Chapter 1 Introduction
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.
Block Diagram of a Typical Digital Communication System

Discrete memoryless source

Information source

Source encoder {$1, 2, \ldots, q$}

Encryptor

Channel encoder

Data modulator

Spread spectrum modulator

Power amplification (power limitation)

Discrete (memoryless) channel

Data demodulator

Spread spectrum desesperator

Receiver front end

Information sink

Source decoder

Decryptor

Channel decoder

Spreading code generator

Noise

Timing and synchronization

Waveform channel (bandwidth limitation)

Code rate:

$$R = \frac{output \text{ bits}}{input \text{ bits}}$$

Source rate:

$$R_m = \frac{1}{T_m} \log_2 q \frac{\text{bits}}{\text{second}}$$
Communication Channels and Their Characteristics

◊ 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 $\alpha$ is the attenuation factor.
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.
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LEAVE THE BEATEN TRACK OCCASSIONALLY AND DIVE INTO THE WOODS. YOU WILL BE CERTAIN TO FIND SOMETHING THAT YOU HAVE NEVER SEEN BEFORE.

IN HONOR OF THE INVENTOR OF THE TELEPHONE ON THE CENTENNIAL OF HIS BIRTH
Here at Bell Labs, on December 12, 1947, John Bardeen and Walter Brattain made one of the greatest inventions of all time – the transistor – which is now a part of virtually every electronic device. William Shockley further refined the transistor and in 1950, built the fundamental architecture in use today. In 1956, Bardeen, Brattain, and Shockley won the Nobel Prize in physics for this work.

Historic Physics Site, Register of Historic Sites
American Physical Society

His creation of the mathematical theory of communication at Bell Labs in 1948 inspired the revolutionary advances in digital communications and information storage that have shaped the modern world.
Bell Laboratories has earned more than a patent a day since it was founded in 1925. These patents include some of the pivotal inventions of the 20th century – the transistor, the laser, the solar cell, digital switching, communications satellites, undersea fiber-optic cable and cellular calling.
Awards

6 Nobel Prizes in Physics shared by 11 scientists
9 U.S. Medals of Science
7 U.S. Medals of Technology
1 Draper Prize
6 Marconi International Fellowship Awards
7 C&C Prizes shared by 12 scientists and engineers
27 IEEE Medal of Honor winners
“Mr. Watson, come here. I want you!” The telecommunications revolution begins when Alexander Graham Bell speaks these words into his prototype telephone on March 10, 1876.