Chapter 1 Introduction

Chapter Outline

- Historical review
- Elements of an electrical communication system
- Communication channels and their characteristics
- Mathematical models for communication channels
- Further reading

Historical Review (1/2)

TABLE 1.1 THE MORSE CODE

A	· —	N	— ·
B	— · · ·	O	— — —
C	— · — ·	P	· — — ·
D	— · ·	Q	— — · —
E	·	R	· — ·
F	· · — ·	S	· · ·
G	— — ·	T	—
H	· · · ·	U	· · —
I	· ·	V	· · · —
J	· — — —	W	· — —
K	— · —	X	— · · —
L	· — · ·	Y	— · — —
M	— —	Z	— — · ·

(a) Letters

1	· — — — —
2	· · — — —
3	· · · — —
4	· · · · —
5	· · · · ·
6	— · · · ·
7	— — · · ·
8	— — — · ·
9	— — — — ·
0	— — — — —

(b) Numbers

Historical Review (2/2)

Period (.)	· — · — · —	Wait sign (AS)	· — · · ·
Comma (,)	— — · · — —	Double dash (break)	— · · · —
Interrogation (?)	· · — — · ·	Error sign	· · · · · · · ·
Quotation Mark (")	· — · · — ·	Fraction bar (/)	— · · — ·
Colon (:)	— — — · · ·	End of message (AR)	· — · — ·
Semicolon (;)	— · — · — ·	End of transmission (SK)	· · · — · —
Parenthesis ( )	— · — — · —		

(c) Punctuation and special characters

Elements of an Electrical Communication System (1/7)

