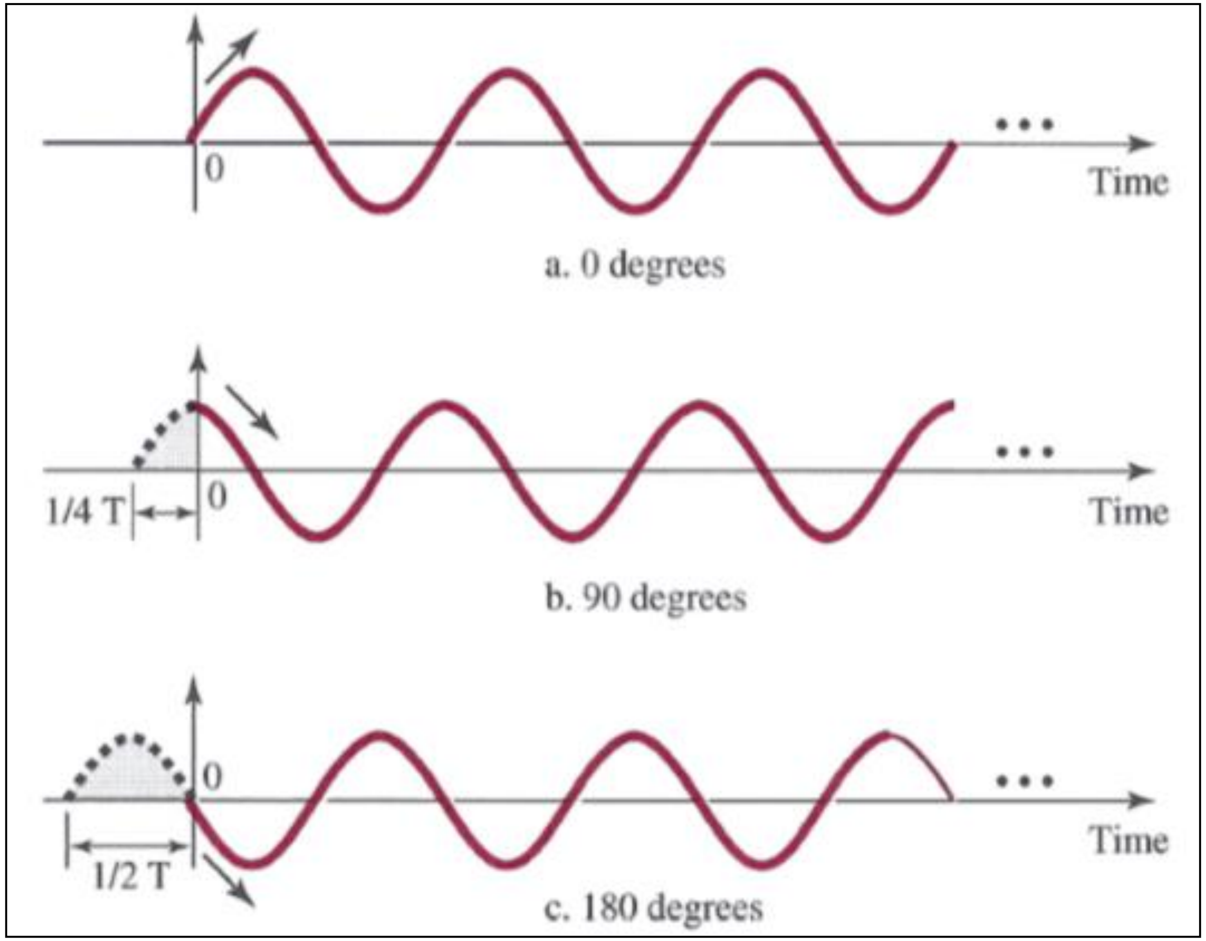
Sine Wave (3/3)

Phase

- Describes the position of the waveform relative to time zero ($t = 0$).

- Phase is measured in degrees or radians [360° is 2π rad; 1 rad is $\frac{360}{2\pi}$].

- So . .
    - a phase shift of 360° corresponds to a shift of a complete period;
    - a phase shift of 180° corresponds to a shift of one-half of a period;
    - a phase shift of 90° corresponds to a shift of one-quarter of a period



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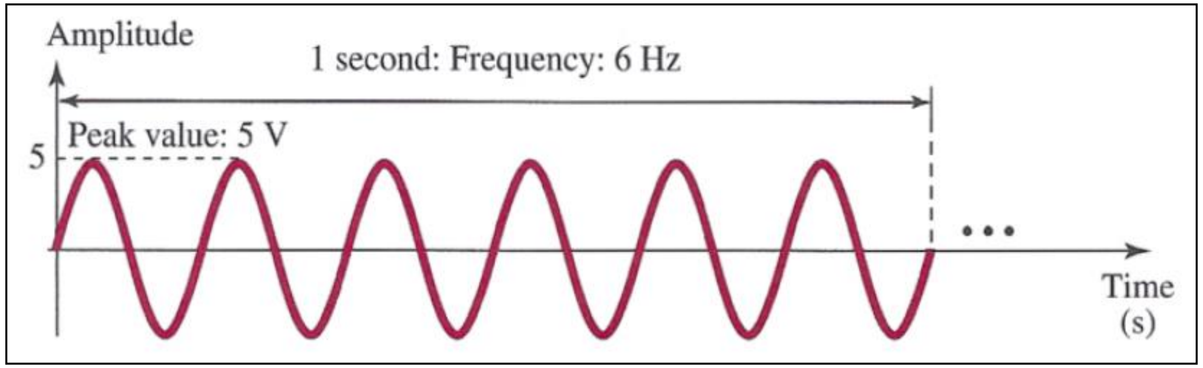
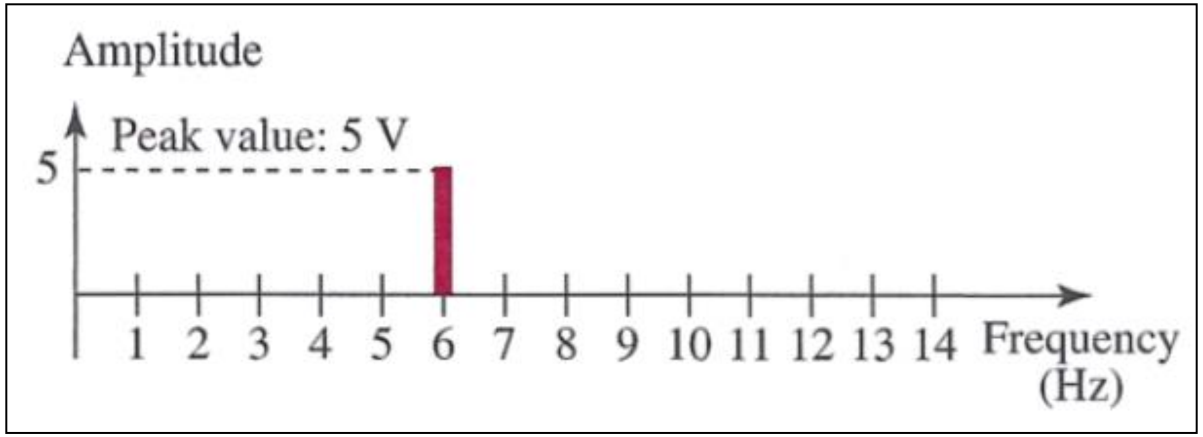
Time vs. Frequency Domain (1/2)

- A sine wave is comprehensively defined by its amplitude, frequency, and phase in a time-domain plot.
- In details, it shows changes in signal amplitude with respect to time (phase is not clearly shown)

