Performance of Spatial Modulation with Multiple Active Transmit Antennas

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***Abstract*— In this paper, a generalized spatial modulation scheme with multiple active transmit antennas, as an alternative to Space Time Block Code, Vertical Bell Lab Layered Space Time etc. named as Multiple Active Spatial Modulation is introducing. This system will achieve high diversity, high transmission rate and multiplexing gain. Since the system is activating only a minimum number of antennas, thereby it can optimize by maximizing the inter-symbol distance and hence reduce the inter channel interference and inter antenna interference. A near optimal maximum likelihood decoding is proposed to reduce the decoding complexity. In this paper, the SER performance between Multiple Active Spatial modulation and Space Time Block Code was simulated. Also using QPSK modulation Multiple Active Spatial Modulation was compared with Vertical Bell Lab Layered Space Time, Space Time Block Code and Generalized Spatial Modulation.**

Keywords— Multiple Active Spatial Modulation (MA-SM), Space Time Block Code (STBC), Vertical Bell Lab Layered Space Time (V-BLAST), Generalized Spatial Modulation (GSM), Spatial modulation (SM), Inter Antenna Interference (IAI), Inter Channel Interference (ICI).

I. INTRODUCTION

Multiple Input Multiple Output (MIMO) systems provide an extension for the developments in antenna array communication. The MIMO systems used in wireless communication provides increased spectral efficiency, reliability and capacity. The MIMO system provides many advantages [2]. The spatial diversity provided by the multiple spatial paths, reduces the sensitivity towards fading. The other advantages such as: better interference suppression, better quality of service (QoS), lower Bit Error Rate (BER) and lower transmission power [2]. There are many several MIMO techniques have been studied such as: Space Time Block Code (STBC) [3] and Spatial Multiplexing (SM), which are general schemes that achieve spatial diversity, coding gain and multiplexing gain.

Space Time Block Code (STBC) effectively uses the potential of multiple antennas because of their simplicity and high performance [4]. The STBC achieve spatial multiplexing gain and diversity. The STBC with full diversity and high transmission rates can be achieved by using algebraic number theory and cyclic division algebras [6], but these causes a maximum likelihood (ML) decodingcomplexity. The Orthogonal Space Time block Code (OSTBC), which is the family of STBC cause significant loss in the MIMO channel capacity and paid attention due to linear complex ML-decoder. Another family of STBC is Quasi-Orthogonal STBC (QOSTBC) that has a very high ML-decoding complexity, which is proportional to the seventh power of the constellation size [5].

The V-Blast, which is the family of SM provide high multiplexing gain and eliminates the space time wastages. They perform detection by using symbol cancellation as well as linear nulling [10]. They allow simultaneous transmission through all the antennas and thereby achieving maximum multiplexing gain. The decoding techniques that used in all cause the performance degradation. The inter channel interference (ICI) and inter antenna interference (IAI) made it difficult to decode the symbols. Therefore it is proven that it is impossible to achieve full rate full diversity and low complex decoding system [8], [9].

II. RELATED WORKS

In Spatial Modulation (SM) having higher capacity by combining the amplitude/phase modulation with antenna index modulation is to extend the constellation into a three dimension such as M-PSK or M-QAM to a third dimension such as spatial dimension [12]. Here in SM only one antenna can be activated during a time slot. Thereby the ICI and IAI can be avoided, but the required transmission rate and multiplexing gain cannot achieve. To overcome this, a Generalized Spatial Modulation (GSM) with multiple active transmits antennas during a time slot is used. But here to achieve higher transmission rates, it required large number of antennas to be activated simultaneously [1]. This will increase ICI and IAI. Hence increase decoding complexity.

