

Draft



**COMMUNICATION SYSTEMS:**  
*Signals, Systems, and Emerging Applications*

**Hüseyin Abut**

**Hüseyin Abut**  
**FERP Professor of Electrical & Computer Engineering**  
**San Diego State University, San Diego, CA 92182-1309**

## Preface

The notion of communication can be described simply as the transmission of information from a given source to a particular destination through a succession of processing stages. Advances in communication systems, computers, high-speed information networks, microelectronics, and multimedia systems have made it possible to send messages over great distances easily, reliably, and most importantly, economically. They have also made it possible to send large amounts of data, both natural and man-made, quickly from one point to another with a very small probability of error.

The objective of these lecture notes is to present an introductory level treatment of traditional as well as current analog, pulse, and digital communication systems with many examples ranging from classical radio systems to emerging applications including many computer simulations completely solved using *de facto* industry standard Matlab<sup>®</sup> Package<sup>1</sup>. Self-explanatory source codes, i.e., m-files as well as outputs for examples and exercises using this package are provided. In addition, a number of excellent examples are included in the body of the text with acknowledgement of the original authors or their publishers.

The first six chapters of these lecture notes is currently being used at San Diego State University and Sabanci University, Istanbul, Turkey in third-year undergraduate courses upon completion of an introductory course on Signals and Systems. Upon successful completion of these courses students normally enroll in subsequent courses in Communications Engineering and the Digital Signal Processing programs. The second half of the text is currently being designed for the second course in communications where the concentration will be on base-band and band-pass digital communication systems, communication under noisy regimes and new applications in the wireless and wired infrastructures.

---

<sup>1</sup> Matlab is a copyrighted Software Simulation Platform by Mathworks, Inc. This textbook uses the latest edition of the Professional Release with Simulink. Both the Sun workstations and the PCs in the College of Engineering Laboratories have site licences. Students normally use the Students Version of the same edition. The implementations of all the Matlab based exercises can be solved using the Student Edition.

**CONTENTS (Draft; Only Chapters 1-2 are current, rest in progress)**

	Page
<b>Chapter 1. Introduction to Communication Systems and Information Theory</b>	5
1.1 Definitions and Terminology	6
1.2 Signals and Classification	10
1.2.1 Deterministic and Random Signals (Continuous Signals)	10
1.2.2 Frequency Band Classification	10
1.2.3 Baseband/Passband Classification	11
1.2.4 Energy and Power Signals	12
1.2.5 Time Signature Classification	12
1.2.6 Discrete-Time Continuous-Amplitude (Discrete Signals or Sampled Signals)	12
1.2.7 Sampling of Analog Signals (A/D and D/A Conversion)	12
1.2.8 Sampling (Nyquist) Theorem	13
1.3 Quantization and Coding	14
1.3.1 Sampling and Coding Performance Measures (SNR and Transmission Rate)	15
1.3.2 Analog versus Digital Communication	16
1.4 Principle of Modulation	18
1.5 Communication System Resources and Performance Measures	20
1.5.1 Signal to Noise Ratio (SNR)	21
1.5.2 Bandwidth	23
1.7 Information Theory Bounds on Communication	24
1.7.1 Self-Information and Entropy	24
1.7.2 Shannon Source Coding Theorem	25
1.7.3 Channel Capacity	26
1.7.4 Shannon Channel Coding Theorem	26
<b>Chapter 2. Analysis of Signals and Systems</b>	28
2.1 Line Spectra and Fourier Series	28
2.1.1 Phasors and Line Spectra	28
2.1.2 Fourier Series	32
2.1.3 Important Signals used in Communications	32
2.1.4 Discrete Sinusoidal Signal	35
2.1.5 Dirichlet Existence Conditions and Gibbs Phenomenon	39
2.1.6 Parseval's Power Theorem and Superposition	39
2.2 Fourier Transform for Continuous Signals	39
2.3 Time and Frequency Relations	44
2.3.1 Superposition Theorem	44
2.3.2 Time Delay	44
2.3.3 Scale Change	44
2.3.4 Frequency Translation and Modulation	44
2.3.5 Differentiation and Integration in Time-Domain	45
2.4 Convolution	45
2.5 Modulation Theorem	50

2.6 Discrete-Time Fourier Transform and its Inverse	51
2.6.1 Forward DTFT	51
2.6.2 Inverse DTFT	51
2.6.3 Convergence of DTFT	51
2.6.4 DTFT Examples	52
2.7 Discrete Fourier Transform (DFT) and its Inverse	53
2.7.1 DFT	53
2.7.2 DFT Examples	53
<b>Chapter 3. Communication in Noiseless and Noisy Channel</b>	<b>54</b>
<b>Chapter 4. Amplitude Modulation Systems</b>	
<b>Chapter 5. Angle Modulation Systems</b>	
<b>Chapter 6. Pulse Modulation Systems</b>	
<b>Appendices</b>	
Appendix A: Mathematical Facts and Fourier Analysis	
Appendix B: Supplementary Problems on Signal Analysis	
Appendix C: Supplementary Problems on Modulation Systems	
Appendix D: Supplementary Problems on Pulse Modulation	