Data Communication

#4 Digital Signals

Susmini I. Lestariningati, M.T

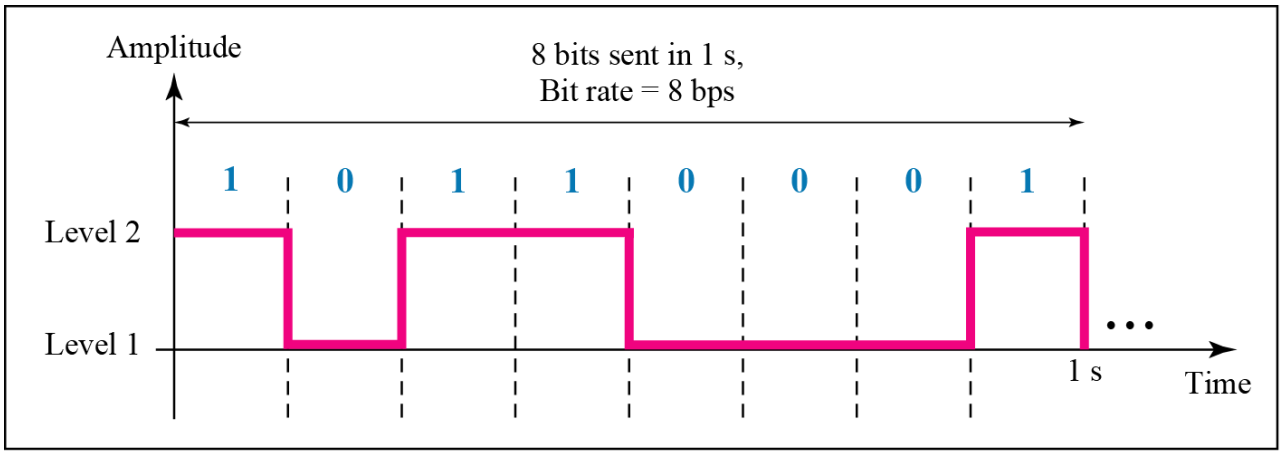
Digital Signal

- 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.