In V-BLAST, which is the family of SM can achieve multiplexing gain, but degrade the error performance of the system due to successive cancellation, linear minimum mean square error (MMSE). Also cause increase in ICI and IAI. In Space Time Block Code (STBC), transmit the symbol in block size. This cause low multiplexing gain and linear complexity as the block size extend to more than two.
In order to reduce those entire problems and to achieve high transmission rates, multiplexing gain etc a near optimal low complex ML-decoding technique named Multiple Active Spatial Modulation (MA-SM) is proposed [13]. Here by carefully selecting the antenna set and the rotation angle applied to the symbols, the diversity gain can be achieved [5], [7]. Also achieving maximum multiplexing gain and transmission rate by using minimum number of active transmit antennas causes reduced antenna interference. Assuming channel state information is known to the receiver. Also along with the information, active antenna information is also transmitted. In this paper a comparative study is made between MA-SM, GSM, STBC and V-

BLAST. Due to IAI interference, the performance of other existing techniques degrades.

III. Multiple active spatial modulation system model

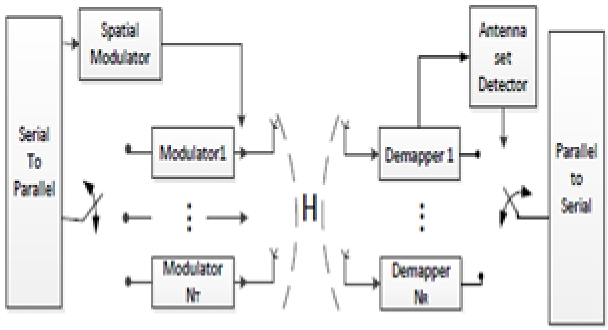

Fig 1: MA-SM system design [10]

We consider a general system model consisting of MIMO wireless link with total number of transmit antennas as Nt and total number of receiving antennas as Nr . During the time period, at the transmitter side, the source information bits is transmitted through Np of the transmit antennas after being mapped through M order Quadrature Amplitude Modulation (M- QAM). The received signal be [10]

$$y = \sqrt{\frac{\rho}{Np}} HX + w \qquad (1)$$

After mapping, the symbol is transmitted through the channel such as Rayleigh fading channel. Here during the transmission, the signals are in serial form, it will be converted to parallel form, therefore a bulk of data can be transmitted at a time and transmitted through the channel.

In reception side the reverse operation such as demodulation take place. The parallel symbols get converted back to serial form. The signals from the multiple diversity branches can be combined using various techniques [8]. In MRC, a weight factor that is proportional to the signal amplitude is multiplied to each signal branches. The branch with strong signal are further amplified and decoded, while the weak signal is attenuated. Since the signals are transmitted through multiple antennas, the spatial multiplexing gain and diversity gain is achieved by this system.

A. Transmission

The working of MA-SM transmitter as follows: Every Np antennas out of Nt antennas are selected as active antennas.Np should be a tradeoff between capacity and reliability and it should be always less than the receiver antenna Nr. In order to keep the bit symbol integral, $2^{\lfloor log_2 \binom{Nt}{Np} \rfloor}$groups are selected and others are coded as illegal. Denote the possible antenna groups are denoted as A. Bits sequence of length $log_2 \begin{bmatrix} N_t \\ N_p \end{bmatrix}$ is transmitted through the Np antennas [8], [10]. The system is optimized by calculating the minimum distance between the antenna sets and this is to avoid interference. The information bits are divided into Np+1 streams in which Np are mapped using the modulation scheme such as: BPSK, 16-QAM [1], [10] and the other one is used to transmit active antenna information. The rotation angle is calculated for each symbol. This is to rotate the constellation set. The rotation angle and antenna set that applied to the symbol; the diversity gain can be achieved. The rotation angle θ of signal vectors is determined for each X, so that more diversity gain can be achieved [1], [10]. The rotation angle minimizes the inter-symbol distanceby rotating the spatial constellation. The mapped Np symbols are transmitted through the Rayleigh faded channel. The MA-SM system is compared with GSM, STBC using BPSK, 16-QAM modulation.

