Communication Engineering
CSE- 214

Prepared by.

MD Abdur Razzak,

Lecturer, DEPT. of CSE.

University of Global Village , Barishal.

Chapter-1 : Introduction

- **CHAPTER OBJECTIVES**
- • How communication systems work
- • Frequency allocation and propagation characteristics
- • Computer solutions (MATLAB)
- • Information measure
- • Coding performance

BLOCK DIAGRAM OF A COMMUNICATION SYSTEM

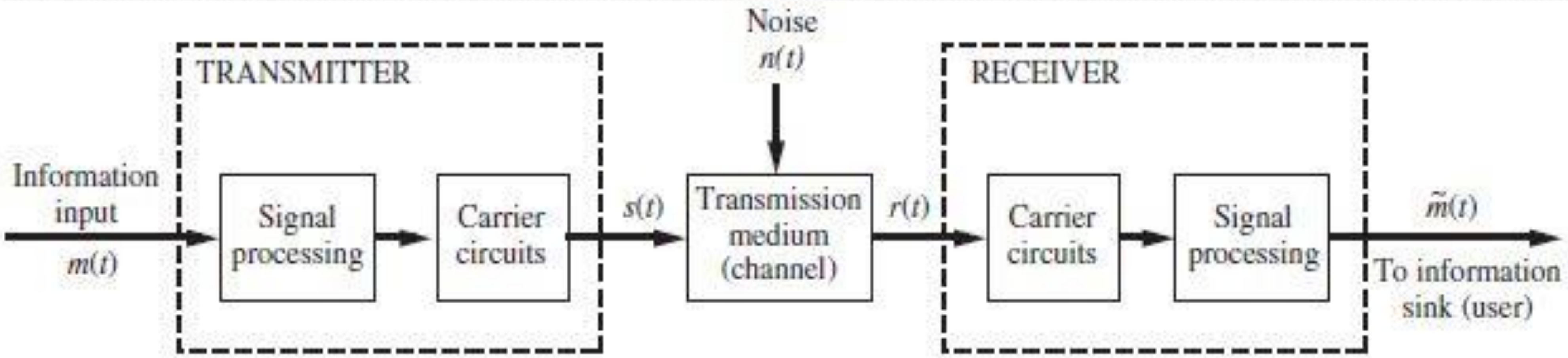


Figure 1–1 Communication system.

DIGITAL AND ANALOG SOURCES AND SYSTEMS

- **DEFINITION.** A *digital information source* produces a finite set of possible messages.
- A telephone touchtone pad is a good example of a digital source. There is a finite number of characters (messages) that can be emitted by this source.
- **DEFINITION.** An *analog information source* produces messages that are defined on a

continuum.

A microphone is a good example of an analog source. The output voltage describes the information in the sound, and it is distributed over a continuous range of values.

DIGITAL AND ANALOG SOURCES AND SYSTEMS

- **DEFINITION.** A *digital communication system* transfers information from a digital source to the intended receiver (also called the sink).
- **DEFINITION.** An *analog communication system* transfers information from an analog source to the sink

Digital communication has a number of advantages:

- • Relatively inexpensive digital circuits may be used.
- • Privacy is preserved by using data encryption.
- • Greater dynamic range (the difference between the largest and smallest values) is possible.
- • Data from voice, video, and data sources may be merged and transmitted over a common digital transmission system.
- • In long-distance systems, noise does not accumulate from repeater to repeater.
- • Errors in detected data may be small, even when there is a large amount of noise on the received signal.
- • Errors may often be corrected by the use of coding.

Digital communication also has disadvantages:

- • Generally, more bandwidth is required than that for analog systems.
- • Synchronization is required.

DETERMINISTIC AND RANDOM WAVEFORMS

- **DEFINITION.** A *deterministic waveform* can be modeled as a completely specified function of time.

For example, if w(t) = A cos (v0t + 0)

v=2*(pi)*f

describes a waveform, where *A*, ω0, and 0 are known constants, this waveform is said to be deterministic because, for any value of *t*, the value w(*t*) can be evaluated. If any of the constants are unknown, then the value of w(*t*) cannot be calculated, and consequently, w(*t*) is not deterministic.

DETERMINISTIC AND RANDOM WAVEFORMS

- **DEFINITION.** A *random waveform* (or stochastic waveform) cannot be completely specified as a function of time and must be modeled probabilistically.

FREQUENCY ALLOCATIONS

- Wireless communication systems often use the atmosphere for the transmission channel.
- Here, interference and propagation conditions are strongly dependent on the transmission frequency.