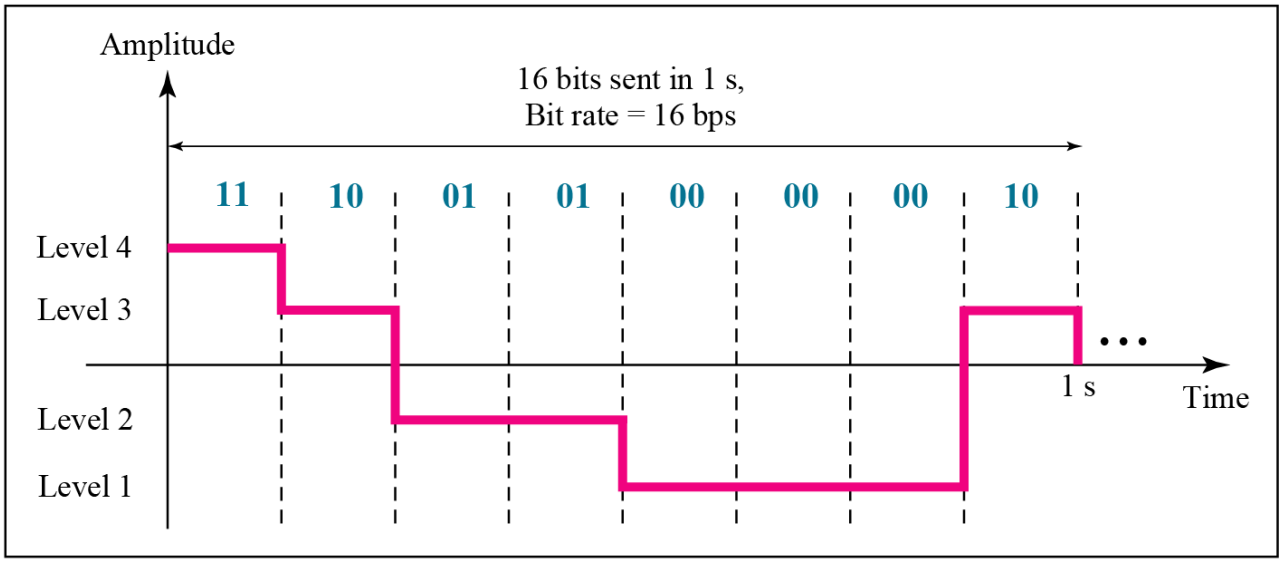
- **Bit Rate**

  Most digital signals are non periodic, 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 Is, expressed in bits per second (bps).

Bit Rate



a. A digital signal with two levels



b. A digital signal with four levels

Example

- A digital signal has eight levels. How many bits are needed per level? We calculate the number of bits from the formula

$$\text{Number of bits per level} = \log_2 8 = 3$$

- Each signal level is represented by 3 bits.

Example

- Assume we need to download text documents at the rate of 100 pages per minute. What is the required bit rate of the channel?
- **Solution**
  - A page is an average of 24 lines with 80 characters in each line. If we assume that one character requires 8 bits, the bit rate is

$$100 \times 24 \times 80 \times 8 = 1{,}636{,}000 \text{ bps} = 1.636 \text{ Mbps}$$

Example

- A digitized voice channel, as we will see in Chapter 4, is made by digitizing a 4kHz bandwidth analog voice signal. We need to sample the signal at twice the highest frequency (two samples per hertz). We assume that each sample requires 8 bits. What is the required bit rate?

- Solution
  - The bit rate can be calculated as

$$2 \times 4000 \times 8 = 64{,}000 \text{ bps} = 64 \text{ kbps}$$

Example

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

- **Solution**
  - HDTV uses digital signals to broadcast high quality video signals. The HDTV screen is normally a ratio of 16 : 9. There are 1920 by 1080 pixels per screen, and the screen is renewed 30 times per second. Twenty-four bits represents one color pixel.

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

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

Bit Length

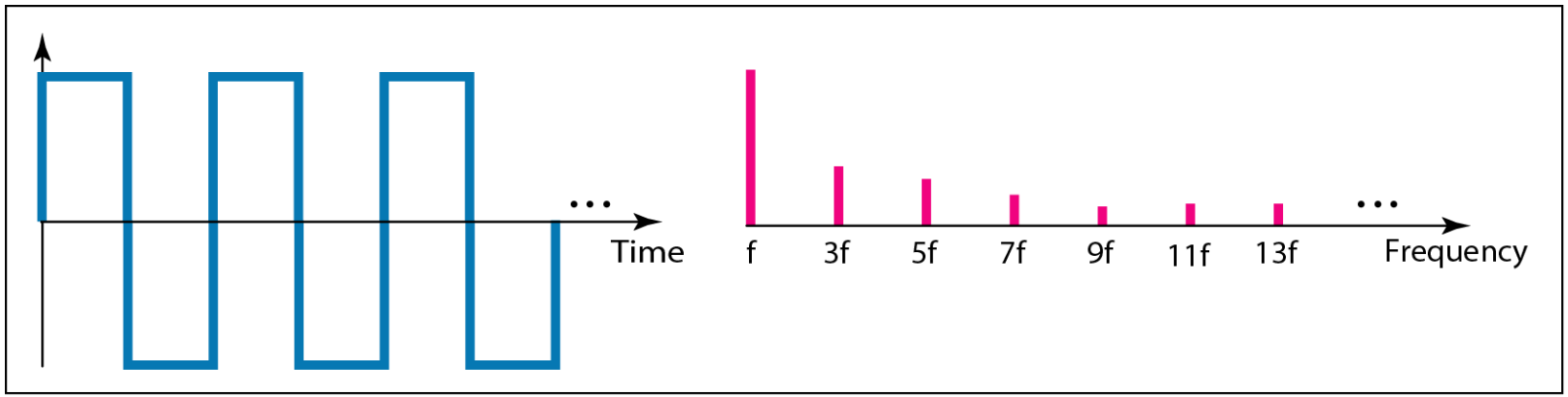
- We discussed the concept of the wavelength for an analog signal: the distance one cycle occupies on the transmission medium. We can define something similar for a digital signal: the bit length. The bit length is the distance one bit occupies on the transmission medium.

