Lecture (2)
" Data Communication”

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Data Classification

Data refers to values that can be collected, stored, processed, and communicated.

Data can represent many different types of information:

- Text: messages, documents, names
- Numbers: measurements, prices, scores
- Audio: human voice, music
- Images: photographs, diagrams
- Video: movies, video calls
- Sensor readings: temperature, pressure, speed, etc.

Data can be classified as:

Analog Data →continuous values

Digital Data →discrete values

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 data take on continuous values. Digital data take on discrete values.

Note

To be transmitted, data must be transformed to electromagnetic signals.

From Data to Electromagnetic Signals

Data must be transformed into electromagnetic signals.

Data →Transmitter →Electromagnetic Signal →Communication Channel →Receiver →Data

Data: Information to be transmitted, such as text, audio, images,

Transmitter: Converts the data into a suitable electromagnetic signal .

Signal: Carries the information through the communication medium .

Receiver: Receives and converts the signal back into the original data .

Example:

A voice message →electrical/digital data →electromagnetic signal →wireless channel →received signal →voice message.

Analog and Digital Data &Signals

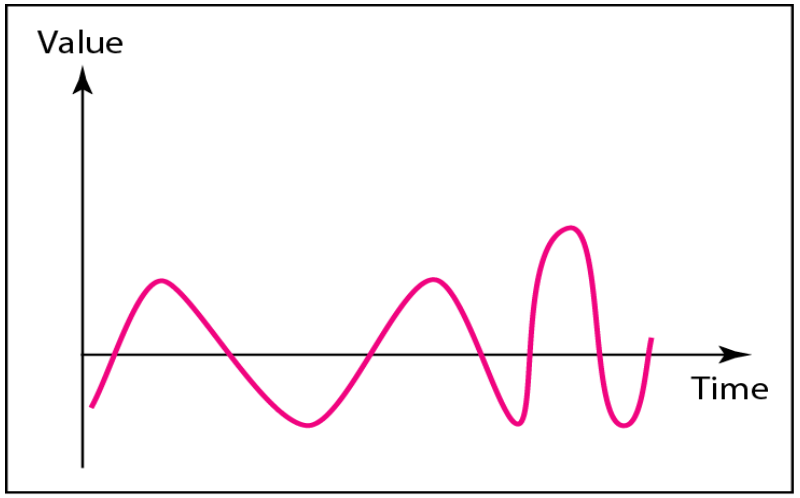
- Data can be analog or digital where **analog data** are continuous and take continuous values.

Digital data have discrete states and take discrete values.

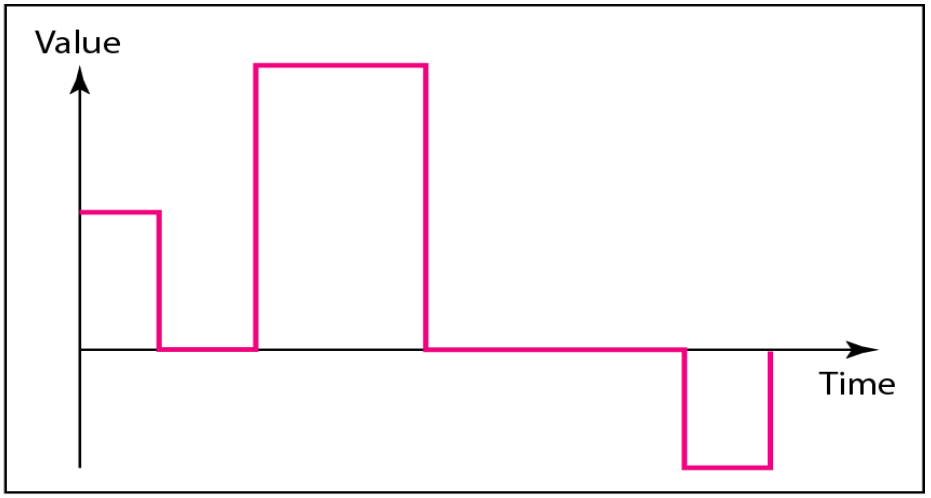
Note

Signals can be analog or digital.
Analog signals can have an infinite number of values in a range; digital signals can have only a limited number of values.