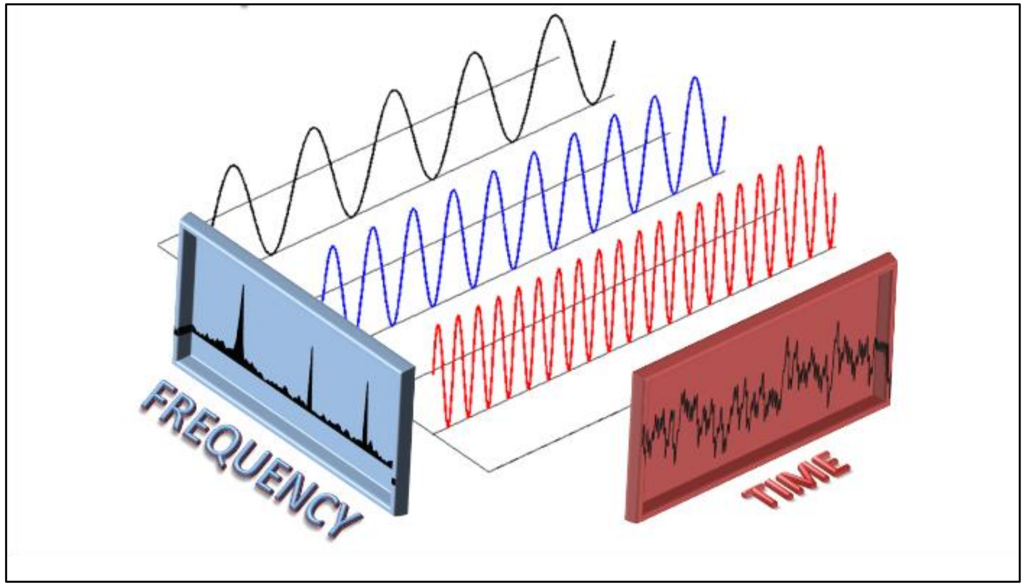


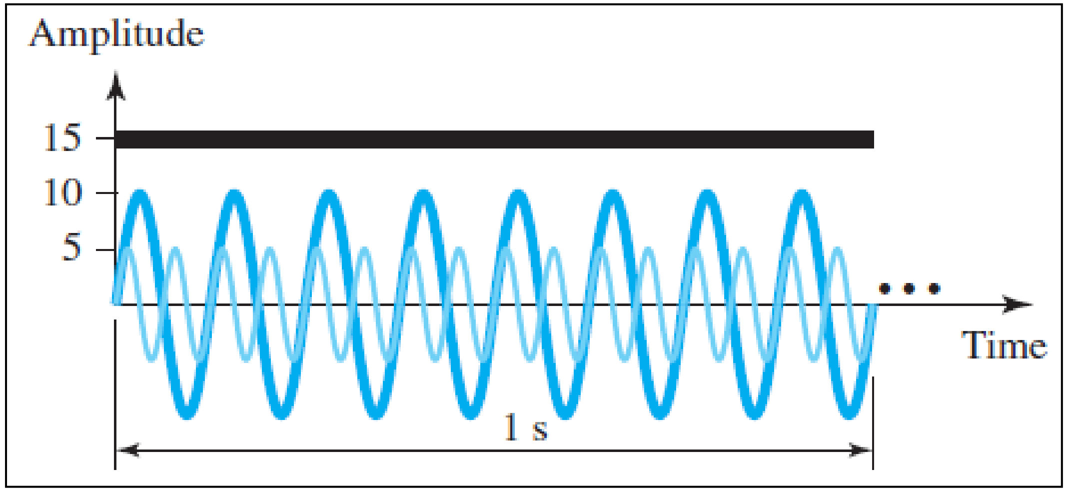
- For a relationship between amplitude and frequency, a *frequency-domain* plot is generally used, which only concern with the peak value (amplitude) and the frequency.
- Here, the changes of amplitude during one period are not shown.

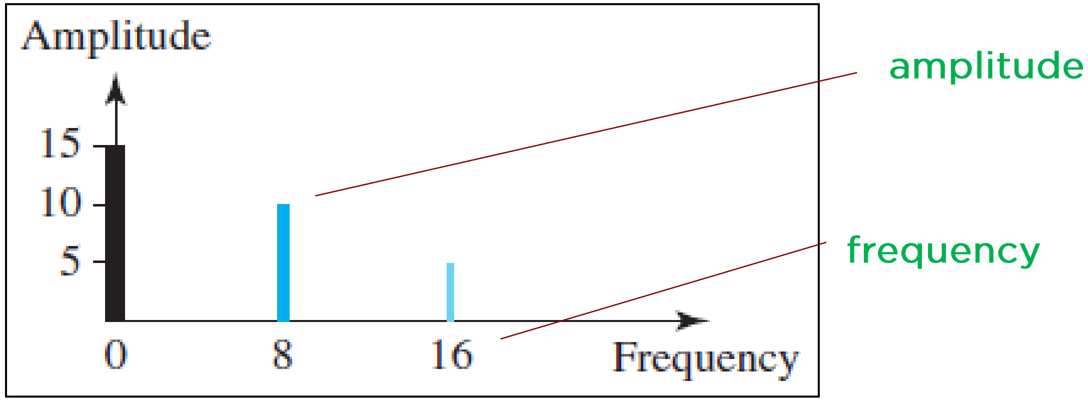


Time vs. Frequency Domain (2/2)

- Advantage of using frequency-domain plot:
  - Easy to plot and conveys the information that one can find in a time domain plot.
  - A complete sine wave is depicted by one spike – showing the frequency and peak amplitude values.







Sine Waves: Composite

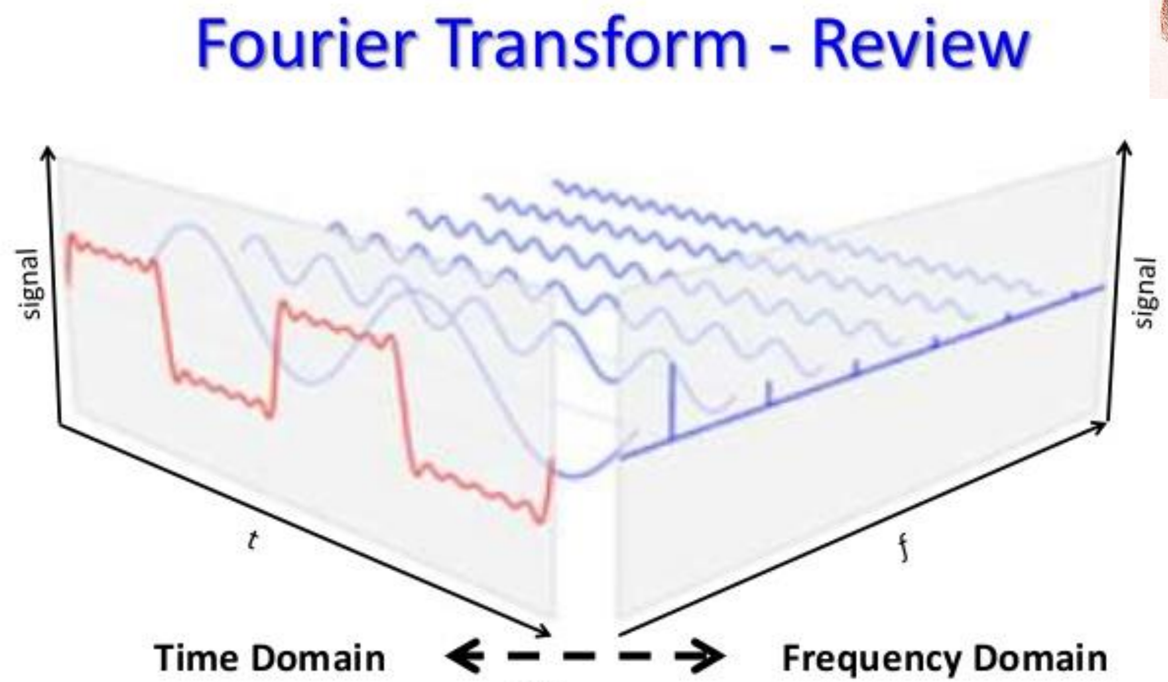
- In data communications, a single-frequency sine wave is not useful. A composite signal which is made of many sine waves is more relevant to communications.

- In the early 1900s, Jean-Baptiste Fourier showed that any composite signal is actually a combination of simple sine waves with different frequencies, amplitudes, and phases.

- According to Fourier analysis, any composite signal is a combination of simple sine waves with different frequencies, amplitudes, and phases.

Fourier Transform

What did he do?



$$\hat{f}(\xi) = \int_{-\infty}^{\infty} f(x)\, e^{-2\pi i \xi x}\, dx$$

$$\mathscr{F}\{g(t)\} = G(f) = \int_{-\infty}^{\infty} g(t)e^{-2\pi i f t}\,dt$$

$$= \int_{-T/2}^{T/2} A e^{-2\pi i f t}\,dt = \frac{A}{-2\pi i f}\left[e^{-2\pi i f t}\Big|_{-T/2}^{T/2}\right]$$

$$= \frac{A}{-2\pi i f}\left[e^{-\pi i f T} - e^{\pi i f T}\right] = \frac{AT}{\pi f T}\left[\frac{e^{\pi i f T} - e^{-\pi i f T}}{2i}\right]$$

$$= \frac{AT}{\pi f T}\sin(\pi f T) = AT\left[\mathrm{sinc}(fT)\right]$$

$$g(t) = a_0 + \sum_{m=1}^{\infty} a_m \cos\left(\frac{2\pi mt}{T}\right) + \sum_{n=1}^{\infty} b_n \sin\left(\frac{2\pi nt}{T}\right)$$

$$= \sum_{m=0}^{\infty} a_m \cos\left(\frac{2\pi mt}{T}\right) + \sum_{n=1}^{\infty} b_n \sin\left(\frac{2\pi nt}{T}\right)$$

$$a_0 = \frac{1}{T}\int_0^T f(t)\,dt$$

$$a_m = \frac{2}{T}\int_0^T f(t)\cos\left(\frac{2\pi mt}{T}\right)dt$$

$$b_n = \frac{2}{T}\int_0^T f(t)\sin\left(\frac{2\pi nt}{T}\right)dt$$

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DIGITAL SIGNAL (square)

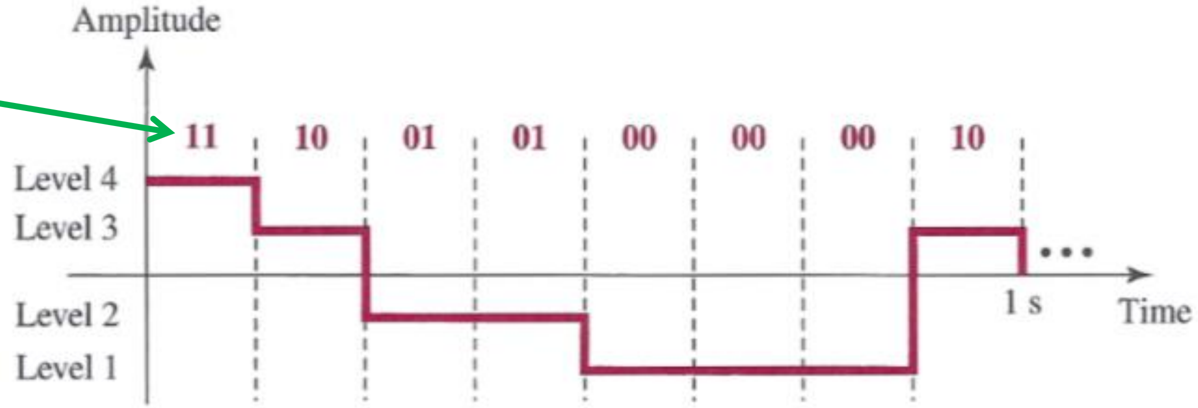
Concept

- In addition to being represented by an analog signal, information can also be represented by a digital signal.