Bit length =propagation speed x bit duration

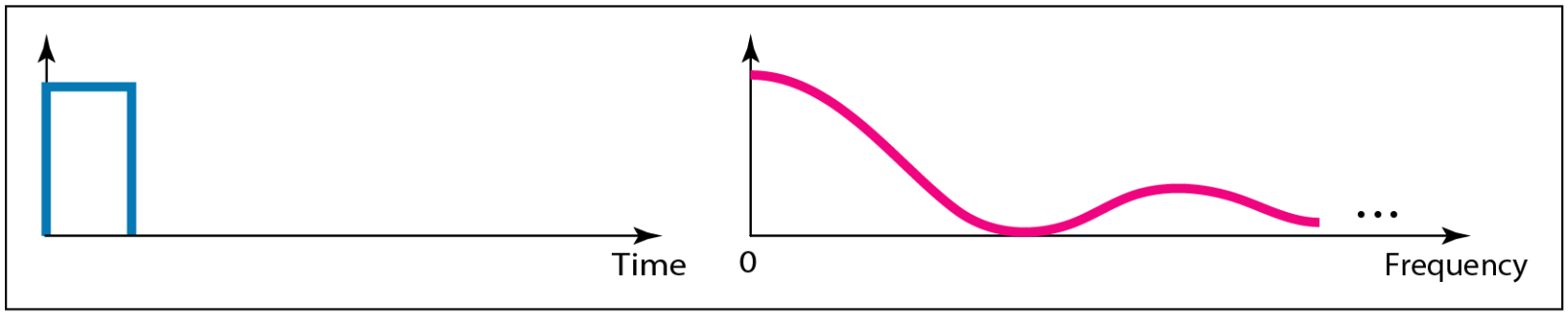
Digital Signal as a Composite Signal

- Based on Fourier analysis, a digital signal is a composite analog signal.
- We can intuitively come up with this concept when we consider a digital signal. A digital signal, in the time domain, comprises connected vertical and horizontal line segments. A vertical line in the time domain means a frequency of infinity (sudden change in time); a horizontal line in the time domain means a frequency of zero (no change in time). Going from a frequency of zero to a frequency of infinity (and vice versa) implies all frequencies in between are part of the domain.
- Fourier analysis can be used to decompose a digital signal. If the digital signal is periodic, which is rare in data communications, the decomposed signal has a frequency- domain representation with an infinite bandwidth and discrete frequencies. If the digital signal is non periodic, the decomposed signal still has an infinite bandwidth, but the frequencies are continuous.

