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Modern Digital Communications

A complete guide to using and understanding modern digital communications systems.

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Foreword

It's almost impossible to overestimate the impact of digital and data systems on our lives. We're all aware of such glamorous uses of digital communications as space telemetry and rocket guidance; and properly so since much of our communications hardware and knowledge evolved from our space efforts. But many of us aren't aware of the extent of this modern revoltuion—its importance rivals that of the invention of the wheel—and its effect on our day-to-day activities. Its impact affects even such commonplace ventures as buying groceries, writing a check, operating a car, or buying a newspaper. Digital systems process our food, stock our stores, balance our checkbooks, help design and operate our vehicles, control the tools that make them, cross-check our licenses, transmit new copy, set type, and so on almost ad infinitum.

Yet digital communications is a mere infant among sciences, growing with the vitality of youth. In reality we've just begun to feel its impact on our lives, for our society grows more complex with each passing day: more people, more technological sophistication, more information to process, transmit, receive, store. Without modern data systems, it would be impossible to handle this mass of information and access to data would be severely limited. Technological progress would approximate the speed of a traffic jam.But the science grows. The systems expand and diversify with our needs; soon, many homes will feature small computers with video and data links to a variety of sources, enabling such futuristic processes as personalized in-home education with immediate feedback, remote monitoring of security and energy use, and shopping from your living room. Cash money may become a rarity, with purchases and payments handled entirely by digital pulses from your home encoder.

Data systems have been vital to big business for some time, but now even smaller businesses are finding them worthwhile, even necessary to remain competitive. The rapid progress in solid-state electronics technology has slashed production costs to the point where small outfits can afford a data system; future growth—particularly in-home applications—are coming with continuing cost breakthroughs.

This book is intended to provide you with the background needed to understand these revolutionary systems, not just the philosophy and overall concepts, but most of the nuts and bolts that make them work. We'll cover how the information is encoded for economical storage and rapid transmission and reception; the media available for data communication and their capabilities, cost, speed, limitations; the processes and circuits that convert human to machine logic and execute that logic; and much more.

Chapter 1

Introduction

Digital and data systems provide a method of transferring digital data to a remote destination in a relatively short time. To others, it means the measurement of a great number of variables and either storing the data or reading it out in the form of digital display or hard copy, or transmitting it to a remote source for further processing.

It can spell the difference between a successful and a mediocre business. Banks have been able to branch out into many subsidiaries to provide better service and function as a single unit because of close communications ties. All the transactions of all the subsidiaries are processed by a central computer. Individual accounts are updated instantaneously, and a banking statement can be had at a moment's notice. Overall bank balancing is now an automatic process.

The Wall Street Journal transmits its daily transactions to 10 key cities throughout the United States, where the paper is printed and distributed from the key cities. A recent improvement in the Dow Jones Co. distribution and printing process is to transmit from the production plant in Chicopee, Mass., to Orlando, Fla., via Westar I satellite, 22,300 miles up. The sending and receiving (including all the encoding and decoding process) takes 3.5 minutes per page. Once the presses are loaded, they are capable of printing 70,000 Wall Street Journals per hour. And it is all done by digital data communication.

Hotels can make a reservation in any of their hotels anywhere in the world in a matter of minutes. Airline reservations, with their constantly changing flight schedules, can not only arrange a flight to any large city in the world but make connections with other airlines in a relatively short period of time.

A police department is able to acquire a hard copy of a fingerprint in the short time it takes to transmit, receive, and retransmit (via facsimile) of any of the millions of fingerprints stored in the FBI and State government files. Mug shots are acquired in the same manner.

Schools are storing lesson programs in a central bank. By means of dialing up a code number, a student can call up a given lesson and proceed to learn at his or her own pace, via closed circuit television. The State of Georgia is in the process of linking its statewide educational system with a central lesson storage bank, whereby a lesson can be called up from any Vocational School or University in the State.

Automated fare collections are used in transportation systems at Bay Area Rapid Transit District (BARTD) of San Francisco and at Washington Metropolitan Area Transit Authority (WMATA) in Washington, D.C. The task consists of five functions; ticket vending, gating, aided fare collections, auditing, and network control.

Tickets are purchased at a ticket vending machine. The tickets are digitally magnetized in accordance with the amount of money inserted into the ticket vending machine. As the passenger enters the entrance gate, the card is inserted into a slot, which opens the gate. It digitally encodes the card with the entry location code, then returns the card.

At the end of the ride, the passenger inserts the card into the exit gate. Here the card is read, the amount consumed is calculated and subtracted from the card. If the ticket contains sufficient "equivalent cash," the card is returned at the output slot of the exit gate. If not, the card is returned to the passenger with instructions to "add value" to the card. This is done by an "Add Value Machine" after the proper amount of money is inserted into the machine.

Besides being controlled by a computer, the system utilizes digital encoders, decoders, printers, card transports, magnetic readers, money handling equipment, bill transports and validators, all performed with digital techniques.

