

Modern Digital and Analog COMMUNICATION SYSTEMS

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Introduction

This book examines communication by electrical signals. In the past, messages have been carried by runners, carrier pigeons, drum beats, and torches. These schemes were adequate for the distances and "data rates" of the age. In most parts of the world, these modes of communication have been superseded by electrical communication systems* that can transmit signals over much longer distances (even to distant planets and galaxies) and at the speed of light.

Electrical communication is reliable and economical; communication technology will alleviate the energy crisis by trading information processing for a more rational use of energy resources. Some examples: Important discussions now mostly communicated face-to-face in meetings or conferences, often requiring travel, will increasingly use "teleconferencing." Similarly, teleshopping and telebanking will provide services by electronic communication, and newspapers will be replaced by electronic news services.

*With the exception of the postal service!

1.1 COMMUNICATION SYSTEM

Figure 1.1 shows three examples of communication systems. A typical communication system can be modeled as shown in Fig. 1.2. The components of a communication system are as follows:

The *source* originates the message, such as a human voice, a television picture, a teletype message, or data. If the data is nonelectrical (human voice, teletype message, television picture), it must be converted by an *input transducer* into an electrical waveform referred to as the *baseband signal* or the *message signal*.

The *transmitter* modifies the baseband signal for efficient transmission.*

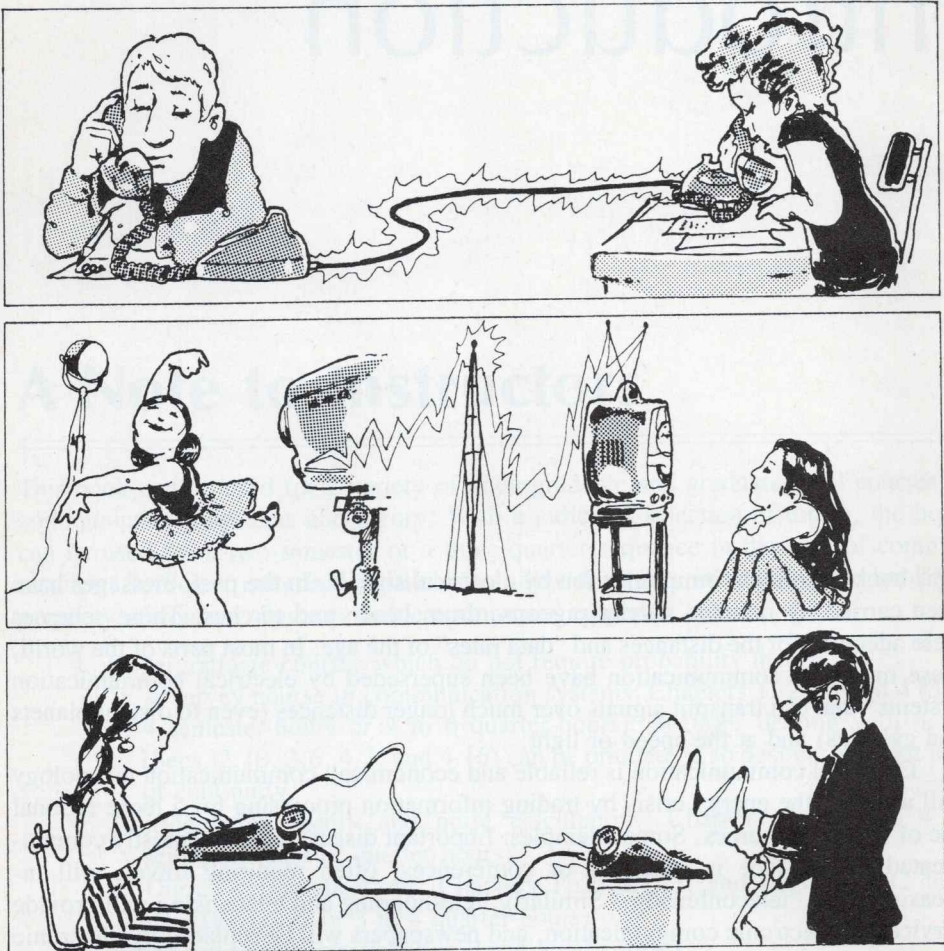


Figure 1.1 Some examples of communication systems.

* The transmitter consists of one or more of the following subsystems: a preemphasizer, a sampler, a quantizer, a coder, and a modulator. Similarly, the receiver may consist of a demodulator, a decoder, a filter, and a deemphasizer.

