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Spatial Division Multiplexing for 4G Wireless Systems under Fading Channels using Spatial Modulation

Arashpal Chahal Amandeep Kaur Ranjeet Singh

Abstract*— *Because of the enormous capacity upsurge a MIMO systems offer, such systems gained a lot of interest in mobile communication research. One indispensable problem of the wireless channel is fading, which occurs as the signal follows multiple paths between transmitter and receiver antennas. Fading can be mitigated by diversity, which means that the information is transmitted not only once but several times, hoping that at least one of the replicas will not undergo severe fading. There are various coding methods, a main issue in all these schemes is the exploitation of redundancy to achieve high reliability, high spectral efficiency and high performance gain for MIMO-OFDM systems earlier. In this paper, we are going to introduce an orthogonal spatial division multiplexing in which divide the central signal streams into both time and frequency. Also to increase the spatial diversity we are going to introduce spatial modulation along with STBC for our new MIMO-OSDM. Experimental results show that, proposed system outperform the existing MIMO-OFDM system in terms of performance measure for various modulation schemes.

***Keywords*— Multiple Input Multiple output (MIMO) system, orthogonal spatial division multiplexing, space time block coding, spatial modulation, 4G wireless communication.**

I. INTRODUCTION

High spectral efficiency and high transmission rat are the challenging requirements of future wireless broadband communications. In a multipath wireless channel environment, the use of Multiple Input Multiple Output (MIMO) systems leads to the accomplishment of high data rate transmission without escalating the total transmission power or bandwidth [1]. Multiple-Input Multiple-Output antenna systems are a type of spatial diversity. An effective & realistic way of approaching the capacity of MIMO wireless channels is to utilize space-time block coding in which data is coded through space & time to improve the reliability of the transmission, as redundant copies of the original data are broadcasted over independent fading channels [2, 3]. Then all the signal copies are collected at the receiver end in a best possible way to extort as much information from each of them as possible. In practice, wireless communications channels are time varying or frequency selective particularly for broadband & mobile applications. To deal with these challenges, a promising amalgamation has been exploited, namely, MIMO with Orthogonal Frequency Division Multiplexing (OFDM), MIMO-OFDM, which has previously been adopted for present & future broadband communication standards such as LTE or WiMax [5-9].

OFDM can diminish the effect of frequency selective channel. This is because OFDM is a multi-carrier transmission scheme, which divides the existing spectrum into many carriers, each one of them being modulated by a low-rate data stream. One popular combination of MIMO & OFDM is the STBC-OFDM. Furthermore, this work is encouraged from such STBC-OFDM system to build up an orthogonal spatial division multiplexing system. In STBC coding is applied across multiple OSDM blocks to improve the system Performance inherent in MIMO-OFDM system. The coding allocates symbols along different transmit antennas & time slots. In this context, the STBC-OSDM system is one of most capable system configurations that is adopted for 4th generation mobile systems [10].

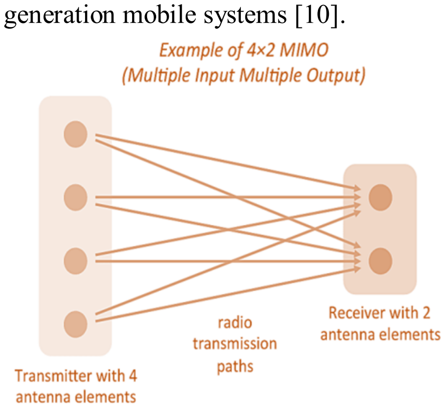

Figure 1. Example of 4*2 MMO (Multiple Input Multiple Output)

The transmission of radio waves through the atmosphere including the ionosphere is not an easy phenomenon to model. Atmospheric propagation can show a wide variety of behaviours based on the aspects like frequency, bandwidth of the signal, and types of antennas utilized, terrain & weather conditions. When there is no fading, the channel can be supposed to be additive. If the samples are independent of each other the additive noise is referred to as 'white' & then they are correlated are known as 'colored'. The straightforward communication channel model is the Additive White Gaussian Noise model under which the signal is exaggerated only by a constant attenuation. In wireless communication channels there will be more than one path in which the signal can travel amid the source & destination. The presence of these paths is due to atmospheric reflections, refractions & scattering. In a multipath fading environment if a line of sight (LOS) component is present then the channel is known as a Rician channel. On the other hand if there is no LOS component then the channel will be referred as the Rayleigh fading channel.

