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Performance Evaluation of a Space Time Trellis Coded MIMO-OFDM Wireless Communication System

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Abstract- ***In wireless communication systems, popularly known as MIMO (Multiple-Input Multiple-Output) technology, the use of multiple antennas at the transmitter and receiver has rapidly gained in popularity over the past decade due to its powerful performance-enhancing capabilities. This research incorporates a comprehensive BER simulation study undertaken on the effectiveness of a Space-Time Trellis Coded multiple-input multiple-output orthogonal frequency division multiplexing (MIMO-OFDM) communication system. The STTC encoded MIMO-OFDM Communication system under present study has integrated two digital modulation schemes (QAM, QPSK) over fading (Rayleigh and Rician) and Additive White Gaussian Noise (AWGN) channels for two transmitting and two receiving antennas. Minimum Mean-Square-Error (MMSE) channel equalization algorithm has been implemented here. Computer simulations are performed with synthetically generated data from audio signal and the results on bit error rate (BER) reveals that the MIMO-OFDM system with STTC coding under QAM modulation technique is highly effective to combat inherent interferences under Rayleigh, Rician fading and Additive White Gaussian Noise (AWGN) channels. It is projected from the study that the retrieving performance of the communication system degrades with the lowering of the signal to noise ratio (SNR).***

Keywords-***Space–Time Trellis Coding (STTC), Multiple-Input Multiple-Output (MIMO), Orthogonal Frequency Division Multiplexing (OFDM), Minimum Mean-Square-Error (MMSE) channel equalization. Additive White Gaussian Noise (AWGN), PCM encoder.***

I. Introduction

With the technological development in wireless communications, it has become a challenging task to design robust wireless networks (fixed and/ or mobile infrastructure based) to ensure a crystal clear voice conversation, live video transmission and high speed internet connectivity. Orthogonal frequency division multiplexing (OFDM) is a multicarrier modulation technique that has recently found wide adoption in a widespread variety of high-data-rate communication systems, including digital subscriber lines, wireless LANs (802.11a/g/n), digital audio broadcasting, digital video broadcasting, and now WiMAX and other emerging wireless broadband systems such as 3G LTE and fourth generation cellular systems. A particularly promising candidate for next-generation fixed and mobile wireless systems is the combination of MIMO technology with orthogonal frequency division multiplexing (OFDM**).** The major challenges in future wireless communications system design are increased spectral efficiency and improved link reliability. The wireless channel constitutes a hostile propagation medium, which suffers from fading and interference from other users. Diversity provides the receiver several (ideally independent) replicas of the transmitted signal and is therefore a powerful means to combat fading and interference and thereby improve link reliability. Common forms of diversity are time diversity (due to Doppler spread) and frequency diversity (due to delay spread). In recent years the use of spatial (or antenna) diversity has become very popular, which is mostly due to the fact that it can be provided without loss in spectral efficiency. Orthogonal frequency division multiplexing (OFDM) significantly reduces receiver complexity in wireless broadband systems. The use of MIMO technology in combination with OFDM, i.e., MIMO-OFDM, therefore seems to be an attractive solution for future broadband wireless systems.

II. Material and Methodology

A simulated MIMO-OFDM wireless communication system is depicted in Fig-1. Space Time Trellis Coding scheme has been implemented here. In this simulated model of communication system, two transmitting antennas (Tx_1 & Tx_2) and two receiving antennas (Rx_1 & Rx_2) and 256-tone OFDM technique has been utilized. Using Window Media player, an audio signal is recoded in 8 bits PCM mono format with a sampling frequency 8 kHz and a segment of recoded audio signal is used as an input information source in the present simulation study. The PCM encoded binary data stream is again encoded separately by different forward error correction (FEC encoder) coding and interleaved. Then the encoded data stream is fed into Space Time Trellis Code (STTC) encoder. In STTC coding section, the binary information bits are spatially de-multiplexed into two sub streams and fed into two OFDM modulating channels.

