Heaven's light is our guide"

Rajshahi University of Engineering & Technology
Department of Computer Science & Engineering

Chapter 3

Data and Signals

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Data

❖ *Analog Data*

- ✓ Refers to information that is continuous.
- ✓ Take on continuous values.
- ✓ Example: an analog clock that has hour, minute and second hands gives information in continuous form.

❖ *Digital Data*

- ✓ Refers to information that has discrete states.
- ✓ Take on discrete values.
- ✓ Example: Data are stored in computer memory in the form of 0s and 1s.

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Signals

❖ ***Analog Signals:***

✓ Analog signals can have an infinite number of values in a range.

❖ ***Digital Signals:***

✓ Digital signals can have only a limited number of values.

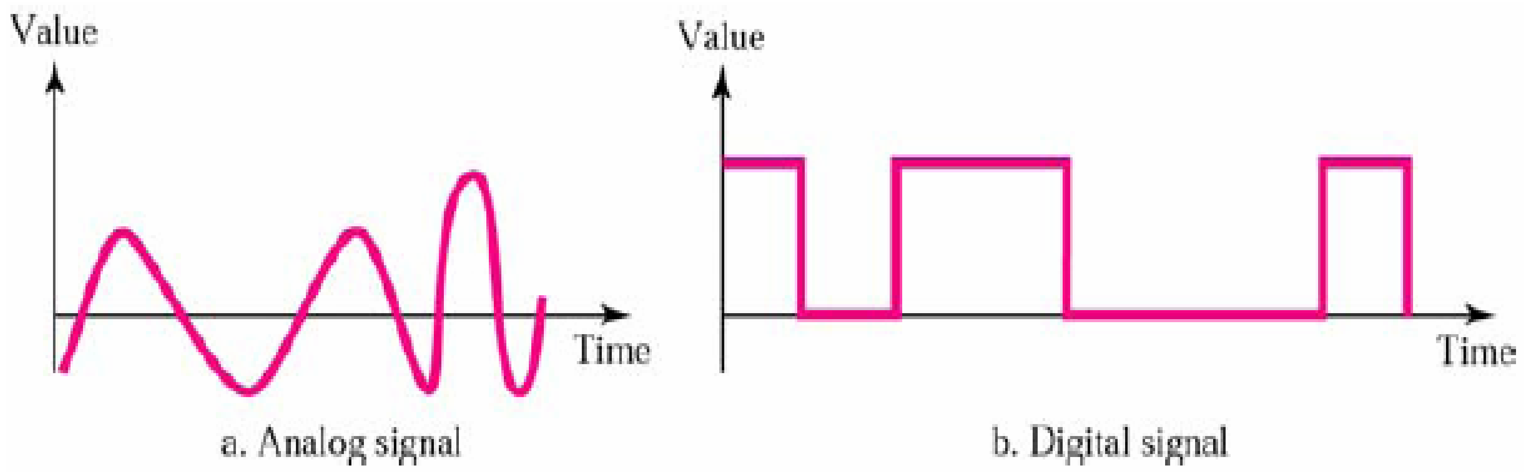


Figure 3.1 Comparison of analog and digital signals

Signals

❖ ***Periodic Analog Signal:***

- ✓ Completes a pattern within a measurable time frame, called a period.
- ✓ Repeats that pattern over subsequent identical periods.
- ✓ The completion of one full pattern is called a ***cycle***.

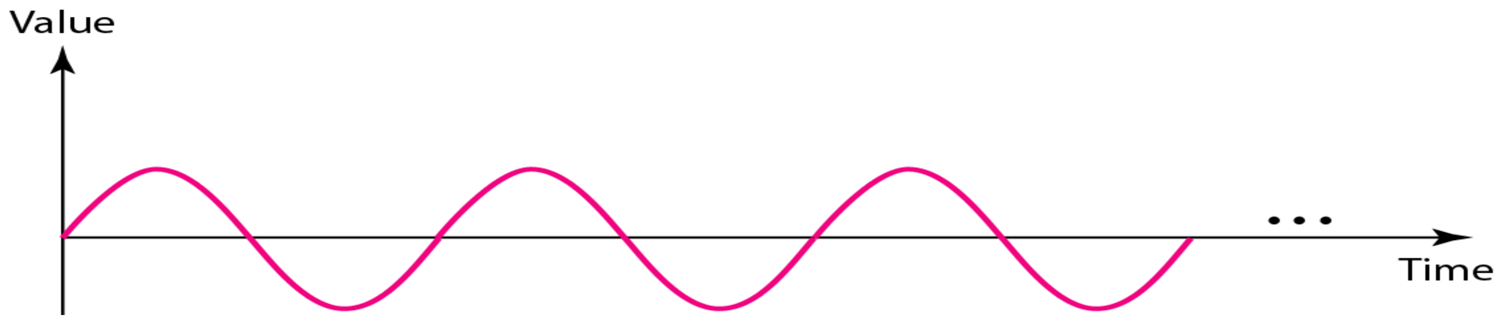
❖ ***Nonperiodic Analog Signal:***

- ✓ Changes without exhibiting a pattern or cycle that repeats over time.

❑ Periodic analog signals can be classified as ***simple*** or ***composite***.

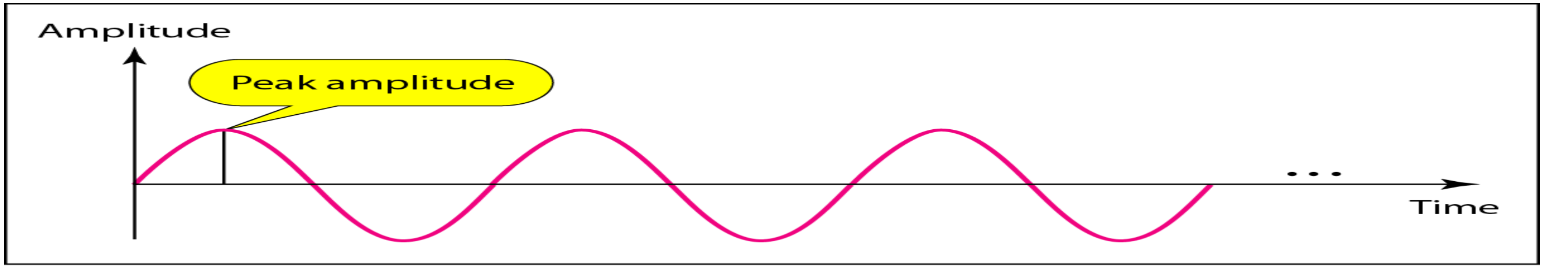
➢ A ***simple periodic analog signal***, a sine wave, cannot be decomposed into simpler signals.

➢ A ***composite periodic analog signal*** is composed of multiple sine waves.

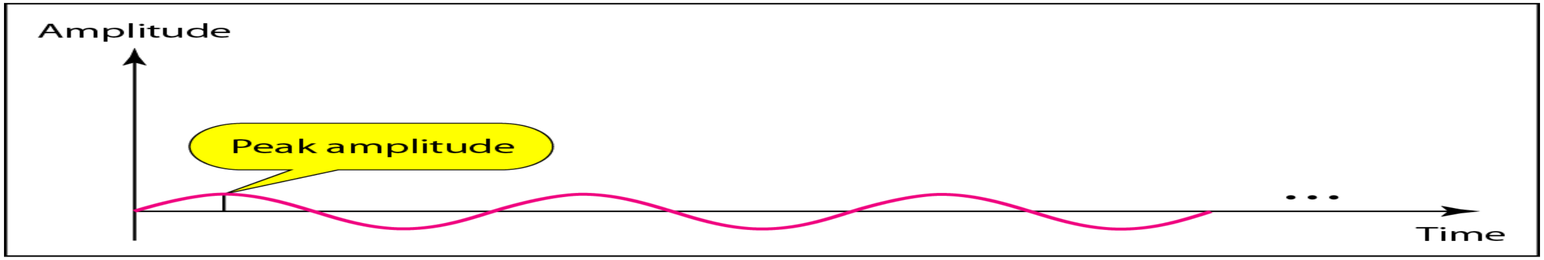


Signals

- ❖ ***Sine Wave***
  - ➢ ***Peak Amplitude*** of the signal is the absolute value of its highest intensity, proportional to the energy it carries.
  - ➢ ***Period and Frequency***
    - ✓ **Period** refer to the amount of time in seconds, a signal needs to complete 1 cycle.
    - ✓ **Frequency** refers to the number of periods in 1 s.