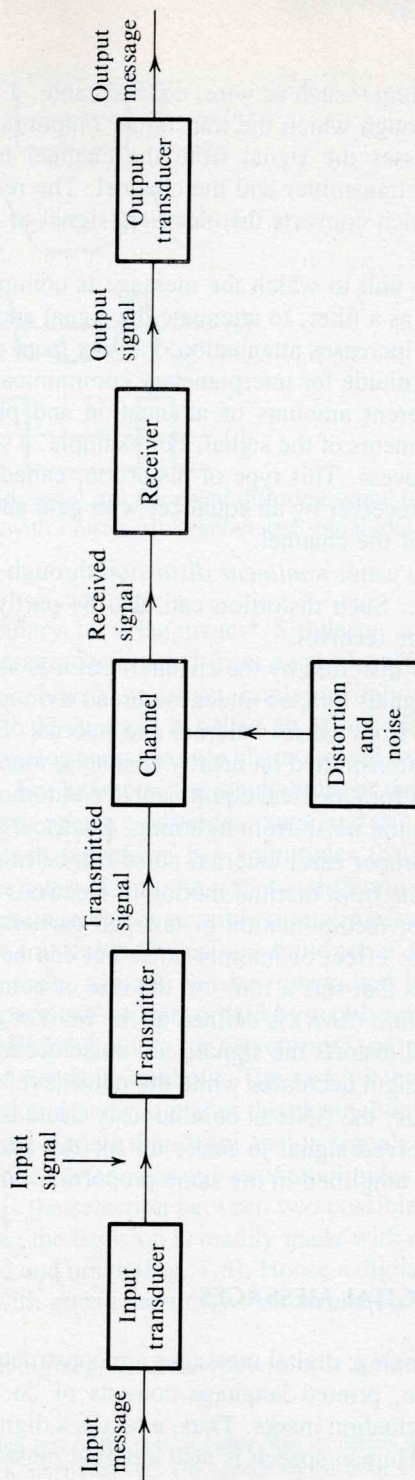


Figure 1.2 A communication system.

The *channel* is a medium—such as wire, coaxial cable, a waveguide, an optical fiber, or a radio link—through which the transmitter output is sent.

The *receiver* reprocesses the signal from the channel by undoing the signal modifications made at the transmitter and the channel. The receiver output is fed to the *output transducer*, which converts the electrical signal to its original form—the message.

The *destination* is the unit to which the message is communicated.

A channel acts partly as a filter, to attenuate the signal and distort its waveform. The length of the channel increases attenuation, varying from a few percent for short distances to orders of magnitude for interplanetary communication. The waveform is distorted because of different amounts of attenuation and phase shift suffered by different frequency components of the signal. For example, a square pulse is rounded or “spread out” by the process. This type of distortion, called *linear distortion*, can be partly corrected at the receiver by an equalizer with gain and phase characteristics complementary to those of the channel.

The channel may also cause *nonlinear distortion* through attenuation that varies with the signal amplitude. Such distortion can also be partly corrected by a complementary equalizer at the receiver.

The signal is not only distorted by the channel, but it is also contaminated along the path by undesirable signals lumped under the broad term *noise* which are random and unpredictable signals from causes external and internal. External noise includes interference from signals transmitted on nearby channels, man-made noise generated by faulty contact switches for electrical equipment, by automobile ignition radiation, fluorescent lights, and natural noise from lightning, electrical storms, solar and intergalactic radiation. With proper care, external noise can be minimized or even eliminated. Internal noise results from thermal motion of electrons in conductors, random emission, and diffusion or recombination of charged carriers in electronic devices. Proper care can reduce the effect of internal noise but can never eliminate it. Noise is one of the basic factors that sets a limit on the rate of communication.

The *signal-to-noise ratio (SNR)* is defined as the ratio of the signal power to the noise power. The channel distorts the signal, and noise accumulates along the path. Worse yet, the signal strength decreases while the noise level increases with distance from the transmitter. Thus, the SNR is continuously decreasing along the channel. Amplification of the received signal to make up for the attenuation is of no avail because the noise will be amplified in the same proportion, and the SNR remains, at best, unchanged.*

1.2 ANALOG AND DIGITAL MESSAGES

Messages are digital or analog; digital messages are constructed with a finite number of symbols. For example, printed language consists of 26 letters, 10 numbers, a “space,” and several punctuation marks. Thus, a text is a digital message constructed from about 50 symbols. Human speech is also a digital message, because it is made

* Actually, amplification further deteriorates the SNR because of the amplifier noise.