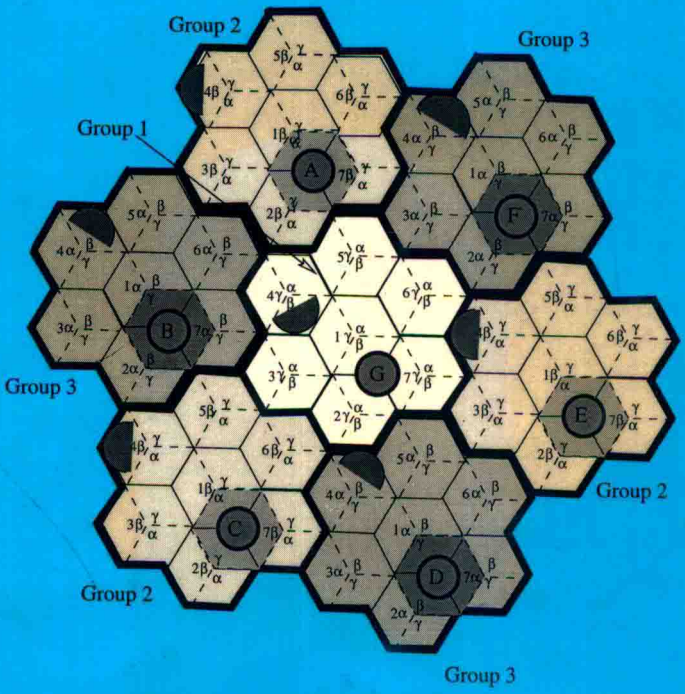
Principles of

MOBILE COMMUNICATION

Second Edition



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Preface

This book follows from my first edition and is intended to provide a thorough, up to date, treatment of wireless physical communications. The book is derived from a compilation of course material that I have taught in a graduate-level course on physical wireless communications at Georgia Tech over the past decade. This textbook differs from others on the subject by stressing mathematical modeling and analysis. My approach is to include detailed derivations from first principles. The text is intended to provide enough background material for the novice student enrolled in a graduate level course, while having enough advanced material to prime the more serious graduate students that would like to pursue research in the area. The book is intended to stress the *fundamentals* of mobile communications engineering that are important to *any* mobile communication system. I have therefore kept the description of existing and proposed wireless standards and systems to a minimum. The emphasis on fundamental issues should benefit not only to students taking formal instruction, but also practicing engineers who are likely to already have a detailed familiarity with the standards and are seeking to deepen their knowledge of the fundamentals and principles of this important field.

Chapter 1 begins with an overview that is intended to introduce a broad array of issues relating to wireless communications. Included is a description of various wireless systems and services, basic concepts of cellular frequency reuse, and the link budget for cellular radio systems.

Chapter 2 treats propagation modeling and was inspired by the excellent reference by Jakes. It begins with a summary of propagation models for narrow-band and wide-band multipath channels, and provides a discussion of channel simulation techniques that are useful for radio link analysis. It concludes with a discussion of shadowing and path loss models. Chapter 3 is a related chapter that provides a detailed treatment of co-channel interference, the primary impairment in high capacity cellular systems.

Chapter 4 covers the various types of modulation schemes that are used in mobile communication systems along with their spectral characteristics. Chapter 5 discusses the performance of digital signal on narrow-band flat fading channels with a variety of receiver structures, while Chapter 6 includes a treatment of antenna diversity techniques.

Chapter 7 provides an extensive treatment of digital signaling on the fading ISI channels that are typical of mid-band land mobile radio systems. The chapter begins with the characterization of ISI channels and goes on to discuss techniques for combating ISI based on symbol-by-symbol equalization and sequence estimation. The chapter concludes with a discussion of co-channel demodulation and co-channel interference cancellation.

Chapter 8 covers bandwidth efficient coding techniques. The chapter begins with a discussion of basic block and convolutional coding. It then goes on to a detailed discussion on the design and performance analysis of convolutional and trellis codes for additive white Gaussian noise channels, and interleaved flat fading channels. The chapter concludes with an introduction to 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 wide-band channels. The chapter wraps up with a discussion of the error probability of direct sequence code division multiple access.

Chapter 10 considers TDMA cellular architectures. The chapter begins with a discussion of conventional TDMA systems and how they are evolved to meet traffic growth. This is followed by hierarchical overlay/underlay architectures. Finally, the chapter wraps up with macrodiversity TDMA architectures. Chapter 11 is the CDMA counterpart to Chapter 10 and considers issues that are relevant to cellular CDMA, such as capacity estimation and power control.

Chapter 10 covers the important problem of link quality evaluation and handoff initiation, and handoff performance, in cellular systems. Chapter 11 provides an overview of the various channel assignment techniques that have been proposed for FDMA and TDMA cellular systems.

The book contains far too much detail to be taught in a one-semester course. However, I believe that it can serve as a suitable text in most situations through the appropriate selection of material. My own preference for a one-semester course is to include the following in order: Chapter 1, Chapter 2, Sections 3.1 and 3.2, Chapter 4, Chapter 5, and Chapter 6. Then choose from Chapters 8 through 13 depending on my interest at the time.

I would like to acknowledge all those who have contributed to the preparation of this book. The reviewers Vijay Bhargava at the University of Victoria and Sanjiv Nanda at Lucent Technologies were very valuable in the early

stages of the first edition of this book. The subsequent review by Upamanyu Madhow at the University of Illinois and in particular the detailed review by Keith Chugg at the University of Southern California were highly useful for improving this book. I am grateful to my doctoral students, past and present, who have contributed significantly to this book. The 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, and John (Yongchae) Kim are particularly noteworthy. Finally, I would like to thank BellSouth, GTE Labs, Motorola, Panasonic, Hitachi, Nortel, Korea Telecom, WiLAN, and the National Science Foundation, for sustaining my research efforts in wireless communications over the past 10 years. This research experience has in many cases lead to material that I brought to the classroom and have included in this book.

GORDON L. STÜBER

To my parents
Beatrice and Lothar Stüber

Contents

Chapter 1

INTRODUCTION

Wireless systems and services have undergone a remarkable development, since the first cellular and cordless telephone systems were introduced in the early 1980s. First generation cellular and cordless telephone systems were based on analog FM technology and designed to carry narrow-band circuit switched voice services. Second generation cellular and cordless telephone systems were introduced in the early 1990s that use digital modulation, and offer improved spectral efficiency, and voice quality. However, these second generation systems are still used for narrow-band voice and data services. Third generation wireless systems, currently under development that offer substantially higher bit rates ranging from 9.6 kb/s for satellite users, 144 kb/s for vehicular users, 384 kb/s for pedestrian users to 2.048 Mb/s for indoor office environments. These systems are intended to provide voice, data, the more bandwidth intensive multimedia services, while satisfying more stringent availability and quality of service (QoS) requirements in all types environments. Fourth generation systems are also on the horizon that will provide broadband wireless access with asymmetric bit rates that approach 1 Gb/s.

Radio access systems are often distinguished by their coverage areas and bit rates, as shown in Fig. 1.1. **Mobile satellite** systems provide global coverage to mobile users, but with very low bit rates. **Land mobile radio systems** use terrestrial cellular and microcellular networks to provide wide area coverage to vehicular and pedestrian users. **Fixed wireless** access systems provide radio connectivity over a campus or neighborhood area to stationary users. Finally, **wireless local area networks** provide stationary in-building users with very high speed services.