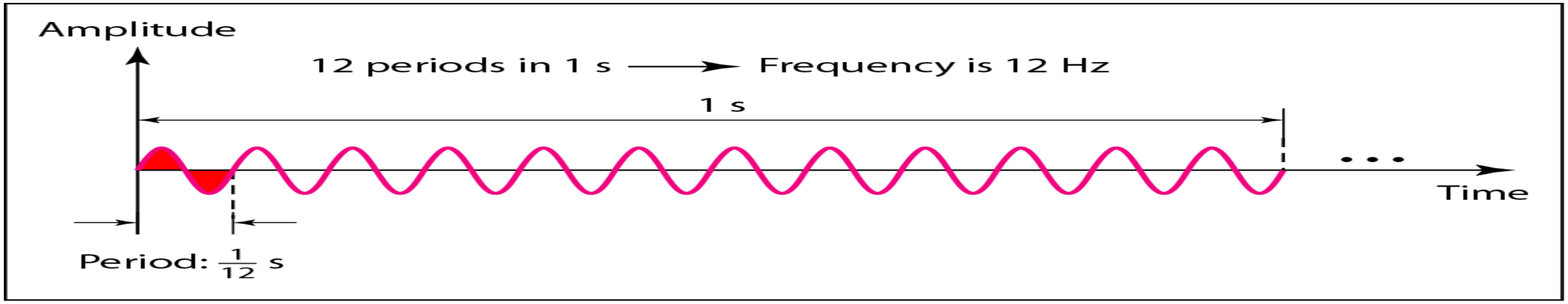
a. A signal with high peak amplitude



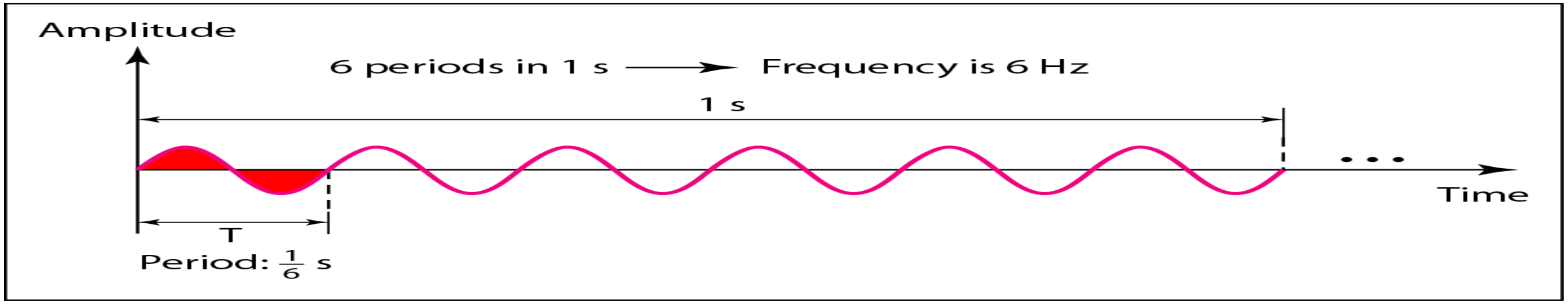
b. A signal with low peak amplitude

Frequency

- ***Frequency*** is the rate of change with respect to time.
  - ✓ Change in a short span of time means high frequency.
  - ✓ Change over a long span of time means low frequency.
  - ✓ If a signal does not change at all, its frequency is zero
  - ✓ If a signal changes instantaneously, its frequency is infinite.
  - ✓ Frequency and period are the inverse of each other, f = 1/ T.



a. A signal with a frequency of 12 Hz

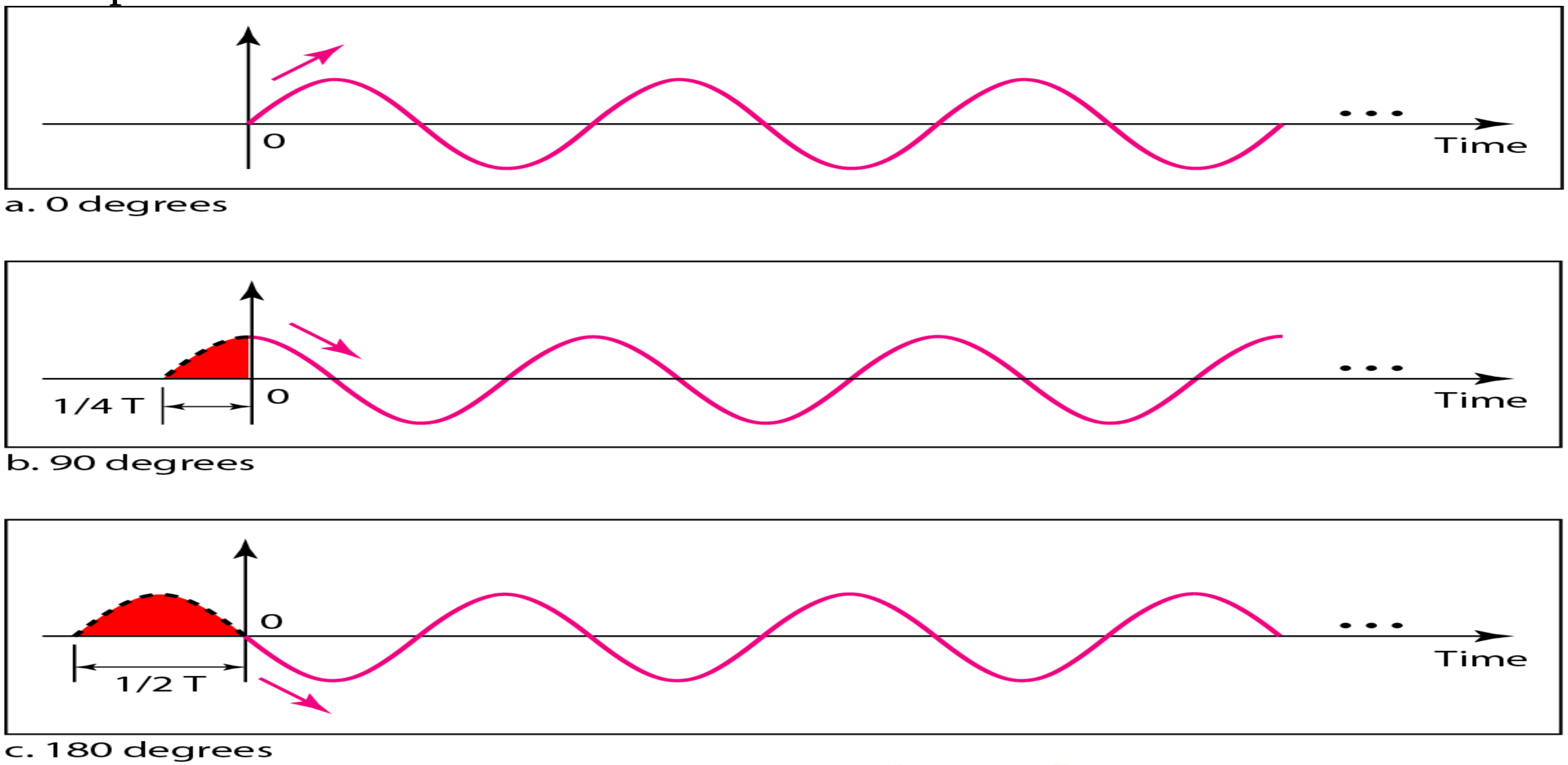


b. A signal with a frequency of 6 Hz

Phase

❖ ***Phase:***

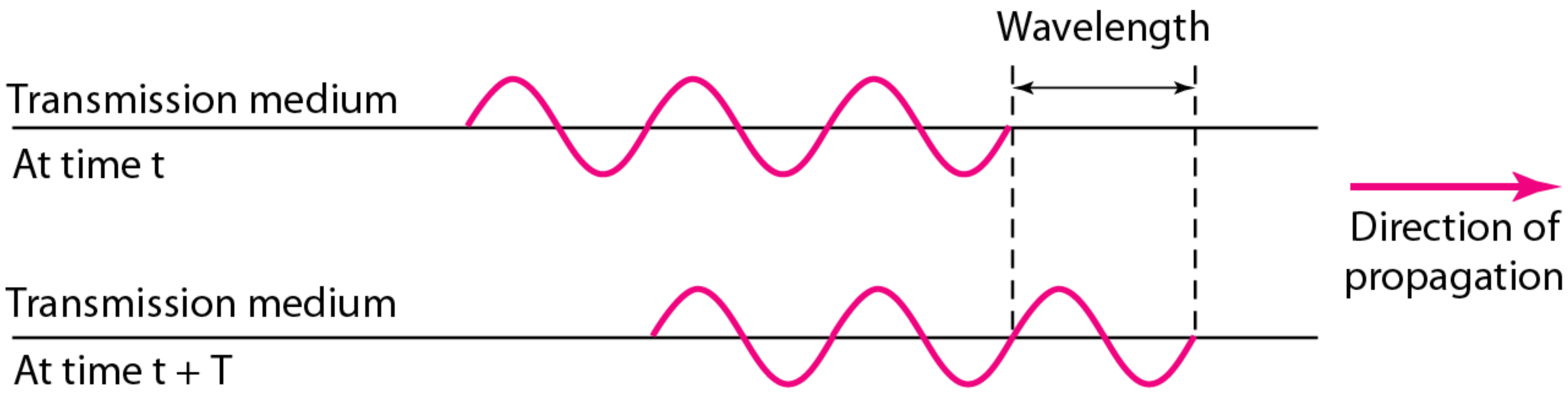
- ✓ Phase describes the position of the waveform relative to time 0.
- ✓ Three sine waves with the same amplitude and frequency, but different phases.



