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RESEARCH ARTICLE

Low Complexity Multiple Active Transmit Antenna For High Transmit Rate

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Abstract— Wireless networks have quickly become part of everyday life. Wireless LANs, cell phone networks, and personal area networks are just a few examples of widely used wireless networks. However, wireless devices are range and data rate limited. A generalized spatial modulation (SM) scheme with multiple active transmit antennas, named as Multiple Active- Spatial Modulation (MA-SM), is alternative to the STBC system. It allows several antennas to be active simultaneously to achieve high transmit rate. In the MA-SM system, the transmitted symbols are mapped into a high dimensional constellation space including the spatial dimension. A general principle for designing the MA-SM code is to carefully designing over the antenna sets and the rotation angle applied to symbols, more diversity gains are available. Finally, these GSM techniques are implemented in MATLAB and analyzed for performance according to their bit-error rates using BPSK, QPSK, 8PSK, and 16-QAM modulation schemes. Simulation results shows that BPSK produce a reduced bit error rate. A closed form bound for the bit error probability (BEP) of the proposed detection scheme is also derived in this paper. Numerical results with the comparison among the existing multiple-input multiple output (MIMO) systems such as space time block code (STBC) and V-BLAST demonstrate the efficiency of MA-SM.

Key Terms: - Generalized Spatial modulation; Spatial modulation; vertical-Bell lab layered space-time; maximum likelihood detection; multiple-input multiple-output (MIMO) system

I. INTRODUCTION

MIMO is a wireless communication scheme which exploits the space dimension to improve wireless systems capacity, range and reliability comparing with single antenna wireless systems. It offers significant increases in data throughput and link range without additional bandwidth or increased transmit power. It achieves this goal by spreading the same total transmit power over the antennas to achieve an array gain that improves the spectral efficiency (more bits per second per hertz of bandwidth) and/or to achieve a diversity gain that improves the link reliability (reduced fading). Advantages of MIMO systems include [1], [2]:

- Beamforming - A transmitter receiver pair can perform beamforming and direct their main beams at each other, thereby increasing the receiver's received power and consequently the SNR.
- Spatial diversity - A signal can be coded through the transmit antennas, creating redundancy, which reduces the outage probability.
- Spatial multiplexing - A set of streams can be transmitted in parallel, each using a different transmit antenna element. The receiver can then perform the appropriate signal processing to separate the signals.

The STBCs offer an excellent way to exploit the spatial diversity gain because of the implementation simplicity as well as their low decoding complexity [3], [4]. As a special family of STBC, the orthogonal STBC (OSTBC) has attracted attention due to its maximum likelihood (ML) decoder with linear complexity [5]. However, it has been proven to be impossible to construct full-rate full-diversity code for more than two transmit antennas with linear complexity [6]. The most widely used V-BLAST scheme can achieve a maximum multiplexing gain by allowing simultaneous transmission over all antennas. The high capacity is obtained by joint ML decoding for the data streams at the receiver, but the complexity grows exponentially with the number of streams. Similar decoding rules that provide soft information to be fed to the decoders of individual data streams are active area of research. However, the available linear sub-optimal decoders for V-BLAST, such as linear decorrelator, successive cancellation and linear minimum mean square error (MMSE) [7] have shown to degrade the error performance of the system significantly. Besides, the Inter Channel Interference (ICI) and Inter Antenna Interference (IAI) make it extremely difficult to decode streams linearly with negligible system performance degradation.

Recently developed MIMO schemes reveal that capacity gain could be further achieved by introducing spatial dimension which is coordinated by the antenna indices. Jeganathan et al. have introduced a so-called space shift keying (SSK) modulation scheme for MIMO channels in which amplitude/ phase modulation is eliminated and only antenna indices are used to convey information. Since only one antenna is permitted to be active during a time slot, the ICI and IAI are totally avoided, which results in further simplification in system design and the reduction in decoding complexity. Also, a novel scheme approaching even higher capacity by combining the amplitude/phase modulation techniques with antenna index modulation, named Spatial Modulation (SM), is proposed to extend the constellation into a three dimension one (both the complex plane and the spatial dimension are involved) [8]. Symbols are emitted from a selected antenna after being mapped through a traditional modulator. Therefore, the information is conveyed not only by the amplitude/ phase modulation techniques, but also by the antenna indices. The ICI and IAI in SM system will also be avoided if only one antenna is active all over the transmission. Hence the low complexity decoder is capable of prominent performance.

Both the SM and SSK modulation systems allow for one' active antenna to eliminate the ICI and IAI, which, however, limits the exploitation of spatial dimension and design flexibility. Recently, an extension of SM, named as generalised SM (GSM), which allows several antennas to be active simultaneously. In order to achieve high transmit rate, GSM requires a large number of transmit antennas that increases the complexity of the system exponentially. Space Time Block Coding-Spatial Modulation (STBC-SM) scheme, in which SM is combined with Space Time Block Code (STBC) to exploit high spectral efficiency from SM and enjoy coding gains from STBC. At the transmitter side, mapped symbols are emitted from several chosen antennas after being coded with STBC encoder. At the receiver side, a demodulator combining ML algorithm along with the linear STBC decoder is shown to be optimal. Similar to STBC, STBC-SM suffers from either low multiplexing gain or high computational complexity when the block code size extends to more than two. Since the ML decoder for STBC-SM employs an exhaustive search of antenna sets, the decoder complexity increases exponentially as the antenna subset expands. Both the low multiplexing gain and the computational complexity limit the applicability of STBC-SM significantly.

