An Extensive Review on MIMO-OFDM: Maximum Diversity Using Maximum Likelihood Detector

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Abstract - In this modern age of high speed wireless data communication, the rapid growth of mobile telephone use, satellite services, and now the wireless Internet and WLANs are generating tremendous changes in telecommunication and networking. As indoor wireless communications become more prevalent, modeling indoor radio wave propagation in populated environments is a topic of significant interest. Multiple input multiple output orthogonal frequency division multiplexing (MIMO-OFDM) schemes have recently drawn wide interests due to their capability of high data rate transmission over multipath fading channels. This research work introduces the study of multi- user and multi-antenna MIMO-OFDM systems.

Keywords: MIMO-OFDM; channel estimation; multipath propagation; MMSE; diversity; spatial multiplexing; space time coding.

I. INTRODUCTION

OFDM is a very popular multi carrier modulation cum multiplexing technique for transmission of signals over wireless fading channels. It converts a frequency selective fading channel into a collection of flat parallel fading sub channels, which mostly simplifies the structure of the receiver. Even though the signal spectra related to different subcarriers overlap in frequency domain but the time domain wave form of the subcarriers are orthogonal. So that the available bandwidth is used efficiently in OFDM systems without the inter carrier interference. OFDM systems can provide a high data rate with long symbol duration by mixing up multiple low data rate sub carriers with long symbol duration. That helps to avoid the inter symbol interference (ISI), which occurs along with signals of a short symbol duration in a multipath channel of MIMO OFDM communication system. Here are listing some major merits of the scheme as follows.

Merits of OFDM systems are:

- Spectral efficiency is high.
- Fast Fourier transform (FFT) implementation makes less complex.
- Complexity is very low at the receiver.

Though the developments of OFDM technology, there are two considerable contributions to OFDM which transform the original “analog” multicarrier system to todays digitally implemented OFDM. For the implementation of OFDM systems the use of Discrete Fourier Transform (DFT) decreased to perform baseband modulation and demodulation which was eliminated the banks of coherent demodulators and sub carrier oscillators required by frequency division multiplexing. DFT based frequency division multiplexing can be fully implemented in digital baseband. FFT for highly efficient processing, a fast algorithm for computing DFT, can even further reduce the number of arithmetic operations to $NlogN$ from N^2.

In a classical parallel-data system, the total signal frequency band is divided into N non-overlapping frequency sub-channels. Each sub-channel is modulated with a separate symbol, and then the N sub-channels are frequency multiplexed. It seems good to avoid spectral overlap of channels to eliminate inter-channel interference. However, this leads to inefficient use of the available spectrum. Hence, go for OFDM.

A multicarrier communication system with orthogonal sub-carriers is called Orthogonal Frequency Division Multiplex (OFDM) system. The word “orthogonal” indicates that there is a precise mathematical relationship between the frequencies of the carriers in the system. The basic principle of OFDM is to split a high-data-rate sequence into a number of low-rate sequences that are transmitted simultaneously over a number of subcarriers. Because the symbol duration is increased for the low rate parallel subcarriers, the relative amount of dispersion in time caused by multipath delay spread is decreased. Inter-symbol interference (ISI) is eliminated almost completely by introducing a guard interval at the start of each OFDM symbol. In the guard interval, a OFDM symbol is cyclically extended to avoid Inter-carrier interference (ICI). Thus, a highly frequency selective channel is transformed into a large set of individual flat fading, non-frequency selective, narrowband channels. An integrated circuit implementation of a discrete Fourier transform removes the need for the entire bank of separate transmitters and receivers.

A guard interval can be used in between consecutive symbols and the raised cosine windowing in the time domain to combat the ISI and the ICI. But over a time dispersive channel the system could not maintain perfect orthogonality between subcarriers. This problem was tackled with the use of cyclic prefix (CP) or cyclic extension. Here they replaced the guard interval with a cyclic extension of the OFDM symbol. The ISI can be eliminated totally if the length of cyclic extension is longer than impulse response of the channel. Further, this scheme well simulates a channel performing cyclic convolution which ensures the orthogonality between subcarriers over a time dispersive channel. The principle of OFDM system is to divide a single high data rate bit stream into a number of lower data rate bit streams those are transmitted over narrower sub channels simultaneously.

Multi-User MIMO-OFDM Communication System

The multi-user MIMO-OFDM system has great potential of providing enormous capacity due to its integrated space-frequency diversity and multi-user diversity. Assuming knowledge of the channel state information (CSI) at the transmitter, significant performance gain can be obtained by efficiently adjusting each user's transmission power and rate on different subcarriers.