The time and frequency domains of periodic and non periodic digital signals



a. Time and frequency domains of periodic digital signal



b. Time and frequency domains of nonperiodic digital signal

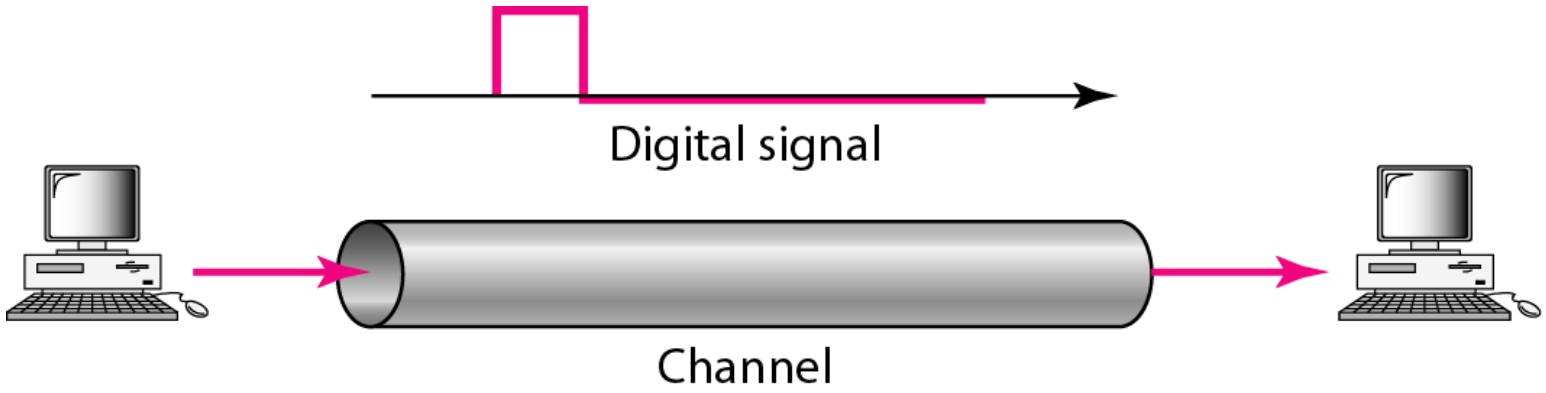
- Note that both bandwidths are infinite, but the periodic signal has discrete frequencies while the non periodic signal has continuous frequencies.

Transmission of Digital Signal

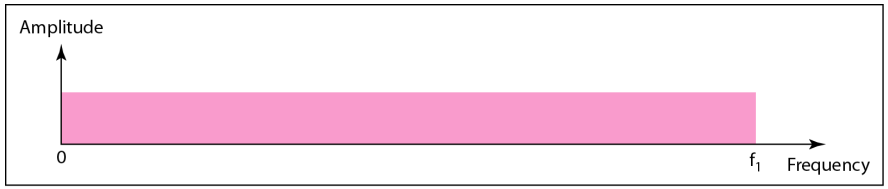
- The previous discussion asserts that a digital signal, periodic or non periodic, is a composite analog signal with frequencies between zero and infinity.
- For the remainder of the discussion, let us consider the case of a non periodic digital signal, similar to the ones we encounter in data communications.
- The fundamental question is, How can we send a digital signal from point A to point B? We can transmit a digital signal by using one of two different approaches:
  - baseband transmission or broadband transmission (using modulation).

Baseband Transmission

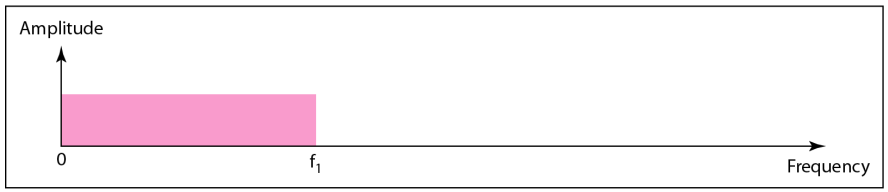
- Baseband transmission means sending a digital signal over a channel without changing the digital signal to an analog signal.



- Baseband transmission requires that we have a low-pass channel, a channel with a bandwidth that starts from zero. This is the case if we have a dedicated medium with a bandwidth constituting only one channel.
  - For example, the entire bandwidth of a cable connecting two computers is one single channel.
  - As another example, we may connect several computers to a bus, but not allow more than two stations to communicate at a time. Again we have a low-pass channel, and we can use it for baseband communication.



