Analog and Digital signals Transmission

Out Lines

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Data and Signals

- One of the major functions of the physical layer is to move data in the form of electromagnetic signals across a transmission medium.
- To be transmitted, data must be transformed to electromagnetic signals.

Analog and Digital

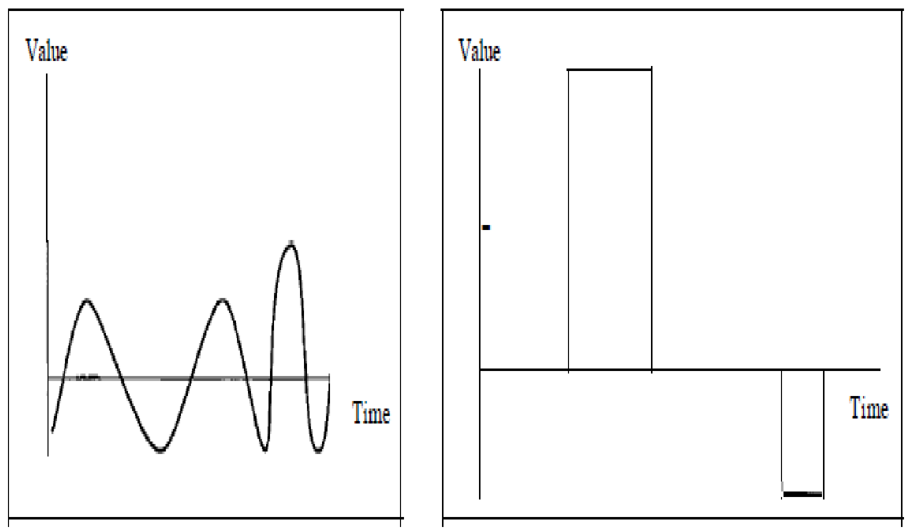
- Both data and the signals that represent them can be either **analog or digital** in form.

Analog and Digital Data

- The term **analog data** refers to information that is **continuous**.
- The term **digital data** refers to information that has **discrete** states.
- Analog data, such as the sounds made by a human voice, take on continuous values. When someone speaks, an analog wave is created in the air. This can be captured by a microphone and converted to an analog signal or sampled and converted to a digital signal.
- Digital data take on discrete values. For example, data are stored in computer memory in the form of 0s and 1s. They can be converted to a digital signal or modulated into an analog signal for transmission across a medium.
- Data can be analog or digital. Analog data are continuous and take continuous values. Digital data have discrete states and take discrete values.

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.
- 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.



a. Analog signal
b. Digital signal

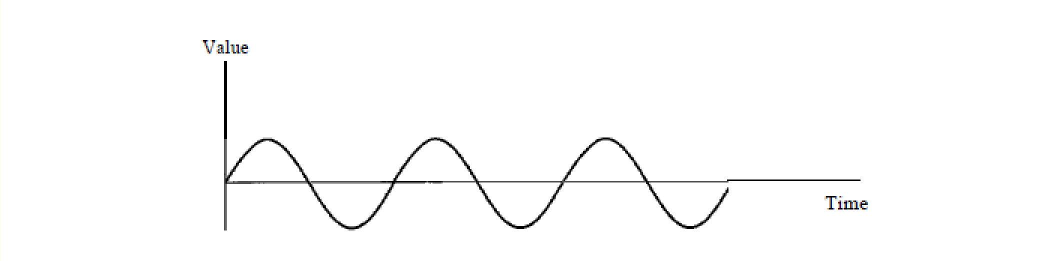
Periodic and Nonperiodic Signals

- Both analog and digital signals can take one of two forms: *periodic* or *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.
- In data communications, we commonly use periodic analog signals and nonperiodic digital signals.

