PREFACE

Continuing the tradition of the first through the seventh editions of *Digital and Analog Communication Systems*, this eighth edition provides the latest up-to-date treatment of digital communication systems. It is written as a textbook for junior or senior engineering students and is also appropriate for an introductory graduate course. It also provides a modern technical reference for the practicing electrical engineer. A *Student Solutions Manual* contains detailed solutions for over 100 selected end-of-the-chapter homework problems. For the selected problems that have computer solutions, MATLAB solution files are available for downloading from the Web. To download the *Student Solutions Manual* and the MATLAB files, go to http://lcouch.us or to http://couch.ece.ufl.edu.

One major change for this eighth edition is the addition of more than 100 examples distributed throughout the chapters of the text. Students are always asking for more examples. Most of these new examples have a problem description that consists of only a few lines of text. The solutions for these examples are contained within MATLAB files (downloaded from the Web site given earlier). These files include the procedure for the solution (as described by comment lines in the MATLAB program) and produce computed and plotted solutions. This presentation procedure has several advantages. First, the description for each example takes only a few lines in this textbook, so the book will not be extended in length. Second, the student will have the experience of learning to work with MATLAB (as demonstrated with the example solutions). Clearly plotted results, which are better than hand calculations, are given. The student can also vary the parameters in the MATLAB example to discover how the results will be affected. The author believes that this approach to examples is a great innovative teaching tool.

To learn about communication systems, it is essential to first understand *how communication systems work.* Based on the principles of communications that are covered in the first five chapters of this book (power, frequency spectra, and Fourier analysis), this understanding is motivated by the use of extensive examples, study-aid problems, and the inclusion of adopted standards. Especially interesting is the material on wire and wireless communication systems. Also of importance is the effect of noise on these systems, since, without noise (described by probability and random processes), one could communicate to the limits of the universe with negligible transmitted power. In summary, this book covers the essentials needed for the understanding of wire and wireless communication systems and includes adopted standards. These essentials are

- How communication systems work: Chapters 1 through 5.
- The effect of noise: Chapters 6 and 7.
- Wire and Wireless Communication Applications: Chapter 8.

This book is ideal for either a one-semester or a two semester course. This book emphasizes basic material and applications that can be covered in a one-semester course, as well as the essential material that should be covered for a two-semester course. This emphasis means that the page count needs to be limited to around 750 pages. For a book with a larger page count, it is impossible to cover all that additional material, even in a two-semester course. (Many schools are moving toward one basic course offering in communications.) Topics such as, coding, wireless signal propagation, Wi MAX, and Long Term Evolution (LTE) of cellular systems are covered in this book. In-depth coverage of important topics such as these should be done by additional courses with their own textbooks.

For a one-semester course, the basics of how communication systems work may be taught by using the first five chapters (with selected readings from Chapter 8). For a two-semester course, the whole book is used.

This book covers *practical aspects* of communication systems developed from a sound *theoretical basis.*

THE THEORETICAL BASIS

- Digital and analog signals
- Magnitude and phase spectra
- Fourier analysis
- Orthogonal function theory
- Power spectral density
- Linear systems
- Nonlinear systems
- Intersymbol interference
- Complex envelopes
- Modulation theory
- Probability and random processes
- Matched filters
- Calculation of SNR
- Calculation of BER
- Optimum systems
- Block and convolutional codes

THE PRACTICAL APPLICATIONS

- PAM, PCM, DPCM, DM, PWM, and PPM baseband signaling
- OOK, BPSK, QPSK, MPSK, MSK, OFDM, and QAM bandpass digital signaling
- AM, DSB-SC, SSB, VSB, PM, and FM bandpass analog signaling
- Time-division multiplexing and the standards used
- Digital line codes and spectra
- Circuits used in communication systems
- Bit, frame, and carrier synchronizers
- Software radios
- Frequency-division multiplexing and the standards used
- Telecommunication systems
- Telephone systems
- DSL modems
- Digital subscriber lines
- Satellite communication systems
- Satellite radio broadcasting systems
- Effective input-noise temperature and noise figure
- Link budget analysis
- SNR at the output of analog communication systems
- BER for digital communication systems
- Fiber-optic systems
- Spread-spectrum systems
- AMPS, GSM, iDEN, TDMA, CDMA, Wi MAX, and LTE cellular telephone systems
- Digital and analog television systems
- Technical standards for AM, FM, TV, DTV, and CATV
- Cable data modems
- Wi-Fi and Wi MAX wireless networks
- Mathcad files on web
- MATLAB M files on web
- Mathematical tables
- Study-aid examples
- Over 100 examples with solutions. About 80 of these examples include MATLAB solutions
- Over 550 homework problems with selected answers
- Over 60 computer-solution homework problems
- Extensive references
- Emphasis on the design of communication systems
- *Student Solutions Manual* (download)