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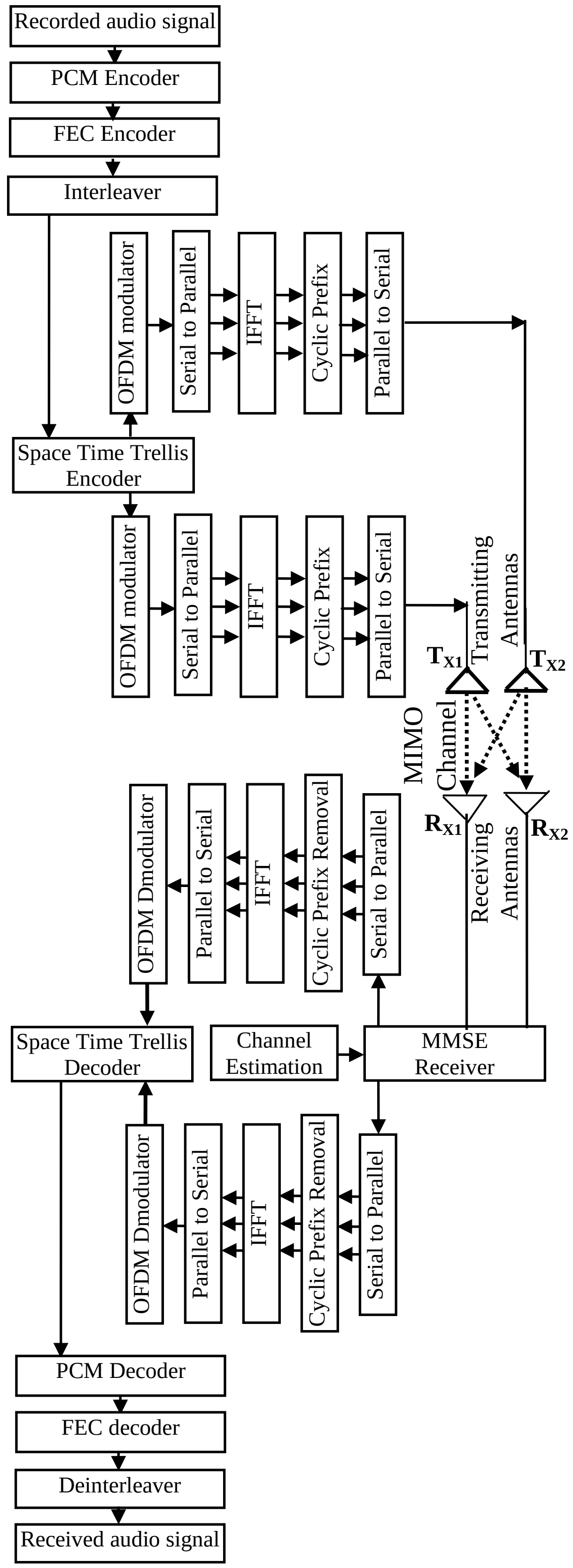

Fig-1: A block diagram of a Space Time Trellis Coded MIMO-OFDM wireless communication system.

In each OFDM transmitting channel with 256 sub-carriers, the STTC encoded symbolic data streams are first passed through OFDM modulator which performs an IFFT on blocks of length 256 followed by a parallel–to-serial conversion. A cyclic prefix (CP) of length L_{cp} (0.1*256) containing a copy of the last L_{cp} samples of the parallel–to-serial converted output of the 256-point IFFT is then pretended. The resulting OFDM symbols of length 256+ L_{cp} are lunched simultaneously from the individual transmit antenna. In the receiver the individual signals are passed through OFDM demodulators which first discard the CP and then perform a 256-point FFT. The outputs of the OFDM demodulators are finally separated and decoded using Minimum Mean –Square Error (MMSE) channel equalization algorithm. The finally detected OFDM symbols in two channels are fed into STTC decoder. Then the output of the STTC decoder is de-interleaved and passed through FEC and PCM decoder. Finally the transmitted audio signal is retrieved.

In Space-Time Trellis Code, the binary data are mapped in to modulation symbols by the encoder, where the mapping function is illustrated by a trellis diagram given in figure 2.

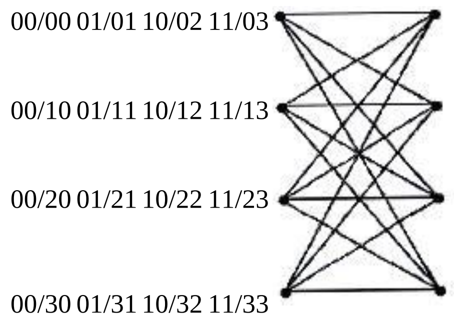

Fig-2: Trellis diagram for a 4-state space-time coded QPSK with 2 antennas.

