Space Time Block Coding - Spatial Modulation for Multiple-Input Multiple-Output OFDM with Index Modulation System

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Abstract

In this paper, review to improve the channel estimation accuracy in OFDM system, channel state information is required for signal detection at receiver and its accuracy affects the overall performance of system and it is essential to improve the channel estimation for more reliable communications. 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. The performance of MIMO-OFDM is evaluated on the basis of Bit Error Rate (BER). The paper is aimed at analyzing the BER performance of the MIMO-OFDM system for Pilot Based Channel along with a simulation channel. We show that in the MIMO-OFDM system for Pilot Based Channel Estimation BER decreases, as the signal to noise ration increases. Simulation results show that the proposed estimator is able to reduce the BER effectively at high SNR's and has a low computational complexity.

Keywords: multiple-input multiple-output (MIMO), orthogonal frequency division multiplexing (OFDM)

1. INTRODUCTION

Wireless communication, as the name suggests is wireless way of transmitting information from one place to another, is replacing most of the wired transmission of today's world. Research in the field of wireless communication is still a hot topic to discover new possibilities [1]. The goal of every research in this topic is to find more effective communication methods. Wireless communication helped the user to move freely without worrying about transfer of data. It dramatically changed the concept of information transfer in homes and in offices. Some of the key advantages gained by wireless communication are [2]:

Efficiency Increase- It improved communications that leads to faster transfer of information with in businesses and between partners/ customers.

Always in reach –There is no need to carry cables or adaptors in order to access some data in your office or home.

Greater flexibility and mobility for users –Workers in an office don't need to sit on dedicated PCs. They can be wirelessly networked together.

Reduced costs – Compared to wired communication, wireless systems are usually cheaper to use, easy to install and maintain.

The OFDM (Orthogonal Frequency Division Multiplexing) is becoming a very popular multicarrier 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. 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. The arrangement of multiple antennas at the transition end and reception end results increase in the diversity gain refers the quality of signal and multiplexing gain refers the transmission capacity.

2. MIMO- OFDM SYSTEM

In this paper, we consider a MIMO-OFDM-IM system equipped with Nt transmit and Nr receive antennas . The block diagram of the MIMO-OFDM-IM transmitter is depicted in Fig. 1. Each M IMO-OFDM-IM frame is comprised of a total number of mNt incoming data bits. These bits are divided into Nt groups for Nt transmit antennas, each of which contains m bits for the generation of an OFDM-IM block to be transmitted from a transmit antenna. These m bits are further divided into G subgroups, each of which consists of p bits, i.e., m = Gp. Assuming NF available subcarriers of each block, each subgroup is then used to generate an OFDM-IM subblock consisting of N = NF /G subcarriers. Unlike classical OFDM, which maps all data bits to the constellation points for all subcarriers, OFDM-IM separates p bits of each subblock into two parts for different purposes: the first part with p1 = blog2 N K c bits is used to select K actisubcarriers, while the remaining N − K subcarriers are set to be idle;1 the second part with p2 = K log2 M bits is mapped into K modulated symbols for the K active subcarriers via M-ary modulation. The mapping between the p1 bits and the subcarrier combination patterns can be implemented by using a look-up table or the combinatorial method [26]. Consider the g-th (1 ≤ g ≤ G) OFDM-IM subblock at the t-th (1 ≤ t ≤ Nt) transmit antenna.

