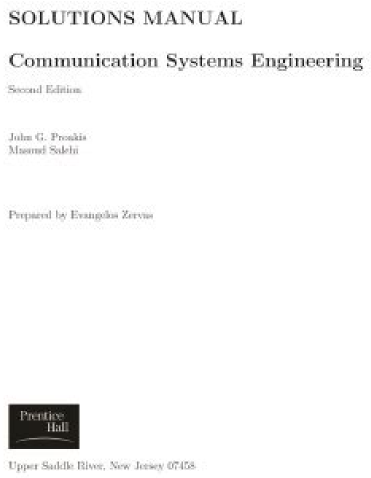
SOLUTIONS MANUAL

Communication Systems Engineering

Second Edition

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Get started with a FREE account. Bryan Greetham. Key Concepts in Politics. Andrew. Heywood. Linguistic Terms and Concepts. Ge.Solutions Manual to Advanced Modern Engineering.A Foundation for Electronic, Electrical, Communications and Systems A Foundation for Electronic, Electrical, Communications and Systems.Get books you want. How can I make that happen Next To add our email address , visit the Personal Document Settings under Preferences tab on Amazon. We are currently\nwitnessing an explosive growth in the development of personal communication systems\n \n xi \n\n \n Proakis50210 proafm August 3, 2001 1553\n \n xii Preface\n \n and ultrahigh speed communication networks, which are based on digital transmission\nof the information, whether it is voice, still images, or video. We anticipate that, in the\nnear future, we will witness a replacement of the current analog AM and FM radio and\ntelevision broadcast by digital transmission systems.\n \n The development of sophisticated, highspeed digital communication systems\nhas been accelerated by concurrent developments in inexpensive high speed integrated\ncircuits IC and programmable digital signal processing chips. All of these technological developments point\nto a continuation in the trend toward increased use of digital communications as a\nmeans for transmitting information.\n \n OVERVIEW OF THE TEXT\n \n It is assumed that students using this book have a basic understanding of linear system\ntheory, both continuous and discrete, including a working knowledge of Fourier series\nand Fourier transform techniques. Chapter 2 provides a review of basic material on sig\nnals and systems and establishes the necessary notation used in subsequent chapters.\nIt is also assumed that students have had a first course in probability. Such courses are\ncurrently required in many undergraduate electrical engineering and computer engi\nneering programs.http://www.croydon.com.br/images/uploads/image/carry-pistol-with-manual-safety.xml

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Chapter 4 provides a review of probability and random processes to\nthe extent that is necessary for a first course in communications.\n \n Chapter 3 treats modulation and demodulation of analog signals. This treatment\nincludes amplitude modulation AM, frequency modulation FM, and phase modu\nlation PM. Radio and television broadcasting and mobile radio cellular systems are\ndiscussed as examples of analog communication systems. Chapter 5 continues the treat\nment of analog communication systems by analyzing the effect of additive noise in the\ndemodulation of AM, FM, and PM signals. The phaselocked loop, which is used for\nestimating the phase of a sinusoidal carrier in both analog and digital communication\nsystems is also described in Chapter 5. The chapter concludes with a treatment of the ef\nfect of transmission losses and the characterization of noise sources in communication\nsystems.\n \n A logical beginning in the introduction of digital communication systems analysis\nand design is the characterization of information sources and source encoding. Chapter 6\nis devoted to this topic. In this chapter we introduce the reader to the modeling of\ninformation sources, both discrete and continuous analog, and the basic mathematical\nconcepts of entropy and mutual information. Our discussion of source encoding for\ndiscrete sources includes the Huffman coding algorithm and the LempelZiv algorithm.\nFor the case of analog sources, we treat both scalar and vector quantization and describe\nthe common waveformcoding techniques, namely, PCM, DPCM, and DM. We also\ndescribe the LPCbased source modeling method. As practical examples of the source\ncoding methods described in this chapter we cite the digital speech transmission systems \n\n \n Proakis50210 proafm August 3, 2001 1553\n \n Preface xiii\n \n in the telephone plant, the digital audio recording systems as embodied in the compact\ndisc CD player and the JPEG imagecoding standard.