II. MULTIPLE ACTIVE SPATIAL MODULATION

A. Generalised Spatial Modulation

A Generalised spatial modulation scheme, where depending on the bits to be transmitted a certain data symbol as well as a certain beamforming vector is chosen. The receiver then has to estimate both the used beamforming vector and the transmitted data symbol for being able to reconstruct the originally transmitted bit sequence. M complex data symbols are simultaneously transmitted using M different antenna elements, thus directly increasing the achievable data rates by a factor of M in the ideal case. However, due to the inherent inter-channel interference (ICI) of such systems, rather complex receiver structures like maximum likelihood receivers are required for achieving a good performance. Here during the transmission the signals are in serial form it will be converted to parallel now the bulk of signals are transmitted at a time .After that the signal is modulated, encoded and it will be transmitted to channel. It will be an any Rayleigh fading channel or Rician fading channel, or correlative fading channel. Then in reception side the reverse operation will be done .Finally will obtain the original signal without any loss. Generalised spatial modulation (GSM) overcomes in a novel fashion the constraint in SM that the number of transmit antennas has to be a power of two. In GSM, a block of information bits is mapped to a constellation symbol and a spatial symbol. The spatial symbol is a combination of transmit antennas activated at each instance. The actual combination of active transmit antennas depends on the random incoming data stream. This is unlike SM where only a single transmit antenna is activated at each instance. GSM increases the overall spectral efficiency by base-two logarithm of the number of antenna combinations. This reduces the number of transmit antennas needed for the same spectral efficiency.

B. Proposed MA-SM Scheme

The general system model consists of a MIMO wireless link with N_T transmit antennas and NR receive antennas, which is illustrated in Figure 1. The source information bits are transmitted from N_P of the transmit antennas after being mapped through an M order Quadrature Amplitude Modulation (M-QAM). Through the $N_T \times N_R$ wireless channel H and the NR-dim additive white Gaussian noise (AWGN) $w = [w1w2...wNR]^T$, the received signal is given by (1) where ρ is the average signal to noise ratio (SNR) at each receive antenna, H and w are independent and identically distributed (i.i.d) entries according to CN(0, 1) (complex Gaussian zero mean distribution with variance 1) and S is the constellation set of M-QAM. The transmitted symbol X is comprised with NP QAM symbols emitted from the antennas $a_1, ...a_{NP}$, respectively. For denoting convenience, the antenna group $(a_1, ...a_P)$ will be written as $\xi j = (0, 1, ...1, ...)$, $j \in \{1, ... \lfloor \binom{Np}{NT} \rfloor_2\}$ where the N_T components stand for the states of N_T transmit antennas and each 0 and 1 represents the off and on of the corresponding antenna, respectively. For example, in a system where $N_T = 4, N_P = 2$, the possible antenna groups could be denoted as ξ1 = (1, 1, 0, 0), ξ2 = (1, 0, 1, 0), ξ3 = (1, 0, 0, 1), ξ4 = (0, 1, 1, 0), ξ5 = (0, 1, 0, 1) and ξ6 = (0, 0, 1, 1).

$$y = \sqrt{\frac{\rho}{Np}}\, HX + \omega$$

$$X \triangleq [0 \ \underset{\substack{\uparrow \\ a_1}}{s_1} \ .... \ \underset{\substack{\uparrow \\ a_{Np}}}{s_{Np}} \ 0]^T \qquad (1)$$

where $s_1, ...s_{Np} \in S$, $a_1 ....a_{Np} \in \{1,...Np\}$

This could be further simplified as (2) where $\boldsymbol{h_{ai}}$ denotes the *ai*-th column of the channel matrix ***H***.

$$y = \sqrt{\frac{\rho}{Np}}\, [h_{a1},....,h_{aNp}][s_1,.....s_{Np}]^T + \omega \qquad (2)$$

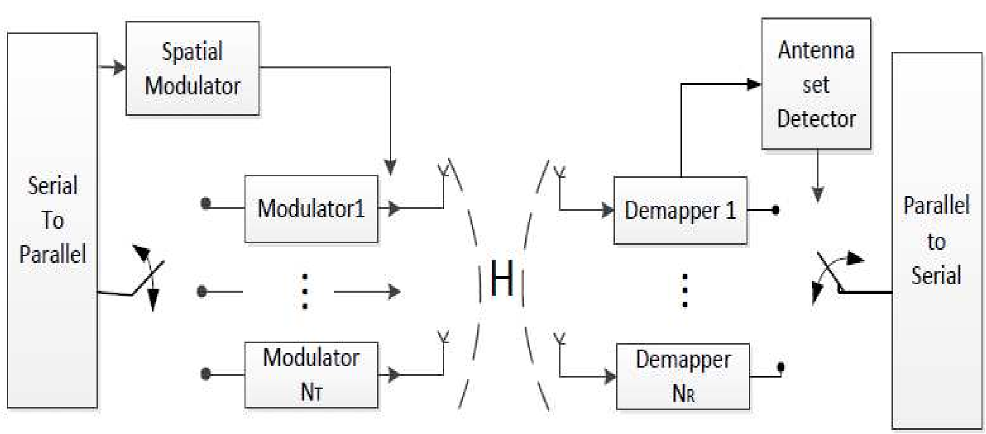

Fig. 1. System model

As we choose N_P from N_T antennas $\left\lfloor \log_2 \binom{N_T}{N_P} \right\rfloor$ bits could be conveyed on antenna indices. At high SNR, the capacity of MA-SM is approximately $N_p C_{norm} + \left\lfloor \log_2 \binom{N_T}{N_P} \right\rfloor$ Where $C_{norm} = \log_2\left(1 + \frac{SNR}{N_P}\right)$ denotes the capacity of a single channel in the MIMO system. In practice, an MA-SM transmitter works as follows: 1) Every appropriate N_P antennas from N_T are selected as an antenna group 2) Encode the antenna sets composed of N_P antennas into bits sequence with length $\left\lfloor \log_2 \binom{N_T}{N_P} \right\rfloor$ 3) Information bits are divided into N_P +1 streams among which N_P streams are mapped into QAM symbols selected from the *M*-QAM symbol subset *S* and the other one determines the selection of antenna group from the set *A*. 4) Determine the rotation angle θ for each $\boldsymbol{X}$, where θ denotes the rotation angle of signal vectors that will be discussed later. 5) Transmit the mapped N_P symbol streams from the chosen N_P antennas. At the receiver side, the decoder estimates both the indices of active antennas and symbols conveyed by them from the received *NR*-dim signal vector with the knowledge of channel state information (CSI).

