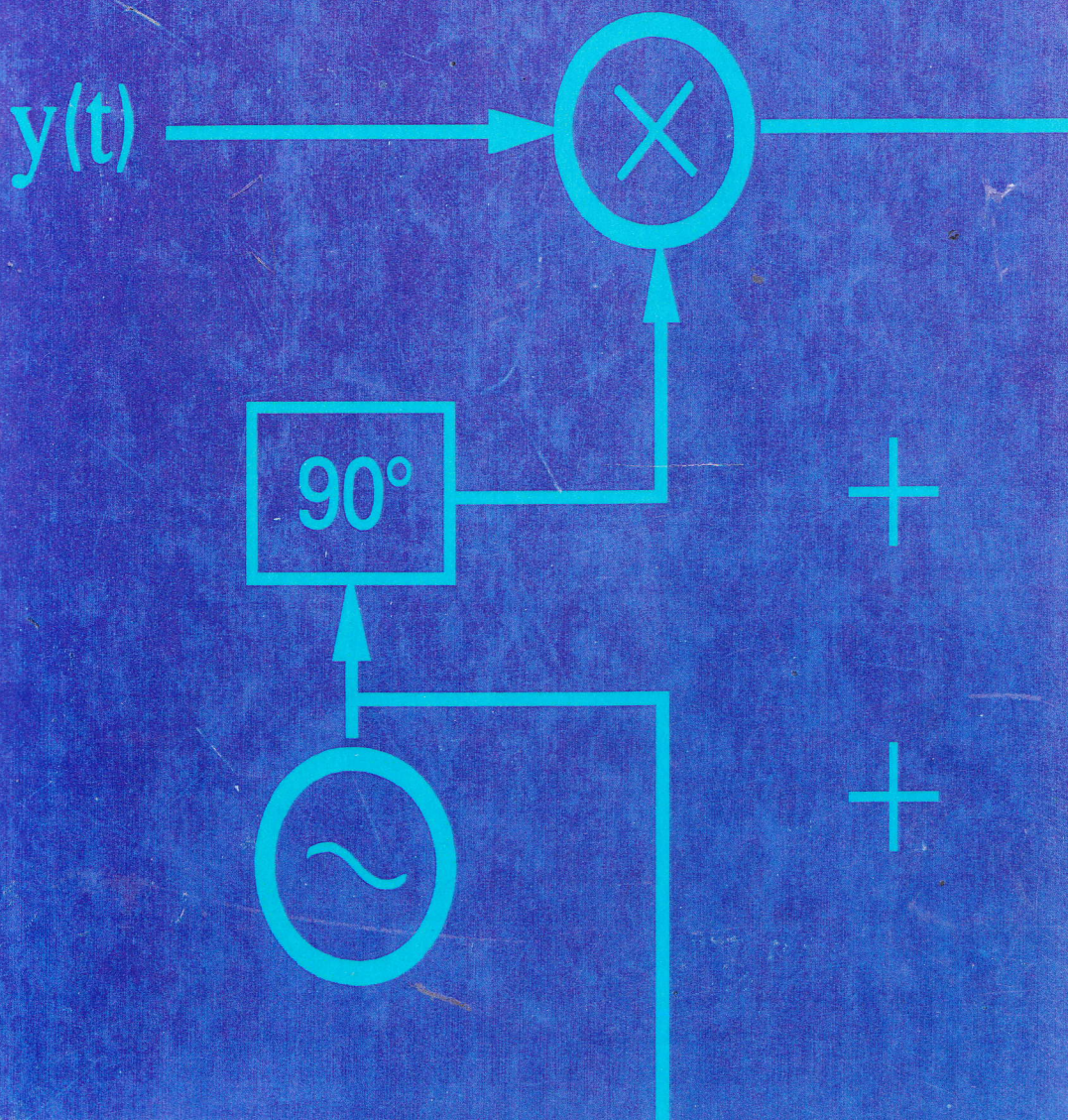


Introduction to

# Communication Systems

Third Edition

Ferrel G. Stremler





# Contents

## CHAPTER

### **1 Introduction**

1

## CHAPTER

### **2 Orthogonality and Signal Representations**

8

- 2.1 Signals and Systems 8
- 2.2 Classification of Signals 10
- 2.3 Classification of Systems 12
- ★ 2.4 ~~Signals and Vectors~~ 13
- ★ 2.5 Orthogonal Functions 15
- ★ 2.6 Choice of a Set of Orthogonal Functions 21
- 2.7 The Exponential Fourier Series 23
- 2.8 Complex Signals and Representations 26
- 2.9 The Trigonometric Fourier Series Representation 29
- 2.10 Extension by Periodicity 33
- 2.11 Parseval's Theorem for Power Signals 36
- 2.12 The Frequency Transfer Function 38
- 2.13 Steady-State Response to Periodic Signals 40
- 2.14 Harmonic Generation 42
- 2.15 The Fourier Spectrum and Examples 44
- ★ 2.16 Numerical Computation of Fourier Coefficients 50
- ★ 2.17 Effects of Alias Terms 53
- 2.18 Singularity Functions 59
- 2.19 Impulse Response 65
- ★ 2.20 Convergence of the Fourier Series 66
- 2.21 Summary 69
- Problems 71

