Data and Signals

Topics of Discussion

- ***Data and Signals***

  - *Analog and Digital Signals*

  - *Periodic and Non Periodic Signals*

- ***Periodic Analog Signals***

  - *Sine Wave*

  - *Amplitude , Frequency, Phase*

  -*Wavelength*

  - *Time domain and Frequency Domain*

  - *Composite Signals*

  - *Bandwidth*

Digital Signals

- *Bit rate*

Analog and Digital Data

- *Data can be **analog or digital**. The term analog data refers to information that is continuous;*
- *Digital data refers to information that has **discrete states**.*

Analog and Digital Signals

- *Like the data they represent, **signals can be either analog or digital**. An analog signal has infinitely many levels of intensity over a period of time. As the wave moves from value A to value B, it passes through and includes an infinite number of values along its path.*
- *A digital signal, on the other hand, can have only a **limited number of defined values**. Although each value can be any number, it is often as simple as 1 and 0.*

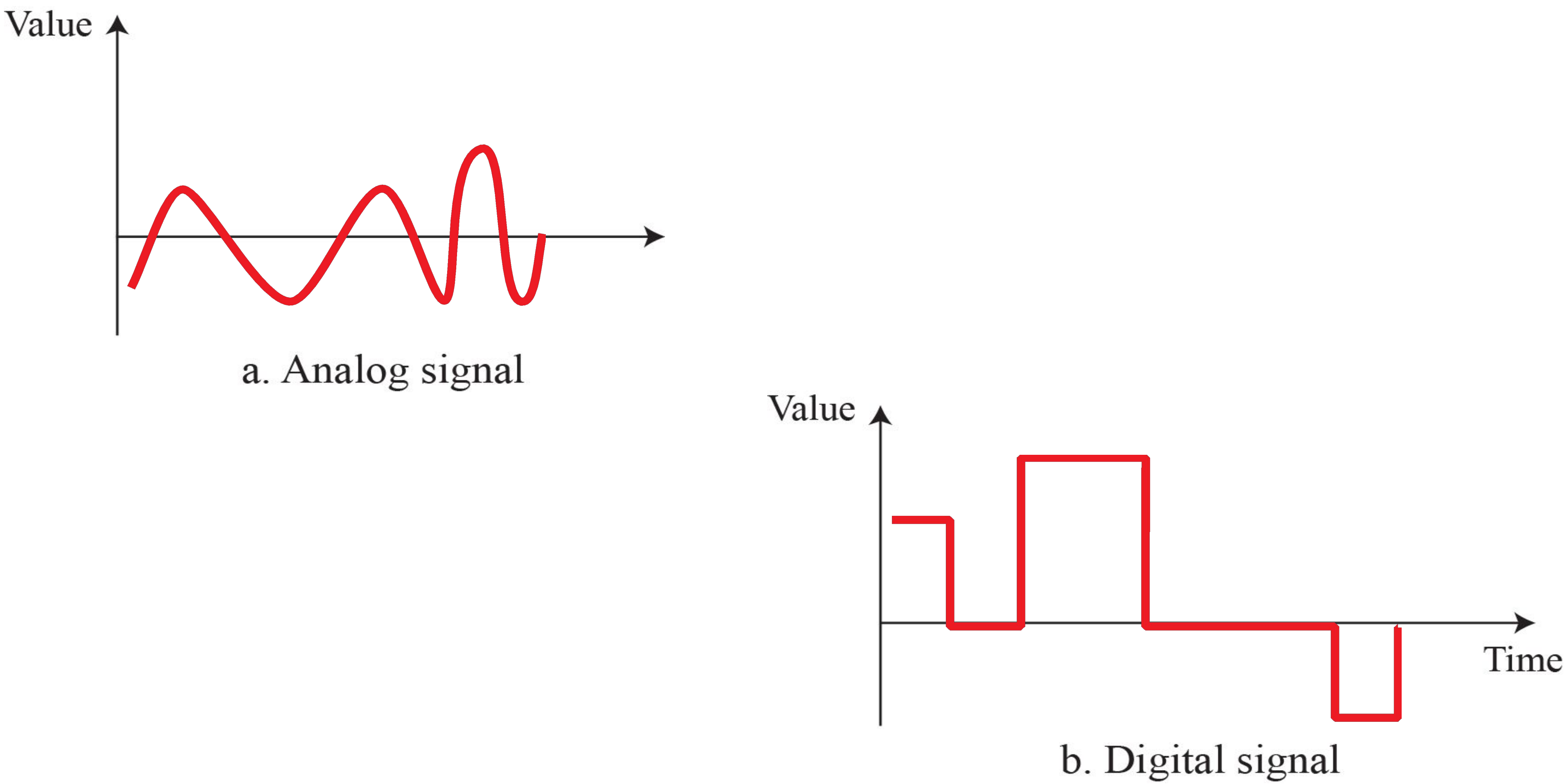


Figure 1: Comparison of analog and digital signals

Periodic and Nonperiodic

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

- *A nonperiodic signal changes without exhibiting a pattern or cycle that repeats over time.*

Periodic Analog Signals

- *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.*

Sine Wave

The sine wave is the most fundamental form of a periodic analog signal. When we visualize it as a simple oscillating curve, its change over the course of a cycle is smooth and consistent, a continuous, rolling flow.