A. Introduction to fourth generation of communication system

The first-generation (1G) radio systems put away analog communication schemes to transmit voice over radio, such as Advanced Mobile Phone Services (AMPS), the Nordic Mobile Telephone (NMT) scheme, & the Total Access Communication System (TACS), which were developed in the 1970s & 1980s. The 2G systems were accumulated in the 1980s & 1990s, & featured the execution of digital technology, such as Global System for Mobile Communications (GSM), Digital-AMPS (D-AMPS), code-division multiple access (CDMA), & personal digital cellular (PDC); among them GSM is the mostly successful & widely used 2G system. 3G mobile technologies offer users with high-data-rate mobile access, which developed rapidly in the 1990s & is still budding today.

However, there are two restrictions with 3G. One is the tricky expansion to very high data rates such as 100 Mb/s with CDMA due to severe interference between services. The other is the difficulty of providing a phase of multirate services, all with different quality of service (QoS) & performance requirements, due to the restrictions required on the core network by the air interference standard. This design is encouraged by the growing demand for broadband Internet access.

B. Principles of space-time (MIMO) systems

Consider the multi-antenna system diagram shown in Figure 2. A compressed digital source in the form of a binary data stream which is supplied to a simplified transmitting block encompassing the functions of error control coding & (possibly joined with) mapping to complex modulation symbols (quaternary phase-shift keying (QPSK), M-QAM, etc.). The last produces several separate symbol streams which varies from independent to partially redundant to fully redundant. Each of them is then mapped onto one of the multiple TX antennas. Mapping can includes linear spatial weighting of the antenna elements or linear antenna space–time precoding. After upward frequency conversion, filtering & amplification, the signals are broadcasted into the wireless channel. At the receiver, the signals are captured perhaps by multiple antennas & demodulation & demapping operations are performed to recuperate the message.

Another dominant effect of smart antennas lies in the concept of spatial diversity. In the existence of random fading caused by multipath propagation, the probability of losing the signal fade away exponentially with the number of decor related antenna elements being used. A major concept here is that of diversity order which is defined by the number of decor related spatial branches accessible at the transmitter or receiver end. When combined together, leverages of smart antennas are shown to enhance the coverage range versus quality trade-offs offered to the wireless user.

This constructs multiple antenna elements transceivers a possibility at both sides of the link, even though pushing much of the processing & cost to the network's side (i.e., BTS) still makes engineering sense. Clearly, in a MIMO link, the advantages of conventional smart antennas are reserved since the optimization of the multi-antenna signals is carried out in a larger space, thus providing extra degrees of freedom. In particular, MIMO systems can offer a joint transmit-receive diversity gain, and array gain upon coherent combining of the antenna elements.

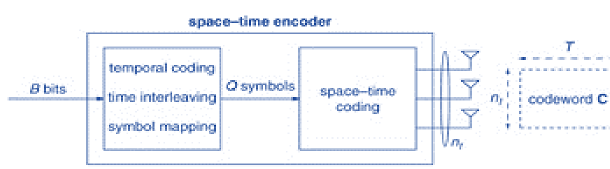

Figure 2. Space-time (MIMO) systems.

C. *Structure of Assessment*

The association steps of this paper is as follows. The Preliminary Section ends with a concise introduction of MIMO systems & its necessity in today's communication. The part A, B & C in introduction shows a brief description about fourth generation of communication, ideology of MIMO system & transmission over multiple input multiple output system.

Section II, explains a common review & related work of different coding & multiplexing techniques in multiple antenna system, many techniques have been proposed for the MIMO systems which are classified in this section.

Section III provides the information about the fundamental problem definition & proposed methodology. This section is further sub-classified into numerous subsections like spatial modulation, spatial division multiplexing, space time coding scheme.