FREQUENCY ALLOCATIONS

TABLE 1–2 FREQUENCY BANDS

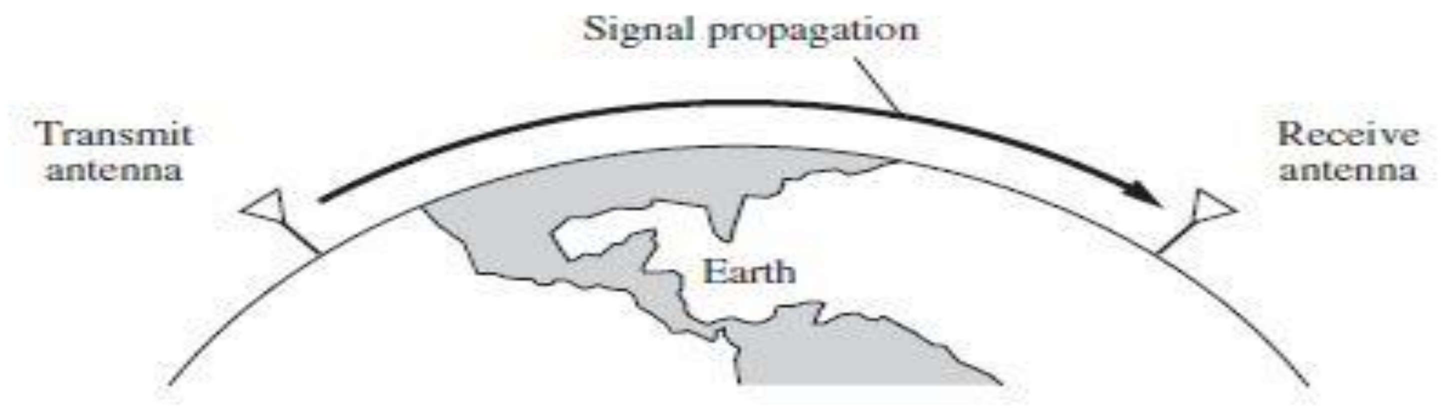
Frequency Band[a]	Designation	Propagation Characteristics	Typical Uses
3–30 kHz	Very low frequency (VLF)	Ground wave; low attenuation day and night; high atmospheric noise level	Long-range navigation; submarine communication
30–300 kHz	Low frequency (LF)	Similar to VLF, slightly less reliable; absorption in daytime	Long-range navigation and marine communication radio beacons
300–3000 kHz	Medium frequency (MF)	Ground wave and night sky wave; attenuation low at night and high in day; atmospheric noise	Maritime radio, direction finding, and AM broadcasting
3–30 MHz	High frequency (HF)	Ionospheric reflection varies with time of day, season, and frequency; low atmospheric noise at 30 MHz	Amateur radio; international broadcasting, military communication, long-distance aircraft and ship communication, telephone, telegraph, facsimile
30–300 MHz	Very high frequency (VHF)	Nearly line-of-sight (LOS) propagation, with scattering because of temperature inversions, cosmic noise	VHF television, FM two-way radio, AM aircraft communication, aircraft navigational aids

FREQUENCY ALLOCATIONS

TABLE 1–2 *(cont.)*

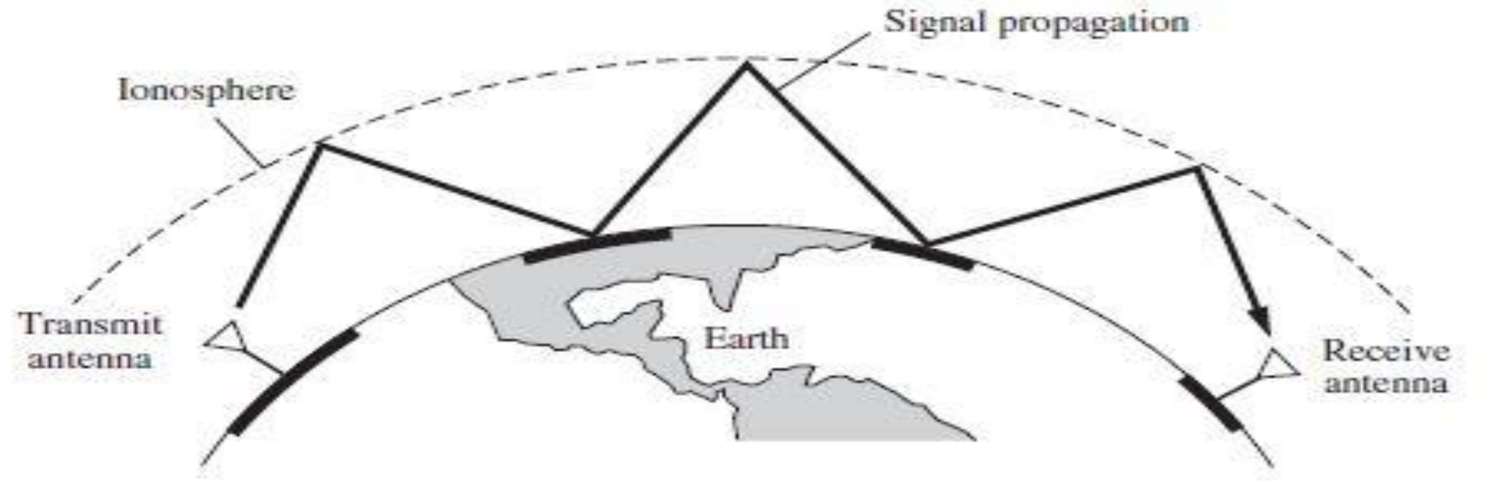
Frequency Band[a]	Designation	Propagation Characteristics	Typical Uses
0.3–3 GHz	Ultrahigh frequency (UHF)	LOS propagation, cosmic noise	UHF television, cellular telephone, navigational aids, radar, GPS, microwave links, personal communication systems
	Letter designation		
1.0–2.0	L		
2.0–4.0	S		
3–30 GHz	Superhigh frequency (SHF)	LOS propagation; rainfall attenuation above 10 GHz, atmospheric attenuation because of oxygen and water vapor, high water-vapor absorption at 22.2 GHz	Satellite communication, radar microwave links
	Letter designation		
2.0–4.0	S		
4.0–8.0	C		
8.0–12.0	X		
12.0–18.0	Ku		
18.0–27.0	K		
27.0–40.0	Ka		
26.5–40.0	R		
30–300 GHz	Extremely high frequency (EHF)	Same; high water-vapor absorption at 183 GHz and oxygen absorption at 60 and 119 GHz	Radar, satellite, experimental
	Letter designation		
27.0–40.0	Ka		
26.5–40.0	R		
33.0–50.0	Q		
40.0–75.0	V		
75.0–110.0	W		
110–300	mm (millimeter)		
10^3–10^7 GHz	Infrared, visible light, and ultraviolet	LOS propagation	Optical communications

