Trellis coded STBC based OFDM for frequency Selective Fading Channels

K.Snehalatha
Department of Electronics and Communication Engineering
J. B. Institute of Engineering & Technology, Hyderabad, Andhra Pradesh, India

Abstract- Multiple-input multiple-output (MIMO) wireless communication system exploits the multiple spatial channels to achieve higher data rate or improved performance in multipath fading environment. Different types of diversity techniques such as temporal, frequency, code and spatial have been developed in the literature. In addition to the destructive multipath nature of wireless channels, frequency selective channels pose inter symbol interference (ISI) while offering frequency diversity for successfully designed systems. Orthogonal frequency division multiplexing (OFDM) has been shown to combat ISI extremely well by converting the frequency selective channel into parallel at fading channels. The space-time block coding (STBC) technique, one of representative multiple antenna techniques, is most attractive for these purposes since it easily provides the diversity at receiver by transmitting a space-time coded signal through multiple antennas. However, these coding techniques are not designed for higher coding gains; hence a novel approach would be to concatenate them with Trellis codes to obtain maximum gain over the frequency selective fading channels. So by using OFDM along with STBC make the frequency selective fading channel into which converts a frequency-selective channel into parallel independent frequency-flat sub channels using the computationally-efficient Fast Fourier Transform (FFT).In order to still enhance the performance of the STBC-OFDM system, one can think of concatenating a convolution code to the STBC-OFDM .As TCM provides coding gain besides error correction, TCM is opted here.

Keywords – Watermarking, Haar Wavelet, DWT, PSNR,MIMO

I. INTRODUCTION

There exists a sharp limit on the achievable data rate on a given channel, the channel capacity. Further increases in the data carrying capacity of a channel can only be achieved by modifying the channel itself. One method is to use many parallel channels, rather than a single channel. For wireless systems, this is achieved by using an array of transmit and an array of receive antennas generally called a MIMO system.

It targets improving the reliability of the link, which can be achieved by the transmission and reception of several replicas of the same information through independent fading paths and, hence, reduces the probability of simultaneous signal fades. The provision of replicas of the same information at the receiver is referred to as diversity. The number of independent receptions of the same information at the receiver is defined as the ―diversity order‖ or the ―diversity gain‖ of the system.

Power and bandwidth are limited resources in modern communications systems, and their efficient exploitation invariably involves an increase in the complexity of a communication system. It has become apparent over the past few decades that while there are strict limits on the power and bandwidth resources, the complexity of systems could steadily be increased to obtain efficiencies ever closer to the these limits. One very successful method of reducing the power requirements without increase in the requirements on bandwidth was introduced by Gottfried Ungerboeck[1–4], subsequently termed trellis-coded modulation (TCM).

While error control coding was long regarded as a discipline with applications mostly for channel with no bandwidth limitations such as the deep-space radio channel, the trellis-coded modulation schemes of Ungerboeck[1–4] provided the first strong evidence that coding could be used very effectively on band-limited channels. Starting in the 1980s and continuing to this day, numerous researchers have discovered new results and new codes. 2

II. PROPOSED TECHNIQUE

Space-time trellis coding (STTC) was introduced as an effective diversity technique to combat fading. For a fixed number of transmit antennas, its decoding complexity increases exponentially with the transmission rate.

The TCM uses many diverse concepts from signal processing. In simplest terms it is a combination of coding and modulation, hence it name Trellis Coded Modulation, where the word trellis stands for the use of trellis (also called convolutional) codes. Whereas we normally talk about coding and modulation as two independent aspects of the communications link, in TCM they are combined.

TCM is a complex concept to understand, particularly due to the non-linear nature of the performance. It uses ideas from modulation and coding as well as dynamic programming, lattice structures and matrix math. A convolutional code that has optimum performance when used independently may not be optimum in TCM.

Space-time codes are originally designed for flat-fading channels, it is challenging to apply them over frequency-selective channels. One approach is to employ orthogonal frequency division multiplexing (OFDM) which converts a frequency-selective channel into parallel independent frequency-flat sub channels using the computationally-efficient Fast Fourier Transform (FFT).

