An Adaptive MIMO-OSDM Prototype for Next Generation Communication Systems under fading Channels

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Abstract— Increasing demand for high-performance 4G broadband wireless is enabled by the use of multiple antennas at both base station and subscriber ends. Multiple antenna technologies enable high capacities suited for Internet and multimedia services, and also dramatically increase range and reliability. However, in fast fading channels, the time variation of a fading channel over an OFDM symbol period results in a loss of sub-channel orthogonality, which leads to inter-carrier interference (ICI). In this paper, 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 bit and symbol error rate for various modulation schemes.

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

INTRODUCTION

The development of wireless communication systems for high-bit-rate data transmission and high-quality information exchange between terminals is becoming one of the new challenging targets in telecommunications research. The market demand for broadband multimedia services, ubiquitous networking, and Internet access via portable devices is expected to grow enormously, pushing the development of modem and system architectures for high-bit-rate transmission. Multiple input multiple output (MIMO) systems are currently stimulating considerable interest across the wireless industry because they appear to be a key technology for future wireless generations.

MIMO systems have been recently under active consideration because of their potential for achieving higher data rate and providing more reliable reception performance compared with traditional single-antenna systems for wireless communications [1, 2]. A space-time (ST) code is a bandwidth-efficient method that can improve the reliability of data transmission in MIMO systems [3]. It encodes a data stream across different transmit antennas and time slots, so that multiple redundant copies of the data stream can be transmitted through independent fading channels. By doing so, more reliable detection can be obtained at the receiver. As an example of MIMO applications, the IEEE 802.11n standard is still being discussed, but one prototype can offer up to 250 Mb/s. This is more than five times the (theoretical maximum) speed of the existing IEEE 802.11g hardware. General configuration of a MIMO communication system is shown below communication system

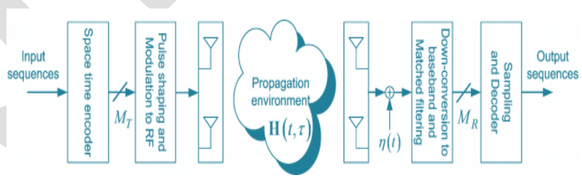

Figure 1. General Configuration of a MIMO

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 multi-rate 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.

Multiple Input Multiple Output Systems

MIMO wireless communication refers to the transmissions over wireless links formed by multiple antennas equipped at both the transmitter and receiver.

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.

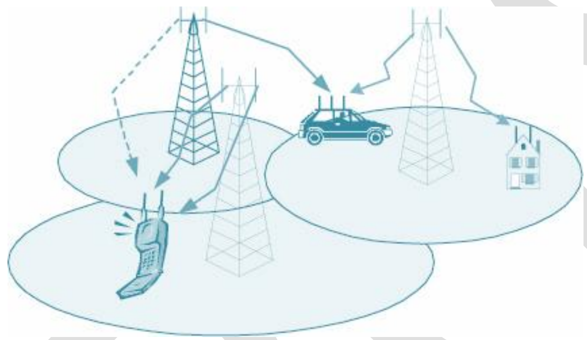

Figure 2. MIMO transmission and reception in a dispersive environment in a MIMO system, different information is transmitted simultaneously on each transmit antenna

The key advantages of employing multiple antennas lie in the more reliable performance obtained through *diversity* and the achievable higher data rate through *spatial multiplexing* [1]. These concepts are briefly discussed below.

Diversity — the signal transmission over broadband wireless channels always suffers from attenuation due to the detrimental effect of multipath fading, and this can severely degrade the reception performance. In the MIMO systems, the similar info can be communicated from the multiple transmit antenna & received at multiple receive antenna concurrently. Meanwhile the fading for every link b/w a couple of transmit & receive antenna can typically be measured to be autonomous, the possibility that the info is detected correctly is improved. Apart from the spatial diversity, other forms of diversity are commonly available, namely, temporal diversity & diversity of frequency, if the imitations of the distressed signals are received in the way of dismissal in the temporal & the frequency--- domains, respectively. The simplest way of achieving variety in the systems of MIMO is through replication coding that sends the similar info symbol at dissimilar slots of time from dissimilar transmit antennas. A more bandwidth efficient coding scheme is ST coding [3], where a block of information symbols are transmitted in the dissimilar order from every antenna.

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.