a. Low-pass channel, wide bandwidth



b. Low-pass channel, narrow bandwidth

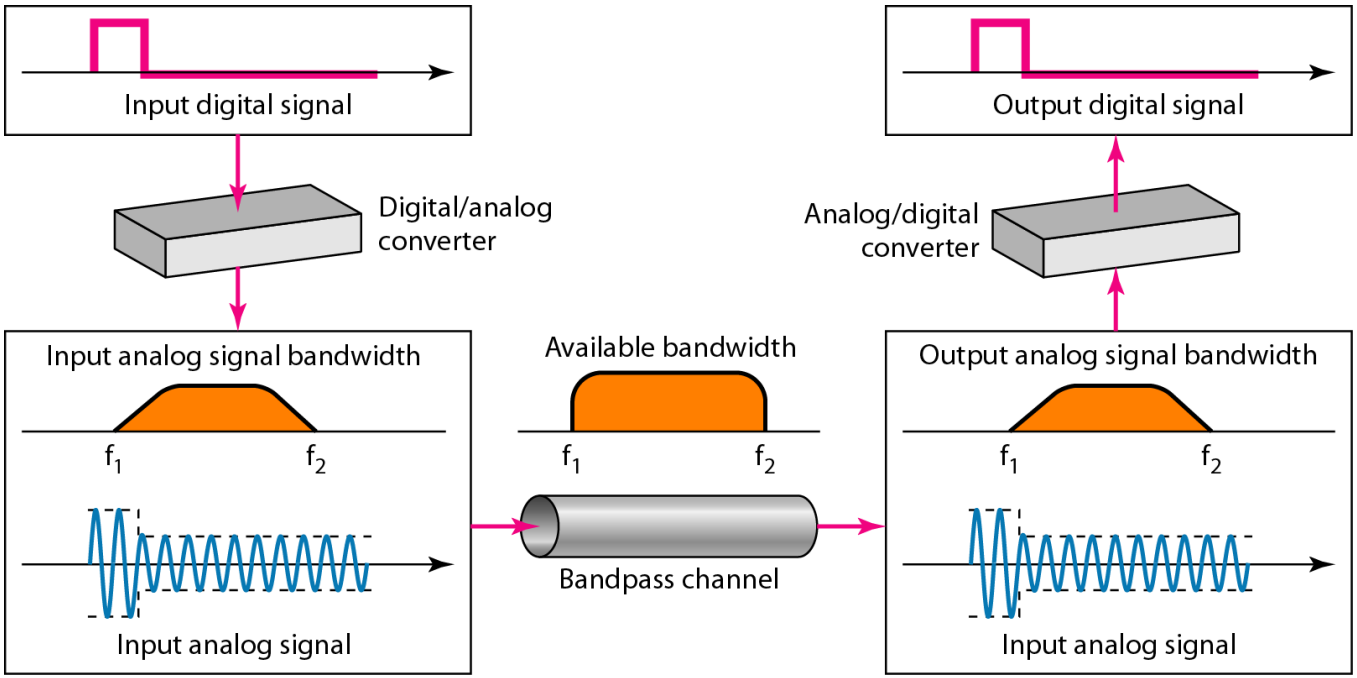
- We need to remember that a low-pass channel with infinite bandwidth is ideal, but we cannot have such a channel in real life

Example

- An example of a dedicated channel where the entire bandwidth of the medium is used as one single channel is a LAN. Almost every wired LAN today uses a dedicated channel for two stations communicating with each other. In a bus topology LAN with multipoint connections, only two stations can communicate with each other at each moment in time (timesharing); the other stations need to refrain from sending data. In a star topology LAN, the entire channel between each station and the hub is used for communication between these two entities. We study LANs in Chapter 14.

Broadband Transmission (using modulation)

- Broadband transmission or modulation means changing the digital signal to an analog signal for transmission. Modulation allows us to use a bandpass channel a channel with a bandwidth that does not start from zero. This type of channel is more available than a low-pass channel.
- Note that a low-pass channel can be considered a bandpass channel with the lower frequency starting at zero.



Example

- An example of broadband transmission using modulation is the sending of computer data through a telephone subscriber line, the line connecting a resident to the central telephone office. These lines are designed to carry voice with a limited bandwidth. The channel is considered a bandpass channel. We convert the digital signal from the computer to an analog signal, and send the analog signal. We can install two converters to change the digital signal to analog and vice versa at the receiving end. The converter, in this case, is called a modem which we discuss in detail in Chapter 5.