

Chapter 1 Introduction



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Introduction



- ◇ The subject of *digital communications* involves the transmission of information in *digital form* from a source that generates the information to one or more destinations.
- ◇ Of particular importance in the analysis and design of communication systems are the characteristics of the *physical channels* through which the information is transmitted.
- ◇ The characteristics of the channel generally affect the design of the basic building blocks of the communication system.

Why Digitize Analog Source ?



- ◇ Advantages of digital transmission over analog transmission:
 - ◇ Digital systems are less sensitive to noise than analog. For long transmission lengths, the signal may be regenerated effectively error-free at different point along the path and the original signal transmitted over the remaining length.
 - ◇ With digital systems, it is easier to integrate different services, for example, video and the accompanying soundtrack, into the same transmission scheme.
 - ◇ The transmission scheme can be relatively independent of the source. For example, a digital transmission scheme that transmits voice at 10 kbps could also be used to transmit computer data at 10 kbps.
 - ◇ Circuitry for handling digital signals is easier to repeat and digital circuits are less sensitive to physical effect such as vibration and temperature.
 - ◇ Digital signals are simpler to characterize and typically do not have the same amplitude range and variability as analog signals. This makes the associated hardware easier to design.

Why Digitize Analog Source ?



- ◇ Digital techniques offer strategies for more efficient use of media, e.g. cable, radio wave, and optical fibers.
 - ◇ Various media sharing strategies, known as multiplexing techniques, are more easily implemented with digital transmission strategies.
 - ◇ There are techniques for removing redundancy from a digital transmission, so as to minimize the amount of information that has to be transmitted. These techniques fall under the broad classification of source coding.
 - ◇ There are techniques for adding controlled redundancy to digital transmission, such that errors occur during transmission may be corrected at the receiver without any additional information. These techniques fall under the general category of channel coding.

Why Digitize Analog Source ?



- ◇ Digital techniques make it easier to specify complex standards that may be shared on a worldwide basis. This allows the development of communication components with many different features (e.g., a cellular handset) and their interoperation with a different component (e.g., a base station) produced by a different manufacturer.
- ◇ Other channel compensations techniques, such as equalization, especially adaptive versions, are easier to implement with digital transmission techniques.
- ◇ It should be emphasized that the majority of these advantages for digital transmission rely on availability of low-cost microelectronics.

Block Diagram of a Digital Communication System

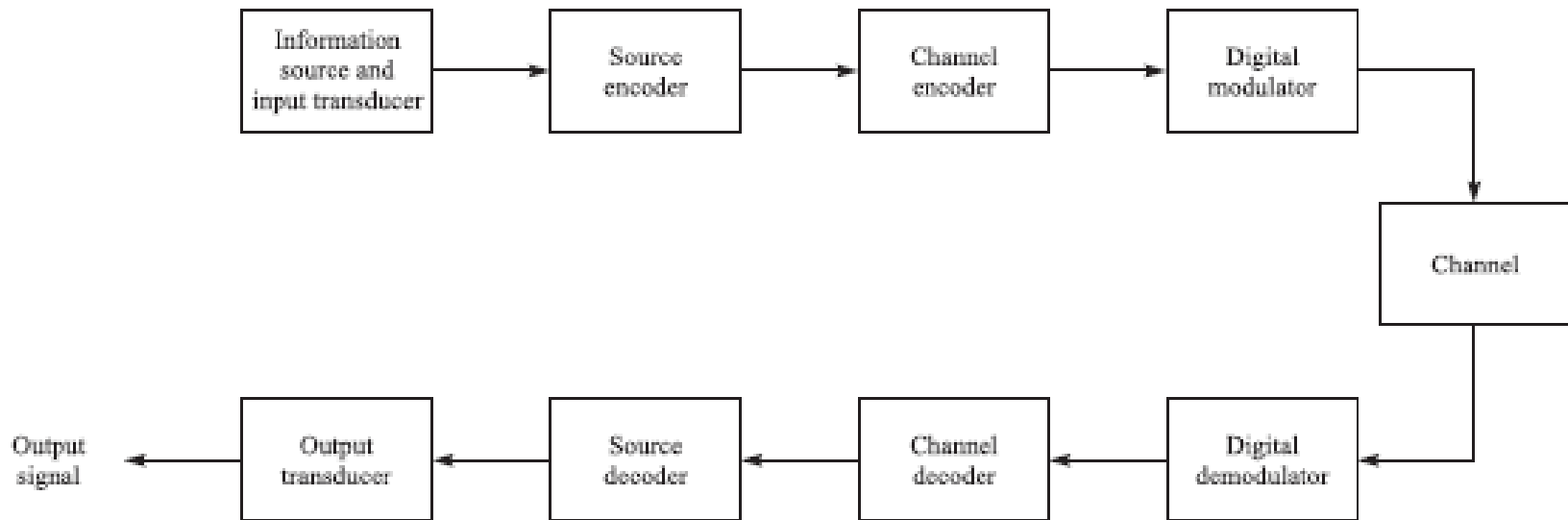


FIGURE 1.1-1
Basic elements of a digital communication system.