Wavelength and period

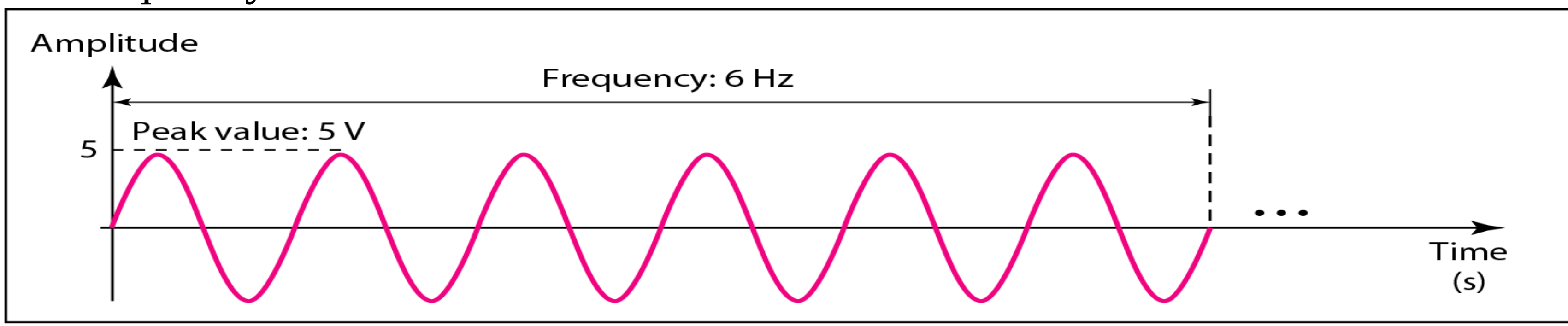
- **Wavelength:**
  - ✓ is another characteristic of a signal traveling through a transmission medium.

$$\text{Wavelength} = \text{Propagation speed} \times \text{Period}$$
$$= \text{Propagation speed} / \text{Frequency}$$

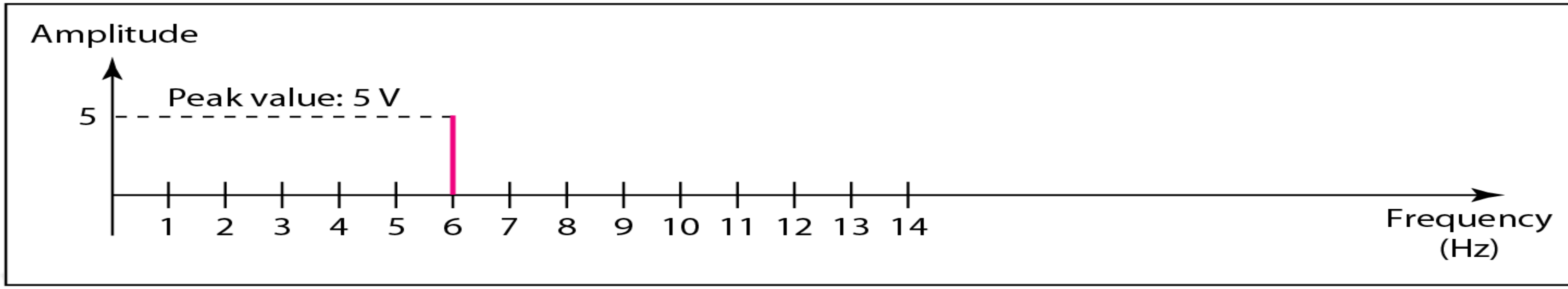


Time and Frequency Domains

- ✓ A complete sine wave in the time domain can be represented by one single spike in the frequency domain.
- ✓ ***Time domain plot*** shows changes in signal amplitude with respect to time.
- ✓ A ***frequency domain*** plot is concerned with only the peak value and the frequency.



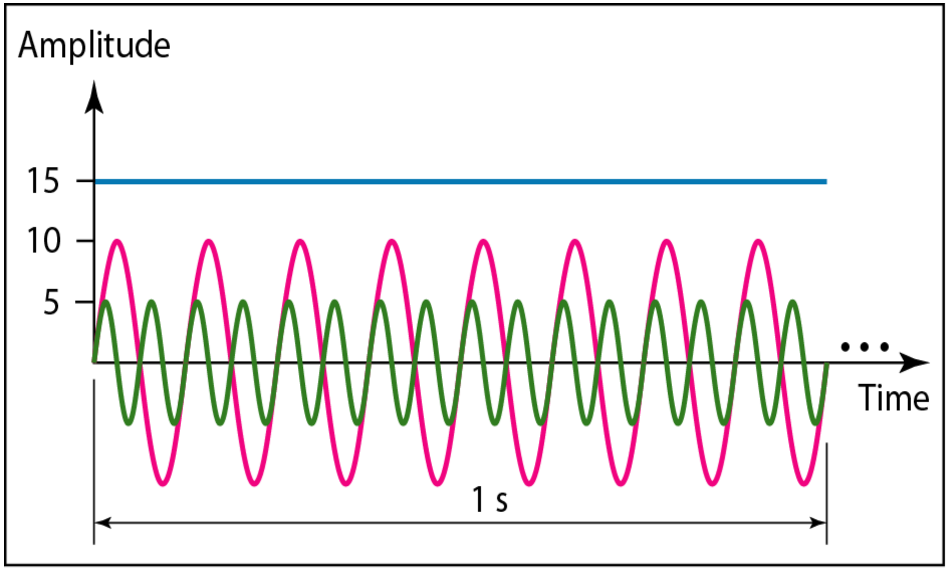
a. A sine wave in the time domain (peak value: 5 V, frequency: 6 Hz)



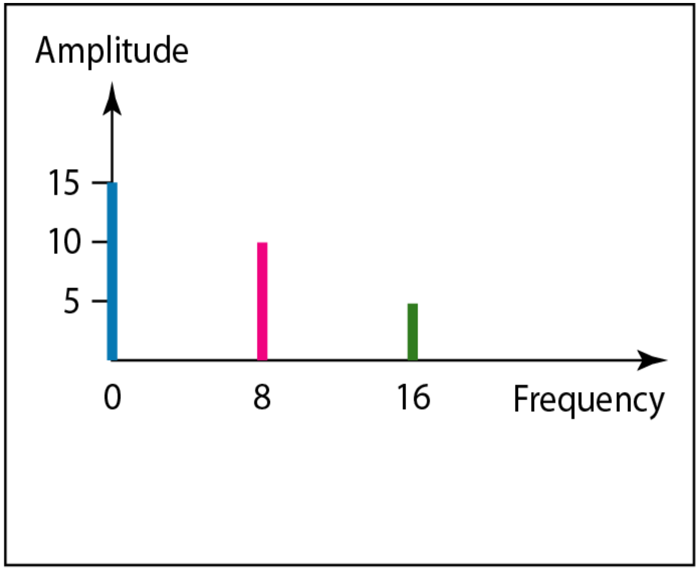
b. The same sine wave in the frequency domain (peak value: 5 V, frequency: 6 Hz)

Frequency Domains

- ❑ Time domain and frequency domain of three sine waves with frequencies 0, 8, 16.



a. Time-domain representation of three sine waves with frequencies 0, 8, and 16



b. Frequency-domain representation of the same three signals

❑The frequency domain is more compact and useful when we are dealing with more than one sine wave.

❑It is easy to plot and conveys information that one can find in a time domain plot.

A composite periodic signal

- If the composite signal is periodic, the decomposition gives a series of signals with discrete frequencies;

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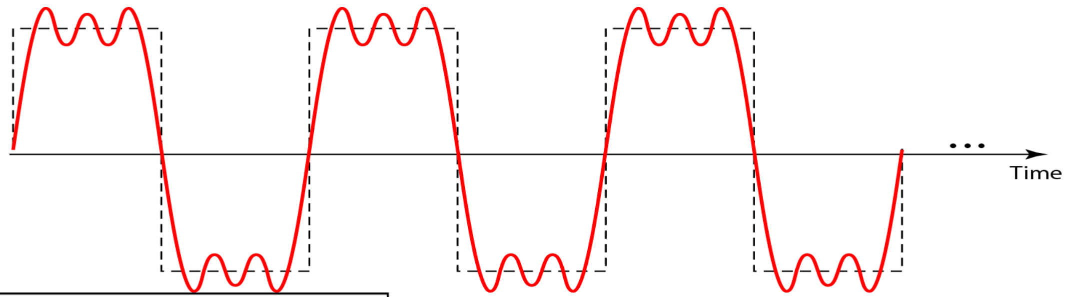
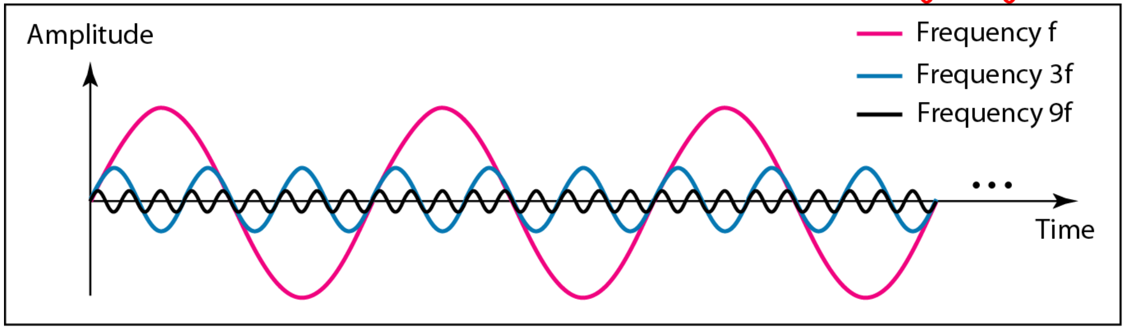
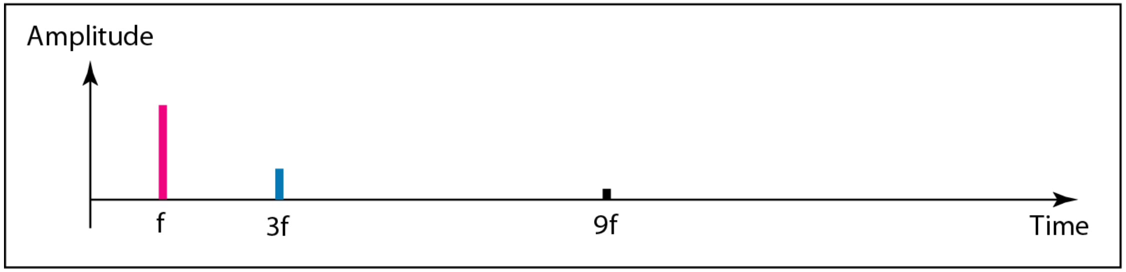