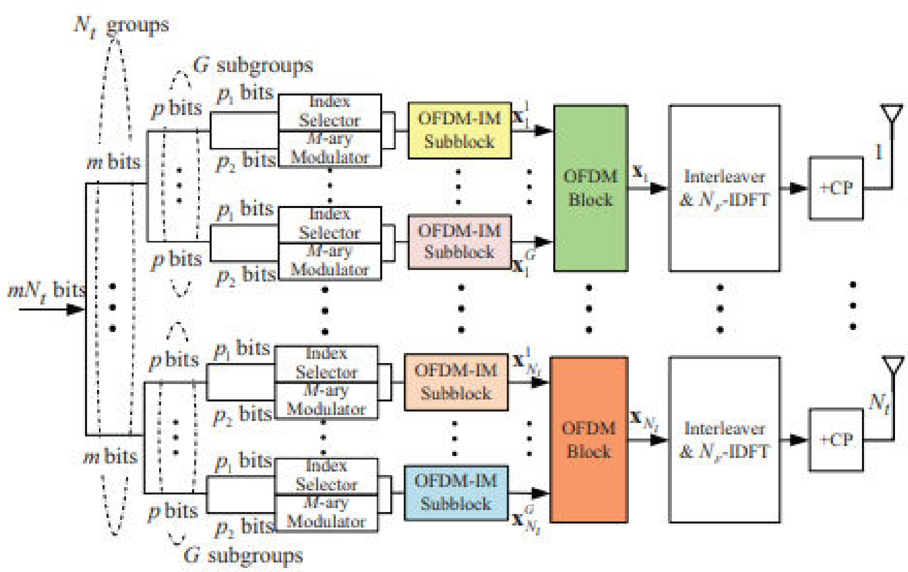

Fig. 1. Block diagram of MIMO-OFDM-IM transmitter.

Accordingly, the output of the first part should be the indices of K active subcarriers, which are given by the following set:

J g t = {j g t (1), . . . , jg t (K)} (1)

where j g t (k) ∈ {1, . . . , N} for k = 1, . . . , K, and the elements of J g t are sorted in an ascending order, i.e., j g t (1) < j g t (2) < · · · < jg t (K). The output of the second part should be K modulated symbols {s g t (n)}n∈J g t , where s g t (n) is drawn from a complex alphabet S˜ with |S| ˜ = M and we assume that E |s g t (n)| 2 = 1 for the normalization of signal constellation.

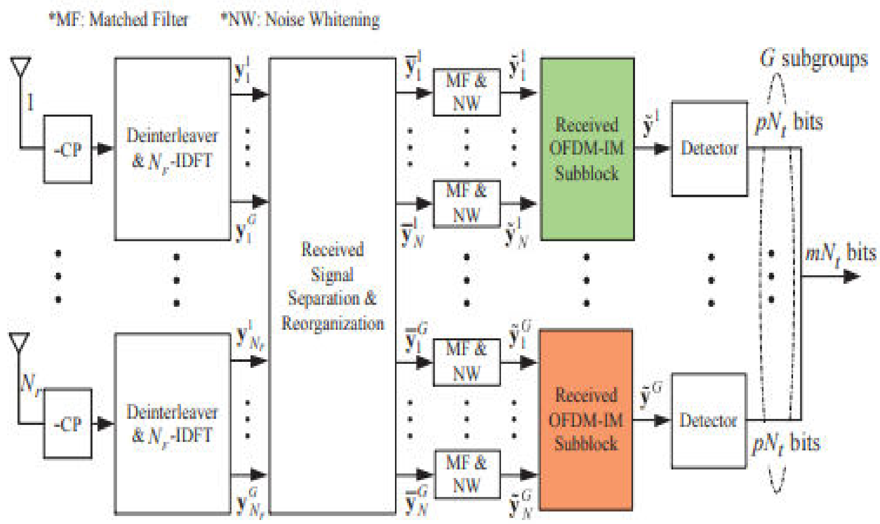

Fig. 2. Block diagram of MIMO-OFDM-IM receiver.

Therefore, the g-th OFDM-IM subblock element at the t-th transmit antenna can be expressed as x g t = [x g t (1) x g t (2) · · · x g t (N)]T , where From above, it is clear that each subblock of the MIMOOFDM-IM contains a fixed number of active subcarriers, whose positions carry information through the subcarrier indices. After generating all OFDM-IM subblocks, each OFDM-IM block is created by concatenating G OFDM-IM subblocks in each branch of the transmitter, which is denoted by xt = h x 1 t T x 2 t T · · · x G t T iT , [xt(1) xt(2) · · · xt(NF)]T , where 1 ≤ t ≤ Nt. To fully benefit from the frequencyselective fading, a G × N block interleaver is employed in each branch of the transmitter. Before transmission, each OFDMIM block is first transformed into the time-domain signal block by employing an NF -point inverse discrete Fourier transform (IDFT), and then appended with a CP of length Ncp, which is longer than the maximum delay spread of the channel.