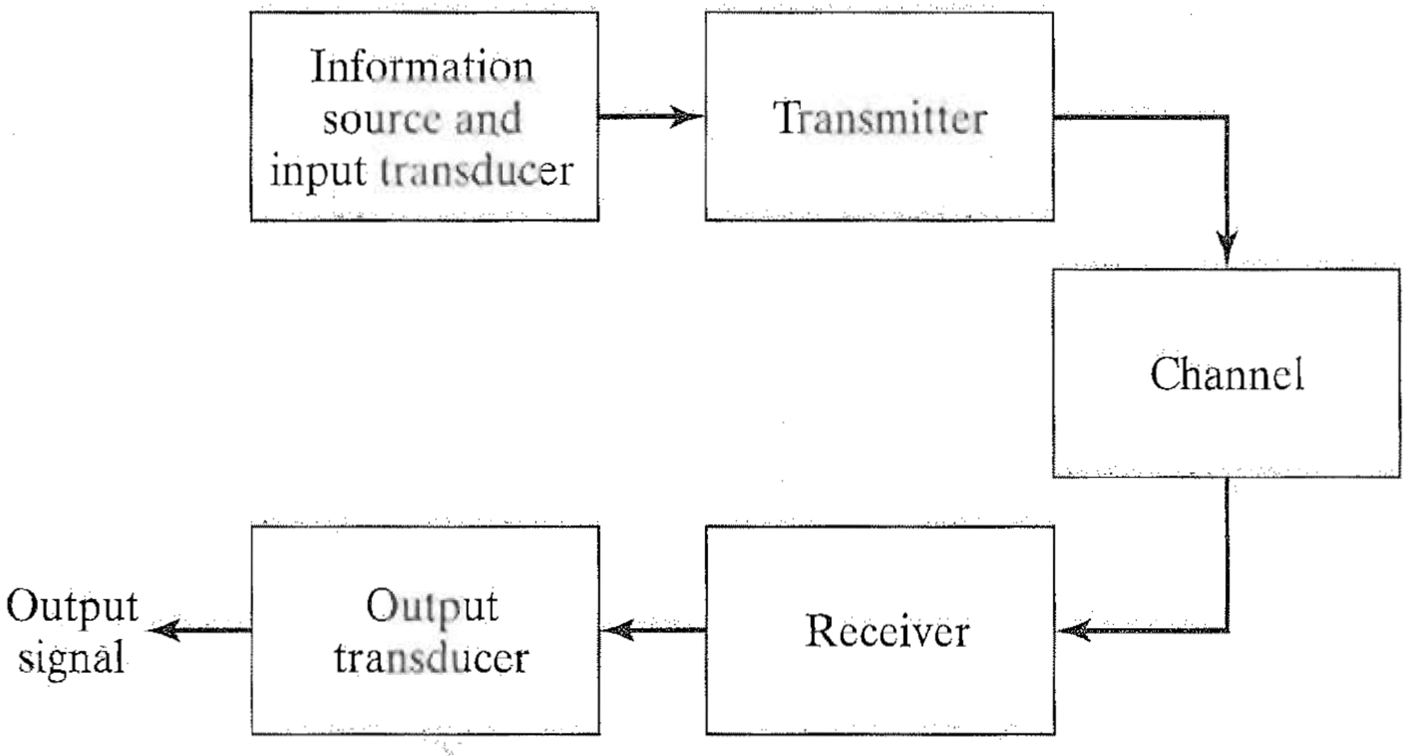

Figure 1.1 Functional diagram of a communication system.

Elements of an Electrical Communication System (2/7)

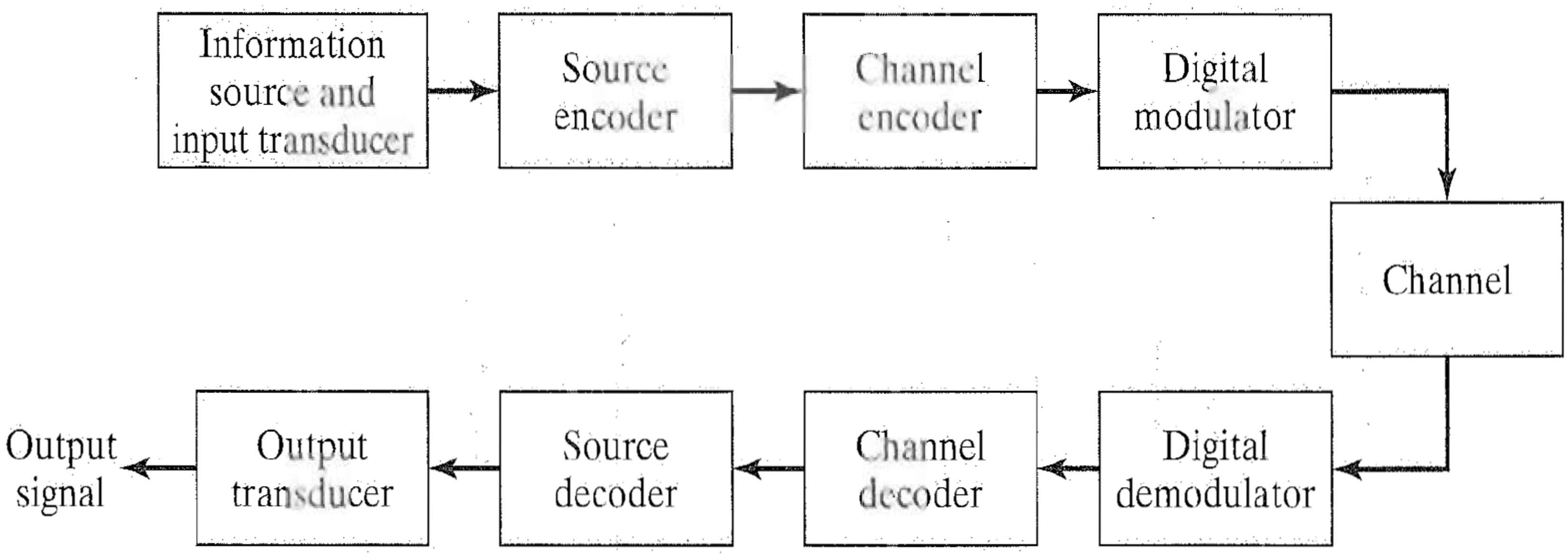

Figure 1.2 Basic elements of a digital communication system.

