DATA COMMUNICATIONS AND NETWORKING

Data and Signals
Part 1 (Continue…)

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PERIODIC ANALOG SIGNALS(continue…)

- 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
- When we change one or more characteristics of a single-frequency signal, it becomes a composite signal made of many frequencies
- According to Fourier analysis, any composite signal is a combination of simple sine waves with different frequencies, phases, and amplitudes
- 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.
- Example 6.
- The figure 11. shows a periodic composite signal with frequency f. This type of signal is not typical of those found in data communications. We can consider it to be three alarm systems, each with a different frequency. The analysis of this signal can give us a good understanding of how to decompose signals.

PERIODIC ANALOG SIGNALS(continue…)

➢ Composite Signals (continue…)

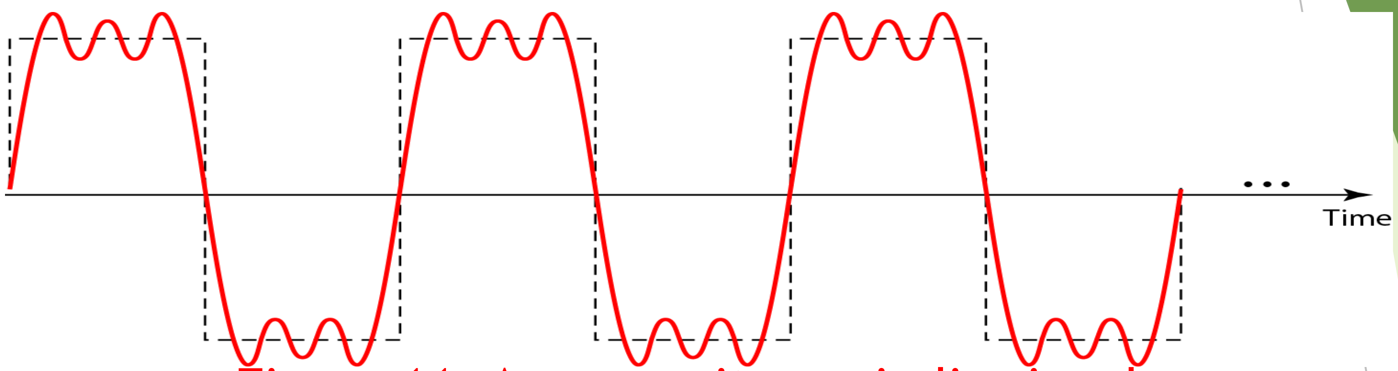


Figure 11. A composite periodic signal

- Figure 12. shows the result of decomposing the above signal in both the time and frequency domains. The amplitude of the sine wave with frequency f is almost the same as the peak amplitude of the composite signal. The amplitude of the sine wave with frequency 3f is one-third of that of the first, and the amplitude of the sine wave with frequency 9f is one-ninth of the first.

- The sine wave with frequency 3f has a frequency of 3 times the fundamental frequency; it is called the third harmonic. The third sine wave with frequency 9fhas a frequency of 9 times the fundamental frequency; it is called the ninth harmonic.

PERIODIC ANALOG SIGNALS(continue…)

➢ Composite Signals (continue…)