Comparison of analog and digital signals



a. Analog signal



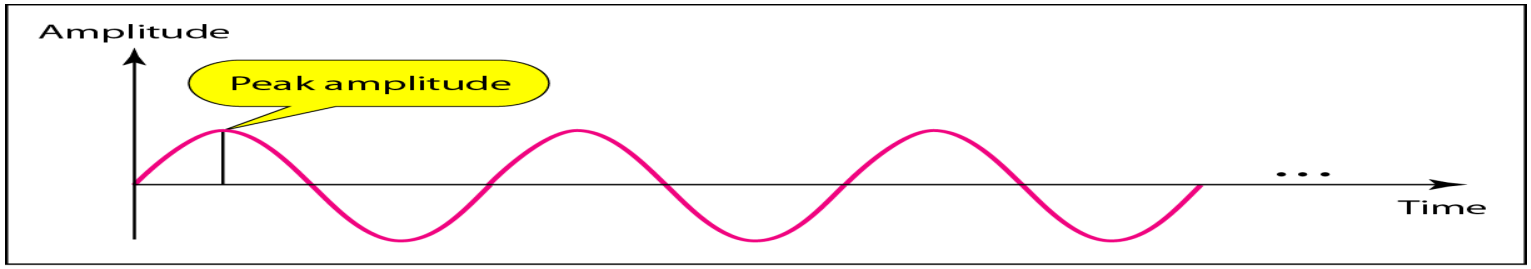
b. Digital signal

Note

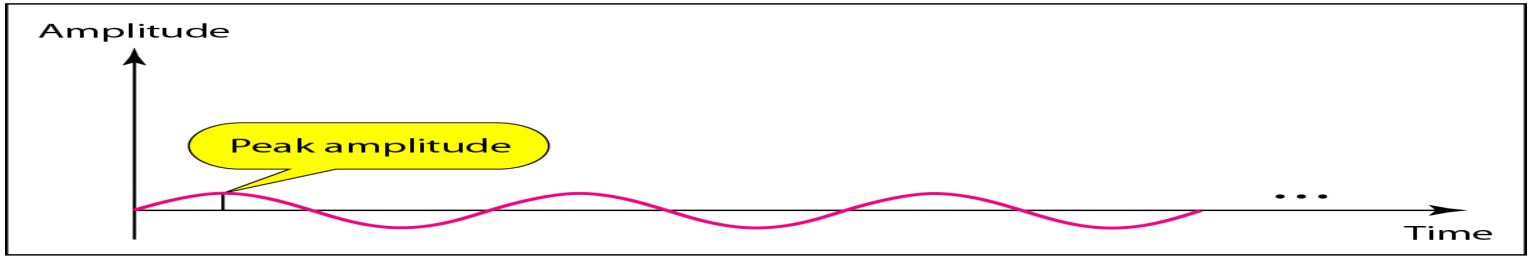
In data communications, we commonly use periodic analog signals and non-periodic digital signals.

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.