C. System Design And Optimization

In MA-SM system, the information bits are conveyed by both the complex symbols and the indices of the active antennas from which those symbols are transmitted. At the transmitter side, N_P antennas are chosen to carry different symbols during the transmission, which results in the increase of multiplexing gain. Theoretically, there is no limitation on N_p, which implies

the constellation set of MA-SM could be denoted as the Cartesian product of the complex set including both the real and imaginary parts of the transmit symbols and the antenna groups with a discrete topology. Besides, the available antenna groups composed of the N_T antennas are always more than $2^{\lfloor \log 2 \rfloor}$ which means that we can carefully select the active antenna groups to minimize interference. Since the minimum distance between codewords dominates the BEP, transmission scheme can be optimized by maximizing the minimum distance involved. Unlike the traditional complex space where Euclidean distance could be applied, the three dimensional space here contains a discrete dimension that confuses the definition of distance. Referring to the most widely used distance definition in discrete metric space as in a similar definition could be derived.

$$\delta(a,b) = \begin{Bmatrix} 0, a = b \\ 1, a \neq b \end{Bmatrix} \qquad (3)$$

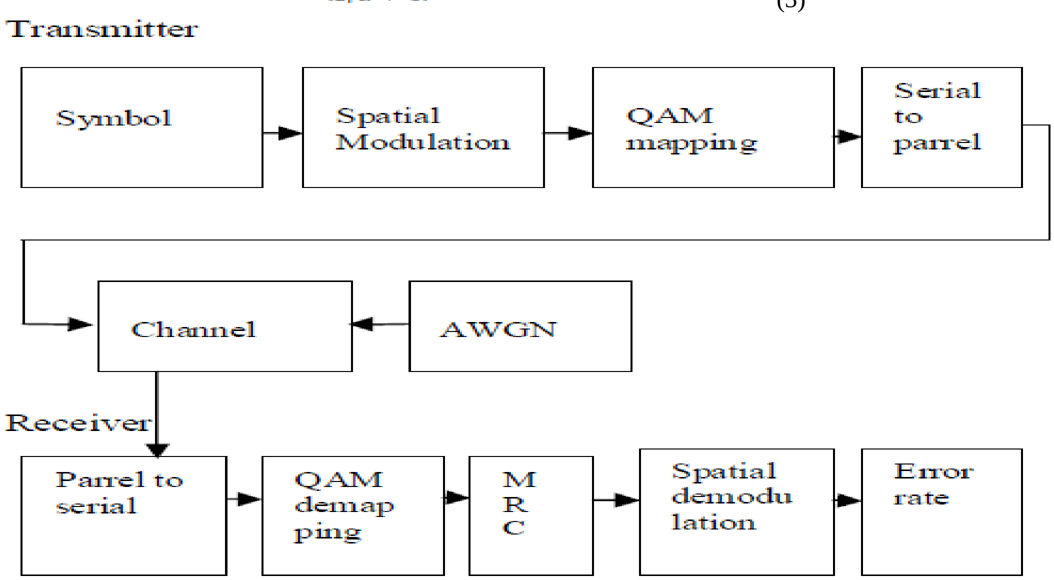

Fig.2. Block Diagram of MA-SM

Substituting a and b with the antenna group ξj in equation (3), we define the hybrid distance d as (4a) in which the Frobenius Norm equals to the Euclidean distance and θξj ,si denotes the rotation angle applied to QAM symbol si ∊ S emitted from antenna group ξj . δ is defined as the number of different indices between two antenna groups as given in (4b). For example, ξe distance between ξ1 and ξ4 listed in subsection A is derived as

$\delta(\xi1, \xi4) = 2$. This definition can be easily proven to satisfy the criterion for metric space. When the minimum distance between two codewords X and $\hat{X}$ is maximized, the performance gain is achieved.

$$d(X,\hat{X}) = \min \{\sqrt{\delta^{2+\left\|s_i \theta_{\xi j,si} - s_{\hat{i}} \theta_{\xi_{\hat{j}},s_{\hat{i}}}\right\|^{2}}}\} \quad (4a)$$

$$\delta(\xi_{j}, \xi_{\hat{j}}) = \begin{cases} 0, xor(\xi_{j}, \xi_{\hat{j}}) = 0 \\ 1, xor(\xi_{j}, \xi_{\hat{j}}) = 1 \\ \dots \dots \\ p, xor(\xi_{j}, \xi_{\hat{j}}) = p \end{cases} \quad (4b)$$

It can be seen from the definition (4a) and (4b) that the optimization could be executed in the selection of antenna groups and complex symbol, respectively. First consider the antenna group optimization denoting $\left\lfloor \log_2 \binom{N_T}{N_P} \right\rfloor = q$, the number of illegal sets is written as $\binom{N_T}{N_p} - 2^q$, which provides redundancy for antenna set selection. When there is no illegal set available, which means $\binom{N_T}{N_p} = 2q$, this selection procedure could be skipped. Otherwise, the distance definition indicates that we should try to avoid overlapping antenna indices between different groups since groups sharing the same antenna indices will lead to the increase of the linear dependence probability of channel space. By maximizing the first part in $d(X,\hat{X})$, antenna groups are made to be far away from each other with least possible overlapped indices.