Elements of an Electrical Communication System (3/7)

- The beginnings of what we now regard as modern digital communications stem from the work of Nyquist (1924)
- Nyquist investigated the problem of determining the maximum signaling rate that can be used over a telegraph channel of a given bandwidth without intersymbol interference
- Nyquist formulated a model of a telegraph system in which a transmitted signal has the form

$$s(t) = \sum_n a_n g(t - nT)$$

Elements of an Electrical Communication System (4/7)

- Nyquist set out to determine the optimum pulse shape that was bandlimited to W Hz and maximized the bit rate $1/T$ under the constraint that the pulse caused no intersymbol interference at the sampling times k/T, $k=0, \pm 1, \pm 2 \ldots.$
- Nyquist concluded that the maximum pulse rate $1/T$ is $2W$ pulses/sec. This rate is now called the Nyquist rate.

  Moreover, this pulse rate can be achieved by using the pulses $g(t)=(\sin 2\pi Wt/2\pi Wt)$

Elements of an Electrical Communication System (5/7)

- The sampling theorem states that a signal of bandwidth W can be reconstructed from samples taken at the Nyquist rate of $2W$ samples/sec using the interpolation formula

$$s(t) = \sum_n s\left(\frac{n}{2W}\right) \frac{\sin 2\pi W(t - n/2W)}{2\pi W(t - n/2W)}$$

- Shannon established basic limits on communication of information and gave birth to a new field that is now called information theory

Elements of an Electrical Communication System (6/7)

- The channel capacity of an additive white Gaussian noise (AWGN) channel can be related as

$$C = W \log_2\left(1 + \frac{P}{WN_0}\right)$$

- P is the average transmitted power and N_0 is the power-spectral density of the additive noise
- If the information rate R from the source is less than C ($R<C$), then it is theoretically possible to achieve reliable (error-free) transmission through the channel by appropriate coding

Elements of an Electrical Communication System (7/7)

- If $R>C$, reliable transmission is not possible regardless of the amount of signal processing performed at the transmitter and receiver

Communication Channels and Their Characteristics (1/5)

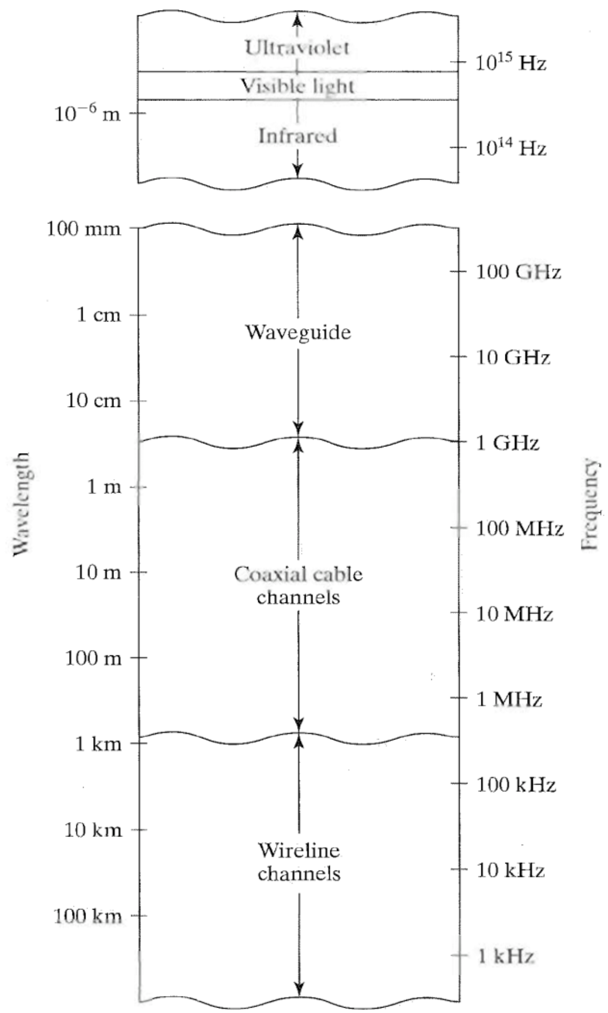

Figure 1.3 Frequency range for guided wireline channels.

