
*Modern
Handbook
for the
Communications
Professional*

Cass Lewart

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Modem Handbook for the Communications Professional

Cass Lewart

Project Engineer
Unisys Corporation



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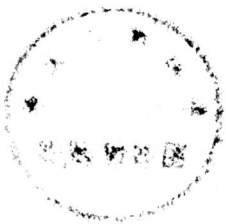
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Preface

As an electrical engineer active for over 30 years in the telecommunications field I have always found data transmission, and specifically modems, to be a fascinating subject. There is more to a modem than just a name for a device that lets one computer talk to another computer over a telephone line. Modem technology combines various disciplines of electrical engineering and computer software such as circuit design, Large Scale Integration, use of microprocessors, switching, data transmission, and programming. My interest in this field and conversations with my coworkers and publisher convinced me of the need for a book dealing with modems as related to data communications.

The need for books describing data communications in practical rather than in abstract terms has been generated largely by the deregulation of the telephone industry in the United States. Deregulation gave the telecommunication manager more challenges, opportunities, and choices than ever before. Selection of a modem, this most important component of a data communications network, used to involve just a quick check for agreement with the applicable standards. In fact, the selection was frequently suggested and performed by a representative of the common carrier, the local telephone company. Now the decision has to be made based on the desirability of options, "smartness" of the modem, software availability, and other criteria determined by specific applications.

Without a thorough understanding of the various available modem features, their relative importance, and how they interact with each other, costly mistakes can easily be made. Sometimes a standard solution, connecting two com-

puters equipped with modems via a telephone line, may be the least desirable. Use of less common modem types, such as short-haul modems, can result in substantial savings.

I wrote this book primarily for the communications professional (manager, supervisor, member of technical staff), who has been working in the field for several years dealing with common carriers and with equipment suppliers. I assume that this person would like to get a better understanding of various elements of the data communications networks which he or she designs in order to make cost-effective specification and planning decisions in modem acquisition.

The book is also written for the electrical engineer, not necessarily active in the data communications field, who would like to expand his or her knowledge of the latest developments in modem technology, relating to both hardware and software.

Finally, the book is written for the personal computer user who would like to select a proper modem to communicate with other computers and to learn about the available options and choices.

At this point I would like to acknowledge help from a number of individuals who helped me in understanding certain arcane areas of data communications and of modem design. I would like to thank in particular Dr. Adam Lender, the scientific consultant to the Lockheed Corporation, Mitch Baker, the field applications engineer at Rockwell International, and Jack Douglas, senior manager of technical services at the Universal Data Corporation. I would also like to thank the Hewlett-Packard Company for letting me use some of their data communications training material. Final thanks go to my wife Ruth for coming up with many new ideas for the book and to my son Dan for general and technical editing.

If the reader, after finishing the last chapter, improves his or her understanding of the data communications field in general and of modem technology in particular, then the purpose of this book will be fulfilled.

Cass Lewart
Holmdel, N.J.

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Introduction

WHAT IS A MODEM?

The need for exchange of digital information between computers over analog transmission facilities, in particular over the telephone network, led to the development of modems. A modem performs the digital-to-analog (D/A) conversion between the computer and the analog transmission facility and it also performs the analog-to-digital (A/D) conversion between the analog transmission facility and the computer. The D/A conversion is performed by modulating the digital information on a "carrier" signal; the A/D conversion is performed by demodulating or extracting the digital information from analog signals carried on the analog transmission facility. The combination of the two words modulator and demodulator formed the word "modem." Modems are always in pairs and perform both a transmitting and a receiving function. The user has to ascertain that the receiving and the transmitting modems use the same protocols, procedures describing the data formats, modulation schemes, etc., in order to carry information.

The rest of this book will explain in considerable depth choices and options of today's modem market, which is currently booming thanks to technological advances and competition caused by the deregulation of the United States telephone industry. The next paragraphs will describe the effects of this deregulation on the communication industry in general and on modems in particular. The following chapters will then give a review of data communications with emphasis on modems, which will be followed by a closer look at personal computer and commercial modem markets. The final chapters will

go into testing and diagnostics of modems, transmission facilities, and other parts of the data channel. In conclusion we will look into the data communications crystal ball to see what developments are to be expected in the next few years.

DEREGULATION OF THE U.S. TELEPHONE INDUSTRY

Prior to 1975, common carriers, AT&T and independent telephone companies in the United States and government-operated Post, Telegraph and Telephone organizations (PTTs) in most other countries owned and maintained all communication equipment attached to the public telephone network. The rationale for it was protection of the fragile telephone network and its users from interfering “foreign” equipment. To show the need for such protection, one can consider a frequency multiplexed carrier system, which in its first stage “stacks” twelve voice channels into a so-called channel bank. The assumptions used in the design and operation of a carrier system are that frequency adjacent channels will not interfere with each other, as long as their bandwidth and power are limited. Due to nonlinearity of modulators and demodulators, a signal more powerful than average could easily generate modulation products falling into other channels, resulting in crosstalk and distortion in the unprotected system.