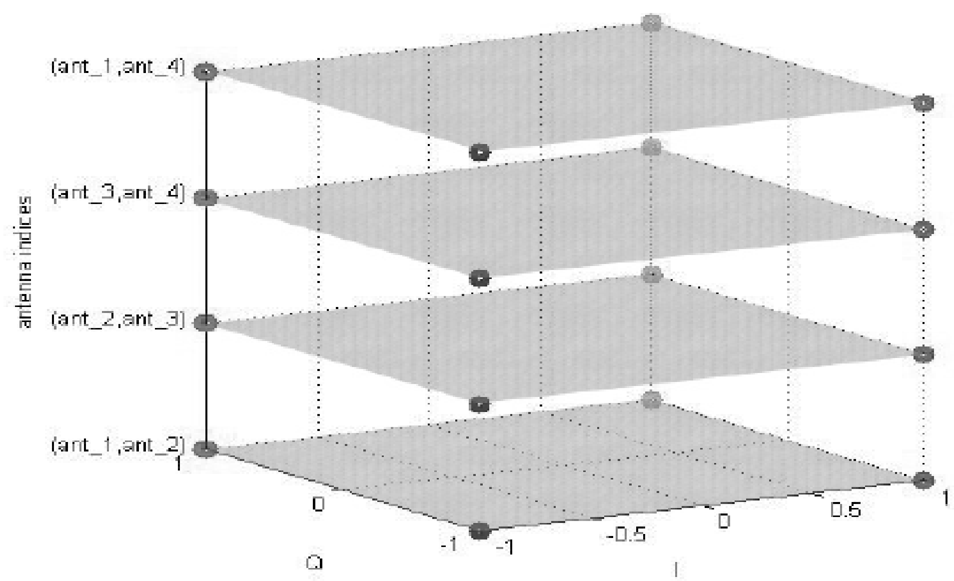

Fig 3 (a) original constellation before rotation

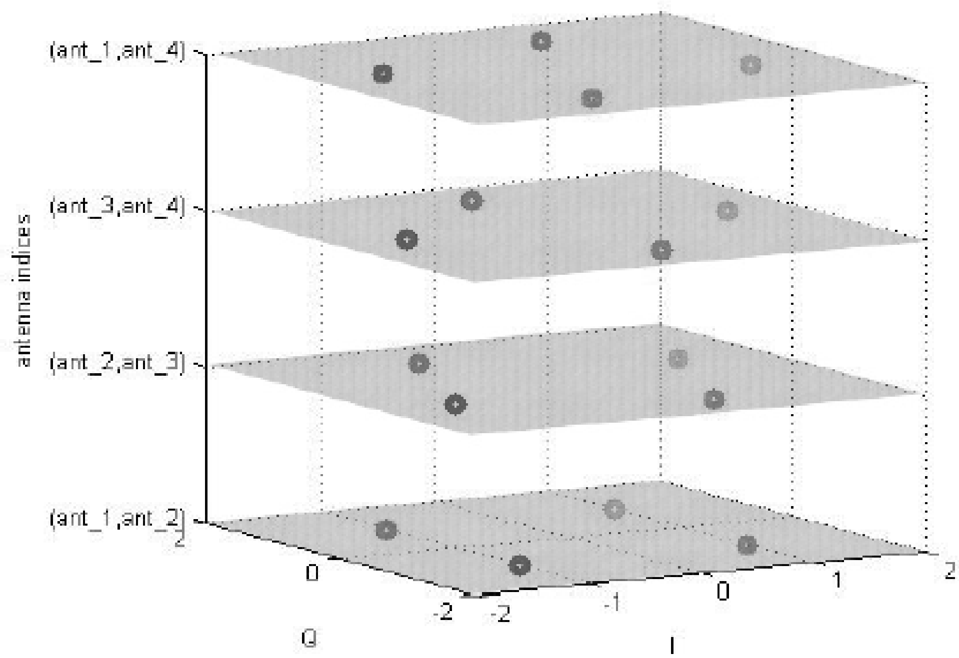

Fig 3 (b) original constellation after rotation

As to the complex symbol optimization, it could be observed from (4) that the minimum distance between symbols could be maximized by properly choosing the rotation angles. The 3-dim constellation could be treated as one constituted by different constellation planes. Each of them is a standard QAM constellation and planes are distinguished by the antenna groups. Since the Euclidean distance between symbols locating on the same complex plane is maximized with the QAM modulation, rotation angles for them on the same plane should be exactly the same. For convenience, it denote the complex plane composed of constellations with the *j*-th antenna group as *Pj* , and the rotation angle applying to it as *θj* . The three dimensional constellation could be divided int $2^{\left\lfloor \log_2 \binom{N_T}{N_p} \right\rfloor}$ complex planes that could be rotated separately. The minimum distance for *M*-Phase Shift Keying (PSK) system could be derived as

$$\min\{d\} = \min\left\{\|s_{j,m}\,\theta_j - s_{j,\bar{m}}\theta_j\|, \sqrt{1 + \|s_{j,m}\,\theta_j - s_{\bar{j},m}\theta_{\bar{j}}\|^2}\right\} \tag{5}$$

Thus the rotation angle for *M*-PSK could be easily derived as (6), where *n* equal to $2^{\left\lfloor \log_2 \binom{N_T}{N_p} \right\rfloor}$. After rotation, **X** is distributed adequately in the three dimension. For M-QAM constellation (M > 4), the selection of θj as in (6) would not work. The optimal angle for M-QAM (M >4) could be derived via extensive computer search.

$$\theta_j = \frac{2(j-1)\pi}{M\,n} \tag{6}$$

Let us consider the 4×4 MA-SM system employing QPSK as an example. Assuming 2 of 4 transmit antennas are active during one time slot, from which we can obtain 2 bits capacity gain. The transmitted symbol ***X*** is given as one of vectors in (7), where *θi* denotes the rotation angle of signal vectors.

$$X_1 = [x_1, 0, x_2, 0]^T e^{j\theta_1}, \quad X_2 = [0, x_1, 0, x_2]^T e^{j\theta_2}$$

$$X_3 = [0, x_1, 0, x_2]^T e^{j\theta_3}, \; X_4 = [x_1, 0, x_2, 0]^T e^{j\theta_4}$$

Where $x_1, x_2 \in S$ (7)

$$\theta_1 = 0,\ \theta_2 = \pi/8,\ \theta_3 = \pi/4,\ \theta_4 = 3\pi/8$$

The 3-dim constellation of the example is shown in Figure 3 in which the Figure (a) shows the original constellations and Figure (b) is the constellations employed with rotation. Both figures employ QPSK with four legal antenna groups and constellations drawn in different layers denote the constellations in different antenna groups. The antenna group coordinate, including but not limited to the given examples in Figure 3, is sorted with the proposed distance constraint in definition (4b). In practice, a target transmission rate could be realized with various kinds of antenna combinations which could be optimized in several ways.

