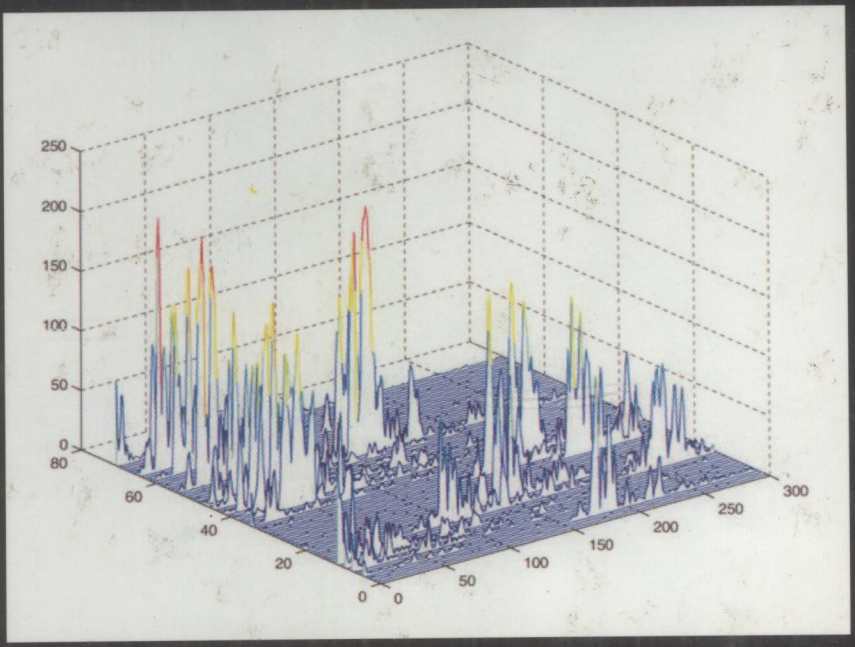
Wireless Communications Theory and Techniques



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WIRELESS COMMUNICATIONS
Theory and Techniques

by

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DEDICATION

This book is dedicated to my wife Parveen, my children Farhana, Fahim and Samia. It would have been impossible to write this book unless my family had not forgone their claim on the time they deserved.

Preface

Wireless communication systems, since their inception in the form of cellular communications, have spread rapidly throughout the western world and the trend is catching on in the developing countries as well. These systems have caused revolutionary changes in the way we live. Cellular Communications have become important both as means of communication and as a new domain of commercial enterprise. Hand held telephones are now rapidly replacing the fixed telephone and in less than twenty years, the number of subscribers has reached nearly three quarters of a billion. In a short span of twenty years, the cellular communications progressed from the first generation to the third generation systems, which started operations in Japan on October 1, 2001. The first generation wireless technology, which was thought to be obsolete is now being used for fixed wired telephony in several countries of Asia, Africa and Latin America. As some commentator said in 1983, the cellular system is the best thing that has happened in telecommunications since the introduction of computers to the masses.

This book is written to provide readers with the fundamental concepts of wireless communications. It is intended for a graduate course on wireless communications but it could be easily adopted at the senior level by skipping material involving difficult mathematical manipulations. The text does not go through the rigorous material on mathematical treatment of electromagnetic waves and propagation, rather it emphasizes more on the practical aspects of this. Besides providing some fundamental concepts, the text goes into discussions on implications of these principles on the wireless system design.

The book is divided into three parts. Following the introductory chapter on the overview of wireless communications, Chapters 2 and 3 examine the arduous radio signal environment in which mobile communications has to provide the subscriber with reliable telecommunication services. The second chapter reviews the basic radio wave propagation theory with a view to predict signal strength at any point within and beyond the radio coverage area of a transmitter. This is termed macro (large scale) characterization of mobile radio channels. The starting point is a theoretical model accurate only under ideal conditions, e.g., a planar perfectly conducting surface surrounding the transmitter. Modifications are then introduced to account for the effects of terrain variation on signal strength. Methods are presented for the prediction

of mean signal strength for a given transmitter-receiver geometry. Chapter 3 proceeds with a study of the micro (small scale) structure of signal variations caused primarily by scatterers in the immediate vicinity of the mobile unit. The starting point is the channel impulse response. The length and variability of the impulse response characterizes channel delay spread, fading and path strengths. In practice, vehicle movement causes rapid variations about a mean, and deep fades will be encountered, which preclude reliable communications over the channel unless sophisticated signal processing methods are used.