a. Time-domain decomposition of a composite signal



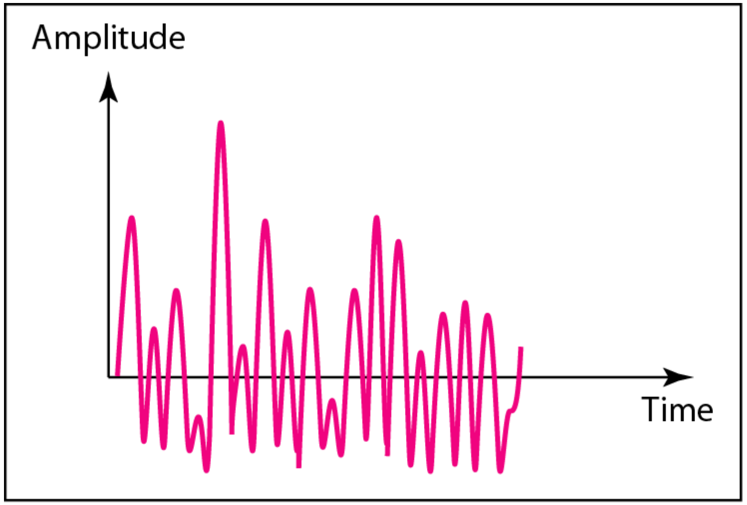
b. Frequency-domain decomposition of the composite signal

Figure- Decomposition of the composite periodic signal in the time and frequency domains

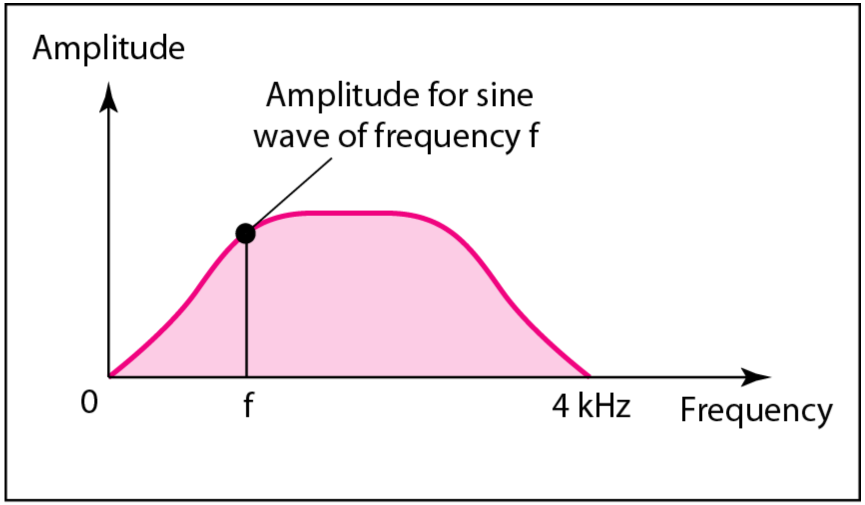
Time and frequency domains of a nonperiodic signal

❖ **A nonperiodic composite signal**

- If the composite signal is nonperiodic, the decomposition gives a combination of sine waves with continuous frequencies.
- It can be a signal created by a microphone or a telephone set when a word or two is pronounced.
- In this case, the composite signal cannot be periodic
  - ➢because that implies that we are repeating the same word or words with exactly the same tone.



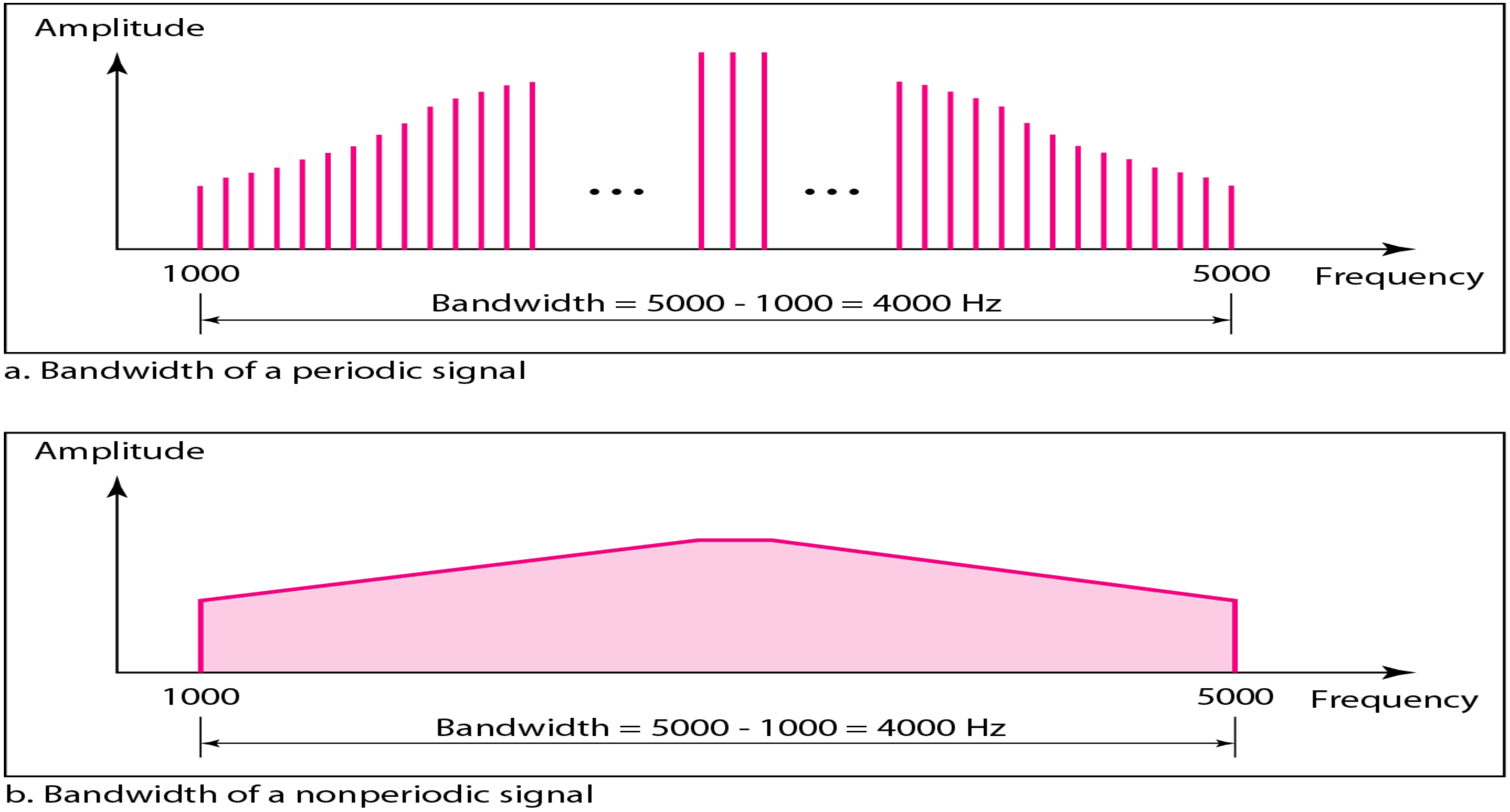
a. Time domain



b. Frequency domain

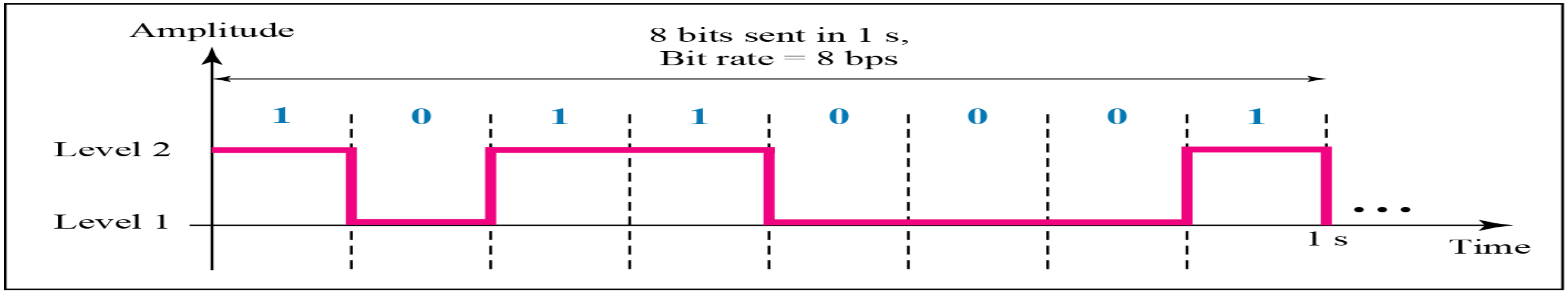
Bandwidth

- The bandwidth of a composite signal is the difference between the highest and the lowest frequencies contained in that signal.