- A digital signal can have more than two levels, i.e. sending more than 1 bit for each level.

Sending 1 bit per level

Sending 2 bits per level



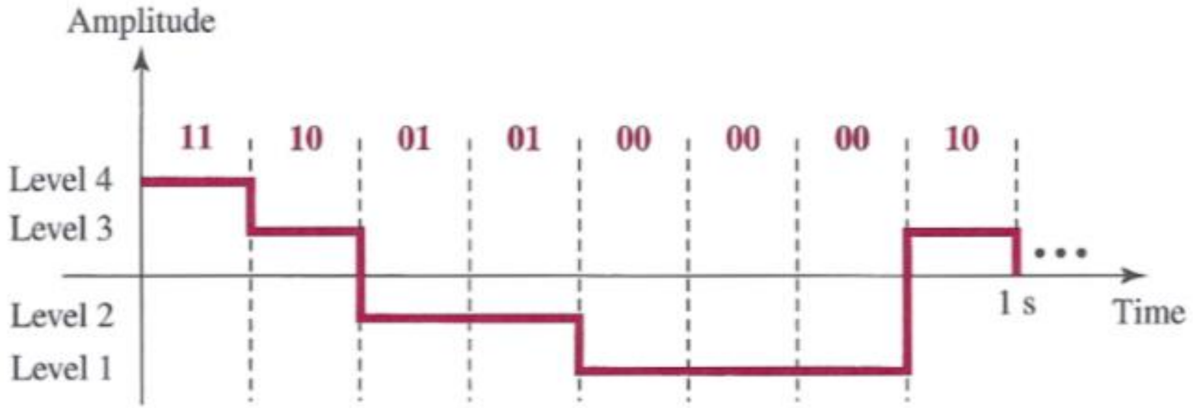
Bit Rate

- Most digital signals are non-periodic, and thus period and frequency are not appropriate characteristics - thus another term is used to describe digital signals, called *bit-rate*.

- Bit-rate is the number of bits sent per-second, expressed in bits-per-second (bps).

8 bits sent per 1s.
Bit-rate = 8 bps.

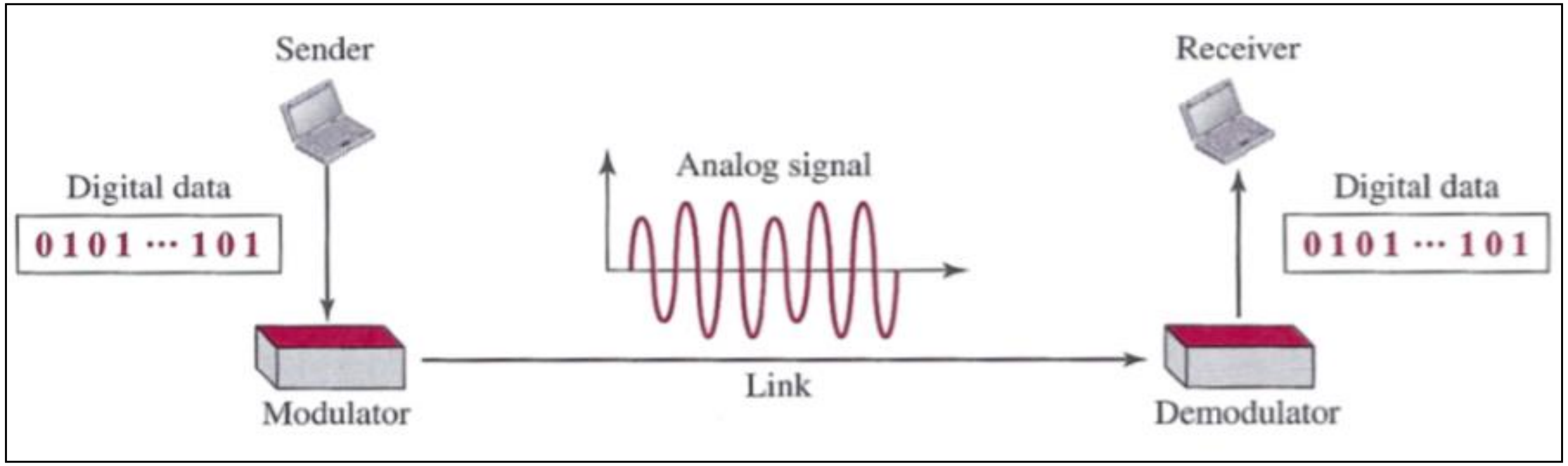
16 bits sent per 1s.
Bit-rate = 16 bps.



ANALOG TRANSMISSION

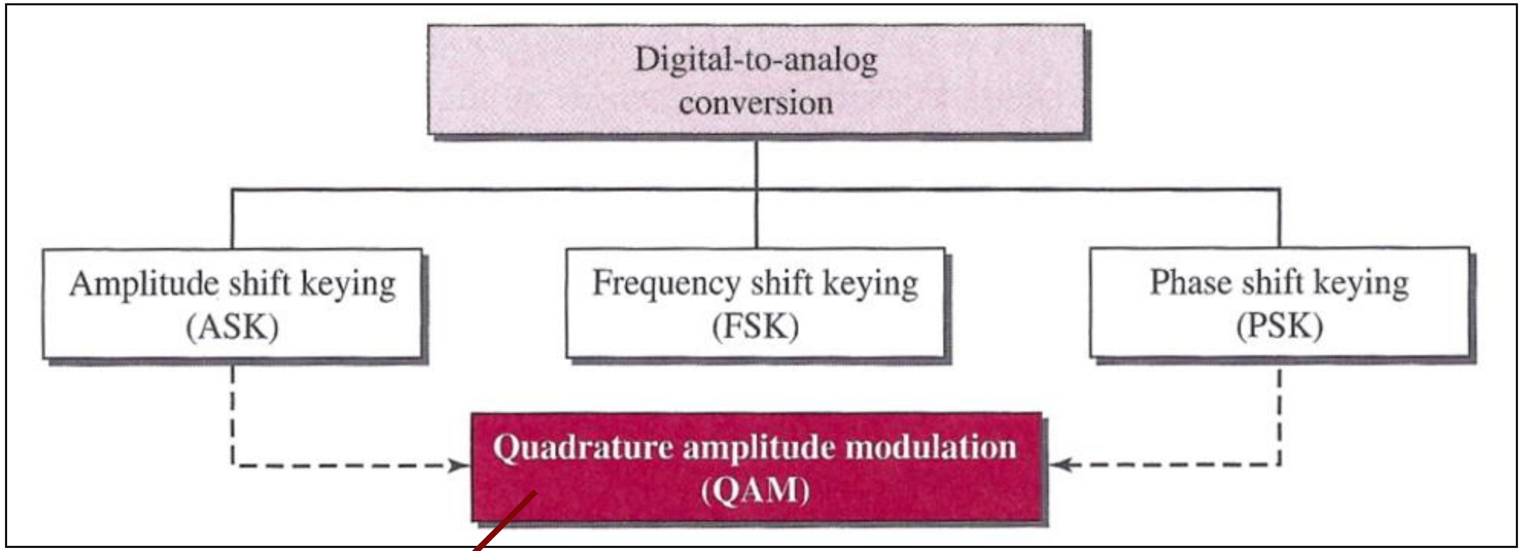
(1) Digital to Analog Conversion

- Digital-to-analog conversion is the process of getting a result of an analog signal based on the information in digital data.



Digital to Analog Conversion

- There are three characteristics of a sine wave that can be altered, yielding three mechanisms for modulating digital data into an analog signal: amplitude shift keying (ASK), frequency shift keying (FSK), and phase shift keying (PSK).

