Performance Improvement of STBC OFDM MC-CDMA with Phase Matrix in Different Channel Models

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Abstract

In this paper, an improvement of space-time, block-coded (STBC) multicarrier code-division multiple-access (MC-CDMA) system using phase matrix in multipath fading channel is proposed, and the performance of the system is analyzed. The bit error rates BER numerical results show that the better performance of the STBC-MC-CDMA system with phase matrix can be achieved when comparing with system without using phase matrix. As a result, it can be seen from the proposed technique that a high performance improvement was obtained over the conventional MC-CDMA, where the Bit Error Rate (BER) is mainly reduced under different channel characteristics for frequency selective fading and the AWGN channel.
Keywords: STBC, MC-CDMA, OFDM, IFFT, FFT, Phase matrix.

1. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) has been adopted as the modulation technique for various current and proposed wireless systems. It provides high data rates, high spectral efficiency. It eliminates the need for multi-tap equalizers in frequency selective channels by dividing the available bandwidth into several narrow band channels. These channels can be allocated to different users to transmit data at a higher rate. Multi-carrier code division multiple access (MC-CDMA), which suits high data rate applications with multiplexing technique, appears to be a promising technique in achieving high data rates (S. Hara and R. Prasad, 1999, Ajra, 2014). MC-CDMA is robust to multi-path fading, inheriting the advantages of conventional CDMA where frequency diversity can be achieved in a broadband channel (S.Hara and R. Prasad, 1997). With its ability of synchronous transmission, MC-CDMA is appropriate for downlink of cellular communication systems (S. Chatterjee, 2003, Leandro D'Orazio, 2011). The challenge of achieving reliable data transmission over wireless link is further difficult due to the fact that received signals from multi-paths add destructively causing multi-cell interference which results in serious performance degradation. To achieve reliable communication over wireless links antenna diversity (G. Foschini and M. Gans, 1998) derived by employing spatially separated antennas at the transmitter and receiver was introduced. Data transmission involves spreading operations by the use of short channelization code and long scrambling code. Short channelization code helps in separating the signals of diverse users present within the cell and long scrambling code mitigates the effects of interference produced by users belonging to other cells. Though, the system faces multi-cell interference due to fading channel resulting in degradation of bit-error rate (BER). We first establish the Alamouti code(S.M. Alamouti, 1998) , which is a easy two branch transmit diversity scheme. The key characteristic of the system is that it achieves a full diversity gain with a simple maximum-likelihood decoding algorithm. The decoding algorithms for space-time block codes with both real and complex signal constellations are used. The performance of the schemes on MIMO fading channels under a variety of channel environment is evaluated by simulations, which combats the effects of fading. OFDM system is used to reduce multi-cell interference (S.M. Alamouti, 1998, Inoue M, 2002, Sadananda Behera, 2014), where space time block code (STBC) is used to gain diversity effect among numerous base stations. STBC site diversity system transmits the encoded signals from numerous base stations and these signals are combined at the receiver with STBC decoding process. STBC branches and the scrambling codes are assigned to each base station to preserve orthogonality of signals between the cells and to reduce interference among them. The similar method is extended to MC-CDMA scheme. Though, the scrambling codes assigned are usually non orthogonal among cells and hence multi-cell interference still exists. Using STBC with multiple antennas at each base station, site diversity was achieved with more reduction in multi-cell interference(Kumaratharan, 2010). In this work STBC-OFDM, multiple antennas at base station with phase matrix is used to obtain high diversity and improvement bit error rate BER for MC-CDMA system.