Communication Channels and Their Characteristics (2/5)

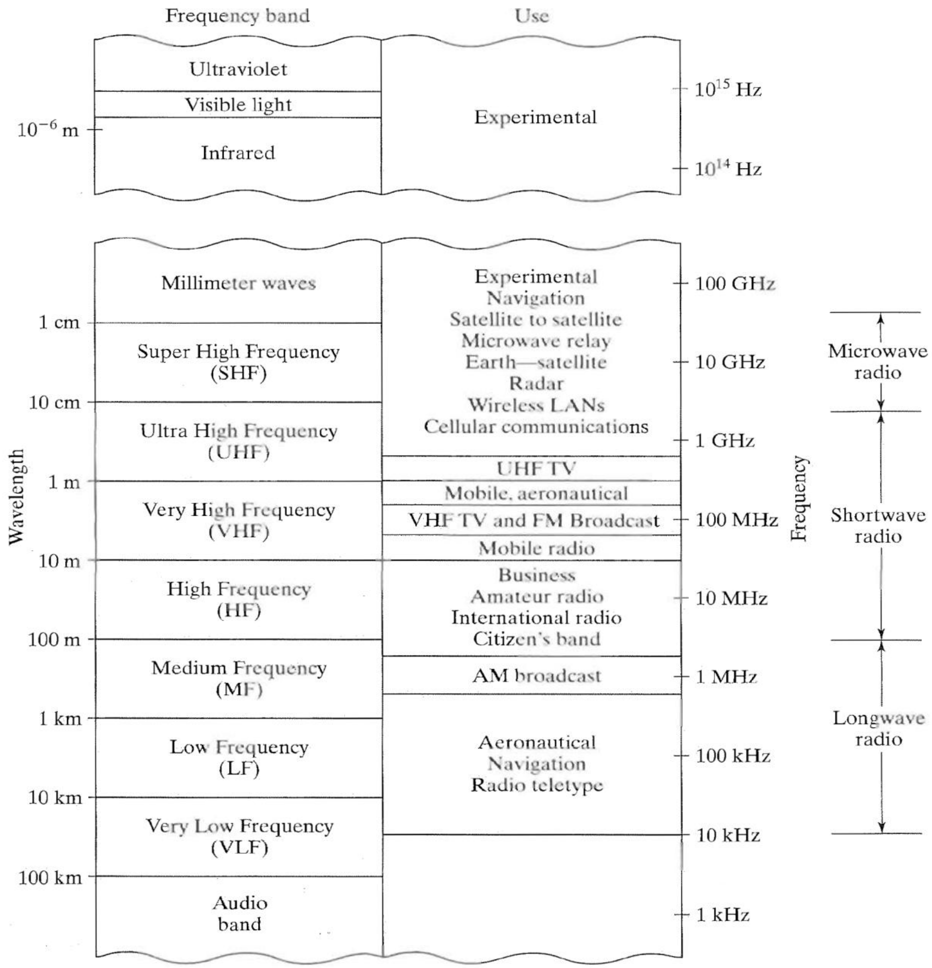

Figure 1.4 Frequency range for wireless electromagnetic channels. (Adapted from Carlson, Sec. Ed.; ©1975 McGraw-Hill. Reprinted with permission of the publisher.)