## CHAPTER

**3****The Fourier Transform and Applications****82**

- 3.1 Representation of an Aperiodic Function Over the Entire Real Line **82**
- 3.2 The Spectral Density Function **85**
- ★ 3.3 Existence of the Fourier Transform **87**
- 3.4 Parseval's Theorem for Energy Signals **88**
- 3.5 Some Fourier Transforms Involving Impulse Functions **89**
- 3.6 Properties of the Fourier Transform **96**
- 3.7 Some Convolution Relationships **109**
- 3.8 Graphic Interpretation of Convolution **111**
- 3.9 Filter Characteristics of Linear Systems **114**
- 3.10 Transversal Filters **116**
- 3.11 Bandwidth of a System **118**
- 3.12 Requirements for Distortionless Transmission **119**
- 3.13 Time Response of Filters **120**
- ★ 3.14 Minimum Time-Bandwidth Product **124**
- 3.15 The Sampling Theorem **126**
- ★ 3.16 Aliasing Effects in Sampling **131**
- ★ 3.17 The Discrete Fourier Transform **135**
- ★ 3.18 The Fast Fourier Transform **141**
- 3.19 Summary **145**  
Problems **147**

## CHAPTER

**4****Spectral Density and Correlation****163**

- 4.1 Energy Spectral Density **163**
- 4.2 Power Spectral Density **168**
- 4.3 Time-Averaged Noise Representations **176**
- 4.4 Correlation Functions **179**
- 4.5 Some Properties of Correlation Functions **184**

4.6	Correlation Functions for Finite-Energy Signals	187
4.7	Band-Limited White Noise	188
4.8	Summary	208
	Problems	209

## CHAPTER

**5 Amplitude Modulation 219**

5.1	Amplitude Modulation: Suppressed Carrier	219
5.2	Amplitude Modulation: Large Carrier (AM)	238
5.3	Frequency-Division Multiplexing (FDM)	249
5.4	Single-Sideband (SSB) Modulation	255
5.5	Vestigial-Sideband (VSB) Modulation	266
5.6	A Time-Representation of Bandpass Noise	268
5.7	Signal-to-Noise Ratios in AM Reception	271
5.8	Propagation Effects	277
5.9	Comparison of Various AM Systems	281
5.10	Summary	282
	Problems	284

## CHAPTER

**6 Angle Modulation 298**

6.1	FM and PM	298
6.2	Narrowband FM	301
6.3	Wideband FM	306
6.4	Average Power in Angle-Modulated Waveforms	317
6.5	Phase Modulation	319
6.6	Generation of Wideband FM Signals	321
6.7	Demodulation of FM Signals	327

6.8	Signal-to-Noise Ratios in FM Reception	345
6.9	Threshold Effect in FM	351
6.10	Signal-to-Noise Improvement Using Deemphasis	355
6.11	Summary	359
	Problems	361

## CHAPTER

**Pulse Modulation****371**

7.1	Pulse-Amplitude Modulation (PAM)	372
7.2	Time-Division Multiplexing (TDM)	377
7.3	Pulse Shaping and Intersymbol Interference	386
7.4	Other Types of Analog Pulse Modulation: PWM and PPM	390
7.5	Signal-to-Noise Ratios in Analog Pulse Modulation	399
7.6	Pulse-Code Modulation (PCM)	402
7.7	Fiber Optic Communication Systems	413
7.8	Use of Parity and Redundancy in PCM	417
7.9	Time-Division Multiplexing of PCM Signals	419
7.10	Integrated Services Digital Network (ISDN)	429
7.11	The Matched Filter	431
7.12	Matched-Filter Codeword Detection	437
7.13	Pseudonoise (PN) Sequences	439
7.14	Summary	443
	Problems	445

## CHAPTER

**Probability and Random Variables****457**

8.1	Probability	457
8.2	Conditional Probability and Statistical Independence	461

8.3	The Random Variable and Cumulative Distribution Function	463
8.4	The Probability Density Function	466
8.5	Statistical Averages	471
8.6	Some Probability Distributions	477
★ 8.7	The Histogram	485
★ 8.8	Transformations of Random Variables	487
8.9	Joint and Conditional Density Functions	490
★ 8.10	Correlation Between Random Variables	493
★ 8.11	The Bivariate Gaussian Distribution	497
8.12	Random Processes	498
8.13	Autocorrelation and Power Spectra	504
★ 8.14	Numerical Computation of Power Spectra	515
8.15	Summary	517
	Problems	519

## CHAPTER

9

## Information and Digital Transmission

531

9.1	A Measure of Information	531
9.2	Channel Capacity	536
9.3	Ideal Demodulator Detection Gain	540
9.4	Quantization Noise	541
9.5	Probability of Error in Transmission	547
9.6	$S/N$ Performance of PCM	558
9.7	Delta Modulation and DPCM	560
★ 9.8	Error Analysis of PCM Repeaters	564
★ 9.9	Power Spectral Densities of Data Waveforms	567
9.10	Partial-Response Signaling	572
9.11	Equalization	577
9.12	$M$ -ary Signaling	584
★ 9.13	Coding for Reliable Communication	589
9.14	Summary	594
	Problems	596