Preface

Principles of Mobile Communication, Fourth Edition, like its earlier editions, stresses mathematical modeling of physical layer wireless communication systems. The basic pedagogic methodology is to include fully detailed derivations from the first principles. The textbook is intended to provide enough principle material to guide the novice student, while at the same time having plenty of detailed material to satisfy graduate students inclined to pursue research in the area. The textbook stresses the *principles* of wireless communications that are applicable to a wide array of wireless systems standards. It is intended to serve as a textbook and reference for graduate students and a useful reference for practicing engineers.

Organization of the Book

Chapter 1 begins with an overview that is intended to introduce a broad array of issues relating to wireless communications. Included is a brief description of the evolution of various wireless standards from first-generation cellular standards through emerging fifth-generation cellular standards. Afterwards, the basic concepts of cellular frequency reuse, the land mobile radio propagation environment, link budget, and coverage and capacity of cellular radio systems are discussed at an introductory level.

Chapter 2 provides an extensive treatment of radio propagation, since a good understanding of the physical wireless channel is essential for the development and deployment of wireless systems. The chapter begins with a treatment of the narrowband fading envelope for conventional fixed-to-mobile channels found in cellular radio systems, and mobile-to-mobile channels found in mobile ad hoc networks. After establishing a foundation for understanding narrowband channels, the chapter next treats the statistical characterization of wideband channels. Polarization and depolarization effects are important in wireless systems, the text goes on to discuss the mechanisms and characteristics of channel depolarization. The emulation of wireless channels is essential for the development and testing of wireless systems, and the chapter provides a detailed discussion of multipath-fading channel simulation techniques. Finally, the chapter concludes with a discussion of shadowing and path loss models for land mobile radio environments, including those for small cells, and emerging mm-wave frequencies.

Chapter 3 provides a treatment of co-channel interference which, is the primary impairment in spectrally efficient cellular frequency reuse systems. Very often the receivers in such systems are affected by multiple co-channel interferers. The probability distribution of the total interfering power, and the power sum of noncoherent co-channel interferers are considered in detail. Additionally, something of interest is a certain received signal-to-interference-plus-noise ratio outage threshold performance under various large- and small-scale fading conditions.

Chapter 4 covers the various types of modulation schemes that are used in mobile communication systems along with their spectral characteristics. The chapter begins with the mathematical representation of bandpass modulated signals, along with Nyquist pulse shaping. Afterwards, a large variety of modulation schemes used in wireless systems are considered, including both single-carrier and multi-carrier modulation, and both linear and nonlinear modulation techniques. This is followed by a treatment of the power density spectrum of modulated signals. Although quite mathematical in nature, power spectrum is an important topic, since wireless systems are required to operate within a specified out-of-band emission mask. For this reason, all modulation schemes in Chap. 4 are expressed in terms of a generalized shaping function. The power spectrum is first derived for the generalized shaping function, followed by that of particular modulation schemes.

Chapter 5 discusses the error probability performance of various digital modulation schemes discussed in Chap. 4 on flat fading channels. The performance is evaluated with a variety of receiver structures, including coherent detectors that assume knowledge of the complex channel gain at the receiver and differentially coherent detectors and noncoherent detectors that do not require carrier phase information.

Chapter 6 includes a treatment of multi-antenna techniques. The chapter begins with a discussion of various receiver diversity techniques for coherent, differentially coherent, and noncoherent detection of signals on fading channels corrupted by additive white Gaussian noise. Next, optimal combining is discussed, a technique that is effective when the primary additive impairment is co-channel interference rather than noise. This is followed by a discussion of classical beam forming with uniform linear arrays. The chapter next considers multiple-input multiple-output (MIMO) channels where multiple antennas are used at both the transmitter and receiver to achieve high spectral efficiency. Next, the Alamouti transmit diversity scheme is presented, followed by a brief treatment of MIMO detection. Then, the chapter explores the concept of spatial modulation where a subset (often one) of an array of antenna elements is excited. The chapter concludes with a treatment of massive MIMO, where many base station antennas are used with one or more mobile station antennas.

Chapter 7 considers digital signaling on intersymbol interference (ISI) channels that are typical of land mobile radio systems. The chapter begins with the characterization of ISI channels and goes on to discuss techniques for combating ISI based on time domain symbol-by-symbol equalization and sequence estimation. Afterwards, error probability for maximum likelihood sequence estimation is considered. The chapter concludes with a discussion of co-channel demodulation on ISI channels and considers a receiver for ISI channels that can reject co-channel interference.