Section IV gives information about the simulation results, it also shows some comparative graphs which proved that the proposed approach surmount the traditional approach.

Section V shows the observations, discussion & tabular comparison of different researches reviewed in earlier sections & a general conclusion of the paper, regarding review is presented.

II. Related Work

With the speedy improvement in wireless communications & the decreased cost of communication devices, wireless networks have become denser & denser while bandwidth efficiency becomes more & more important.

Employing multiple-input multiple-output (MIMO) in wireless communication systems has been proven to present plenty of benefits in both increasing the system capacity and steadiness of reception in rich scattering atmosphere [11, 12]. To take benefit of these a space-time block coding (STBC)-oriented diversity scheme has been usually adopted in future wireless communication standards [13], for example 3GPP LTE, WiMax, etc. The STBC technique was originally proposed by Alamouti in [14], achieves transmit diversity exclusive of channel information. Although Alamouti's STBC was initially designed for two transmit antennas & one receive antenna, this scheme has been generalized by Tarokh in [15] & enlarged to the system for four transmit antennas.

A space-time block coding (STBC) scheme was originally anticipated by Alamouti as an effective technique to achieve a transmit diversity gain [16]. Recently, increasing demands for high data rate wireless communication services requires data transmissions over wideband channels. The combination of STBC along with OFDM is deemed to be a promising solution for combating frequency-selective fading [17]. For both single carrier & multi-carrier transmission systems, the Alamouti scheme performs well if the channel is time-invariant over two successive symbol durations. The impact of a time-varying fading channel on the performance of Alamouti transmit technique has been explored in [18] for a single-carrier system & in [19] for an OFDM system. In both the papers, the spatial correlation amid the time-varying multipath Rayleigh fading sub-channels has not been taken into account. However, it has been revealed in [20] by simulations that the performance of a STBC-OFDM scheme depends not only on temporal correlation but also on spatial correlation.

Space time Block Coding is a set of realistic signal design techniques aimed at approaching the information theoretic capacity bounds of Multiple-Input Multiple-Output (MIMO) channels. Since the initial work of Alamouti [21], space-time coding has been a rapid growing field of research. In the last decade, numerous coding techniques have been proposed. These includes orthogonal (OSTBCs) [21]–[23], quasi-orthogonal (QOSTBCs) [24], [25] & non-orthogonal STBCs (NOSTBCs) [26]

The revolutionary works on the cooperative diversity address information-Theoretical aspects of cooperative networks examining achievable rate regions & outage probabilities. The outage analysis in [20] relies on the random coding argument & demonstrates that full spatial diversity can be achieved employing such a rich set of codes. Laneman et al. [27] proposes the use of "conventional" orthogonal space-time block coding (STBC) in a "distributed" manner for realistic implementation of user cooperation. Nabar et al. [28], [29] evaluates distributed STBC operating in an amplify-&-forward (AF) mode through the derivation of pairwise error probability (PEP) terms. However, uncomplicated extensions result in an excessive complexity mainly for higher-order modulation schemes and/or long channel memory [30].

III. PROPOSED MIMO SYSTEM

The figure below shows the transmitter side block diagram of proposed scheme

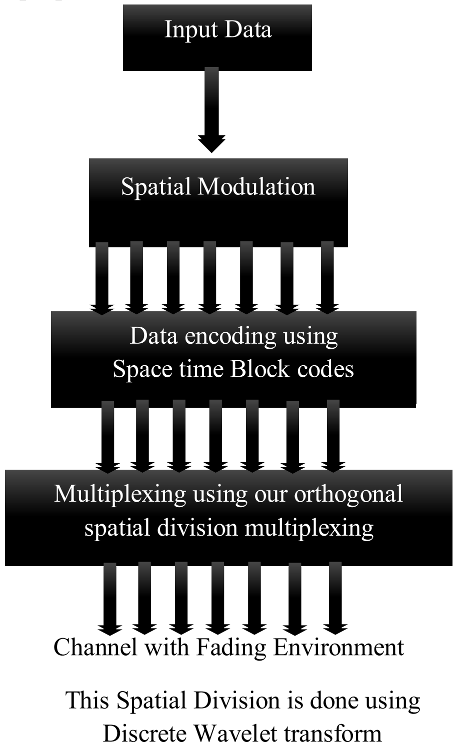

Figure 3. Shows the transmitter side model of proposed work, we have to send only constellation points with respect to antenna number.

