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# Nonlinear Constellation Precoding For MIMO-OFDM Systems With Subcarrier Grouping

**E. Divya and C. Manikandan,**
*School of Electrical & Electronics Engineering,*
*SASTRA University, Thanjavur.*
*ivya92@gmail.com.*

## Abstract

In this paper Nonlinear Constellation Precoding (NCP) with Subcarrier Grouping for MIMO-OFDM systems has been proposed. MIMO-OFDM system transfers frequency selective MIMO channel into number of parallel flat fading MIMO channel. Linear Constellation Precoding (LCP) technique is generally adopted to mitigate the multipath diversity in OFDM systems. In subcarrier grouping full group of subcarriers are divided into subgroup of smaller groups, thereby reducing the complexity of decoding. In this paper, LCP technique is replaced by the NCP technique which provides better BER performance when compared with the LCP technique. NCP technique with MIMO-OFDM system hikes the data rate when compared with the OFDM system. BER performance of NCP- OFDM and NCP MIMO-OFDM systems with subcarrier grouping is simulated and compared with simulation results.

**Keywords:** MIMO-OFDM, Linear Constellation Precoding (LCP), Nonlinear Constellation Precopding (NCP), Subcarrier grouping, BER.

## Introduction

OFDM is a multicarrier modulation technique with superior performance. The functional principle of OFDM is to divide a high rate data stream into many number of lower rate data stream and transmit them vianumber of subcarriers. It converts the frequency- selective fading channel into many number of parallel flat- fading sub channels. OFDM technique face the problem of Inter- carrier interference (ICI) due to the loss of orthogonality between the subcarriers. Guard intervals are introduced to reduce the ICI.

In wireless communication, fundamental problems include presence of obstruction between the transmitter and receiver, reflection, scattering, etc.. The multiple reflections of the same signal results in multipath fading. Linear constellation precoding (LCP) has been introduced for OFDM systems to benefit frequency diversity in a multipath fading channel. LCP combined with subcarrier grouping maximize the diversity and coding gain. Subcarrier grouping is nothing but dividing the full set of subcarriers into smaller groups. In LCP, the information bits are first mapped to multiple symbols corresponding to a regular constellation, which are then sequently rotated by a square spreading matrix.

LCP technique is later replaced by the Nonlinear Constellation Precoding (NCP) technique. In NCP, the input information bits are first encoded by encoder followed by mapping. LCP technique is encoded over the complex field whereas NCP encoding process is over binary field. NCP technique when implemented in OFDM systems results with improved BER performance than the LCP OFDM system. In this paper, NCP technique is extended to MIMO-OFDM concept. Multiple-Input Multiple-Output (MIMO) has been implemented to overcome the multipath fadingeffects in OFDM process. The major advantage of MIMO is the increased BER performance. This technique makes use of multiple spatial channels for data transmission and reception. MIMO-OFDM together increases the link capacity by simultaneously transmitting multiple data streams using multiple transmit and receive antennas and provide improved data rate.

## Proposed Work

The basic block diagram of the NCP technique with subcarrier grouping for MIMO-OFDM systems is shown in Figure 1. In Nonlinear constellation precoding, the information bits are first encoded by Maximum Distance Separable(MDS) encoder followed by mapping. The codes which satisfies the Singleton bound condition are called MDS codes NCP has the adaptability to support diversity channels and diversity order irrespective of their number. In NCP instead of ML decoder Diversity Channel Selection(DCS) decoder is used. DCS decoder has lower computational complexity at the price of lesser performance loss.