WHAT'S NEW IN THIS EDITION

- addition of over 100 examples with solutions that are distributed throughout the chapters of the book. Most of them have MATLAB computer solutions obtained via electronic M files which are downloaded free-of-charge from author's Web site.
- includes up-to-date descriptions of popular wireless systems, LTE (long-term evolution) and WiMax 4G cellular systems, and personal communication applications.
- includes latest updates on digital TV (DTV) technology.
- brings terminology and standards up-to-date.
- brings references up-to-date.
- updates all chapters.
- includes additional and revised homework problems.
- includes suggestions for obtaining the latest information on applications and standards by using the appropriate keyword queries on internet search engines, such as Google.
- continues the emphasis on MATLAB computer solutions to problems. This approach of using computer solutions is very important in training new communication engineers. This is one of the very few books that include the actual electronic files for MATLAB solutions (available for free downloading from the internet). This is done so that the reader does not have to spend days in error-prone typing of lines of computer code that are listed in a textbook.
- updates all MATLAB files to run on Version R2010b.
- extends list of Answers to Selected Problems at the end of the book, with MATLAB solutions if appropriate.

Many of the homework problems are marked with a personal computer symbol, 💻. This indicates that MATLAB and Mathcad computer solutions are available for this problem.

Homework problems are found at the end of each chapter. Complete solutions for those marked with a ★, approximately 1/3, are found in the *Student Solutions Manual*, available for free download from http://LCouch.us or http://www.couch.ece.ufl.edu. Student M-files are also available for download. Complete solutions for all problems, including the computer solution problems, are given in the *Instructor Solutions Manual* (available only to instructors from Prentice Hall). These manuals include Acrobat pdf files for the written solutions. Also, for the problems with computer solutions, MATLAB M files and Mathcad files are given. These files can be downloaded from the text's page at www.prenhall.com.

This book is an outgrowth of my teaching at the University of Florida and is tempered by my experiences as an amateur radio operator (K4GWQ). I believe that the reader will not understand the technical material unless he or she works some homework problems. Consequently, over 550 problems have been included. Some of them are easy, so that the beginning student will not become frustrated, and some are difficult enough to challenge the more advanced students. All of the problems are designed to provoke thought about, and understanding of, communication systems.

I appreciate the help of the many people who have contributed to this book and the very helpful comments that have been provided by the many reviewers over the years.

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List of Symbols

There are not enough symbols in the English and Greek alphabets to allow the use of each letter only once. Consequently, some symbols may be employed to denote more than one entity, but their use should be clear from the context. Furthermore, the symbols are chosen to be generally the same as those used in the associated mathematical discipline. For example, in the context of complex variables, x denotes the real part of a complex number (i.e., $c = x + jy$), whereas in the context of statistics, x might denote a random variable.

Symbols

a_n	a constant
a_n	quadrature Fourier series coefficient
A_c	level of modulated signal of carrier frequency f_c
A_e	effective area of an antenna
b_n	quadrature Fourier series coefficient
B	baseband bandwidth
B_p	bandpass filter bandwidth

B_T	transmission (bandpass) bandwidth
c	a complex number ($c = x + jy$)
c	a constant
c_n	complex Fourier series coefficient
C	channel capacity
C	capacitance
°C	degrees Celsius
dB	decibel
D	dimensions/s, symbols/s ($D = N/T_0$), or baud rate
D_f	frequency modulation gain constant
D_n	polar Fourier series coefficient
D_p	phase modulation gain constant
e	error
e	the natural number 2.7183
E	modulation efficiency
E	energy
$\mathcal{E}(f)$	energy spectral density (ESD)
E_b/N_0	ratio of energy per bit to noise power spectral density
f	frequency (Hz)
$f(x)$	probability density function (PDF)
f_c	carrier frequency
f_i	instantaneous frequency
f_0	a (frequency) constant; the fundamental frequency of a periodic wavefonn
f_s	sampling frequency
F	noise figure
$F(a)$	cumulative distribution function (CDF)
$g(t)$	complex envelope
$\widetilde{g}(t)$	corrupted complex envelope
G	power gain
$G(f)$	power transfer function
h	Planck's constant, 6.63×10^{-34} joule-s
$h(t)$	impulse response of a linear network
$h(x)$	mapping function of x into $h(x)$
H	entropy
$H(f)$	transfer function of a linear network
i	an integer
I_j	information in the jth message
j	the imaginary number $\sqrt{-1}$
j	an integer
k	Boltzmann's constant, 1.38×10^{-23} joule/K
k	an integer
$k(t)$	complex impulse response of a bandpass network
K	number of bits in a binary word that represents a digital message
K	degrees Kelvin (°C + 273)
l	an integer