In this paper, the MA-SM system is compared with GSM, STBC using QPSK modulation and also the SER performance is calculated between MA-SM and STBC. For the transmission, we are assuming four transmit antennas. Out of which two antennas are selected for transmission, which avoid inter channel interference. From each antenna, two symbols are transmitted. As the order of the modulation scheme increases, MA-SM shows better performance. The transmission scheme can be optimized, by maximizing the minimum distance between the antenna sets that dominates the BEP (Bit Error Probability) [1], [10]. Also for the system optimization, the rotation angle is calculated, in such the spatial constellation can be rotated. Also the symbol error rate (SER) is calculated between MA-SM and STBC.

B. Detection

In the receiver side,the complexity increases exponentially when the optimal ML decoder, which detects the antenna set together with the symbols for high order constellation, since the exhaustive search space increases at the speed as Npgrows.For the MA-SM scheme with low complexity, a near-optimal detection method with low computational complexity is introduced. The bulk of parallel symbols that transmitted through the Rayleigh faded channel are converted to serial form. The receiver signal information contains both symbol information and antenna information. Along with the channel information, the active antenna information is also transmitted [15].

The transmitted antenna set is first detected by the receiver. According to that information, the receiver antenna is activated. The Channel State Information (CSI) is considered to be known by the receiver. The Maximal Ratio Combining (MRC) will detect the signal from the diversity branches [11]. From each pair of transmit and receive antennas, the signal with maximum Signal to Noise ratio (SNR) is detected. After the symbols detected from the diversity branches, they undergo spatial demodulation.

As Np varies optimal Maximum Likelihood decoding, increases the complexity exponentially. Therefore to overcome this, a near optimal ML- decoding is used [10], [12]. It is one of the most efficient methods to decode a signal from a noisy channel. This decoding takes the advantage of minimum distance decoding. The decoder will calculate the minimum distance between the received symbol and the estimated symbol. It will minimize the hamming distance [13]. The hamming distance is denoted as, it is the numbers of coefficients in which they are differ. The receiver first decodes the antenna groups that transmit the symbols.

The working of MA-SM receiver as follows: Here we are assuming five receive antennas. The symbols that are received undergo demodulation (BPSK, 16-QAM). Using the Maximal Ratio combining technique, the signal is detected from the diversity branches having highest SNR. The receiver knows the knowledge about channel State Information. A near optimal ML decoding will detect the antenna set first. Based on the detected antenna sets, the receiver will detects the symbol with minimum hamming distance. SER between MA-SM and STBC is simulated. Also the performance of MA-SM is compared with other traditional system using QPSK modulation.

There is a chance for error occurring at the receiver. The first error is due to the error in detection of active antennas and the second error is due to signal demapping. These two errors dominate in Bit Error Probability (BEP) [14], [12]. These errors can be avoided by the proper detection of active antennas from the signal space and the proper detection of signals using the syndrome decoding technique.

IV. NUMERICAL RESULTS

The GSM, STBC etc, also simultaneously transmit the symbol through the active antennas. So it is necessary to compare the performance with MA-SM. Figure 2 show the comparison of MA-SM with other techniques using QPSK modulation. After 10 dB, the MA-SM show less error than other systems.

The order of the transmission rate is important to achieve the required rate. As the order of the system increases, the MA-SM shows better performances. For higher constellation order, it can achieve higher transmission rates. The reduced interference due to antenna group selection and also as M value increases the traditional demapping with the selected antenna become correct.

This dominates the performance of MA-SM. Along with this the symbol error rate is compared between STBC and MA-SM. MA-SM achieve better transmission rate. SER is comparatively better for MA-SM. Since the maximum correlated symbol is detected by the near-optimal demodulator. Also only less number transmit antennas are activated to avoid inter symbol interference. In the simulation, for a rate of 7-8 dB, the MA-SM show less SER than STBC.

In the figure 4, the MA-SM is compared with almouti scheme. Almouti contain two transmit and two receive antennas. The required transmission rate cannot be achieved. For higher transmission rates, the required antennas were not sufficient. Also for higher SNR the error rate is high.