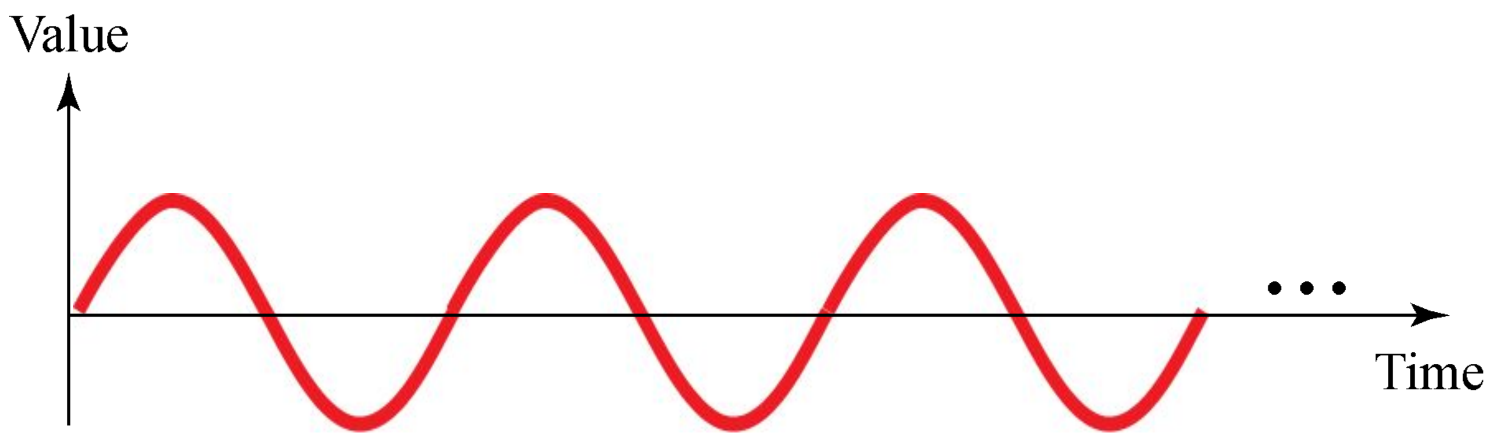


Figure 2: A sine wave

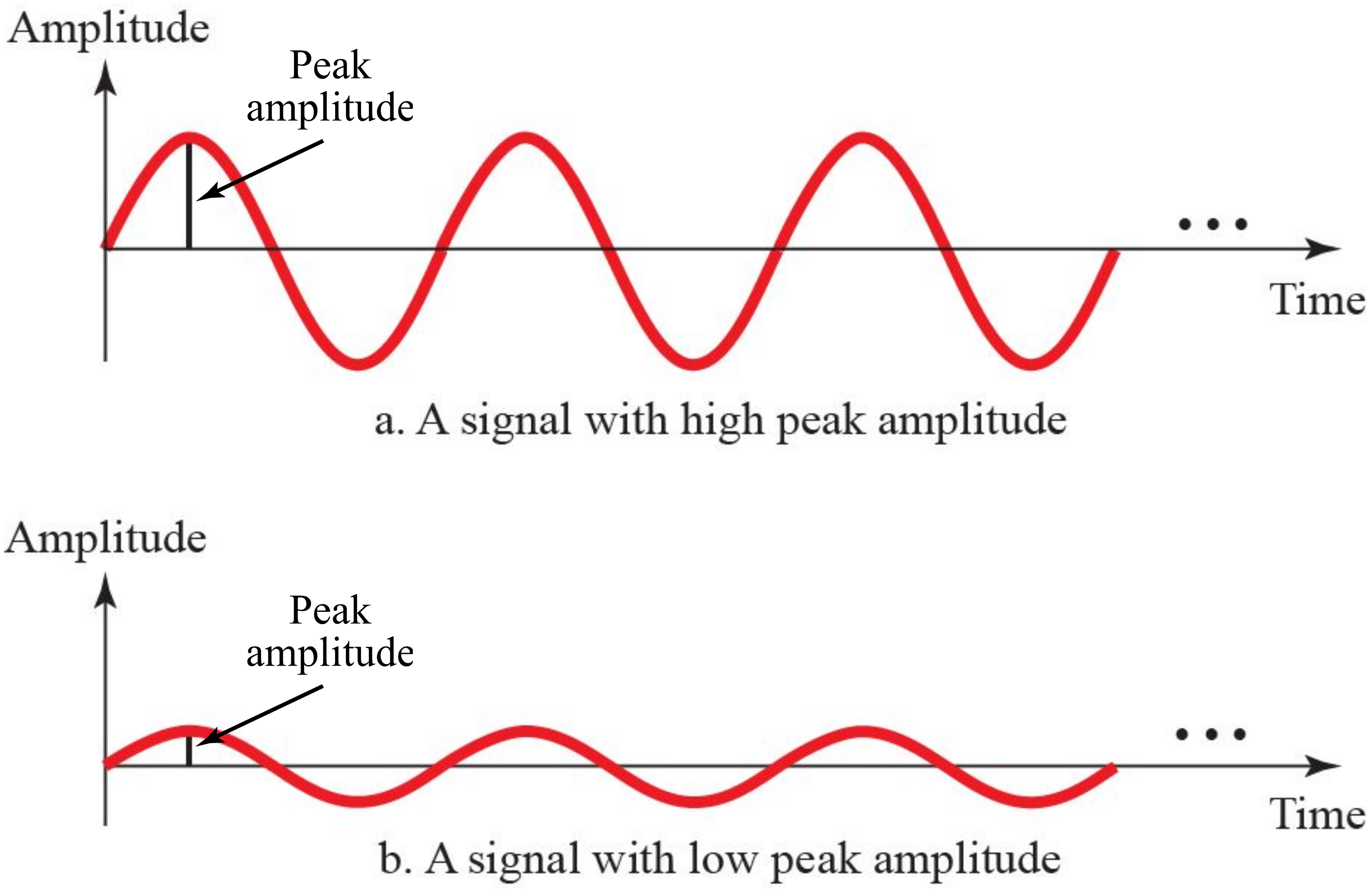


Figure 3: Two signals with two different amplitudes

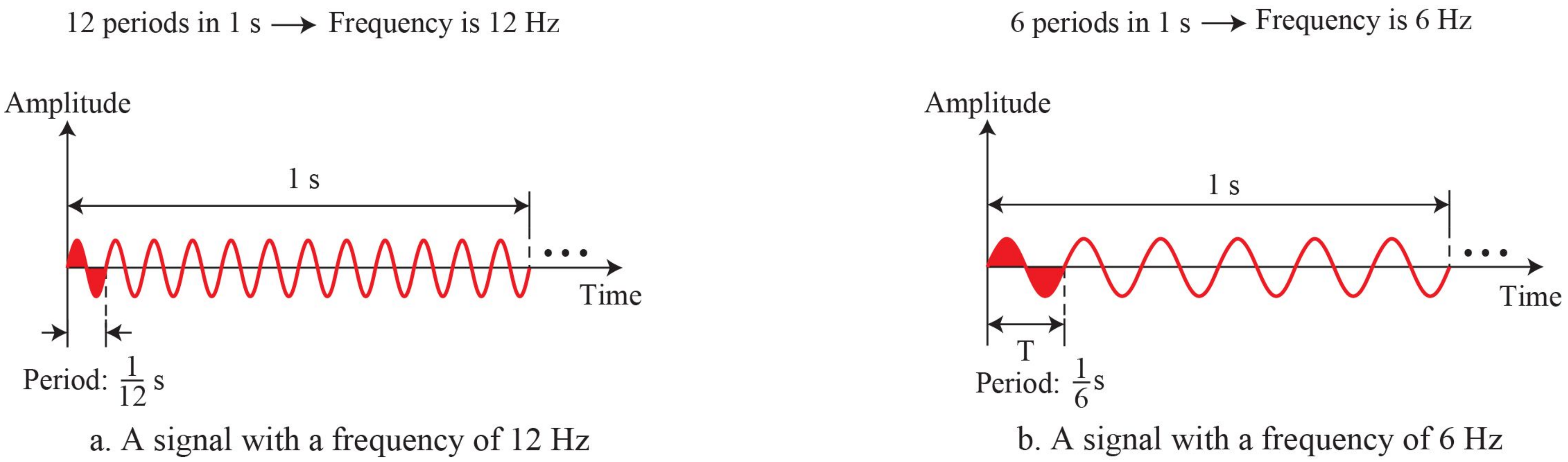


Figure 4: Two signals with the same phase and amplitude, but different frequency

Table 1: **Units of period and frequency**

Period		*Frequency*	
Unit	*Equivalent*	*Unit*	*Equivalent*
Seconds (s)	1 s	Hertz (Hz)	1 Hz
Milliseconds (ms)	10^{-3} s	Kilohertz (kHz)	10^{3} Hz
Microseconds (μs)	10^{-6} s	Megahertz (MHz)	10^{6} Hz
Nanoseconds (ns)	10^{-9} s	Gigahertz (GHz)	10^{9} Hz
Picoseconds (ps)	10^{-12} s	Terahertz (THz)	10^{12} Hz

Example 1: Express a period of 100 ms in microseconds

$$100 \text{ ms} = 100 \times 10^{-3} \text{ s} = 100 \times 10^{-3} \times 10^{6} \text{ }\mu\text{s} = 10^{2} \times 10^{-3} \times 10^{6} \text{ }\mu\text{s} = 10^{5} \text{ }\mu\text{s}$$