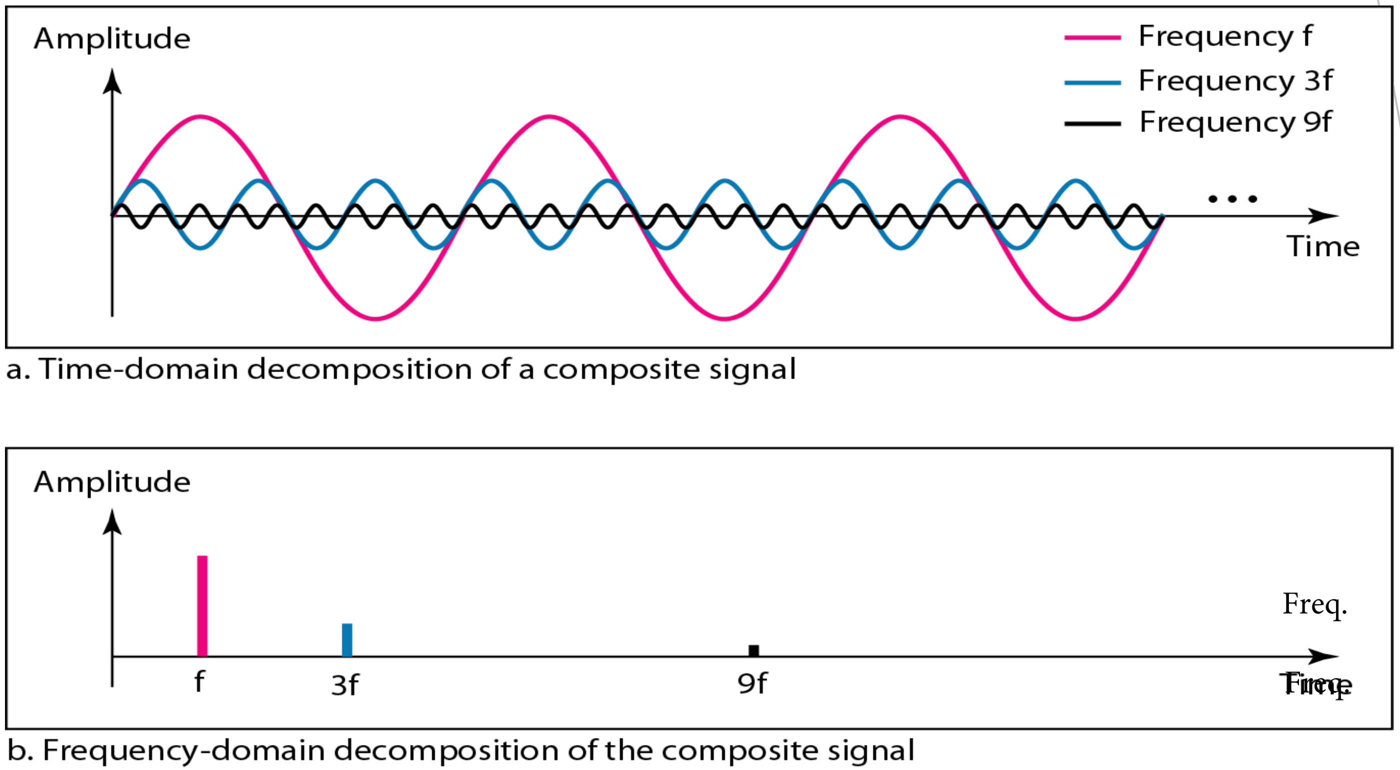


Figure 12. Decomposition of a composite periodic signal in the time and frequency domains

PERIODIC ANALOG SIGNALS(continue…)

- Composite Signals (continue…)
- Example 7. :-
- Figure 13. shows a nonperiodic composite signal. It can be the signal created by a microphone or a telephone set when a word or two is pronounced. In this case, the composite signal cannot be periodic, because that implies that we are repeating the same word or words with exactly the same tone.
- In a time-domain representation of this composite signal, there are an infinite number of simple sine 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.