2. System Model

The block diagram of the proposed STBC OFDM-CDMA transceiver is shown in Figure 1.This Figure illustrates a typical STBC-OFDM system used for Multicarrier modulation. The transmitter accepts data, and converts it into lower rate sequences via serial to parallel conversion, these lower rate sequences are mapped to give sequences of channel symbols. This process will convert data to corresponding value of M-ary constellation which is complex word, i.e. real and imaginary part. The bandwidth is divided into N equally spaced subcarriers. At the transmitter, information bits are grouped and mapped into complex symbols. In this system, quaternary, QPSK (Quadrature Phase Shift Keying) with constellation QPSK is assumed for the symbol mapping. According to the Space time coded code, are transmitted from the two antennas simultaneously, we assume half of the virtual carriers are on both ends of the spectral band (Zhi Zliang and Li Guoqing, 2001). The training frame (pilot sub-carriers frame) will be inserted and sent prior to information frame. This pilot frame will been used to make channel estimation that's used to compensate the channel effects on the signal. To modulate spread data symbol on the orthogonal carriers, an N-point Inverse Fourier Transform IFFT will be used, as in conventional OFDM. Zeros will be inserted in some bins of the IFFT in order to make the transmitted spectrum compact and reduce the adjacent carriers' interference. The added zeros to some sub-carriers will limit the bandwidth of the system, while the system without zeros pad has a spectrum which is spread in frequency. The last case is unacceptable in communication systems, since one limitation of communication systems is the width of bandwidth. The addition of zeros to some sub-carriers means that not all the sub-carriers will be used. Therefore, Orthogonality between carriers is normally destroyed when the transmitted signal is passed through a dispersive channel. When this occurs, the inverse transformation at the receiver cannot recover the data that was transmitted perfectly. Energy from one sub channel leaks into others, leading to interference. However it is possible to Rescue orthogonality by introducing a cyclic prefix (CP). At the receiver of STBC OFDM-MC-CDMA, if there is an error occurred due to multipath, and then at the output of the FFT there will be a high error occurred at the other bits due to mixing of phases and values of signal by FFT. So, if there is an algorithm that be able to inhibits the error in this bit from spreading or affecting on the other bits at the output of the FFT at the receiver then, the BER will reduce, such algorithm can be done by multiplying the transmitted signal by a Phase Matrix (PM) (Salih Mohammed Salih, 2009) at the transmitter side and the Inverse of Phase Matrix (IPM) at the receiver side. This property can be verifying because the same bits are modulated on different subcarriers. So, it is possible to transmit each bit on different ordered phase. In the same time if the output of IFFT vectors are directly multiplied by a phase vector, then it is impossible to arrange the output phases of transmitted vector in a constant increasing or decreasing order, because every bit out of IFFT at the transmitter side has a related phase value and the multiplication of this vector by an ordered vector will not be able to arrange the phase values. Another advantages of phase matrix related with the power of the transmitted signal via the channel, the output signal power from the IFFT will be reduced to a very low level compared with the input value to it, the phase matrix will be able to retrieve the signal power to its normal level as the same input mean value to the IFFT. The transmitted symbol which consist of N-IFFT bins can be multiplied by a Phase Matrix (PM) which can be simply generated as in Eq. (1)(Salih Mohammed Salih, 2009) :

$$X(n,i) = \sum_{v=0}^{N-1} X(n^{*}N-(N-1)+v,i)\,e^{-j\left(\frac{2\pi}{N}\right)i,v} \qquad (1)$$

Where;
n: data bit stream number.
I: frequency bin of the FFT or IFFT (from 1 to N)
N: the window size of FFT.

It can be seen that the Phase Matrix in equation (1) is a square matrix with a dimension of N*N points. The phase of this matrix is changed as the frequency bin of the FFT is changed. If the FFT has 64 points, then the Phase Matrix in Eq. (1) can be formulated in the form (Salih Mohammed Salih, 2009):

$$PM = \begin{bmatrix} e^{-j\left(\frac{2\pi}{64}\right)*0} & \cdots & e^{-j\left(\frac{2\pi}{64}\right)*63} \\ \vdots & \vdots & \vdots \\ e^{-j\left(\frac{2\pi}{64}\right)*0} & \cdots & e^{-j\left(\frac{2\pi}{64}\right)*4032} \end{bmatrix} \qquad (2)$$

If the signal is multiplied by this PM at the transmitter side then it must be multiplied by the Inverse of Phase Matrix (IPM) at the receiver side in order to retrieve it, or in other form (Salih Mohammed Salih, 2009):

$$Y_{receiver} = y_{received\ signal} * \textit{Inverse Phase Matrix} \qquad (3)$$

Reminder that the last equation is a general equation, which means it depends on the location of the received signal that must be processed, and this location dependent on the transmitter side, because at the receiver the inverse procedure will be done to process the signal.