a. A signal with high peak amplitude



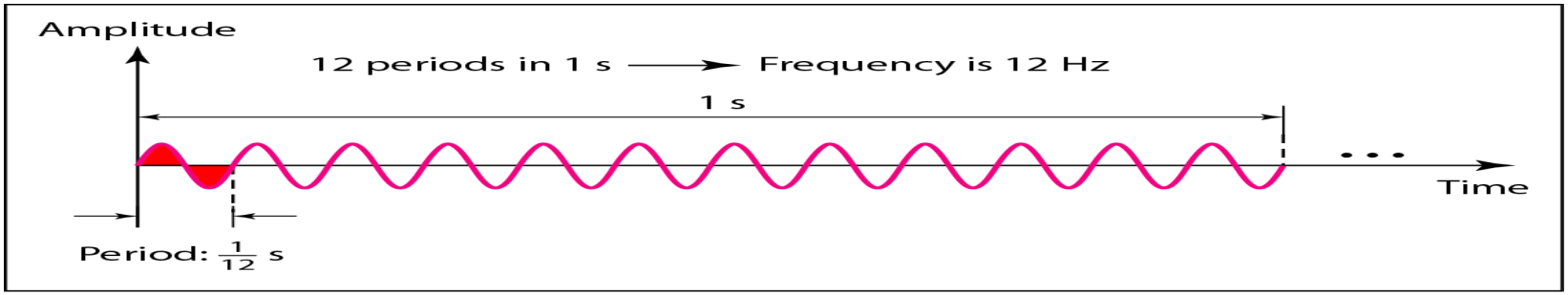
b. A signal with low peak amplitude

Analog and Digital Data & Signals

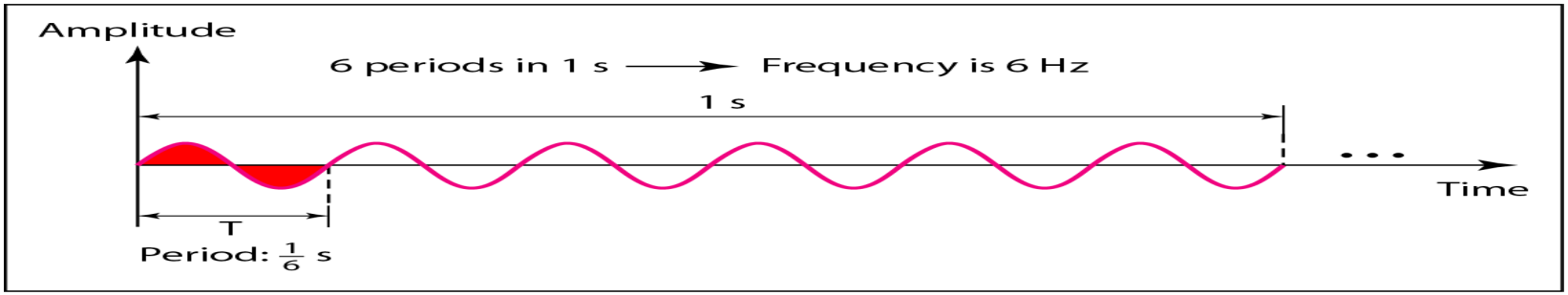
Note

Frequency and period are the inverse of each other.

$$f = \frac{1}{T} \quad \text{and} \quad T = \frac{1}{f}$$



a. A signal with a frequency of 12 Hz



b. A signal with a frequency of 6 Hz

Units of period and 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

The power we use at home has a frequency of 60 Hz. The period of this sine wave can be determined as follows:

$$T = \frac{1}{f} = \frac{1}{60} = 0.0166 \text{ s} = 0.0166 \times 10^{3} \text{ ms} = 16.6 \text{ ms}$$

Example

1-Express a period of 100 ms in microseconds.

Solution

we find the equivalents of 1 ms (1 ms is 10^{-3} s) and 1 s (1 s is 10^{6} μs). We make the following substitutions:.

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

Example

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

Solution

First we change 100 ms to seconds, and then we calculate the frequency from the period (1 Hz = 10^{-3} kHz).

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

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

Note

Frequency is the rate of change with respect to time.

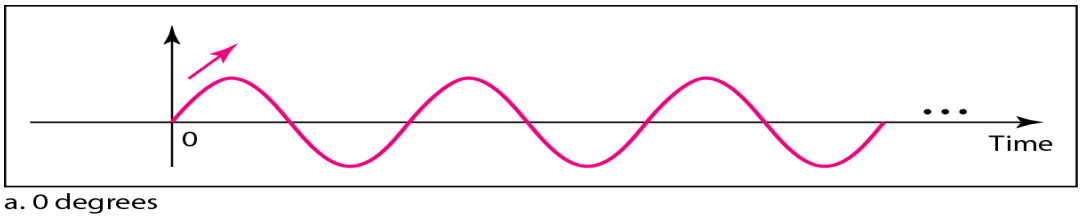
Change in a short span of time means high frequency.