We consider MIMO–OFDM systems with two transmit antennas and two receive antennas. The total number of subcarriers is N. Basically, the MIMO-OFDM transmitter has Nt parallel transmission paths which are very similar to the single antenna OFDM system, each branch performing serial-to-parallel conversion, pilot insertion, N-point IDFT and cyclic extension before the final TX signals are up-converted to RF and transmitted. It is worth noting that the channel encoder and the digital modulation, in some spatial multiplexing systems, can also be done per branch, where the modulated signals are then space-time coded using the Alamouti algorithm [3] before transmitting from multiple antennas [4] not necessarily implemented jointly over all the Ntbranches. Subsequently at the receiver, the CP is removed and N-point DFT is performed per receiver branch. Subsequent the DFT block, the guard interval, which is chosen to be greater than the delay spread and contains the cyclically extended part of the OFDM symbol for eliminating inter-carrier interference, is inserted to avoid inter-symbol interference. Next, the transmitted symbol per TX antenna is combined and outputted for the subsequent operations like digital demodulation and decoding. Finally all the input binary data are recovered with certain BER.

3. ADVANTAGES OF MIMO OFDM

MIMO OFDM has several advantages that make it a possible alternative for CDMA and other future wireless technologies. Some of the main advantages are discussed below.

- Multipath Delay Spread Tolerance OFDM is immune to multi-path delay spread, which causes ISI in wireless networks. Making the symbol duration larger reduces the effect of delay spread. It is done by converting high rate data signal into lower rate data signal. ISI is eliminated by the introduction of guard time.
- Immunity to Frequency Selective Fading Channels For single carrier modulation techniques, complex equalization techniques are required if channel imposes frequency selective fading, while in OFDM the bandwidth is split in many orthogonal narrow flat fading subcarriers. Hence it can be assumed that the subcarriers experience flat fading only, though the channel gain/phase associated with the subcarriers may vary. In the receiver, each subcarrier just needs to be weighted according to the channel gain/phase encountered by it. Even if some subcarriers are completely lost due to fading, the user data can be recovered by proper coding and interleaving at the transmitter.
- Efficient Modulation and Demodulation Modulation and demodulation of the sub-carriers is done using IFFT and FFT methods respectively, which are computationally efficient. The modulation and demodulation in digital domain avoids the need of high frequency stable oscillators.

4. SIMULATION RESULTS

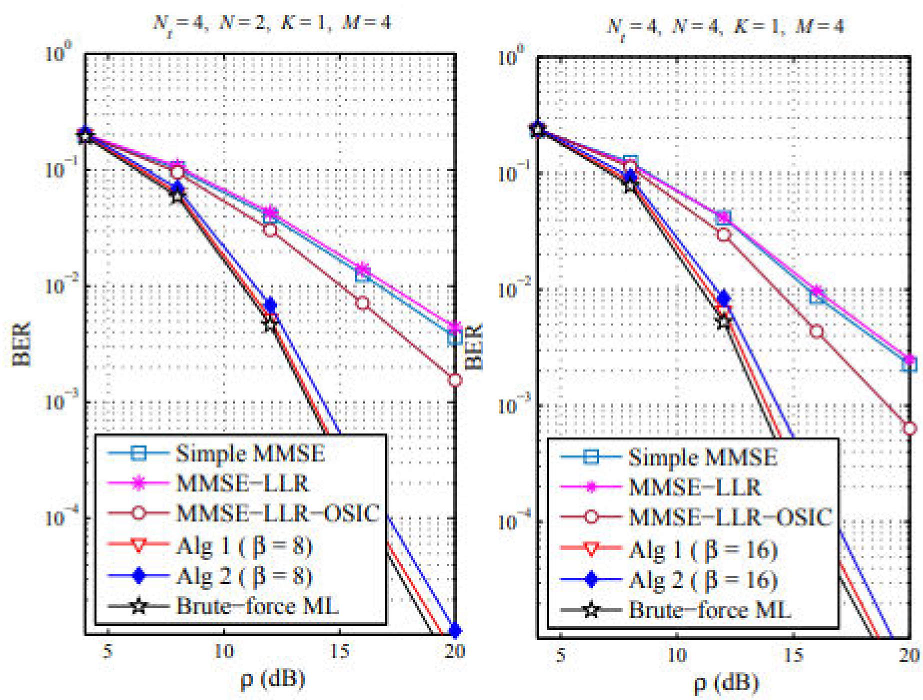

Fig. 3. BER performance comparison of different detection algorithms for MIMO-OFDM-IM with Nt = 4, K = 1, and QPSK modulation