\n \n Digital modulation and demodulation techniques are described in Chapter 7. Bi\nnary and nonbinary modulation methods are described based on a geometric representa\ntion of signals, and their errorrate performance is evaluated and compared. This chapter\nalso describes symbol synchronization methods for digital communication systems.\n \n Chapter 8 treats digital transmission through bandlimited AWGN channels. In this\nchapter we derive the powerspectral density of linearly modulated baseband signals\nand consider the problem of signal design for a bandlimited channel. We show that the\neffect of channel distortion is to introduce intersymbol interference ISI, which can\nbe eliminated or minimized by proper signal design. The use of linear and nonlinear\nadaptive equalizers for reducing the effect of ISI is also described.\n \n Chapter 9 treats the topic of channel coding and decoding. The capacity of a\ncommunication channel is first defined, and the capacity of the Gaussian channel is\ndetermined. Linear block codes and convolutional codes are introduced and appropriate\ndecoding algorithms are described. The benefits of coding for bandwidth constrained\nchannels are also described. The final section of this chapter presents three practical\napplications of coding.\n \n The last chapter of this book treats topics in wireless communications. First, we\nconsider the characterization of fading multipath channels and describe the effects of\nsuch channels on wireless digital communication systems. The design of signals that\nare effective in mitigating this type of channel distortion is also considered. Second, we\ndescribe the class of continuousphase modulated signals, which are especially suitable\nfor digital communication in wireless channels. Finally, we treat the class of spread\nspectrum signals, which are suitable for multiuser wireless communication systems.

\n \n EXAMPLES AND HOMEWORK PROBLEMS\n \n We have included a large number of carefully chosen examples and homework prob\nlems. The text contains over 180 workedout examples and over 480 problems. Ex\namples and problems range from simple exercises to more challenging and thought\nprovoking problems. A Solutions Manual is available free to all adopting faculty, which\nis provided in both typeset form and as a diskette formatted in LATEX. Solutions are not\navailable for sale to students. This will enable instructors to print out solutions in any\nconfiguration easily.\n \n COURSE OPTIONS\n \n This book can serve as a text in either a one or twosemester course in communication\nsystem. An important consideration in the design of the course is whether or not the\nstudents have had a prior course in probability and random processes. Another important\nconsideration is whether or not analog modulation and demodulation techniques are to\nbe covered. Here, we outline three scenarios. Through these media we are able to\ncommunicate nearly instantaneously with people on different continents, transact our\ndaily business, and receive information about various developments and events of note\nthat occur all around the world. Electronic mail and facsimile transmission have made\nit possible to rapidly communicate written messages across great distances.\n \n Can you imagine a world without telephones, radio, and TV. Yet, when you think\nabout it, most of these modernday communication systems were invented and devel\noped during the past century. Here, we present a brief historical review of major develop\nments within the last two hundred years that have had a major role in the development of\nmodern communication systems.\n \n 1.1 HISTORICAL REVIEW\n \n Telegraphy and Telephony. One of the earliest inventions of major signifi\ncance to communications was the invention of the electric battery by Alessandro Volta\nin 1799.

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This invention made it possible for Samuel Morse to develop the electric tele\ngraph, which he demonstrated in 1837. The first telegraph line linked Washington with\nBaltimore and became operational in May 1844. Morse devised the variablelength bi\nnary code given in Table 1.1, in which letters of the English alphabet were represented\nby a sequence of dots and dashes code words. This cable failed after about four\nweeks of operation. A second cable was laid a few years later and became operational\nin July 1866.\n \n Telephony came into being with the invention of the telephone in the 1870s.\nAlexander Graham Bell patented his invention of the telephone in 1876, and in 1877 es\ntablished the Bell Telephone Company. Early versions of telephone communication sys\ntems were relatively simple and provided service over several hundred miles. Significant\nadvances in the quality and range of service during the first two decades of the twentieth\ncentury resulted from the invention of the carbon microphone and the induction coil. \n\n \n Proakis50210 book August 3, 2001 132\n \n Section 1.1 Historical Review 3\n \n The invention of the triode amplifier by Lee De Forest in 1906 made it possible to\nintroduce signal amplification in telephone communication systems and, thus, to allow\nfor telephone signal transmission over great distances. For example, transcontinental\ntelephone transmission became operational in 1915.\n \n Two world wars and the Great Depression during the 1930s must have been a\ndeterrent to the establishment of transatlantic telephone service. It was not until 1953,\nwhen the first transatlantic cable was laid, that telephone service became available\nbetween the United States and Europe.\n \n Automatic switching was another important advance in the development of tele\nphony. The first automatic switch, developed by Strowger in 1897, was an electrome\nchanical stepbystep switch. This type of switch was used for several decades.