Propagation of radio frequencies.



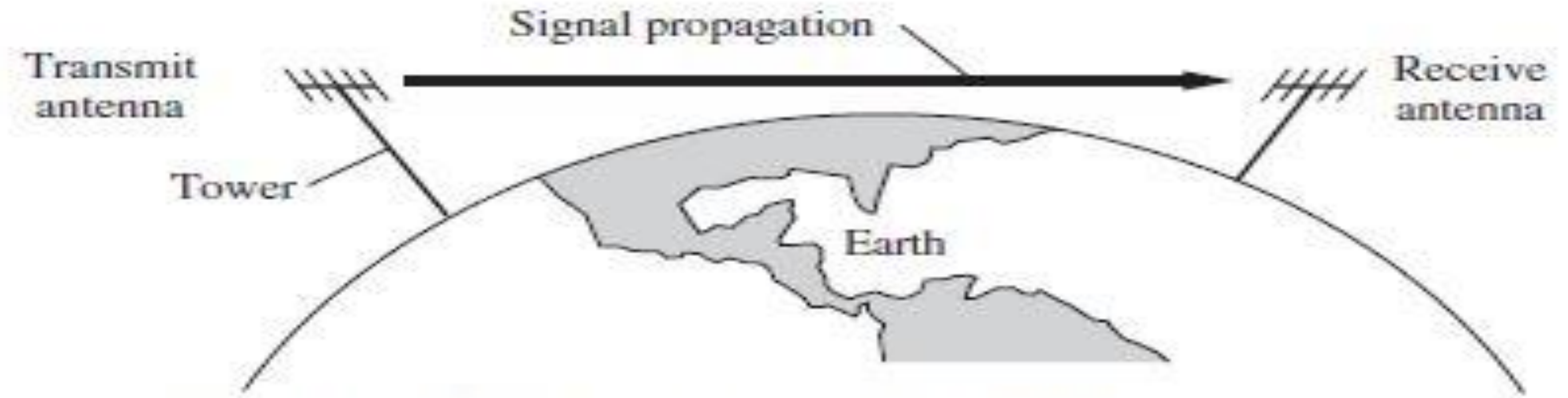
(a) Ground-Wave Propagation (Below 2 MHz)

Propagation of radio frequencies.



(b) Sky-Wave Propagation (2 to 30 MHz)

Propagation of radio frequencies.



(c) Line-of-Sight (LOS) Propagation (Above 30 MHz)

Figure 1–2 Propagation of radio frequencies.

Calculation of distance to horizon.

