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Introduction to Digital Communications

 Springer

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Preface

Digital communication has found an increasing interest in the past 70 years starting with the telephone network on copper wires, the development of the optical transmission, and the emerging Internet based on wire-line and wireless transmission technologies. Today, the trend to serve an increasing number of mobile users and also machines with information through digital networks is unbroken.

The new book *Introduction to Digital Communications* is aiming at graduate students, scientists, and engineers, who are interested in getting an introduction to modern digital communications. The main focus is on the fundamentals of the physical layer from the perspective of the theory of linear time-invariant as well as time-variant systems. The book draws a bow from single input single output to multiple input multiple output systems with an emphasis on wireless transmission over time-variant channels. The main concern lies in an accurate mathematical description, wherein the findings and lemmas are proven in detail. Various chapters are enriched by numerical examples and also illustrated with results from computer simulations provided by the open platform “webdemo” of the Institute of Telecommunications at the University of Stuttgart, <http://www.inue.uni-stuttgart.de>.

Organization of the Book

The book covers three main parts and the fourth part with two Appendices.

Part I

It deals with the principles of digital transmission, which are important for wire-line as well as wireless communications. It describes the main building blocks for single input single output (SISO) systems. The concept of quadrature amplitude modulation is introduced. An important part is the design of the overall system for

minimal intersymbol interference with Nyquist's first criterion. The introduction of the equivalent baseband system allows the concise definition of the link between the transmitter input and the receiver output as a "black box" without details of the modulation, the spectral signal shaping, and the channel. For the receive signal, several detection methods are described in detail, such as threshold decision, maximum likelihood, and maximum a posteriori detection. Also, the difference between symbol-by-symbol and sequence detection is addressed, and the maximum likelihood sequence estimator is described as an example. With an adequate model of the noise at the receiver, the symbol error probability is calculated.

The following chapters in Part I are devoted to the wireless transmission. The main difference is the wireless channel, which changes its characteristic with time. Therefore, the theory of linear time-variant systems is introduced to describe the building blocks of the system with time-variant impulse responses and delay spread functions. As not all students and engineers are frequently involved with this topic, the book contains an own Part II devoted to the theory of linear time-variant systems. Selected points are briefly reported for Part I; hence, the reader is not required to study Part II beforehand. However, for a deeper understanding, the reader should get involved in Part II. The introduction of the equivalent baseband system, which is then time-variant, follows. With this model, the increase of the output signal bandwidth at the receiver compared to the transmit signal is shown as an example. The multipath channel model is described in detail. As the wireless transmission link is multifaceted, a statistical characterization of the channel is helpful. To this end, various channel models are reviewed, such as the Rayleigh and Nakagami- m fading as well as the model according to Clarke and Jakes.

Part II

It is devoted to the theory of linear time-variant systems. In many cases, this topic is just touched upon during the education of graduate students in Electrical Engineering and Computer Science. Therefore, this dedicated Part II is provided. The input-output relation given by the time-variant convolution is addressed in detail and the mathematical properties are derived. We outline the relation with the well-known (time-invariant) convolution used by engineers in most applications. The time-variant impulse response and the delay spread function turn out to be the proper system descriptions in the time domain. Also, the system functions in the frequency domain are presented, such as the time-variant transfer function and the Doppler spread function. For the statistical description of randomly changing time-variant systems, autocorrelation functions as well as power spectral densities of the system functions are studied.

Part III

It deals with multiple input multiple output (MIMO) systems. First, the input–output relation is derived using matrix notation. We discuss the principle MIMO channel models, such as the time-variant finite impulse response and the i.i.d. Gaussian model. Furthermore, spatial correlations at the transmitter and the receiver are incorporated leading to the Kronecker model. Linear and nonlinear MIMO receivers are investigated in detail, such as the zero-forcing, the minimum mean squared error, and the maximum likelihood receiver. An important question is how many bits per channel use can be transmitted over an MMO channel. This issue is studied together with the maximization of the channel capacity. Next, the principles of spatial prefiltering and space-time encoding are investigated to improve transmission quality and to increase the data rate. In the last chapter, we leave the single-user transmission and consider the MIMO principle for a multitude of users in a network. Various multi-user MIMO schemes for the uplink and downlink are discussed, which can reduce the interference when the users transmit their signals in the same time slots and frequency bands.

