



Simulative Investigations on MIMO-OFDM Wireless Communication System Using Orthogonal Space Time Block Coding and Space Time Trellis Coding Techniques

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Abstract – Orthogonal frequency division multiplexing (OFDM) is popular method for high data rate wireless transmission. The next generation of broadband wireless communication system is expected to provide user with wireless multimedia services such as high-speed internet access, wireless television and mobile television. OFDM may be combined with antenna arrays at the transmitter and receiver to increase the diversity gain and/or to enhance the system capacity on time-variant and frequency-selective channels, resulting in a multiple-input multiple-output (MIMO) configuration. Multiple input and multiple output (MIMO) can be a solution for such demands. In MIMO systems, multiple antennas at both transmitter & receiver and diversity techniques can be used to reduce multi-path fading and interference. But transmit diversity scheme are growing increasingly popular as they promise high data rate transmission over wireless fading channels in both the uplink and downlink while putting the diversity burden on the base station and the coding schemes like space time block coding and space time trellis coding are explored, out of which space time block codes provide full diversity with no coding gain and space time trellis coding provides full diversity and coding gain with complex receivers. This paper presents the design of a MIMO system which takes advantage of both these coding schemes. The results confirm the superiority of the represented methods over the existing ones in terms of bandwidth efficiency and frame error rate.

Keywords— Alamouti, Diversity, Multiple Input and Multiple Output, Space Time Block Coding

I. INTRODUCTION

As wireless channel is random and unpredictable by its nature, and in general channel error rates are poorer over a wireless channel than over a wired channel. A major problem in the wireless channel is that out-of-phase reception of multi-path causes deep attenuation in the received signal, known as fading. The distortion induced by the time-varying fading is caused by the superposition of delayed, reflected, scattered and diffracted signal components. Another problem of the

wireless channel is variation over time, due to the movements of the mobile unit and objects in the environment. This results into severe attenuation of the signal, referred to as deep fade. This instantaneous decrease of the signal-to-noise ratio (SNR) results in error bursts which degrades the performance significantly. MIMO OFDM system model provides high speed links that offer good quality of service, this will minimize the probability of error. Real life issues are minimize complexity and cost of implementation of proposed system, minimize the transmission power required and bandwidth used.

In a wireless communication system, channel consists of multiple signal paths from the transmitter to the receiver. This multiplicity of paths leads to a phenomenon known as multi-path fading [4]. These multiple paths are caused by the presence of objects in the physical environment that, through the mechanisms of propagation, alter the path of radiated energy. This result in rapid fluctuation in amplitude, phase or multi-path delays of a transmitted signal over a small period of time or travel distance [6]. In some cases, the multiple signals add destructively at the receiver, creating points in space where the composite received signal is greatly attenuated [1]. Also the relative motion between the communicating devices induce Doppler shift on multi-path components and results in fading of the signal.

To meet the demand for higher data rates and to combat the effect of fading, an emerging technology called multiple input and multiple output (MIMO) has appeared. In MIMO systems, multiple antennas at both transmitter & receiver and diversity techniques can be used to reduce multi-path fading and interference. Diversity can be achieved by providing a copy of the transmitted signal over frequency, time and space.

Space-time block coding (STBC) possesses the advantage of possible diversity both spatially and temporally. Extensive efforts have been made in designing space-time block coding (STBC) to achieve full rate and full diversity because of its relative simplicity of implementation. A more recent review of Space-Time coding scheme has been given in [6] [5]. There are some advantages of STBC for MIMO systems are transmit diversity at the base station is easier to implement because handheld mobiles always create a lot of problems in achieving



antenna diversity at the receiver. Also, in STBC, easily increase the size of the code from two to three and to four, with a very little increase in decoding complexity, due to the fact that only linear processing is required for decoding. Space time trellis coding (STTC) for MIMO systems operate on one input symbol at a time producing a sequence of vector symbols whose length represents number of antennas. STTC also provides coding gain. This paper presents the design of a MIMO system which takes the advantages of both STBC and STTC schemes.