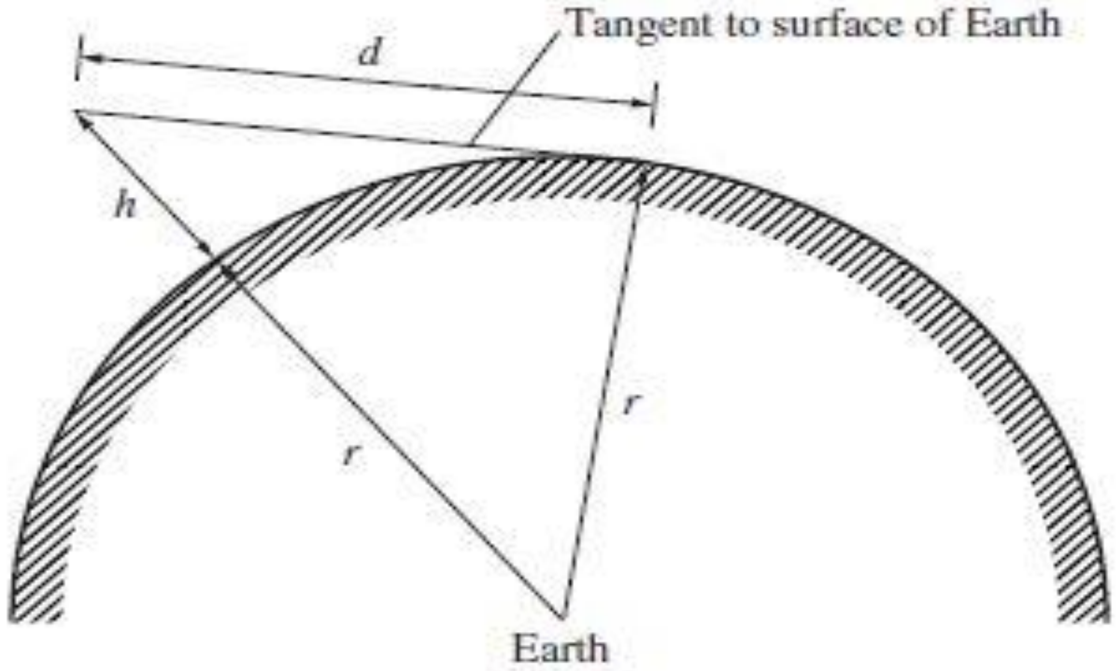


Figure 1–3 Calculation of distance to horizon.

Calculation of distance to horizon.

"see" the transmitting antenna. A formula for the distance to the horizon, d, as a function of antenna height can be easily obtained by the use of Fig. 1–3. From this figure,

$$d^2 + r^2 = (r + h)^2$$

or

$$d^2 = 2rh + h^2$$

where r is the radius of the Earth and h is the height of the antenna above the Earth's surface. In this application, h^2 is negligible with respect to $2rh$. The radius of the Earth is 3,960 statute miles. However, at LOS radio frequencies the effective Earth radius† is $\frac{4}{3}$ (3,960) miles. Thus, the distance to the radio horizon is

$$d = \sqrt{2h} \text{ miles} \tag{1–6}$$

INFORMATION MEASURE

Definition. The *information* sent from a digital source when the jth message is transmitted is given by

$$I_j = \log_2\left(\frac{1}{P_j}\right) \text{bits} \tag{1–7a}$$

where P_j is the probability of transmitting the jth message.†

INFORMATION MEASURE

DEFINITION. The *average information* measure of a digital source is

$$H = \sum_{j=1}^{m} P_j I_j = \sum_{j=1}^{m} P_j \log_2\left(\frac{1}{P_j}\right) \text{ bits} \tag{1–8}$$

where m is the number of possible different source messages and P_j is the probability of sending the jth message (m is finite because a digital source is assumed). The average information is called *entropy*.

Example 1–3 EVALUATION OF INFORMATION AND ENTROPY

Find the information content of a message that consists of a digital word 12 digits long in which each digit may take on one of four possible levels. The probability of sending any of the four levels is assumed to be equal, and the level in any digit does not depend on the values taken on by previous digits.

In a string of 12 symbols (digits), where each symbol consists of one of four levels, there are $4 . 4 \ldots 4 = 4^{12}$ different combinations (words) that can be obtained. Because each level is equally likely, all the different words are equally likely. Thus,

$$p_j = \frac{1}{4^{12}} = \left(\frac{1}{4}\right)^{12}$$

or

$$I_j = \log_2\left(\frac{1}{\left(\frac{1}{4}\right)^{12}}\right) = 12 \log_2(4) = 24 \text{ bits}$$