In both BARTD and WMATA transportation systems, digital communication between the central control facility and the train, via wayside equipment and track contained equipment, is extensively utilized. Acceleration, deceleration, automatic speed controls, jerk-limiting, slip-slide control, speed sensing, programmed stopping, car door and lobby door controls, route requests, route alignment and locking, multiplexed wayside switch control, block occupancy, braking control, and many other controls are used. These functions are carried out by the exchange of encoded signals between the vehicle and wayside, via car carried antennas and track imbedded antennas.

Computers are used to optimize (not control) the system in that when a route request is made by a central control operator, the computer selects the optimum route to be taken, based on existing traffic conditions and other requests. After a safe route and direction are established, the route is aligned and locked electronically, preventing illegal entry by any other vehicle until the assigned vehicle has passed and cleared the route. In addition, the computer also optimizes the use of power by staggering vehicle starting times. In general, it disallows any control request which could cause an unsafe condition to exist.

Wiring in today's jet aircraft can be simplified because of the great many monitor, control, and communication functions that can be "multiplexed" over a relatively small number of wires. Because electronic response is much more accurate and more rapid than the human, the pilot is given hundreds of digital circuits, electronic controls, and a computer to help him fly his plane. Without them, he and his copilot(s) would be extremely busy, and flying would be nearly impossible. With them, there is no limit to the size and complexity of the aircraft the pilot can "fly."

Television pictures transmitted from the moon to the earth would not have been practical, if not impossible, without the digital techniques known today. A storage type camera was used. The video signals were converted into digitally coded pulses and transmitted to earth. These pulses were decoded via a computer and reconverted into video signals which represented the original video signals taken by the camera on the moon.

To perform this same task by conventional means would have required the launching of large and heavy equipment which is against economical and practical rocket launching practices. The trade-off was to place the bulky and more expensive equipment on earth. Consquently, the only disadvantage (if one can call it a disadvantage) is a time delay in the processing of the TV picture by the computer.

The instrumentation industry has gone almost completely digital. Even present day analog instruments are "digital at heart." Accuracies in the vicinity of eight decimal places as seen in present-day digital voltmeters, as an example, is not unheard of.

Take the hand held calculator as another example. Complex mathematical problems can be solved, stored in a memory, and read out on eight-digit display panel, all in a fraction of a second. Repeatable type problems can be programmed and placed on an insertable piece of tape for repeated use. All operations are digital.

To those who manufacture digital equipment, it is a constant effort to maintain a state-of-the-arts level commensurate with the rapidly growing, constantly changing industry. This multibillion dollar industry has mushroomed and outperformed most forecasts. The government alone spent in excess of $10 million (1975) for digital and data communication. It plans to spend even more in areas of global communication (the most of which will be digitally oriented) as well in the military instrumentation field.

Data and digital communication systems described in this book apply to non-computer and non-voice systems but explanations will be provided where necessary for interface purposes. Similarly, computers will be discussed only to the degree that is needed to understand a digital communication or a data handling process. Detailed computer operation is a field in itself and will not be included herein.

Communication Systems

From a system point of view, digital and data communication systems can vary widely. There are as many possible systems as there are applications, nevertheless, there is a specific commonality which can be depicted as a base. Figure 1-1 shows the fundamentals of conveying information from one point to another. The information to be transmitted is the message; be it analog or digital, a spoken word or measured variable. This message is "prepared" for transmission by various means, which shall be discussed later. The transmitter in itself is a coupling device which transfers the prepared message to the medium.

The medium can be either space, a light beam or a form of hard wire which carries the message to the receiver. At the

