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On the Performance of Spatial Modulation for MIMO Communication

B.Revathi[1], P.Poonguzhali[2], A.Angelin[3], C.Arunachalaperumal[4]

PG Student, Dept. of ECE, S.A. Engineering College, Chennai, Tamilnadu, India[1,2,3]

Associate Professor, Dept. of ECE, S.A. Engineering College, Chennai, Tamilnadu, India[4]

ABSTRACT– Spatial Modulation (SM) provides many advantages when compared to other conventional Multiple Input Multiple Output (MIMO) schemes in which multiple antenna transmit simultaneously. In SM only one antenna will be active during data transmission. This completely eliminates Inter Channel Interference (ICI) and reduces decoding complexity. In other coding techniques coding and modulation is done separately, but in Trellis Coded modulation (TCM), coding and modulation are combined together. In this paper the performance of SM-TC is compared to the performance of other techniques like Space Shift Keying (SSK), Spatial Modulation and Vertical Bell Labs Layered space time (VBLAST). SM-TC achieves better error performance when compared to previous MIMO techniques with minimum decoding complexity.

KEYWORDS– Spatial modulation, Multiple Input Multiple Output, Trellis coded modulation.

I. INTRODUCTION

The increasing demand for the high data rate in wireless communication system needs transmission techniques, which achieves high spectral efficiency.Recently, it was realized that the Multiple Input Multiple Output wireless communication systems seems to be inevitable in the accelerated evolution of high data rates applications. This MIMO communication systems, have received considerable attention of commercial companies and researchers due to their potential to dramatically increase the spectral efficiency and simultaneously sending individual information to the corresponding users in wireless system. In MIMO scheme, multiple antennas are used at the transmitter and receiver. This will achieve diversity gain and antenna gain.The well-known vertical Bell Labs layered space-time (V-BLAST) technique, in which multiple complex datasymbols are transmittedsimultaneously using multiple antennas, which directly increases the achievable data rate and spectral efficiency. As this architecture uses multiple antennas at the transmitter and receiver, it causes Inter Channel Interference (ICI). And the major drawback of this technique is that it uses Maximum Likelihood decoder for achieving a good bit error rate performance, but it produces very high decoding complexity, which increases exponentially with respect to the number of transmit antennas. When compared to V–BLAST, SM does not have any restriction on the minimum number of receive–antennas, whereas in V–BLAST it has to be greater than thenumber of transmit–antennas. Another classical MIMO technique is Space Shift Keying (SSK), which uses only one information carrying unit. It map the block of information bits only to the antenna index rather than transmitted symbols.

In order to reduce the decoding complexity at the receiver side, a new modulation technique called spatial modulation has been recently proposed. Spatial Modulation is a novel data transmission technique for MIMO wireless communication systemin which depending upon the input bits both a transmit antenna and a symbol will be selected. The basic idea of spatial modulation technique is to map the input information to: 1) single antenna index chosen from multiple transmit antennas and 2) a symbol selected from signal constellation diagram. Since only one antenna is active during data transmission, ICI is completely eliminated and the decoding complexity at the receiver will be reduced. Spatial modulation does not require synchronization between the antennas and it needs only one Radio Frequency chain at the transmitter side. The receiver uses the antenna number and the data symbol to retrieve the original block of information bits.

In wireless communication, in addition to spectral efficiency, energy efficiency is another eminent issue. TCM is a well-known technique which is a combined effect of coding and modulation. TCM reduces power requirement without

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expanding bandwidth. The developers of SM developed a Spatial Modulation-Trellis coding (SM-TC), where the main idea is to apply the concept of TCM to SM to achieve better performance in both correlated and uncorrelated channels.In SM-TC, trellis encoder and SM mapper are jointly designed. In TCM, the block of information bit is divided into two sequences; the first sequence enters into SM mapper after passing through convolutional encoder of rate; and the second sequence directly enters into SM mapper. SM mapper selects the transmit antenna that is active by modulating the bits that are coded and selects the symbol by modulating uncoded bits. TCM uses Ungerboeck set partitioning which partitions the signal constellation into subsets called cosets. The constellation must be partitioned in such a way thatthe minimum Euclideandistance between the twopoints is increased. The decoding complexity reduces as the Euclidean distance increases. At the receiver side soft decision Viterbi decoder is used for coded bits and then combines with demodulated uncoded bits to produce the estimate of the input information sequence.

A. Literature Survey

a. New Trellis code design for spatial modulation

In this paper it is explained what is MIMO and Spatial Modulation with Trellis coding. Trellis encoder and SM mapper are jointly designed. In this design a soft decision Viterbi decoder is used at the receiver.Pairwise Error Probability upper bound derived for SMTC. SMTC scheme achieve better error performance than classical space-time trellis codes and coded V-BLAST systems at the same spectral efficiency and with reduced decoding complexity.

b.Trellis coded spatial modulation

In this paper the idea is to apply TCM concept to antenna constellation points of SM. And the aim is to enhancing SM performance in correlated channel condition. TCSM partitions the entire set of transmit antennas into subsets such that the spacing between antennas within a particular subset is maximized. Performance and complexity of TCSM is compared to performance of SM, coded V-BLAST and alamouti scheme combined with TCM.The complexity in this scheme is 80 % less than V-BLAST complexity.

c. Space-Time Block Coded Spatial Modulation

STBC-SM combines both STBC and SM. In this paper, transmitted symbols are expanded not only on time and space domain but also to the spatial (antenna) domain. A low complexity maximum likelihood is given for this scheme. STBC scheme use MIMO because of their implementation simplicity as well as their low decoding complexity.Orthogonal STBC have attached attention due to their single symbol ML receiver with linear decoding complexity. But symbol rate of OSTBC is upper bounded by ¾ sumbols per channel use (pcu) for more than two transmit antennas.