BACKGROUND AND RELATED WORK IN DETAIL

In wireless communication systems, deploying the multiple-input multiple-output (MIMO) concept together with an efficient coding and modulation scheme has been shown to be an effective way to increase link capacity without sacrificing bandwidth [6]. In the case of frequency-nonselective fading channels, space-time (ST) codes [7]–[9] have been proposed to explore spatial and temporal diversities that are available in MIMO links. In the case of frequency-selective channels, the MIMO concept has been deployed with orthogonal frequency- division multiplexing (OFDM) modulation, called MIMO-OFDM, to obtain available diversities and combat frequency selectivity of the channels. Various space-frequency (SF) codes [10]–[12] (and references therein) and space-time-frequency (STF) codes [13]–[15] were proposed for MIMO-OFDM systems.

SF coding aims to exploit both spatial and frequency diversities, whereas the additional temporal diversity can be obtained when STF coding is employed under time-varying channels. However, most of the above coding techniques require reliable multichannel estimation, which inevitably increases the cost of frequent retraining and number of estimated parameters to the receiver. Although the channel estimates may be available when the channel changes slowly compared with the symbol rate, it may not be possible to acquire them in fast fading environment. Differential space-time (DST) modulation [16]–[19] has been widely known as one of many practical alternatives that bypasses multichannel estimation in frequency-nonselective MIMO systems. The differential scheme in [16] and [17] utilizes unitary group constellation which can be applied for arbitrary number of transmit antennas. The differential space-time block codes (DSTBC) in [18] and [19] differentially encode the existing space-time block codes in [8] and [9] and allow possible multilevel amplitude modulation to improve the MIMO link performance.

As a consequence of advantages of MIMO wireless systems have captured the attention of international standard organizations. The use of MIMO has been proposed multiple times for use in the high-speed packet data mode of third generation cellular systems (3G) [20], [21] as well as the fourth generation cellular systems (4G) [22], [23], [24]. MIMO has also influenced wireless local area networks (WLANs) as the IEEE 802.11n standard exploits the use of MIMO systems to acquire throughputs as high as 600Mbps [25], [26].

Focusing on MIMO systems using STBC, one class of approaches exploits the structure of the space time codes to enable channel estimation [27]–[36]. Budianu and Tong [27] and Larsson et al. [28] present training based schemes for the orthogonal codes of Alamouti [37] and Tarokh [38]. Training bits, however, reduce effective throughput and such schemes are inappropriate for systems where bandwidth is scarce. By restricting themselves to real signals and transmit diversity order, Ammar and Ding estimate channels for STBC from the null space of the received signal [29]. Swindlehurst and Leus present a scheme for blind channel estimation with a generalized set of space-time codes [30]. Larsson et al. [32] present a blind optimal, in maximum likelihood (ML) sense, scheme for channel estimation. Ma and co-authors [33]–[35] simplify the problem by exploiting the O-STBC structure and semi-definite relaxation [11] or sphere decoding [34]. However, the complexity of ML decoding remains. Similarly, Shahbazpanahiet al. present a closed form channel estimate used for ML decoding of transmitted symbols [36].

Space–time coding methodologies, includes space–time trellis coding (STTC) [39], [40] & the Space–Time Block Coding (STBC) [41-43], which assimilate the methods of the antenna array spatial diversity & the channel coding. As shown by Tarokhet al. in [39], the STTC executes well in gently fading atmospheres, but has the disadvantage that complexity of decoding produces the exponentially with the no. of antenna. The unconventional multi-antenna transmit concept of diversity of the STBC appeared in work of Alamouti [41] & was further established & put into the hypothetical framework by the Tarokhet al. in [42]. The vital characteristics of the STBC is its intrinsic orthogonality, thus the guaranteeing that a humble technique of linear decoding offers the all-out likelihood results. In fact, Tarokhet al. in [42] showed that if the fades connecting pairs of transmit & receive the elements of antenna are uncorrelated, the STBC proposals the large growth in the quality of signal as associated with the uncoded systems.

Although the above-mentioned supposition of the uncorrelated fading has been complete in numerous earlier works that discover the presentation of the STBC systems [41], [42], [43], there are numerous conditions in which fading is correlated amongst the channels. For e.g., in the actual propagation atmospheres, the physical restraints may not permit use of the spacing of antennas that is essential for the independent fading crossways the elements of antenna.

PROPOSED MIMO SYSTEM

In this paper, 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.