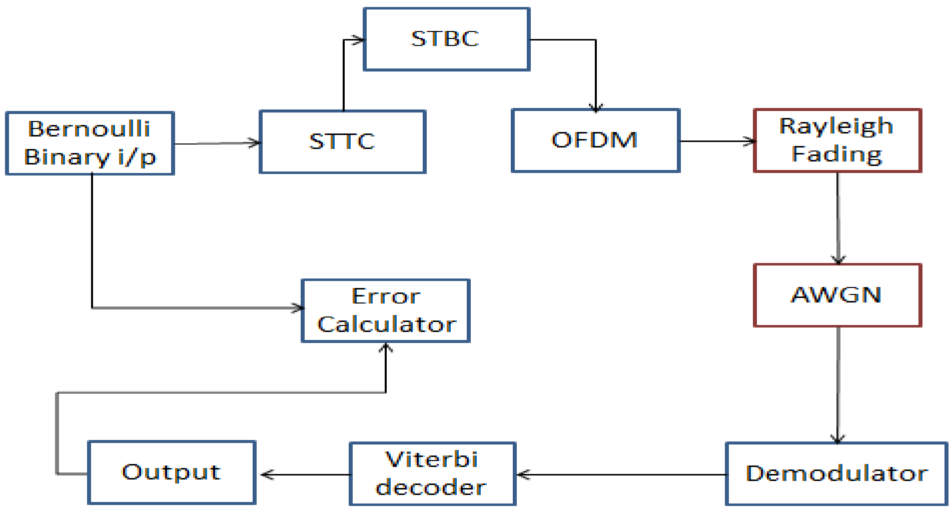


Figure 1. Block Diagram of STTC-STBC-OFDM

III. RESULTS AND DISCUSSION

The results indicate that inclusion of STBC in STTC OFDM reduces the BER. The results also indicate that ISI introduced due to the channel is greatly reduced. The following experiments are case studies conducted in Simulink. These experiments were conducted in order to determine the performance of the STTC-OFDM and STTC-STBC–OFDM blocks developed as a part of the experimentation, its response to various SNR maintaining the BW= 15MHz.

This model can be used for selection of BW upto 20 MHz and SNR staring from 6.4dB and selecting the cyclic prefix values as 1/4,1/8,1/16,1/32). The testing is done for different SNR starting from 6.4 dB values on both the schemes assuming the BW of the channel to be some constant here 15MHz and cyclic prefix=1/8.

Simulation Results: SNR at 7dB for STTC-OFDM

The test comprised of maintaining the BW of the channel to be 15 MHz, with a cyclic prefix of 1/8.

