Chapter 23
Aspects of OFDM-Based 3G LTE Terminal Implementation

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ABSTRACT

3GPP standardized an evolved UTRAN (E-UTRAN) within the release 8 Long Term Evolution (LTE) project. Targets include higher spectral efficiency, lower latency, and higher peak data rate in comparison with previous 3GPP air interfaces. The E-UTRAN air interface is based on OFDMA and MIMO in downlink and on SCFDMA in uplink. Main challenges for a terminal implementation include an efficient realization of fast and precise synchronization, MIMO channel estimation and equalization, and a turbo decoder for data rates of up to 75 Mbps per spatial MIMO stream. In this study, the authors outline the current 3GPP LTE standard and highlight some implementation details of an LTE terminal. Efficient sample algorithms are presented for key components in the baseband signal processing including synchronization, cell search, channel estimation and equalization, and turbo channel decoder. Their performances, computational and memory requirements, and relevant implementation challenges are discussed.

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1. INTRODUCTION

The mobile radio network technology family of the 3GPP (3rd Generation Partnership Project) as well as its predecessor ETSI (European Telecommunications Standards Institute), including GSM/EDGE (Global System for Mobile communications/Enhanced Data rate for GSM Evolution) and UMTS/HSPA (Universal Mobile Telecommunication System/High Speed Packet Access) technologies, now accounts for nearly 90% of all mobile subscribers worldwide. The further increasing demand on high data rates in new applications such as mobile TV, online gaming, multimedia streaming, etc., has motivated the 3GPP to work on the long term evolution (LTE) project since late 2004. Overall target was to select and specify technology that would keep 3GPP's technologies at the forefront of mobile wireless well into the next decade.

Key objectives of the 3GPP LTE, whose radio access is called Evolved UMTS Terrestrial Radio Access Network (E-UTRAN), include substantially improved end-user throughputs, sector capacity, reduced user plane latency, significantly improved user experience with full mobility, simplified lower-cost network and reduced User Equipment (UE) complexity. Currently, first 3GPP LTE specification is being finalized within 3GPP release 8. Specifically, the physical layer has become quite stable recently for a first implementation.

The air interface of E-UTRAN is based on OFDMA (Orthogonal Frequency Division Multiple Access) and MIMO (Multiple-Input Multiple Output) in downlink (DL) and on SCFDMA (Single Carrier Frequency Division Multiple Access) in uplink (UL) direction. Main challenges for a terminal implementation include efficient realization of the synchronization, channel estimation and equalization, and the turbo decoding algorithms. We show that for quick and robust synchronization and cell search, algorithms based on auto- and cross-correlation provide the best performance-complexity trade-off. Although the inner receiver processing, mainly channel estimation and equalization, can nicely and straightforwardly be parallelized due to frequency domain processing, careful algorithm design is required to achieve low complexity and high performance. Due to the high data rate of up to 75 Mbps per spatial MIMO stream, the turbo decoder design demands a special consideration. In addition, flexibility for different MIMO modes, low power consumption and small silicon area need to be taken into account in the implementation of most of the core algorithms (Berkmann, Carbonelli, Dietrich, Drewes & Xu, 2008).

This chapter is structured as follows: In section 2, we first give an overview on the 3GPP LTE system and its evolution to LTE-advanced, especially the physical layer. Then in the following sections, according to the functional signal flow, efficient sample algorithms for key components in the baseband signal processing are presented. The computational and memory requirements for the example implementations are evaluated, and the challenges are highlighted. Specifically, section 3 deals with LTE-relevant synchronization and cell search, including symbol timing and identification, frame timing and cell identification based on the primary and secondary synchronization signals. In section 4, channel estimation based on the LTE reference signals is described. The algorithm used is the 2x 1-dimentional Wiener filtering In section 5, different equalization algorithms such as the linear MMSE, and the non-linear M-algorithm, the tree search based fixed sphere decoder (FSD) and parallel smart candidate adding (PSCA) algorithm are compared. The LTE-specific turbo coding and decoding algorithm including the newly specified turbo interleaver, and its implementation, are discussed in section 6. Finally, some concluding remarks are given in section 7.