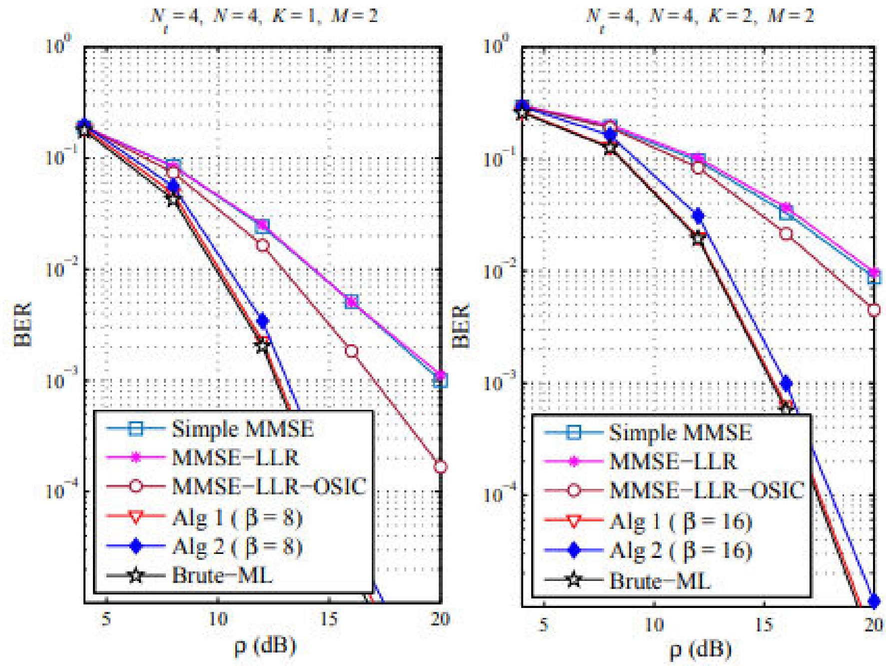

Fig. 4. BER performance comparison of different detection algorithms for MIMO-OFDM-IM with Nt = 4, N = 4, and BPSK.

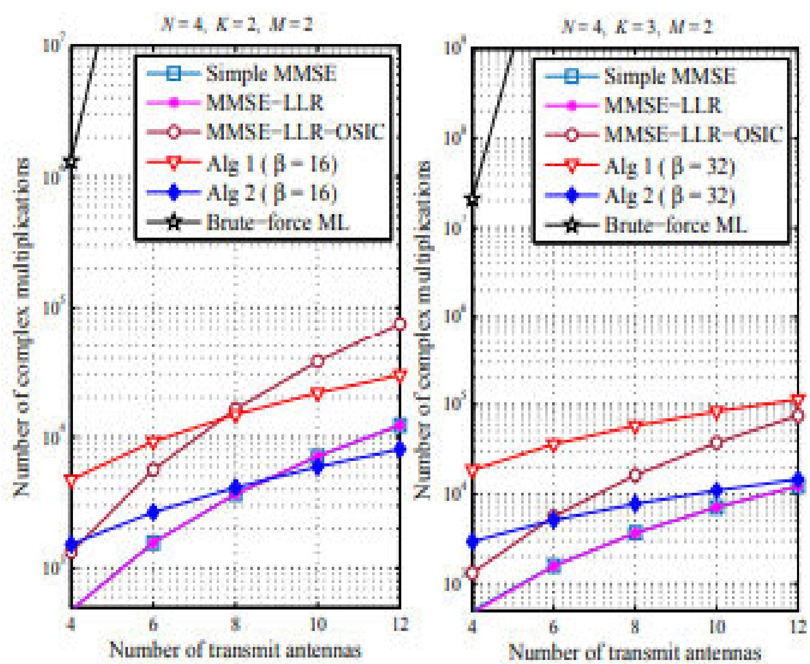

Fig. 5. Complexity comparison of different detection algorithms for MIMOOFDM-IM with N = 4, and BPSK modulation.