Coding

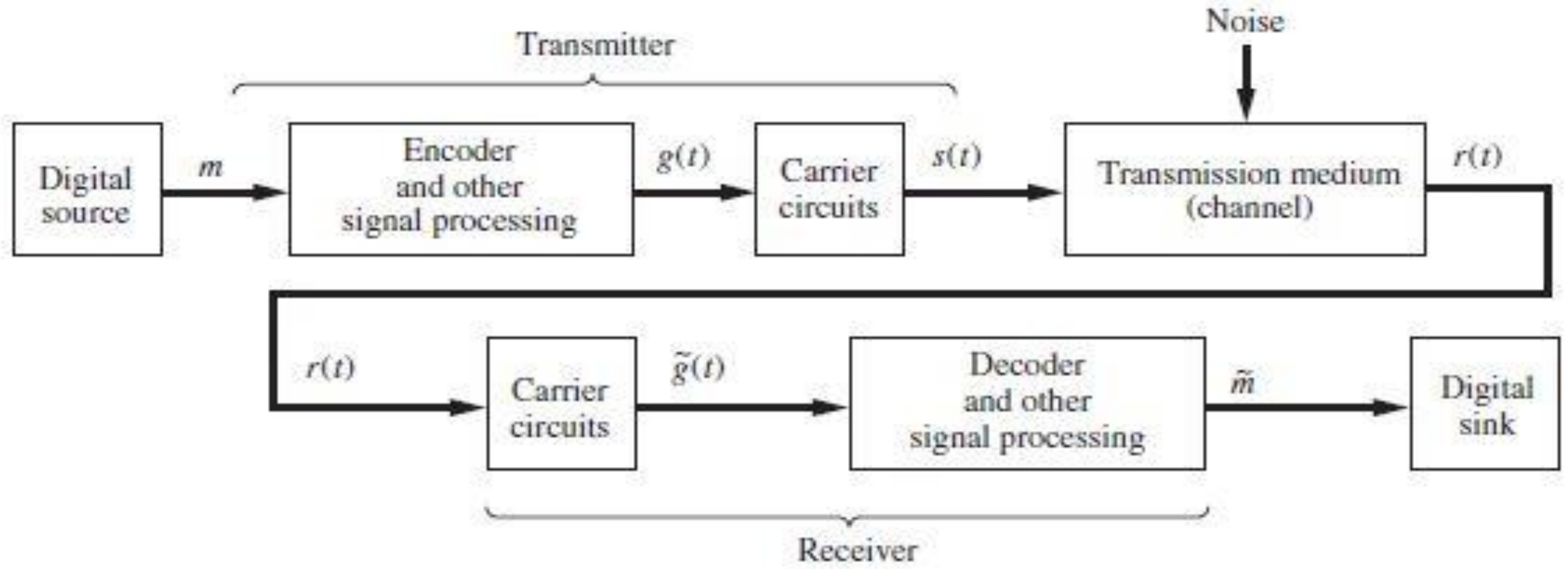


Figure 1–4 General digital communication system.

Coding

Codes may be classified into two broad categories:

- *Block codes*. A block code is a mapping of k input binary symbols into n output binary symbols. Consequently, the block coder is a *memoryless* device. Because $n > k$, the code can be selected to provide redundancy, such as *parity bits*, which are used by the decoder to provide some error detection and error correction. The codes are denoted by (n, k), where the code rate $R^{\dagger}$ is defined by $R = k/n$. Practical values of R range from $\frac{1}{4}$ to $\frac{7}{8}$, and k ranges from 3 to several hundred [Clark and Cain, 1981].
- *Convolutional codes*. A convolutional code is produced by a coder that has *memory*. The convolutional coder accepts k binary symbols at its input and produces n binary symbols at its output, where the n output symbols are affected by $v + k$ input symbols. Memory is incorporated because $v > 0$. The code rate is defined by $R = k/n$. Typical values for k and n range from 1 to 8, and the values for v range from 2 to 60. The range of R is between $\frac{1}{4}$ and $\frac{7}{8}$ [Clark and Cain, 1981]. A small value for the code rate R indicates a high degree of redundancy, which should provide more effective error control at the expense of increasing the bandwidth of the encoded signal.