Periodic Analog Signals

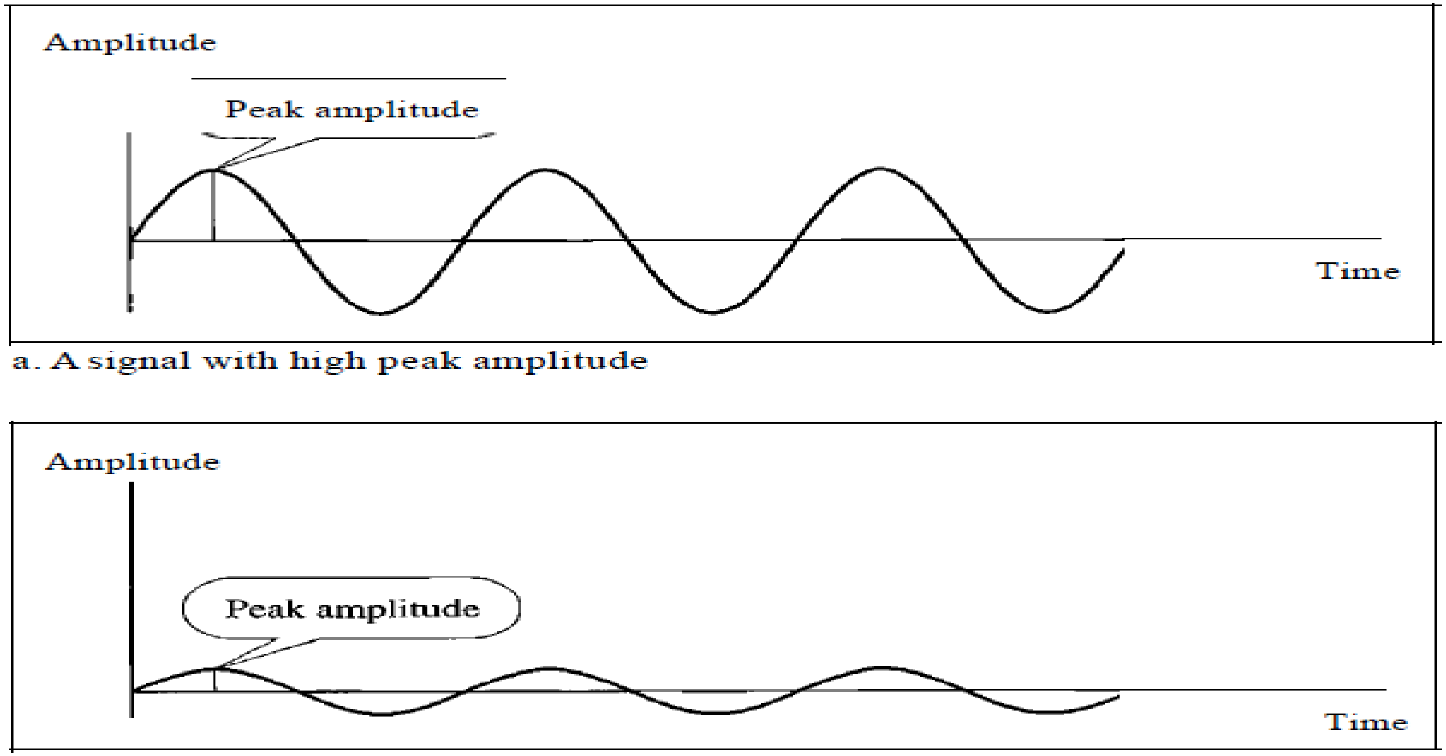
- Periodic analog signals can be classified as **simple or composite.** A simple periodic analog signal, a sine wave, cannot be decomposed into simpler signals. A composite periodic analog signal is composed of multiple sine waves.

- ***Sine Wave***
- The sine wave is the most **fundamental** form of a periodic analog signal.
- A sine wave can be represented by three parameters: **the *peak amplitude,* the *frequency,* and the *phase*.** These three parameters fully describe a sine wave.



Peak Amplitude

- The peak amplitude of a signal is the absolute value of its highest intensity.