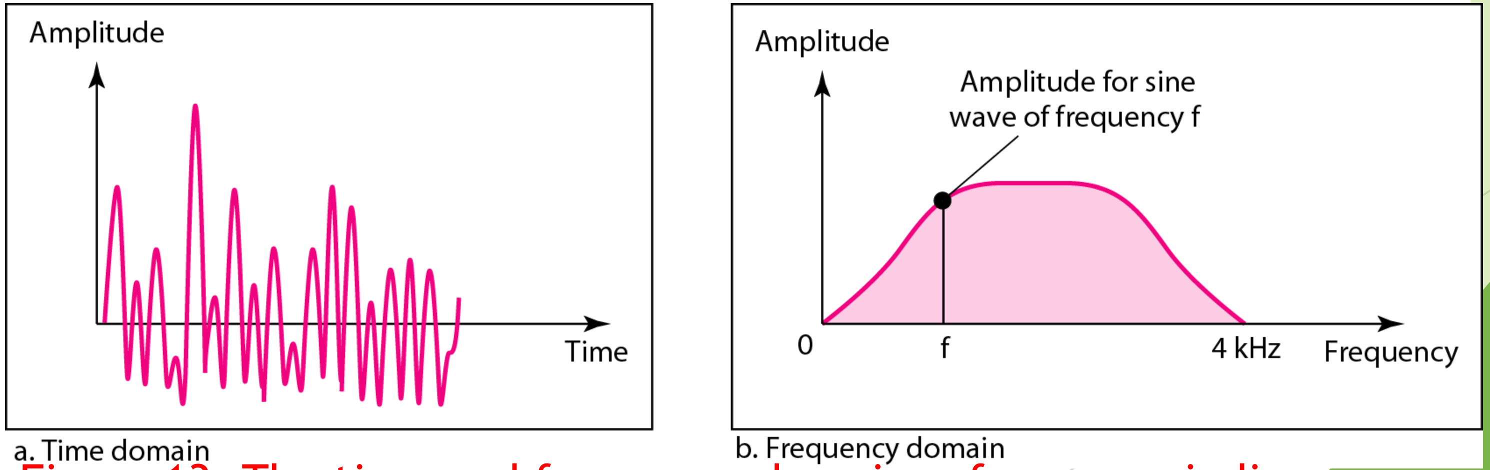


Figure 13. The time and frequency domains of a nonperiodic signal

PERIODIC ANALOG SIGNALS(continue…)