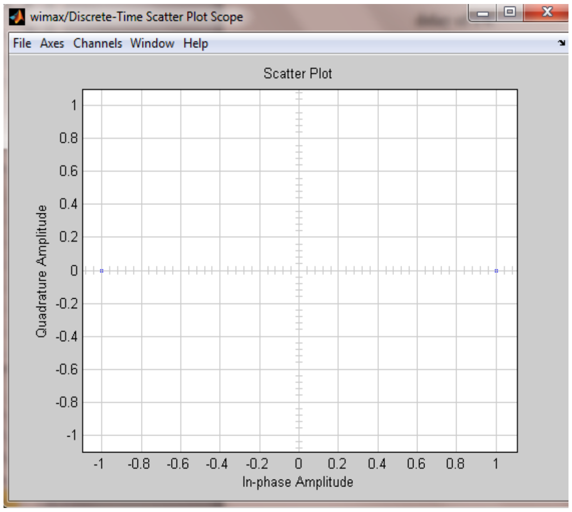


Fig: 2 Constellation observed at Modulator for SNR=7dB

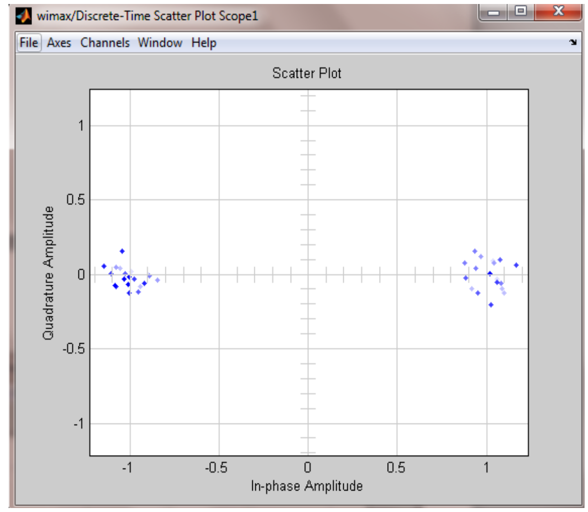


Fig: 3 Constellation observed at Receiver for SNR=7dB

The eye diagram also explains the effect of ISI

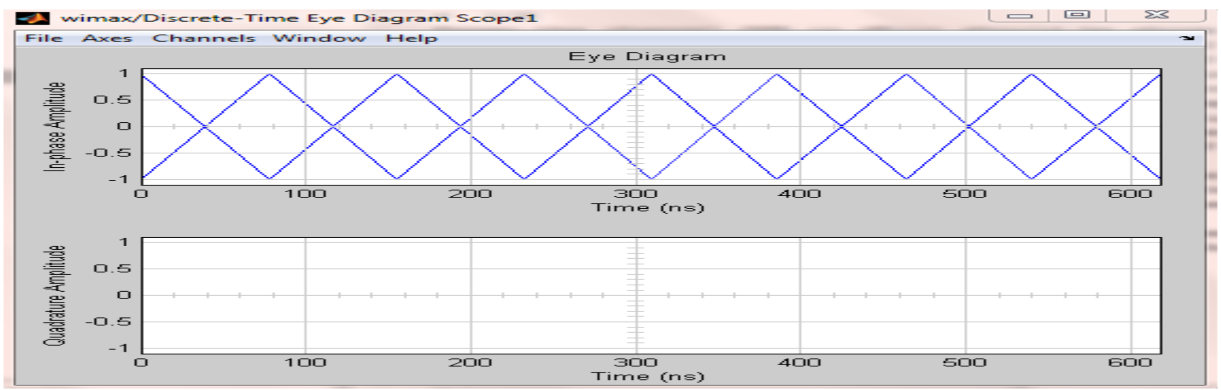


Fig: 4 Eye diagram of modulated signal at the transmitter

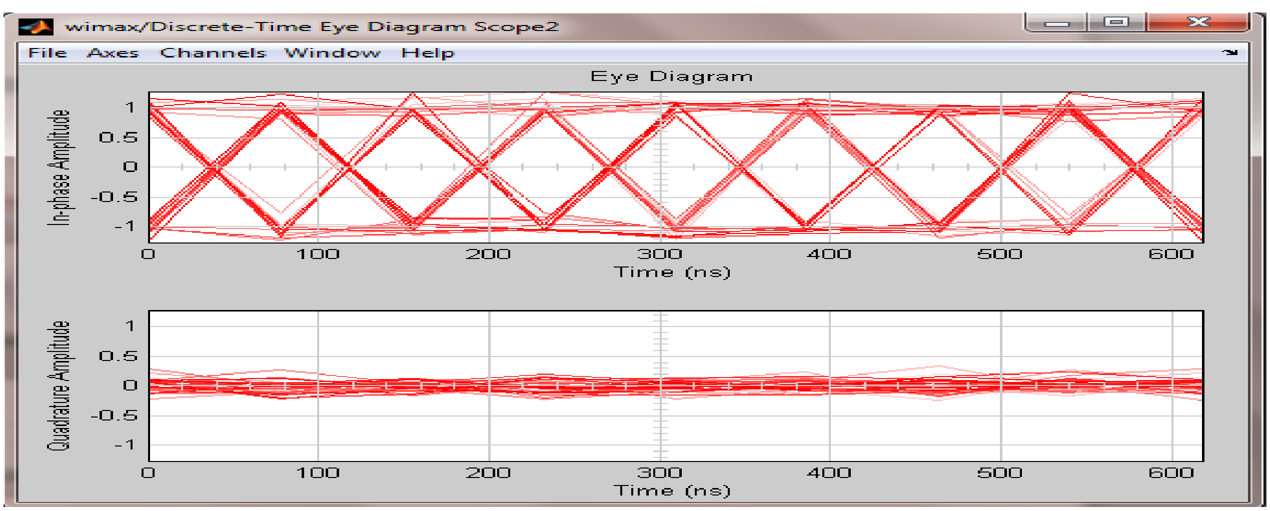


Fig: 5. Eye diagram of signal after passing through the channel

Even from the eye diagram observed at the modulator and at the receiver we can deduce that the Quadrature component of the signal is zero and the signal distorted by small amount. We can observe from above eye diagrams that the openings of the eye before and after passing through the channel are nearly similar. Hence there is less ISI this is since the clear opening of the eye implies the decrease in the ISI.