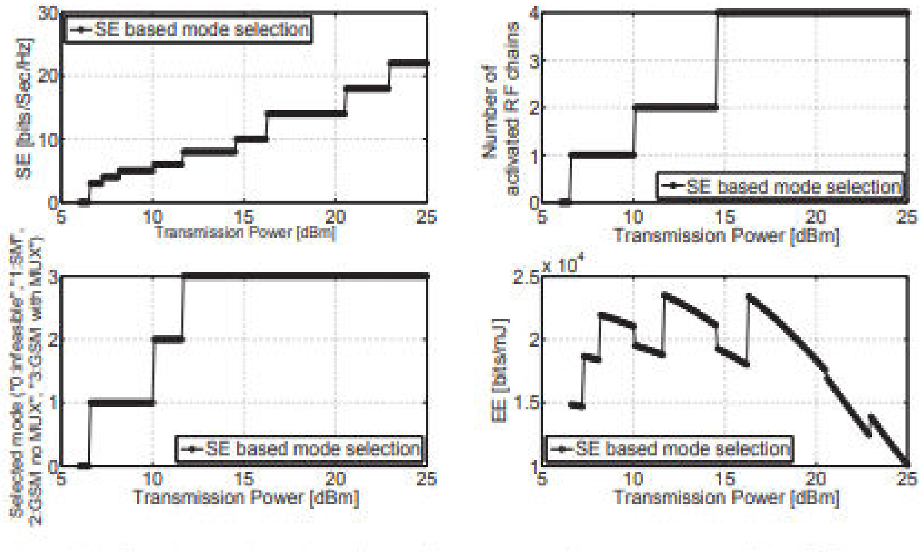

Fig. 6: SE based selection for MIMO system with Nt = 8, Nr = 4

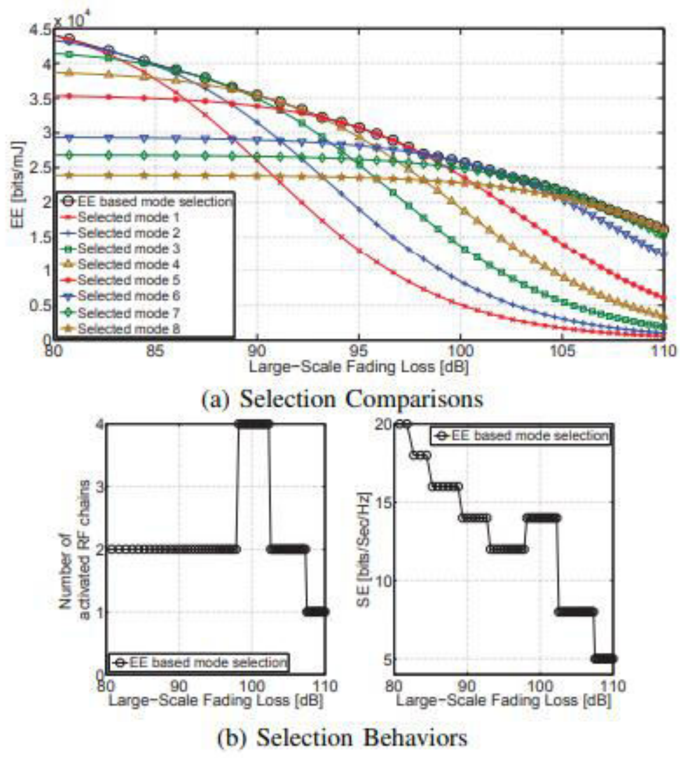

Fig. 7: EE based selection for MIMO systems with Nt = 8, Nr = 4

In Fig. 4, the BER performance of different detection algorithms is compared for the MIMO-OFDM-IM system with N = 4, K = 4, and BPSK modulation. From Fig. 8, we observe that the subcarrier-wise detector also has the potential to achieve almost the same performance as the subblock wise one for this configuration. This can be understood since both proposed detectors can approach the optimal performance when the number of particles is large enough (e.g., $\beta = 32$). Therefore, the deterministic

SMC aided detectors are able to provide a flexible trade-off between the computational complexity and the error performance by adjusting the number of particles. Fig. 5 shows the BER comparison results of different detection algorithms for the MIMO-OFDM-IM system with Nt = 4, N = 4, and K = 3. It still can be observed that when the number of particles is large enough, the subcarrier wise detector achieves almost the same performance as the subblock-wise one for different modulation orders. Moreover, the performance of all detectors degrades with the increase of the modulation orders. Specially, the performance gain of the MMSE-LLR-OSIC detector over the MMSE-LLR one is smaller with higher modulation orders.

5. CONCLUSION

Results analysis shows that the presence of Pilot channel estimation very vital role in improving the BER performance of the MIMO-OFDM system. The performance of the system enhanced to significant extent on suitable value of Pilot channel estimation along with suitable modulation technique. However, there is further possibility of improving the BER performance by developing new technique to compensate ISI effect, as the Pilot channel insertion affects system efficiency due to increased overhead.

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