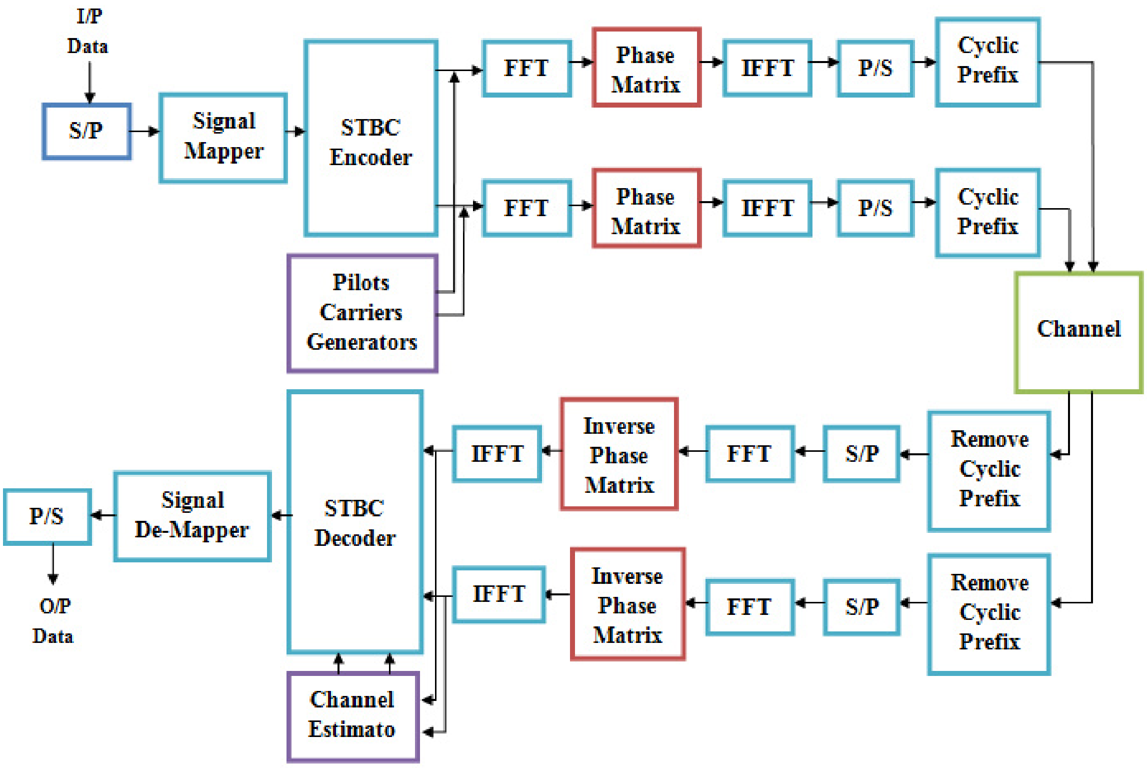

Figure 1 Block Diagram of the Proposed STBC OFDM MC-CDMA Transceiver

3. Simulation Results

In this part, the group of conventional STBC OFDM MC-CDMA and the proposed STBC OFDM MC-CDMA with phase matrix will be deliberate, in this work the Walsh-Hadamard (code 20) has been used with 32 bits of zeros are added. A simulation of the two systems has been made using MathWorks TM in the MATLAB® R20013a software package. And the BER performance of the two systems will be considered in different channel models which are AWGN, and AWGN+ frequency selective fading channel, with a bit rate of 5 Mbps and 64 subcarriers are used in this simulation. Table. 1 shows the parameters of the system used in the simulation

Table.1: Simulation Parameters

Antenna Transmitter	2T
Antenna Receiver	2R
Modulation Types	QPSK
Bandwidth	10MHz.
Number of sub-carriers	64
Number of FFT points	64
Walsh-Hadamard Code	20
Cyclic Prefix	26 Symbol
Bit Rate	5 Mbps
Channel model	Flat Fading + AWGN
	Frequency Selective Fading +AWGN