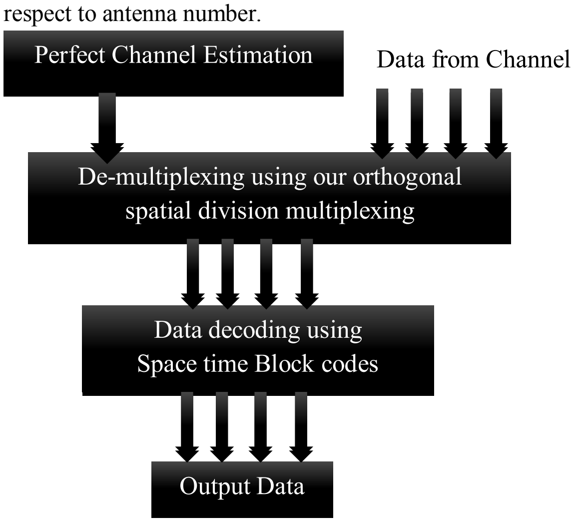

Figure 4. Shows the receiver side model for the proposed work. Perfect channel estimation is done to find best suited channel. Also, Channel consist with Rayleigh Fading Environment.

Furthermore, this chapter also explains a detailed view of technologies used in the proposed work as follow:

A. *Spatial Modulation*

Spatial modulation (SM) is a recently developed transmission technique that uses multiple antennas. The basic idea is to map a block of information bits to two information carrying units:

1. A symbol that was chosen from a constellation diagram and
2. A unique transmit antenna number that was chosen from a set of transmit antennas.

The use of the transmit antenna number as an information-bearing unit increases the overall spectral efficiency by the base-two logarithm of the number of transmit antennas. At the receiver, a maximum receive ratio combining algorithm is used to retrieve the transmitted block of information bits. Here, we apply SM to orthogonal spatial division multiplexing (OSDM) transmission.

In general, any number of transmit antennas and any digital modulation scheme can be used. The constellation diagram and the number of transmit antennas determine the total number of bits to be transmitted on each sub-channel at each instant.

Instead, four quadrature-amplitude modulation (QAM) and two transmit antennas can be used to transmit the same number of information bits from spatial modulation mapping table.

In SM, a block of any number of information bits is mapped into a constellation point in the signal domain and a constellation point in the spatial domain. At each time instant, only one transmit antenna of the set will be active. The other antennas will transmit zero power. Therefore, ICI at the receiver and the need to synchronize the transmit antennas are completely avoided. At the receiver, maximum receive ratio combining (MRRC) is used to estimate the transmit antenna number, after which the transmitted symbol is estimated. These two estimates are used by the spatial demodulator to retrieve the block of information bits.

B. *Orthogonal Spatial Division Multiplexing*

In our case the spatial division multiplexing is performed using complex wavelet transform as fast Fourier transform used in orthogonal frequency division multiplexing can split the signal into frequency signal only. The transform of a signal is just another form of representing the signal. It does not change the information content present in the signal.

The Wavelet Transform provides a time-frequency representation of the signal. It was developed to overcome the short coming of the Short Time Fourier Transform (STFT), which can also be used to analyze non-stationary signals. While STFT gives a constant resolution at all frequencies, the Wavelet Transform uses multi-resolution technique by which different frequencies are analyzed with different resolutions.

A wave is an oscillating function of time or space and is periodic. In contrast, wavelets are localized waves. They have their energy concentrated in time or space and are suited to analysis of transient signals. While Fourier Transform and STFT use waves to analyse signals, the Wavelet Transform uses wavelets of finite energy.