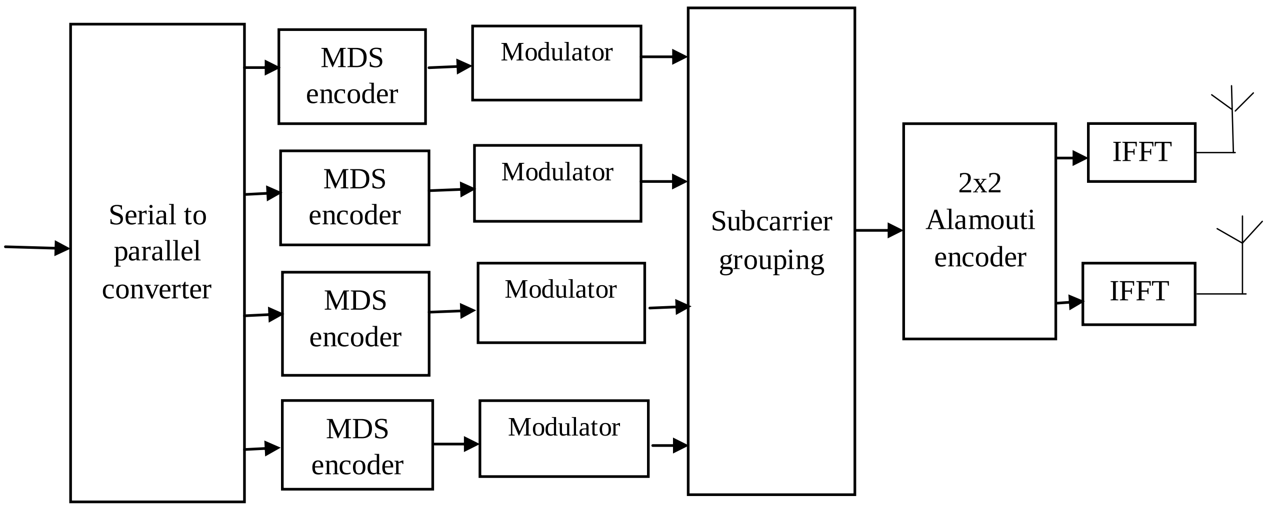


**Figure 1:** Transmitter part of NCP MIMO-OFDM

The input binary bits 'b' are given to serial to parallel converter which converts them parallely. Each parallel stream is encoded by the MDS encoder. The generator matrix of MDS encoder is given by

$$G_{m,d} = (I_n / F) \tag{1}$$

where m is the diversity channel, d is the diversity order and In is the Identity matrix of order n x n and F is a n x t(d-1) binary matrix. The F matrix is designed in 3 ways and by comparing the results one of its design proved to maximize the coding gain. In first case, F matrix is designed to be simply an Identity matrix. In second case, based on theorem 3, it is designed as,

$$F_{1,1} = \begin{bmatrix} 1 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 1 & 1 & 1 \\ 0 & 1 & 1 & 0 & 0 & 1 \\ 1 & 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 & 0 & 1 \end{bmatrix} \tag{2}$$

$$F_{2,1} = \begin{bmatrix} 0 & 0 & 1 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 & 1 \\ 1 & 0 & 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 0 & 1 & 1 \\ 1 & 0 & 1 & 0 & 0 & 1 \end{bmatrix} \tag{3}$$

In third case, violating the theorem 3 requirements F matrix is designed. It provides the same coding gain as that of second case. It is given by,

$$F_{1,1} = \begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 & 0 & 1 \end{bmatrix} \tag{4}$$

$$F_{2,1} = \begin{bmatrix} 0 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 \end{bmatrix} \tag{5}$$

The output codeword from the encoder is given by

$$C = G_{m,d} b \tag{6}$$

The ouput from the encoder is given as the input to the modulator. The modulator is designed to have a value of q according to the Singleton bound,

$$2^n \leq q^{m-d+1} \tag{7}$$

The output from the modulator undergoes subcarrier grouping. Subcarrier grouping splits the set of correlated sub channels into subset of uncorrelated sub channels. The n carriers are classified into V nonintersecting subsets of group size W. Thus n can be written as n = V W.

The subcarrier grouping output is given to the Alamouti encoder. Alamouti encoder is a type of Space Time Block Codes (STBC) usually used to implement the MIMO systems. Here, 2x2 MIMO-OFDM system is considered i.e., 2 transmitting antennas and 2 receiving antennas. The encoding method of Alamouti scheme is described such that, output from the subcarrier grouping will be encoded into two separate signal. At time instant t , S0 and S1 are transmitted by antenna 1 and antenna 2 respectively. At time instant T+t, -S1* and S0* are transmitted by antenna 1 and antenna 2 respectively. The signal is transmitted over Rayleigh channel.