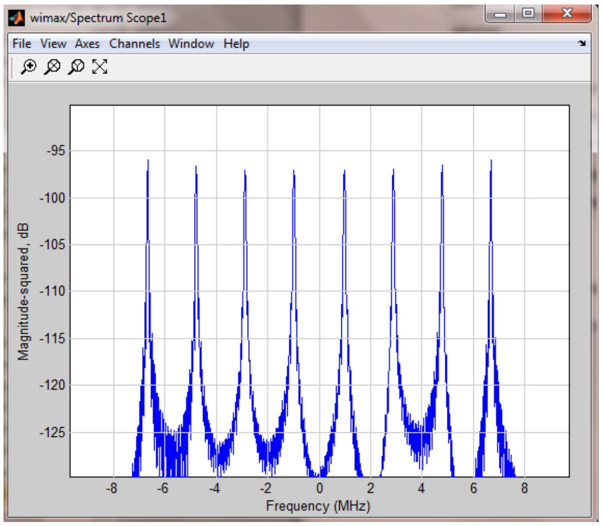


Fig.6. Frequency Spectrum at transmitter

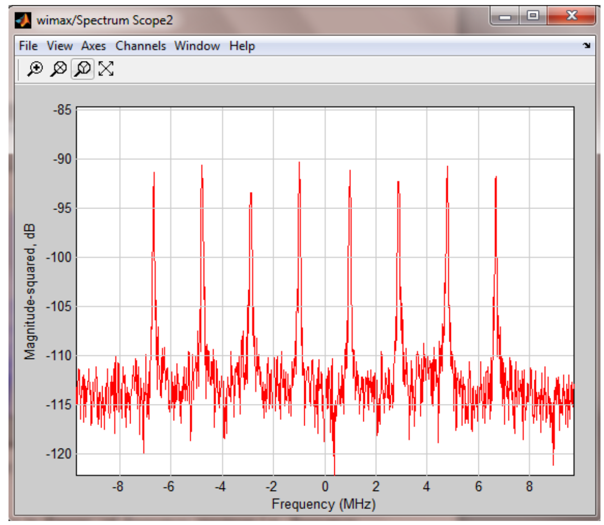
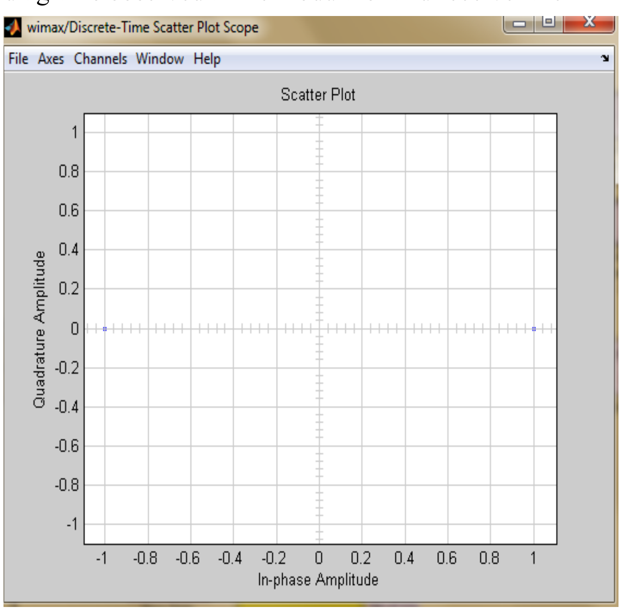


Fig. 7. Frequency Spectrum at receiver

Experimental Results: SNR at 7dB for STTC-STBC-OFDM

Experiment is repeated for same BW, delay and SNR but this time the MIMO is included. The Constellation diagrams observed at the modulator and receiver are