Change over a long span of time means low frequency.

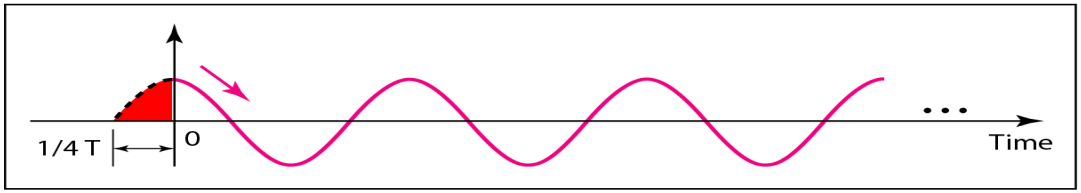
If a signal does not change at all, its frequency is zero.
If a signal changes instantaneously, its frequency is infinite.

Note

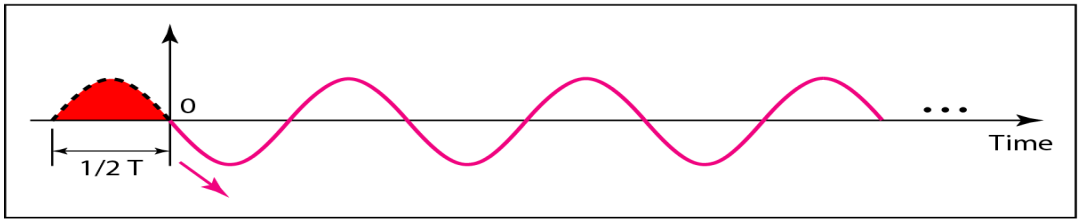
Phase describes the position of the waveform relative to time 0.



a. 0 degrees



b. 90 degrees



c. 180 degrees

Three sine waves with the same amplitude and frequency, but different phases

Example

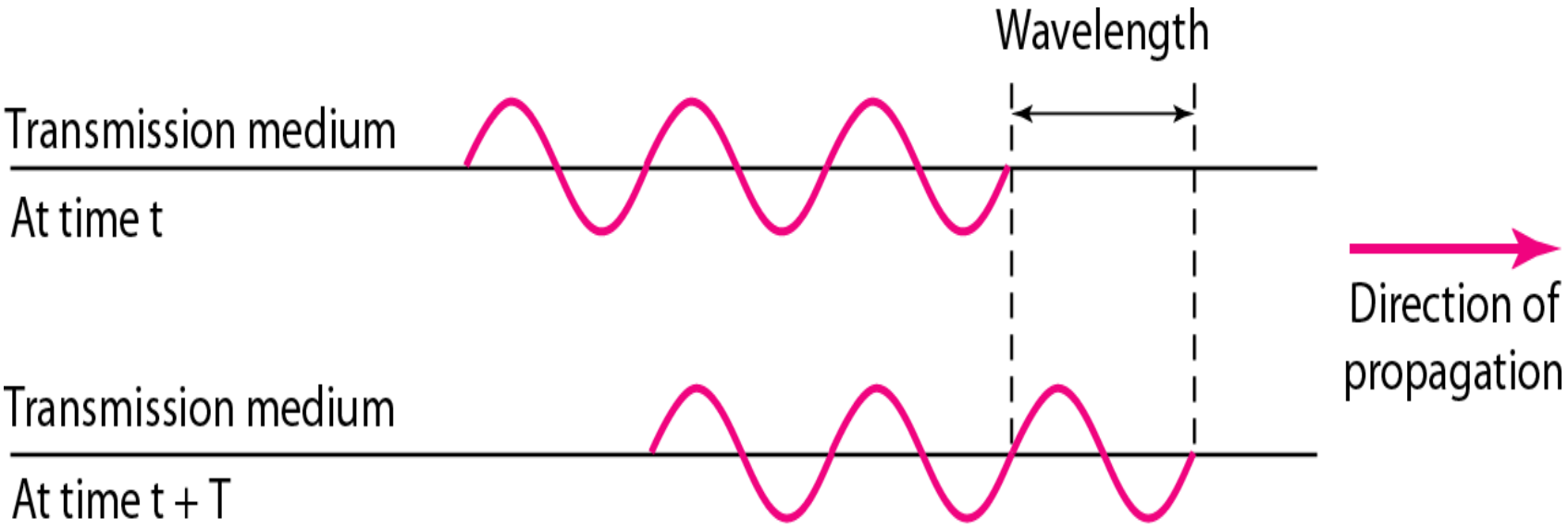
A sine wave is offset 1/6 cycle with respect to time 0. What is its phase in degrees and radians?