The wavelet analysis is done similar to the STFT analysis. The signal to be analyzed is multiplied with a wavelet function just as it is multiplied with a window function in STFT, and then the transform is computed for each segment generated. However, unlike STFT, in Wavelet Transform, the width of the wavelet function changes with each spectral component. The Wavelet Transform, at high frequencies, gives good time resolution and poor frequency resolution, while at low frequencies, the Wavelet Transform gives good frequency resolution and poor time resolution [29].

C. *Transceiver of proposed OSDM system*

The general block diagram of an OSDM transceiver has been shown in Figure 7. The digital data if first up-converted by a modulation scheme and then the symbols are put into parallel streams that the CWT block is going to work on. After ICWT is taken an appropriately sized cyclic prefix is appended at the end of the signal. Finally, the signal is sent into the channel. This channel is either the AWGN or the flat fading Rayleigh channel. At the receiver the first task is to remove the cyclic prefix and then apply CWT. Afterwards, the parallel streams are serialized and then the symbols put through the demodulator for obtaining the input source data.

Once the cyclic prefix is removed taking IFFT of the signal is equivalent to multiplying the constellation points by sinusoids whose frequencies are equal to the frequency of a carrier signal and then summing these products.

The **complex wavelet transform (CWT)** is a complex-valued extension to the standard discrete wavelet transform (DWT). It is a two-dimensional wavelet transform which provides multi-resolution, sparse representation, and useful characterization of the structure of an image. Further, it purveys a high degree of shift-invariance in its magnitude. However, a drawback to this transform is that it is exhibits 2^d (where d is the dimension of the signal being transformed) redundancy compared to a separable (DWT).

D. *Space-time Coding*

Space-Time Codes (STCs) have been implemented in cellular communications as well as in wireless local area networks. Space time coding is performed in both spatial and temporal domain introducing redundancy between signals transmitted from various antennas at various time periods. It can achieve transmit diversity and antenna gain over spatially uncoded systems without sacrificing bandwidth. The research on STC focuses on improving the system performance by employing extra transmit antennas. In general, the design of STC amounts to finding transmit matrices that satisfy certain optimality criteria. Constructing STC, researcher have to trade-off between three goals: simple decoding, minimizing the error probability, and maximizing the information rate.

There are several distributions used to model the fading statistics. The most commonly used distribution functions for the fading envelopes are Rice, Rayleigh and Nakagami-m. Rayleigh is a special case of Nakagami-m, when m equals one. The fading models are related to some physical conditions that determine what distribution that best describe the channel.

- The Rayleigh distribution assumes that there are a sufficiently large number of equal power multipath components with different and independent phase.
- The Nakagami one distribution equals the Rayleigh distribution above. It is a general observation that an increased m value corresponds to a lesser amount of fading and a stronger direct path.

In Figure 7, a MIMO 4x4 system with Alamouti STBC algorithm is shown. The MIMO channels are shown in four colors to split them into four groups. The choice of a 4x4 MIMO instead of usual 2x1 or 2x2 is motivated by the necessity of increasing diversity in the space domain (and therefore robustness against fading effects) together with the spectral efficiency. Nowadays, a 4-element MIMO array can be implemented with affordable cost and the yielded performance improvement in terms of spectral efficiency may justify such an additional (non-prohibitive) cost.

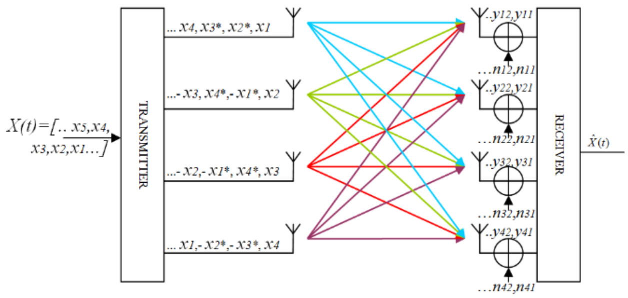

Figure 7: The 4x4 MIMO-STBC system

IV. Results & Discussion

In this section we will be presenting the link level performance of STBC and SM coded OSDM using either BPSK or QPSK modulation. All simulations have been carried out using the readily available MATLAB platform and writing dedicated functions for different parts. The simulation results obtained have been presented in four parts. The first part provides the bit error rate performance for BPSK modulated data transmitted over a Rayleigh fading channel. This is then followed by a performance analysis of OFDM over the AWGN channel using either BPSK or QPSK modulation. Third part demonstrates the BER vs. SNR for STBC and Spatial modulation coded data transmitted over a Rayleigh fading channel without using OSDM. Finally, part four will provide STBC and SM coded OFDM performance when BPSK and QPSK are the preferred modulation and the channel is again the Rayleigh fading channel.