The trellis diagram in fig-2 consists of $2^v = 4$ states represented by state nodes. At each time the encoder takes m = 2 bits as input. There are $2^m = 4$ branches living from each state corresponding to four different input patterns. Each branch is labeled by $c_t^1 c_t^2 / x_t^1 x_t^2$. where c_t^1 and c_t^2 are a pair of encoder input bits, and x_t^1 and x_t^2 represent two encoded QPSK symbols transmitted through antennas 1 and 2, respectively.

In the STTC encoder as shown in Fig-3, *m* binary input sequences $c^1.\ c^2... c^m$ are fed into the encoder, which consists of *m* feedforward shift registers. The *k*-th input sequence $c^k = (c_0^k.c_1^k.c_2^k....c_t^k....).k = 1.2....m,$ is passed to the *k*-th shift register and multiplied by an encoder coefficient set. The multiplier outputs from all shift registers are added modulo *M*giving the encoder output x = $(x^1.x^2....x^{nT})$.
The encoder output at time ***t*** for transmit antenna ***i***, denoted by x_t^i, can be computed as

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$$x_t^i = \sum_{k=1}^{m}\sum_{j=o}^{vk} g_{j,i}^{k} c_t^{k} - j \mod M.\ i = 1,2...nT \text{ ....} \quad (1)$$

These outputs are elements of an *M*-PSK signal set The space time trellis coded *M*-PSK can achieve a bandwidth efficiency of *m* bits/s. The total memory order of the encoder, denoted by *v*, is given by

$$v = \sum_{k=1}^{m} vk \cdots\cdots\cdots (2)$$

where, k =1,2...m, is the memory order for the *k*-th encoder branch. The value of *vk* for *M*- PSK constellations is determined by $vk = \frac{v+k-1}{\log_2 M} \cdots\cdots\cdots (3)$

The total number of states for the trellis encoder is 2^v. The m multiplication coefficient set sequences are also called the generator sequences, since they can fully describe the encoder structure. Let us consider a simple space-time trellis eroded QPSK with two transmit antenna. The encoder consists of two feedforward shift registers. The encoder structure for the scheme with memory order of *v* is shown in Fig-3. Two binary input streams $c^1 = (c_0^1.c_1^1.....c_t^1....)\ and\ c^2 = (c_0^2.c_1^2....c_t^2....)$ are fed into the upper and lower encoder registers. The memory orders of the upper and lower encoder registers are v_1 and v_2 respectively, where $v = v_1+v_2$.

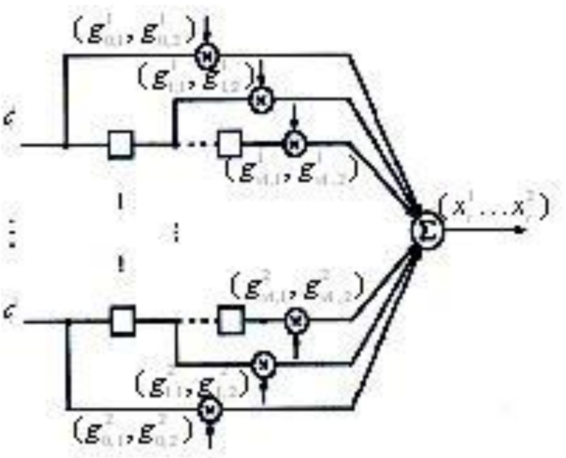


Fig-3: STTC encoder for two transmit antennas.

The two input streams are delayed and multiplied by the coefficient pairs given-

$$g^1 = [(g_{0,1}^1, g_{0,2}^1),(g_{1,1}^1, g_{1,2}^1),\ldots\ldots(g_{v1,1}^1, g_{v1,2}^1)]$$
$$g^2 = [(g_{0,1}^2, g_{0,2}^2),(g_{1,1}^2, g_{1,2}^2),\ldots\ldots(g_{v2,1}^2, g_{v2,2}^2)]$$