Before the deregulation of the U.S. telephone industry all common carrier and PTT equipment was thoroughly tested, before being put into service, thus assuring proper operation of the network. Because the equipment was leased, rather than sold, and the cost of maintenance was included in the monthly lease, the equipment was conservatively designed, and was thus highly reliable and expensive. A typical charge for a low-speed modem leased from a telephone company was around \$50 per month.

The path to proliferation of communication equipment was opened in the United States with the famous 1968 Carterphone decision. The Federal Communication Commission decided then that the communication user has the right to own and maintain equipment, as long as it does not interfere with the public network. The first approach of the Common Carriers to assure that no interference would be caused by such equipment was to lease to the end users, for a fee of around \$7 per month, the so-called Data Access Arrangement devices (DAA). The DAA was an amplitude and frequency limiter to protect the telephone network. The economical problem DAA created was that the monthly fee for users with private modems and other attached devices, such as

answering machines and memory dialers, was not required on equipment leased from Common Carriers. The Common Carriers claimed that their equipment had been thoroughly tested and would not require the protection provided by the FCC. This created a considerable advantage to Common Carriers and was strongly opposed by equipment manufacturers selling to the private market.

The next step in the deregulation process was the decision by the FCC to let the equipment vendors build the protective circuitry into their equipment and not require a separate DAA box to be supplied by the common carriers. This decision was made effective in June 1977 after several appeals by AT&T and by the communication equipment manufacturers. From then on only "type" certification of the equipment would be required, in addition to individual registration of the equipment by the user with the local telephone company. These two measures are supposed to protect the public telephone network. The policy is apparently working well as the privately owned communication equipment has been operating now for several years in the public telephone network environment without any ill effects.

The subsequent breakup of the Bell System in the early 1980s and the competition of Far East equipment makers lowered modem prices and introduced a large variety of equipment available to the data communications user. Large Scale Integration (LSI) made manufacturing of high volume items, such as modems, more of an assembly than an engineering and development enterprise. This is particularly true for 300 bits per second (bps), 1200 bps, and 2400 bps modems, where a handful of chip makers, like Fairchild, Rockwell, and RCA, make modem chips used by dozens of manufacturers. Changing a mask during the chip fabrication or changing a few strap settings can give an individuality to a particular modem to differentiate it from similar products.

Part One

Modems and Data Communications

While reading the first part of this book the reader should become familiar with the basics of data communications. By doing this the terms and concepts found in the remainder of the book, even for a person not familiar with the subject, should start making some sense. If the reader has worked for a while in the data communications field, then I would suggest just paging through the first part of this book and treating it as a refresher course in data communications.

In the first chapter I explain the principal terms of data communications, and describe the basic transmission parameters, such as attenuation and delay distortion. I also explain how these parameters affect the transmitted data signal as it is being carried over the Public Telephone Network. A discussion of the Public Telephone Network, the backbone of most voice and data communications and of the OSI model of the data network, concludes the first chapter. In Chapter 2, I describe leased and private lines used to a large extent for commercial data transmission. Chapter 3 deals with transmission speed and bandwidth as related to the transmission facility. Then comes the fourth chapter, in which the reader will find out about the modulation methods used by modems at various transmission speeds and about assorted modem standards. Chapters 5 and 6 cover the asynchronous and synchronous transmission and various ways in which a modem can be interfaced to a computer.

1. INTRODUCTION TO DATA COMMUNICATIONS

This chapter will provide a short overview of the relevant aspects of data transmission, and of some of the terms used in the rest of this book, which will be required for a better understanding of applications and technology of modems. We will start with short definitions of a few important data transmission terms, which will be explained in more detail in the following chapters. This will be then followed with a description of the Public Telephone Network and the Open System Interconnect (OSI) model of the data network.

DATA COMMUNICATIONS TERMS

Voice Band

The French physicist Fourier was the first to recognize that even the most complex time-varying analog signals can be decomposed into separate frequency components, each one a simple sinusoid of a different frequency. Though the human ear recognizes sound frequencies between 50 and 20,000

Hz, most intelligible speech is concentrated between approximately 300 and 3000 Hz. To satisfy a voice subscriber, a standard telephone channel therefore has a bandwidth, the range of frequencies which it can accommodate, of approximately 300 to 3200 Hz. Such a channel is usually referred to as the voice-band channel, because it can pass a range of the most important frequencies associated with the human voice.

Transmission Medium

An electrical transmission medium, which can carry analog or digital information, can be anything from a pair of wires to a satellite link. In general we will not concern ourselves with the physical aspects of a transmission medium, but rather with its transmission parameters, like bandwidth, circuit loss, and various forms of electrical distortion associated with transmission of information.

Two- and Four-Wire Transmission

The local telephone loop, the pair of wires connecting the local telephone subscriber to the local telephone office, consists of two copper wires. Because both directions of transmission using the loop share the same physical medium, they may interfere with each other. The two-wire transmission is adequate for voice and certain types of data on short connections. However, four-wire transmission, where each direction of transmission is carried on a separate pair of wires, is frequently required for high-speed data transmission. Four-wire transmission is also used by the telephone company for their long distance transmission between toll offices. An analogy would be a divided highway versus a country road. An example of two-wire and of four-wire telephone connection is shown in Figures 1.1 and 1.2.