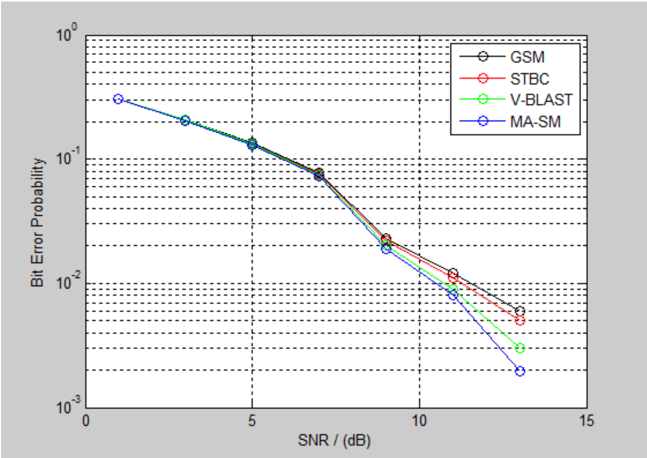

Fig 2: comparison of MA-SM with existing techniques for QPSK modulation

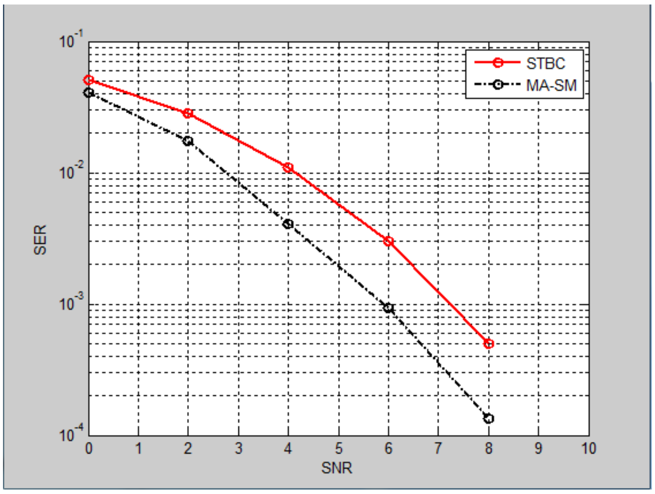

Fig 3: SER performance between MA-SM and STBC

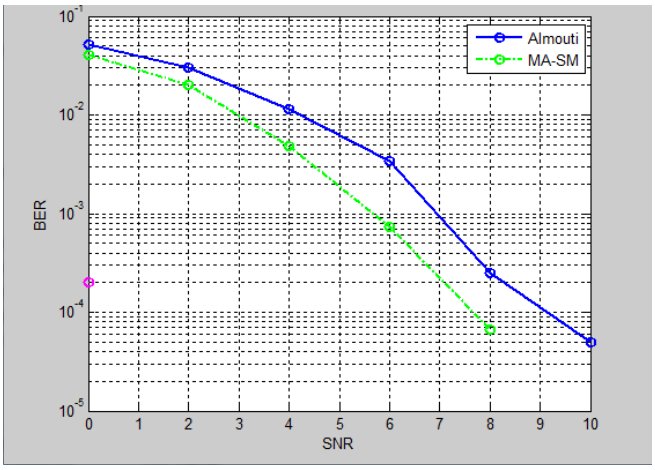

Fig 4: Performance comparison between MA-SM and Almouti scheme

V. CONCLUSION

In this paper as an alternative to other systems, a Spatial Modulation technique with multiple active transmit antenna, named Multiple Active Spatial modulation (MA-SM) is introduced. For the construction of the MA-SM, a general technique has been proposed, in which the system was optimized by maximizing the intersymbol distance. On comparing the performance of MA-SM with GSM and SM using QPSK modulation, the MA-SM showed better performance and also when compared the SER performance of MA-SM with STBC, simulation results showed better performance for MA-SM. Therefore it can be concluded that MA-SM produces better performance with minimum error rate.

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