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Special Block Coding for Spatial Modulation

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***Abstract*— Spatial Modulation is a new technique for Multiple-Input-Multiple Output (MIMO) systems that reduces the complexity of the transceiver and provides high data rate. It uses one or more selected antennas to transmit by utilizing antenna indices as a source of information. Maximum likelihood detector is used to detect the transmitted antenna indices and the transmitted symbol. If either the transmitted antenna index or the corresponding transmitted symbol is detected incorrectly, the other part is likely to be wrongly detected.**

In this paper, we introduce a block coding technique for the spatial modulation with more protection assigned to the antenna selection bits. After decoding process, the corrected antenna indices are fed back to the maximum likelihood detector to detect the new related transmitted message which achieves high Bit Error Rate (BER) performance with relatively low redundancy

***Keywords*—Space Time, Trellis Space Time , Convolutional Codes, SO-STBC.**

I. INTRODUCTION

Spatial Multiplexing (SM) is a transmitting approach for MIMO where the transmit antennas are used to send information [1].

Part of the information bits are used to select the transmit antenna and the other are transformed into modulation constellation points. In a sense that one active antenna is used per time slot. Both the antenna index and the transmitted symbol are detected at the receiver [1]. SM increases data rate as the multiple transmit antennas become a source of information. In [2], Trellis Coded Modulation is used to divide the transmit antennas into sub-groups such as the space between antennas in the same group is maximized. Recently more than one antenna have been used in SM so the number of transmit antennas can be flexible and not only power of 2 as in previous schemes [3-5].

SM detection can be done by the detection the antenna indices and the transmitted symbols separately as in [1]. However, an optimum Maximum Likelihood (ML) detection that requires joint detection for antenna index and symbols was introduced in [5].

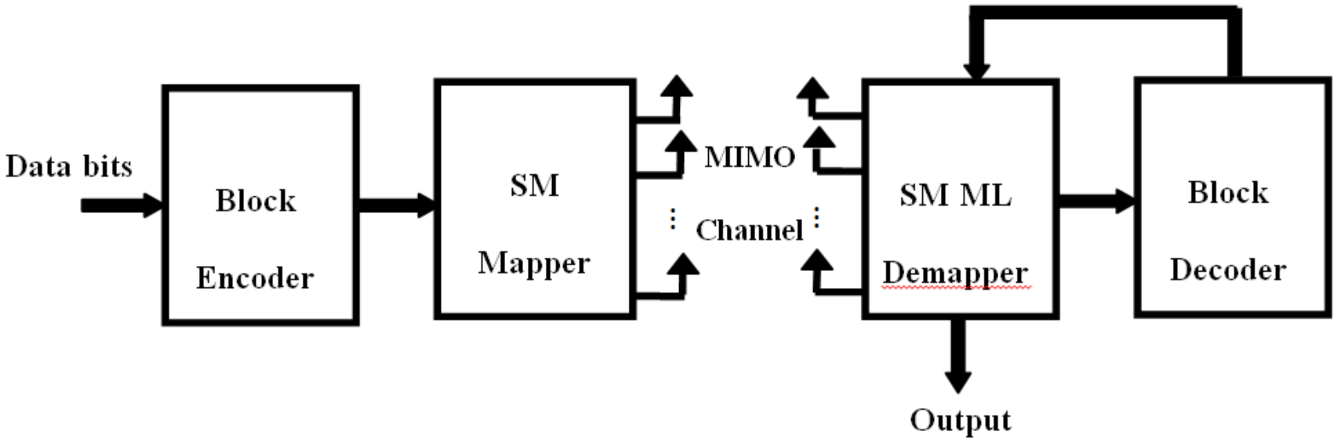

Figure 1: System model.

In the ML scheme, a wrong decision of the transmit antenna means that the transmitted symbol is most probably detected incorrectly because the decision was made for both in the same time.

In this research paper, strong block code is used for the selection bits. The error locations specify the antenna indices which have been wrongly detected. This information is fed back to the ML receiver, so it modifies the search for the message associated with these antennas.

II. SYSTEM MODEL

The general system model is a MIMO system with N_t, and N_r transmit and receive antennas, respectively. A random sequence of L independent bits enters the SM mapper in fig.1 where the first $b = \log_2(N_t)$ bits are used to select the unique transmitting antenna with index i. The remaining $L- b$ is modulated into s_k using m-PSK modulation ($m = 2^{L-b}$) and transmitted over the i^{th} antenna. The received vector is given by,

$$y = HS_{i,k} + \left(\frac{1}{\rho}\right) v, \qquad (1)$$

where

$$S_{i,k} = \begin{cases} 0 & l = 1, 2, \dots, N_t \quad l \neq i, \\ s_k & l = i, \end{cases}$$

