



universal personal communications

**Uma Shanker Jha  
Ramjee Prasad**

# **OFDM**

**TOWARDS FIXED AND MOBILE  
BROADBAND WIRELESS ACCESS**

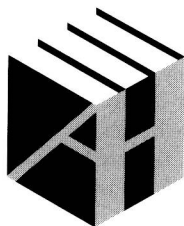
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# OFDM Towards Fixed and Mobile Broadband Wireless Access

Uma Shanker Jha  
Ramjee Prasad



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# **OFDM Towards Fixed and Mobile Broadband Wireless Access**

For a complete listing of the  
*Artech House Universal Personal Communications Series*,  
turn to the back of this book.

*To my wife Mamta and our sons Abhisek and Sachin*  
—Uma Shanker Jha

*To my wife Jyoti, our daughter Neeli, our sons Anand and Rajeev,  
our granddaughters, Sneha and Ruchika, and our grandson Akash*  
—Ramjee Prasad

## Preface

नियतं सङ्गरहितमरागद्वेषतः कृतम् ।  
अफलप्रेप्सुना कर्म यत्तत्सात्त्विकमुच्यते ॥

*niyatam sanga-rahitam araga-dvesatah kritam  
aphala-prepsuna karma yat tat sattvikam ucyate*

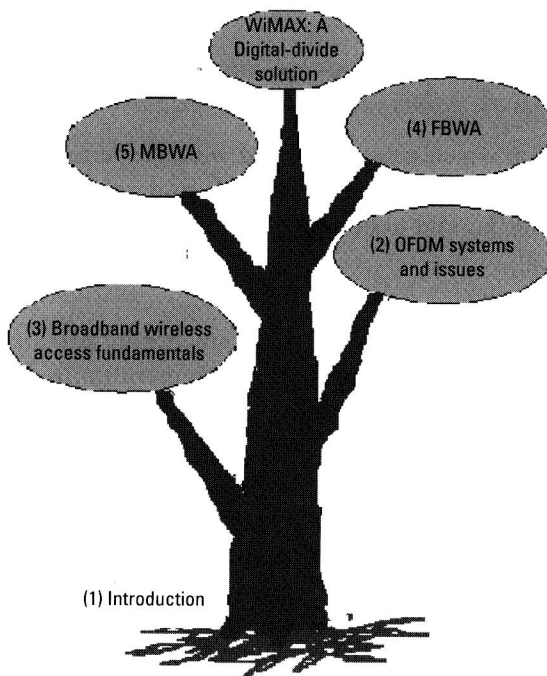
“That action which is regulated and which is performed without attachment, without love or hatred, and without desire for fruitive results is said to be in the mode of goodness.”

—*The Bhagavad-Gita* (18.23)

Broadband wireless access (BWA) requirements are driving the next generation wireless systems and gaining a lot momentum in the industry and academia alike. The next generation of wireless systems will be built to provide mobile Internet access. Although users and practitioners may have differing views about its capabilities and features, the majority of them nonetheless agree that orthogonal frequency division multiplexing (OFDM) will be the air interface of choice for next generation broadband wireless systems.

This book tackles both OFDM system fundamentals and issues including the essential features of the IEEE 802.16 family of standards. BWA technologies are increasingly coming into existence and thus knowledge about this topic is of utmost importance to the wireless community. We have realized that the standards bodies that set the standards for these systems generally produce documents that consist of hundreds and hundreds of pages, which are time consuming to read and to understand to say the least. The purpose of this book is to provide information about the topic in a simple manner, all at one point, by summarizing the key aspects of the BWA standard specified by IEEE 802.16 standards organization.

Figure P.1 details the organization of this book. This book provides a great deal of insight into the IEEE 802.16 standard. Although the term *worldwide interoperability for microwave access* (WiMAX) has become



**Figure P.1** Coverage of this book.



synonymous with the IEEE 802.16 standard, in fact WiMAX only looks into the end-to-end interoperability aspects and certification of products built on their specific profiles. The IEEE 802.16 committee specifies the physical and media access control layers but does not deal with the end-to-end systems' requirements and interoperability criteria of systems built on these requirements. The WiMAX consortium was organized to fill this void and to address two connectivity modes, namely, fixed broadband wireless access (FBWA) and mobile broadband wireless access (MBWA) for interoperability and certification purposes. These two modes are dealt with separately in this book. The OFDM technique is the fundamental building block of the IEEE 802.16 standards. Therefore, a separate chapter is devoted to OFDM and its variants. This book is the first of its kind to provide a simple physical layer and medium access control layer delineation of the standard. It is not our intent to provide substantial details about the standard, but to instead cover the salient features and to provide a basic understanding of the standard.