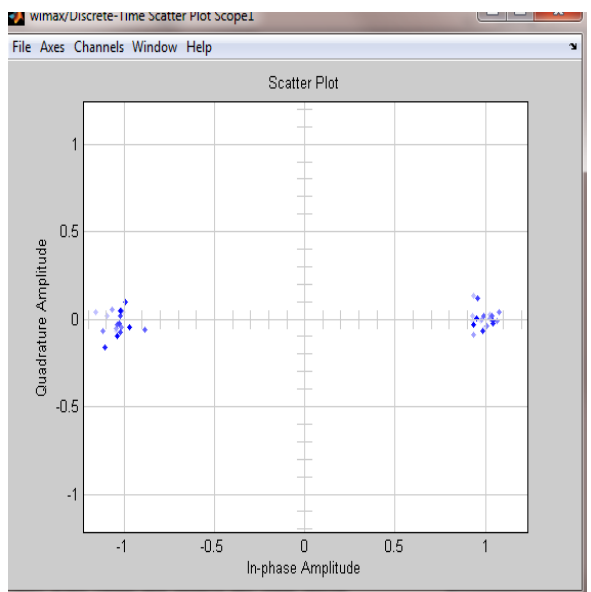


Fig: 8 Constellation observed at Modulator for SNR=7dB

Fig. 9Constellation observed at receiver for SNR=7dB

From constellation diagram we can observe that even in this case the modulator selected is BPSK and signal is distorted by small amount at the receiver. And also the ISI is less since the constellations are at significant distance.

