Abstract

"Analysis and Implementation of Equalization Methods for MIMO systems in Frequency Domain"

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Introduction

The demand for capacity in cellular and wireless local area networks has grown very fast during the last decade. For example, the need for wireless Internet access and the use of multimedia applications require an increase in information throughput with orders of magnitude compared to the data rates made available by today's technology. The data rates in wireless local area networks are bounded due to some issues, like wide area cover, possible receiver movement and the allowable frequency range. One major technological breakthrough that will make this increase in data rate possible is the use of multi antenna systems.

The multi antenna systems can be defined like a wireless communication system, in which the transmitter and receiver have many antennas (Multiple Input Multiple Output - MIMO). The basic idea of MIMO systems is that the signals which being transmitted and received from several antennas, are combined in such a way to improve the link quality, or equivalently the bit error rate (BER). The basic feature of MIMO systems is that they convert the main disadvantage of wireless systems, the multipath fading, in a main advantage for the system. The study of MIMO systems begun quite recently and it has been proven that they can provide high capacity in wireless systems. The use of MIMO systems is the latest development in current communication research, and their practical implementation is in a pilot stage.

Case Study

In simple SISO (Single Input - Single Output) channels, channel equalization is one of the receiver operations, which is a proper process of the received signal in order to eliminate the Intersymbol Interferance (ISI). The equalization procedure has the same importance in the case of MIMO systems. The case study of this diploma is the analysis and implementation of equalizers, which range from the optimal case of Maximum Likehood receivers to practical equalizers based on DFE techique, like V-BLAST.

The last techique can be proved very attractive due to its simplicity. For a V-BLAST MIMO system, the transmiter antennas are sending independed coded data sequencies at the same frequency band. The receiver detects the symbols successively, and the order of detection can optimize the system efficiency. It is known that the frequency domain processing has advantage against the time domain processing. With simulations we compare different algorithms and we conclude that these advantages carry on for the case of V-BLAST architecture.

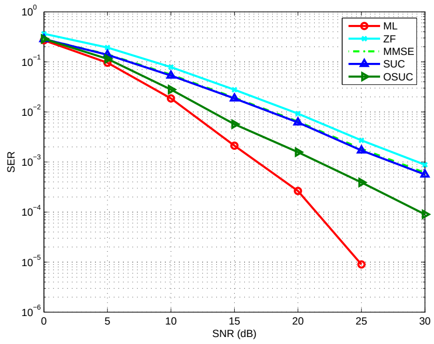

Figure 1: Comparison of the SER performance for a 2×2 MIMO system. Simulations use 4-QAM modulation, for 1000 channel realizations.

Flat Channel Equalizers

We study some equilazation methods which apply at frequency flat channel, extending them for multiple antenna MIMO systems. We analyze the optimum receiver based on Maximum Likehood techique, since that receiver gives the minimum error probability. However, ML method has high computational complexity, so the method is not much effective in cases with long packets or many channel coefficients. Also, we analyze suboptimal linear receivers with ZF and MMSE architectures, as well as suboptimal nonlinear receivers with SUC and V-BLAST architectures.

In figure 1, we compare the analyzed methods for the case of a 2×2 MIMO system. It can be observed that V-BLAST outperforms the other methods, except of course the optimum ML receiver. We note that the realized V-BLAST method is based on MMSE criterion. The performance of SUC method is near the performance of MMSE method, which emphasizes the importance of stream ordering before cancellation. As expected, the worst performance is observed by ZF method.

Frequency Selective Channel Equalizers

In order to extend the analysis for the case of frequency selective channels, there are two known methods. The first one uses the OFDM architecture, which is a multicarrier technique, while the second one uses DFE architecture and is a single carrier techique. For each one we study two subcases. For the first method we analyze OFDM-MMSE method, which is a linear equalization method and applies at each individual frequency, and OFDM-VBLAST, which uses successive detection and cancellation techique. For the second method we analyze DFE-MIMO method, which is the extension of the simple DFE equalization method for MIMO systems, and DFE-

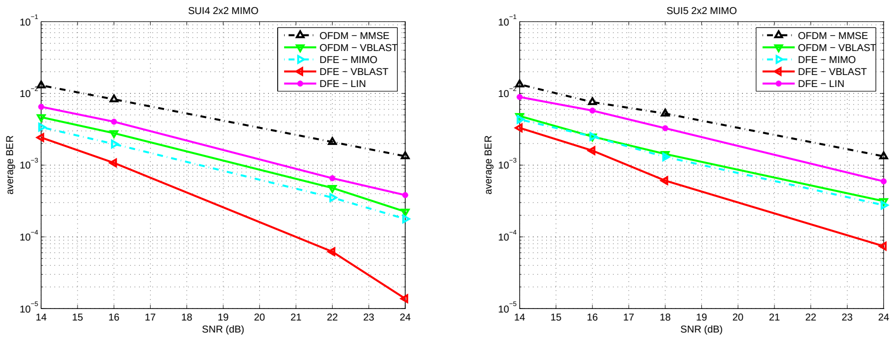

Figure 2: Comparison of the BER for a 2×2 MIMO system with SUI-4 channel (left) and SUI-5 channel (right)

VBLAST, which uses also successive detection and cancellation methods.

For the analysis of error rate we use two channel models, SUI-4 and SUI-5. These models represent the generated channel from omnidirectional antennas. In figure 2 left, we depict the error rate for a 2×2 MIMO system with SUI-4 channel. We conclude that DFE methods outerperform OFDM methods. The BER curve of OFDM-VBLAST method lies very close to the curve of DFE-MIMO method, due to successive detection and cancellation method which the former uses.

In figure 2 right we demonstrate BER curves for the case of a SUI-5 channel. Also OFDM-VBLAST lies close to DFE-MIMO method and much higher than DFE-VBLAST method. For mean BER equal to 10^{-3}, DFE-VBLAST is 2 dB better than DFE-MIMO and OFDM-VBLAST methods.

Conclusion

Our main interest was focused at receivers which apply the multi layer equilization methods based on V-BLAST. These methods successively detect and cancel each stream in an ordered way. In the case of flat channels, we conclude that V-BLAST methods are superior to the other equalization methods, like MMSE and ZF, due to their better approximation of Maximum Likehood optimum detection.

In the case of frequency selective channels, we realized multi layered receivers for the uncoded OFDM architecture and for the DFE architecture. From the results of simulations we conclude that DFE architecture outperforms the other methods, especially when used with V-BLAST technics. However, the linear DFE equalizer showed a slightly worse performance than the multi layerd OFDM method with successive cancellations. In general, OFDM methods have worse performance than DFE methods but they are characterized by simplicity in implementation and low computational complexity. One reason for low performace is the transmittion of uncoded sequences of data, while in the opposite case OFDM methods will have a much better performace.

We conclude that, DFE methods while are much complex, are characterized by high performance and low error rates, and that fact makes them more suitable for high data rate telecommunication systems.