Example 2: The period of a signal is 100 ms. What is its frequency in kilohertz?.

$$100 \text{ ms} = 100 \times 10^{-3} \text{ s} = 10^{-1} \text{ s}$$

$$f = \frac{1}{T} = \frac{1}{10^{-1}} \text{Hz} = 10 \text{ Hz} = 10 \times 10^{-3} \text{ kHz} = 10^{-2} \text{ kHz}$$

Phase

- *The term phase, or phase shift, describes the position of the waveform relative to time 0. If we think of the wave as something that can be shifted backward or forward along the time axis, phase describes the amount of that shift. It indicates the status of the first cycle.*

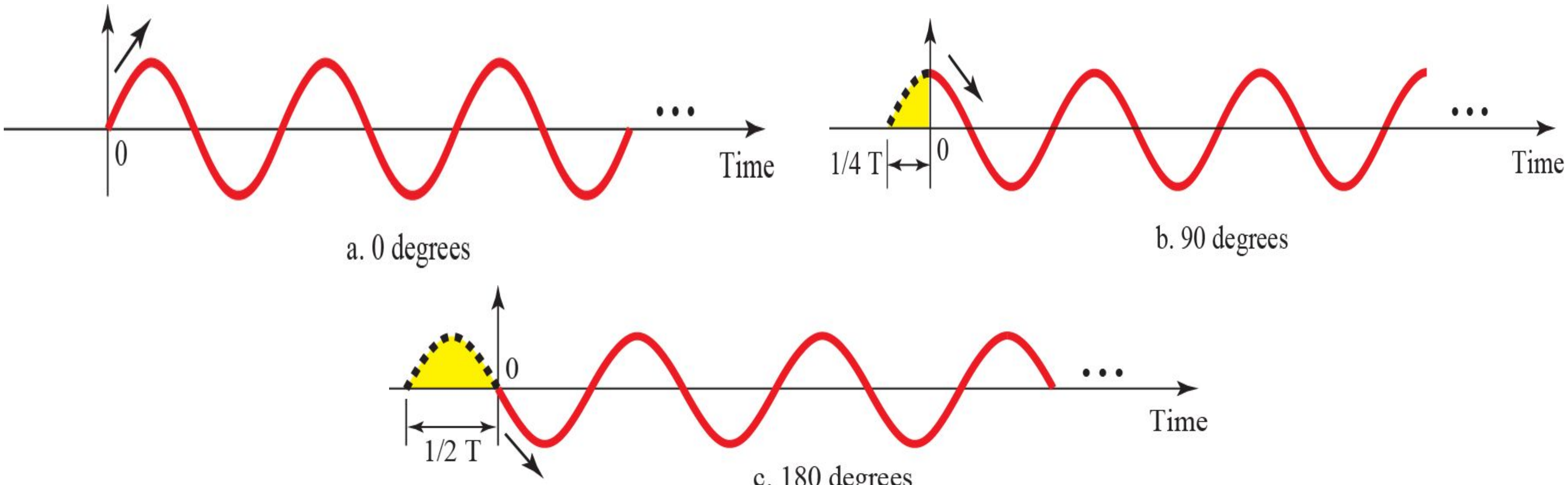


***Figure 5:* Three sine waves with different phases**

Wavelength

- *Wavelength is another characteristic of a signal traveling through a transmission medium. Wavelength binds the period or the frequency of a simple sine wave to the propagation speed of the medium .*