Solution

We know that 1 complete cycle is 360°. Therefore, 1/6 cycle is

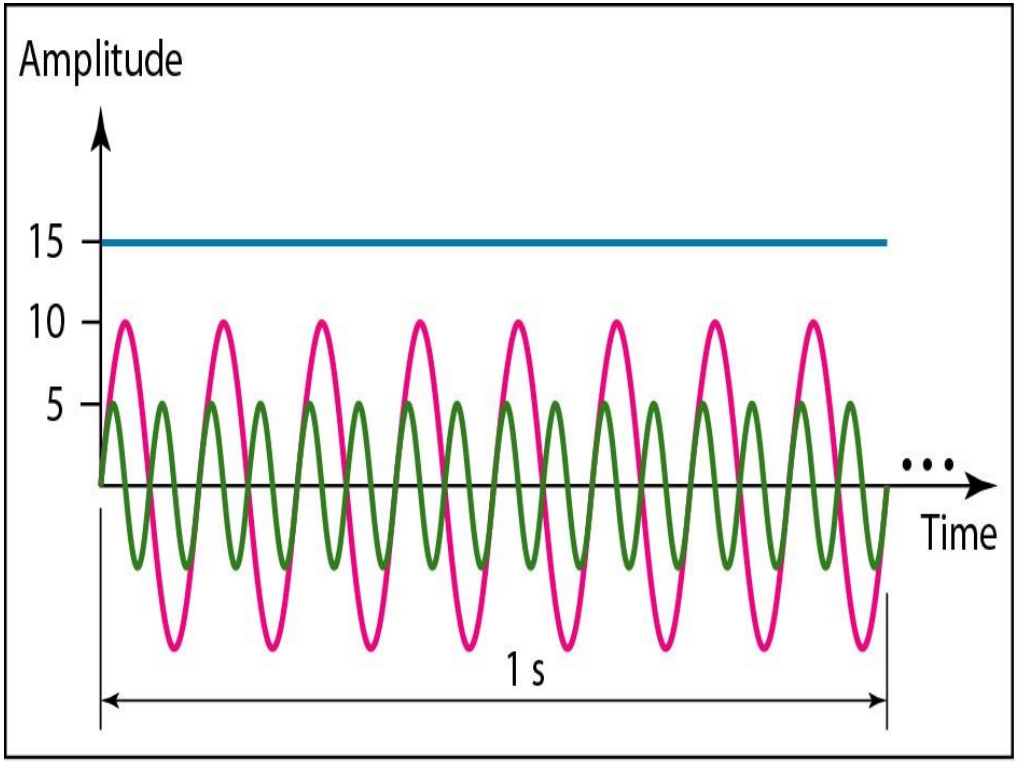
$$\frac{1}{6} \times 360 = 60° = 60 \times \frac{2\pi}{360} \text{ rad} = \frac{\pi}{3} \text{ rad} = 1.046 \text{ rad}$$