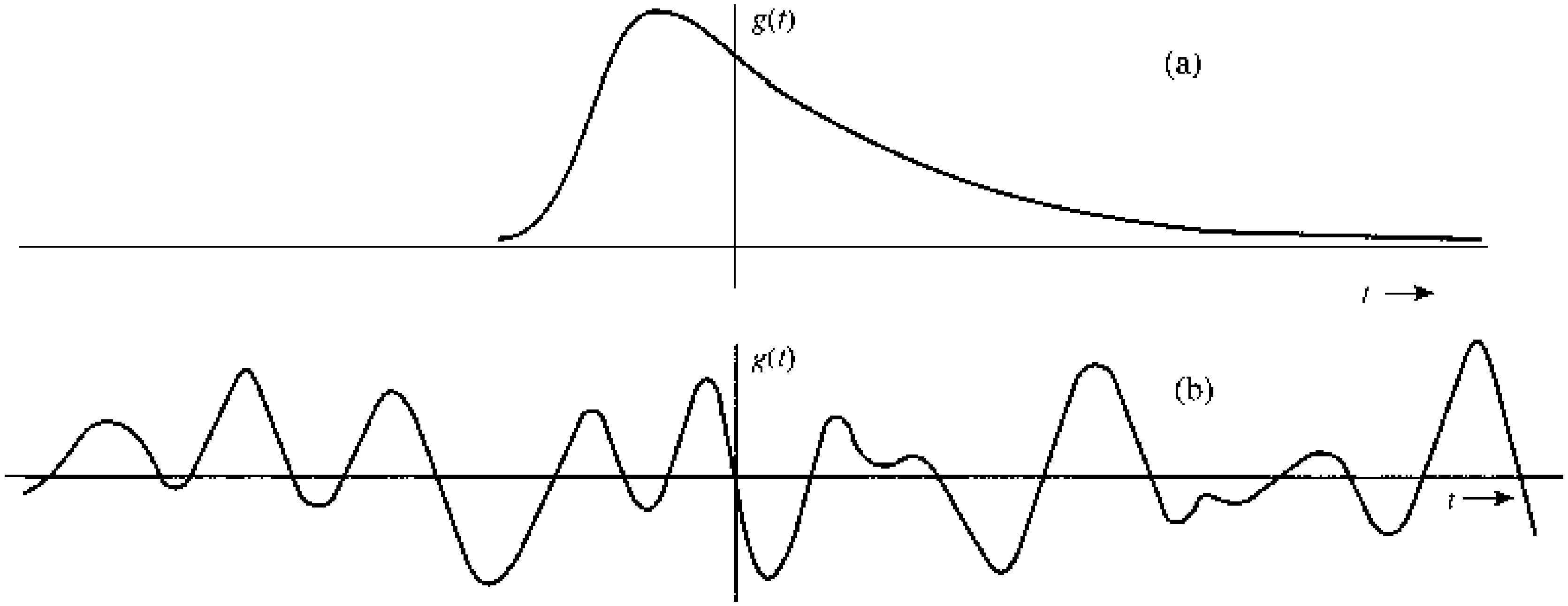
Chap: 2
Signal and Signal Space

SIZE OF A SIGNAL

Signal Energy

The size of any entity is a quantity that indicates its strength. Generally speaking, a signal varies with time. To set a standard quantity that measures signal strength, we normally view a signal $g(t)$ as a voltage across a one-ohm resistor. We define **signal energy** E_g of the signal $g(t)$ as the energy that the voltage $g(t)$ dissipates on the resistor. More formally, we define E_g

Figure 2.1
Examples of signals.
(a) Signal with finite energy.
(b) Signal with finite power.



(for a real signal) as

$$E_g = \int_{-\infty}^{\infty} g^2(t)\, dt \tag{2.1}$$

This definition can be generalized to a complex-valued signal $g(t)$ as

$$E_g = \int_{-\infty}^{\infty} |g(t)|^2\, dt \tag{2.2}$$

Signal Power

To be a meaningful measure of signal size, the signal energy must be finite. A necessary condition for energy to be finite is that the signal amplitude goes to zero as $|t|$ approaches infinity (Fig. 2.1a). Otherwise the integral in Eq. (2.1) will not converge.

If the amplitude of $g(t)$ does not go to zero as $|t|$ approaches infinity (Fig. 2.1b), the signal energy is infinite. A more meaningful measure of the signal size in such a case would be the time average of the energy (if it exists), which is the average power P_g defined (for a real signal) by

$$P_g = \lim_{T\to\infty} \frac{1}{T} \int_{-T/2}^{T/2} g^2(t)\, dt \qquad (2.3)$$

We can generalize this definition for a complex signal $g(t)$ as

$$P_g = \lim_{T\to\infty} \frac{1}{T} \int_{-T/2}^{T/2} |g(t)|^2\, dt \qquad (2.4)$$

CLASSIFICATION OF SIGNALS

There are various classes of signals. Here we shall consider only the following pairs of classes, which are suitable for the scope of this book.

1. Continuous time and discrete time signals
2. Analog and digital signals
3. Periodic and aperiodic signals
4. Energy and power signals
5. Deterministic and probabilistic signals

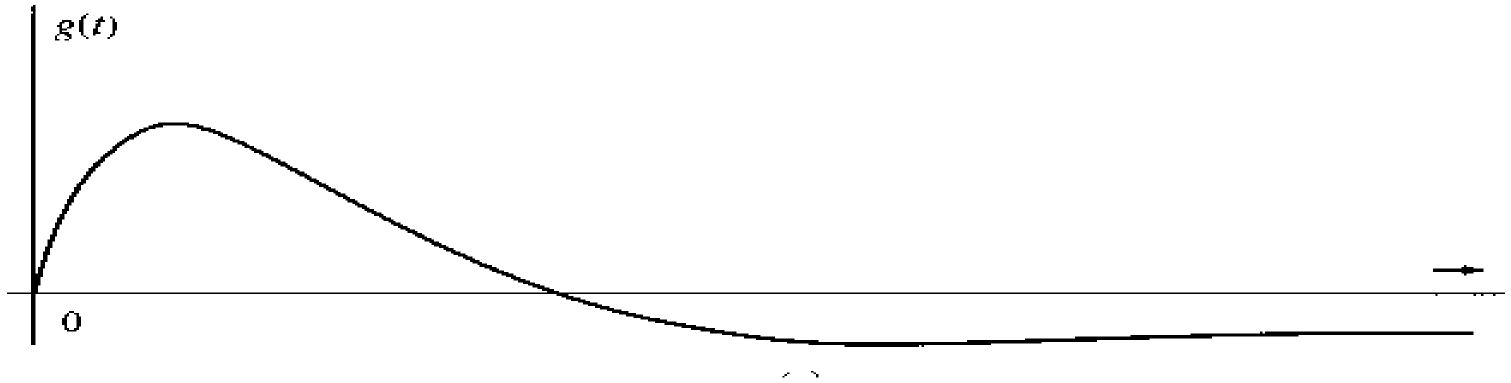
Continuous Time and Discrete Time Signals

A signal that is specified for every value of time t (Fig. 2.3a) is a **continuous time signal**, and a signal that is specified only at discrete points of $t = nT$ (Fig. 2.3b) is a **discrete time signal**. Audio and video recordings are continuous time signals, whereas the quarterly gross domestic product (GDP), monthly sales of a corporation, and stock market daily averages are discrete time signals.