Communication Channels and Their Characteristics



- ◇ Problems in signal transmission through channels:
 - ◇ *Thermal noise*: generated internally by components such as resistors and solid-state devices.
 - ◇ *External noise* and *interference* from other users.
 - ◇ *Signal attenuation*.
 - ◇ *Amplitude and phase distortion*.
 - ◇ *Multi-path distortion*.
- ◇ Two limitations constrain the amount of data that can be transmitted reliably over any communication channel:
 - ◇ Power.
 - ◇ Available channel bandwidth.

- ◇ Physical channels:
 - ◇ A pair of *wires* that carry the electrical signal;
 - ◇ An *optical fiber* that carries the information on a modulated light beam;
 - ◇ An *underwater ocean channel* in which the information is transmitted acoustically;
 - ◇ *Free space* over which the information-bearing signal is radiated by use of an antenna;
 - ◇ *Data storage media*, such as magnetic tape, magnetic disks, and optical disks.

- ◇ In the design of communication systems for transmitting information through physical channels, we find it convenient to construct mathematical models that reflect the most important characteristics of the transmission medium.
- ◇ The mathematical model for the channel is used in the design of the channel encoder and modulator at the transmitter and the demodulator and channel decoder at the receiver.

- ◇ The additive noise channel
 - ◇ The transmitted signal $s(t)$ is corrupted by an additive random noise process $n(t)$.
 - ◇ Thermal noise is characterized statistically as a Gaussian noise process.
 - ◇ When the signal undergoes attenuation in transmission through the channel, the received signal is
$$r(t) = \alpha \cdot s(t) + n(t)$$
 where α is the attenuation factor.

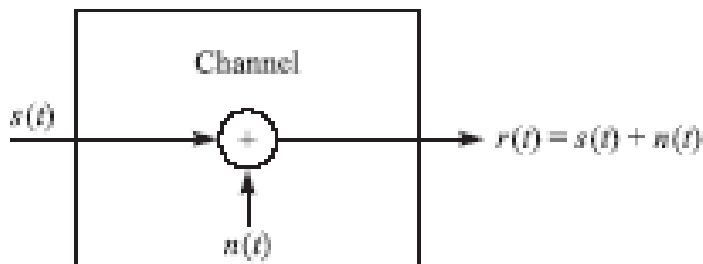
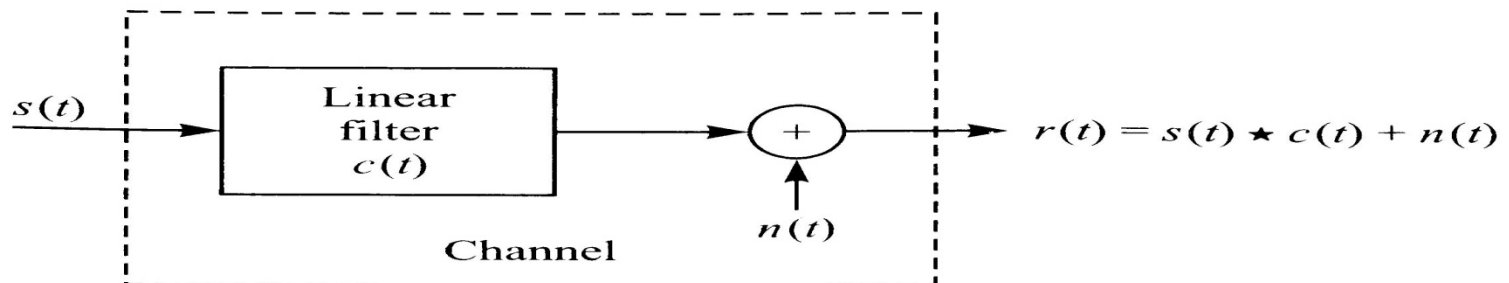


FIGURE 1.3-1
The additive noise channel.

- ◇ The linear filter channel
 - ◇ In some physical channels, such as wire-line telephone channels, filters are used to ensure that the transmitted signals do not exceed specified bandwidth limitations and thus do not interfere with one another.
 - ◇ Such channels are generally characterized mathematically as linear filter channels with additive noise.

$$r(t) = s(t) * c(t) + n(t) = \int_{-\infty}^{\infty} c(\tau) s(t - \tau) d\tau + n(t)$$



Channel Capacity



- ◇ Of practical interest in many communication applications is the number of bits that may be reliably transmitted per second through a given communications channel.
- ◇ **Shannon's third theorem, the information capacity theorem:**
 - ◇ The information capacity of a continuous channel of bandwidth B Hertz, perturbed by additive white Gaussian noise of power spectral density $N_0/2$ and limited in bandwidth to B , is given by

$$C = B \log_2 \left(1 + \frac{P}{N_0 B} \right) \text{ bits per second}$$

where P is the average transmitted power.