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

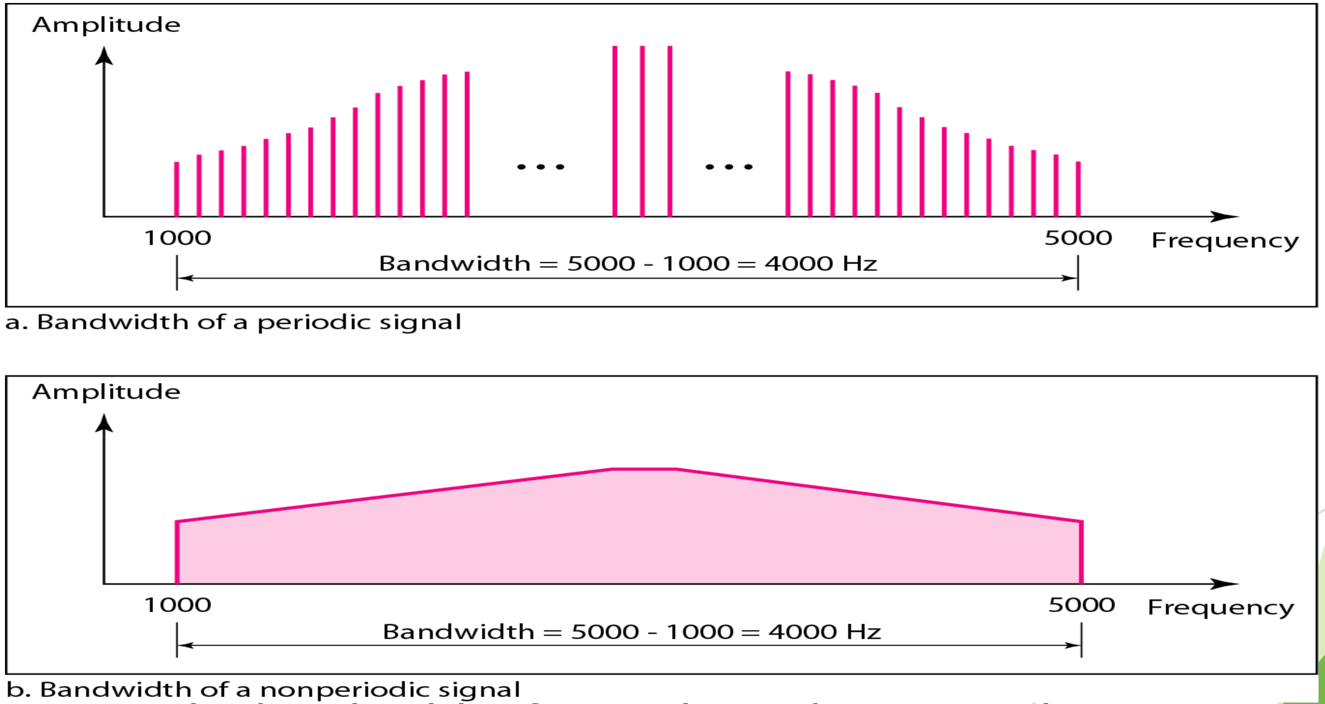


Figure 14. The bandwidth of periodic and nonperiodic composite signals

PERIODIC ANALOG SIGNALS(continue…)

- Bandwidth (continue…)

Example8:- A 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 integral frequencies of the same amplitude.

B = fh - fl, 20 = 60 – fl, fl = 60 - 20 = 40 Hz

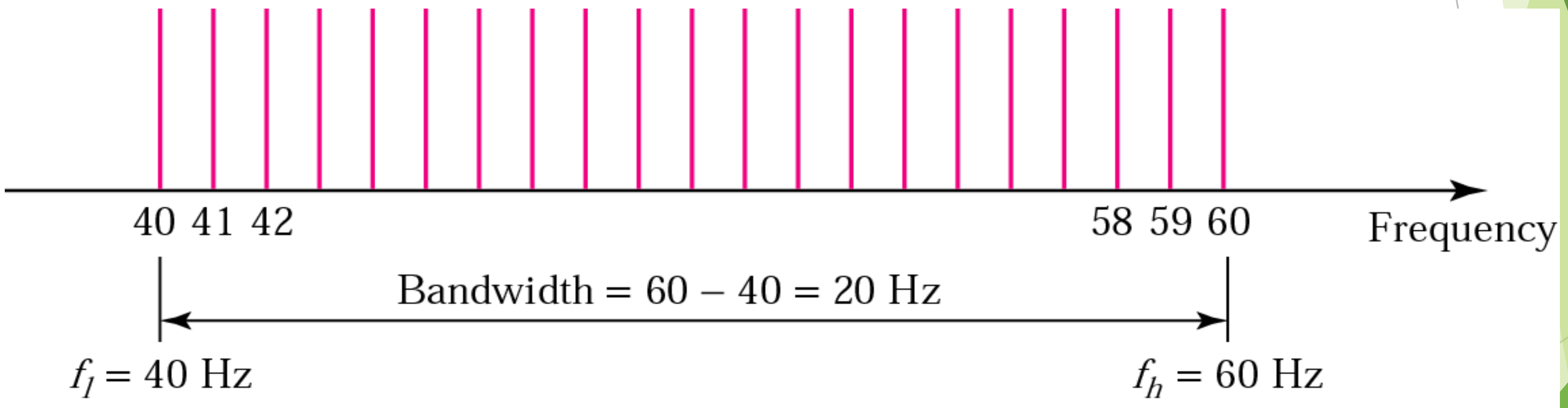
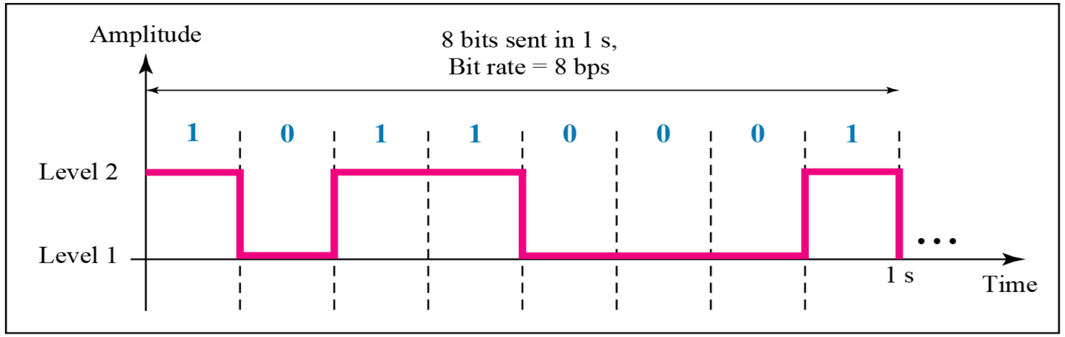