Analog and Digital Signals

One should not confuse analog signals with continuous time signals. The two concepts are not the same. This is also true of the concepts of discrete time and digital. A signal whose amplitude can take on any value in a continuous range is an **analog signal**. This means that

Figure 2.3
(a) Continuous time signal.
(b) Discrete time signals.



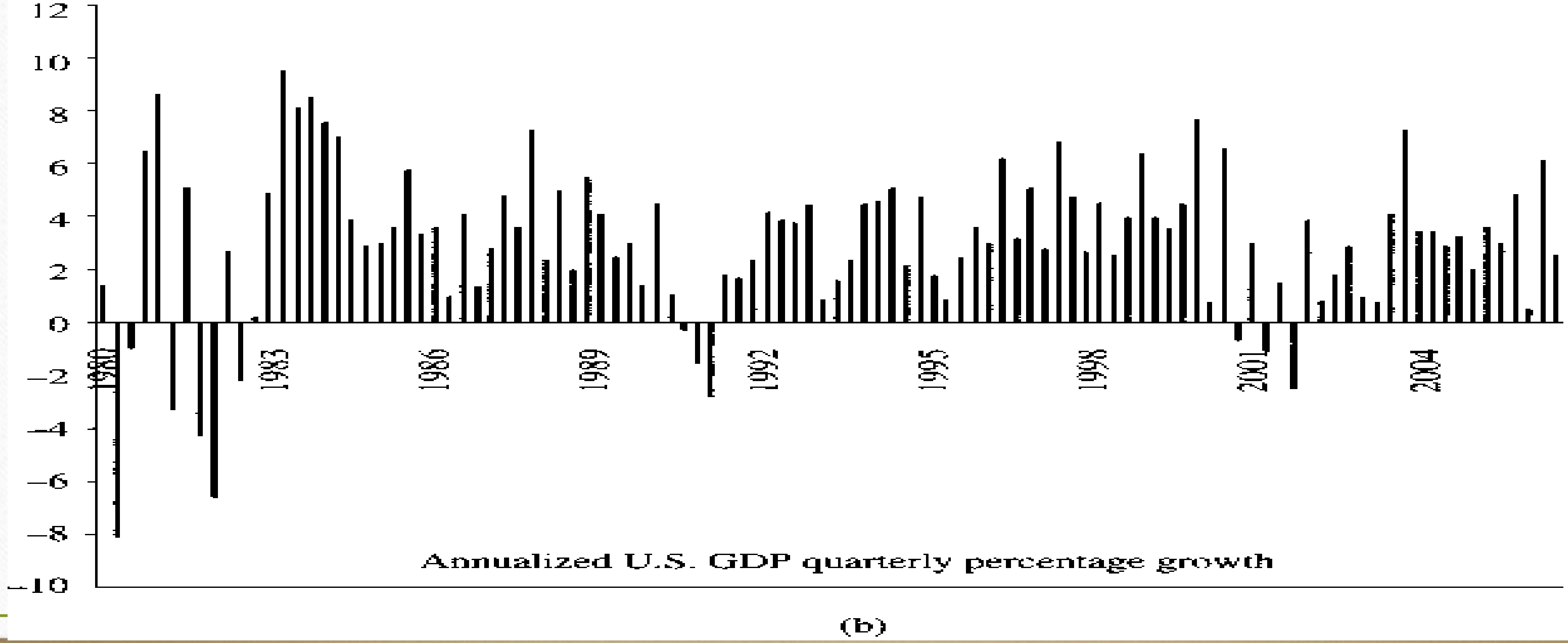
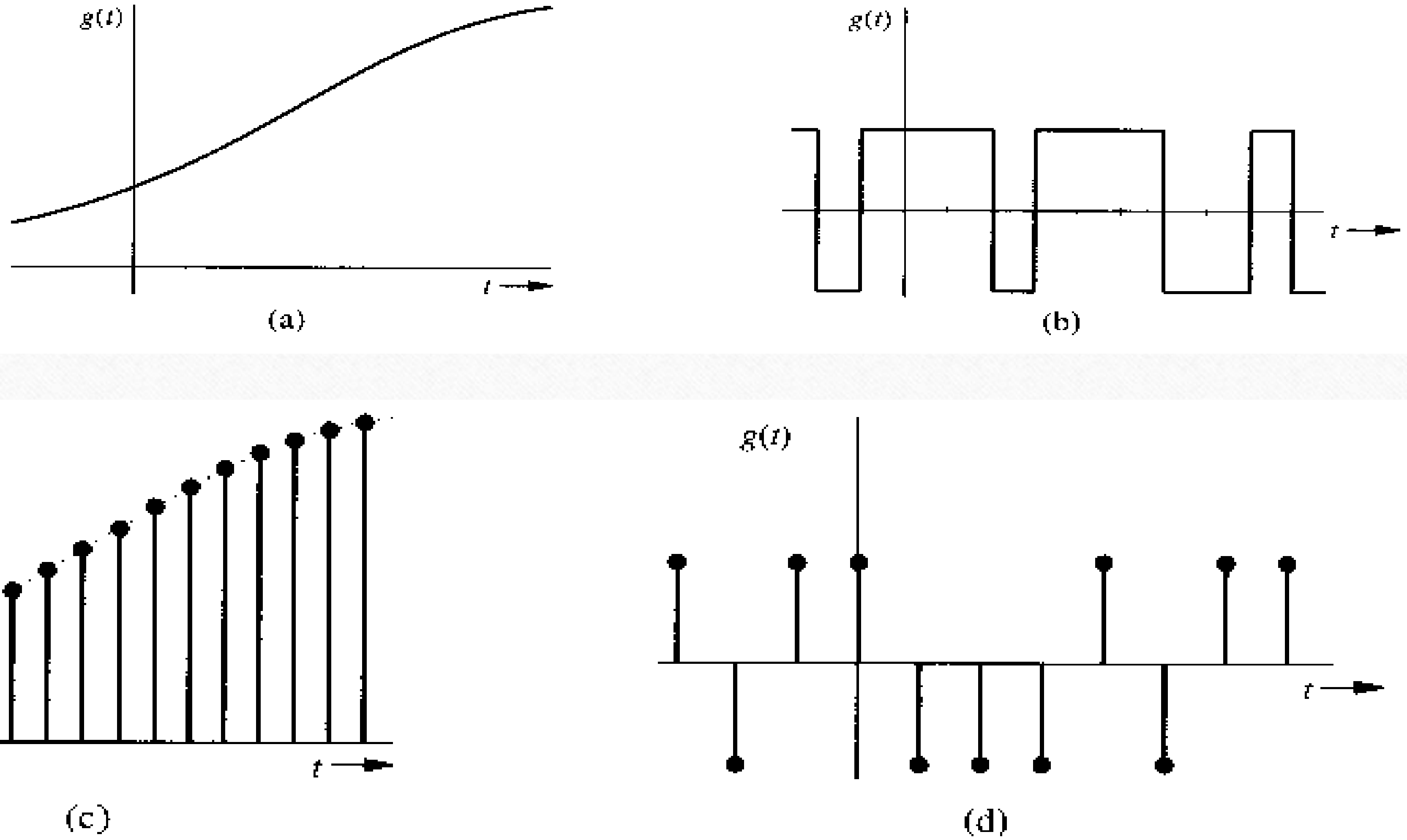