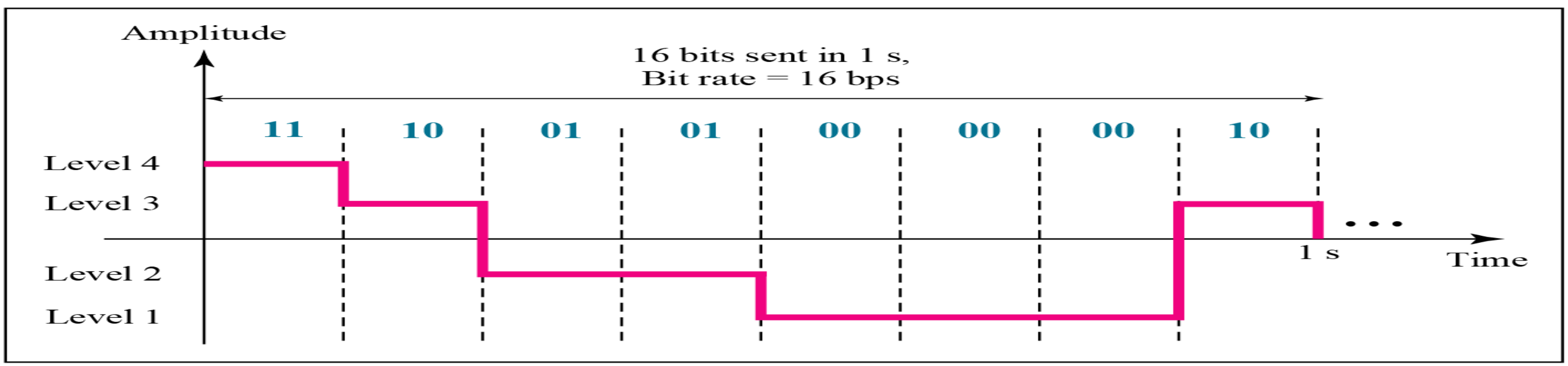


DIGITAL SIGNALS

- In addition to being represented by an analog signal, information can also be represented by a digital signal.
- For example, a 1 can be encoded as a positive voltage and a 0 as zero voltage.
- A ***digital signal*** can have more than two levels.
- In this case, we can send more than 1 bit for each level.



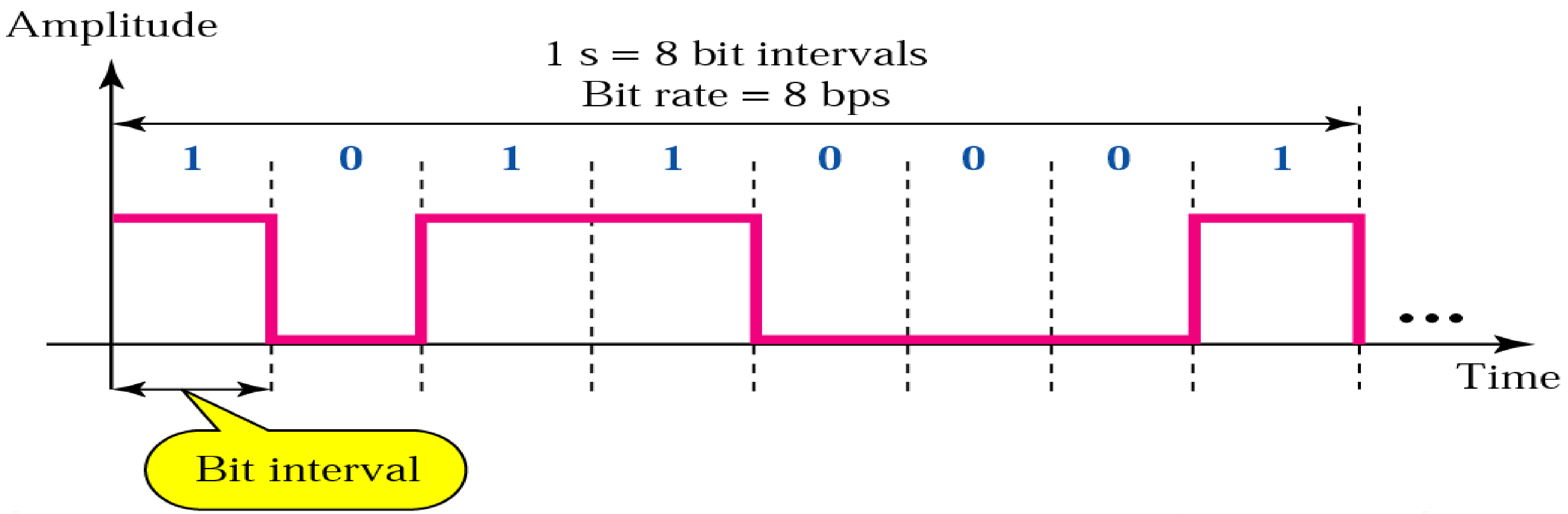
a. A digital signal with two levels



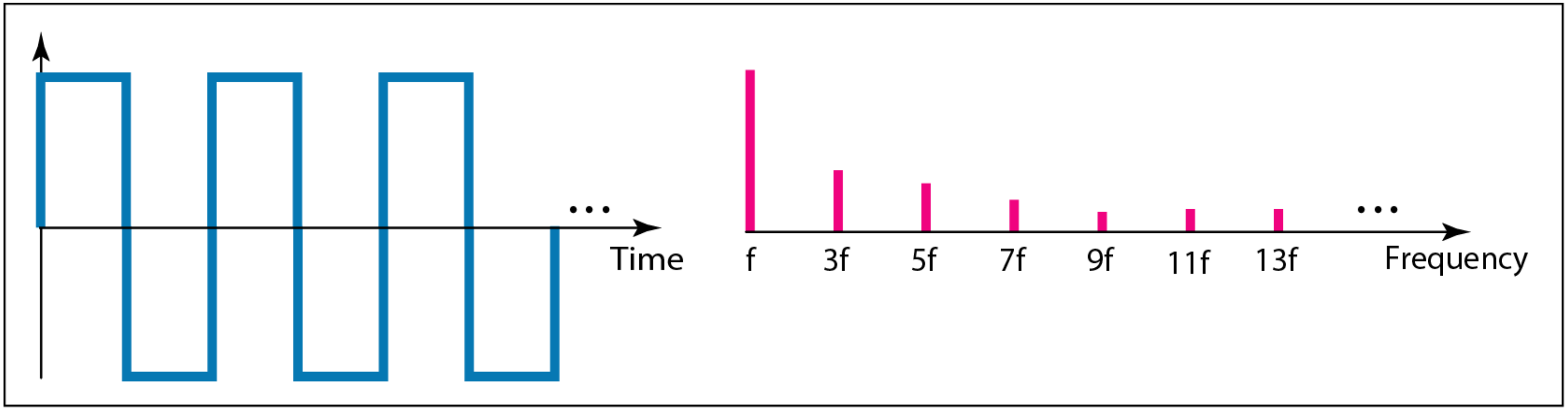
b. A digital signal with four levels

Bit Rate and Bit Interval

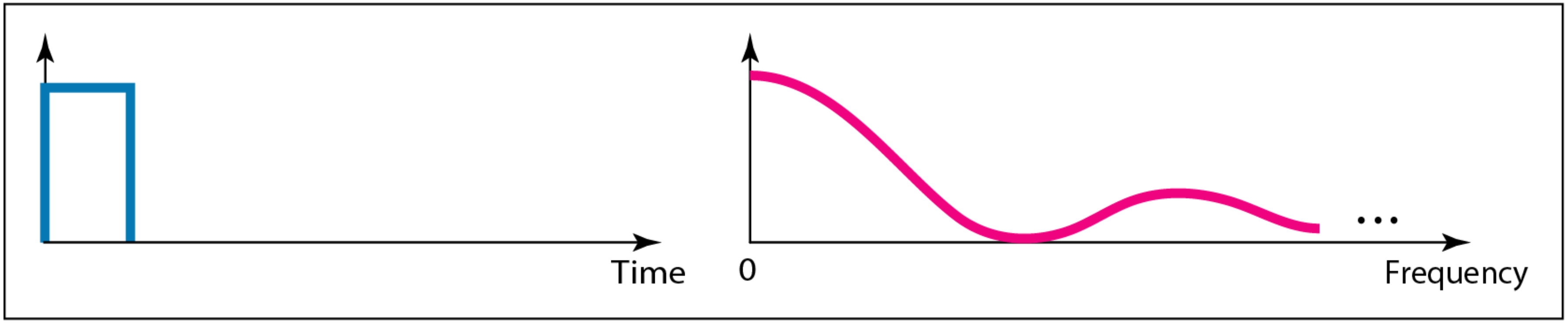
- ***Bit rate –***
  - ✓ is the number of bits sent in 1s.
  - ✓. Expressed in bits per second(bps).
- ***Bit length*** –
  - ✓ is the distance one bit occupies on the transmission medium.
  - ✓ Bit length = propagation speed x bit duration.



Digital Signal as a Composite Analog Signal



a. Time and frequency domains of periodic digital signal



b. Time and frequency domains of nonperiodic digital signal

Transmission of Digital Signals

- ***Baseband Transmission***
  - means sending a digital signal over a channel without changing the digital signal to an analog signal.
    - A ***digital signal*** is a composite analog signal with an infinite bandwidth.
  - **Case1:** ***Low-Pass Channel with Wide Bandwidth***
    - ✓ Baseband transmission of a digital signal that preserves the shape of the digital signal is possible only if we have a low-pass channel with an infinite or very wide bandwidth.
  - **Case2:** ***Low-Pass Channel with Limited Bandwidth***
    - ✓ In baseband transmission, the required bandwidth is proportional to the bit rate; if we need to send bits faster, we need more bandwidth.