Communication Channels and Their Characteristics (3/5)

- Ground-wave propagation, illustrated in Fig. 1.5, is the dominant mode of propagation for frequencies in the MF band (0.3-3 MHz). This is the frequency band used for AM broadcasting and maritime radio broadcasting.
- Atmospheric noise, man-made noise, and thermal noise from electronic components at the receiver are dominant disturbances for signal transmission at MF

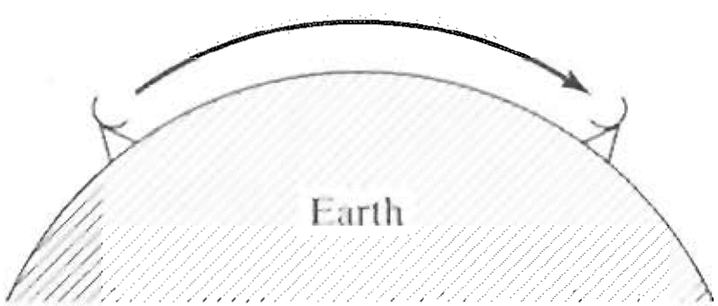

Figure 1.5 Illustration of ground-wave propagation.

Communication Channels and Their Characteristics (4/5)

- Sky-wave ionospheric propagation ceases to exist at frequencies above approximately 30 MHz, which is the end of the HF band

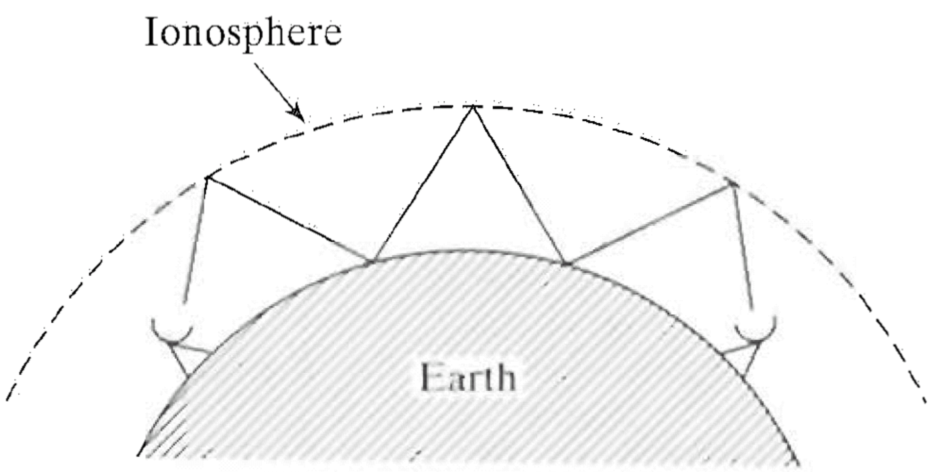

Figure 1.6 Illustration of sky-wave propagation.

Communication Channels and Their Characteristics (5/5)

- The dominant noise limiting the performance of communication systems in the VHF and UHF frequency ranges is thermal noise generated in the front end of the receiver and cosmic noise picked up by the antenna
- At frequencies above 10 GHz in the SHF band, atmospheric conditions play a major role in signal propagation

Mathematical Models for Communication Channels (1/4)

- **The Additive Noise Channel.** The simplest mathematical model for a communication channel is the additive noise channel
- The additive noise process may arise from electronic components and amplifiers at the receiver of the communication system, or from interference encountered in transmission

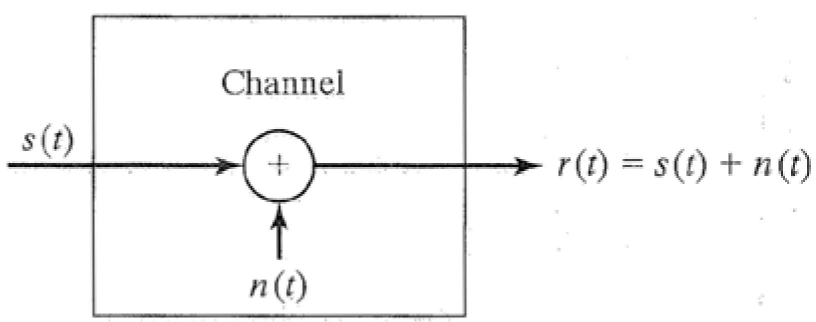

Figure 1.7 The additive noise channel.

