A Review on the Successive Interference Cancellation Performance of MIMO OFDM Systems

*Subhash Patel

**Praveen Patidar

***A. C. Tiwari

ABSTRACT

Wireless communication is one of the most demanding areas of the communication. It is the transfer of the information between two points that are not physically connected. Quality of this transmission depends upon the number of errors at the receiver. There must be minimum number of errors. These errors are caused by interference between transmitted data. So Interference Cancellation(IC) technology is essential for wireless communication. There are various types of Interference Cancellation(IC) but the most preferably used technology is Successive Interference Cancellation (SIC). It provides minimum Bit Error Rate and also reduces overall computational complexity at the receiver Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing (MIMO OFDM) systems increases capacity of link to a great extent. Minimum Mean Square Error (MMSE) equalizer with Successive Interference Cancellation reduces complexity as well as errors.

In this paper we present a review on performance of Minimum Mean Square Error Successive Interference Cancellation (MMSE SIC) for different single antenna and multiple antenna Orthogonal Frequency Division Multiplexing systems. We will study which antenna configuration provides minimum Bit Error Rate (BER).

Key words- MIMO, OFDM, Equalizer, SIC, MMSE, BER, ISI, Fading.

*Subhash Patel, M. Tech. student, Department of ECE, Lakshmi Narain College Of Technology, Indore, subhpatel83@gmail.com

**Praveen Patidar, Assistant Professor, Department of ECE, Lakshmi Narain College Of Technology, Indore, pravinkpatidar@gmail.com

***A. C. Tiwari, HOD, Department of ECE, Lakshmi Narain College Of Technology, Indore, achandra0@gmail.com

INTRODUCTION:

Orthogonal Frequency Division Multiplexing (OFDM) has the most promise as a future high data rate wireless communication system due to its advantage of high bit rate transmission over a frequency selective fading channel [2]. Also it provides minimum errors and mitigates Inter symbol Interference (ISI). The main reasons for the OFDM popularity are (a) the achievement of a high data rate performance due to the provision of spectral efficiency in comparison to prior modulation schemes, such as Code Division Multiple Access (CDMA) and (b) the efficient adaptation to the frequency selectivity of the channel, due to the orthogonality principle [1]. Also the quality of service is an important parameter of communication. In OFDM interference at the receiver causes signal to be distorted and increases errors. More than any other single effect, interference can lead to quite catastrophic results at a typical OFDM receiver [3], [4].So interference cancellation (IC) technology plays an important role here.

IC can be divided in two types- Pre IC and Post IC. Pre IC techniques are applied on the transmitter side. Some examples are Selective Mapping (SLM) and Dirty Paper Coding (DPC) [9] [5]. These techniques are applicable when interference amount at the receiver is known and there must be proper Channel State Information (CSI). Although exact CST is difficult to measure, these techniques are no longer useful. Post IC techniques are applied on the receiver side. They can be defined as the class of techniques that decode desired information and then use this information along with channel estimates to cancel a fraction of the received interference from the overall received signal [3], [6], [7]. They are divided in two types:- Parallel Interference Cancellation (PIC) and Successive Interference Cancellation (SIC).

In the PIC all the users are detected simultaneously at a time. So this technique requires a large amount of concentration. Furthermore, PIC requires precious hardware gear in order to operate in parallel, which makes it unprofitable for numerous practical implementations [8] [3].

SIC operates by detecting all the users successively. Therefore it is more practical approach. If one user is decoded, then its effect from aggregate received signal is eliminated before next user is decoded. This process is repeated until all the users are decoded. If we want to decode the user with highest Signal to Noise Ratio (SNR) first, this is also possible by applying optimal ordering procedure with SIC [10].

In this paper we are studying various techniques for SIC enabled OFDM systems with MIMO. The study concerns the conventional single-antenna and the multiple-antenna OFDM transceiver modes for SIC reception. Different equalizer like MMSE, ZF and ML are also combined with SIC for reducing complexity. This is also studied in this paper. Finally we are concentrating on the parameter BER. We are studying BER for various MIMO OFDM systems with MMSE SIC, ZF SIC and ML SIC receiver.

STUDY OF SUCCESSIVE INTERFERENCE CANCELLATION

Typically, OFDM provides great spectrum efficiency by allowing adjacent subchannels to spectrally overlap, yet remain orthogonal in time [11]. Multiple antenna technology is used when increased capacity of the link is required. It provides increased throughput also. Multiple-antenna adaptation holds the premise of achieving significant performance improvement and capacity enhancement in such systems [12]. MIMO OFDM systems are increasing data rate as well as capacity of the link in communications.