Part IV

In **Appendix A**, a summary of the characterization of random variables and stochastic processes is given.

Appendix B provides an overview on the most important lemmas of linear algebra required for the understanding of some topics of this book.

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Actual notes can be found at:

http://www.inue.uni-stuttgart.de/institut/mitarbeiter/joachim_speidel_01.en.html

Contents

Part I Digital Communications Over Single Input Single Output Channels

1	Transmission System with Quadrature Amplitude Modulation	3
1.1	Introduction	3
1.2	The Transmitter	4
1.3	Signal Constellation Diagrams	8
1.4	Transmission Channel	9
1.5	Receiver	10
1.6	Equivalent Baseband System Model	13
1.7	Intersymbol Interference	14
	References	14
2	Removal of Intersymbol Interference	17
2.1	Nyquist’s First Criterion in the Time Domain	17
2.2	Nyquist’s First Criterion in the Frequency Domain	18
2.3	Raised Cosine Nyquist Lowpass Filter	20
	References	22
3	Characterization of the Noise at the Receiver	23
3.1	Channel Noise $n_C(t)$	23
3.2	Noise After Demodulation and Lowpass Filtering	25
3.3	Noise After Sampling	26
3.4	Summary	28
4	Detection Methods.	31
4.1	Receive Signal Under Detection	31
4.2	Maximum Likelihood Symbol-by-Symbol Detection	31
4.2.1	Maximum Likelihood Detection	31
4.2.2	Threshold Detection	32
4.2.3	Symbol Error Probability for Threshold Detection	33

4.3	Maximum A-Posterior Symbol-by-Symbol Detection	36
4.4	Maximum Likelihood Sequence Detection	38
4.4.1	System Model	38
4.4.2	State Space Trellis Diagram	39
4.4.3	Maximum Likelihood Sequence Detection	40
4.4.4	Solution Using the Viterbi Algorithm	42
4.4.5	Viterbi Equalizer	45
	References	45
5	Digital Transmission over Wireless, Time-Variant Channels	47
5.1	Transmission System with Time-Variant Channel	47
5.2	Overall Time-Variant Impulse Response	49
5.3	Overall Delay Spread Function	51
5.4	Overall Doppler Spread Function	52
5.4.1	Fourier Transform of the Overall Delay Spread Function	52
5.4.2	Principal System Model Parameters	54
5.5	Equivalent Time-Variant Baseband System and Receiver Output Signal	57
5.5.1	Equivalent Time-Variant Baseband System	57
5.5.2	Receiver Output Signal	58
6	Basic Parameters of Wireless Channels	63
6.1	Path Loss	63
6.2	Shadowing	64
	References	65
7	Wireless System with Multipath Propagation	67
7.1	Multipath Model of Time-Invariant Channel	67
7.2	Multipath Model of Time-Variant Channel	69
7.2.1	Delay Spread Function of the Time-Variant Multipath Channel	69
7.2.2	Delay Spread Function of the Equivalent Time-Variant Multipath Baseband System	70
7.2.3	Doppler Spread Function of the Equivalent Time-Variant Multipath Baseband System	71
7.2.4	Receiver Output Signal $q_R(t)$	72
7.2.5	Fourier Spectrum $Q_R(f_i)$ of the Receiver Output Signal	72
7.3	Multipath Channel and Mobile Receiver	73
7.3.1	System Model	73
7.3.2	Doppler Shift	74

7.3.3	Delay Spread Function	75
7.3.4	Receiver Output Signal $q_R(t)$ with Doppler Shift	75
7.4	Frequency Selective Fading of Multipath Channel	77
	References	78
8	Statistical Description of Wireless Multipath Channel	81
8.1	Complex Gaussian Multipath Model	81
8.2	Channel Model with Rayleigh Fading	82
8.3	Channel Model with Rician Fading	83
8.4	Channel Model with Nakagami- m Fading	83
8.5	Channel Model of Clarke and Jakes	84
	References	88
 Part II Theory of Linear Time-Variant Systems		
9	Introduction and Some History	91
	References	93
10	System Theoretic Approach for the Impulse Response of Linear Time-Variant Systems	95
10.1	Continuous-Time, Time-Variant Impulse Response	95
10.2	Modified Time-Variant Impulse Response—the Delay Spread Function	96
10.3	Discrete-Time, Time-Variant System	98
10.3.1	Discrete-Time Delay Spread Function	98
10.3.2	Transition to Continuous-Time Delay Spread Function	100
11	Properties of Time-Variant Convolution	103
11.1	Relation Between Time-Variant and Time-Invariant Convolution	103
11.2	Properties	104
11.3	Summary	108
11.4	Examples	110
12	System Functions and Fourier Transform	113
12.1	Time-Variant Transfer Function	113
12.2	Delay Doppler Spread Function	114
12.3	Doppler Spread Function	115
12.4	Spectrum of the Output Signal	115
12.5	Cascades of Time-Variant and Time-Invariant Systems	116
12.5.1	Cascade of Time-Invariant $g_1(\tau)$ and Time-Variant System $g_2(t, \tau)$	116