The second part of this book consists of five chapters that consider methods of transmission, reception, and processing of signals, which had been affected by the harsh propagation conditions. Chapter 4 examines signal transmission and reception techniques. The main emphasis in this chapter is on performance analysis under fading and frequency selective conditions. The performance of several digital modulation systems are examined under the above mentioned conditions. Interference in wireless communications has a very significant impact on the performance, quality of service and system capacity. It is a major cause of inefficiencies in spectrum utilization. Chapter 5 goes into considerable depth of interference, distortion and noise. Interference, modeling, signal outage because of channel impairments are the main topics of discussion. The impact of interference and channel fading on frequency reuse and receiver performance is analyzed.

Antennas are essential part of any wireless communications. Chapter 6 describes the various types of antennas and their characteristics. Again rigorous mathematical treatment is avoided. The chapter considers methods whereby a suitable antenna system can be employed to combat fading and substantially enhance performance. It is seen that fading can severely degrade the performance of various modulation schemes. This theme is followed up in Chapter 7 in the context of signal processing. Multiple signals distinguished, for example, by frequency, space, time or carrier polarization can be combined to minimize the effect of fading. The impact of diversity on the signal restoration is emphasized. The role of equalization, coding and interleaving in improving the performance is discussed in this chapter. Multiple access communications is introduced in Chapter 8. It discusses the methods of using spectrum resource in the multi-user environment. In this chapter, analyses on the impact of access schemes on the system capacity are presented. This chapter sets the scene for the requirements on multiuser communications introduced in the third part of the book. Conventional and multichannel trunked systems in addition to modern cellular systems are introduced.

The third part of the book consists of six chapters mostly on system aspects. This part of the book does not have solved examples or problems.

Chapter 9 introduces the principles of several wireless systems. It describes, paging, private land mobile systems and gives a brief account of wireless systems. The chapter takes a broader perspective, dealing with details on the implementation of systems operating in the mobile wireless environment. A closely related topic, treated in Chapter 10, is that of Private Mobile Data Communications Systems (PMDCS) such as packet switched radio, and voice-data integrated systems. An important application of packet switched radio is the mobile data distribution network, which has both civilian and military applications. Other applications include transportation, public safety, ambulance, and wireless local area networks (WLANS) and high speed wireless networks using ATM technology. Chapter 11 outlines the principles of designing cellular systems. It makes distinction between designing a TDMA and CDMA systems. Principles of mobile wireless systems; frequency assignment, control architecture, vehicle location and handoff are included in the discussion.

The details on several mobile communications systems in operation are explored in Chapter 12. In particular, the first two generations of cellular systems are described. These include AMPS, GSM, and CDMA. The new emerging applications in telecommunications is steering wireless communications towards multimedia wireless communications. In Chapter 13, five new standards for 3G are described. However, WCDMA (IMT-DS) is described in some detail. Chapter 14 examines a logical extension of the cellular network concept, that is systems beyond 3G. The chapter presents a window into the future by speculating on the shape of the future networks. This chapter also looks at technologies suitable for the wideband 4G systems.

I would like to acknowledge the contributions made by several of my present and former colleagues who encouraged me into writing the book. In particular, I would like to thank Professor J.S. Riordon who agreed to co-author this book. Unfortunately, he could not continue because of his heavy commitments to the administration and later due to my departure from Carleton University, Ottawa, Canada. However, his contributions at the start of this project are much appreciated. My thanks also go to Mohammad Abdullah Bugshan who persuaded Lucent Technologies in creating the Chair in Telecommunications that I currently hold. I would like to acknowledge the support of King Fahd University of Petroleum and Minerals in providing research facilities and reducing my teaching load to facilitate completion of this project. I should not forget to thank my students who kept me on toes by asking interesting questions and insisting on seeing the book in print.

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Dhahran, Saudi Arabia
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