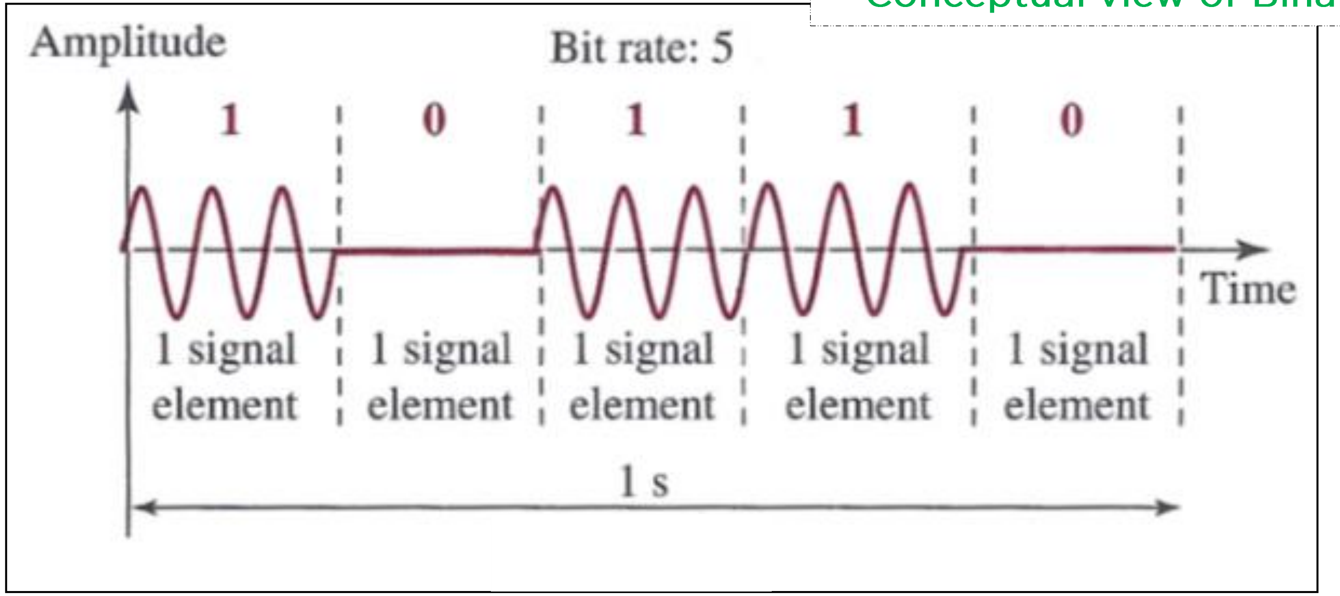


> *Note*
> *There is a better and efficient mechanism that combines changing both the amplitude and phase characteristics, called quadrature amplitude modulation (QAM). But we won't look at this on this course.*

ASK

- In amplitude shift keying, the amplitude of the carrier signal is varied to create signal elements, while both frequency and phase remain constant.
- ASK is normally implemented using only two levels, or so-called binary ASK or on-off keying (OOK).
- Characteristics: The peak amplitude of one signal level is 0; the other is the same as the amplitude of the carrier frequency.

Conceptual view of Binary ASK

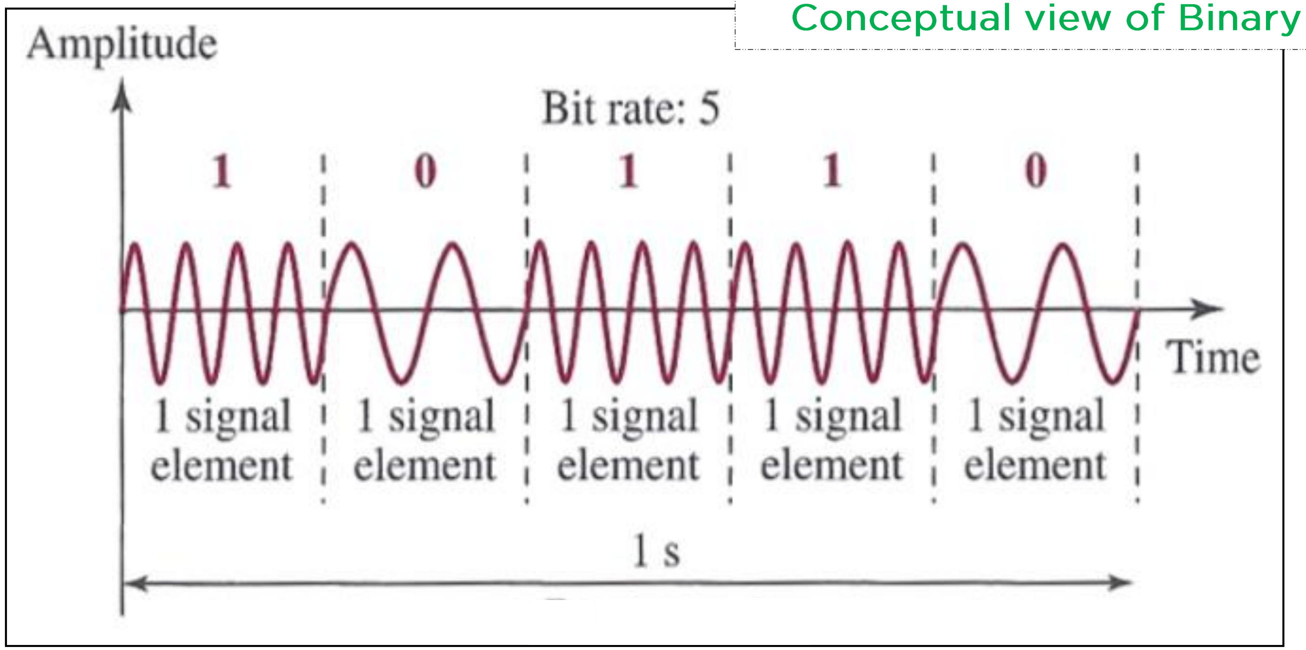


FSK

- ❑ In frequency shift keying, the frequency of the carrier signal is varied to represent data.

- ❑ Characteristics:
  - The frequency of the modulated signal is constant for the duration of one signal element, but changes for the next signal element if the data element changes.
  - Both peak amplitude and phase remain constant for all signal elements.

Conceptual view of Binary FSK



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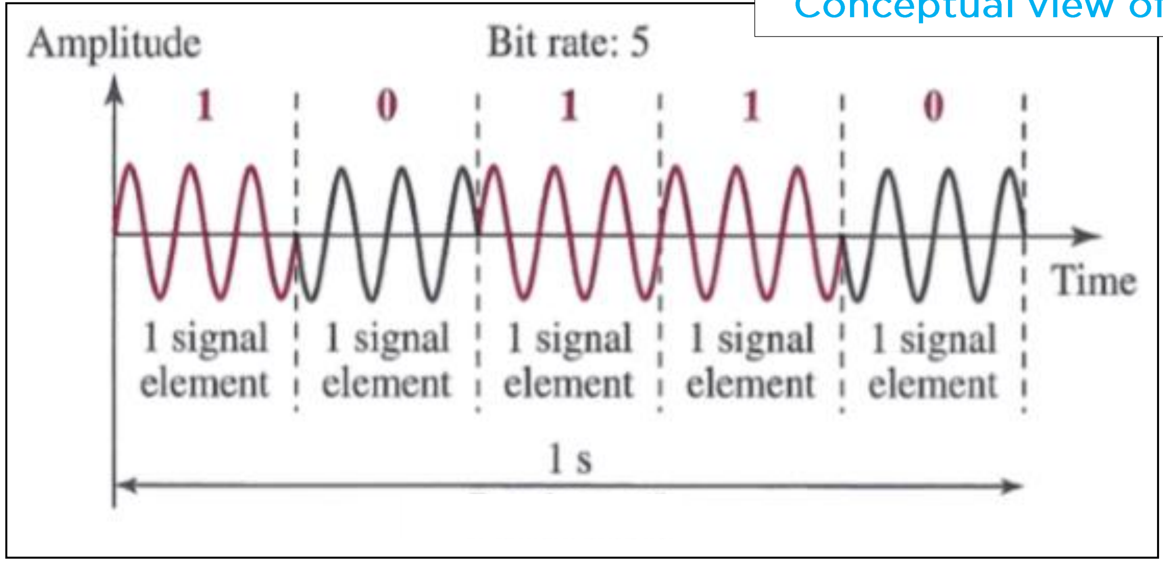
PSK

- In phase shift keying, the phase of the carrier is varied to represent two or more different signal elements.

- Characteristics:
  - Both peak amplitude and frequency remain constant as the phase changes.

- The simplest PSK is binary PSK, in which we have only two signal elements, one with a phase of 0°, and the other with a phase of 180°.