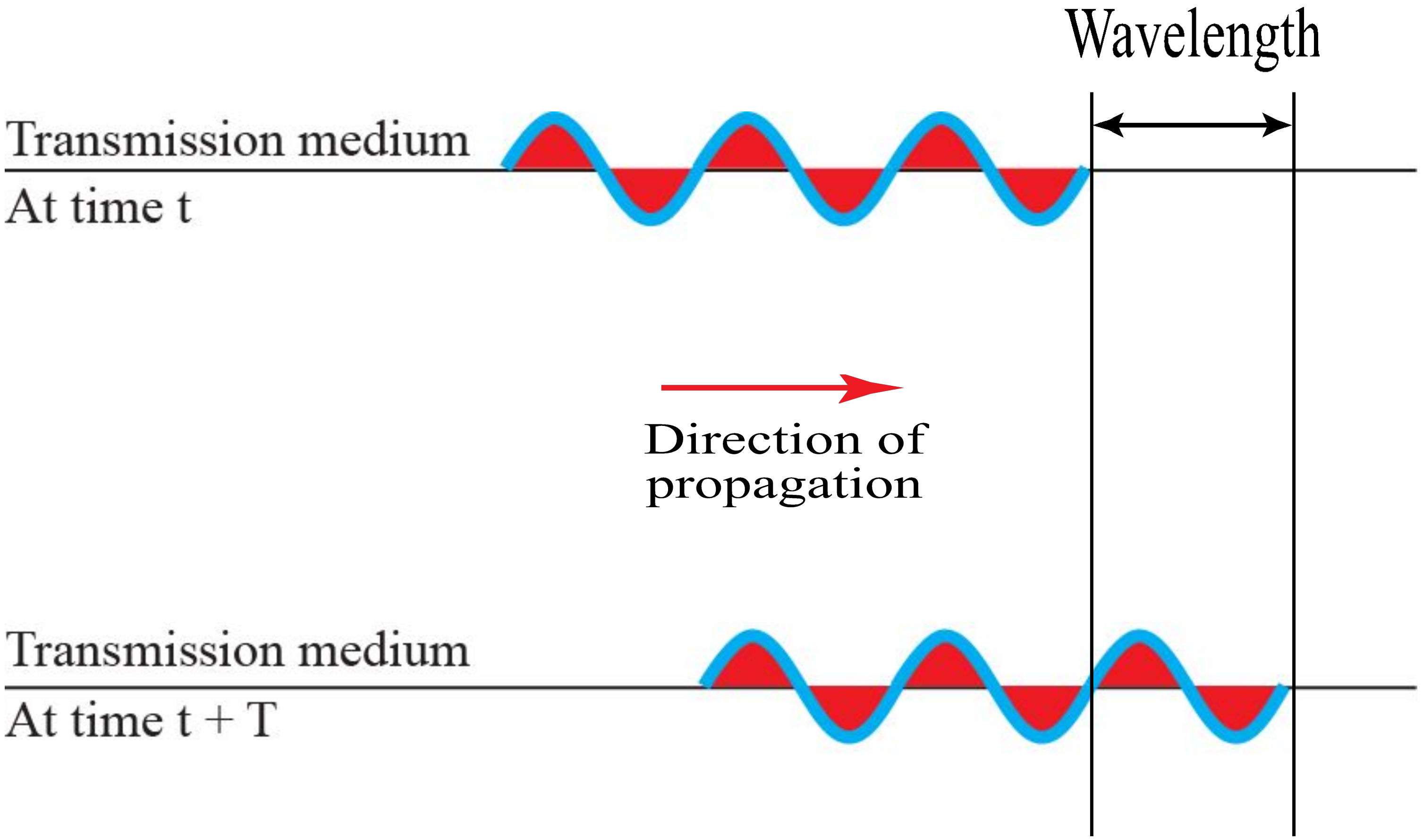
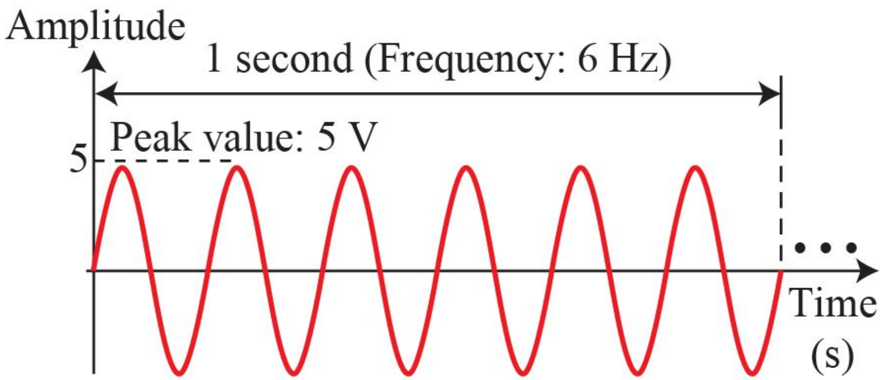