The eye diagrams observed at the modulator and receiver are as follows

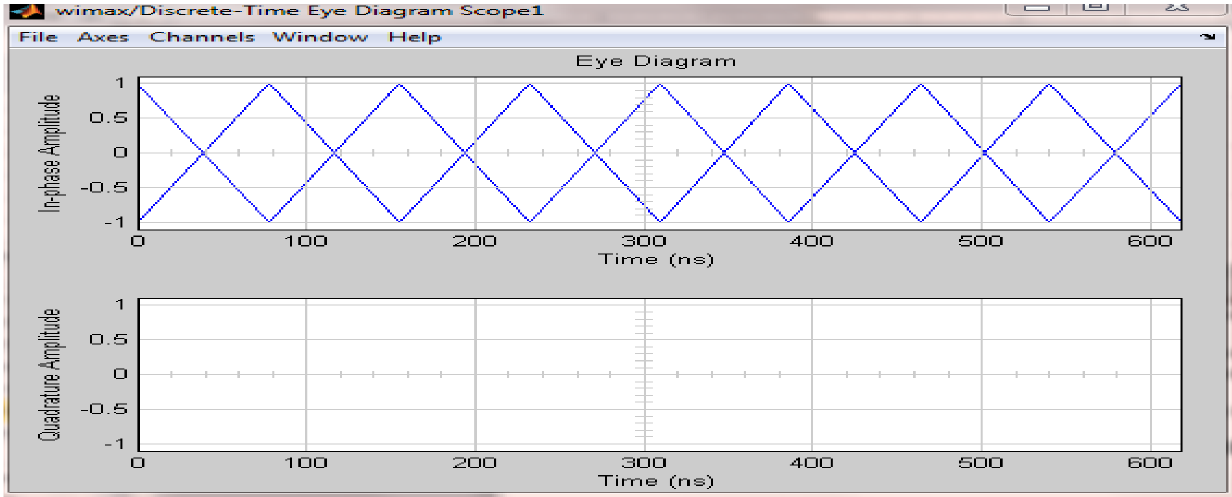


Fig 10: Eye observed at the modulator

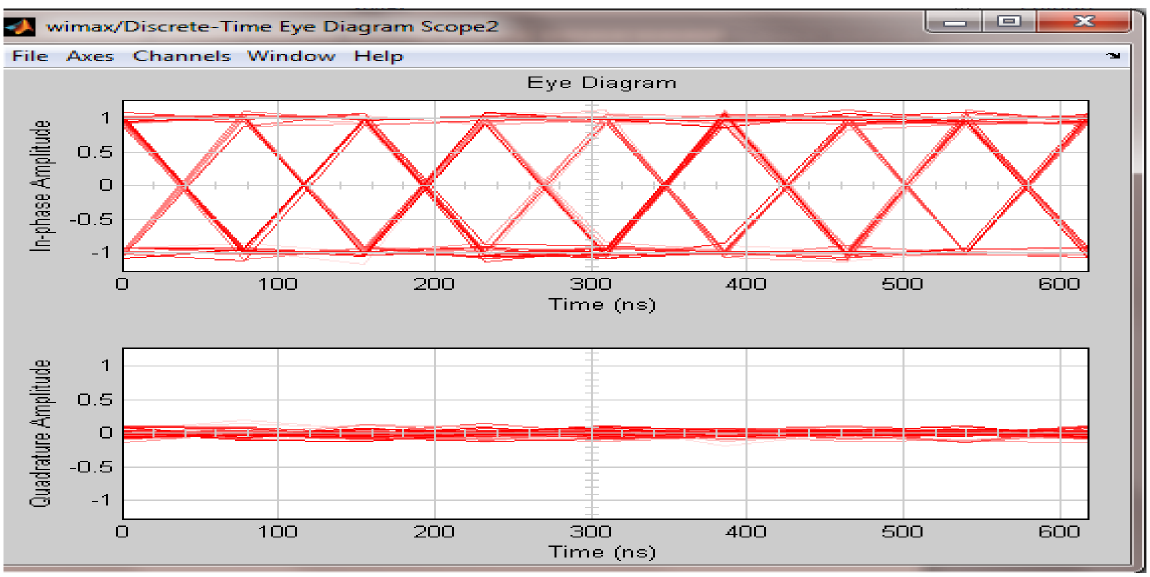


Fig: 11 Eye observed at the receiver

The eye diagram also explains the fact that ISI is less and the quadrature component is zero. The frequency plot i.e., frequency vs. power at the two antennas and at the receiver respectively is observed as is shown as follows