Conceptual view of Binary PSK



(2) Analog to Analog Conversion

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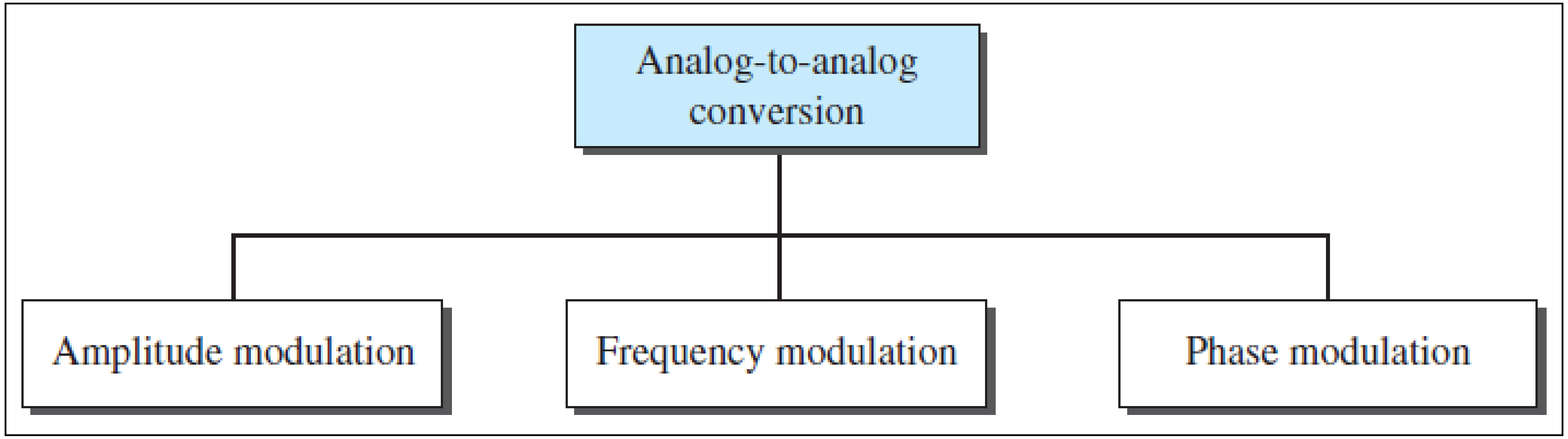

DIGITAL TRANSMISSION

(1) Digital to Digital conversion

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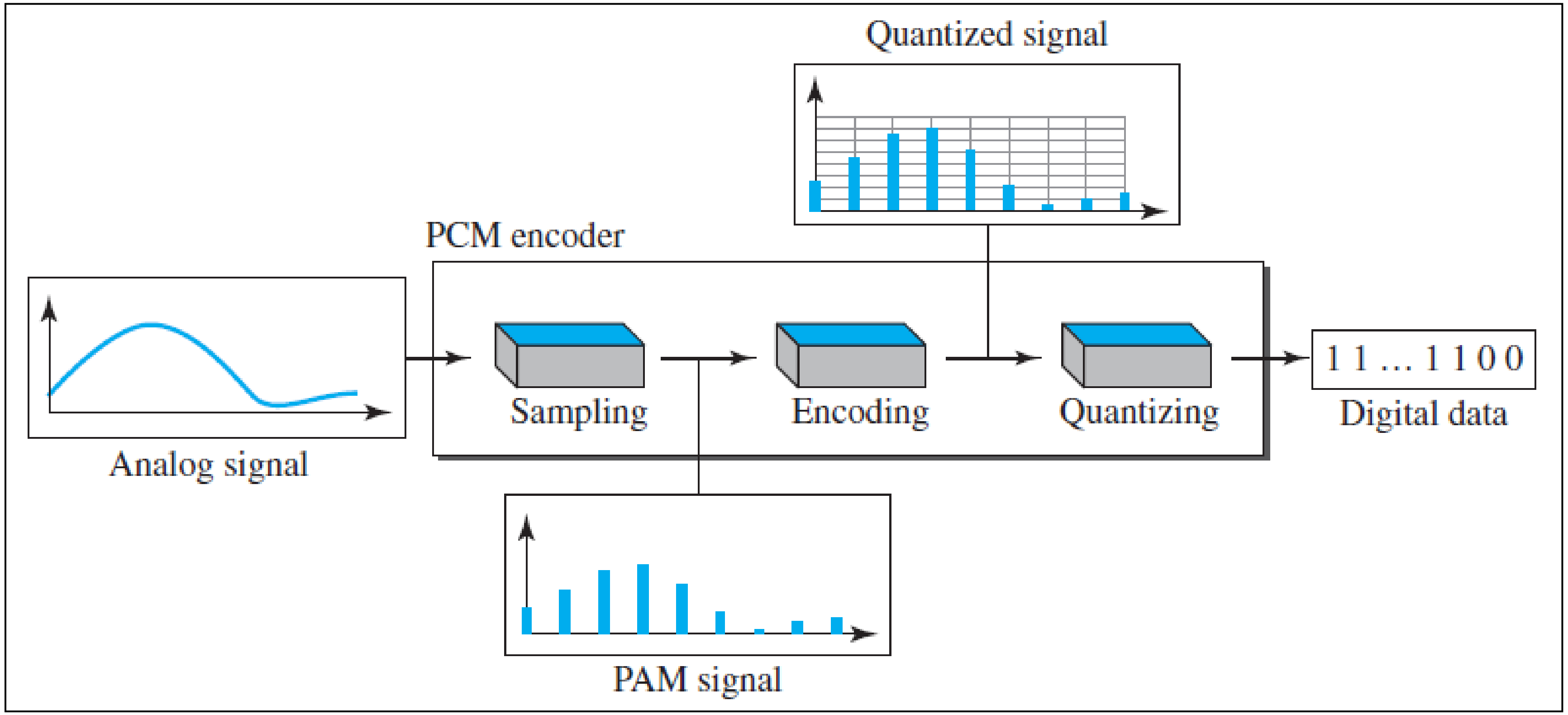
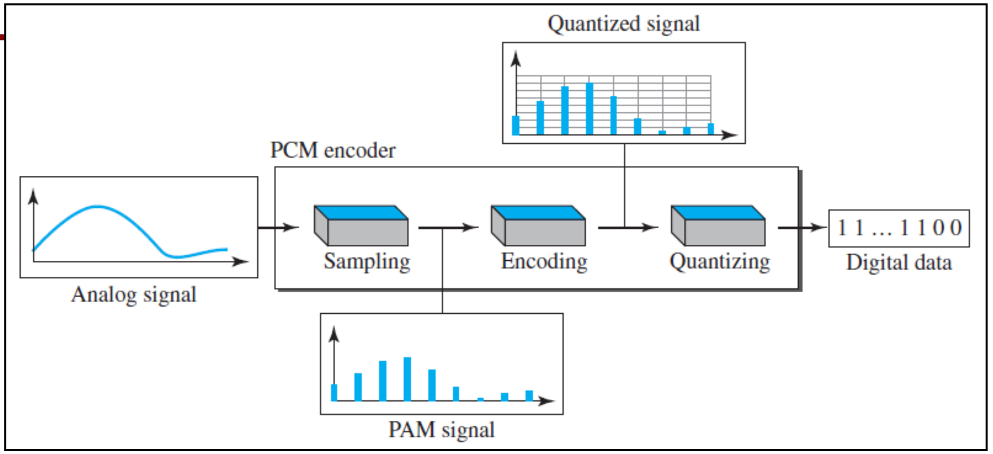
(2) Analog to Digital conversion

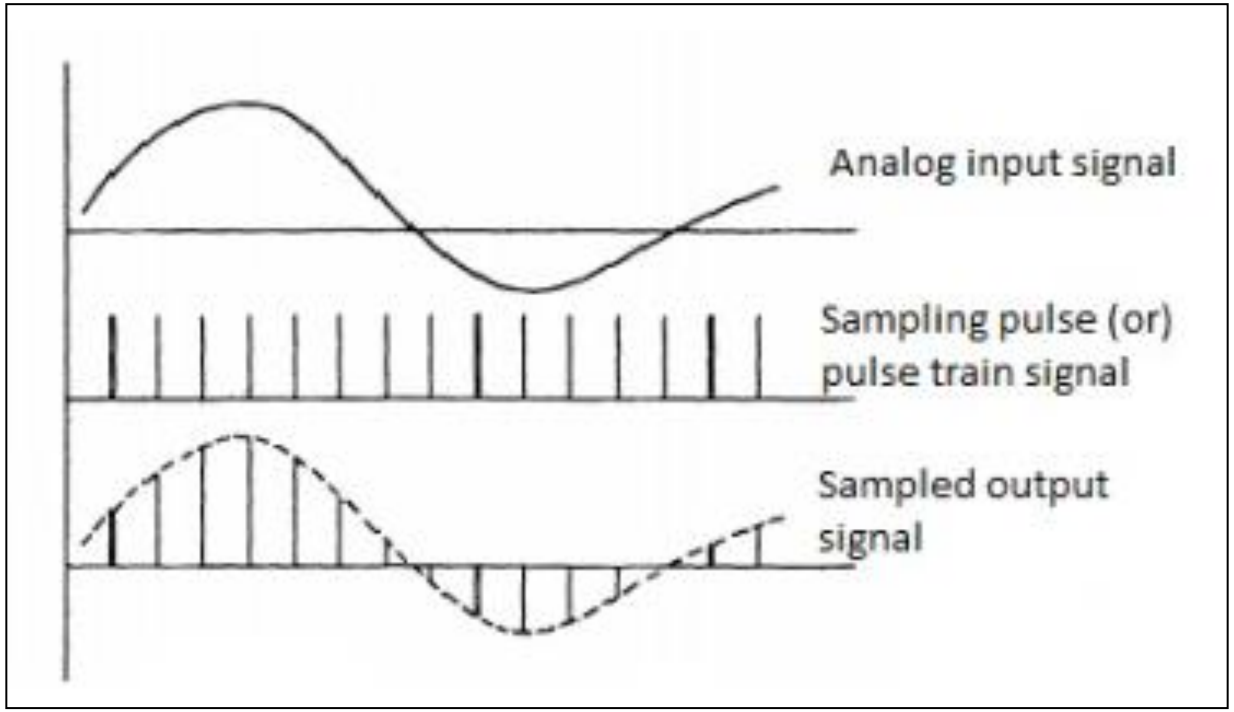
- The most common technique to change an analog signal to digital data (digitization) is called Pulse Code Modulation (PCM)
- PCM has three processes: sampling, quantizing, and encoding.