Transmission of Digital Signals

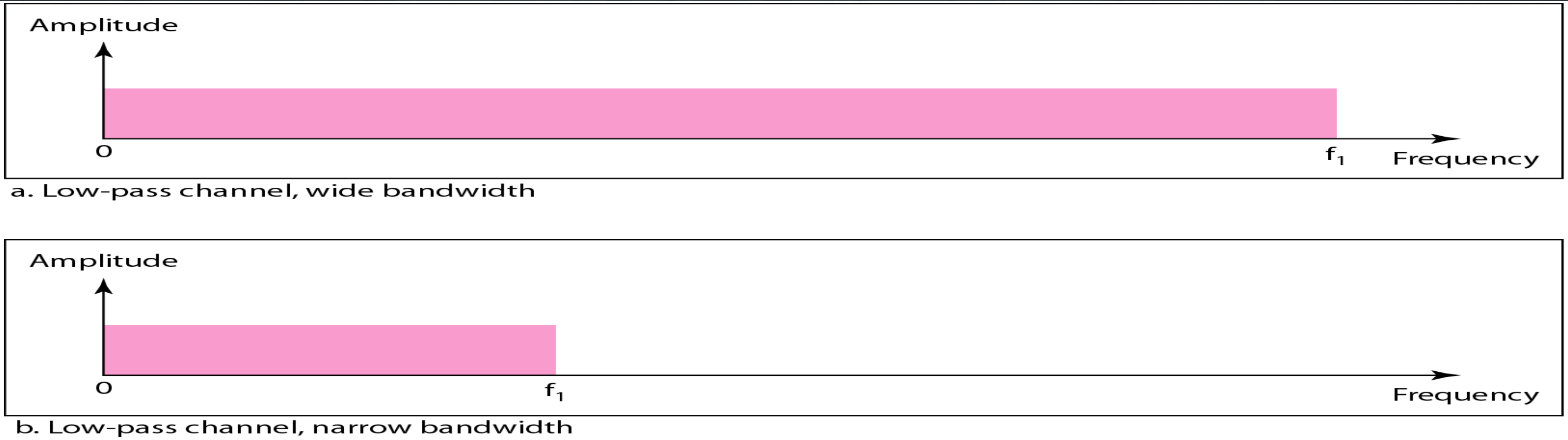


Figure- Bandwidths of two low-pass channels

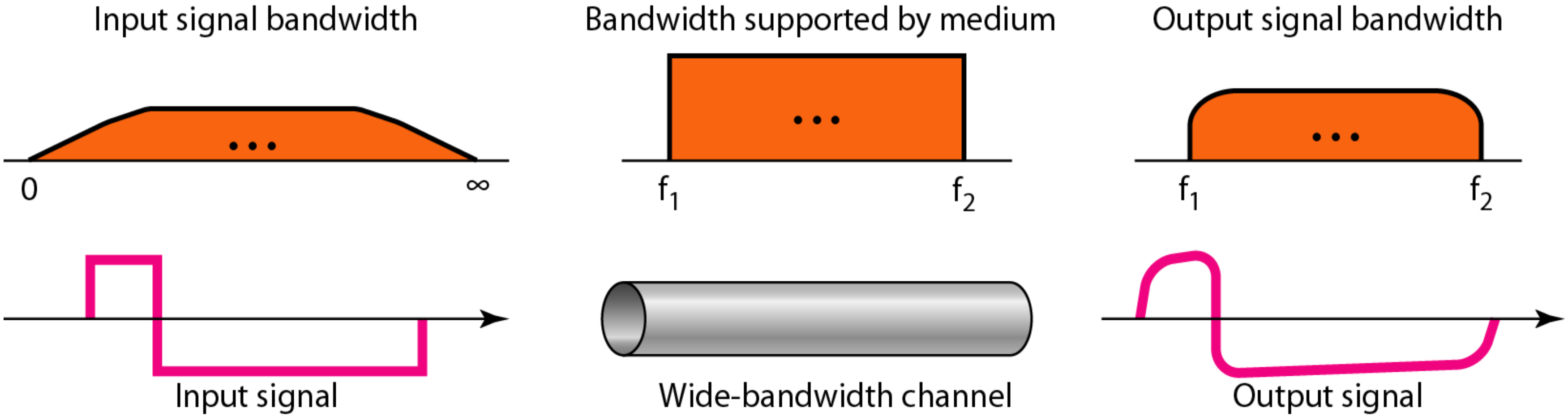


Figure - Baseband transmission using a dedicated medium

Transmission of Digital Signals

- ***Low-Pass Channel with Limited Bandwidth***

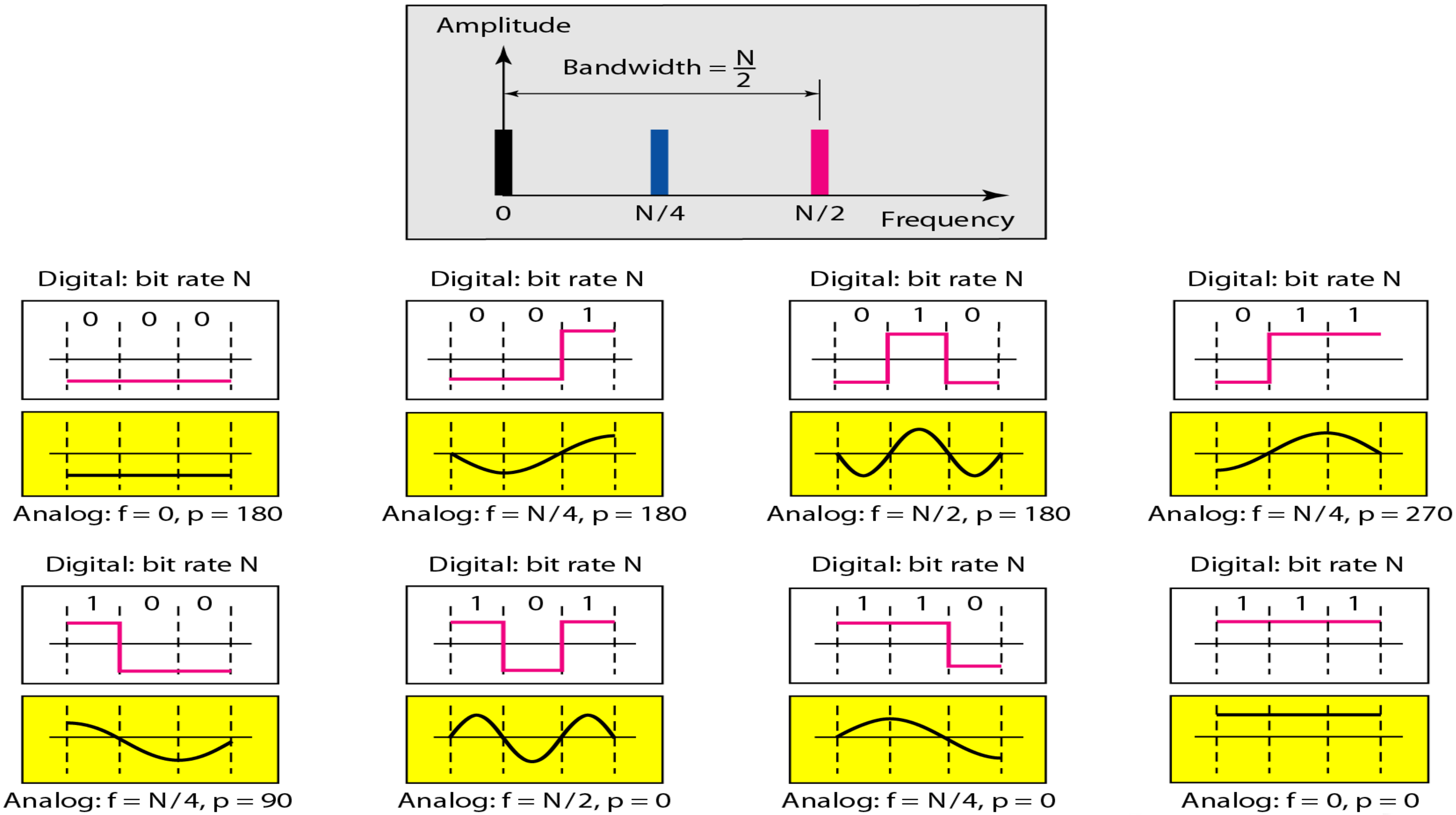


Figure - Rough approximation of a digital signal using the first harmonic for worst case