The channel model is designed with Inverse Fast Fourier Transform (IFFT) at the transmitter (i.e) post multiplication of channel matrix H by Fn' and Fast Fourier Transform (FFT) at the receiver (i.e) pre multiplication of channel matrix H by Fn. This results with the diagonal equivalent channel matrix as

$$\begin{aligned} D_H &= diag[H_1, H_{2,} \ldots H_n] \\ D_H &= F_n H F_n^{'} \end{aligned} \tag{8}$$

With perfect cyclic prefix insertion and deletion, the received signal is represented as

$$r = D_H s + w \tag{9}$$

where w is the noise vector. The receiver block diagram is shown in Figure 2. At the receiver, Alamouti decoder decodes the signal by multiplying the received signal with the Hermitian of diagonal channel matrix. It is followed by subcarrier degrouping and demapping. In NCP technique, DCS decoder is used for decoding purpose. It reduce the computational complexity at the cost of marginal performance loss.

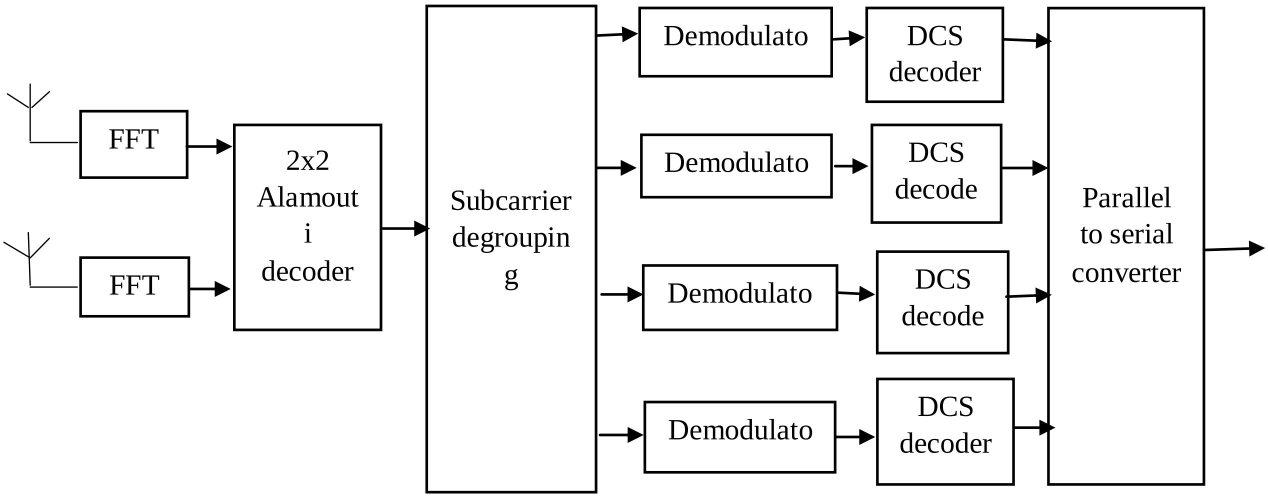


**Figure 2:** Receiver part of NCP MIMO-OFDM

The DCS decoder decodes the signal based on the algorithm.

1) Select the best r1 channels from the first group based on their SNR.
2) The value of r1 should lie between 1 and m-d+1.
3) The symbols that are transmitted through selected r1 channels are decoded by hard decision.
4) The detection is made by using minimum Euclidean distance search among all the codewords that are specified by r1 decoded components.

## Results and Discussion

For simulation results, the BER performance of NCP technique with and without subcarrier grouping in OFDM systems is compared with the NCP technique with and without subcarrier grouping in MIMO-OFDM systems.Here all the three cases of the F matrix is considered.The system design consists of 4 parallel transmitter links each carries 12 bit data totally 48 bits/frame. It makes use of 64 QAM and the total number of subcarriers is n = 12. For subcarrier grouping, the total number of subcarriers are splitted into 4 groups and each group has group size of 3. The groups are defined as {1,5,9},{2,6,10},{3,7,11},{4,8,12}. Both the systems are implemented with the same specification except that OFDM uses single antenna for transmission and reception while MIMO-OFDM uses 2x2 antenna system. The BER performance of both the systems are compared.

Figure 3 shows the BER performance of three cases of NCP MIMO-OFDM systems under DCS decoding.Third case has less BER than first and second case. Figure 4 shows the BER performance comparison of NCP OFDM and NCP MIMO-OFDM systems with subcarrier grouping. Figure 5 shows the BER performance comparison of NCP OFDM and NCP MIMO-OFDM systems without subcarrier grouping.