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

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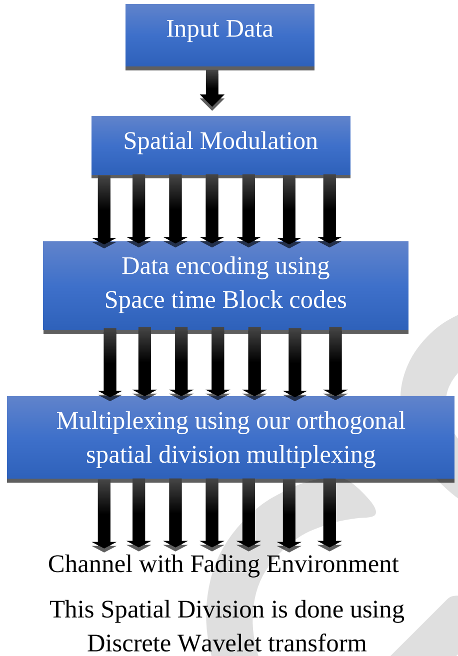

Figure 3. Shows the transmitter side model of proposed work, we have to send only constellation points with respect to antenna number.

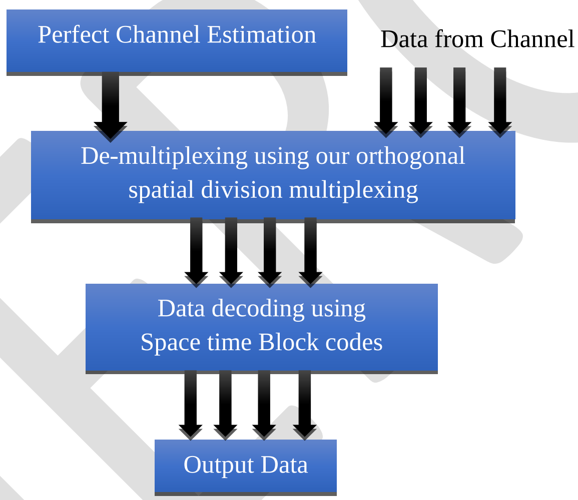

Figure 4. Shows the receiver side model for the proposed work. Perfect channel estimation is done to find best suited channel. Also, Channel consist with Rayleigh Fading Environment.

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.

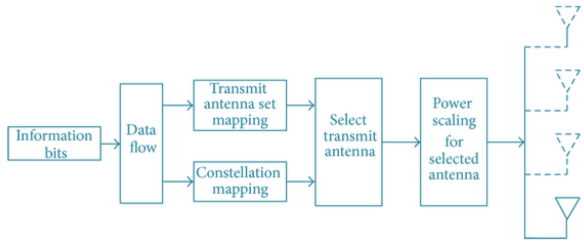

Figure 5: Block diagram of SM-MIMO system.

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.

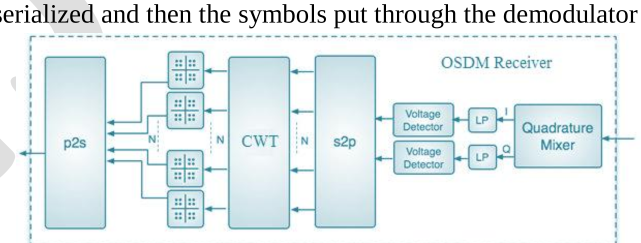

Figure 6. Block diagram of Proposed OSDM Receiver

Once the cyclic prefix is removed taking ICWT 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.

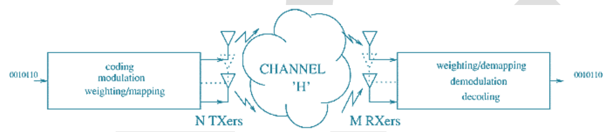

Figure 7: Diagram of a MIMO wireless transmission system. The transmitter and receiver are equipped with multiple antenna elements. Coding (STBC), modulation, and mapping of the signals onto the antennas may be realized jointly or separately.

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.

Receiver Reconfigurability

As presented in figure 3, the reconfigurable receiver has two main tasks. First, according to information provided by the channel estimation block, the adaptation module will compute the Condition number and prepare a decision vector. Then the demodulation and spatial processing stages are configured to support the selected communication scheme.