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With the\ninvention of the transistor, electronic digital switching became economically feasible.\nAfter several years of development at the Bell Telephone Laboratories, a digital switch\nwas placed in service in Illinois in June 1960.\n \n During the past thirty years there have been numerous significant advances in tele\nphone communications. Fiber optic cables are rapidly replacing copper wire in the tele\nphone plant and electronic switches have replaced the old electromechanical systems.\n \n Wireless Communications. The development of wireless communications\nstems from the works of Oersted, Faraday, Gauss, Maxwell, and Hertz. In 1820, Oersted\ndemonstrated that an electric current produces a magnetic field. On August 29, 1831,\nMichael Faraday showed that an induced current is produced by moving a magnet in the\nvicinity of a conductor. Thus, he demonstrated that a changing magnetic field produces\nan electric field. With this early work as background, James C. Maxwell in 1864\npredicted the existence of electromagnetic radiation and formulated the basic theory\nthat has been in use for over a century. Guglielmo Marconi is credited with the devel\nopment of wireless telegraphy. Marconi demonstrated the transmission of radio signals\nat a distance of approximately 2 kilometers in 1895. Two years later, in 1897, he patented\na radio telegraph system and established the Wireless Telegraph and Signal Company.\nOn December 12, 1901, Marconi received a radio signal at Signal Hill in Newfoundland,\nwhich was transmitted from Cornwall, England, a distance of about 1700 miles.\n \n The invention of the vacuum tube was especially instrumental in the development\nof radio communication systems. The vacuum diode was invented by Fleming in 1904\nand the vacuum triode amplifier was invented by De Forest in 1906, as previously indi\ncated. The invention of the triode made radio broadcast possible in the early part of the\ntwentieth century.

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Amplitude modulation AM broadcast was initiated in 1920 when\nradio station KDKA, Pittsburgh, went on the air. From that date, AM radio broadcast\ning grew rapidly across the country and around the world. The superheterodyne AM\nradio receiver, as we know it today, was invented by Edwin Armstrong during World\nWar I. Another significant development in radio communications was the invention \n\n \n Proakis50210 book August 3, 2001 132\n \n 4 Introduction Chapter 1\n \n of Frequency modulation FM , also by Armstrong. In 1933, Armstrong built and\ndemonstrated the first FM communication system. However, the use of FM was slow\nto develop compared with AM broadcast. It was not until the end of World War II that\nFM broadcast gained in popularity and developed commercially.\n \n The first television system was built in the United States by V. K. Zworykin and\ndemonstrated in 1929. Commercial television broadcasting began in London in 1936\nby the British Broadcasting Corporation BBC. Five years later the Federal Commu\nnications Commission FCC authorized television broadcasting in the United States.\n \n The Past Fifty Years. The growth in communications services over the past\nfifty years has been phenomenal. The invention of the transistor in 1947 by Walter\nBrattain, John Bardeen, and William Shockley; the integrated circuit in 1958 by Jack\nKilby and Robert Noyce; and the laser by Townes and Schawlow in 1958, have made\npossible the development of smallsize, lowpower, lowweight, and highspeed elec\ntronic circuits which are used in the construction of satellite communication systems,\nwideband microwave radio systems, and lightwave communication systems using fiber\noptic cables. A satellite named Telstar I was launched in 1962 and used to relay TV\nsignals between Europe and the United States. Commercial satellite communication\nservices began in 1965 with the launching of the Early Bird satellite.