II. SYSTEM MODEL

As shown in Fig.1, consider a SM-TC model which contains Nt transmit antennas and Nr receive antennas. Suppose M-ary PSK modulation technique is used and then define n = log2 (MNt).

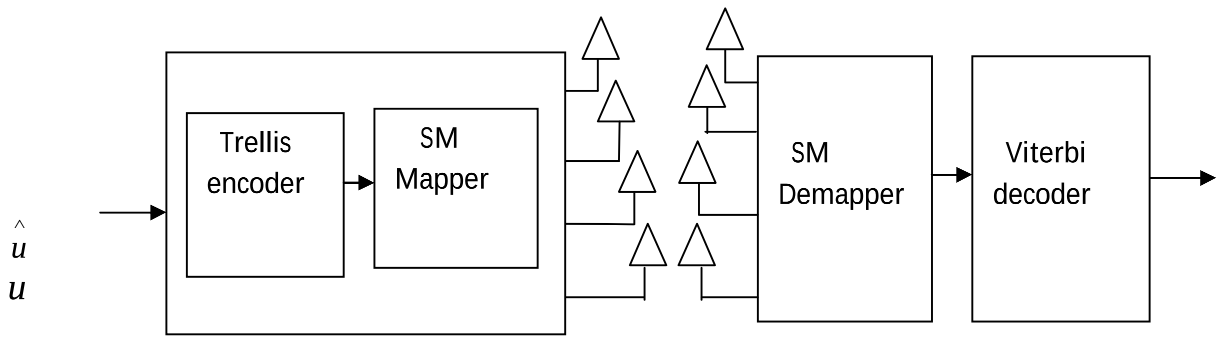

Fig.1.SM-TC system model.

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At the transmitter side, SM-TC system includes one trellis encoder (convolutional encoder) and SM mapper jointly designed. The input sequence is first encoded by trellis encoder at a rate k/k+1 and mapped into a SM mapper. The SM mapper first maps the index of the transmit antenna which can be determined by first log2(Nt) bits of the coded sequence. Then it maps the left log2(M) bits of the coded sequence onto signal constellation.

The signal which is emitted by the active antenna then enters through a wireless channel. Due to the different spatial positionsoccupied by the transmit–antenna in the antenna–array, the signal transmitted by each antenna experiences different propagation conditions. Since only one transmit antenna will be active at any time instance, so only one signal will be actually received. The other antennas will not radiate any power.

The receiver detects the signal which is coming from the transmitter. Channel impulse responses (NtNr) need to be estimated which depends upon the number of transmitting and receiving antennas. At the receiver side, a soft decision viterbi decoder is used which is fed with Soft information. The information is supplied by the SM decoder in order to produce the estimated version of the input information sequence.

UngerboeckSet Partitioning

The functions of TCM is the combined effect of a convolutional coder of a code rate R = k / k +1 and an M-ary signal mapper that maps $M = 2^k$ input points into a larger constellation of $M = 2^{k+1}$ constellation points.For k = 2, and code rate of 2/3that takes a QPSK signal(M=4) and put out an 8- PSK signal (M=8). So instead of expanding the bandwidth As the signal goes from QPSK to 8PSK, it instead doubles the constellation points. Thus it conserves bandwidth by doubling the number of constellation points of the signal.

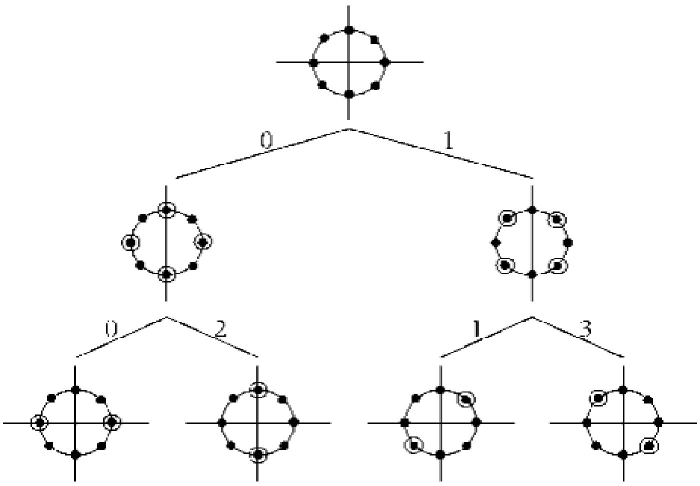

Fig.2. Ungerboeck 8PSK set partitioning.