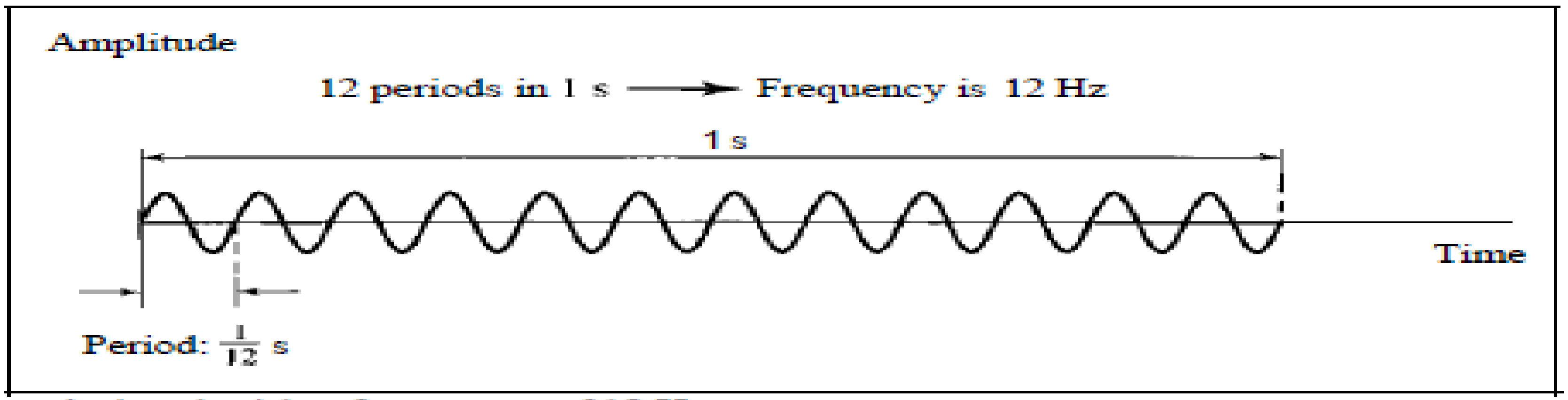
a. A signal with high peak amplitude

b. A signal with low peak amplitude

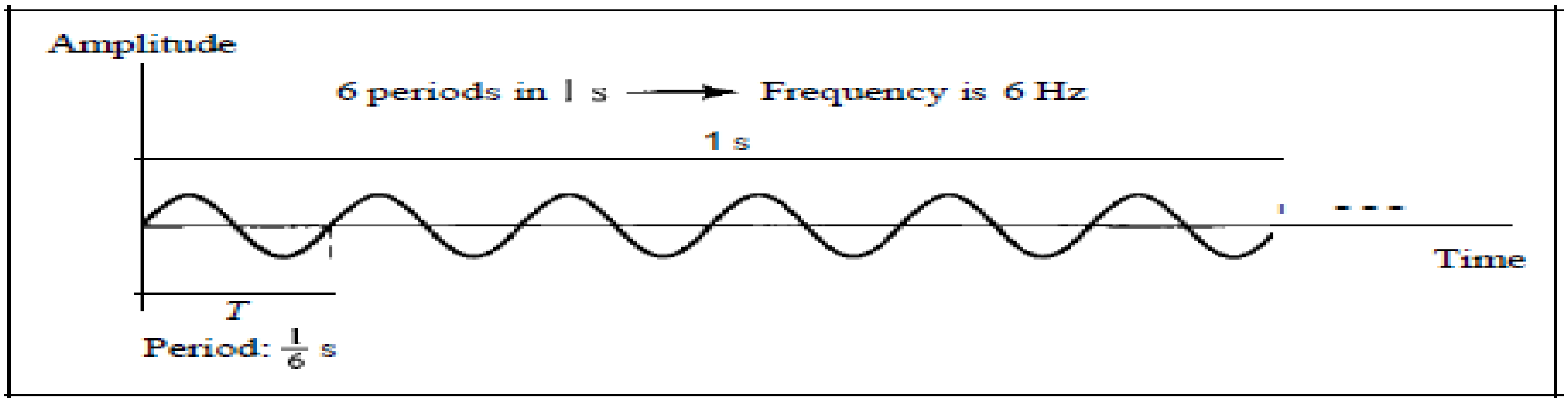
Period and Frequency

- Period refers to the amount of time, in seconds, a signal needs to complete 1 cycle.
- Frequency refers to the number of periods in I s. Note that period and frequency are just
- one characteristic defined in two ways. Period is the inverse of frequency, and frequency is the inverse of period, as the following formulas show.
- Period is formally expressed in seconds. Frequency is formally expressed in Hertz (Hz)
- 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.

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



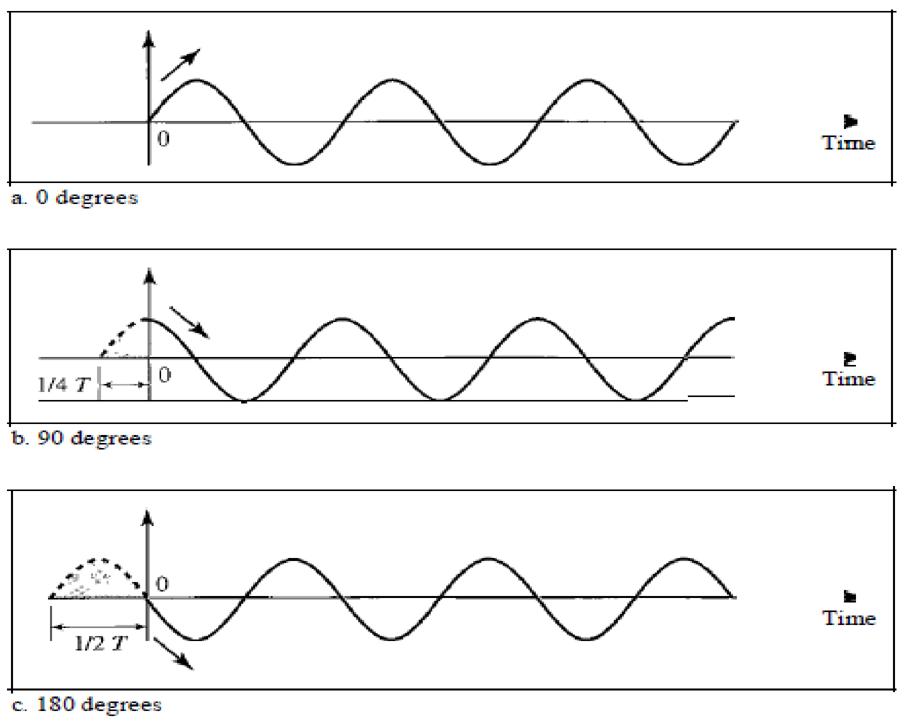
a. A signal with a frequency of 12 Hz



b. A signal with a frequency of 6 Hz

Phase

- The term phase 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.