In the paper [1], a comprehensive survey on the performance of SIC for single- and multiple-antenna OFDM and spread OFDM (OFCDM) systems was presented. They focused on all the possible OFDM formats that have been developed. They studied the performance of SIC by examining closely two major aspects, namely the BER performance and the computational complexity of the reception process. They had shown results for ZF SIC, MMSE SIC and ML SIC for varying antenna configurations. From all parameters and study, they concluded that MMSE SIC provides better result in all above equalizers in terms of BER.

In the paper [13], a novel time-domain recursive algorithm was proposed for a minimum-mean-squared error (MMSE) with successive interference cancellation (SIC) scheme. Here firstly the classical MMSE SIC scheme for MIMO OFDM is shown. Them they showed their approach and modifications to the classical approach. They had shown LDL Based algorithm. Here L is lower triangular matrix, D is diagonal matrix. In the classical method whole channel matrix G was used. So to reduce more complexity LDL matrix was used in place of channel matrix. Then the result of MMSE SIC receiver with optimal ordering and without optimal ordering and proposed new system, for MIMO OFDM were compared. The new algorithm proposed in this paper has shown better results in terms of BER then older one. Also MMSE SIC with optimal ordering has given better results than MMSE SIC without optimal ordering.

In the paper [14], the LDL^H decomposition based algorithm with backward substitution (LDBABS), which is shown to require as many multiplications as two other most efficient algorithms WAS Studied. Then they proposed a modified LDBABS algorithm that utilizes the scheme of incomplete LDL^H decomposition together with the initial ordering information. The modified LDBABS algorithm requires averagely fewer multiplications than any other implementation algorithm under the independent identically distributed Rayleigh fading channel. Finally they proposed a fast algorithm for the real-valued MMSE-SIC detector with optimal detection order. The number of real-valued multiplications required by this fast algorithm is approximately 1.57 times that required by the complex-valued LDBABS algorithm. In this paper they obtain fast algorithms for several MMSE-SIC detectors and the MMSE detector. Then they apply the idea of initial order to the LDBABS algorithm and arrive at the modified LDBABS algorithm for the MMSE-SIC-LMSE detector. The modified LDBABS algorithm requires, in the worst case, the same number of multiplications as the efficient algorithms in [15], [16]; but, it requires averagely fewer multiplications. Finally, they propose a fast algorithm for the real-valued MMSE-SIC- LMSE detector. Although the real-valued MMSE-SIC-LMSE detector has 1 dB performance advantage, it needs to pay approximately 1.57 times more computational cost than its complex-valued counterpart.

In the paper [16], Detection of transmitted symbols in a V-BLAST system using the minimum mean squared error criterion with successive interference cancellation (MMSE-SIC) was done. This process provides satisfactory bit error rate performance at the cost of moderate computational complexity. Here the Fast Recursive Algorithm proposed in previous papers was modified to compute an ordered set of nulling vectors from the estimated channel information. Modified FRA can was used with the transformation based successive interference cancellation procedure to process a V-BLAST frame that contains the preamble and payload. As compared to LDL^H approach in paper [13], they provided well-studied solution for finding the inverse of a conjugate symmetric positive definite matrix. Finally they concluded by applying their modified FRA in to compute an order set of nulling vectors and applying the TBSIC procedure to process the payload, they obtain an implementation algorithm for the MMSE-SIC detection that has the lower complexity as compared to [17].

From the all above papers we extracted a common algorithm for SIC. We can summarize most important steps of SIC based reception more specifically as

1) Upon a signal reception, calculate the equalization N × N matrix J, where J could be either an ML, a ZF or an MMSE detector.

2) Apply an optional detection ordering on J.

3) Calculate $< J, y >_l$ where $<.>_l$ denotes the l-th row of a matrix. The resulting term denotes an estimation of the detected symbol x, which can subsequently be decoded according to the modulation type which is used.

4) Subtract the decoded information from the remaining signal as ynew = yprevious − $x[G]_l$, where $[.]_l$ denotes the l-th column of a matrix.

5) Relax the channel matrix in terms of interference contribution as Gnew $=G_{l'}$, where l' is the deflated version of a matrix whose 1,2,...,l-th columns have been zeroed.

6) Repeat steps 1 to 5 until all the OFDM symbols have been decoded.

In all the studied papers that algorithm is common. The channel matrix is taken according to different assumptions and calculations. But the procedure is common.

CONCLUSION

Interference cancellation represents one of the most remarkable considerations in modern receiver designs for wireless communication networks. In this paper we studied various aspects of SIC clarification, because if has shown most effectiveness in interference cancellation. Also OFDM is most dominant modulation scheme, joint OFDM SIC is studied widely. We also reviewed SIC implementation strategies for MIMO OFDM systems, in order to survey the performance of SIC at all the multi-carrier networks. We also studied some equalization techniques and found that MMSE SIC gives better result in terms of BER.