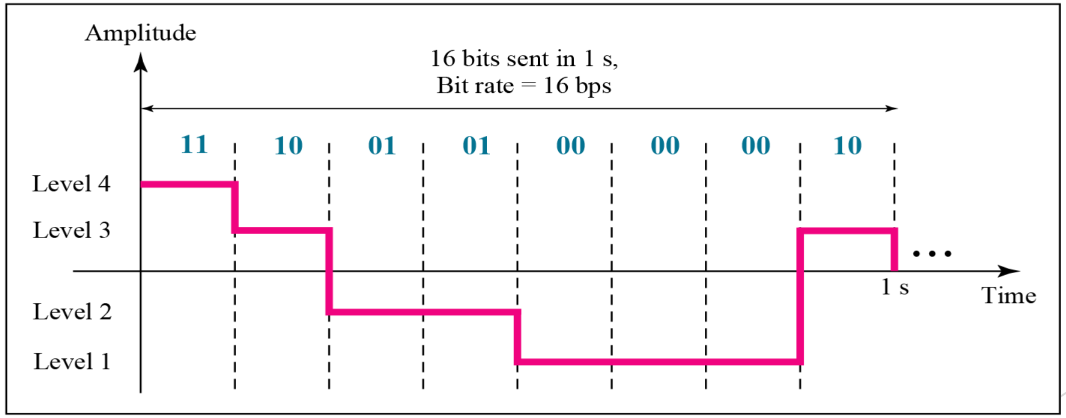
Figure 15. The bandwidth for Example 8

DIGITAL SIGNALS

- In addition to being represented by an analog signal, information can also be represented by a digital signal. For example, a I 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.



a. A digital signal with two levels



b. A digital signal with four levels

Figure 16 Two digital signals: one with two signal levels and the other with four signal levels

- Bit rate and interval
- 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). Figure 17. shows the bit rate for two signals. The bit Interval is the time required to send one signal bit.

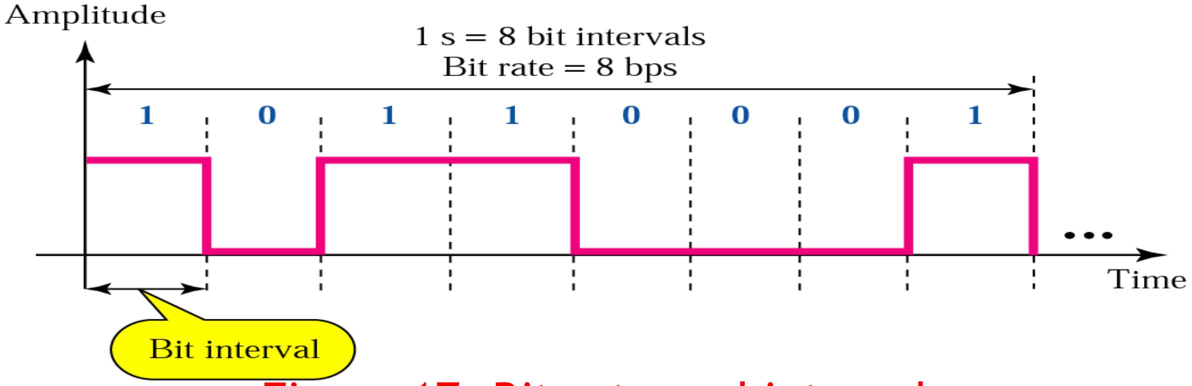


Figure 17. Bit rate and interval

- Example 9 :-
- Assume we need to download text documents at the rate of 100 pages per second. 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