Consider any two point at (X1,Y1) and (X2,Y2), then the Euclidean distance between the two point is given by the formula $\sqrt{(X1-Y1)^2+(X2-Y2)^2}$ Ungerboeckproposed such method which is based on the principle of mapping using set partitioning. In set partitioning, the M-ary constellation is divided into subsets with larger minimum Euclidean distance.Set partitioning technique follows three Ungerboeck rules:

1. Parallel transitions are considered as the members of the same partition;
2. Adjacent transitions are considered members of the next larger;

3. To make all the signals to be used equally.

In the first partitioning, the 8-points constellation is subdivided into two 4-point subsets as shown in the Fig.2.The square of the minimum Euclidean distance d_{min}^2increases to $2d^2$ from d^2. In the second partitioning, each of the two 4-point subsets is subdivided into two subsets of 2-point, and the square of the minimum Euclidean distance d_{min}^2 is increasedto $4d^2$. This process continues on the subsets until each subset has only two points.

III. SPACE-TIME BLOCK CODED SPATIAL MODULATION (STBC-SM)

In the STBC-SM scheme, both STBC and SM are combined together to take the advantage of both.In this method, both STBC symbols and the indices of transmit antennas from which these symbols aretransmitted carry information. A low complexity Maximum likelihood (ML)is derived for the proposed STBC-SM system Alamouti's code is chosen which transmits only one symbol per channel use, which provides advantage in terms of spectral efficiency and simplified ML detection.Furthermore, it is shown that this scheme achievesbetter error performance than OSTBC.

IV. VBLAST versus SM

The use of multiple antennas at both the transmitter and receiverside is shown to be an effective way of improving the capacity and reliability of single antenna wireless systems. Two general MIMO transmission techniques, space-time block coding and spatial multiplexing, have been proposed in the past decade. A novel concept called spatial modulation has been introduced by Mesleh et al. as an alternative method to these two transmission techniques [2]. The basic idea of SM is an extension of two dimensional signal constellations to a third dimension, which is called the spatial dimension.

V. TRELLIS CODED SPATIAL MODULATION

In TC-SM method, the trellis encoder and the SM mapper arejointly designed and a soft decision Viterbi decoder is used at the receiver which is fed with the soft information supplied by the optimal SM decoder. For TC-SM, the general conditional pairwise error probability (CPEP) is derived, and then for quasi-static Rayleigh fading channels, the unconditional PEP (UPEP) of TC-SM is obtained with path lengths two and three. Code design criteria are used to obtain the optimum codes with optimized distance spectra.Performance and complexity of TCSM is compared to performance of SM, coded V-BLAST applying near optimum sphere decoder.

VI.SIMULATION RESULTS AND COMPARISON

The simulation results and comparisons are shown in this section. Spatial Modulation technique is compared with different techniques like STBC and SMTC.

A. Comparisonof SM and STBC-SM

It is shown in figure.3, Under Rayleigh fading conditions the STBC-SM provides SNR gains 3.5 dB over SM. This result shows that one can optimize the error performance without expanding the spatial constellation to improve spectral efficiency.

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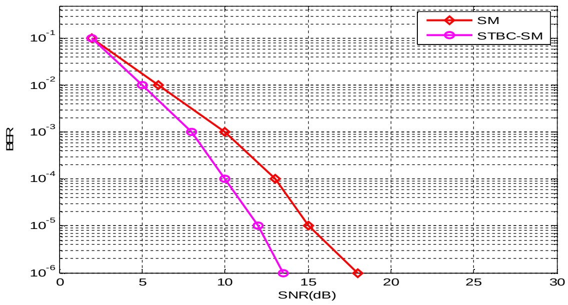

Fig.3.BER performance at for STBC-SM and SM

B. Comparison of SM and SMTC

The Graph shown in figure 4 shows the BER of a Spatial Modulation MIMO scheme for different scenarios. It is shown that spatial modulation with trellis coding has outperformed conventional spatial modulation scheme. Thus we can conclude that SMTC with higher r value gives better error performance which is very much necessary for wireless communication system.

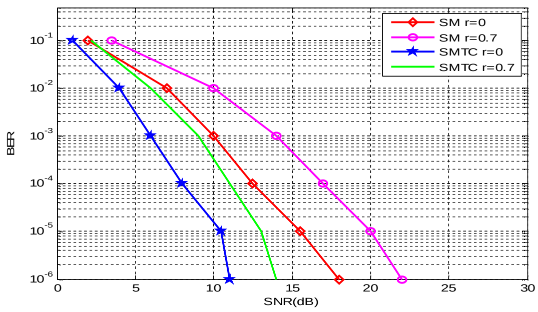

Fig.4.Comparison of SM and SM-TC

VII. CONCLUSION

It has been shown via computer simulations and also supported by a theoretical upper bound analysis that the combined effect of Spatial Modulation and Trellis coding offers significant advantages in BER compared V-BLAST and SM systems. Set partitioned TCM achieves better error performance and improves spectral efficiency with reduced decoding complexity compared to other classical MIMO schemes.

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