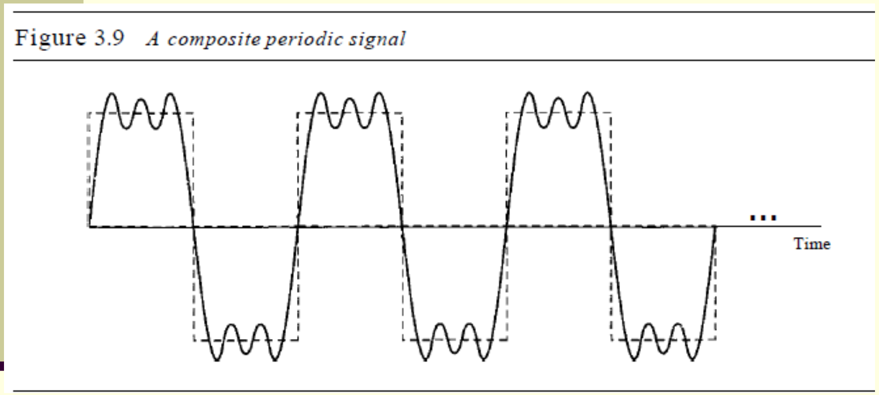
Wavelength

- Wavelength binds the period or the frequency of a simple sine wave to the propagation speed of the medium.
- See textbook page 64-65.

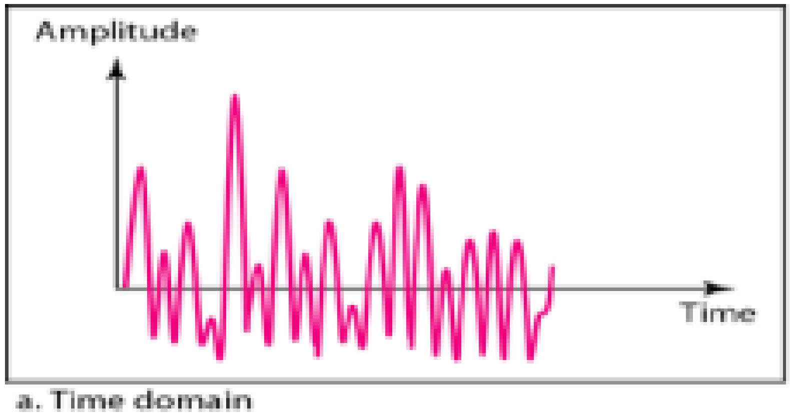
$$\text{Wavelength} = \text{propagation speed} \times \text{period} = \frac{\text{propagation speed}}{\text{frequency}}$$

Composite Signals

- A composite signal can be periodic or nonperiodic.



Composite periodic signal



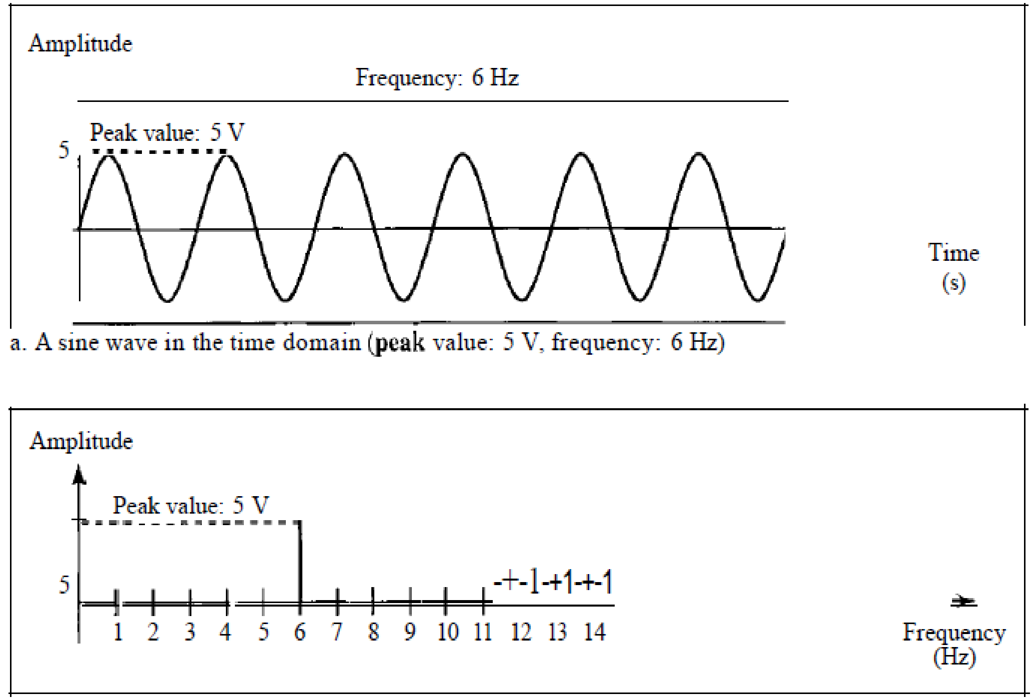
Composite non-periodic signal

Time and Frequency Domains

Sin wave

- A sine wave is 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).