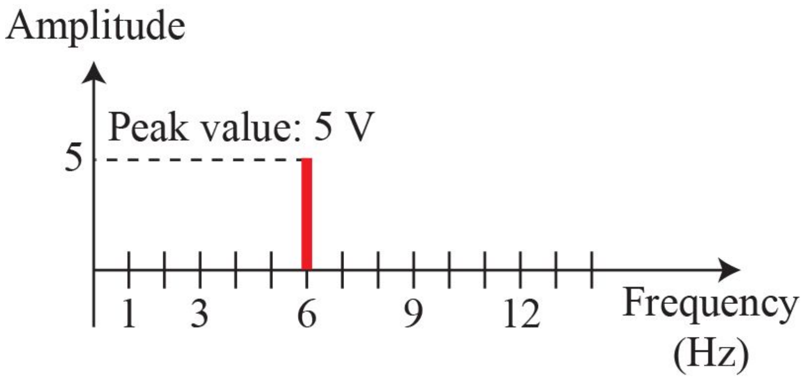
Figure 6:* *Wavelength and period

Time and Frequency Domains

A sine wave is comprehensively defined by its amplitude, frequency, and phase. We have been showing a sine wave by using what is called a time domain plot. The time-domain plot shows changes in signal amplitude with respect to time (it is an amplitude-versus-time plot).



a. A sine wave in the time domain



b. The same sine wave in the frequency domain

***Figure 7:** The time-domain and frequency-domain plots of a sine wave*

Example

The frequency domain is more compact and useful when we are dealing with more than one sine wave. Figure 8 shows three sine waves, each with different amplitude and frequency. All can be represented by three spikes in the frequency domain.

