Data and Signals (Ibe, 2017)

Data must be transformed to electromagnetic signals. These signal-converted data are classified as either analog (or continuous time) or digital (or discrete time).

- **Analog signals**, which include speech, audio, and video, have an infinite number of values. These are represented as a sine wave.
- **Digital signals** are predominantly binary in nature and thus are represented by two (2) values or bits: 0 and 1. These are represented as a square wave.

Both analog and digital signals can take one of two (2) forms:

- **Periodic signal** – It completes a pattern within a measurable time frame, called a period, and repeats that pattern over subsequent identical periods. The completion of one (1) full pattern is called a cycle.
- N**onperiodic signal** – It changes without exhibiting a pattern or cycle that repeats over time. Both analog and digital signals can be periodic or nonperiodic.

Signal Terminologies

- **Wavelength** is directly related to the frequency of a given waveform.
  Formula for Wavelength

$$\lambda = \frac{c}{f}$$

  where:
  λ – wavelength (m)
  f – Frequency (Hz)
  c – wave speed or speed of light (m/s)

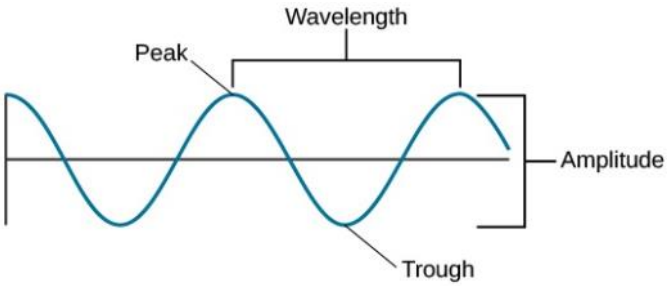


Figure 1. Parts of a Signal
Source: Fundamentals of Data Communication Networks, 2017

- **Frequency** refers to the number of waves that pass a given point in each time period and is often expressed in terms of **hertz (Hz)** or **cycles per second**.
  Formula for Frequency

$$f = \frac{1}{T}$$

  where:
  f – Frequency (Hz)
  T – Period (s)

- **Amplitude** is a measure of how big the wave is, which is measured as follows:
  - The height from the equilibrium point to the highest point of a **crest**
  - The depth from the equilibrium point to the lowest point of a **trough**.

Examples:

1) What is the wavelength of a radio wave with a given frequency of $900\ kHz$?

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8\ m/s}{900\ kHz} = 333.33\ m$$

2) What is the frequency of violet light with a wavelength of $400\ nm$?

$$f = \frac{c}{\lambda} = \frac{3 \times 10^8\ m/s}{400\ nm} = 7.5 \times 10^{14}\ Hz$$

3) What would be the frequency of a signal with a period of 0.00235?

$$f = \frac{1}{T} = \frac{1}{0.00235} = 425.53\ Hz$$

4) If a sampling signal with frequency $50\ Hz$ is to be passed in a modulator, what will its period be over 1 second?

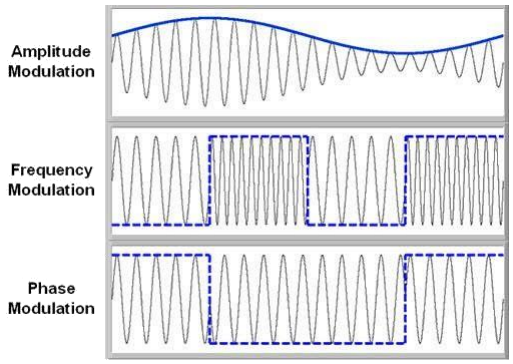
$$T = \frac{1}{f} = \frac{1\ sec}{50\ Hz} = 0.02\ sec/cycle$$

Modems

The term "modem" is a contraction of the words "**mo**dulator" and "**dem**odulator." The sending modem modulates the data into a signal that is compatible with the phone line, and the receiving modem demodulates the signal back into digital data. **Modulation** is the process of converting data into radio waves by adding information to an electronic or optical carrier signal. A carrier signal is one with a steady waveform—constant height, or amplitude, and frequency.

Kinds of Modulation

- **Amplitude modulation (AM)** – It is the modulation technique in which carrier amplitude varies based on analog baseband information signal to be transmitted in a wireless medium.
- **Frequency modulation (FM)** – It is the modulation technique in which carrier frequency varies based on analog baseband information signal to be transmitted in a wireless medium.
- **Phase modulation (PM)** – It is the modulation technique in which the carrier phase varies based on analog baseband information signal to be transmitted in a wireless medium.