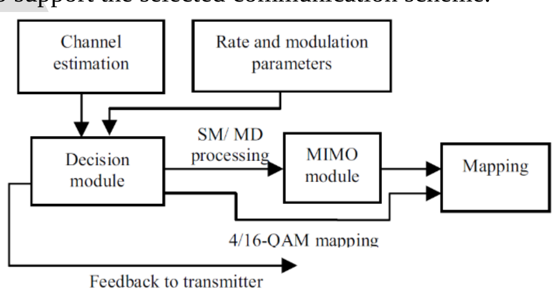

Figure 7. Receiver reconfigurable architecture

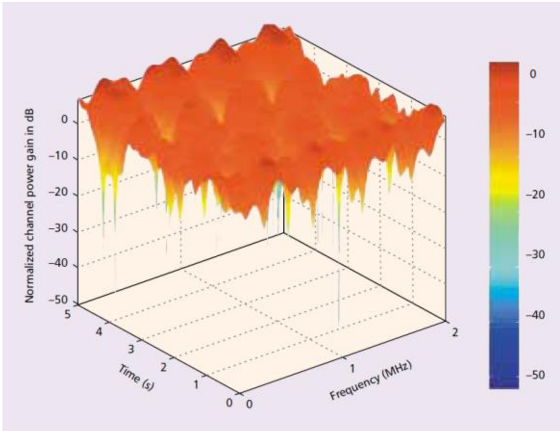

Figure 8. Frequency response vs. time for a multipath channel.

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 MIMO system needs to be integrated and be backward compatible with an existing non MIMO network. MIMO signalling imposes the support of special radio resource control (RRC) messages. The terminals need to know via broadcast down link signalling if a base station is MIMO capable. The base station also needs to know the mobile's capability, i.e., MIMO or non-MIMO. This capability could be declared during call set up. Handsets are also required to provide feedback to the base station on the channel quality so that MIMO transmission can be scheduled if the channel conditions are favourable. These downlink and uplink RRC messages are then mapped on to the layer 2 signalling messages.

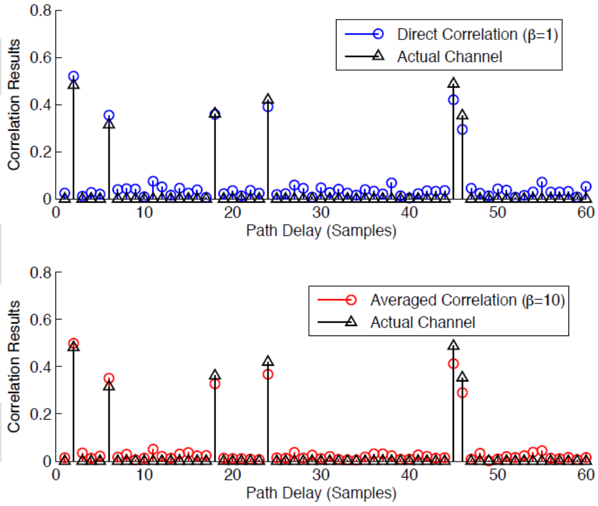

Figure 9. Averaged path delay estimation over the communication channel considering the fading environment between the links.

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

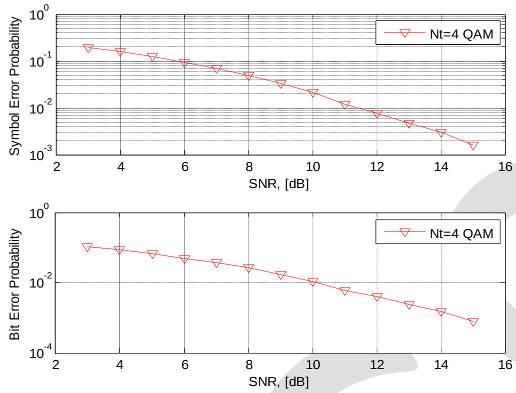

Figure 10. Comparison of Bit error probability and symbol error probability with respect to signal to noise ratio in case of 4 antenna quadrature amplitude modulation.

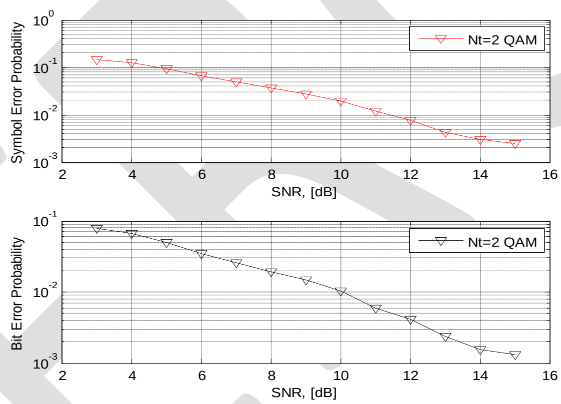

Figure 11. Comparison of Bit error probability and symbol error probability with respect to signal to noise ratio in case of 2 antenna quadrature amplitude modulation

