Chapter 1

Introduction

In recent decades of years, communication technologies have been developed rapidly. The first-generation (1G) radio systems transmit voice over radio by using analog communication techniques, such as Advanced Mobile Phone Services (AMPS), which were developed in the 1970s and 1980s. The 2G systems were built in the 1980s and 1990s, and featured the adoption of digital technology, such as Global System for Mobile Communications (GSM), Digital-AMPS (D-AMPS), and code division multiple access (CDMA); among them GSM is the most successful and widely used 2G system. 3G mobile technologies provide users with high-data-rate mobile access, which developed rapidly in the 1990s and is still developing today. The major radio air interface standard for 3G is wideband CDMA (WCDMA), whose transmission data rate can be up to 2 Mb/s in good conditions. However, there are some limitations with 3G, such as the difficulty in extending to very high data rates due to excessive interference between services, and the difficulty in providing multi-rate services with different quality of service (QoS) due to the restrictions imposed on the core network by the air interference standard. Therefore, the future mobile communication system having the features of high-data-rate transmission and open network architecture, called 4G, is desired to meet the increasing demand for broadband wireless access. In fact, the combination of multiple-input multiple-output (MIMO) signal processing with orthogonal frequency division multiplexing (OFDM) has been regarded as a promising solution for enhancing the data rates of next-generation wireless communication systems [1].

OFDM has become a popular technique for transmission of signals over wireless channels, and its most well known advantage is the capability of converting a frequency-selective channel into a parallel collection of frequency flat sub-channels, which makes the receiver simpler. Therefore, OFDM has been adopted in several wireless standards such as digital audio broadcasting (DAB), terrestrial digital video broadcasting (DVB-T), the IEEE 802.11a/g wireless local area network (WLAN) standard, and the IEEE 802.16-2004 standard. These show its potential of being a candidate for future-generation (4G) mobile wireless systems.

MIMO techniques are also popular recently; it can basically be categorized into two groups. The first one aims to improve the power efficiency and transmission reliability by maximizing spatial diversity; one popular example is the space-time block codes (STBC) [2]. The second type uses a layered approach to increase capacity; one popular example of such a system is the vertical-Bell Laboratories layered space-time (V-BLAST) architecture [3], in where independent data signals are transmitted over antennas to increase the data rate. Moreover, there is still another hybrid structure of STBC and BLAST system, called group wise STBC (G-STBC) [4][5], which the transmit antennas are partitioned into several groups, and each group applies Alamouti STBC. Thus, G-STBC can be viewed as a tradeoff between the consideration of throughput and reliability, and we note that the scheme exists only when there are more than four transmit antennas since at least two Alamouti STBC structures have to be applied. In order to obtain the best overall performance in a changing environment, we need to adopt the most suitable techniques at all time. In a MIMO system, the channel condition can be evaluated by some characteristics of the MIMO channel, such as the condition number. Therefore, we can further develop a mechanism for mode selection to ensure that the most suitable scheme is chosen for the present environment.

The goal of this thesis is to realize an adaptive 4×4 MIMO-OFDM system on FPGA and DSP, where we intend to verify the above-mentioned space-time algorithms. The complete functional blocks in both the transmitter and receiver are provided, and the associated algorithms applied in each functional block are also presented. The reason that we adopt four antenna pairs is mainly for the compatibility of three MIMO modes, including STBC, V-BLAST, and especially G-STBC. The actual MIMO mode can be adaptively selected to suit the MIMO channel condition through some feedback channel information from the receiver. After giving an overview of system architecture, we propose a total solution to build up a fast prototyping platform for realizing the adaptive 4×4 MIMO-OFDM system. The developed system contains a baseband transmitter, a digital-analog converter, an analog-digital converter, and a baseband receiver. The baseband transceiver is realized by a Universal Serial Bus (USB) module, a Digital Signal Process (DSP) module, and a Field Programmable Gate Array (FPGA) module. USB mainly provides the interface between the fast-prototyping platform and personal computers (PC); DSP can perform various algorithms we develop and is flexible and capable of reprogramming instantaneously; FPGA is a programmable logic component, which can be used to verify the algorithms we develop by some hardware description languages. By partitioning the whole tasks on those modules separately, we can realize the adaptive 4×4 MIMO-OFDM system on the platform. Moreover, some useful experiences during realization will be provided, which serve as a good guidance for those who want to build up an analogous system; they include the preliminary system-level evaluation, hardware partition, implementation tips on either FPGA or DSP, and a good, realistic example during implementation.

The organization of this thesis is as follows. Chapter 2 describes the proposed MIMO OFDM transceiver architecture and its corresponding schemes. In Chapter 3, the development environment of the proposed fast prototyping system is introduced. In Chapter 4, the overall system realization is presented, and the performance evaluation is also included. Later, some useful experiences are provided in Chapter 5. Finally, we make our concluding remarks in Chapter 6.