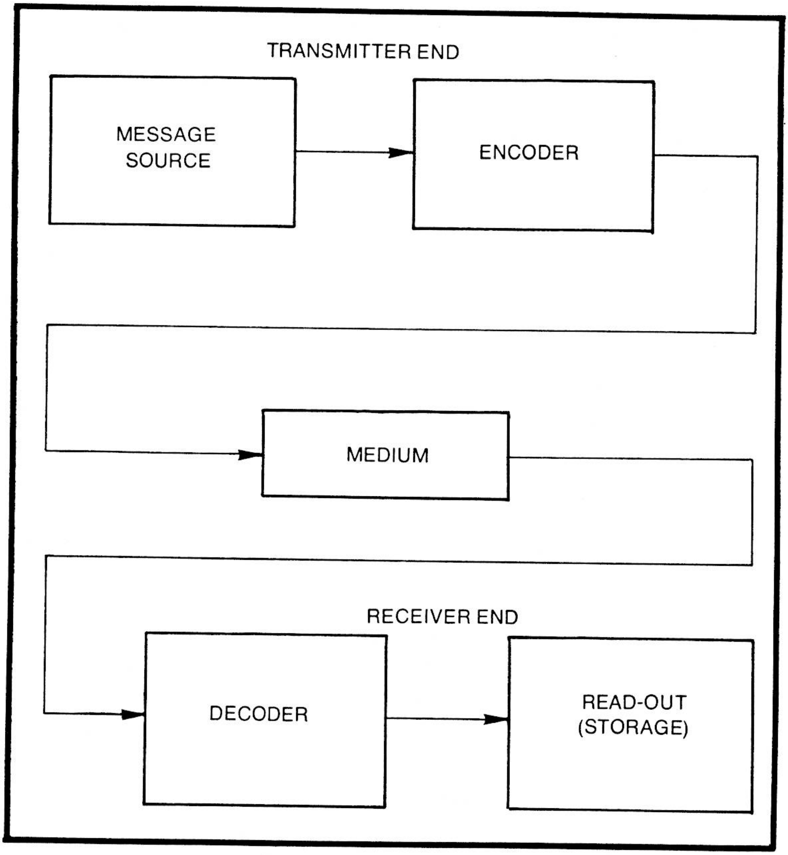

Fig. 1-1. Simplex method.

receiver, the process is reversed. That is, the message is uncoupled from the medium, demodulated or decoded, then reconverted into its original form, thereby reproducing the original message. This method is a one-way type of transmission and is called *simplex* (SX).

Suppose that it would be desirable to send the message back to its origin for matters of verification, comparison or control. To do this over the same medium would normally require an extra pair of wires. However, with the alternate use of a single transmission line, the transmitter of station 1 in Fig. 1-2 is connected to the receiver at station 2 for a transmission in one direction, then the transmitter of station 2 is connected to the receiver of station 1 for a transmission in the opposite direction. Although communication is in both directions the communication is only one-way at any one time. Hence, this method is called *half duplex* (HDX).

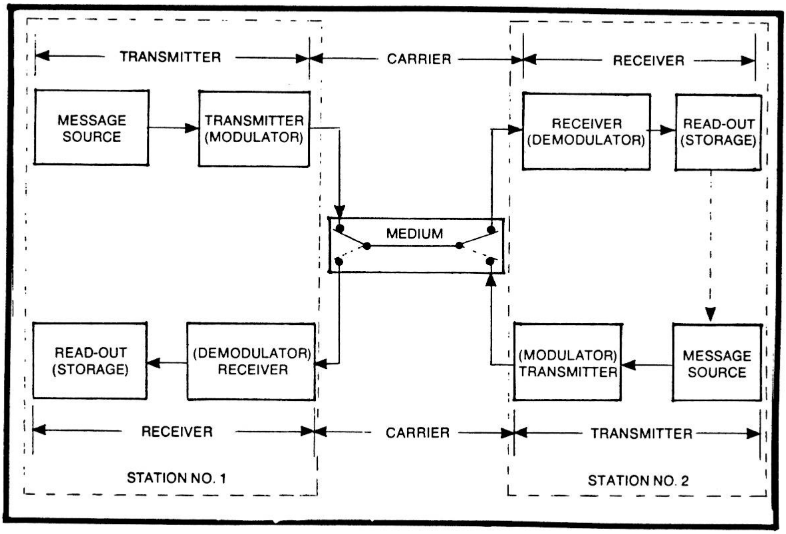

Fig. 1-2. Half duplex.

To take the sequence one step further, refer to Fig. 1-3, where a *full duplex* (FDX) system is shown. In the full duplex method, communication is accomplished in both directions at the same time. To achieve this, using hard wire transmission lines, there must be either a separation in frequency or the addition of a second transmission line. Notice that in both HDX and FDX the device that drives the transmitter is referred to as the modulator and the device at the receiver is called the demodulator. Putting these two terms together (MOdulator and DEModulator) forms the popular acronym, *modem*.

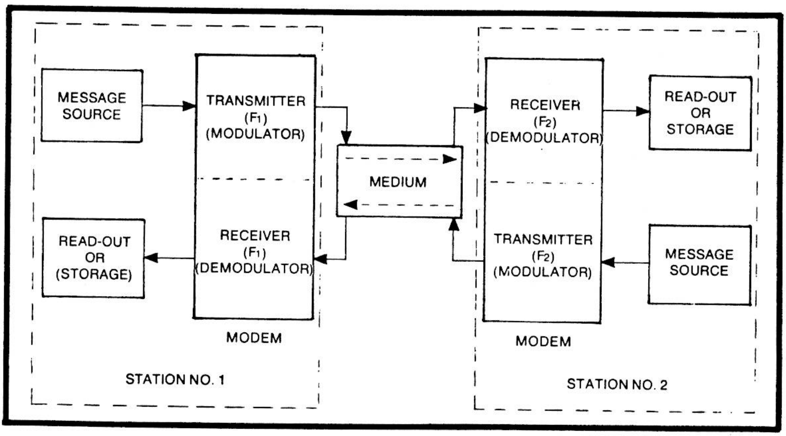

Fig. 1-3. Full duplex.