Figure 2.4 Examples of signals: (a) analog and continuous time, (b) digital and continuous time, (c) analog and discrete time, (d) digital and discrete time.



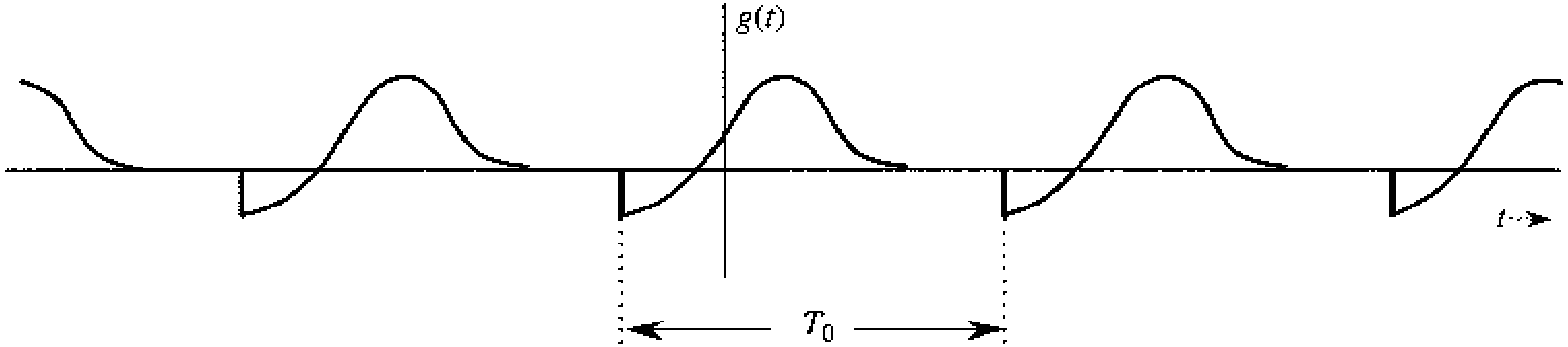
Periodic and Aperiodic Signals

A signal $g(t)$ is said to be **periodic** if there exists a positive constant T_0 such that

$$g(t) = g(t + T_0) \quad \text{for all } t \tag{2.5}$$

The **smallest** value of T_0 that satisfies the periodicity condition of Eq. (2.5) is the **period** of $g(t)$. The signal in Fig. 2.2b is a periodic signal with period of 2. Naturally, a signal is **aperiodic**

Figure 2.5 A periodic signal of period T_0.



with period mT_0, where m is any integer. However, by definition, the period is the smallest interval that satisfies periodicity condition of Eq. (2.5). Therefore, T_0 is the period.