Simulations are carried out in MATLAB R2013b (Version 8.2.0.703), graphical user interface is created for the simulation of proposed work on MIMO systems. When there is a direct path between the transmitter and receiver the channel is usually referred to as the Rician channel and when LOS component is missing it will be referred to as the Rayleigh fading channel. In this section we demonstrate the BER performance of BPSK modulated data over a single path Rayleigh fading channel. The analytical expression for the BER for BPSK modulated data in a Rayleigh fading channel is

$$P_b = 0.5\left(1 - \sqrt{\frac{(E_b/N_0)}{(E_b/N_0)+1}}\right)$$

And for the AWGN channel P_b is defined as:

$$P_b = 0.5\, erfc\left(\sqrt{\frac{E_b}{N_0}}\right)$$

This section will provide BER analysis for Alamouti STBC and SM over slow fading Rayleigh channels. For both schemes the simulations have been carried out using two transmit and one receive antenna.

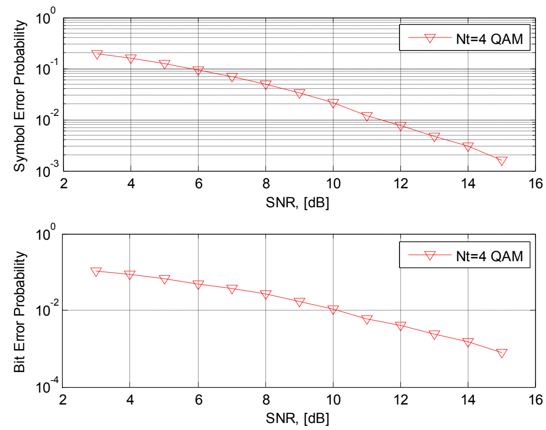

Figure 8. Comparison of Bit error probability and symbol error probability with respect to signal to noise ratio in case of 4 antenna quadrature amplitude modulation.

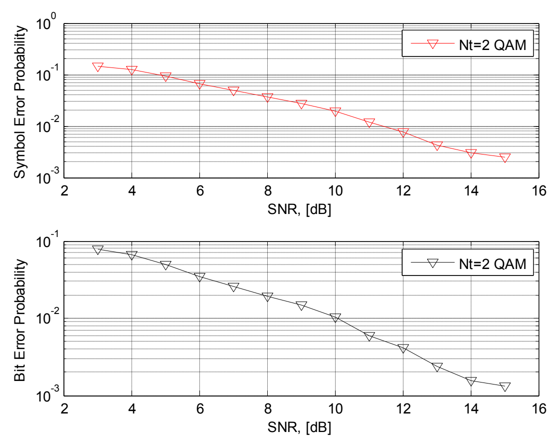

Figure 9. Comparison of Bit error probability and symbol error probability with respect to signal to noise ratio in case of 2 antenna quadrature amplitude modulation.

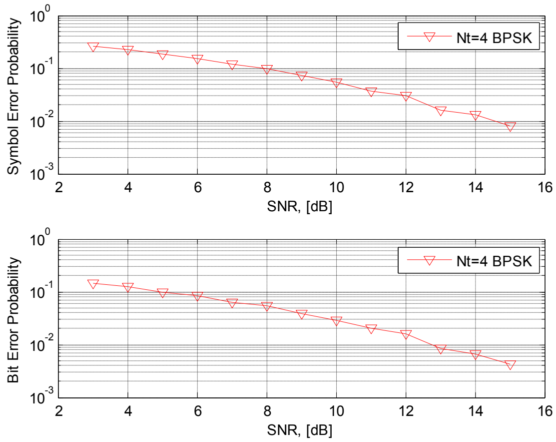

Figure 10. Comparison of Bit error probability and symbol error probability with respect to signal to noise ratio in case of 4 antenna binary phase shift keying modulation.