12.5.2	Cascade of Time-Variant $g_1(t, \tau)$ and Time-Invariant system $g_2(\tau)$	117
12.5.3	Cascade of Two Time-Variant Systems $g_1(t, \tau)$ and $g_2(t, \tau)$	118
12.6	Summary	120
13	Applications	121
14	Interrelation Between Time-Variant and Two-Dimensional Convolution	125
14.1	Input–Output Relation	125
14.2	Fourier Spectrum of the Output Signal	126
15	Randomly Changing Time-Variant Systems	127
15.1	Prerequisites	127
15.2	Correlation Functions of Randomly Changing Time-Variant Systems	128
15.3	Wide Sense Stationary Time-Variant Systems	130
15.3.1	Wide Sense Stationarity	130
15.3.2	Autocorrelation Functions and Power Spectral Densities	130
15.4	Time-Variant Systems with Uncorrelated Scattering	132
15.4.1	Delay Cross Power Spectral Density of $g(t, \tau)$	133
15.4.2	Autocorrelation Function of Time-Variant Transfer Function	133
15.5	Wide Sense Stationary Processes with Uncorrelated Scattering	134
15.5.1	Delay Cross Power Spectral Density of $g(t, \tau)$	134
15.5.2	Doppler Power Spectrum	134
15.5.3	Autocorrelation Function of Time-Variant Transfer Function	134
15.6	Simplified Parameters for Time-Variant Systems	135
15.6.1	Coherence Bandwidth	135
15.6.2	Coherence Time	136
	References	137
 Part III Multiple Input Multiple Output Wireless Transmission		
16	Background	141
	References	142
17	Principles of Multiple Input Multiple Output Transmission	143
17.1	Introduction	143
17.2	MIMO Transmission System with Quadrature Amplitude Modulation	143

- 17.2.1 System Model 143
- 17.2.2 Input–Output Relation of MIMO System with Time-Variant Channel 146
- 17.3 Deterministic Models for Wireless MIMO Channels 148
 - 17.3.1 Uniform Linear and Uniform Circular Antenna Arrays 148
 - 17.3.2 Finite Impulse Response Channel Model 149
 - 17.3.3 Spatial Channel Models 150
 - 17.3.4 Spectral Properties of the Channel Model 150
- 17.4 Statistical Models for MIMO Channels 153
 - 17.4.1 I.I.D. Gaussian MIMO Channel Model 153
 - 17.4.2 Covariance Matrix of the MIMO Channel 154
 - 17.4.3 MIMO Channel Model with Correlation 156
 - 17.4.4 MIMO Channel Model with Transmit and Receive Correlation (Kronecker Model) 158
 - 17.4.5 Exponential Covariance Matrix Model 162
- References 162
- 18 Principles of Linear MIMO Receivers 165**
 - 18.1 Introduction 165
 - 18.2 Operation Modes for MIMO Systems 166
 - 18.3 Zero-Forcing Receiver for Equal Number of Transmit and Receive Antennas 168
 - 18.4 Zero-Forcing Receiver for Unequal Number of Transmit and Receive Antennas 169
 - 18.4.1 Receiver with More Antennas than Transmitter, $N > M$ 169
 - 18.4.2 Receiver with Less Antennas than Transmitter, $N < M$ 174
 - 18.5 Signal-to-Noise Ratio of Linear Receivers 177
 - 18.5.1 Signal-to-Noise Ratio with Zero-Forcing Receiver 178
 - 18.5.2 Normalization of the Channel Matrix H 179
 - 18.6 Minimum Mean Squared Error receiver 181
 - 18.6.1 Prerequisites 181
 - 18.6.2 Receiver Matrix 182
 - 18.7 Linear Combiner for single Input Multiple Output System 185
 - 18.7.1 Principle of Linear Combining and the Signal-to-Noise Ratio 185
 - 18.7.2 MMSE Receiver for SIMO System (Maximum Ratio Combiner) 186
 - 18.7.3 Equal Gain Combiner 188
 - 18.8 Decision of Receiver Output Signal 190
 - References 191

