

Preface

This book provides an overview of the designs of energy and bandwidth-efficient or spectrum-efficient modulation and transmission for wireless cellular and Wireless Local Area Network (WLAN) systems, and focuses especially on system-on-chip (SoC) architecture that integrates all-digital, analog/mixed-signal, and often radio-frequency functions on a single chip substrate. Because of the unique aspects of the SoC architecture, the properties of energy efficiency (EE) and spectrum efficiency (SE) are two high-priority targets in these system designs and highly depend on the modulation scheme that is chosen and the operation region where a power amplifier runs. Trade-offs between EE and SE due to their contradictory nature, however, should be made depending on the specific modulation scheme and actual transmission system.

As demand has grown for high-data-rate applications in wireless networks, energy consumption in wireless communications has recently drawn increasing scientific and industrial attention. Energy-efficient solutions to reducing energy consumption in order to achieve significant reductions in the amount of carbon dioxide emissions in wireless radio communications are classified under the rubric Green Radio. To enhance energy-efficient utilization in wireless communications, different Green Radio programs across the world aim at investigating and creating innovative techniques for the reduction of the total energy used to operate radio access networks and to identify appropriate radio architectures that enable such power reduction.

In the early years of digital satellite communication (i.e., the-1980s and 1990s), energy and bandwidth-efficient modulation techniques and schemes were studied and developed in applications for digital satellite earth station systems in which voice and data transmissions in digital form were supported. Overlapped pulse-shaping modulation formats, such as raised-cosine pulse shaping or other doubled-symbol interval pulse-shaping methods were proposed and developed for these earth station systems so that on-board power amplifiers could operate in saturated or close to saturated regions to achieve high energy efficiency. These overlapped pulse-shaping modulation schemes have an advantage over Nyquist-type-

signaling-based modulation formats in achieving higher energy efficiency because of their smaller envelope fluctuations; meanwhile they also have satisfactory spectrum efficiency. When further modifications were applied to the existing overlapped pulse-shaping modulation schemes in 2000s, the most representative modulation format, called Feher-patented quadrature phase shift keying (FQPSK), showed a good trade-off between energy and spectrum efficiency and lead to its application to deep-space communications.

After the launch of the 802.11a WLAN standard using 52-subcarrier orthogonal frequency division multiplexing (OFDM) format signaling in 1999 and the adoption of OFDM technology as the core technology of 4G in 2010 because of its anti-multipath-fading characteristics and high spectrum efficiency, achieving energy efficiency (EE) becomes more difficult. Improving the EE usually involves running the power amplifier in a saturated or close to saturated region, which is a great challenge for most transmitters used in the 802.11 WLAN systems and the 4G cellular communication systems due to large Peak-to-Average Power Ratio (PAPR) of the OFDM signaling. The trade-off between energy efficiency and spectrum efficiency for OFDM signals becomes particularly important and can be achieved by using a number of techniques and methods described in this book.

In 2002, I changed my career focus from traditional digital communication fields, where I had worked for a decade on included satellite/earth station and microwave systems, to the newly developed personal digital communication field, which mainly focuses on 2G/3G cellular and 802.11b/g/a WLAN communication systems implemented with SoC architectures, where I have worked until now. Since then, I have been involved with many new system concepts and circuit block implementations that are different from what I had learned from textbooks or classes in colleges and what I had experienced with traditional digital communication systems. These new concepts, architectures, and hardware implementations covered in cellular and WLAN communication systems initially motivated me to write a technique book and to share my design experiences with readers who are interested in these practical system design concepts.

The book primarily covers some major energy and bandwidth-efficient modulation and transmission techniques with applications to cellular and the 802.11 WLAN systems. For either constant envelope modulation or nearly constant envelope modulation formats, the transmitter can operate in a saturated region to achieve high energy efficiency. For non-constant envelope modulation schemes with large peak-to-average power ratio (PAPR) values, on the other hand, the power amplifier employing a pre-distortion technique is capable of operating close to a saturated region to improve energy efficiency. A variety of fundamental and practical topics associated with the SoC architectures, from communication system design concepts to baseband signal-processing algorithms and trade-offs are introduced in the book. These topics and some design examples are drawn from projects and products I previously designed or was involved with.

This book is aimed at recently graduated college students with electrical-engineering related backgrounds and practicing engineers who may be new to digital modulations and digital transmission systems, but already have a general

broad knowledge of some digital communication system concepts. Especially for those readers who wish to learn and understand the system concepts and circuit block designs of RF IC systems, the book provides a variety of design examples and practical topics with analysis graphics to assist them for easily understanding these contents. After reading this book, the reader should have gained a strong system-level overview of various wireless systems associated with SoC-based implementations, and should understand the advantages and disadvantages that particular modulation techniques and certain system architectures have.

I would like to acknowledge my previous colleagues at the Communication Division of Harris Corp. and Via Communication Corp. where we worked together to make great contributions to many microwave modem products, 2G/3G cellular and Wi-Fi transceiver chips. I would also like to thank Broadcom for giving me a chance to contribute to and support their cellular and Wi-Fi transceiver chips and their applications.

Finally, I wish to express my great gratitude to my parents for their lifelong love and constant encouragement; my wife, Lutong, for her endless love, tolerance, and support during the long journey of writing the book; and my son, Will, for his feedback and opinions as a first reader of the manuscript during his last year pursuing his master's degree in Electrical and Computer Engineering.

Milpitas, CA
June, 2016

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Energy and Bandwidth-Efficient Wireless Transmission

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2017, XXIII, 485 p. 268 illus., 55 illus. in color.,

Hardcover

ISBN: 978-3-319-44220-4