Wavelength and period

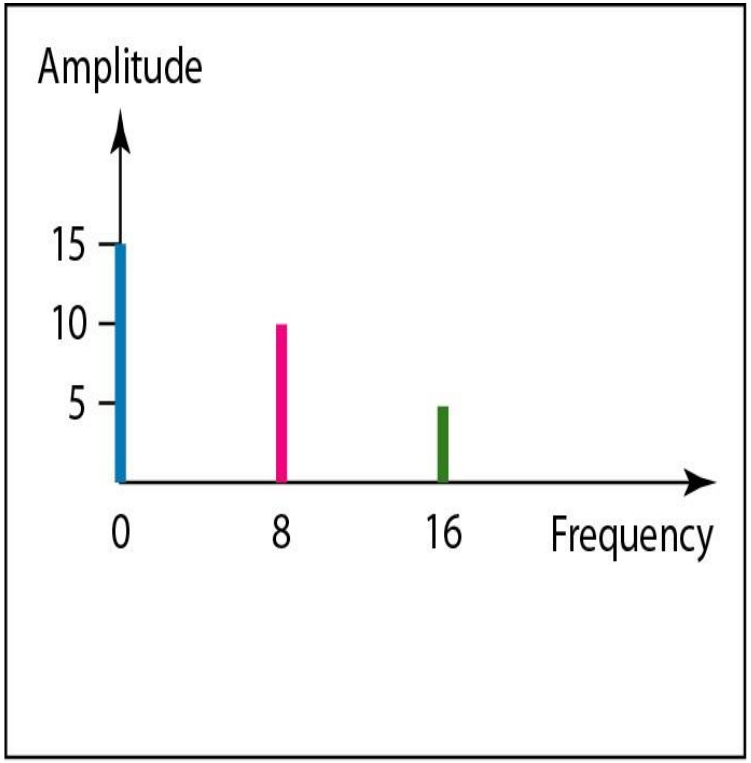


A complete sine wave in the time domain can be represented by one single spike in the frequency domain.

The time domain and frequency domain of three sine waves



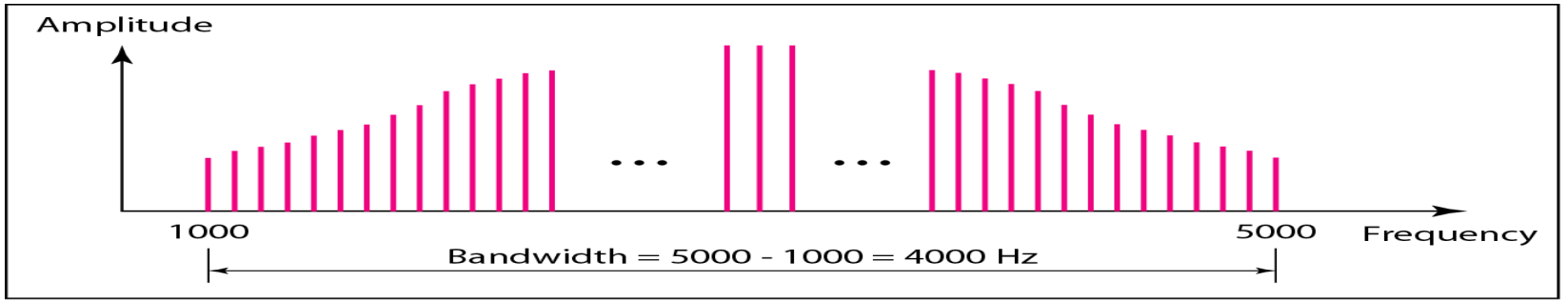
a. Time-domain representation of three sine waves with frequencies 0, 8, and 16



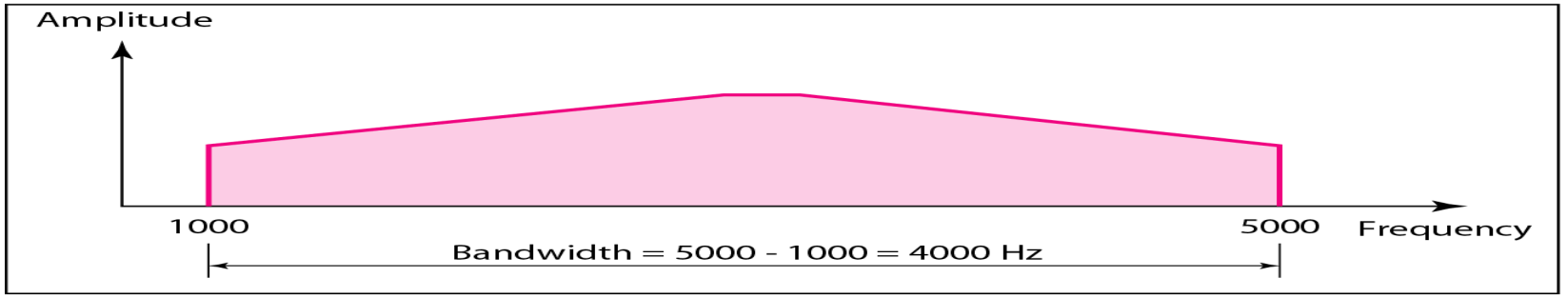
b. Frequency-domain representation of the same three signals

