Hamed Al-Raweshidy Shozo Komaki editors

# Radio over Fiber Technologies

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To the memory of my late brother Rashid, and to Father and Mother, and all of my family who have helped me complete this book

—H. Al-Raweshidy

#### **Preface**

He said that there was one only good, namely, knowledge; and one only evil, namely, ignorance.

—Diogenes Laërtius, Socrates

With the development of the third generation of mobile communications, IMT 2000, radio over fiber technology will play a significant role in solving problems facing this technology. Envisioning a global village, people could transmit and receive "any time, anywhere, and anything." In addition, the explosive growth in Internet applications, such as the World Wide Web, demonstrates the tremendous increase in bandwidth and low power that the coming world of multimedia interactive applications will require from future networks. Radio over fiber systems have many advantages such as enhanced microcellular coverage, higher capacity, lower cost, lower power, and easier installation. Therefore, radio over fiber technology is the most suitable candidate for indoor applications such as airport terminals, shopping centers, and large offices, in addition to outdoor applications such as those underground, tunnels, narrow streets (i.e., dead zone areas), and highways.

The next generation of cellular mobile phone systems will make extensive use of microcells. This will permit a large increase in the numbers of users and will also allow a significant increase in the available channel bandwidth, so that broadband services can be offered, in addition to the voiceband services offered with current systems. The introduction of large numbers of microcells will result in the need to interconnect huge numbers

of cells and microcells, and this can be carried out effectively using optical fiber, which offers a high transmission capacity at low cost. The transmission of radio signals over fiber, with simple optical-to-electrical conversion, followed by radiation at remote antennas, which are connected to a central station, has been proposed as a method of minimizing costs. The reduction in cost is brought about in two ways. First, the remote antenna or radio distribution point needs to perform only simple functions, and it is small in size and low in cost. Second, the resources provided by the central stations can be shared among many antenna sites. This technique of modulating the RF subcarrier onto an optical carrier for distribution over a fiber network is known as radio over fiber (RoF) technology. In addition to the advantages of potential low cost, RoF technology has the further benefit that transferring the RF frequency allocation to a central station can allow flexible network channel allocation and rapid response to variations in traffic demand.

It is very clear that the synergy of wireless and optical fiber communications is an important issue, taking into consideration future requirements for the fourth generation, such as software radio and intelligent networks, in which RoF technology will play a significant role through its macrodiversity.

This book provides a comprehensive introduction to RoF technology. It provides the technical background necessary to understand how RoF systems are designed, starting from components and system requirements and ending with analysis and applications. It also provides a proposal for a simulation model for a RoF system in third generation (3G) and fourth generation (4G).

Chapter 1 of this book introduces various aspects of components, such as laser diode behavior, losses, and noise with comprehensive analysis.

Chapter 2 describes and presents results on single-mode fiber optic transmission of microwave QAM signals, and how to improve system performance. In addition, theoretical and some experimental bit error rate performance results are described for two types of 256-QAM signals.

Chapter 3 introduces the optical fiber link in mobile communication systems. The chapter starts with a system-level analysis and continues with considerations about requirements for cellular base station remote antenna links. We then show that these requirements can be fulfilled with direct, intensity-modulated analog optical fiber links. A comparison of conventional coaxial links and optical fiber links, considering technical as well as economical aspects, and hybrid fiber/coaxial solutions, are also presented in this chapter.

Chapter 4 covers the UMTS RoF and the 4G RoF such as HiperLAN2. This chapter suggests an integrated RoF simulation model and discusses

some benefits of RoF systems, such as macrodiversity. A full analysis for UMTS/WCDMA performance and voice activities is also presented.

In Chapter 5, RoF for in-building coverage is described, and the use of RoF for cellular in-building distributed antenna systems. It examines the problems associated with these issues and assesses the competing technologies and architectures that can be used. Both current and emerging RoF technologies are included.

Fiber optic radio networking and radio highways are discussed in Chapter 6. This includes software radio principles, with three main classifications: software radio terminals, software radio base stations, and software radio networks. In addition, various types of link configuration and photonic multiplexing schemes, such as SCMA, photonic FDMA or WDMA, photonic TDMA, photonic CDMA, and chirp multiple transform access and routing methods, are also discussed.

Chapter 7 explains the historical aspects of this technology's development and the evolution of key factors in more recent applications, such as that used by Tekmar Sisterni in the 2000 Olympics in Sydney, and also Bluewater by Tekmar. The different scenarios for RoF market issues are also discussed in this chapter.

Finally, the applications of RoF in intelligent transport systems and multiple service wireless systems based on RoF, such as CATV and fixative, are discussed in Chapter 8.

This book is intended for everyone involved in the field of mobile communications, optical fiber technologies, and internal and outdoor coverage. It provides treatment of the subject matter at different levels for system designers, researchers, managers, and graduate students. The majority of chapters provide both a general review for the beginner and a more thorough approach for the reader interested in technical details. The views expressed in this book are from both academia and industries in Europe, Japan, and the United States.

The contributors have tried their best to make each chapter quite self-contained. We hope that this book will help to stimulate many new research avenues and solutions for future mobile data communications problems.

We cannot claim that this book is errorless. Any remarks to improve the readability and to correct any errors would be highly appreciated.

#### **Acknowledgments**

The material in this book originates from several research institutes in Europe, Japan, and the United States, and I would like to thank all the contributors of this book.

I would like to thank everyone in my group, especially Habib Ali, Ammar Daher, Nazim Khashjori, Stephen Ampem, Kamiran Haider, Adrin Sivarajah, Mudar Barry, Maswood Jahromi, and Haider Ali, for their kind help on this book.

Hamed Al-Raweshidy Kent, England February 2002

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