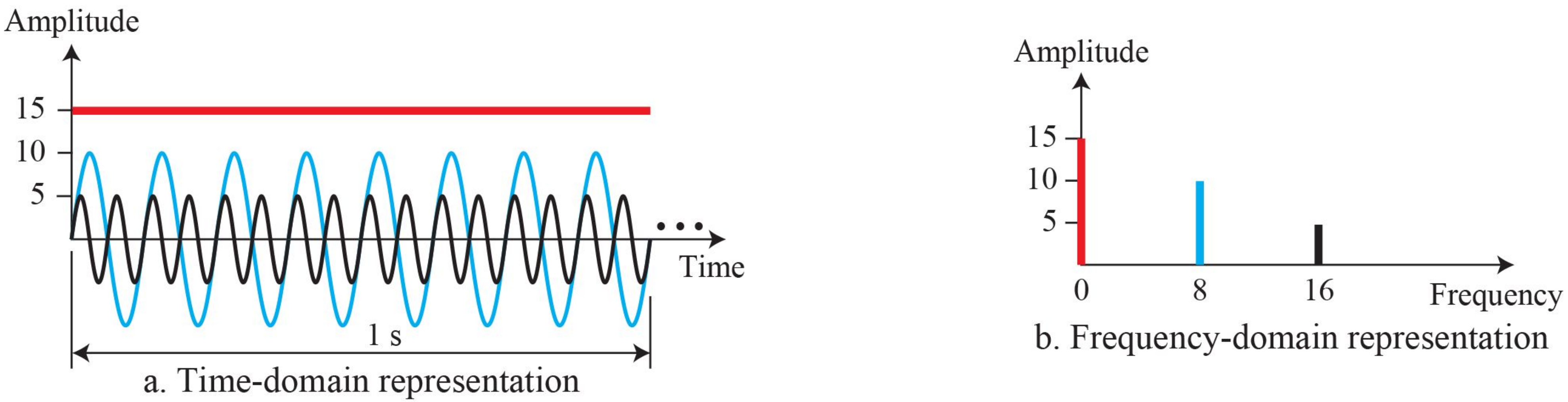


Figure 8: The time domain and frequency domain of three sine waves

Composite Signals

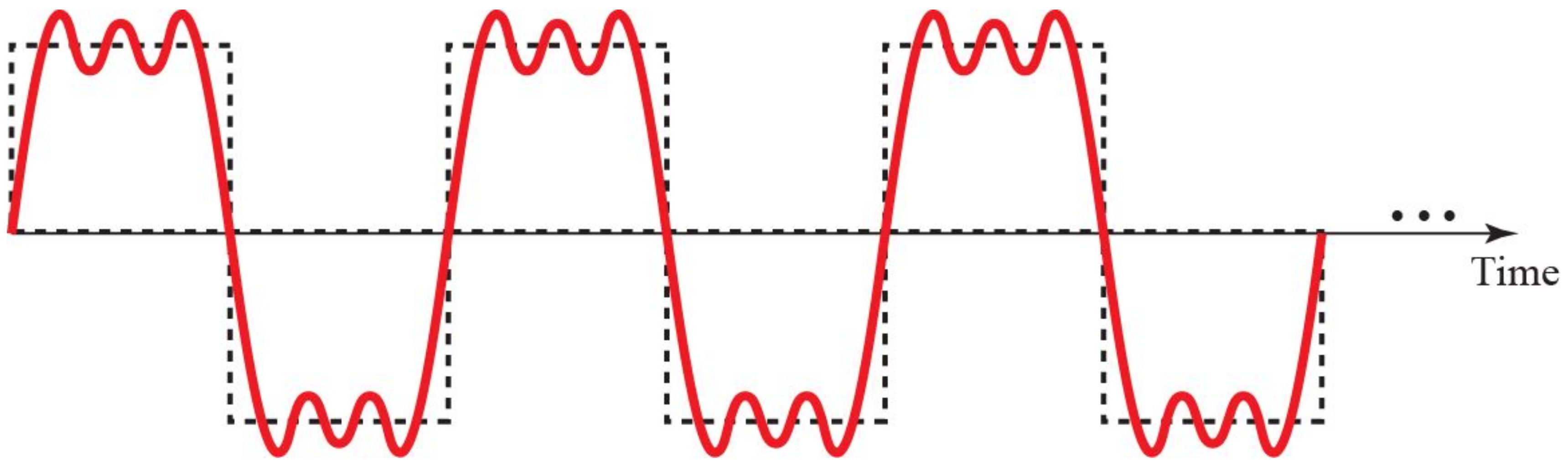
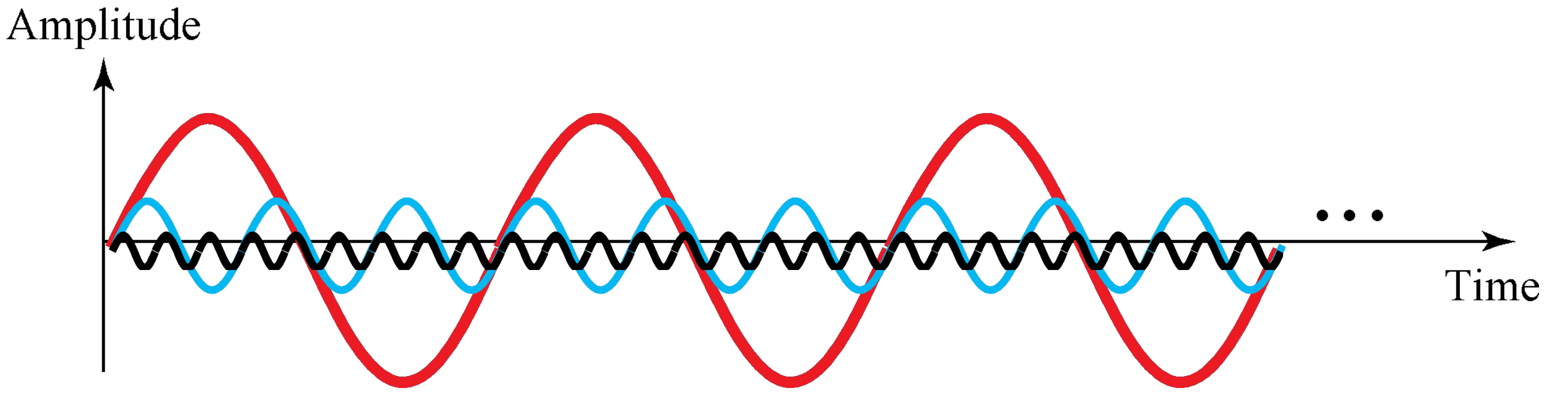
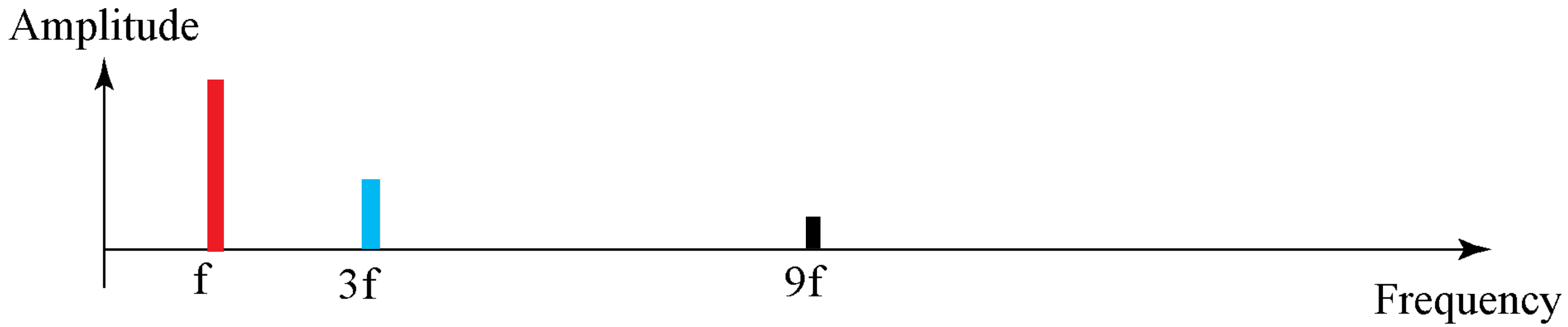


Figure 9: A composite periodic signal

Decomposition of a composite periodic signal



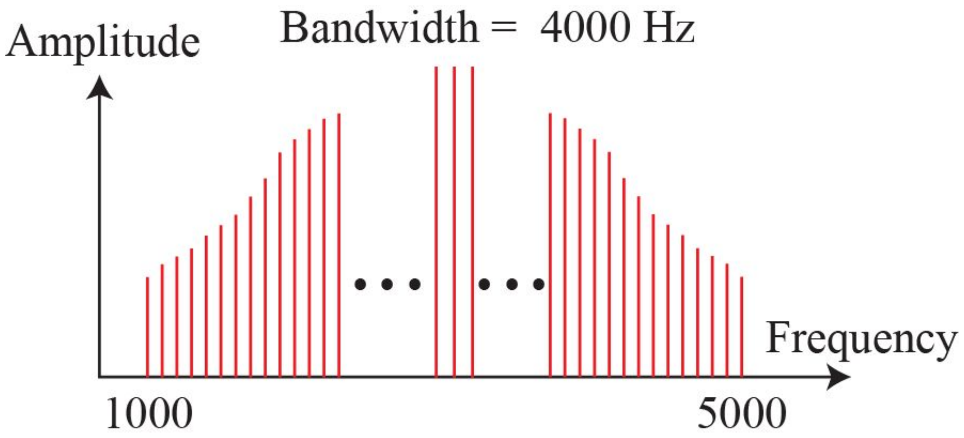
a. Time –Domain decomposition of the composite signal