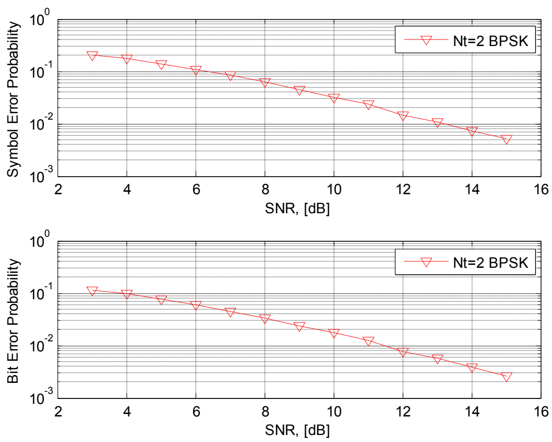

Figure 11. Comparison of Bit error probability and symbol error probability with respect to signal to noise ratio in case of 2 antenna binary phase shift keying modulation.

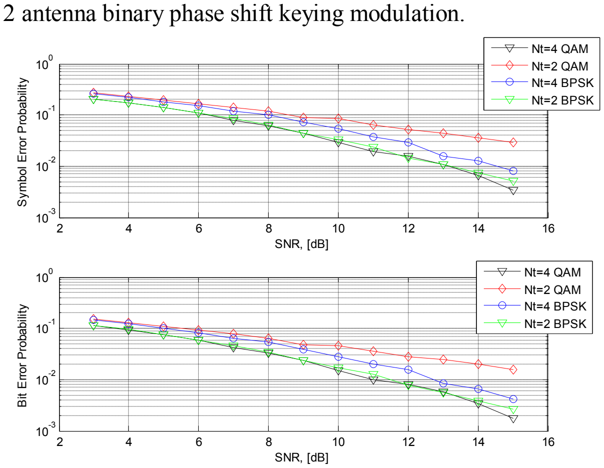

Figure 12. Overall Comparison of proposed SM-STBC-OSDM system for different modulation schemes and antenna numbers.

V. Conclusion & Discussion

In this paper, we first compared the BER performance of 4×1 and 2×1 transmit diversity STBC data transmission over a Rayleigh fading channel using both BPSK and QPSK modulation. The communication system used spatial modulation to encode random data signal to achieve a higher transmit diversity. The proposed multiplexing system using complex wavelet transform we named it as orthogonal spatial division multiplexing which is motivated from orthogonal frequency division multiplexing performs better in multiple input multiple output system. Results with BPSK modulation indicate that using two antennas at the receiver instead of one will bring approximately an extra gain of 9dB at a BER value of 10-4.

Also comparison between 2×1 STBC using BPSK and 2×1 STBC using QPSK indicate that STBC with BPSK modulation would be ~4.2 dB better than the 2×1 STBC with QPSK for BER value of 10-3. These results indicate that to get a better performance over a Rayleigh fading channel MIMO approach would be better than MISO case and low level modulation should be preferred.

In the second phase of the simulations, transmission of data encoded using STBC and spatial modulation over a Rayleigh fading channel was compared. Since the STBC scheme makes use of a channel estimate and spatial modulation does not for both BPSK and QPSK modulations, the BER performance for STBC was better using spatial modulated encoded data. This however does not mean that spatial modulation should not be considered. In fact when there is high mobility and the channel conditions are fluctuating rapidly it may be difficult to obtain estimates for the channel and the detection of transmitted.

The improvement in BER performance when OSDM is used mainly comes due to the use of the guard interval. When the duration of the guard interval is selected larger than the maximum excess delay time of the radio channel this will help reduce the inter-symbol interference in a fading environment and help improve the BER results. Secondly since OSDM splits a broadband channel into multiple spatial sub-channels this changes the behavior of each sub-channel to be flat fading and hence better performance can be observed.

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