- To show the relationship between amplitude and frequency, we can use what is called a frequency-domain plot. A frequency-domain plot is concerned with only the **peak value and the frequency.**
- A complete sine wave in the time domain can be represented by **one single spike in the frequency domain.**



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)

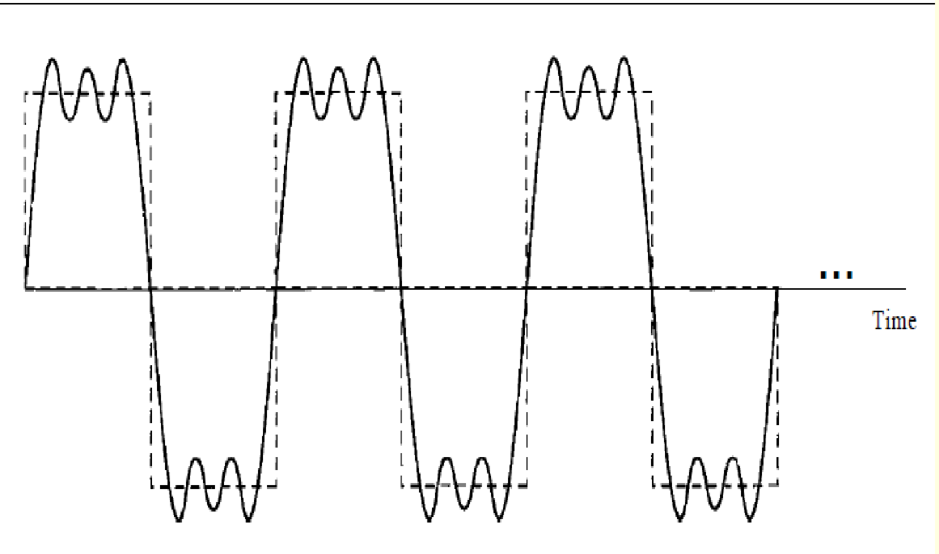
Time and Frequency Domains

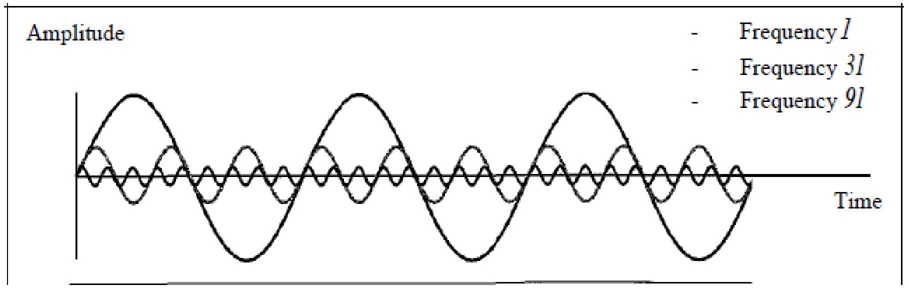
Composite Signals

- A single frequency sine wave is not useful in data communications; we need to send a composite signal, a signal made of many simple sine waves.
- The French mathematician Jean-Baptiste Fourier showed that **any composite signal is** actually a **combination of simple sine waves** with different frequencies, amplitudes, and phases.
- If the **composite signal is periodic**, the decomposition gives a series of signals with **discrete frequencies**; if the **composite signal is nonperiodic**, the decomposition gives a combination of sine waves with **continuous frequencies**.

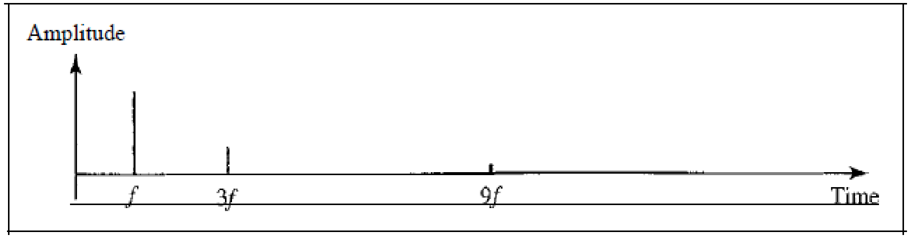
Time and Frequency domain of a periodic composite signal