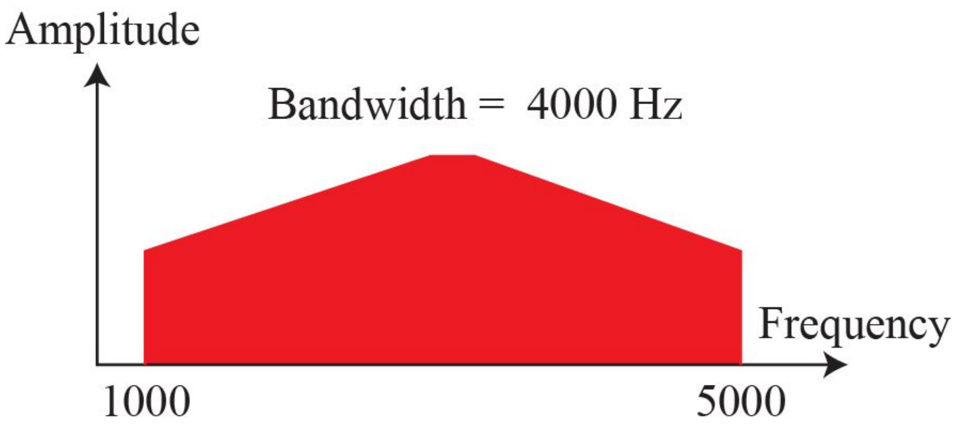
b. Frequency-domain decomposition of the composite signal

Bandwidth

The range of frequencies contained in a composite signal is its bandwidth. The bandwidth is normally a difference between two numbers. For example, if a composite signal contains frequencies between 1000 and 5000, its bandwidth is 5000 − 1000, or 4000



a. Bandwidth of a periodic signal



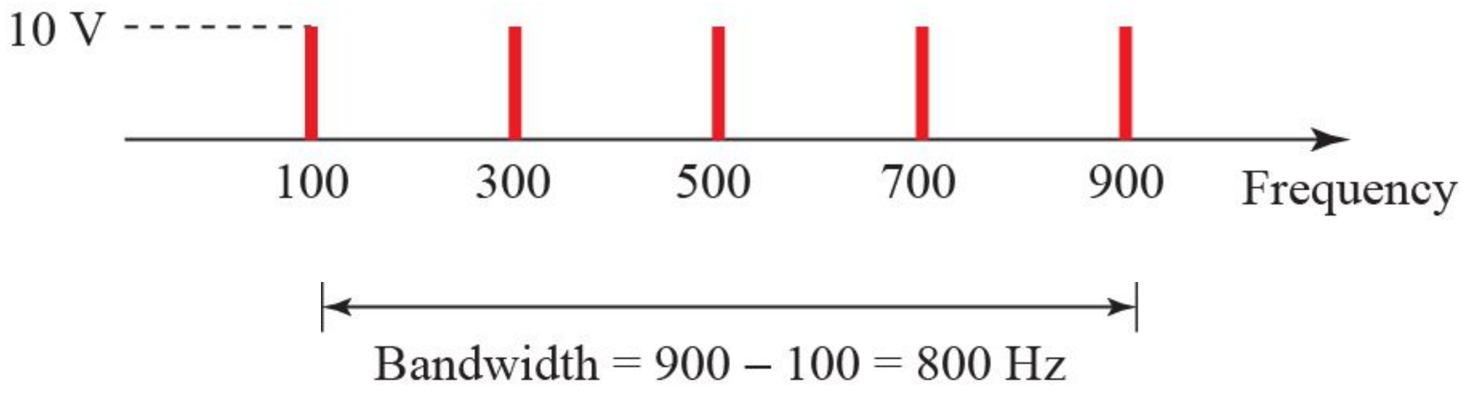
b. Bandwidth of a nonperiodic signal

***Figure 10:** The bandwidth of periodic and nonperiodic composite signals*

Example 1: *If a periodic signal is decomposed into five sine waves with frequencies of 100, 300, 500, 700, and 900 Hz, what is its bandwidth? Draw the spectrum, assuming all components have a maximum amplitude of 10 V.*

Solution: *Let f_h be the highest frequency, f_l the lowest frequency, and B the bandwidth. Then*

$$B = f_h - f_l = 900 - 100 = 800 \text{ Hz}$$



Example 2: A periodic signal has a bandwidth of 20 Hz. The highest frequency is 60 Hz. What is the lowest frequency? Draw the spectrum if the signal contains all frequencies of the same amplitude.

Solution: *Let f_h be the highest frequency, f_l the lowest frequency, and B the bandwidth. Then*

$$B = f_h - f_l \longrightarrow 20 = 60 - f_l \longrightarrow f_l = 60 - 20 = 40 \text{ Hz}$$

The spectrum contains all integer frequencies. We show this by a series of spikes.