\n \n Currently, most of the wireline communication systems are being replaced by\nfiber optic cables which provide extremely high bandwidth and make possible the\ntransmission of a wide variety of information sources, including voice, data, and video.\nCellular radio has been developed to provide telephone service to people in automobiles,\nbuses, and trains. Highspeed communication networks link computers and a variety\nof peripheral devices literally around the world.\n \n Today we are witnessing a significant growth in the introduction and use of per\nsonal communications services, including voice, data, and video transmission. Satellite\nand fiber optic networks provide highspeed communication services around the world.\nIndeed, this is the dawn of the modern telecommunications era.\n \n There are several historical treatments in the development of radio and telecom\nmunications covering the past century. In general, a communi\ncation system can be represented by the functional block diagram shown in Figure 1.1.\nThe information generated by the source may be of the form of voice speech source,\na picture image source, or plain text in some particular language, such as English,\nJapanese, German, French, etc. Otherwise, there would be no need to transmit the message.\n \n A transducer is usually required to convert the output of a source into an elec\ntrical signal that is suitable for transmission. For example, a microphone serves as the\ntransducer that converts an acoustic speech signal into an electrical signal, and a video\ncamera converts an image into an electrical signal. At the destination, a similar trans\nducer is required to convert the electrical signals that are received into a form that is\nsuitable for the user; e.g., acoustic signals, images, etc.\n \n The heart of the communication system consists of three basic parts, namely,\nthe transmitter, the channel, and the receiver. The functions performed by these three\nelements are described next.

\n \n The Transmitter. The transmitter converts the electrical signal into a form that\nis suitable for transmission through the physical channel or transmission medium. For\nexample, in radio and TV broadcast, the Federal Communications Commission FCC\nspecifies the frequency range for each transmitting station. Hence, the transmitter must\ntranslate the information signal to be transmitted into the appropriate frequency range\nthat matches the frequency allocation assigned to the transmitter. Thus, signals trans\nmitted by multiple radio stations do not interfere with one another. Similar functions\nare performed in telephone communication systems where the electrical speech signals\nfrom many users are transmitted over the same wire.\n \n In general, the transmitter performs the matching of the message signal to the\nchannel by a process called modulation.

Usually, modulation involves the use of the\ninformation signal to systematically vary either the amplitude, frequency, or phase of\na sinusoidal carrier. For example, in AM radio broadcast, the information signal that is\ntransmitted is contained in the amplitude variations of the sinusoidal carrier, which is\nthe center frequency in the frequency band allocated to the radio transmitting station.\nThis is an example of amplitude modulation. In FM radio broadcast, the information\nsignal that is transmitted is contained in the frequency variations of the sinusoidal\ncarrier. This is an example of frequency modulation. Phase modulation PM is yet a\nthird method for impressing the information signal on a sinusoidal carrier. \n\n \n Proakis50210 book August 3, 2001 132\n \n 6 Introduction Chapter 1\n \n In general, carrier modulation such as AM, FM, and PM is performed at the trans\nmitter, as indicated above, to convert the information signal to a form that matches the\ncharacteristics of the channel.

Thus, through the process of modulation, the information\nsignal is translated in frequency to match the allocation of the channel. The choice of\nthe type of modulation is based on several factors, such as the amount of bandwidth\nallocated, the types of noise and interference that the signal encounters in transmission\nover the channel, and the electronic devices that are available for signal amplification\nprior to transmission. In any case, the modulation process makes it possible to accom\nmodate the transmission of multiple messages from many users over the same physical\nchannel.\n \n In addition to modulation, other functions that are usually performed at the trans\nmitter are filtering of the informationbearing signal, amplification of the modulated\nsignal, and in the case of wireless transmission, radiation of the signal by means of a\ntransmitting antenna.\n \n The Channel. The communications channel is the physical medium that is\nused to send the signal from the transmitter to the receiver. In wireless transmission, the\nchannel is usually the atmosphere free space. On the other hand, telephone channels\nusually employ a variety of physical media, including wirelines, optical fiber cables,\nand wireless microwave radio. Whatever the physical medium for signal transmission,\nthe essential feature is that the transmitted signal is corrupted in a random manner by a\nvariety of possible mechanisms. The most common form of signal degradation comes\nin the form of additive noise, which is generated at the front end of the receiver, where\nsignal amplification is performed. This noise is often called thermal noise. In wireless\ntransmission, additional additive disturbances are manmade noise, and atmospheric\nnoise picked up by a receiving antenna. Automobile ignition noise is an example of\nmanmade noise, and electrical lightning discharges from thunderstorms is an example\nof atmospheric noise.