Chapter 8 covers error control coding techniques for wireless systems. The chapter begins with a discussion of basic block coding, including space-time block codes. Convolutional coding is considered next along with the Viterbi and BCJR algorithms for decoding convolutional codes, followed by trellis coded modulation. The chapter then provides a detailed discussion on the design and performance analysis of convolutional and trellis codes for AWGN channels, interleaved flat fading channels, and fading ISI channels. Afterwards, space-time trellis codes are treated, and the chapter concludes with Turbo coding.

Chapter 9 is devoted to spread spectrum techniques. The chapter begins with an introduction to direct sequence and frequency hop spread spectrum. This is followed by a detailed treatment of spreading sequences. Also included is a discussion of the effects of tone interference on direct sequence spread spectrum and the RAKE receiver performance on wideband channels. This is followed by a discussion of the error probability of direct sequence code division multiple access (CDMA) with a conventional correlation detector. The chapter wraps up with a discussion of CDMA multiuser detection.

Chapter 10 is devoted to multi-carrier techniques. The chapter first considers the performance of OFDM on frequency-selective channels. The effects of residual intersymbol interference (ISI) due to an insufficient guard interval are considered, followed by a remedy. Afterwards, the chapter examines single-carrier frequency domain equalization (SC-FDE) techniques. This is followed by a treatment of orthogonal frequency division multiple access (OFDMA) on both forward, and reverse links. The chapter concludes with a discussion of single-carrier frequency division multiple access (SC-FDMA).

Chapter 11 considers frequency planning techniques for cellular systems. The chapter begins with a discussion of cell sectoring, cell splitting, and reuse partitioning. Afterwards, the chapter considers radio planning for OFDMA cellular systems. This is followed by a detailed treatment of hierarchical overlay/underlay architectures based on cluster planning. Finally, the chapter wraps up with macrodiversity TDMA cellular architectures.

Chapter 12 considers CDMA cellular systems, considering topics such as capacity and power control. This is followed by a discussion of hierarchical macrodiversity CDMA architectures and their performance. Such systems allow, for example, the signals that are received at multiple base stations to be forwarded to a central point for coherent combining, rather than simple selection diversity.

Chapter 13 is devoted to cellular radio resource management. The chapter begins with an introduction to basic hard and soft handoff. Afterwards, the chapter considers the important problem of link quality evaluation, including signal strength averaging, velocity estimation, and velocity adaptive handoff algorithms. Afterwards, a detailed analysis of hard and soft handoff is provided. Finally, the chapter wraps up with methods for estimating the received carrier-to-interference-plus-noise ratio (CINR), which is an important quantity in many types of wireless systems.

Chapter 14 considers channel assignment techniques. This chapter first discusses basic channel assignment techniques and then presents the details of some channel assignment techniques including centralized and decentralized dynamic channel assignment.

Appendix A is a brief and focused tutorial discussion of probability and random processes. A good understanding of the material in Appendix A is essential, since the concepts are widely used throughout the textbook.

Using This Book for Instruction

The book has been developed from a graduate-level course on physical wireless communications that I have taught at Georgia Tech since 1993. The book contains more material than can be taught in a one-semester course. My own preference is to cover material in Chaps. 1 through 6, followed by other material as time permits. Some adjustments will have to be made to account for course prerequisites or the lack thereof.

Acknowledgments

I would like to acknowledge all those who have contributed to the preparation of this book and its earlier editions. The reviewers Prof. Vijay Bhargava, Dr. Sanjiv Nanda, Prof. Upamanyu Madhow, and Prof. Keith Chugg were highly useful for improving the first edition of this book. Prof. Mohsen Kaverhad provided good suggestions for the fourth edition. I am grateful to my doctoral students, past and present, who have contributed to this book through their thesis research. The technical contributions of Wern-Ho Sheen, Khalid Hamied, Mark Austin, Jeff (Lihbor) Yiin, Ming-Ju Ho, Li-Chun (Robert) Wang, Krishna Narayanan, Dukhyun Kim, Jinsoup Joung, John (Yongchae) Kim, Alenka Zajić, and Seok-Chul Kwon are greatly appreciated.

Atlanta, GA, USA
May 2017

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http://www.springer.com/978-3-319-55614-7

Principles of Mobile Communication

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2017, XXII, 717 p. 409 illus., 7 illus. in color., Hardcover
ISBN: 978-3-319-55614-7