Transmission of Digital Signals

- ***Low-Pass Channel with Limited Bandwidth***

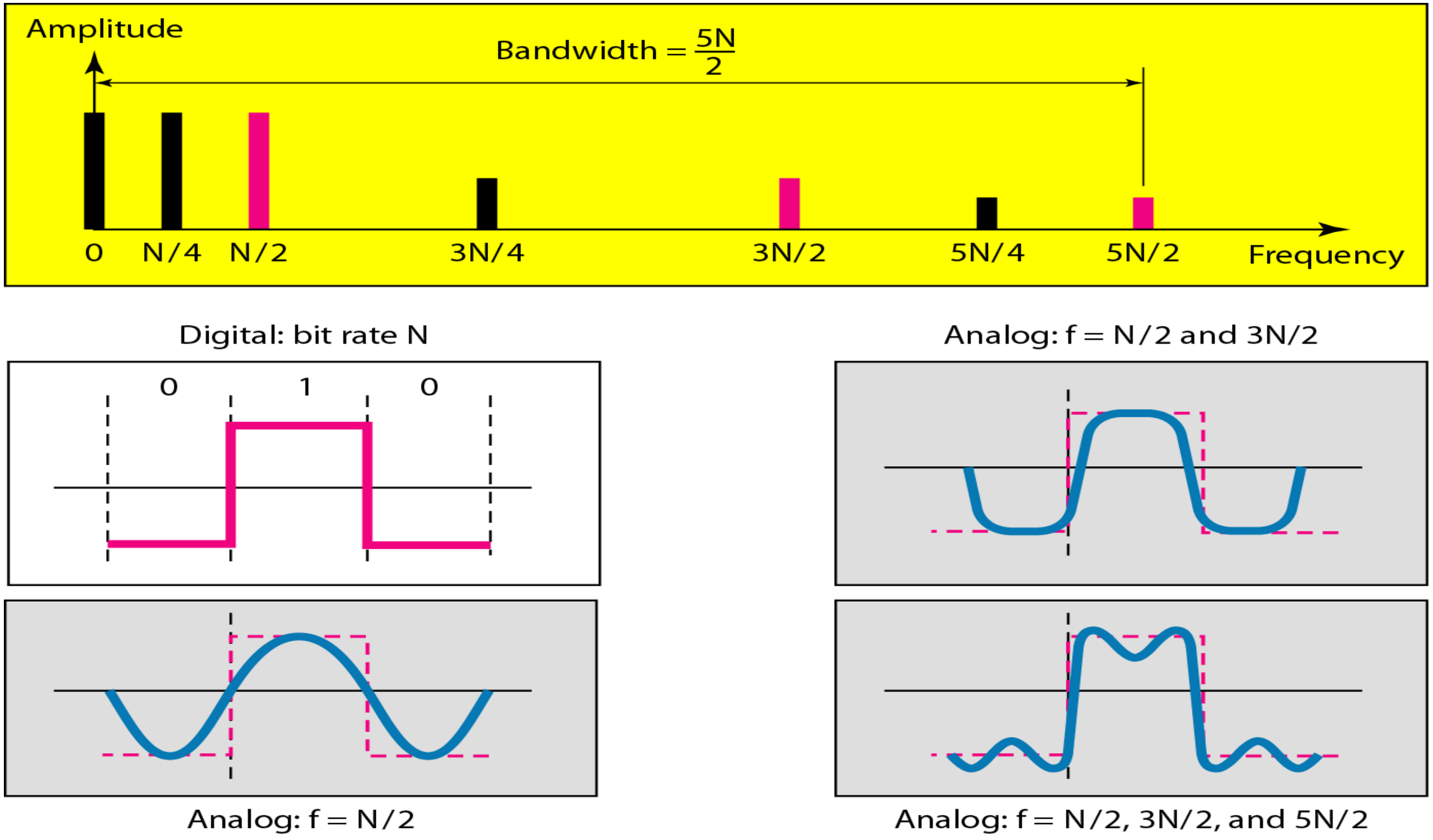


Figure - Simulating a digital signal with first three harmonics

Transmission of Digital Signals

❑ *Broadband Transmission*

- ✓ Modulation allows us to use a bandpass channel.
- ✓ If the available channel is a bandpass channel, we cannot send the digital signal directly to the channel; we need to convert the digital signal to an analog signal before transmission.

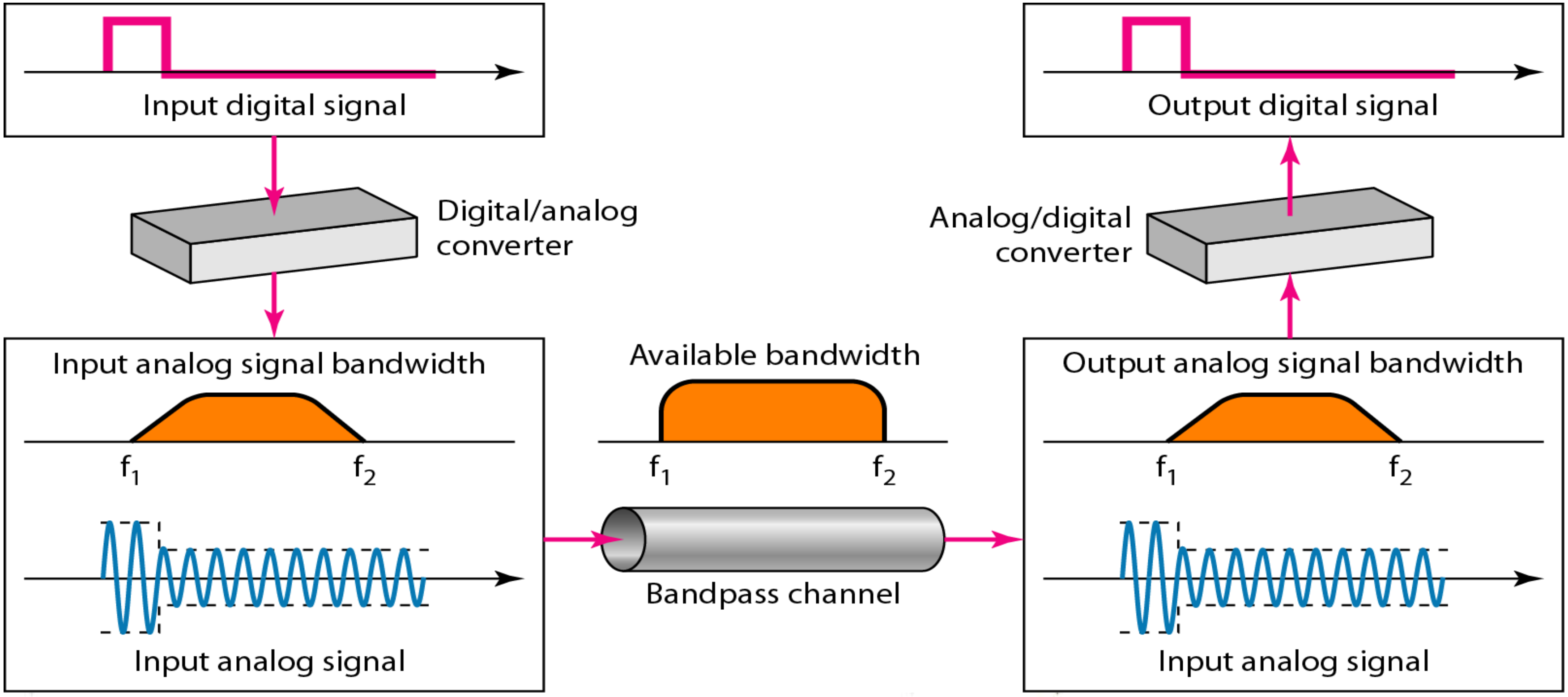
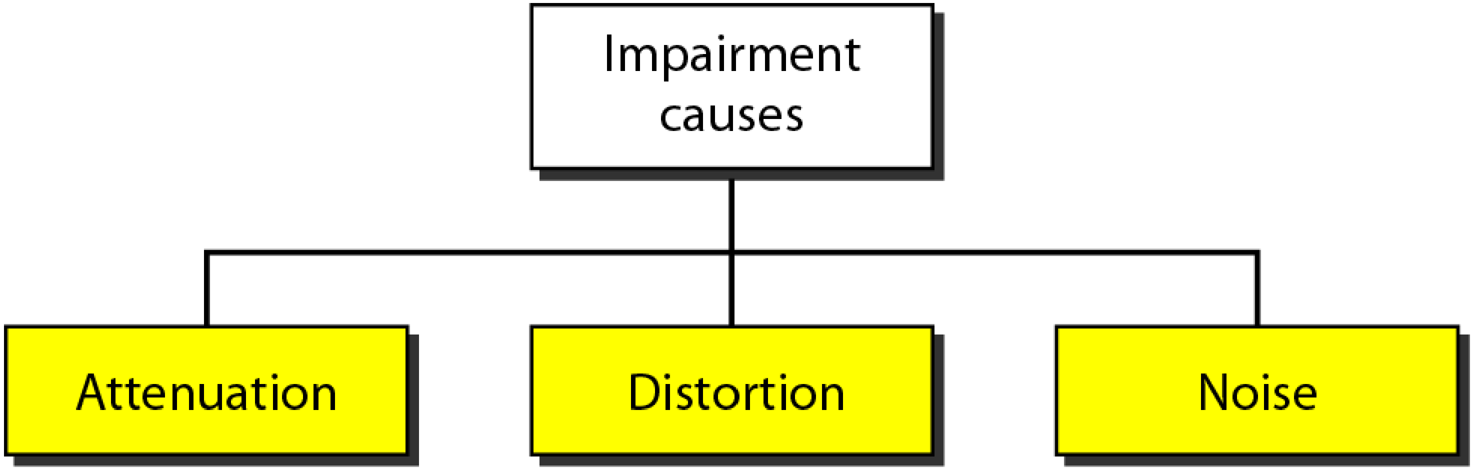


Figure - Modulation for Bandpass Channel

Transmission Impairment

- ***Transmission Impairment***
  - ✓ Signals travel through transmission media, which are not perfect.
  - ✓ The imperfection causes signal impairment.
  - ✓ Means that the signal at the beginning of the medium is not same as the signal at the end of the medium.
  - ✓ What is sent is not what is received.