Interference from other users of the channel is another form of\nadditive noise that often arises in both wireless and wireline communication systems.\n \n In some radio communication channels, such as the ionospheric channel that is\nused for long range, shortwave radio transmission, another form of signal degradation\nis multipath propagation. Such signal distortion is characterized as a nonadditive signal\ndisturbance which manifests itself as time variations in the signal amplitude, usually\ncalled fading. This phenomenon is described in more detail in Section 1.3.\n \n Both additive and nonadditive signal distortions are usually characterized as ran\ndom phenomena and described in statistical terms. The effect of these signal distortions\nmust be taken into account on the design of the communication system.\n \n In the design of a communication system, the system designer works with mathe\nmatical models that statistically characterize the signal distortion encountered on phys\nical channels. Often, the statistical description that is used in a mathematical model is\na result of actual empirical measurements obtained from experiments involving signal\ntransmission over such channels. In such cases, there is a physical justification for the\nmathematical model used in the design of communication systems. On the other hand,\nin some communication system designs, the statistical characteristics of the channel \n\n \n Proakis50210 book August 3, 2001 132\n \n Section 1.2 Elements of an Electrical Communication System 7\n \n may vary significantly with time. In such cases, the system designer may design a\ncommunication system that is robust to the variety of signal distortions. This can be ac\ncomplished by having the system adapt some of its parameters to the channel distortion\nencountered.\n \n The Receiver. The function of the receiver is to recover the message signal\ncontained in the received signal.

If the message signal is transmitted by carrier modu\nlation, the receiver performs carrier demodulation in order to extract the message from\nthe sinusoidal carrier. Since the signal demodulation is performed in the presence of\nadditive noise and possibly other signal distortion, the demodulated message signal is\ngenerally degraded to some extent by the presence of these distortions in the received\nsignal. As we shall see, the fidelity of the received message signal is a function of the\ntype of modulation, the strength of the additive noise, the type and strength of any other\nadditive interference, and the type of any nonadditive interference.\n \n Besides performing the primary function of signal demodulation, the receiver\nalso performs a number of peripheral functions, including signal filtering and noise\nsuppression.\n \n 1.2.1 Digital Communication System\n \n Up to this point we have described an electrical communication system in rather broad\nterms based on the implicit assumption that the message signal is a continuous time\nvarying waveform. We refer to such continuoustime signal waveforms as analog sig\nnals and to the corresponding information sources that produce such signals as analog\nsources. Analog signals can be transmitted directly via carrier modulation over the\ncommunication channel and demodulated accordingly at the receiver. We call such a\ncommunication system an analog communication system.\n \n Alternatively, an analog source output may be converted into a digital form and the\nmessage can be transmitted via digital modulation and demodulated as a digital signal\nat the receiver. There are some potential advantages to transmitting an analog signal by\nmeans of digital modulation. The most important reason is that signal fidelity is better\ncontrolled through digital transmission than analog transmission.