Analog-to-Digital Conversion: From PAM to PCM

This method is used to convert an analog signal, such as voice and video, into a digital signal. Each time a sample is taken, it is measured by the **ADC (Analog-to-Digital Converter)** that converts the analog value to a digital (binary) equivalent.

- **Sampling** lays out of the analog signal in a graph. The sampling process essentially converts analog amplitudes to discrete levels and is a type of modulation called **pulse amplitude modulation (PAM)**.
- The next step is to *quantize* the digital pulses, which means to approximate the amplitude value of a pulse to the nearest integer on a predefined set of permitted integers. **Quantization** layers the discrete signal in the analog signal with less margin of error.
- **Encoding (pulse code modulation [PCM])** converts discrete signals into highs (1) and lows (0), making these the binary equivalent of a time-bound discrete signal. *Line coding* is the process of converting digital data into digital signals. It is the representation of the digital signal to be transmitted by a digital waveform.

Channel Impairments

As a signal propagates along a communication path from its source to its destination, it is subject to different types of impairments.

- **Attenuation** – The strength of a signal decreases as it travels along a transmission medium. The amount of attenuation depends on the medium, but in general, it increases with distance.
- **Noise** – It is usually defined as an unwanted signal that is superimposed on a desired signal.
  - ***Atmospheric noise*** is the noise that is caused by such natural atmospheric phenomena as lightning discharge in thunderstorms and other electrical disturbances that occur in nature.
  - ***Man-made noise*** is an electromagnetic (EM) noise that is caused by human activities, which are associated with the use of electrical equipment. High-voltage wires and fluorescent lamps also produce this type of noise.
  - ***Extraterrestrial noise*** is the noise that comes from outside the earth and includes solar noise and cosmic noise. *Solar noise* is the noise that originates from the sun, while *cosmic noise* is generated by distant stars.

- ***Thermal noise*** occurs in electrical conductors and is caused by the thermal agitation of the charges in the material.
- ***Shot noise*** arises from the time-dependent fluctuations in electrical current. This is caused by the discrete nature of electron charges. It is particularly noticeable in semiconductor devices.

- **Distortion** – It refers to the change or alteration of an object. Thus, in terms of data transmission, distortion means that the signal changes its form or shape. ***Delay distortion*** is a phenomenon that is peculiar to guided transmission media.

Signal-to-Noise Ratio

It is often useful to have a quantitative method for describing the quality of a signal in terms of its corruption by noise. Signal-to-noise is the ratio of the magnitude of the signal to that of the noise.

$$S/N\ ratio = 10\log_{10}\left(\frac{P_s}{P_n}\right) dB$$

$$S/N\ ratio = 10\log_{10}\left(\frac{V_s}{V_n}\right)^2 dB$$

$$S/N\ ratio = 20\log_{10}\left(\frac{V_s}{V_n}\right) dB$$

P_s – Signal Power

P_n – Noise Power

V_s – Signal Voltage

V_n – Noise Voltage

Examples:

1) A signal of $2.5\ volts\ rms$ is corrupted by $10\ mV\ rms$ of noise in a circuit. What is the $S/N\ ratio$ at this point?

$$SNR = 20\log_{10}\left(\frac{V_s}{V_n}\right) = 20\log_{10}\left(\frac{2.5}{0.01}\right) = 48\ dB$$

2) A signal with 350 watts is transmitted through a cable medium with 60 watts of noise. What is its $S/N\ ratio$?

$$SNR = 10\log_{10}\left(\frac{P_s}{P_n}\right) = 10\log_{10}\left(\frac{350}{60}\right) = 7.66\ dB$$

References:

Ibe, O. (2018). *Fundamentals of data communication networks* (1st ed.). Wiley & Sons, Inc.

Kurose, F. & Ross, K. (2017). *Computer networking: A top-down approach* (7th ed.). Pearson.

Patniak, S., Yang, X., Tavana, M., Popentiu-Vlădicescu, & F., Qiao, F. (2019). *Digital business: Business algorithms, cloud computing and data engineering*. Springer International.

Sklar, B. (2017). *Digital communications: Fundamentals and applications* (2nd ed.). Prentice Hall.

Speidel, J. (2019). *Introduction to digital communications.* Springer Nature.