D. Detection

In the MA-SM system, the receiver must solve the $\left\lfloor \binom{N_T}{N_P} \right\rfloor_2 \times$ M-hypothesis problem with the proper algorithm. The optimal ML decoder, which detects the antenna set together with the symbols, increases exponentially in complexity for high order constellation since the exhaustive search space increases at the speed of $N_p M^{N_p}$ as N_P grows. We will introduce a near-optimal detection method with low complexity for MA-SM scheme. Considering the signal transmission model as in (1) and assuming that the indices of active antennas are $a_1, \ldots a_{NP}$, we could rewrite it into (8) to simplify notation.

$$\mathrm{y} = \sum_{j=1}^{N_P} \mathrm{h}_{a_j} \mathrm{s}_j + \omega \tag{8}$$

This illustrates the linear structure of the signal space that the received signal **y** is the linear combination of the channel vector corresponding to the active antennas. If the noise could be ignored, **y** lies in the subspace G_k spanned by ha_1 , $\ldots h_{NP}$. Supposing that the dimension of G_k is p_k, we can judge whether the vector is in the subspace or not via projecting **y** onto the subspace G_k to derive the vertical distance between them. Since projection is a linear operation, we can represent it using a p_k by N_R matrix T_k, the rows of which form an orthogonal basis of G_k. The vector $y - T_{ky}$ should be interpreted as the vertical distance from the vector y to subspace T_k, but expressed in terms of the coordinates defined by the basis of G_k formed by the rows of T_k. Based on Tse's decorrelator described in (8), the decorrelator for the kth stream T_k is the k-th row of the pseudoinverse H^T of matrix H, defined by (9).

$$H^T \triangleq (H^H H)^{-1} H^H \tag{9}$$

Hence the antenna group detection could be written as (10)

$$(a_{1,\ldots\ldots} a_{N_P}) = arg\max_k \{T_k y\} \tag{10}$$

The inter-group detection will be successful (that is, the resulting projection of G_k is distinct) if the columns in H are not a linear combination of the spatial signatures of the other channel vectors. It is noted in [7] that, we should choose the number of active antennas to be no more than N_R to ensure the successful detection. For notational convenience, we will consider only the transmit antennas that are used, by just making the assumption $N_P < N_R$ in the decoder discussion henceforth. We are now confronting the symbol detection with the selected antenna group. Focusing on the a_m-th antenna, we

can get

$$y = h_{a_m} s_m + \sum_{a_j \neq a_m} h_{a_j} s_j + \omega \tag{11}$$

It can be seen that the m-th data stream faces an extra source of interference, which is from the other active antennas. One method that can be used to remove this inter stream interference is to project the received signal y onto the subspace orthogonal to the one spanned by the vectors $h_{a_1}, \ldots . h_{a_{m-1}}, h_{a_{m+1}}, \ldots h_{a_{Np}}$ (denoted henceforth by V_m). Suppose that the dimension of V_m is d_m. Projection is a linear operation and we can represent it by a d_m by N_R matrix Q_m. The rows of Q_m form an orthonormal basis of V_m and they are all orthogonal to $h_{a_1}, \ldots . h_{a_{m-1}}, h_{a_{m+1}}, \ldots h_{a_{N_P}}$. The vector $Q_m v$ should be interpreted as the projection of the vector v onto V_m, but expressed in terms of the coordinates defined by the basis of V_m formed by the rows of Q_m. This projection could be denoted as

$$\hat{y} = Q_m y = Q_m h_{u_m} x_m + \tilde{\omega} \tag{12}$$

After the projection, the optimal demodulation of the mth stream can be performed by match filtering the vector $Q_m h_m$. Since the projection and matched filtering are both linear operations, the decoder can be viewed as a linear filter. The filter c_m is given by

$$c_m = (Q_m^H Q_m) h_{a_m} \tag{13}$$

Since the matched filter maximizes the output SNR, the decoder can also be interpreted as the linear filter that maximizes the output SNR subject to the constraint that the filter eliminates the interference coming from all other data streams. Intuitively, we project the received signal in the direction within V_m that is closest to h_{a_m} in the proposed detection method. Hence the coefficient of decoder filter for the m-th stream is the m-th column of the pseudo inverse H_p^T.

E. Complexity

The complexity of both the transmitter and receiver are taken into consideration. The complexity of the decoder for MA-SM is compared to the complexity of the ML decoder and some other optimal decoders for SM and GSM. The number of operations needed is used to estimate the receiver complexity. The number of transmit antennas needed for a target transmission rate has enormous implications on the complexity of the transmitter.

Since there are multiple antennas being active simultaneously conveying different symbols, the number of antennas needed decreases prominently for a given size of constellation. For example, let R = 10 bits/s/Hz, QPSK employed, at least 8 transmit antennas are needed in a GSM scheme and 64 antennas are needed in SM system while only 4 transmit antennas are essential in an MA-SM system. To estimate the computational complexity of the proposed MA-SM decoder, we use the number of multiplications required in the detection process. The number of additions can be shown to have a similar view. Generally speaking, the optimal ML decoder applies exhaustive search employing as high as $\left\lfloor \binom{N_T}{N_P} \right\rfloor_2 M^{N_P} N_R (N_P + 2)$ multiplication. As to the proposed decoder, assuming Gaussian Elimination is employed in deriving the matrix inverse, the total multiplications involved are $(2N^3{}_P + 3N^2{}_P - 5N_P)/6 + 2N_R N^2{}_P + N_P N_R + f(M)$, in which the first term denotes the multiplication needed for matrix inverse operation , the second term corresponds to the matrix multiplication, the third one is for the projection needed and the last one denotes the complexity of QAM demapper employed. Since there are various algorithms for QAM demodulator to demap constellations without any multiplications involved, $f(M)$ could be omitted in the complexity derivation. Thus the whole complexity does not increase exponentially as the QAM constellation expands. The complexity derivation also shows that it is the matrix inverse that dominates the whole decoding complexity. Fortunately, for most systems, the Matrix Inverse Lemma is available to further simplify the complexity for low order matrix since the iteration algorithm helps decrease the multiplications significantly. In particular, only two multiplications are needed for matrix inverse when $N_P = 2$. For instance, in a 4 × 4 MIMO system with $N_P = 2$ and 16QAM modulation, the optimal ML needs 16384 multiplications while the proposed decoder only employs 43 multiplications in which only two multiplications are introduced from matrix inverse. This result motivates the use of our detection scheme in practical systems. In order to be convincing, more complexity comparisons between existing schemes and decoders are to be made. The number of essential multiplications of the optimal SM decoder given in is equal to to $NTM(3N_R+1)$ and the GSM decoder introduced in employs $NRNCM(N_P+2)$ multiplications where $Nc = \left\lfloor \binom{N_T}{N_P} \right\rfloor_2$. For fairness, all the comparison will be made under the same transmission rate. From the derivation of system capacity, we have the equality that for a target rate, MNC(GSM)= MN_T (SM)= $MNPNC$(MA-SM). Thus we get (14) in which γ_1 denotes the complexity ratio of optimal MA-SM receiver to optimal GSM decoder under the same target rate R, γ_2 denotes the ratio of optimal MA-SM decoder to optimal SM decoder introduced in, γ_3 denotes the ratio of proposed low complexity MASM decoder to optimal GSM decoder and γ_4 denotes the ratio of proposed MA-SM decoder to optimal SM decoder.