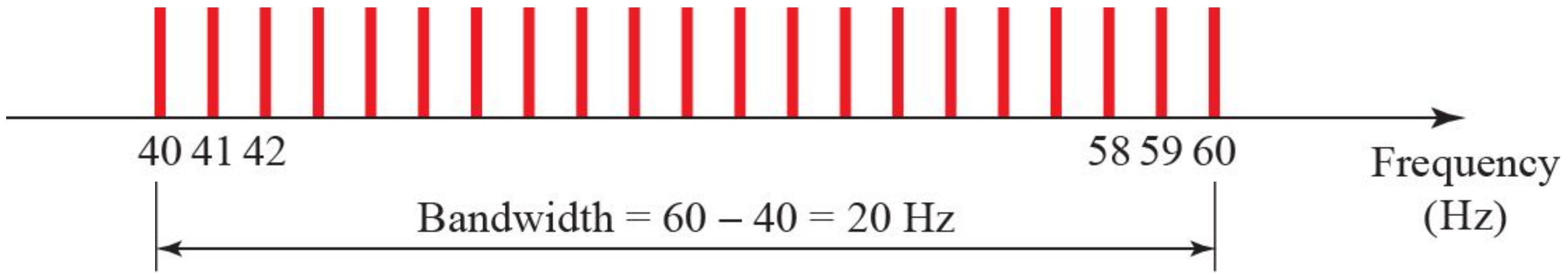
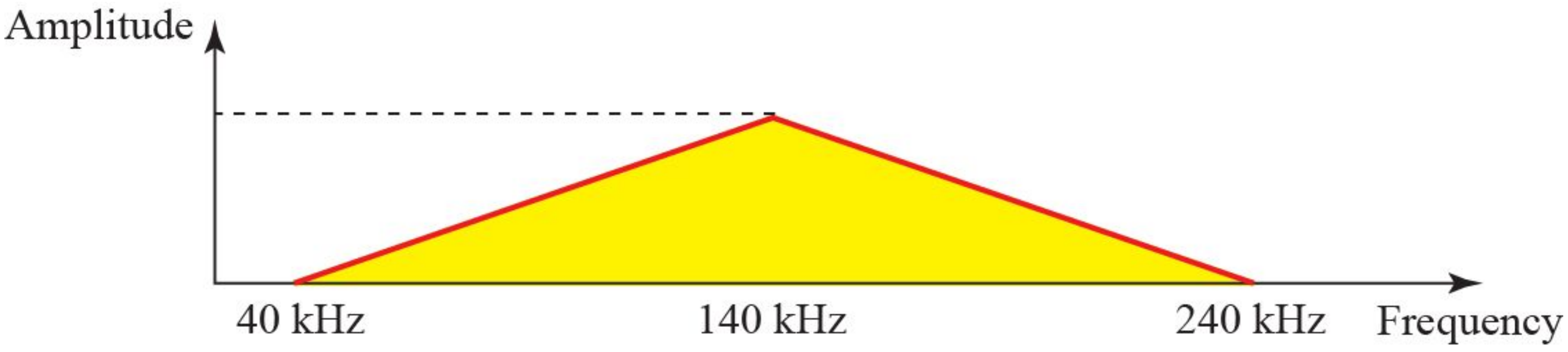


***Figure 11:* The bandwidth for example 3.11**

Example : *A non-periodic composite signal has a bandwidth of 200 kHz, with a middle frequency of 140 kHz and peak amplitude of 20 V. The two extreme frequencies have an amplitude of 0. Draw the frequency domain of the 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.

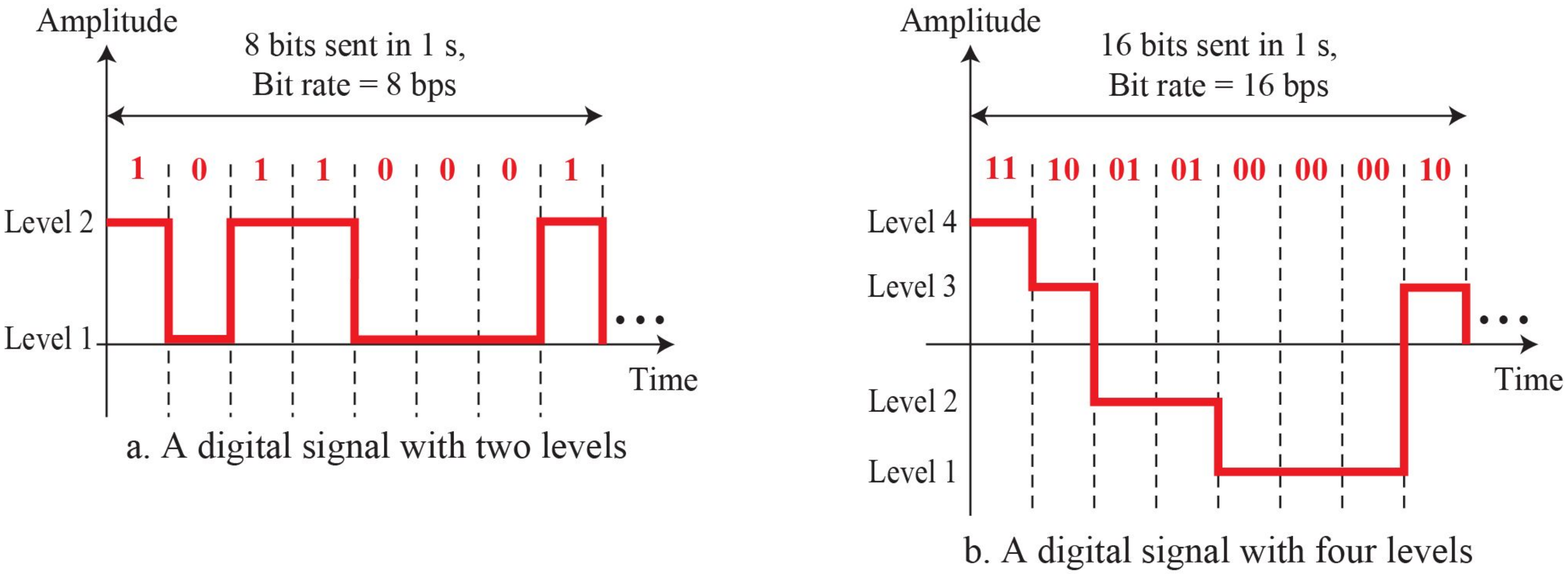


Figure 12: Two digital signals: one with two signal levels and the 0ther with four signal levels

Bit Rate

Most digital signals are nonperiodic, and thus period and frequency are not appropriate characteristics. Another term—bit rate (instead of frequency)—is used to describe digital signals. The bit rate is the number of bits sent in 1s, expressed in bits per second (bps).

Example: What is the bit rate for high-definition TV (HDTV)?

HDTV uses digital signals to broadcast high quality video signals. There are 1920 by 1080 pixels per screen, and the screen is renewed 30 times per second. Twenty-four bits represents one color pixel. We can calculate the bit rate as

$$1920 \times 1080 \times 30 \times 24 = 1{,}492{,}992{,}000 \approx 1.5 \text{ Gbps}$$

The TV stations reduce this rate to 20 to 40 Mbps through compression.

Summary of Discussion

In this session we have mainly discussed:

✔Data and Signals

✔Periodic analog signals

✔Digital signals

Thanks