Chapter 1

Introduction

Mobile communication systems have become a large importance for everyone in our society, which can be observed by the worldwide use of mobile phones for voice communication. New services like video streaming and web browsing will require large data rates for future systems and applications.

Therefore the objective of this thesis is to contribute with new modules or techniques for broadband wireless networks based on the Orthogonal Frequency Division Multiplexing (OFDM) transmission technique, Multiple Input Multiple Output (MIMO) antenna systems and Spatial Time Block Codes (STBCs) modulation schemes. For achieving this purpose a deep study of related wireless systems was carried out. Also the wireless channel was studied, considering different available models and channel estimation techniques usually used in this kind of systems. Several techniques, extremely important for wireless broadband communication systems have been also considered.

The thesis content considers systems with extremely high data rate and Bandwidth Efficiency (BE). Therefore a system with multiple transmit and multiple receive antennas (MIMO) is analyzed. To increase the data rate performance, Amplitude and Phase Shift Keying (APSK) modulation techniques will be considered instead of pure PSK schemes. Due to the radio channel and the multipath propagation inside the radio channel, the OFDM transmission technique will be used. The particular good performance of OFDM systems in multipath fading environments was one important reason for this decision. Once the combination MIMO-OFDM between transmission and antenna systems was selected, the next step was to cope with the complexity of channel estimation in MIMO systems. Due to the computation complexity of all radio channel estimation procedures a differential modulation technique was considered. Then it was proposed to study a new Differential Space Time Block Code (DSTBC) technique, which offers very good performance at high BE, keeping the system complexity at low level.

1.1 Wireless System Model

Here the basic wireless scheme considered in this thesis is introduced. It is well known that wireless communication systems have a large range of different applications, they are present in Personal Area Network (PAN), where the distances between transmitter (Tx) and receiver (Rx) are only few meters and also in satellite systems, where the distances are tens of thousands km. But basically, the majority of them can be described in some way similar to the block diagram shown in Fig. 1.1.

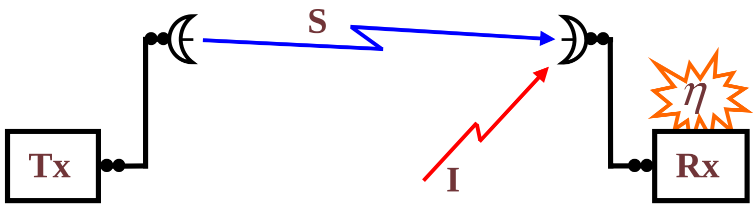

Figure 1.1: Scheme of a wireless system.

In this figure, several of the main components of a general wireless system can be seen. Tx, is the transmitter device, commonly each telecommunication device has integrated one or several transmitters and receivers. A single transmitter (Tx) is connected in this case to a single receiver (Rx).

Tx takes the data to transmit and applies over them a number of procedures in order to improve the transmission quality over the corresponding radio channel. For example in a wireless system some typical modules are the channel encoder, the interleaver, the modulator, and the amplifier.

Connectors, cables and antennas are very important topics in wireless systems, but their analysis is out of the scope of this thesis. In particular a good knowledge of antenna parameters is extremely important for a good radio link design. Antenna design is one very active research topic and the variety of existent devices is incredibly big, going from very small patch antennas to antennas of tens of meters (as the ones used in radio astronomy) [1].

The *radio channel* is probably the main challenge in wireless system design and specially in mobile wireless systems, because of its great variations with time and frequency. Due to these variations, special techniques have to be used, in other case the performance will not be acceptable. Several channel models are presented in Chapter 2. In this thesis the frequency bands Ultra High Frequency (UHF) (0.3-3 GHz) and Super High Frequency (SHF) (3-30 GHz) are mainly considered.

The *receiver* processes the received signal coping with the *noise* (η) and the *interference* (I) if it exists. Basically the Rx performs the reverse operations of those made in the Tx. S in Fig. 1.1 represents the signal (message) sent from the transmitter to the receiver.

In the following chapters, the elements presented here will be analyzed in more detail.

1.2 Contributions and Structure of this Thesis

Several possible new techniques for broadband wireless systems have been studied and rigorously tested. One new approach for the use of DSTBC systems was considered and a new class of DSTBCs was proposed. The performance and the robustness of this technique is very good, among the best reported up to now -as far as the author knows- and it is still quite simple to be implemented (see Section 7.1). The performance of this technique was verified over different channel models, showing always an excellent performance and system robustness. Then a possible improvement was proposed (see Section 7.2.1). When the proposed technique was tested in WSSUS channels, it was found that the relative improvement (relative to some previously published techniques) is increased, when the mobile terminal velocity is increased. Later the increment of spatial diversity by increasing the number of receive antennas has been considered. In this case, a technique equivalent to Maximum Ratio Combining in coherent systems, was developed for DSTBCs. Finally the performance of the proposed technique in a channel coded system was evaluated.

This thesis is structured into 9 chapters as follows:

Chapter 1. In this chapter the main goals and the description of the considered wireless system model were introduced.

Chapter 2. Wireless channel concepts and models are discussed in this chapter. It is essential because the wireless channel is probably the most important challenge to cope with in wireless systems. In particular the *AWGN*, *uncorrelated Rayleigh fading* and *WSSUS* channel models used for analyzing the proposed technique are presented.

Chapter 3. OFDM, the transmission technique behind the most successful Wi-Fi and WiMAX standards, is the area where the contributions of this thesis were focused. OFDM is a particularly promising technique due to robust behavior in frequency selective channels. In this chapter a description of the technique and its models is presented.

Chapter 4. An analysis of different channel estimation techniques is presented in this chapter. Normally this is the way to cope with wireless channels when coherent demodulation schemes are used. This chapter makes a review of some well known channel estimation techniques and their complexities; also allows to appreciate the saved complexity by using differential modulation schemes, where channel estimation is not necessary.

Chapter 5. Usually the wireless channel is so variable, that only by being very flexible and well adapted to the channel conditions, the best performance that they allow can be achieved. For this reason this chapter is dedicated to the analysis of some well known techniques as link adaptation and diversity. The proposed technique is a space diversity technique, kind of diversity careful explained in this chapter. The other presented techniques allow a comparison of advantages, disadvantages and also of complexity level.

Chapter 6. Multiple Input Multiple Output (MIMO) systems allow a very important improvement of performance by exploiting space diversity. Some aspects of MIMO techniques are discussed in this chapter in order to show the potential of these techniques, which is shared by the proposed technique.

Chapter 7. The DSTBCs are presented and also a new class of them is proposed, which is the main contribution of this thesis. In this chapter is explained and evaluated in a detailed way the proposed technique.

Chapter 8. In this chapter the convolutional channel coding technique is described and later used to evaluate the proposed technique in a channel coded system.

Chapter 9, Summary and Conclusions. Here the main contributions of this work are summarized and discussed.