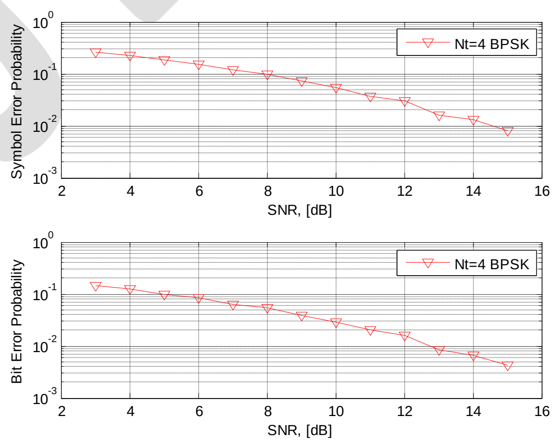

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Figure 12. Comparison of Bit error probability and symbol error probability with respect to signal to noise ratio in case of 4 antenna binary phase shift keying modulation.

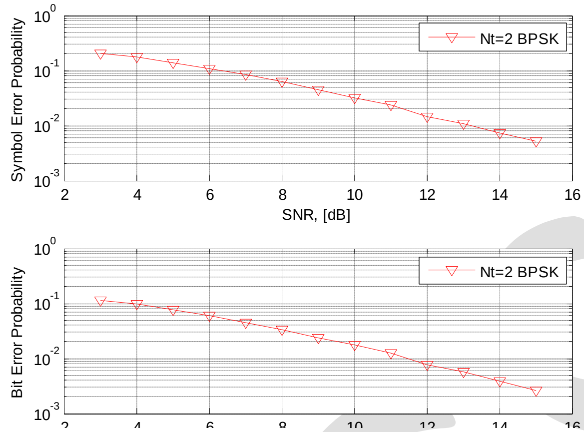

Figure 13. Comparison of Bit error probability and symbol error probability with respect to signal to noise ratio in case of 2 antenna binary phase shift keying modulation.

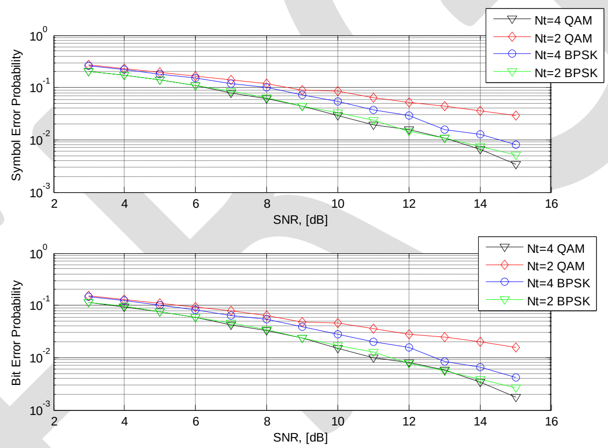

Figure 14. Overall Comparison of proposed SM-STBC-OSDM system for different modulation schemes and antenna numbers

CONCLUSION & DISCUSSION

Following the development of a system concept for future wide-area macro cellular wireless networks, a prototype has been built to evaluate its feasibility and investigate the implementation of MIMO and OFDM technologies. This prototype has been used to evaluate performance in different conditions typical of macro-cellular wireless networks.

With MIMO-related research entering a maturing stage and with recent measurement campaign results further demonstrating the benefits of MIMO channels, the standardization of MIMO solutions in third generation wireless systems (and beyond) has recently begun, mainly in fora such as the International Telecommunications Union and the 3GPPs. Several techniques, seen as complementary to MIMO in improving throughput, performance and spectrum efficiency are drawing interest, especially as enhancements to present 3G mobile systems.

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.

We provided a brief overview of MIMO wireless technology covering channel models, capacity, coding, receiver design, performance limits, and MIMO-OFDM. The field is attracting considerable research attention in all of these areas. Significant efforts are underway to develop and standardize channel models for different systems and applications. Understanding the information-theoretic performance limits of MIMO systems, particularly in the multiuser context, is an active area of research. Space–time code and receiver design with particular focus on iterative decoding and sphere decoding allowing low complexity implementation have attracted significant interest recently.

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