$$\gamma_1 - \frac{N_R N_c M^{N_P}(N_P+2)}{N_R N_C M(N_P+2)} - 1$$

$$\gamma_2 = \frac{N_R N_C M^{N_P}(N_P+2)}{N_R N_T M(3N_P+1)} = \frac{N_R(N_P+2)}{3N_R+1} \tag{14}$$

$$\gamma_3 = \frac{(2N^3{}_P + 3N^2{}_P - 5N_P)/6 + 2N_R N^2{}_P + N_P N_R + f(M)}{N_R N_C M(N_P+2)}$$

$$\gamma_4 = \frac{(2N^3{}_P + 3N^2{}_P - 5N_P)/6 + 2N_R N^2{}_P + N_P N_R + f(M)}{N_R N_T M(3N_P+1)}$$

Since the complexity of the proposed decoder is unrelated to the size of QAM employed, we could readily observe the degradation in complexity compared to the other schemes. As the rate of transmission grows, more complexity margins are available with the proposed decoder for MA-SM. The trends of receiver complexity as the transmission rate increases are plotted in Figure 4.4. Parameters for different rates of transmission are chosen according to Table4.1. It could be readily observed that the complexity margin achieved by the proposed decoder increases prominently as the transmission rate grows.

Rates	6 bits/s/Hz	10 bits/s/Hz	15 bits/s/Hz
N_T	4	4	5
N_P	2	2	3
Modulation	QPSK	16-QAM	16-QAM
Γ	(1,3), (2,4), (1,4), (2,3),	(1,3), (2,4), (1,4), (2,3),	(1,2,3),(1,2,4), (1,2,5),(1,3,4), (1,3,5),(1,4,5), (2,3,5),(2,4,6)
Rotation Angle	$\theta_1 = 0$, $\theta_2 = \pi/8$, $\theta_3 = \pi/4$, $\theta_4 = 3\pi/8$	$\theta_1 = 0$, $\theta_2 = \pi/8$, $\theta_3 = \pi/4$, $\theta_4 = 3\pi/8$	$\theta_1 = 0, \theta_2 = \pi/16$, $\theta_3 = \pi/8, \theta_2 = 3\pi/16$, $\theta_5 = \pi/4, \theta_2 = 5\pi/16$, $\theta_7 = 3\pi/8, \theta_8 = 7\pi/16$

Table1 MA-SM Solution for Various Transmission Rates

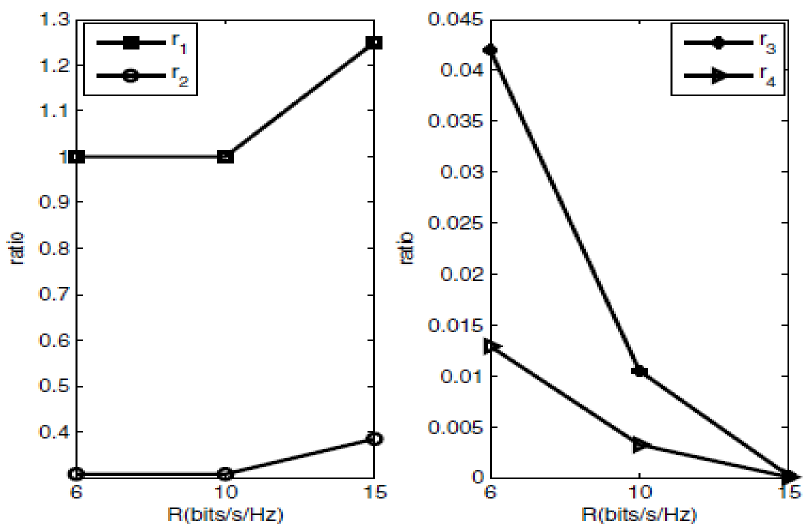

Fig 4.Comparison of Complexity among Schemes

III. THEORETICAL ANALYSIS

We now derive the bit error probability (BEP) for the proposed detector in uncoded system to estimate its performance. To be brief, we will mainly focus on system with *NT* transmit antennas and *NP* active antennas employing bit phase shift keying (BPSK). The analysis could easily be extended to other cases. For convenience, we assume that the power of the transmit symbols is normalized and the Gaussian noises added on all the receive antennas are with the same variance $\sigma 2$. Thus the system model could be rewritten as

$$y = HX + \tilde{w} \qquad (14)$$

An error that occurs in the demodulator could be categorized into two scenarios due to the separated steps in demodulator. The first kind is the error occurs in the active antenna detection (denoted by PAntErr) and the second one is that the error occurs in traditional demapping when antenna detection is correct (denoted by PModErr). The overall BEP could be bounded as

$$P_{error} = 1 - (1 - P_{AntErr})(1 - P_{ModErr}) \qquad (15)$$

be denoted as (16) with the corresponding noise w˜k distributed according to CN(0, σ2||$\mathbf{T}_k$||2).

$$\lambda_k = \mathrm{T}_{ky} = \mathrm{T}_k \mathrm{HX} + \tilde{\omega}_k \qquad (16)$$

The total BEP is bounded as (17) which implies the performance degradation caused by the IAI and ICI between active antennas.

$$BEP < \frac{1}{\log B}\left\{\frac{N_p(N_T-N_p)}{2}\left(\frac{1}{1+{SNR}/{N_p}}\right)^{N_R-N_P} + \binom{2N_R-1}{N_R}\left(\frac{1}{4SNR}\right)^{N_R-N_P+1}\right\} \tag{17}$$

