ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, Vol 8(22), DOI: 10.17485/ijst/2015/v8i22/79103, September2015 ISSN (Online) : 0974-5645

OFDM Techniques for MIMO-OFDM System: A Review

C. Manikandan*, P. Neelamegam and E. Divya

School of Electrical and Electronics Engineering, SASTRA University, Thanjavur – 613401, Tamil Nadu, India; cmanikandan87@gmail.com, neelkeer@gmail.com, ivya92@gmail.com

Abstract

MIMO-OFDM technology converts frequency selective MIMO channel into number of parallel flat fading MIMO channel. It fundamentally simplifies the baseband receiver processing by eliminating the need of complex MIMO equalizer. In this paper every one of the strategies that provide increased BER performance for OFDM has been discussed. Linear Constellation Precoding (LCP) with subcarrier grouping technique has been introduced to overcome the multipath fading that result from conventional OFDM. Later on Nonlinear Constellation Precoding (NCP) without subcarrier grouping is introduced to replace the LCP technique. NCP strategy is adaptable to diversity channels and diversity order irrespective of their number which is not in case of LCP scheme. At end Nonlinear Constellation Precoding (NCP) with subcarrier grouping is introduced. As a conclusion, in future if the same procedures are implemented in the OFDM part of MIMO-OFDM system it will provide improved BER than conventional MIMO-OFDM system.

Keywords: Bit Error Rate, Diversity Channel Selection, Linear Constellation Precoding, Maximum Distance Separable codes, Nonlinear Constellation Precoding

1. Introduction

Orthogonal Frequency Division Multiplexing is a multicarrier modulation technique. Based on basic principle of multicarrier modulation technique it divide the high rate information stream into various lower rate information stream and transmit them through number of subcarriers shape a single frequency- selective channel into group of parallel flat-fading sub channels. OFDM system face the problem of Inter-Carrier Interference (ICI) due to the carrier frequency offset. Guard intervals and cyclic prefix are introduced to reduce the ICI. There are several methods[1] developed to show the effect of ICI on the performance of OFDM.

In wireless communication, central issues is presence of obstructions between the transmitter and receiver, the obstruction produces multiple reflections of the same signal results in multipath fading. Multiple-Input Multiple-Output (MIMO) has been implemented to overcome this multipath fading. The major advantage of MIMO is the increased BER performance. This technique makes use of multiple spatial channels for data transmission and reception. MIMO is primarily utilized as a part of 802.11n however it can also be implemented in other standards of 802.11. MIMO-OFDM opens the door to various applications and enables more cost-effective implementation for practical applications.

2. Technological Improvement of OFDM and MIMO-OFDM

2.1 Linear Constellation Precoding of OFDM with Subcarrier Grouping

OFDM converts frequency selective channel into a group of parallel flat-fading sub channels, thus reducing the channel equalization and symbol decoding. However this simplicity comes at the cost of multipath diversity loss because every symbol is transmitted via an independent flat channel that undergoes fading. This result in performance degradation of OFDM and some counter measure has to be taken to overcome this disadvantage. Finally, linear constellation precoding is introduced to benefit the frequency diversity in multipath fading channel.

**Author for correspondence*

Moreover, linear constellation precoding maximizes both diversity and coding gain. Maximum Likelihood (ML) decoding technique is used in LCP for decoding process. To reduce the decoding complexity, subcarrier grouping is combined with LCP technique without degrading the coding and diversity gains. Subcarrier grouping divides the group of correlated sub channels into subgroups of uncorrelated or less correlated sub channels and it reduces the decoding complexity.

In general LCP-OFDM scheme has higher decoding complexity because every single information symbol is transmitted through all subcarriers. To reduce the decoding complexity, subcarrier grouping is done which partition the group of all subcarriers into non intersecting subgroups of subcarriers, and transmit every information symbol via subcarriers within one of these subsets. This type of LCP-OFDM is termed as grouped LCP-OFDM (GLCP-OFDM). The diversity gain and coding gain is given by[2],

$$K_d = \min_{\forall e \neq 0} K_{e,d} \quad \text{And} \quad K_c = \min_{\forall e \neq 0} K_{e,c} \tag{1}$$

The maximum diversity gain and maximum coding gain achieved by LCP-OFDM

Technique is given respectively as

$$K_{d,\max} = L+1 \quad \text{And} \quad K_{c,\max} = [\det(R_h)]^{1/L+1} \Delta_{\min}^2 \tag{2}$$

Where L is the number of channel taps, R_h is the correlation matrix, Δ_{min} is the minimum Euclidean distance Liu Z et al[2]. It suggests that this solution is applicable only if the group size is same as that of the number of channel taps. In this method, subcarrier grouping concentrates only the diversity and coding gains and does not affect the BER performance.