TABLE I
SM MAPPING TABLE: 3 b/SYMBOL/SUBCHANNEL [1]

Input bits	N_t=2, M=4		N_t=4, M=2	
	Antenna number	Transmit symbol	Antenna Number	Transmit Symbol
000	1	+1+j	1	-1
001	1	-1+j	1	+1
010	1	-1-j	2	-1
011	1	+1-j	2	+1
100	2	+1+j	3	-1
101	2	-1+j	3	+1
110	2	-1-j	4	-1
111	2	+1-j	4	+1

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s_k is modulated symbol, i is the index of transmitting antenna, ρ is the average signal to noise ratio (SNR) at each receive antenna, H is $N_r \times N_t$ channel matrix, and v is 1 x N_r additive white Gaussian noise (AWGN). Both H and v have independent and identically distributed (iid) with zero mean and unity variance.

Table I shows an example of signal mapping in SM for 3 b/s[1]. In the first scenario two antennas are used, so b =1 bit is used to select the antenna and the remaining 2 bits are transmitted using 4-PSK. Whereas in the 2nd scenario, 4 antennas are used, so b =2 and the remaining bit is transmitted using BPSK.

Thr likelihood (ML) detector is used at the receiver and given by,

$$argmin\ abs(H^H y - S_{i,k}) \quad \forall i, \forall k, \qquad (2)$$

Where H^H is the Hermitian inverse of H. From (2), the antenna index as well as the transmitted symbol can be determined as i, and s_k, respectively.

After the ML decision, the antenna selection bits are decoded and error positions are found. Assume new antenna index i' is found so for previous wrongly detected antenna the ML search is repeated using

$$S' = \text{argmin}\ \text{abs}(H^{\text{H}} y - S_{i,k}) \quad i = i', \forall k \, (3)$$

The new search is done only over the modulation constellations as the antenna index is already known.

III. SIMULATION RESULTS

System with N_t = 4 and N_r = 2 is taken as an example. L is considered to equal 5 which mean the modulation scheme is 8-PSK. An (15, 5) BCH code [6] is used to encode the antenna selection bits and an (15, 11) BCH code [6] is used to encode the symbol bits. The overall code rate is r = 0.573. After decoding the antenna selection bits, the ML decision is repeated for the messages associated with the corrected antenna indices. The (15, 11) BCH code is then used to decode the message bits. The Bit Error Rate (BER) performance is plotted against the bit energy to noise ratio in Fig. 2. In the same graph, the performance for the same system with (15, 7) BCH code applied to all bits equally is also plotted for the sake of comparison. The code rate in this case is r = 0.4667.

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It is clear that the multilevel scheme has achieved 6.99 dB gain in EBN0 compared to uncoded Spatial modulation at BER = 10^{-4}. It has also a better performance than on level protection code with lower code rate (higher redundancy) up to EBN0 equal to 9.01 dB.

IV. Simulation Results

The trellis code used in this paper is based on trellis given in Fig. 1 with different constitute code leaving from node 1, 2, 3 and 4. In case of SOSTTC used with Alamouti code in [11] as inner code the result is depicted in fig. 2.0. The set partition is given in table I for the QPSK constellation points. Comparison with STTC in [1] is given in details [4]. It is proven error performance of the SO-STTC is far better than the STTC as it takes advantage of the orthogonilaity of the inner space time block code.

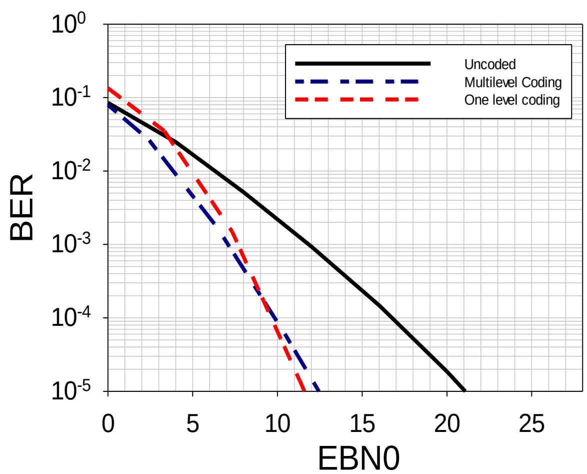

Figure 2: BER performance for the uncoded SM, SM with multilevel coding ((15,7) BCH for antenna selection bits and (15,11) BCH for the message bits), and SM with (15,7) one level coding.

V. Conclusion

In this paper, a new coding approach for Spatial Modulation is introduced. In this approach, a higher protection code allows for the corrected antenna selection bits to achieve better performance by helping the ML SM de-mapper to assign a new message to the modified antenna index. The complexity associated is low as the repeated ML search is linearly dependent only on the modulation constellation size. The code has achieved better results than codes with higher error correcting capability at low and moderate SNR.

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