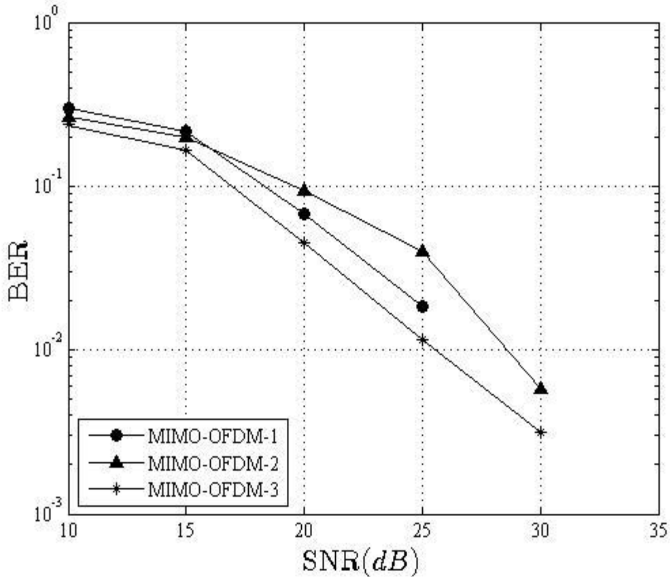


**Figure 3:** BER performance comparison of MIMO-OFDM-1, MIMO-OFDM-2 and MIMOOFDM-3 system

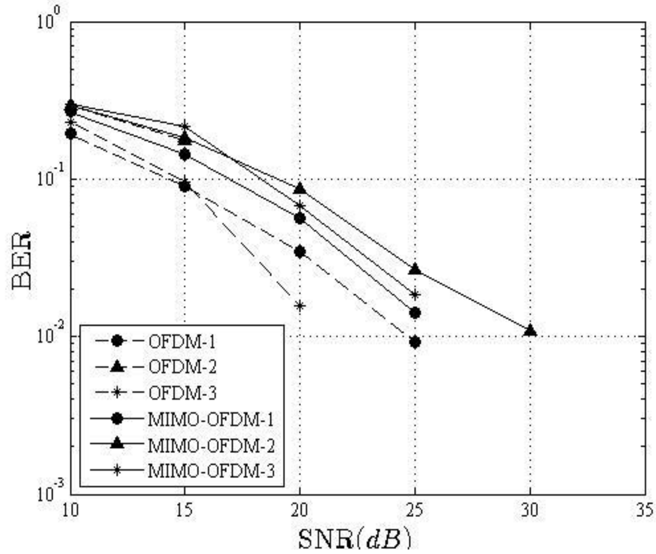


**Figure 4:** BER performance comparison of NCP OFDM and NCP MIMO-OFDM systems with Subcarrier grouping

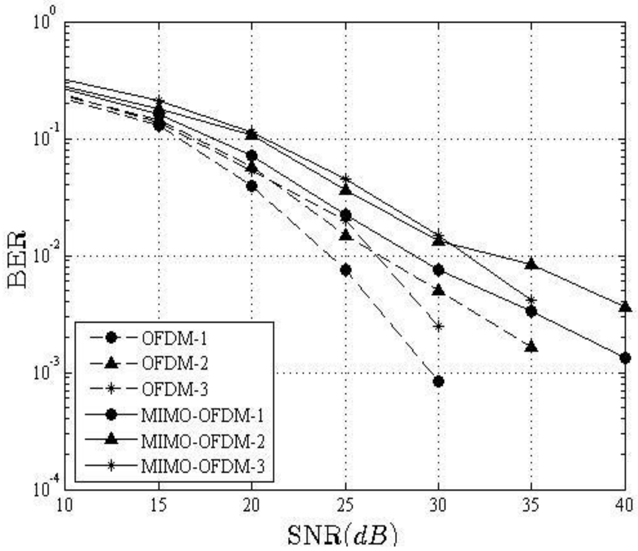


**Figure 5:** BER performance comparison of NCP OFDM and NCP MIMO-OFDM systems without Subcarrier grouping

## Conclusion

The BER performance of all the three cases of NCP MIMO-OFDM has been compared. Third case of MIMO-OFDM system has the better BER while compared to other two cases. The BER performance of NCP OFDM and NCP MIMO-OFDM systems has been compared with subcarrier grouping and without subcarrier grouping. Subcarrier grouping does not affect the BER performance of the system, it just reduce the decoding complexity at the receiver part of the system. However the BER of MIMO-OFDM is little higher when compared with the OFDM system due to the increased data rate. But the overall performnace of the MIMO-OFDM system is superior than OFDM system.

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