2.2 Subcarrier Grouping of LCP-OFDM with Group Size S > L

LCP-OFDM technique provides performance improvement of a communication system. It finds application in many OFDM systems functioning over frequency-selective channels. However, this technique has the disadvantage that it provides the solution only when the subcarrier group size F is equal to the number of channel taps L i.e. S = L. Further there is no clarification about the idea, that when S = L the system produce unique solution or not. It leads to the investigation of LCP-OFDM technique with values of S ≥ L. The rotation matrix used in this method is given by

$$\theta = \frac{1}{\beta} \begin{bmatrix} 1 & \alpha_1 & \dots & \alpha_1^{F-1} \\ : & : & \dots & : \\ : & : & \dots & : \\ 1 & \alpha_F & \dots & \alpha_F^{F-1} \end{bmatrix} \tag{3}$$

Based on these values, maximum diversity gain is achieved as long as S > L and maximum coding gain is achieved with S ≥ L where F is an Euler number or an integer power of 2. These two concepts were proved with the following theorems[3]. It concludes that when the group size S is equal to the number of channel taps L i.e., S = L, then the system has unique solution. Further optimum subcarrier grouping was derived to obtain the maximum diversity gain and coding gain.

- **Theorem 1**
  The maximum diversity gain $K_{d,max} = L$ can always be achieved by employing the rotation matrix and any subcarrier grouping approach as long as S ≥ L.
- **Theorem 2**
  Using the subcarrier grouping solution and the rotation matrix, the maximum coding gain is achieved if S > L and $S \in \mathcal{F}$. If S > L and $S \in ! \mathcal{F}$, the coding gain approaches at least 70% of the maximum one.

Moreover there is an improvement in BER performance of the scheme when S > L. It was proved with analytical results[3]. This scheme is also based on ML decoding; therefore the decoding complexity is still higher.

2.3 Nonlinear Constellation Precoding with MDS Encoder and DCS Decoder

Signal space diversity process is adopted to mitigate the channel fading. In spite of its various advantages it is still replaced by new idea of Nonlinear Constellation Precoding (NCP) technique. The NCP technique is flexible for all diversity channels and diversity orders. It uses Maximum Distance Separable (MDS) codes and new concept of Diversity Channel Selection (DCS) decoding. DCS decoding substantially reduce the decoding complexity but there is marginal performance loss compared to ML optimal decoding.

In LCP - OFDM, binary information bits are initially mapped to signal constellation which is then rotated by the square spreading matrix. Then the copies of each bit are transmitted through many diversity channels to attain both diversity and coding gain. The diversity order is defined as the minimum hamming distance whereas the coding gain is defined as the minimum product distance between coordinate vectors of constellation points.

NCP technique is based on MDS codes. The codes which satisfy the Singleton Bound are called MDS codes. It maximizes the minimum distance between code words. LCP technique functions at the complex field but NCP functions at the binary field, designated by MDS codes. The basic encoding function of NCP scheme is described in Figure 1.

The information bits are encoded by generator matrix $C_{m,d}$ is given by

$$C_{m,d} = (I_n / A) \tag{4}$$

Where I_n is the Identity matrix of order n × n and A is n × p (d – 1) binary matrix, d is the minimum hamming distance. The binary codeword c is then mapped on the constellation to give the codeword x. DCS decoding follows an algorithm to decode[4] and perform detection with reduced decoding complexity. Triple Channel Joint Modulation (TCJM) and Quaternary Channel Joint Modulation (QCJM) are the two types of NCP techniques based on MDS encoding and DCS decoding which results with improved BER performance than the LCP technique. In TCJM and QCJM subcarrier grouping is exempted.