where $g_{j,i}^k \in \{0,1,2,3\}, k = 1,2; i = 1,2; j = 0,1,\ldots,vk.$

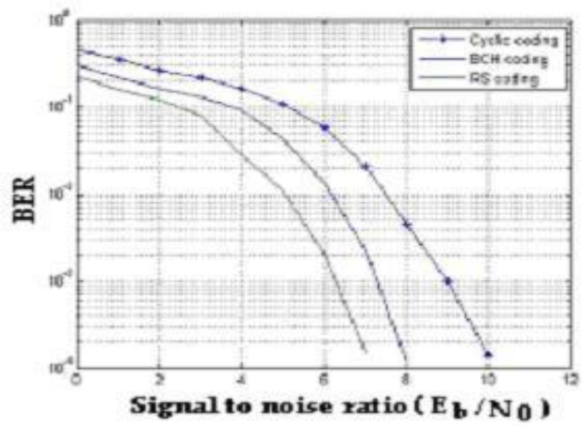
The multiplier outputs are added modulo 4, giving the output

$$X_t^i = 2\sum_{k=1}\sum_{j=0}^{vk} g_{j,i}^k c_{t-j}^k \bmod 4, i = 1,2\cdots\cdots\cdots(4)$$

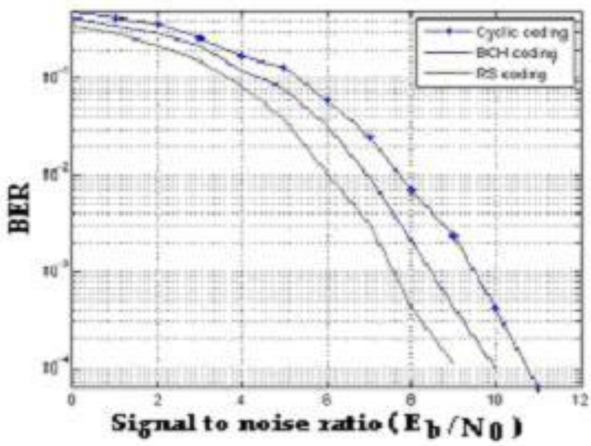
The adder outputs x_t^1 and x_t^2 are points from a QPSK constellation. They are transmitted simultaneously through the first and second antenna, respectively.

III. Result and Table

Matlab simulation has been executed to evaluate the BER performance of the STTC encoded MIMO- OFDM system under different modulation techniques. In each phase the simulated result is deployed with the FEC encoder (Cyclic, BCH and RS) under fading (Rayleigh and Rician) ana AWGN channel. On comparative study, it is observed that the system is better in performance with RS coding under QAM modulation.



(a) QAM modulation



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(b) QPSK modulation

Fig-4: BER performance analysis with different channel coding in a Space-Time Trellis coded 2 X 2 MIMO-OFDM wireless system under AWGN channel and digital modulation (a) QAM and (b) QPSK.

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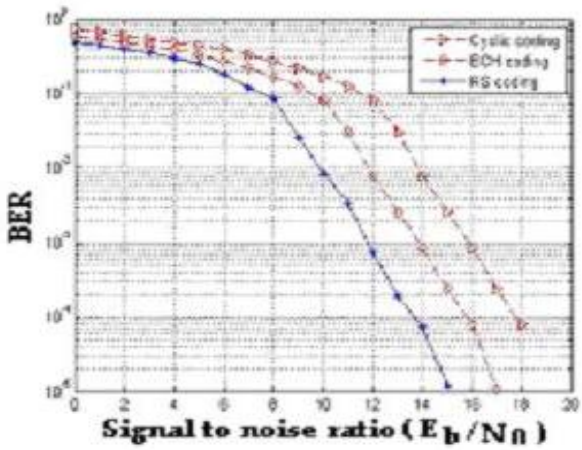
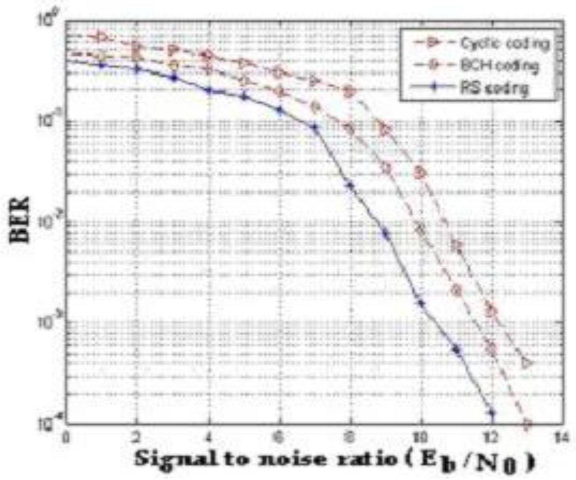
The BER performance of the system in RS coding has been improved by 33.73 dB and 31.39 dB for a typical SNR value of 4 dB under QAM and QPSK schemes separately (Fig: 4(a) and 4(b)). The system performance is significantly degraded in Cyclic coding under Raleigh fading channel but gives satisfactory performance in RS coding.