re 3.9 *A composite periodic signal*





a. Time-domain decomposition of a composite signal

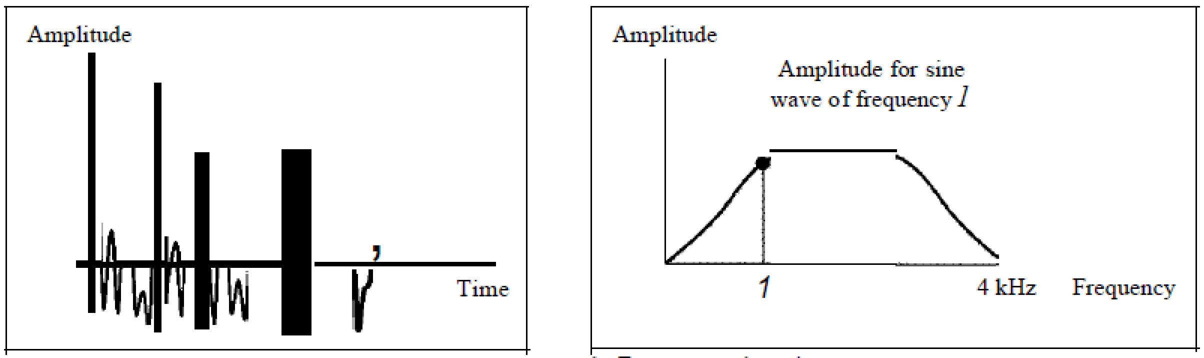


b. Frequency-domain decomposition of the composite signal

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

Time and Frequency domain of a non-periodic composite signal

Figure 3.11 *The time and frequency domains of a nonperiodic signal*



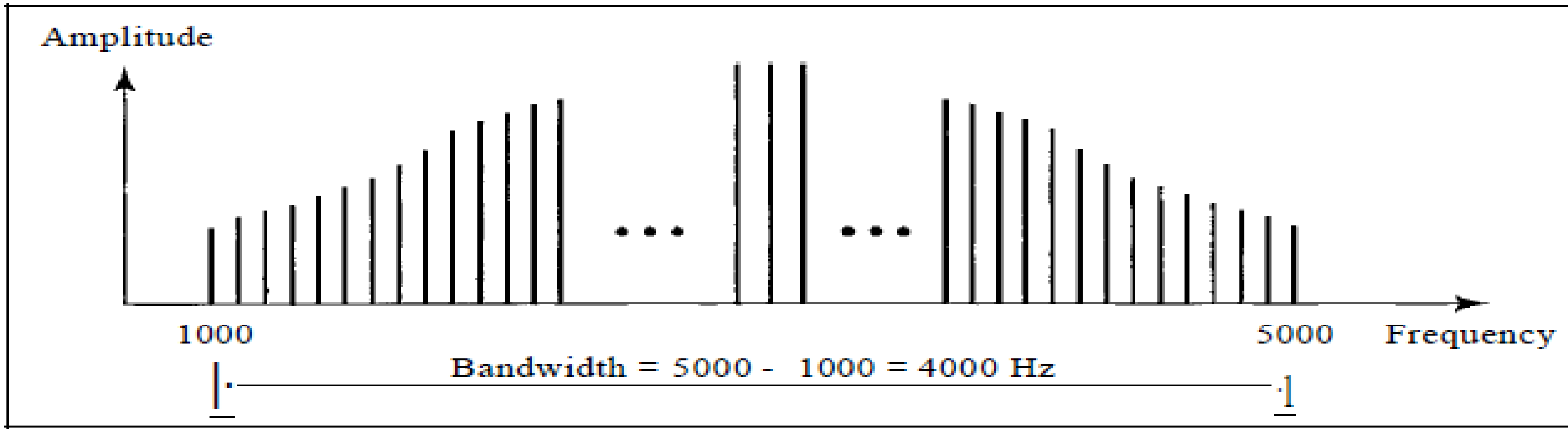
a. Time domain b. Frequency domain

if the composite signal is nonperiodic, the decomposition gives a combination of sine waves with continuous frequencies.

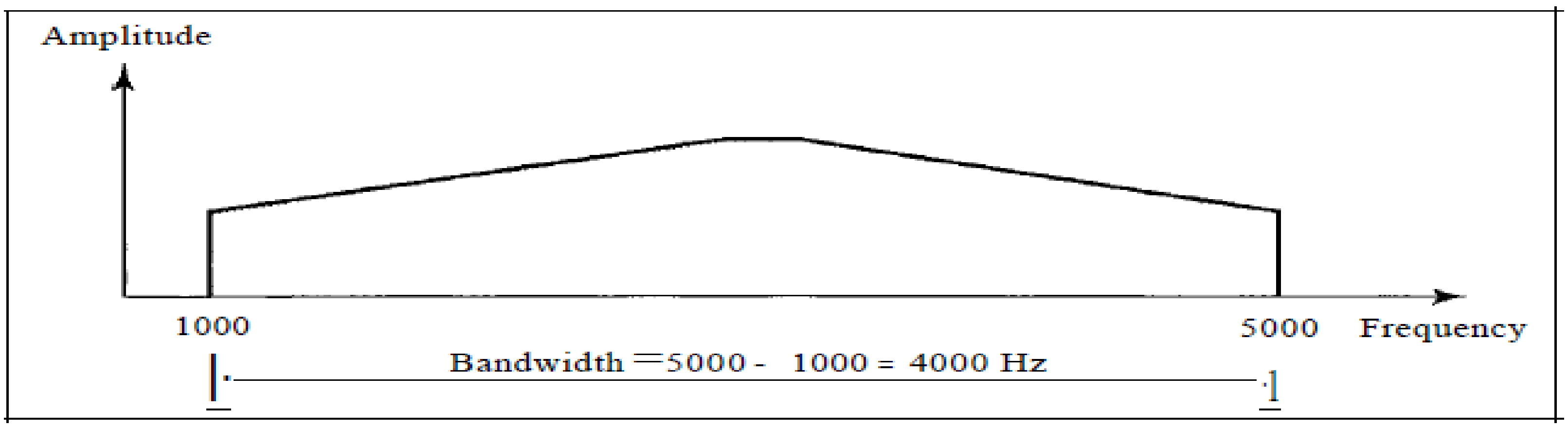
Although the number of frequencies in a human voice is infinite, the range is limited. A normal human being can create a continuous range of frequencies between 0 and 4 kHz.