REFERENCES

1. Nikolaos I. Miridakis and Dimitrios D. Vergados, "A Survey on the Successive Interference Cancellation Performance for Single-Antenna and Multiple-Antenna OFDM Systems," IEEE COMMUNICATIONS SURVEYS & TUTORIALS, VOL. 15, NO. 1, FIRST QUARTER 2013, pp. 312-335.
2. Kwanghoon Kim and Hyuncheol Park, "A Low Complexity ICI Cancellation Method for High Mobility OFDM Systems," 0-7803-9392-9/06/$20.00 (c) IEEE, aug. 2006, pp. 2528-2532.
3. Jeffrey G. Andrews, "Interference Cancellation for Cellular Systems: A Contemporery Overview," IEEE Wireless Communications, April 2005, pp. 19-29.
4. Paulo Cardieri, "Modeling Interference in Wireless Ad Hoc Networks," IEEE COMMUNICATIONS SURVEYS & TUTORIALS, VOL. 12, NO. 4, FOURTH QUARTER 2010, pp. 551-571.

5. Miin-Jong Hao, “Precoding for PAPR Reduction of OFDM Signals With Minimum Error Probability,” IEEE TRANSACTIONS ON BROADCASTING, VOL. 56, NO. 1, MARCH 2010, pp. 120-128.
6. Steven P. Weber, Jeffrey G. Andrews, Xiangying Yang, and Gustavo de Veciana, “Transmission Capacity of Wireless Ad Hoc Networks With Successive Interference Cancellation,” IEEE TRANSACTIONS ON INFORMATION THEORY, VOL. 53, NO. 8, AUGUST 2007, pp. 2799-2814.
7. Jeffrey G. Andrews, Wan Choi, and Robert W. Heath., “Overcoming Interference in Spatial Multiplexing MIMO Cellular Networks,” IEEE Wireless Communications, December 2007, pp. 95-104.
8. Dariush Divsalar, Marvin K. Simon, and Dan Raphaeli, “Improved Parallel Interference Cancellation for CDMA,” IEEE TRANSACTIONS ON COMMUNICATIONS, VOL. 46, NO. 2, FEBRUARY 1998, pp. 258-268.
9. Ioannis Krikidis, and John S. Thompson, “Opportunistic Relay Selection in Cooperative Systems With Dirty-Paper Coding,” IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, VOL. 58, NO. 7, SEPTEMBER 2009, pp. 3322-3332.
10. M. Debbah, P. Loubaton, and M. de Courville’ “Asymptotic Performance of Successive Interference Cancellation in the Context of Linear Precoded OFDM Systems,” IEEE TRANSACTIONS ON COMMUNICATIONS, VOL. 52, NO. 9, SEPTEMBER 2004, pp. 1444-1448.
11. Zhongshan Zhang, Wei Zhang, and Chintha Tellambura, “Robust OFDMA Uplink Synchronization by Exploiting the Variance of Carrier Frequency Offsets,” IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, VOL. 57, NO. 5, SEPTEMBER 2008, pp. 3028-3039.
12. Jan Mietzner, Robert Schober, Senior, Lutz Lampe, , Wolfgang H. Gerstacker, and Peter A. Hoeher, “Multiple-Antenna Techniques for Wireless Communications – A Comprehensive Literature Survey,” IEEE COMMUNICATIONS SURVEYS & TUTORIALS, VOL. 11, NO. 2, SECOND QUARTER 2009, pp. 87-103.
13. Ji-Hyun Park, Younghoon Whang, and Kwang Soon Kim, “Low Complexity MMSE-SIC Equalizer Employing Time-Domain Recursion for OFDM Systems,” IEEE SIGNAL PROCESSING LETTERS, VOL. 15, 2008, pp. 633-636.

14. Tsung-Hsien Liu' "Some Results for the Fast MMSE-SIC Detection in Spatially Multiplexed MIMO Systems," IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, VOL. 8, NO. 11, NOVEMBER 2009, pp. 5443-5448.
15. Katsutoshi Kusume, Michael Joham, Wolfgang Utschick, and Gerhard Bauch, "Cholesky Factorization With Symmetric Permutation Applied to Detecting and Precoding Spatially Multiplexed Data Streams," IEEE TRANSACTIONS ON SIGNAL PROCESSING, VOL. 55, NO. 6, JUNE 2007, pp. 3089-3103.
16. Tsung-Hsien Liu, "Modified Fast Recursive Algorithm for Efficient MMSE-SIC Detection of the V-BLAST System", IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, VOL. 7, NO. 10, OCTOBER 2008, pp. 3713-3717.
17. L. Szczeci´nski and D. Massicotte, "Low complexity adaptation of MIMO MMSE receivers, implementation aspects," in Proc. IEEE Global Telecommun. Conf. (GLOBECOM), St. Louis, Nov. 2005, pp. 2327-2332.