Note

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



a. Bandwidth of a periodic signal



b. Bandwidth of a nonperiodic signal

The bandwidth of periodic and nonperiodic composite signals

Example

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

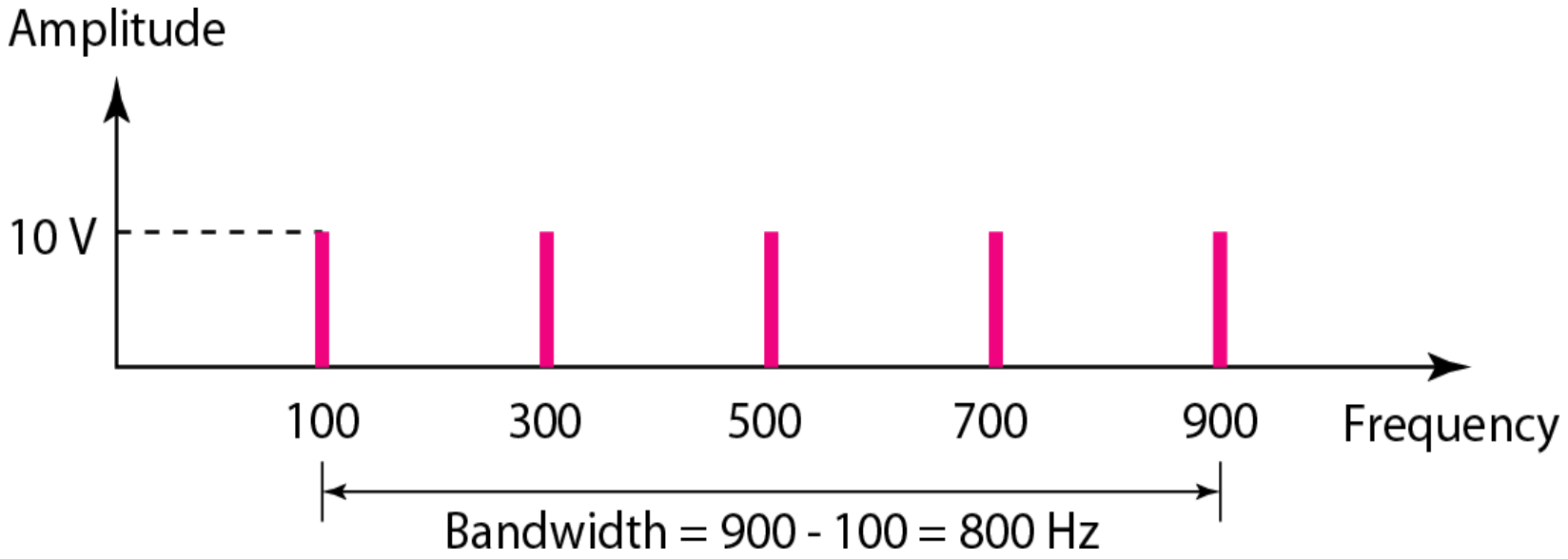
Let f_h be the highest frequency, f_l the lowest frequency, and B the bandwidth. Then

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

The spectrum has only five spikes, at 100, 300, 500, 700, and 900 Hz

Example

Draw the spectrum, assuming all components have a maximum amplitude of 10 V.



Question Of the Lecture!! Think!!

How do you send a message from your mobile phone to another person, and how does the message reach them ”?

Thank you!