(a) QAM modulation

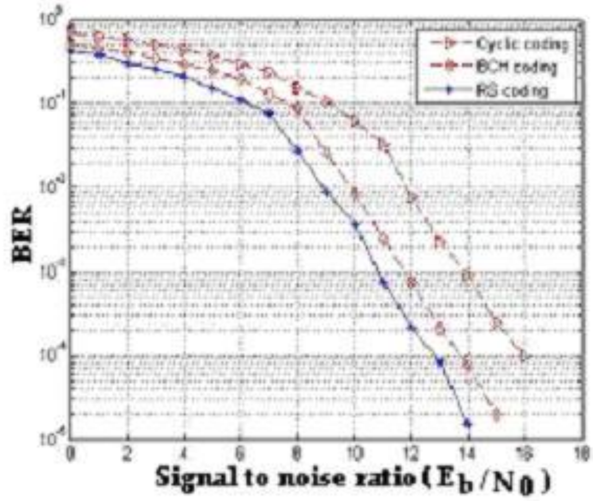


(b) QPSK modulation

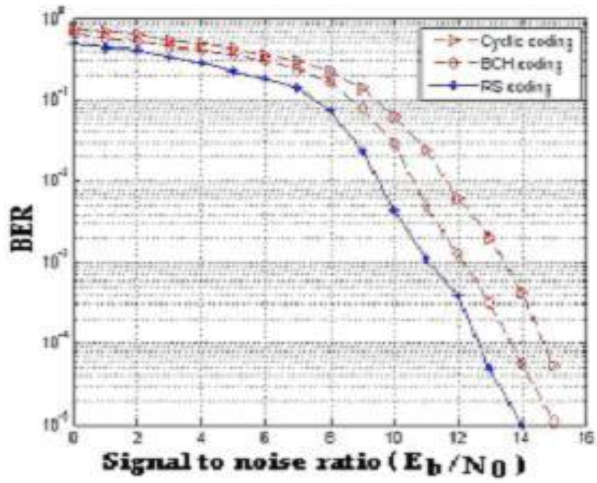
Fig-5: BER performance analysis with different channel coding in a Space-Time Trellis Coded 2 X 2 MIMO-OFDM wireless system under Raleigh fading channel and digital modulation (a) QAM and (b) QPSK.

The BER performance of the system has been improved by 0.22 dB for a typical SNR value of 5dB under QAM as compared to QPSK. In the same typical value of SNR, the system performance is improved with RS coding by 3.88 dB and 2.27 dB respectively on comparing Cyclic coding separately under QAM and QPSK modulation (Fig: 5(a) and 5(b)). Finally we have studied the BER performance of the system under Rician fading channel. The system in such environment offers better performance in QAM modulation with RS coding.

The bit error rate for QAM and QPSK modulations for a typical SNR value of 5 dB are 0.174 and 0.2223 respectively i.e. the BER performance has been improved by 1.55 dB (Fig: 6(a) and 6(b)).



(a) QAM modulation



(b) QPSK modulation

Figure 6: BER performance analysis with different channel coding in a Space-Time Trellis coded 2 X 2 MIMO-OFDM wireless system under Racian fading channel and digital modulation, (a) QAM and (b) QPSK.

IV. Conclusion

In this contribution, a comparative study has been made on the performance evaluation of a concatenated (channel coding and diversity) STTC encoded MIMO-OFDM wireless system. The simulated results of the system performance indicate the impact of channel coding under fading channels. In the context of system performance, it can be concluded that the implementation of QAM digital modulation technique in channel (RS coding) and diversity (STTC) encoded MIMO-OFDM wireless system provides satisfactory result.

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