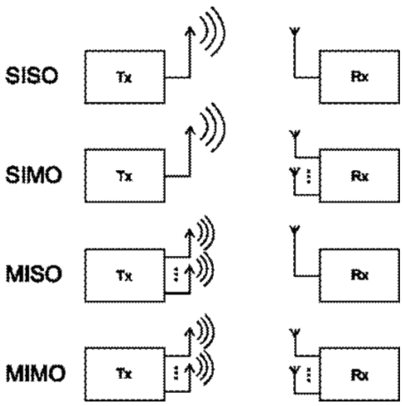

Figure 1 Transformation of SISO systems to MIMO System

Many multiplexing techniques like TDMA, FDMA, and SDMA are used to transmit data from Multiple User through channel in case of MIMO-OFDM wireless communication systems. Multiuser MIMO systems are largely unexplored. Making progress in the area of multiuser MIMO systems is of key importance to the development of practical systems that exploit MIMO gains on the system level also. The recently launched EU FP6 STREP Multiple-Access Space-Time Coding Testbed (MASCOT) is aimed at developing, analyzing, and implementing (in hardware) concepts and techniques for multiuser MIMO communications. Specific areas of relevance in the context of multiuser MIMO systems include multiple-access schemes, transceiver design and space-frequency code design. In particular, the variable amount of collision-based framework for multiple accesses needs to be further developed to account for the presence of out-of-cell interference and to allow for variable amounts of collision in space, time, and frequency.

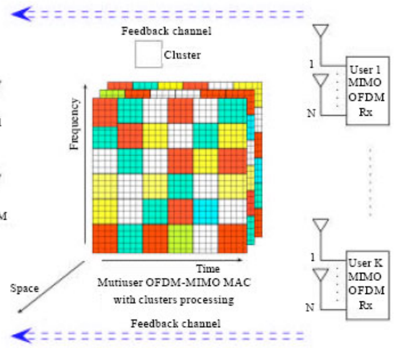

Figure 2 Block Diagram for Multi-User MIMO-OFDM System

II. LITERATURE SURVEY

A. A. Sahrab and I. Marghescu,[1] Multiple-Input Multiple-Output (MIMO) systems offer considerable increase in data throughput and link range without additional bandwidth or transmit power by using several antennas at transmitter and receiver to improve wireless communication system performance. At the same time, Orthogonal Frequency Division Multiplexing (OFDM) has becoming a very popular multi-carrier modulation technique for transmission of signals over wireless channels. OFDM eliminate Inter-Symbol-Interference (ISI) and allows the bandwidth of subcarriers to overlap without Inter Carrier Interference (ICI). A MIMO-OFDM modulation technique can achieve reliable high data rate transmission over broadband wireless channels. This paper deals with the analysis of a MIMO-OFDM system by using a MATLAB program. The performance of the system is evaluated on the basis of Bit Error Rate (BER) and Minimum Mean Square Error (MMSE) level.

J. Xuehua and C. Peijiang, [2] Based on the analysis of the technical principles and the system model of the MIMO and OFDM technologies, a simple MIMO-OFDM wireless communication system is constructed. The system is composed of transmitter, channel, receiver, and so on. Space-time coding is done in the transmitter, the signal is launched after OFDM modulation, and the process of the receiver is the inverse process of the transmitter. The system performance is simulated by using the software Matlab, the experiment result shows that the MIMO-OFDM wireless communication system has better performance when there are more antennas. But, with the increase of the carrier number, the system performance will reduce because of the interference between sub-carriers.

Bara'u Gafai Najashi and Tan Xiaoheng [3] Multiple-Input Multiple-Output systems (MIMO) were regarded as one of the most promising technologies in field of wireless communication. Generally considered as one of the several forms of smart antenna technology, it offers considerable increase in data throughput and link range without additional bandwidth or transmit power. The general idea involves the use of several antennas at the transmitter and the receiver to improve system performance. One of the approaches employed in combating ISI in MIMO transmission was through the use of equalizers. Approach: In this study a proposed MIMO system was simulated using MATLAB software. The different equalization schemes Zero Forcing (ZF) equalizer and Minimum Mean Square Error (MMSE) which aid in the elimination of Inter Symbol Interference (ISI) thus improving overall performance were compared to analyze the BER of the designed system.

Abhishek Sharma, and Anil Garg, [4] With the increasing demand of various multimedia applications, it becomes necessary to enhance the capacity of system without need of expansion in spectrum. The system combines the MIMO system and the OFDM system together, space-time coding is done in the transmitter firstly, the signal is launched after BPSK modulated, and the process of the receiver is the inverse process of the transmitter. The paper compares Alamouti Space time coding with Maximal Ratio Combining. The Bit Error Rate is calculated using software MATLAB for varying Signal to Noise Ratio, the experimental result shows that the MIMO-OFDM wireless communication system has better performance when Alamouti space time coding technique is used for transmit diversity.

