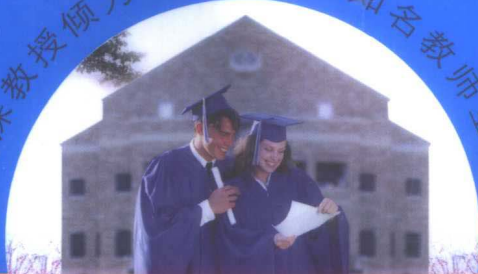


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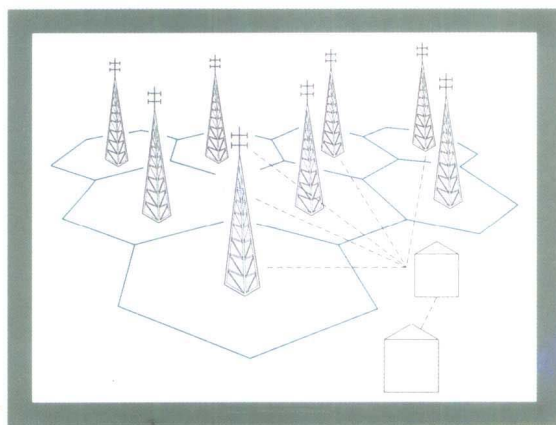
# 数字与模拟通信系统

(第六版)

Digital and Analog Communication Systems

(Sixth Edition)

(英文影印版)



Leon W. Couch II 著



科学出版社

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北京

## 内 容 简 介

本书为国外高校电子信息类优秀教材(英文影印版)之一。

本书涵盖了数字通信与模拟通信的内容,并着重介绍了数字通信系统的设计。书中除向读者提供了经典的数学分析方法外,还提供了利用计算机进行分析、设计和模拟现代通信系统的方法, MATLAB 的使用贯穿全书。

本书可作为通信专业本科生教材,也可作为相关领域工程技术人员的参考书。

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*To my wife,  
Margaret Wheland Couch,  
and  
to our children,  
Leon III, Jonathan, and Rebecca*



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## PREFACE

Continuing the tradition of the first to fifth editions of this book, this new edition provides the latest up-to-date treatment of digital communication systems. It includes a number of new study-aid examples and homework problems, many of which require solutions via a personal computer. It is written as a textbook for junior or senior engineering students and is also appropriate for an introductory graduate course or as a modern technical reference for practicing electrical engineers.

To learn about communication systems, it is essential to first understand *how communication systems work*. Based on the principles of communications (power, frequency spectra, and Fourier analysis) that are covered in the first five chapters of this book, 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 Systems: Chapter 8.

This book is ideal for either a one-semester or a two-semester course. 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  | • Complex envelopes                |
| • Magnitude and phase spectra | • Modulation theory                |
| • Fourier analysis            | • Probability and random processes |
| • Orthogonal function theory  | • Matched filters                  |
| • Power spectral density      | • Calculation of SNR               |
| • Linear systems              | • Calculation of BER               |
| • Nonlinear systems           | • Optimum systems                  |
| • Intersymbol interference    | • 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
- Digital subscriber lines
- Satellite communication 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, and CDMA cellular telephone and PCS systems
- Digital and analog television systems
- Technical standards for AM, FM, TV, DTV, and CATV
- Protocols for computer communications
- Technical standards for computer communications
- MATLAB M files
- Mathematical tables
- Study-aid examples
- Over 550 homework problems with selected answers
- Over 60 computer-solution homework problems
- Extensive references
- Emphasis on the design of communication systems

Many of the equations and homework problems are marked with a personal computer symbol, , which indicates that the given equation or problem has a MATLAB and MATH-CAD solution on an available floppy disk or via the Internet at [www.couch.ece.ufl.edu](http://www.couch.ece.ufl.edu) or [www.prenhall.com/couch](http://www.prenhall.com/couch).

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 the problems are designed to provoke thought about, and understanding of, communication systems.

I appreciate the help of the many persons who contributed to this book and the very helpful comments that have been provided by the reviewers—in particular, Marvin Siegel of the Department of Electrical Engineering at the University of Michigan and J. B. O’Neal of North Carolina State University. I also appreciate the help of my colleagues at the University of Florida. I thank my wife, Dr. Margaret Couch, who typed the original and revised manuscripts.

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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
$^{\circ}\text{C}$	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 waveform
$f_s$	sampling frequency
$F$	noise figure
$F(a)$	cumulative distribution function (CDF)
$g(t)$	complex envelope
$\tilde{g}(t)$	corrupted complex envelope
$G$	power gain
$G(f)$	power transfer function
$h$	Planck's constant, $6.2 \times 10^{-34}$ 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 $j$ th message
$j$	the imaginary number $\sqrt{-1}$
$j$	an integer
$k$	Boltzmann's constant, $1.38 \times 10^{-23}$ 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 ( $^{\circ}\text{C} + 273$ )

$l$	an integer
$\ell$	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
$\tilde{m}(t)$	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 $k$ th 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
$\tilde{s}(t)$	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
$\alpha$	a constant
$\beta$	a constant
$\beta_f$	frequency modulation index
$\beta_p$	phase modulation index
$\delta$	step size of delta modulation
$\delta_{ij}$	Kronecker delta function
$\delta(t)$	impulse (Dirac delta function)
$\Delta F$	peak frequency deviation (Hz)
$\Delta\theta$	peak phase deviation
$\epsilon$	a constant
$\epsilon$	error
$\eta$	spectral efficiency [(bits/sec)/Hz]
$\theta(t)$	phase waveform
$\lambda$	dummy variable of integration
$\lambda$	wavelength
$\Lambda(r)$	likelihood ratio
$\pi$	3.14159
$\rho$	correlation coefficient
$\sigma$	standard deviation
$\tau$	independent variable of autocorrelation function
$\tau$	pulse width
$\varphi_j(t)$	orthogonal function
$\phi_n$	polar Fourier series coefficient
$\omega_c$	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
$\text{Sa}(z)$	$(\sin z)/z$
$u(\cdot)$	unit step function
$\Lambda(\cdot)$	triangle function
$\Pi(\cdot)$	rectangle function

## OPERATOR NOTATION

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



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