II. SPACE-TIME TRELLIS CODES

STTCs were originally proposed by Tarokh et al. as an extension of trellis coding to space-time signal structures. Just as trellis codes impose structure within each codeword (over the code space) and also between code words transmitted in sequence (over time), STTCs impose similar constraints in physical space and time by distributing the symbols comprising each codeword over the elements of the transmit antenna array. Thus they are able to provide a diversity gain as well as a coding gain. As in standard trellis coding notation, each node corresponds to a particular encoder state. They are decoded using the Viterbi Algorithm (VA), which scales exponentially with the number of trellis states; the decoder complexity grows exponentially with the spectral efficiency and diversity of the scheme. This very high complexity is one of the main disadvantages of space-time trellis coding. During each symbol period, the space-time encoder takes as its input

one symbol x and generates output symbol s_1, \dots, s_N . Note that the encoder is always initialized to its zero state before beginning a codeword transmission. Therefore the block length $L = Q$ and the rate of the STTC is 1 sym/s/Hz. The overall data rate is then specified by the base-2 logarithm B of the symbol alphabet [7][11].

III. SPACE-TIME BLOCK CODES

STBCs have been proposed by the pioneering work of Alamouti [1]. The Alamouti code promises full diversity and full data rate (on data symbol per channel use) in case of two transmit antennas. The key feature of this scheme is the orthogonality between the signals vectors transmitted over the two transmit antennas. This scheme was generalized to an arbitrary number of transmit antennas by applying the theory of orthogonal design. The generalized schemes are referred to as Space-time block codes[8]. However, for more than two transmit antennas no complex valued STBCs with full diversity and full data rate exist. Thus, many different code design methods have been proposed providing either full diversity or full data rate [10], [9], [3]. If we want to increase the coding gain further, we should apply an additional high performance outer code concatenated with an appropriate STBC used as an inner code. Such schemes have been proposed e.g. under the name of Super Orthogonal Space-Time Trellis Codes [2]. In a general form, an STBC can be

seen as a mapping of n_N complex symbols $\{s_1, s_2, \dots, s_N\}$ onto a S matrix of dimension

$$\{s_1, s_2, \dots, s_N\} \rightarrow S \quad (1)$$

An STBC code matrix S taking on the following form:

$$S = \sum_{n=1}^{n_N} \begin{pmatrix} - \\ s_n A_n + j \tilde{s}_n B_n \end{pmatrix} \quad (2)$$

Where $\{s_1, s_2, \dots, s_N\}$ is a set of symbols to be transmitted with $\bar{s}_n = \text{Re}\{s_n\}$ and $\tilde{s}_n = \text{Im}\{s_n\}$, and with

fixed code matrices $\{A_n, B_n\}$ of dimension $n_t \times N$ are called linear STBCs. The following STBCs can be regarded as special cases of these codes. The Alamouti scheme brought in a revolution of sorts in multiantenna systems by providing full diversity of two without CSI at the transmitter and a very simple maximum likelihood decoding system at the receiver. Maximum likelihood decoders provide full diversity gain of

M_R at the receiver. Such a system provides a guaranteed overall diversity gain of $2M_R$, without CSI at the transmitter. This is achieved by the key feature of orthogonality between the sequences generated by the two transmit antennas. Due to these reasons, the scheme was generalized to an arbitrary number of transmit antennas by applying the theory of orthogonal designs. The generalized schemes are referred to as space-time block codes (STBCs). These codes can achieve the full transmit diversity of $M_T M_R$, while allowing a very simple maximum likelihood decoding algorithm, based only on linear processing of received signals.

IV. SIMULATION RESULTS

To achieve full diversity of orthogonal space time block coding technique and coding gain of trellis code modulation a concatenation of orthogonal space time coding and trellis code modulation has been proposed, the proposed technique perform to achieve the diversity and coding gains of the concatenation proposed Simulink model of concatenated OSTBC and TCM. Figure 1 shows a baseband transmission multiple antenna system with M transmit and N receive antennas over the Rician fading channel and the Bernoulli Binary Generator block produces the information source for the simulation.