Mathematical Models for Communication Channels (2/4)

- When the signal undergoes attenuation in transmission through the channel, the received signal is

$$r(t) = as(t) + n(t)$$

where a represents the attenuation factor

Mathematical Models for Communication Channels (3/4)

- **The Linear Filter Channel.** If the channel input is the signal $s(t)$, the channel output is the signal

$$r(t) = s(t) \star h(t) + n(t)$$

where $h(t)$ is the impulse response of the linear filter and $\star$ denotes convolution

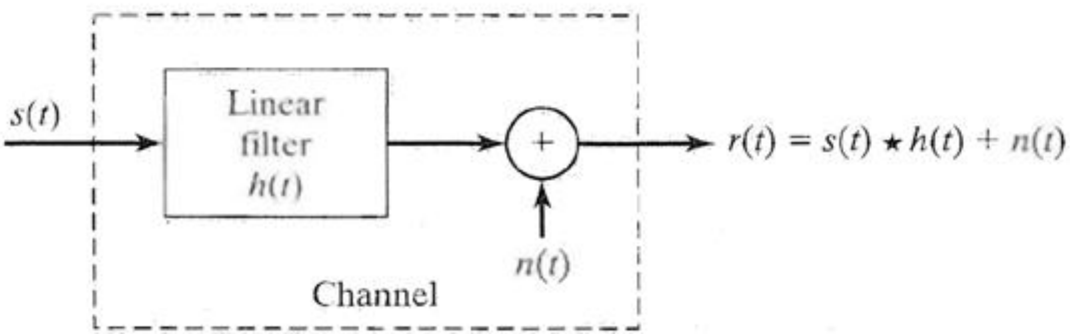

Figure 1.8 The linear filter channel with additive noise.

Mathematical Models for Communication Channels (4/4)

- **The Linear Time-Variant Filter Channel.** The filter coefficient is time-variant. Such linear filters are characterized by the time-variant channel impulse response $h(\tau;t)$, where $h(\tau;t)$ is the response of the channel at time t and τ represents the "age" (elapsed time) variable

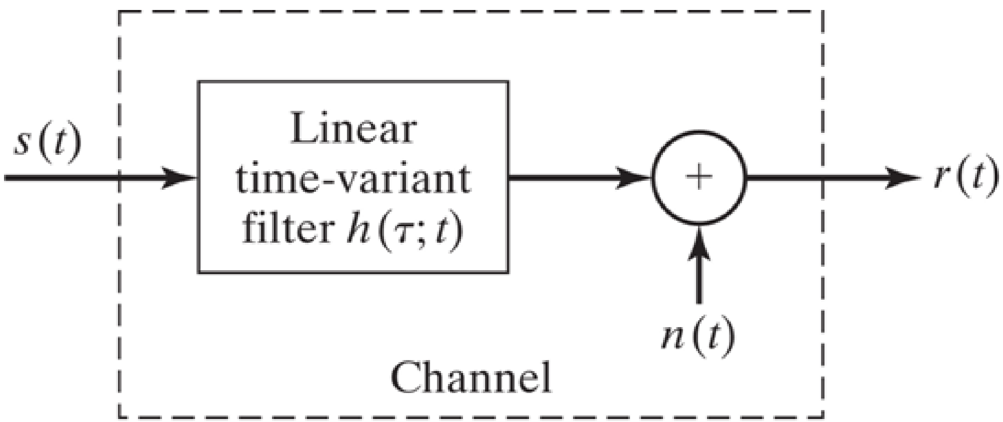

Figure 1.9 Linear time-variant filter channel with additive noise