In particular, digital\ntransmission allows us to regenerate the digital signal in longdistance transmission,\nthus eliminating effects of noise at each regeneration point. In contrast, the noise added\nin analog transmission is amplified along with the signal when amplifiers are used\nperiodically to boost the signal level in longdistance transmission. Another reason\nfor choosing digital transmission over analog is that the analog message signal may\nbe highly redundant. With digital processing, redundancy may be removed prior to\nmodulation, thus conserving channel bandwidth. Yet a third reason may be that digital\ncommunication systems are often cheaper to implement.\n \n In some applications, the information to be transmitted is inherently digital; e.g.,\nin the form of English text, computer data, etc. Additional\nfunctions include redundancy removal, and channel coding and decoding.\n \n Figure 1.2 illustrates the functional diagram and the basic elements of a digital\ncommunication system. The source output may be either an analog signal, such as audio\nor video signal, or a digital signal, such as the output of a computer which is discrete in\ntime and has a finite number of output characters. In a digital communication system,\nthe messages produced by the source are usually converted into a sequence of binary\ndigits. Ideally, we would like to represent the source output message by as few binary\ndigits as possible. In other words, we seek an efficient representation of the source\noutput that results in little or no redundancy. The process of efficiently converting the\noutput of either an analog or a digital source into a sequence of binary digits is called\n source encoding or data compression. We shall describe sourceencoding methods in\nChapter 6.\n \n The sequence of binary digits from the source encoder, which we call the in\nformation sequence is passed to the channel encoder.

The purpose of the channel\nencoder is to introduce, in a controlled manner, some redundancy in the binary infor\nmation sequence which can be used at the receiver to overcome the effects of noise\nand interference encountered in the transmission of the signal through the channel.\nThus, the added redundancy serves to increase the reliability of the received data and\nimproves the fidelity of the received signal. In effect, redundancy in the information\nsequence aids the receiver in decoding the desired information sequence. For example,\na trivial form of encoding of the binary information sequence is simply to repeat\neach binary digit m times, where m is some positive integer. More sophisticated non\ntrivial encoding involves taking k information bits at a time and mapping each k bit\nsequence into a unique n bit sequence, called a code word. In this manner, each\nbit from the channel encoder is transmitted separately. Hence, when the channel bit rate R\n is fixed, the amount of time available to transmit one of the M waveforms corresponding\nto a b bit sequence is b times the time period in a system that uses binary modulation.\n \n At the receiving end of a digital communications system, the digital demodulator\n processes the channelcorrupted transmitted waveform and reduces each waveform to a\nsingle number that represents an estimate of the transmitted data symbol binary or M \nary. For example, when binary modulation is used, the demodulator may process the\nreceived waveform and decide on whether the transmitted bit is a 0 or a 1. In such a case,\nwe say the demodulator has made a binary decision. As one alternative, the demodulator\nmay make a ternary decision; that is, it decides that the transmitted bit is either a 0 or\n1 or it makes no decision at all, depending on the apparent quality of the received\nsignal. When no decision is made on a particular bit, we say that the demodulator has\ninserted an erasure in the demodulated data.

Using the redundancy in the transmitted\ndata, the decoder attempts to fill in the positions where erasures occurred. More precisely, the average probability\nof a biterror at the output of the decoder is a measure of the performance of the\ndemodulatordecoder combination. Due\nto channeldecoding errors and possible distortion introduced by the source encoder\nand, perhaps, the source decoder, the signal at the output of the source decoder is an\napproximation to the original source output. The difference or some function of the\ndifference between the original signal and the reconstructed signal is a measure of the\ndistortion introduced by the digital communications system.\n \n 1.2.2 Early Work in Digital Communications\n \n Although Morse is responsible for the development of the first electrical digital commu\nnication system telegraphy, the beginnings of what we now regard as modern digital\ncommunications stem from the work of Nyquist 1924, who investigated the problem\nof determining the maximum signaling rate that can be used over a telegraph channel\nof a given bandwidth without intersymbol interference. This rate is now called the Nyquist rate. This pulse\nshape allows the recovery of the data without intersymbol interference at the sampling\ninstants. This problem arises in signal demodulation. Wiener determined the\nlinear filter whose output is the best meansquare approximation to the desired signal\n st. Based on such\na statistical formulation, he adopted a logarithmic measure for the information content\nof a source. He also demonstrated that the effect of a transmitter power constraint, a\nbandwidth constraint, and additive noise can be associated with the channel and incor\nporated into a single parameter, called the channel capacity.