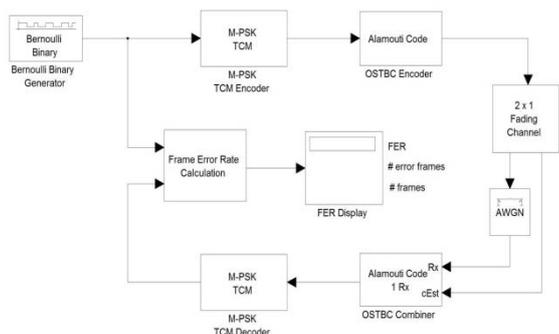


Figure 1: OSTBC Concatenated with TCM Simulink Model

Simulations for calculating the FER performance have been done on Matlab. Here first a random bit stream is generated. Then signal power level is defined and using the encoding scheme the symbols are generated that are supposed to be transmitted. The encoded symbols are transmitted through multipath faded channel. Here channel is assumed to be flat faded and channel distortion is assumed to be multipath. The channel is generated as CN (m, N) where CN stands for circularly symmetric Gaussian random variable, m is mean and N is variance. The symbols are estimated at the receiver using ML detection. Then AWGN is added in the system which is generated using normally distributed and generated as N (0, 1), where N stands for normally distributed RV with 0 mean and variance 1. The system performance is then checked at different values of SNR and for different modulation schemes. 10,000 symbols are generated for each simulation and then the FER Vs SNR curves are plotted under Rician fading environment.

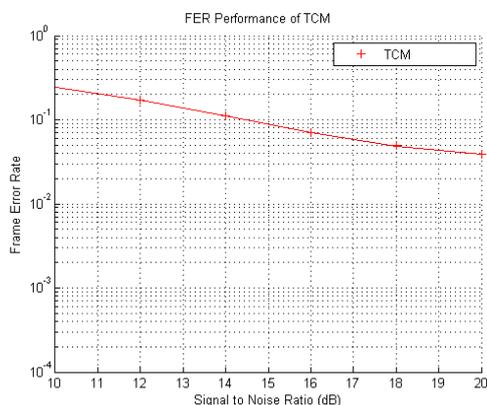


Figure 1: FER vs SNR for TCM under Rician Fading

Table 1: Simulation results of evaluation of FER vs. SNR performance of TCM under Rician Fading

Signal to Noise Ratio (SNR)	Frame Error Rate (FER)
10	0.32
12	0.23
14	0.17
16	0.10
18	0.06
20	0.05

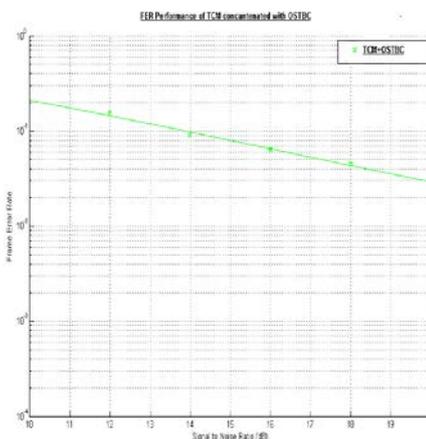


Figure 2: Simulation Results of FER vs SNR for concatenated OSTBC and TCM under Rician Fading

Table 2: Simulation results of evaluation of FER vs. SNR performance of concatenated OSTBC and TCM under Rician Fading.

Signal Noise Ratio (SNR)	Frame Error Rate (FER)
10	0.21
12	0.16
14	0.09
16	0.06
18	0.05
20	0.03

From figure1,figure2 and table1,table2, it has been concluded that for a given value of signal to noise ratio, using orthogonal space time block coding and space time trellis coding techniques , results in lowest FER.

I. CONCLUSION AND FUTURE WORK

Orthogonal space time block coding is an attractive technique for MIMO Systems and produces full diversity, on the other hand space time trellis coding is a band efficient scheme which provides large coding gain,

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