2.4 NCP – OFDM with Subcarrier Grouping

NCP – OFDM technique with subcarrier grouping increase the BER performance than the NCP – OFDM technique without subcarrier grouping. 3-Diversity Channel Joint Modulation Technique (DCJMT - OFDM) is based on the NCP – OFDM scheme. It outperforms the previous techniques such as TCJM and other linear techniques based on BER performance. The MDS encoder converts the *n* information bits **b** into code word **s** of length *m* with diversity order of d. The generator matrix of MDS encoder is given by

$$C_{m,d} = (I_n / F) \tag{5}$$

I_n is the identity matrix of order n × n and F is n × t (d – 1) binary matrix. The output code word from the encoder is given by

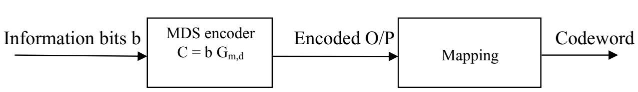

Figure 1. Encoding process of NCP technique.

$$W = C_{m,d} b \tag{6}$$

This output is given as the input to the modulation scheme which should have the value of q as low as possible. Based on the Singleton bound q is defined as $q = 2^t$, where t = m – d + 1/n.

These t bits are mapped to the constellation and the output signal from the mapper is denoted by s of length m. Subcarrier grouping splits the n carriers into V nonintersecting subsets, that is n = VW

$$I_n = \{I_1, I_2, \ldots. I_V\} \tag{7}$$

The total number of subsets should be equal to the number of diversity channel m. After applying IFFT, it is transmitted over the channel and at receiver side inverse of IFFT is applied. Thus the OFDM system yields a diagonal equivalent channel matrix as

$$D_H = diag[H_1, H_2, \ldots H_n] \tag{8}$$

$$D_H = F_n H F_n^{'}$$

The received signal is represented by $r = D_H s + w$, where w is the noise vector. DCS decoder is used at receiver end to minimize the decoding complexity but there is marginal performance loss. Individual DCS decoder block are used for each group of transmitted signals. DCS decoder follows a certain algorithm to decode the received signal[5] for each group independently. This method provides a better BER performance when compared to LCP technique.

2.5 MIMO-OFDM with Space Time Block Codes

MIMO-OFDM stands for Multiple Input Multiple Output-Orthogonal Frequency Division Multiplexing. It has been acknowledged as one of the most developing techniques to facilitate high data rate and improved performance in different channel conditions. Space time block codes are usually adopted to implement MIMO-OFDM due to its less decoding complexity and have low BER.

In MIMO-OFDM, the information bits are first converted to parallel streams by serial to parallel converter. The bits are then modulated. After modulation it is encoded by Space Time Block Code (STBC) encoder. The encoder output is given to Inverse Fast Fourier Transform (IFFT) which is then followed by addition of Cyclic Prefix (CP). This part implements the OFDM concept. After transmitting through the channel, the reverse part of the transmitter takes place at the receiver to attain the original signal.

The technique is implemented with different number of transmitting and receiving antennas. It is concluded that the BER of the systems with 4 antennas is lower than that of the system with 2 antennas[6].

3. Conclusion

In this paper recent improvement over OFDM system has been studied. If the same techniques are implemented in OFDM part of MIMO – OFDM system, it will provide improved BER than conventional MIMO – OFDM system.

4. References

1. Le KN. Inter-carrier interference power of OFDM in a uniform scattering channel. Computer Communications. 2008 Nov; 31(17):4130–5.
2. Liu Z, Xin Y, Giannakis GB. Linear constellation-precoding for OFDM with maximum multipath diversity and coding gains. IEEE Trans Commun. 2003 Mar; 51(3):416–27.
3. Tran NH, Nguyen HH, Le-Ngoc T. Subcarrier grouping for OFDM with linear constellation precoding over multipath fading channels. IEEE Trans Veh Technol. 2007 Sep; 56(6):3607–13.
4. Shang Y,Wang D, Xia TXG. Signal space diversity techniques with fast decoding based on MDS codes. IEEE Trans Commun. 2010 Sep; 58(9):2525–36.
5. Raja M, Muthuchidambaranathan P. A Novel Nonlinear Constellation Precoding for OFDM Systems with subcarrier Grouping. Wireless Personal Communications. 2013 Dec; 73(3):867–84.
6. Jie Z, Liang LIU, Jin LI. Performance analysis of Space Time Block Code in MIMO-OFDM systems. Communication Software and Networks (ICCSN); 2011 May. p. 13–6.