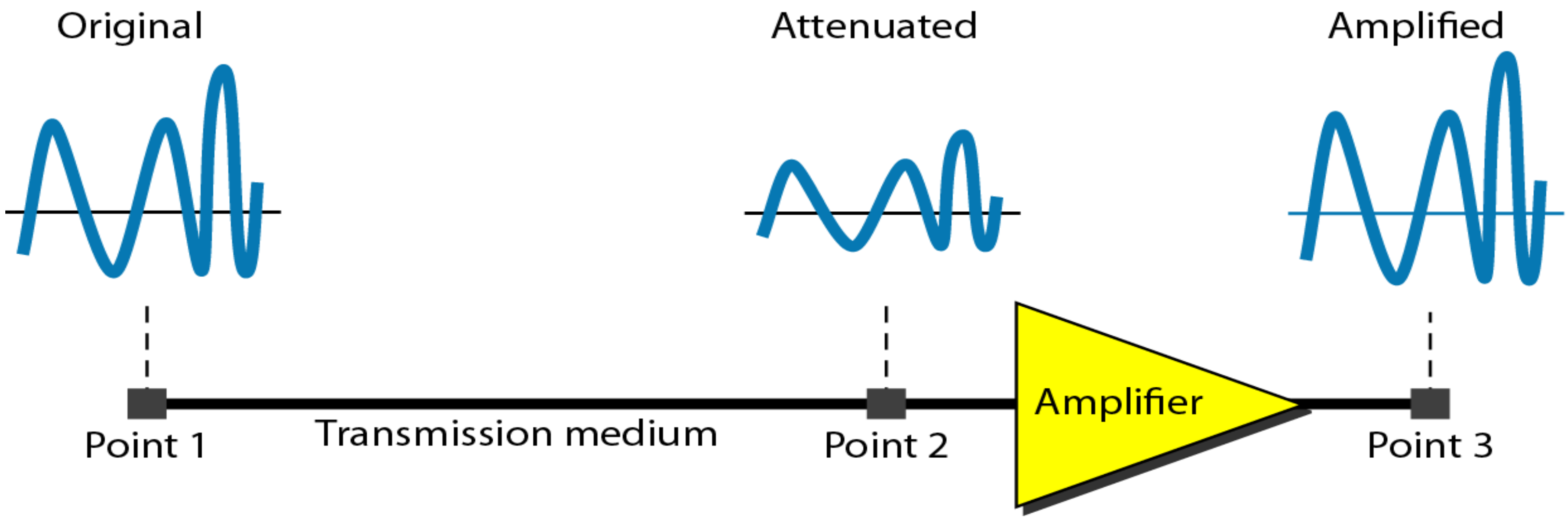


Transmission Impairment

❖ ***Attenuation***

✓ Means loss of energy to overcome the resistance of the medium like as heat.

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

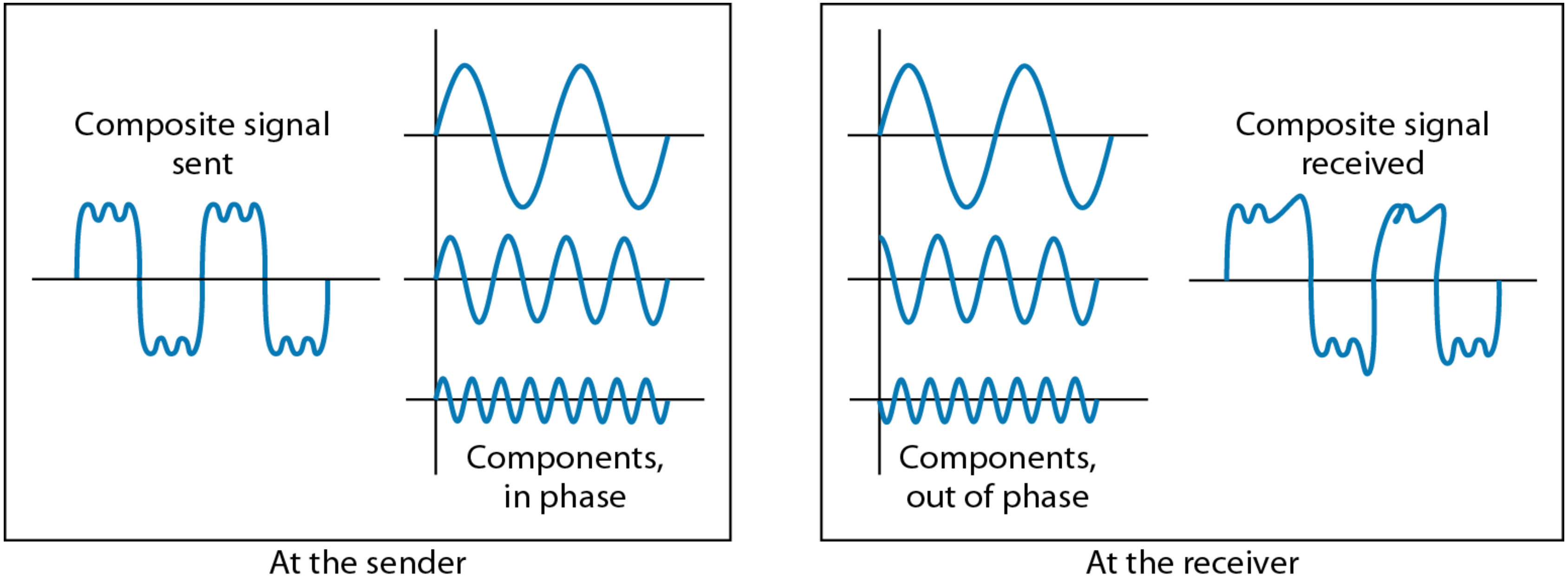


❑ ***Decibel (dB)*** measures the relative strengths of two signals or one signal at two different points.

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

Transmission Impairment

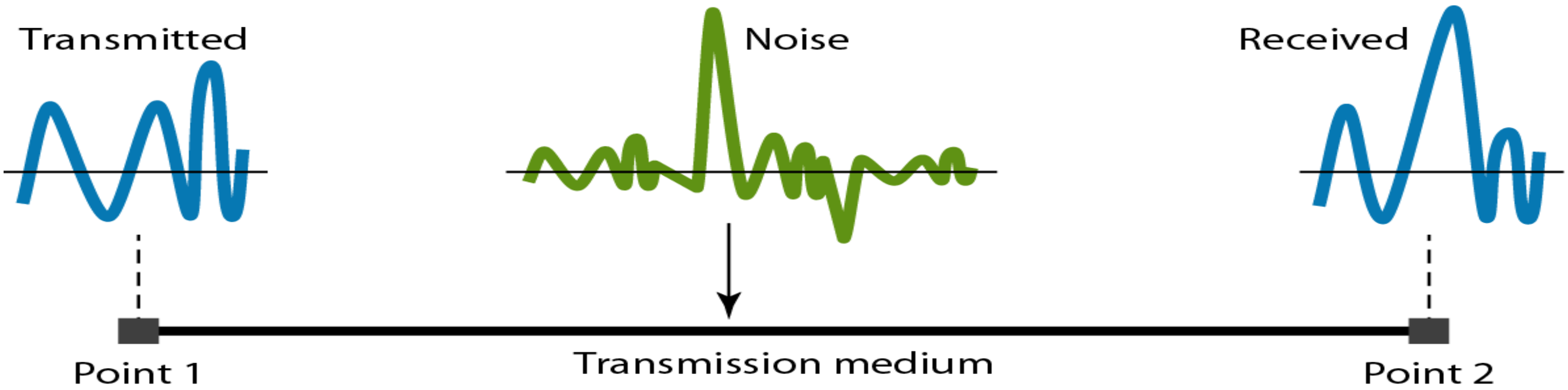
- ❖ ***Distortion***
  - ✓ The signal changes its form or shape.
  - ✓ Each signal component in a composite signal has its own propagation speed.
  - ✓ Differences in delay may cause a difference in phase.



Transmission Impairment

❖ ***Noise***

✓ Several types of noises, such as thermal noise, induced noise, crosstalk, and impulse noise, may corrupt the signal.



❖ ***Signal-to-Noise Ratio (SNR)***

- To find the theoretical bit rate limit
- SNR = average signal power/average noise power
- $SNR_{dB} = 10 \log_{10} SNR$

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)

❖ **Noiseless channel: *Nyquist Bit Rate***

Bit rate = 2 * Bandwidth * $\log_2 L$,   L is number of signal level

- ✓ Increasing the levels may cause the reliability of the system

❖ **Noisy channel: *Shannon Capacity***

Capacity = Bandwidth * $\log_2(1 + SNR)$

➢ The Shannon capacity gives us the upper limit; the Nyquist formula tells us how many signal levels we need.

Performance

- ***Bandwidth (in two contexts)***
  - ***Bandwidth in hertz***, refers to the range of frequencies in a composite signal or the range of frequencies that a channel can pass.
  - ***Bandwidth in bits per second***, refers to the speed of bit transmission in a channel or link.

- ***Throughput***
  - Measurement of how fast we can actually send data through a network.

- ***Latency (Delay)***
  - Define how long it takes for an entire message to completely arrive at the destination from the time the first bit is sent out from the source.
  - Latency = propagation time + transmission time + queuing time + processing delay.
  - Propagation time = Distance/Propagation speed
  - Transmission time = Message size/Bandwidth

Thank To All …