ℓ	number of bits per dimension or bits per symbol
L	inductance
L	number of levels permitted
m	an integer
m	mean value
$m(t)$	message (modulation) waveform
$\widetilde{m}(t)$	corrupted (noisy received) message
M	an integer
M	number of messages permitted
n	an integer
n	number of bits in message
$n(t)$	noise waveform
N	an integer
N	number of dimensions used to represent a digital message
N	noise power
N_0	level of the power spectral density of white noise
$p(t)$	an absolutely time-limited pulse waveform
$p(t)$	instantaneous power
$p(m)$	probability density function of frequency modulation
P	average power
P_e	probability of bit error
$P(C)$	probability of correct decision
$P(E)$	probability of message error
$\mathcal{P}(f)$	power spectral density (PSD)
$Q(z)$	integral of Gaussian function
$Q(x_k)$	quantized value of the kth sample value, x_k
$r(t)$	received signal plus noise
R	data rate (bits/s)
R	resistance
$R(t)$	real envelope
$R(\tau)$	autocorrelation function
$s(t)$	signal
$\widetilde{s}(t)$	corrupted signal
S/N	ratio of signal power to noise power
t	time
T	a time interval
T	absolute temperature (Kelvin)
T_b	bit period
T_e	effective input-noise temperature
T_0	duration of a transmitted symbol or message
T_0	period of a periodic waveform
T_0	standard room temperature (290 K)

T_s	sampling period
u_{11}	covariance
$v(t)$	a voltage waveform
$v(t)$	a bandpass waveform or a bandpass random process
$w(t)$	a waveform
$W(f)$	spectrum (Fourier transform) of $w(t)$
x	an input
x	a random variable
x	real part of a complex function or a complex constant
$x(t)$	a random process
y	an output
y	an output random variable
y	imaginary part of a complex function or a complex constant
$y(t)$	a random process
α	a constant
β	a constant
β_f	frequency modulation index
β_p	phase modulation index
δ	step size of delta modulation
δ_{ij}	Kronecker delta function
$\delta(t)$	impulse (Dirac delta function)
ΔF	peak frequency deviation (Hz)
$\Delta\theta$	peak phase deviation
ϵ	a constant
ϵ	error
η	spectral efficiency [(bits/sec)/Hz]
$\theta(t)$	phase waveform
λ	dummy variable of integration
λ	wavelength
$\Lambda(r)$	likelihood ratio
π	3.14159
ρ	correlation coefficient
σ	standard deviation
τ	independent variable of autocorrelation function
τ	pulse width
$\varphi_j(t)$	orthogonal function
ϕ_n	polar Fourier series coefficient
ω_c	radian carrier frequency, $2\pi f_c$
$\equiv$	mathematical equivalence
$\triangleq$	mathematical definition of a symbol

DEFINED FUNCTIONS

$J_n(\cdot)$	Bessel function of the first kind, *n* th order
$\ln(\cdot)$	natural logarithm
$\log(\cdot)$	base 10 logarithm
$\log_2(\cdot)$	base 2 logarithm
$Q(z)$	integral of a Gaussian probability density function
$\mathrm{Sa}(z)$	$(\sin z)/z$
$u(\cdot)$	unit step function
$\Lambda(\cdot)$	triangle function
$\Pi(\cdot)$	rectangle function

OPERATOR NOTATION

$\mathrm{Im}\{\cdot\}$	imaginary part of
$\mathrm{Re}\{\cdot\}$	real part of
$\overline{[\cdot]}$	ensemble average
$\langle[\cdot]\rangle$	time average
$[\cdot] * [\cdot]$	convolution
$[\cdot]^*$	conjugate
$\underline{/[\cdot]}$	angle operator or angle itself, see Eq. (2–108)
$\lvert[\cdot]\rvert$	absolute value
$[\hat{\cdot}]$	Hilbert transform
$\mathcal{F}[\cdot]$	Fourier transform
$\mathcal{L}[\cdot]$	Laplace transform
$[\cdot] \cdot [\cdot]$	dot product