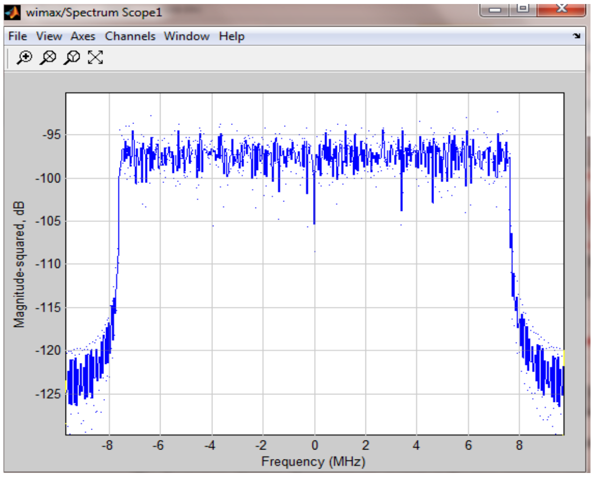


Fig: 12 Frequency Spectrum at antenna1

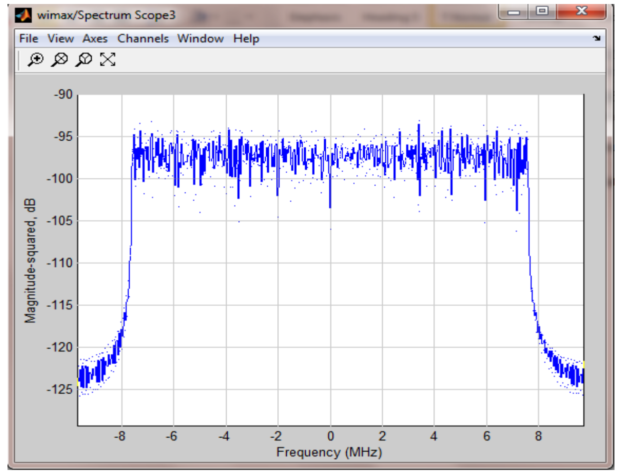


Fig: 13 Frequency Spectrum at antenna2

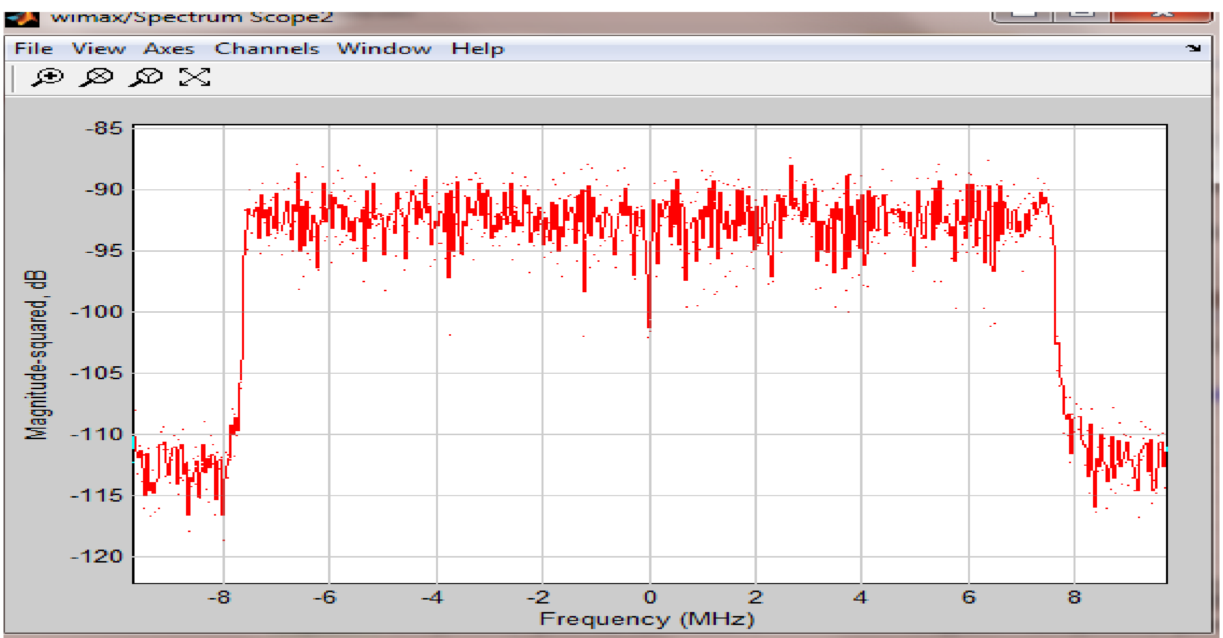


Fig: 14 Frequency Spectrum at receiver

By observing the frequency plots we can deduce that power loss in this scheme compared to first scheme is less and also the receiver can be designed with a particular range say -100dB to -90dB to get all the frequency components where as in the first scheme the receiver has to be designed with range -130 to -90dB to get all the frequency components. Hence there is less data loss in this case which proves the Alamouti concept of sending the data twice will reduce the data loss. We can conclude that for a BW of 15 MHz and at a SNR of 7dB in this scheme the signal is slightly distorted but the Inter Symbol Interference is less. The power loss and data loss is less compared to the scheme of STTC-OFDM and also the receiver complexity is reduced. Also the number of fault bits and the BER observed at receiver is zero which is seen in Display 4 of Simulink model. So the experiment is repeated for different SNR such as 11, 13, 17, 19, 23, and 25 and the analysis is tabulated.

Analysis

The designed models are tested for Hard type and Soft type decoder and the BER is observed. It is observed that the BER reduces as we go for higher modulation techniques such as BPSK, QPSK, 16 QAM and 64 QAM. And the BER further reduces as the code rate changes. It is also observed that the BER in the system without STBC is less compared to the system with STBC.

Table1. Tabular column for comparison of two schemes

BW=4MHz								
SNR (dB)	Modulator selected	Code-Rate selected	Without STBC			With STBC		
			BER			BER		
			Inputs	Hard Type	Soft type	Inputs	Hard Type	Soft type
7	BPSK	1/2	5.993e+004	Zero	0.5007	6.002e+004	Zero	0.4999
11	QPSK	1/2	6.017e+004	Zero	0.4997	6.035e+004	Zero	0.4985
13	QPSK	3/4	6.020e+004	Zero	0.4964	6.048+e004	Zero	0.4965
17	16 QAM	1/2	6.054e+004	Zero	0.4980	6.091+e004	Zero	0.4948
19	16 QAM	3/4	6.078e+004	Zero	0.4962	6.134e+004	Zero	0.4916
23	64 QAM	2/3	6.080e+004	Zero	0.4946	6.156e+004	Zero	0.4882
25	64 QAM	3/4	6.078e+004		0.4939	6.163e+004	Zero	0.4868

Simulation stops at fault bits of 3e4

BER is 0.006724 for input bits of 6e4 & no. fault bits is 472

IV.CONCLUSION

In this paper the performance of STTC-OFDM is enhanced by introducing the STBC system. The two schemes involving trellis coded system with OFDM and trellis coded system along with OFDM and STBC have been successfully modeled. The STTC-OFDM scheme& STTC-STBC-OFDM scheme modeled as a part of this experiment successfully emulates characteristics of the ISI using the different modulators and code rate selected automatically at different bandwidths for a constant SNR.

Future scope

All the Current simulations for both the schemes observed in this paper are based on Hard Decision type decoding which uses binary information for decoding process. The performance of the schemes can be further enhanced by using the soft type decision Viterbi decoder where it uses multi-bits information and Euclidean distance as metric for decision. More research is going on in Soft decision development though it is costlier to implement. The performance of the proposed scheme can also be enhanced by increasing diversity using more number of transmitter and receiver antennas.

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