IV. Numerical Results

In this section, we present some simulation results for the MA-SM system for different modulation schemes and make comparisons with MIMO STBC system. The bit error rate (BER) performance of these systems was evaluated by Monte Carlo simulations for various spectral efficiencies as a function of the average SNR per receive antenna and in all cases the independence of channels is assumed unless otherwise specified. In order to be convincing, comparisons are realized under the same transmission rate without restraint on the constellations. The GSM employs the detection algorithm in [9]. Rotation parameters and antenna groups for different transmission rates in MA-SM are selected according to Table I unless otherwise specified. The transmitted signals must traverse a potentially difficult environment with scattering reflection and so. In MIMO transmits the multiple data at the same time so that the data's are occurs aliasing, to avoid this aliasing the signal are mapped and the transmitted to the channel it's very useful to find the distance between the data's and avoid interference. Comparison with some traditional MIMO schemes are presented for 10bits/Hz of MASM with N_T=4,N_R=2with 16-QAM modulation, Alamouti's STBC. Comparison of STBC & GSM for BPSK shows that for GSM it produces a reduced bit error rate. It is seen that for GSM with different modulation scheme BPSK shows a better result. BER, SER & FER for different modulation scheme are plotted.

Comparisons with some traditional MIMO schemes are presented here over different transmission rates. Figure 5 gives comparison at 6 bits/s/Hz of MA-SM with $N_T = 4, N_P = 2$ and QPSK modulation, Alamouti's STBC with $N_R = 4$ and 64QAM, STBC-SM with $N_T = 8$ and 16QAM, V-BLAST with $N_T = 3$ and QPSK modulation. Four receive antennas are assumed for all the schemes. It could be observed that MA-SM provides 1.5 dB SNR gains over Alamouti's STBC at BER value of 10^{-2}. With higher diversity gain achieved from the STBC, STBC-SM outperforms MA-SM at high SNRs while at low SNRs, MA-SM performs better. The SNR gap between V-BLAST and MA-SM is because of the detection of employed, the performance advantages of MA-SM degrade as it is the error occurring in antenna set detection that dominates. In Figure 6, the BER curves of 10 bits transmission with 5 receive antennas are plotted. MA-SM uses $N_T = 4, N_P = 2$ with 16 QAM modulation, Alamouti's STBC uses 1024 QAM modulation, STBC-SM employs 256 QAM modulation and 8 transmit antennas and V-BLAST uses $N_T = 2$ and 32 QAM modulation. It shows that MA-SM provides SNR gains of 1.5dB, 5dB and 11dB over V-BLAST, STBC-SM and Alamouti's STBC at BER value of 10^{-2}, respectively. This verifies the analysis that MA-SM becomes more efficient at high transmission rate. Another conclusion that can be made from the figure is that one can optimize the error performance without expanding the signal constellation but expanding the spatial constellation to improve spectral efficiency for MA-SM system. Based on these examples, it can be seen that MA-SM provides a prominent alternative for high rate transmission since the three dimension constellation maximize the minimum inter symbol distance.