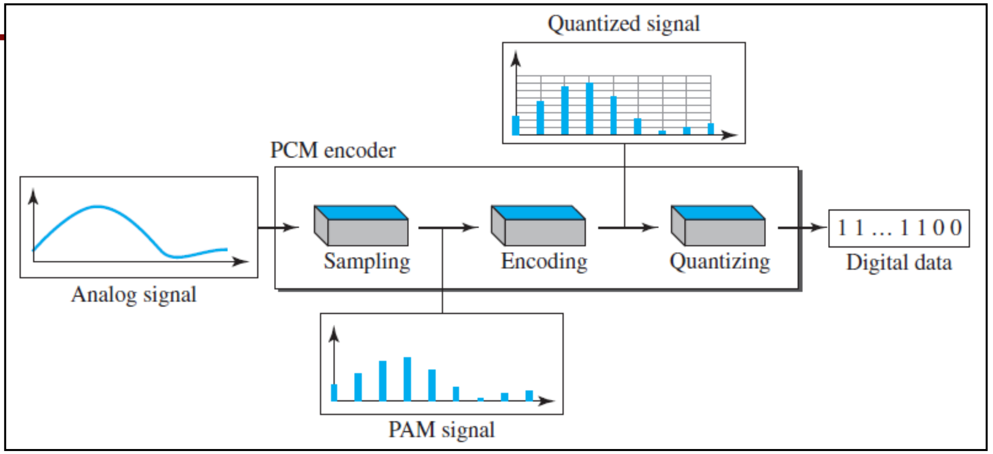
Sampling

- ❑ Concept:

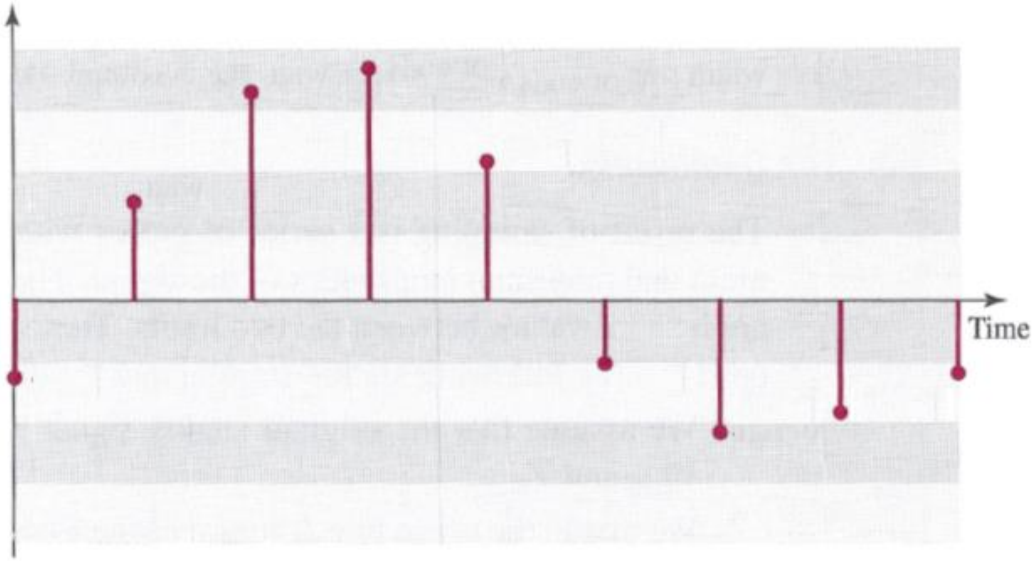




Sampling → Quantizing



- The result of sampling is a series of pulses with amplitude values between the maximum and minimum amplitudes of the signal.



Assume there is a sampled signal of -20 V and +20 V amplitude.

We decide to have eight levels (L = 8).

This means each level has 5 V value ($D = \frac{2 \times 20\,V}{8} = 5$)

- The next step would be quantization, i.e. to divide the peak-to-peak amplitude values ($2V_P$) into several level (L), which each level has height value (D).

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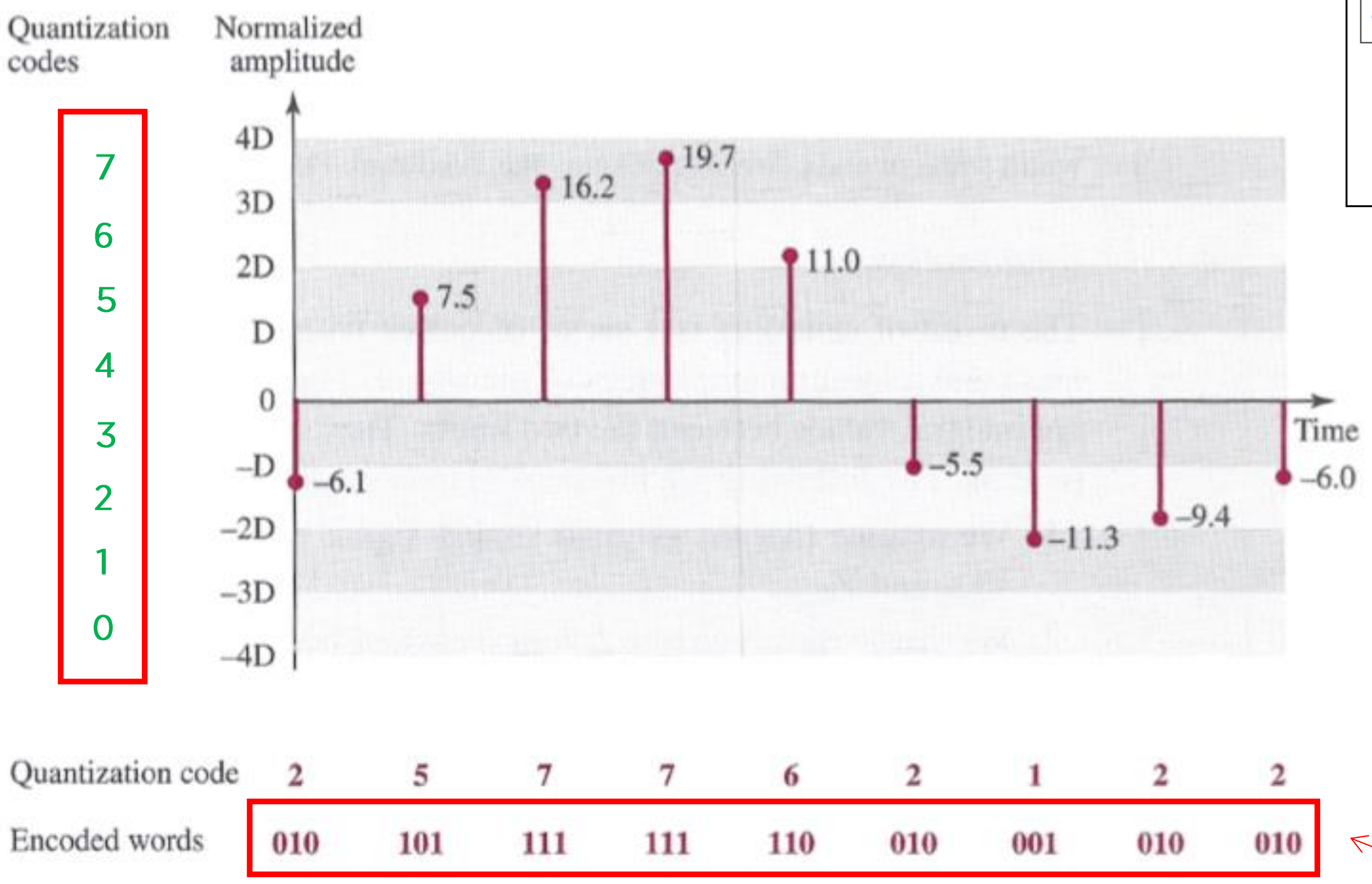
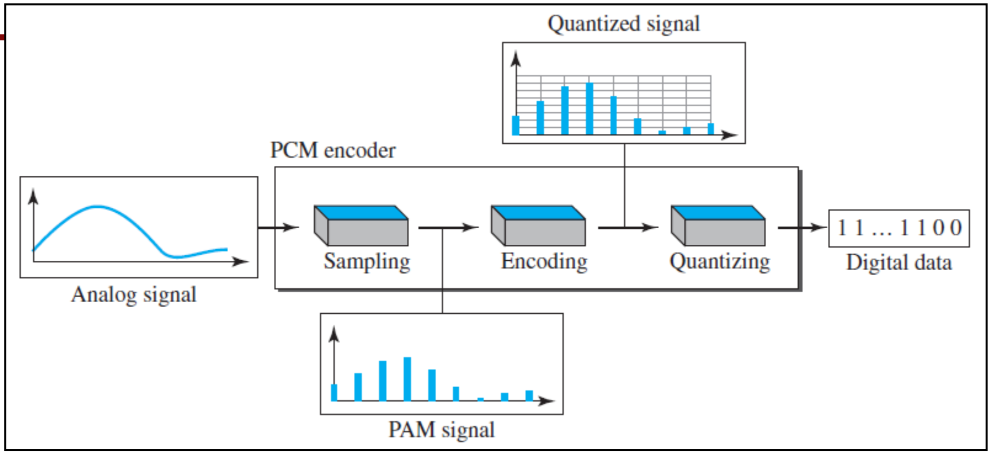
Quantizing → Coding