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



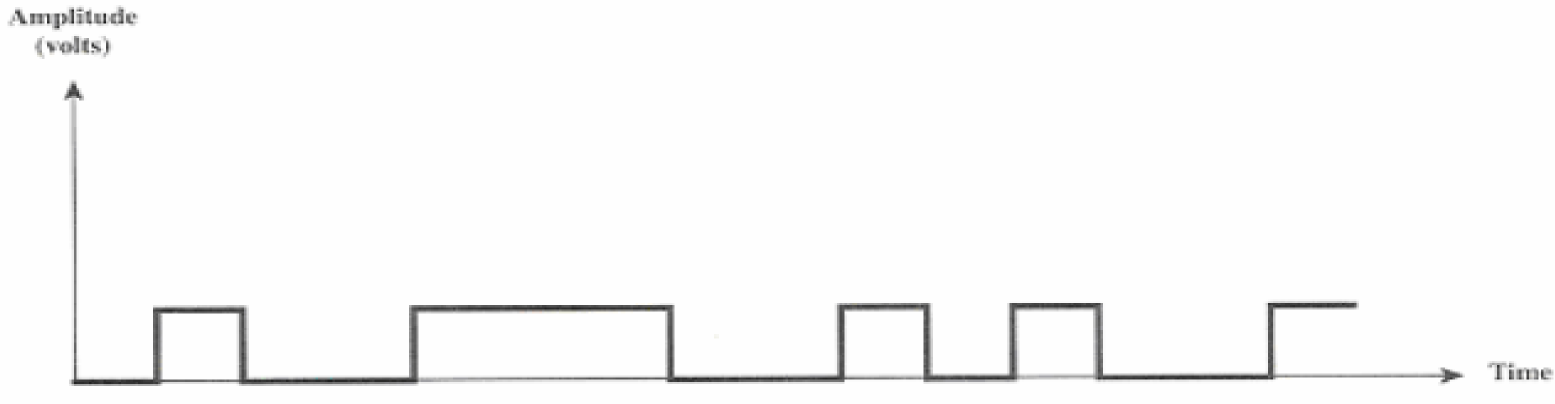
b. Bandwidth of a nonperiodic signal

Digital Signals

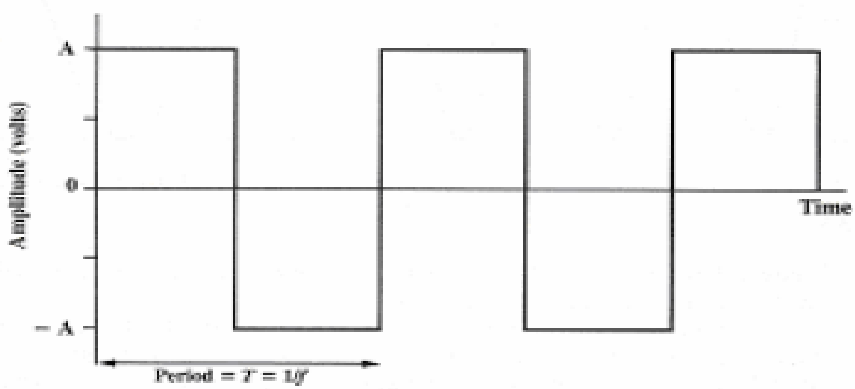
- In addition to being represented by an analog signal, information can also be represented by a digital signal.
- For example, a 1 can be encoded as a positive voltage and a 0 as zero voltage.
- A digital signal can have more than two levels. In this case, we can send more than 1 bit for each level.
- We send 1 bit per level in part a of the figure and 2 bits per level in part b of the figure. In general, if a signal has L levels, each level needs **log2L bits**.