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

DIGITAL SIGNALS (continue…)

- Bit rate and interval (continue…)
- 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 nonperiodic, the decomposed signal still has an infinite bandwidth, but the frequencies are continuous. Figure 18. shows a periodic and a nonperiodic digital signal and their bandwidths.

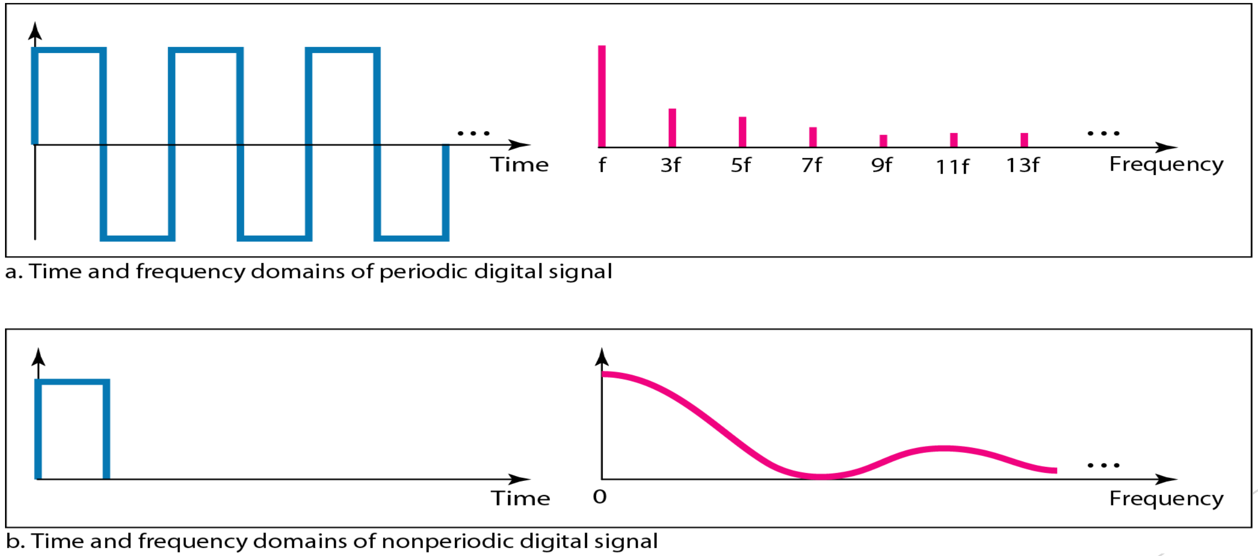


Figure 18. The time and frequency domains of periodic and nonperiodic digital signals

Summary

- Data must be transformed to electromagnetic signals to be transmitted.
- Data can be analog or digital. Analog data are continuous and take continuous values. Digital data have discrete states and take discrete values.
- 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.
- In data communications, we commonly use periodic analog signals and nonperiodic digital signals.
- Frequency and period are the inverse of each other.
- Frequency is the rate of change with respect to time.
- Phase describes the position of the waveform relative to time 0.
- A complete sine wave in the time domain can be represented by one single spike in the frequency domain.
- 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.
- According to Fourier analysis, any composite signal is a combination of simple sine waves with different frequencies, amplitudes, and phases.
- The bandwidth of a composite signal is the difference between the highest and the lowest frequencies contained in that signal.
- A digital signal is a composite analog signal with an infinite bandwidth.