19	Principles of Nonlinear MIMO Receivers	193
19.1	Maximum Likelihood MIMO Receiver	193
19.2	Receiver with Ordered Successive Interference Cancellation	196
19.3	Comparison of Different Receivers	199
	References	201
20	MIMO System Decomposition into Eigenmodes	203
20.1	MIMO System Transformation Using Singular Value Decomposition	203
20.2	Implementation of the MIMO Eigenmode Decomposition	206
21	Channel Capacity of Single-User Transmission Systems	209
21.1	Channel Capacity of SISO System	209
21.1.1	AWGN Channel with Real Signals and Noise	209
21.1.2	AWGN Channel with Complex Signals and Noise	211
21.2	Channel Capacity of MIMO Systems with Statistically Independent Transmit Signals and Noise	213
21.2.1	Prerequisites	213
21.2.2	Instantaneous MIMO Channel Capacity	215
21.2.3	Alternative Formulas for the MIMO Channel Capacity	219
21.3	MIMO Channel Capacity for Correlated Transmit Signals	220
21.4	Channel Capacity for Correlated MIMO Channel	221
21.5	Maximizing MIMO System Capacity Using the Water Filling Algorithm	222
21.5.1	Prefilter for Transmit Power Allocation	222
21.5.2	Computation of the Optimal Power Allocation Coefficients a_i	224
21.5.3	Graphical Interpretation of the Water Filling Solution	227
21.5.4	Iterative Solution and Example	228
21.6	Capacity of a Stochastic MIMO Channel	230
21.6.1	Ergodic Channel Capacity	231
21.6.2	Outage Capacity	231
	References	231
22	MIMO Systems with Precoding	233
22.1	Principle of MIMO Precoding	233
22.2	Zero-Forcing and MMSE Precoding	236
22.2.1	Zero-Forcing Precoder	236
22.2.2	MMSE Precoder	238
22.3	Precoding Based on Singular Value Decomposition	240
22.3.1	SVD-Based Precoder and Receiver	240

22.3.2	Comparison of Zero-Forcing and SVD-Based Precoding	243
References		244
23	Principles of Space-Time Coding	245
23.1	Space-Time Block Coding	245
23.2	Spatial Multiplexing	249
23.3	Orthogonal, Linear Space-Time Block Coding	250
23.3.1	The Alamouti Encoder for MISO System with Two Transmit Antennas	251
23.3.2	The Alamouti Space-Time Encoder for a 2×2 MIMO System	255
23.3.3	Orthogonal Space-Time Block Codes for More Than Two Transmit Antennas	257
23.4	Principle of Space-Time Trellis Coding	260
23.5	Layered Space-Time Architecture	261
23.5.1	Vertical Layered Space-Time Coding	262
23.5.2	Horizontal Layered Space-Time Coding	264
23.5.3	Diagonal Layered Space-Time Coding	265
23.5.4	Iterative Receivers for Layered Space-Time Systems	265
References		266
24	Principles of Multi-user MIMO Transmission	269
24.1	Introduction	269
24.2	Precoding for Multi-user MIMO Downlink Transmission	270
24.2.1	Precoding by “Channel Inversion”	270
24.2.2	Precoding with Block Diagonalization	274
24.2.3	Alternative Multi-user MIMO Precoding	280
24.3	Beamforming for Multi-user Downlink	281
24.4	Principles of Multi-user MIMO Uplink Transmission	286
24.4.1	System Model of the Uplink	286
24.4.2	Receive Signal at the Base Station	287
24.4.3	Zero-Forcing Receiver for Multi-user Uplink Interference Reduction	287
24.5	Outlook: Massive MIMO for Multi-user Applications	289
References		290
	Correction to: Introduction to Digital Communications	E1
	Appendix A: Some Fundamentals of Random Variables and Stochastic Processes	293
	Appendix B: Some Fundamentals of Linear Algebra	313
	Index	327

About the Author

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