ب- الإشارات الرقمية ((Digital Signals

هي تلك الإشارات التي تأخذ قيما محددة عند تغيرها مع الزمن لكنها منفصلة أي غير متصلة مثال ذلك الإشارات الكهربية الصادرة عن أجهزة الحاسب الآلي أو الآلات الحاسبة أو التلغراف ...... الخ كما هو مبين بالشكل(٢ -٣) وشكل (٢ -٤)

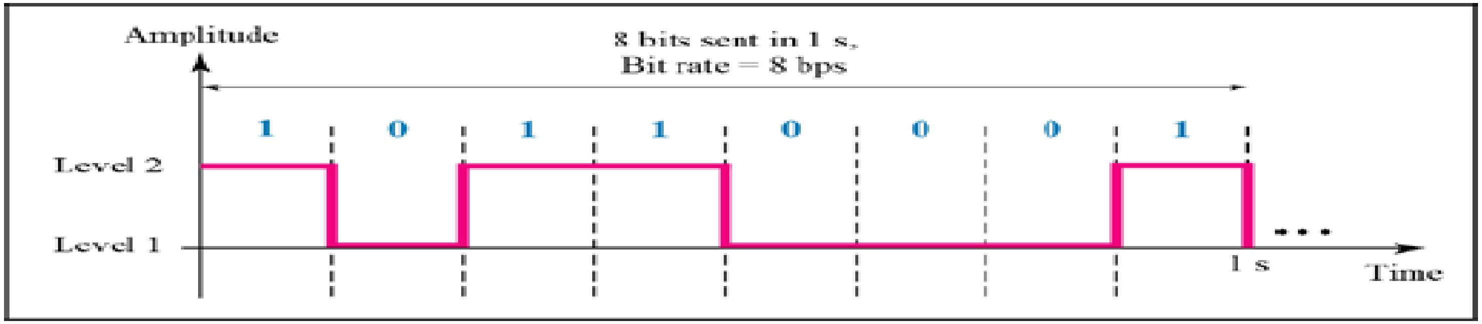


شكل ٢-٣

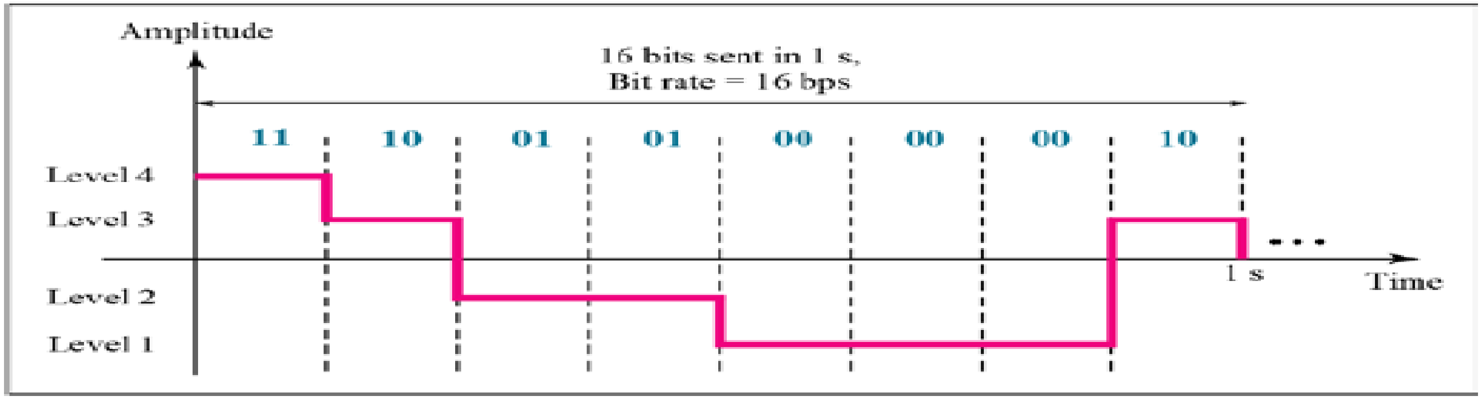


شكل ٢-٤

Two digital signals: one with two signal levels and the other with four signal levels.



a. A digital signal with two levels



b. A digital signal with four levels

Bit Rate and Bit Length

- 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).
- We discussed the concept of the wavelength for an analog signal: the distance one cycle occupies on the transmission medium.
- We can define something similar for a digital signal: the bit length. The bit length is the distance one bit occupies on the transmission medium.
- **Bit length =propagation speed x bit duration**

Bandwidth

- The term can be used in two different contexts with two different measuring values: bandwidth in **hertz** and bandwidth in **bits per second**.
- ***Bandwidth in Hertz***
- We have discussed this concept. Bandwidth in hertz is the range of frequencies contained in a composite signal or the range of frequencies a channel can pass. For example, we can say the bandwidth of a subscriber telephone line is 4 kHz.
- ***Bandwidth in Bits per Seconds***
- The term bandwidth can also refer to the number of bits per second that a channel, a link, or even a network can transmit. For example, one can say the bandwidth of a Fast Ethernet network (or the links in this network) is a maximum of 100 Mbps. This means that this network can send 100 Mbps.
- *Relationship between BW (Hz) & BW (bps)*

There is an explicit relationship between the bandwidth in hertz and bandwidth in bits per seconds.

Advantages of Digital Transmission

- The signal is exact
- Signals can be checked for errors
- Noise/interference are easily filtered out
- A variety of services can be offered over one line
- Higher bandwidth is possible with data compression