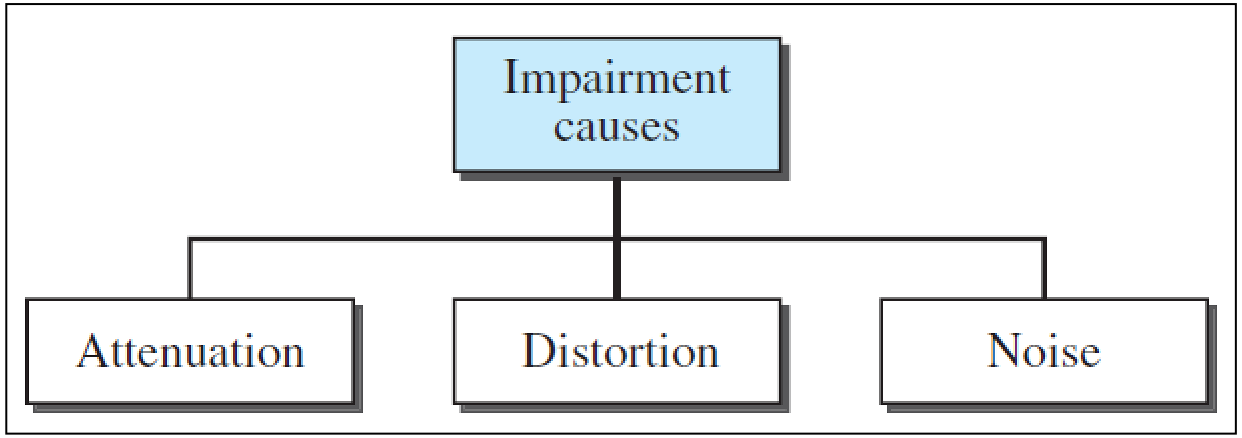
After each sample is quantized and the number of bits per sample is decided, each sample can be changed to a digital code (encoding).

SIGNAL IMPERFECTION

Imperfection

- 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.

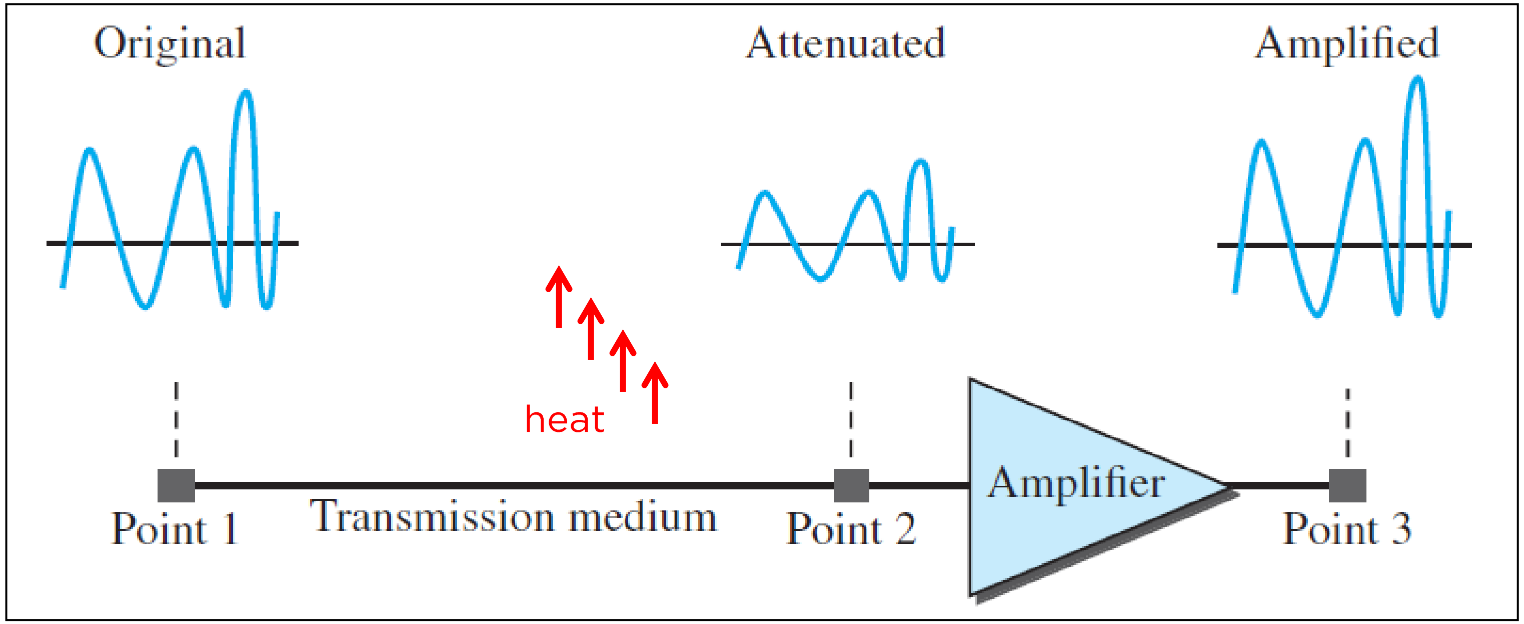


Attenuation

- ❑ Attenuation ➔ loss of energy.

- ❑ When a signal 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/hot after a while -- the electrical energy in the signal is converted to heat.

- ❑ To compensate for this loss, amplifiers are used to amplify the signal.



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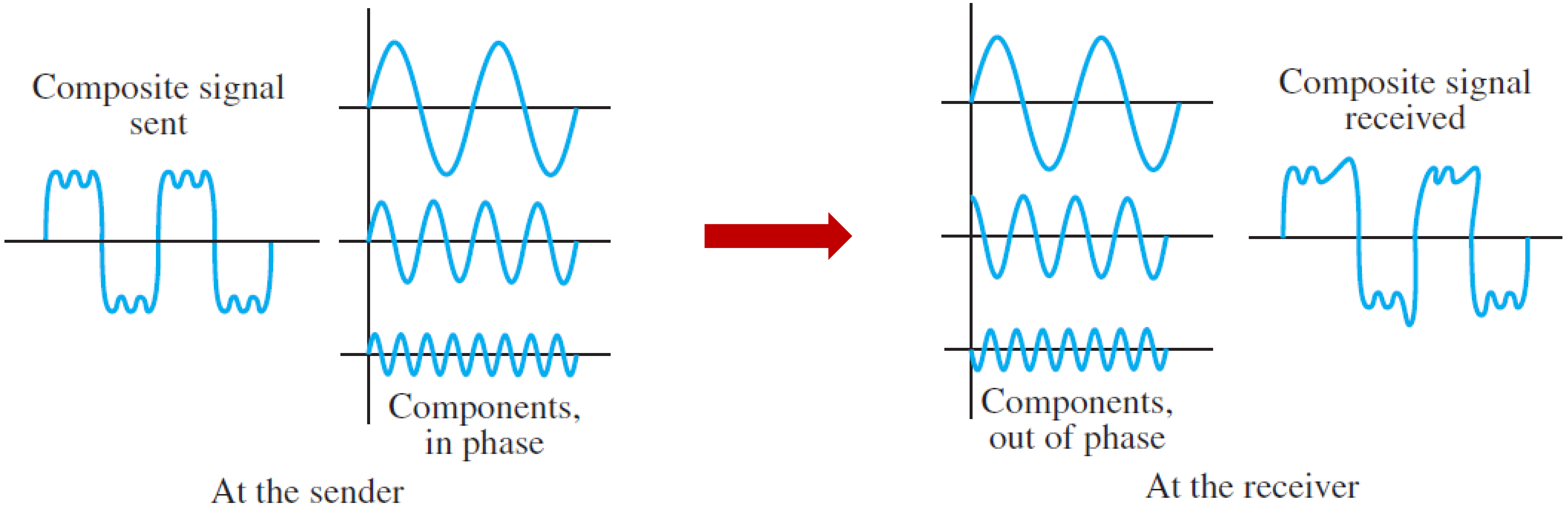
Distortion