Completing this book gives us a sense of immense pleasure. We have tried our level best to make each chapter quite complete in itself. The purpose of this book is to provide supplemental reading material to young research students, engineers, undergraduate, graduate, and post-graduate students or anyone else who is interested in the development and deployment of next generation broadband wireless access systems.

As is often said, "Nothing is perfect"—which is true for this book as well in that we cannot claim that this book is error free. Any feedback to improve the content and correctness of the material would be highly appreciated.

## **Acknowledgments**

We would like to convey our heartfelt appreciation to Junko and Shradha without whom this book would have never been completed. They gave their support in preparing the typewritten version of the book.

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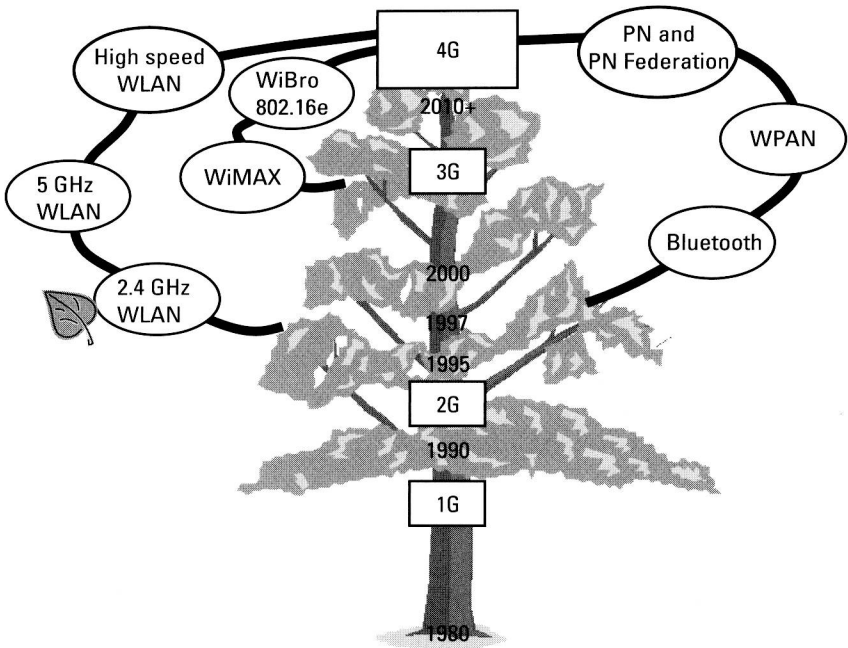
# 1

## Introduction

Since the day Guglielmo Marconi demonstrated the ability of radio to provide instant communication, new wireless communication methods have been evolving [1]. People throughout the world are passionately accepting the new wireless communication methods and services. There has been rapid growth in the field of wireless communications in the past two decades, fueled by the need to be always connected, anywhere and anytime. Large-scale deployment of affordable, easy-to-use radio communication networks have given consumers the ability to be in continuous contact. Mobile communication has gone through generations of evolution to bring enhanced and value-added features and services to consumers. Second generation (2G), 2.5G, and third generation (3G) standards of mobile systems are being deployed while efforts are ongoing toward the development and standardization of beyond 3G (B3G) systems and, ultimately, to the much talked about fourth generation (4G) [2]. Figure 1.1 illustrates how the progress toward the next generation in communication technology, 4G, can be perceived as a tree with many branches.

2G services have been used predominantly for voice communications. Although 3G provides data services efficiently at lower cost, it lacks the capabilities to provide broadband real-time services with the required





**Figure 1.1** The progress tree for communication technology. (From: [3]. © 2006 Artech House, Inc. Reprinted with permission.)

quality of service (QoS) to support simultaneous voice, data, and multimedia services to a large group of subscribers. The global demand for multimedia data services has grown at a remarkable pace, which has led to the expansion of system capacity in terms of the number of subscribers supported, higher data rate, and ubiquitous coverage with high mobility. Thus, it is an important consideration for both equipment manufacturers and service providers [4] to attract customers and collect healthy return on investments. Figure 1.2 shows how the technology has progressed from 2G cellular systems toward existing ones and how this in a natural way leads toward fulfilling the ever-increasing demands of the consumers and service providers and, thus, to next generation [5].

Broadband wireless access systems can provide multimedia services to large numbers of customers and thus have evolved as the solution for the persistent demand for enhancement in multimedia data services.