Table 1: Summary of Literature Review

Sr. No.	TITLE	AUTHORS	YEAR	METHODOLOGY
1	MIMO-OFDM: Maximum diversity using maximum likelihood detector	A. A. Sahrab and I. Marghescu	2014	MIMO systems offer considerable increase in data throughput and link range without additional bandwidth or transmit power by using several antennas at transmitter and receiver to improve wireless communication system performance.
2	Study and Implementation of MIMO-OFDM System Based on Matlab	J. Xuehua and C. Peijiang	2009	A simple MIMO-OFDM wireless communication system is constructed. The system is composed of transmitter, channel, receiver, and so on.
3	A Comparative Performance Analysis of Multiple-Input Multiple-Output using MATLAB with Zero Forcing and Minimum Mean Square Error Equalizers	Bara'u Gafai Najashi, and Tan Xiaoheng	2011	Generally considered as one of the several forms of smart antenna technology, it offers considerable increase in data throughput and link range without additional bandwidth or transmit power.
4	BER Analysis Based on Transmit and Recieve Diversity Techniques in MIMO-OFDM System	Abhishek Sharma, and Anil Garg	March 2012	Compares Alamouti Space time coding with Maximal Ratio Combining.
5	Implementation of a MIMO OFDM-based wireless LAN system	A. van Zelst and T. C. W. Schenk	Feb. 2004	The OFDM-based wireless local area network (WLAN) standard IEEE 802.11a is considered.

A. van Zelst and T. C. W. Schenk, [5] The combination of multiple-input multiple-output (MIMO) signal processing with orthogonal frequency division multiplexing (OFDM) is regarded as a promising solution for enhancing the data rates of next-generation wireless communication systems operating in frequency-selective fading environments. To realize this extension of OFDM with MIMO, a number of changes are required in the baseband signal processing. An overview is given of the necessary changes, including time and frequency synchronization, channel estimation, synchronization tracking, and MIMO detection. As a test case, the OFDM-based wireless local area network (WLAN) standard IEEE 802.11a is considered, but the results are applicable more generally. The complete MIMO OFDM processing is implemented in a system with three transmit and three receive antennas, and its performance is evaluated with both simulations and experimental test results. Results from measurements with this MIMO OFDM system in a typical office environment show, on average, a doubling of the system throughput, compared with a single antenna OFDM system. An average expected tripling of the throughput was most likely not achieved due to coupling between the transmitter and receiver branches.

Bhanu, and Lavish Kansal, [6]A multiple-input multiple-output (MIMO) communication system combined with the orthogonal frequency division multiplexing (OFDM) modulation technique can achieve reliable high data rate transmission over broadband wireless channels. Channel state information for both single-input single-output (SISO) and MIMO systems based on pilot aided arrangement is investigated in this paper. The estimation of channel at pilot frequencies with conventional Least Square (LS) and Minimum Mean Square (MMSE) estimation algorithms is carried out through Matlab simulation. The performance of MIMO OFDM and SISO OFDM are evaluated on the basis of Bit Error Rate (BER) and Mean Square Error (MSE) level. Further enhancement of performance can be achieved through maximum diversity Space Time Block Coding (STBC) and Maximum Likelihood Detection at transmission and reception ends respectively. MMSE estimation has been shown to perform much better than LS but is more complex than LS for the MIMO system using pilot carriers.

III. PROBLEM IDENTIFICATION

The performance of MIMO-OFDM communication systems is evaluated on the basis of BER and using MMSE (aids in the elimination of ISI thus improving overall performance) level with Alamouti and SM algorithms. It was shown that further enhancement of performance can be achieved through maximum diversity STBC, SFBC and ML Detection at transmission and reception ends respectively. The modulation type (BPSK, QPSK, 16QAM, and 64QAM) are clearly affecting the performance. In the case of AWGN channel the performance of single carrier and OFDM systems are comparable but the overall performance of the second one is higher having in mind that the OFDM systems achieve a higher capacity, coverage and reliability. In a future paper we shall discuss the results obtained in case of a multipath channel changing other parameters like: the number of transmit and/or receive antennas, transmit and receive antennas correlation coefficient and Ricean K factor, using other space time coding techniques, etc.

IV. CONCLUSION

OFDM (Orthogonal Frequency Division Multiplexing) is becoming a very popular multi-carrier modulation technique for transmission of signals over wireless channels. OFDM divides the high-rate stream into parallel lower rate data and hence prolongs the symbol duration, thus helping to eliminate Inter Symbol Interference (ISI). It also allows the bandwidth of subcarriers to overlap without Inter Carrier Interference (ICI) as long as the modulated carriers are orthogonal. OFDM therefore is considered as an efficient modulation technique for broadband access in a very dispersive environment. In this new information age, high data rate and strong reliability in wire-less communication systems are becoming the dominant factors for a successful exploitation of commercial networks. MIMO-OFDM (multiple input multiple output orthogonal frequency division multiplexing), a new wireless broadband technology, has gained great popularity for its capability of high rate transmission and its robustness against multi-path fading and other channel impairments.

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