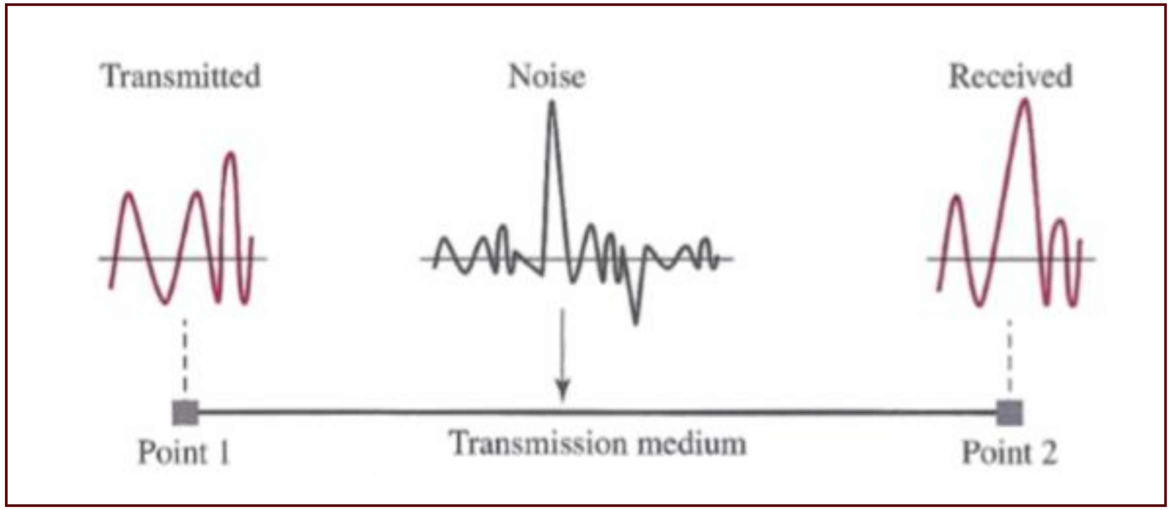
- ❑ Distortion means that the signal changes its form or shape.

- ❑ Distortion can occur in a composite signal made of different frequencies.
  - Note that each signal component has its own propagation speed through a medium – therefore differences in delay may create a difference in phase.
  - Thus, signal components at the receiver receive different phases from what they had at the sender.

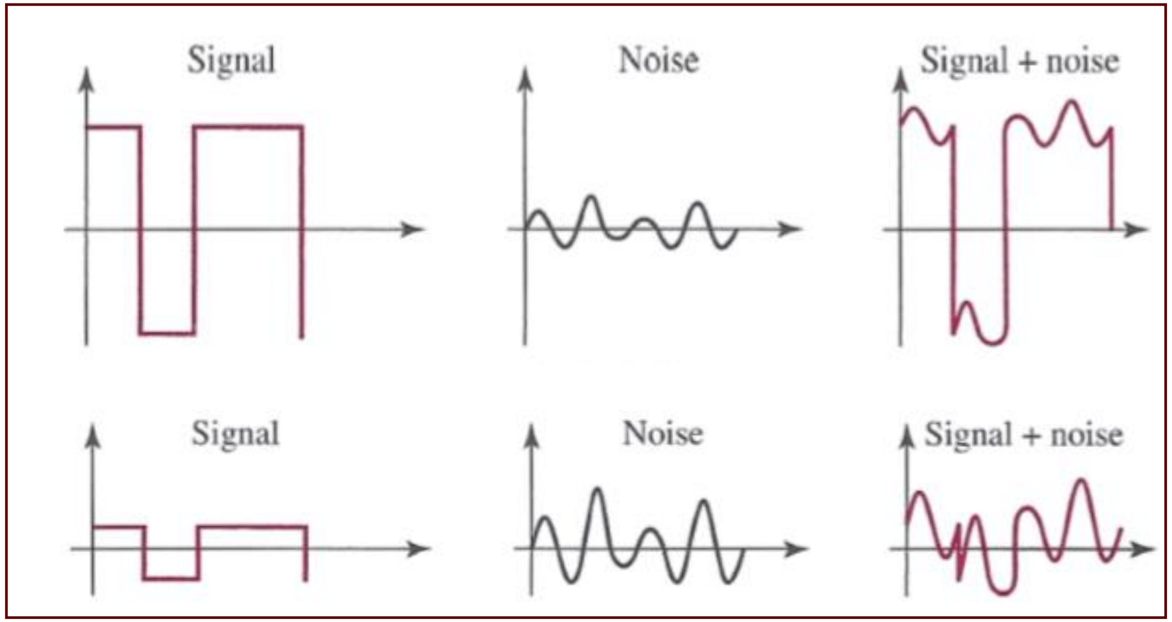


Noise & SNR

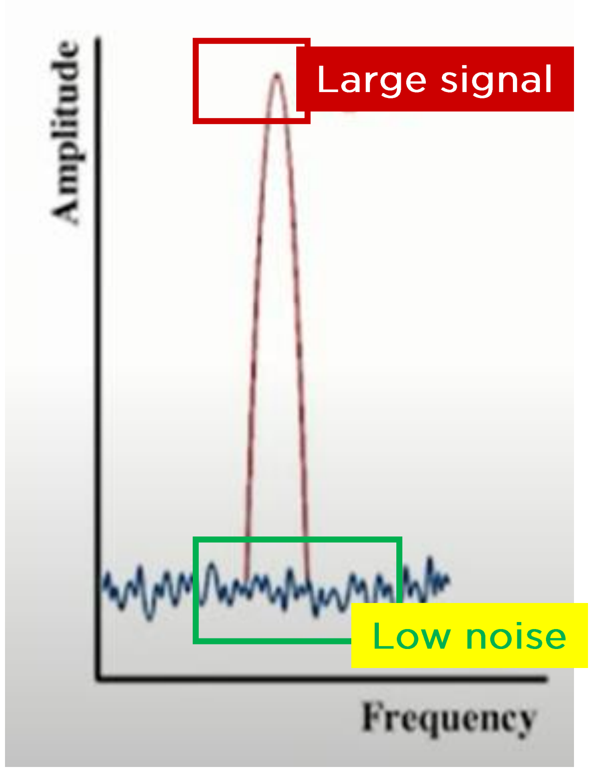
- Noise is another cause of impairment.
- Several types of noise, such as thermal noise, induced noise, crosstalk, and impulse noise, may corrupt the signal.



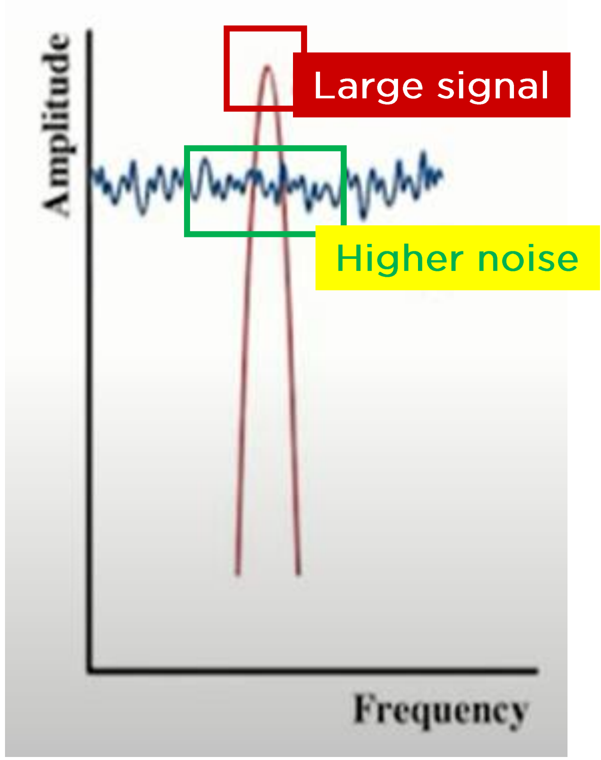
- **Signal-to-noise ratio** (SNR) is a measure used to compare the level of a desired signal to the level of noise.
- It is defined as the ratio of signal power to the noise power, often expressed in decibels (dB).



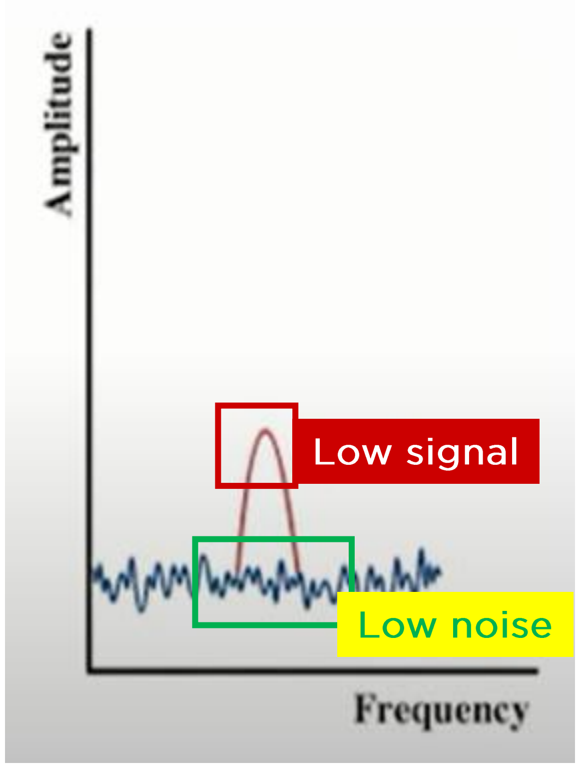
More of SNR



Good SNR



Worse SNR



Worse SNR

You have a large signal
doesn't mean you will have good SNR.

You have a low noise
doesn't mean you will have good SNR.

to be continued