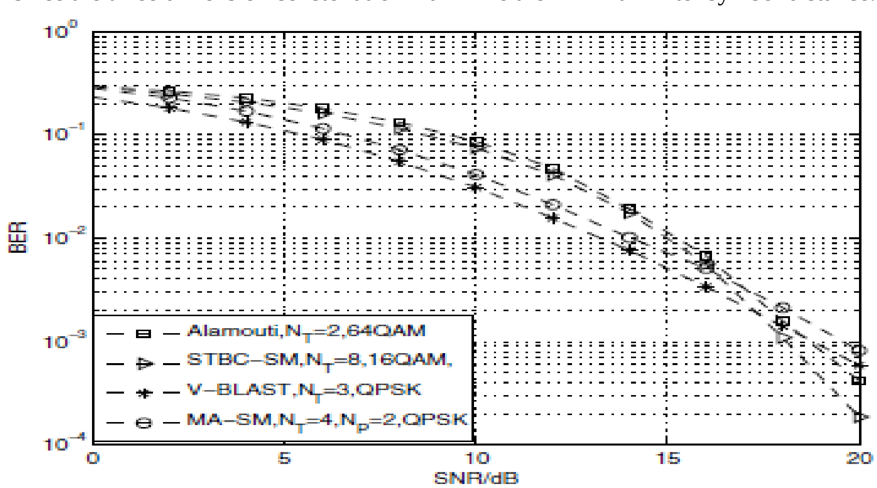

Fig 5.Comparison among some existing schemes at 6 Bits/s/Hz

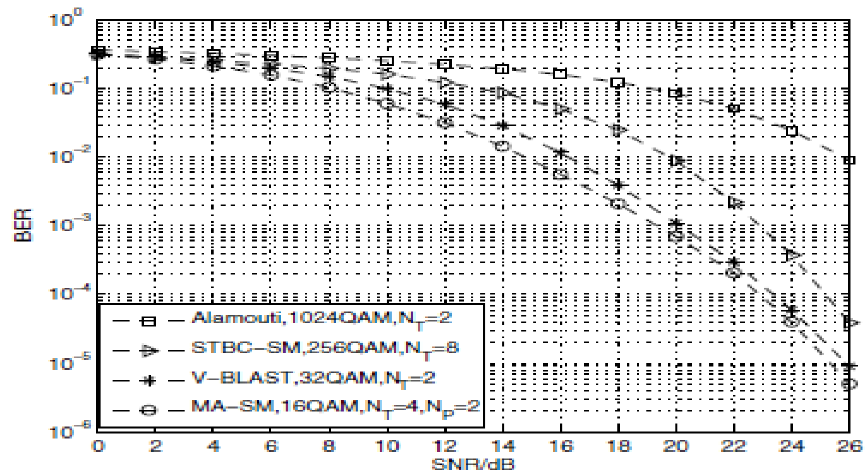

Fig 6.Comparison among some existing schemes at 10 Bits/s/Hz

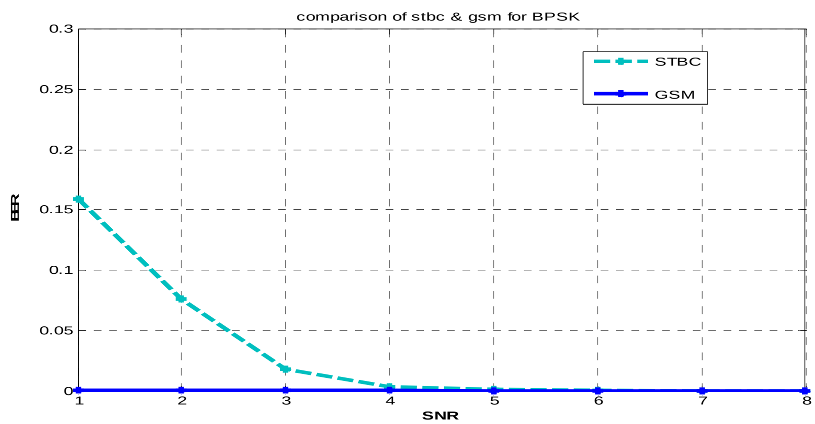

Fig 7.comparison of STBC with MA-SM for BPSK

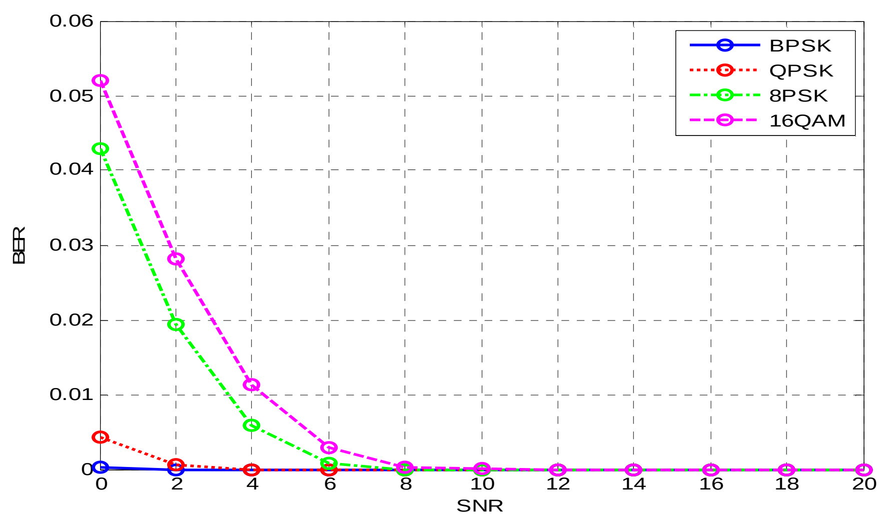

Fig 8. BER for different modulation scheme for MA-SM

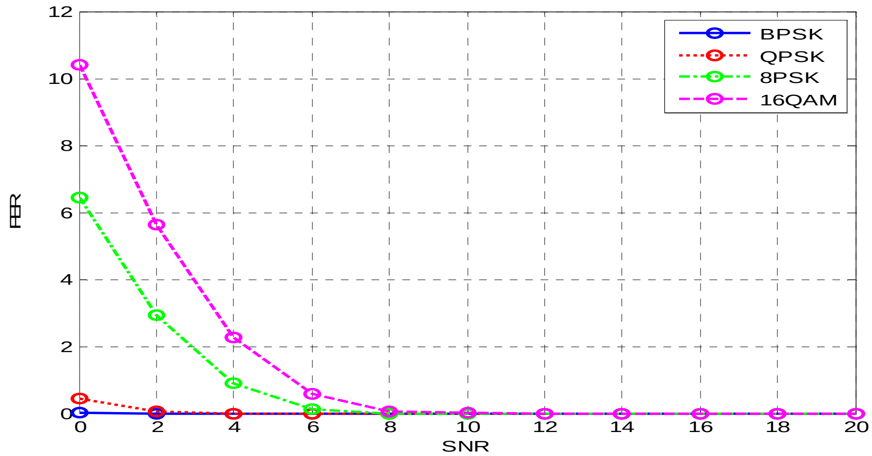

Fig 9. FER for different modulation scheme for MA-SM

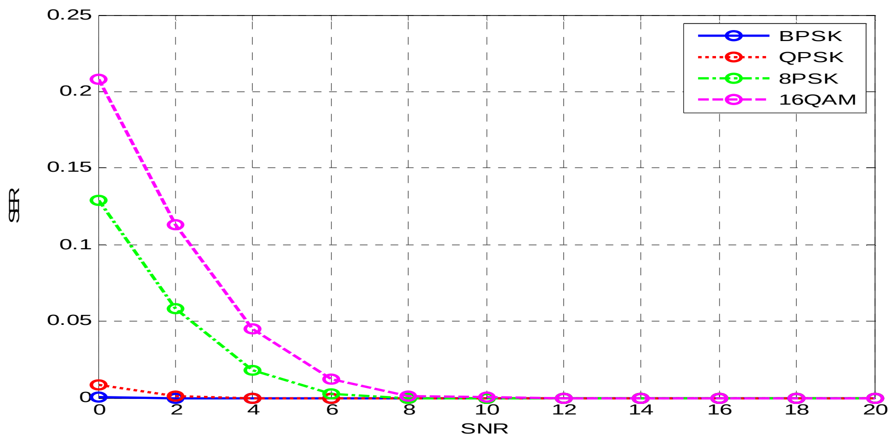

Fig 10. SER for different modulation scheme for MA-SM

V. CONCLUSION

A novel high-rate, low complexity MIMO transmission scheme, called MA-SM, as an alternative to existing techniques, such as STBC, SM and VBLAST. The proposed MA-SM scheme employs both conventional modulation techniques and antenna indices to convey information and exploit the transmit multiplexing potential of MIMO channels. It will produce reduced bit error rate compare to all other modulation techniques such as space shift keying, adaptive modulation, Spatial Modulation. Basically in MIMO two things are important .1 .Diversity, 2.Spatial Multiplexing. Both the diversity and Spatial Multiplexing are achieved by this modulation. It has been shown via computer simulations that MA-SM offers significant improvements of system performance compared with STBC systems. In generalized spatial modulation 16-QAM, QPSK, 8PSK, BPSK modulation. Compare to 16-QAM, the BPSK produce a reduced bit error rate. It can be concluded that the MA-SM scheme can be useful for high-rate wireless communication systems.

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