3.1 Performance of the Proposed STBC OFDM MC-CDMA with Phase Matrix in AWGN Channel

In this section, the channel here is modeled as an Additive White Gaussian Noise, from Figure.2, it is found that the proposed system STBC OFDM MC-CDMA with phase matrix does worked with SNR= 5dB at BER=10^{-3}, while in the conventional STBC OFDM MC-CDMA the bit error rate of BER=10^{-3}at SNR=16.2dB, It is shown clearly that the proposed model is much better than conventional model.

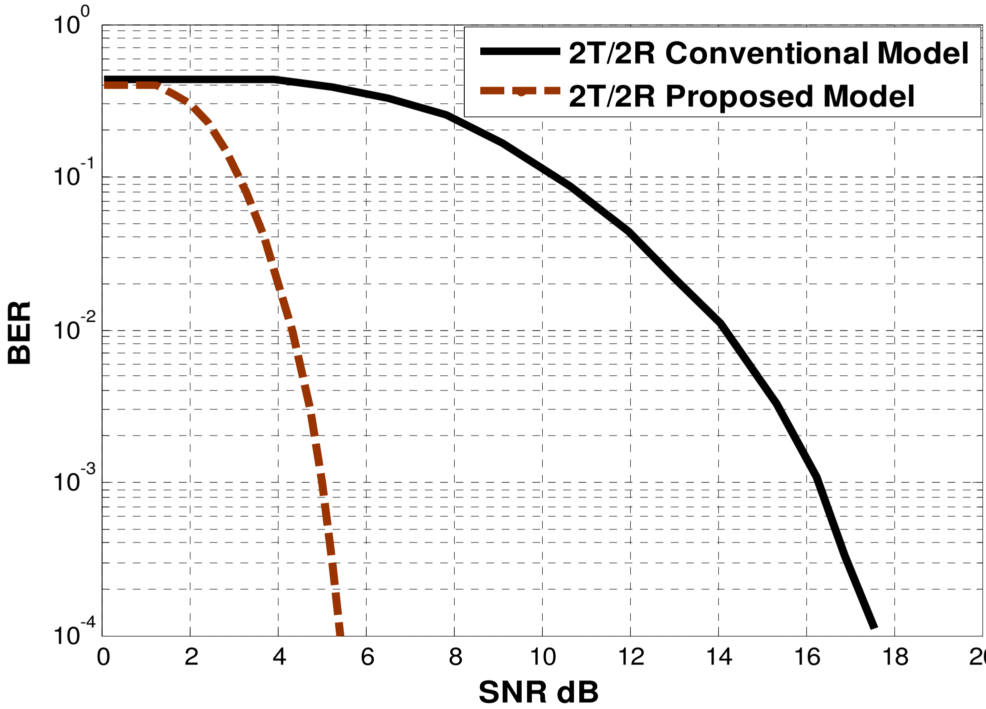

Figure.2 BER Performance of Proposed Model in AWGN

3.2 Performance of the Proposed STBC OFDM MC-CDMA with Phase Matrix in Flat Fading Channel

In this type of channel, the signal will be affected by the flat fading in addition to AWGN; in this case all the frequency components in the signal will be affected by a constant attenuation and linear phase distortion of the channel, which has been chosen to have a Rayleigh's distribution. A Doppler frequency of 10 Hz is used in this simulation. From Figiure.3, it can be seen that for BER= 10^{-3} the SNR required for STBC OFDM MC-CDMA with phase matrix is about 8.5dB, while in STBC OFDM MC-CDMA without phase matrix the SNR about 19.5dB. Alternative Doppler Shifts are used, the values taken are 100Hz, 500Hz and the BER vs. SNR are given in the two Figure.4 and Figure.5 below. From all previous Figures the SNR required achieving a BER at $10^{-3}$is decreased for the proposed system as the path gain was changed according to the vector values, while it is increased for the conventional one.

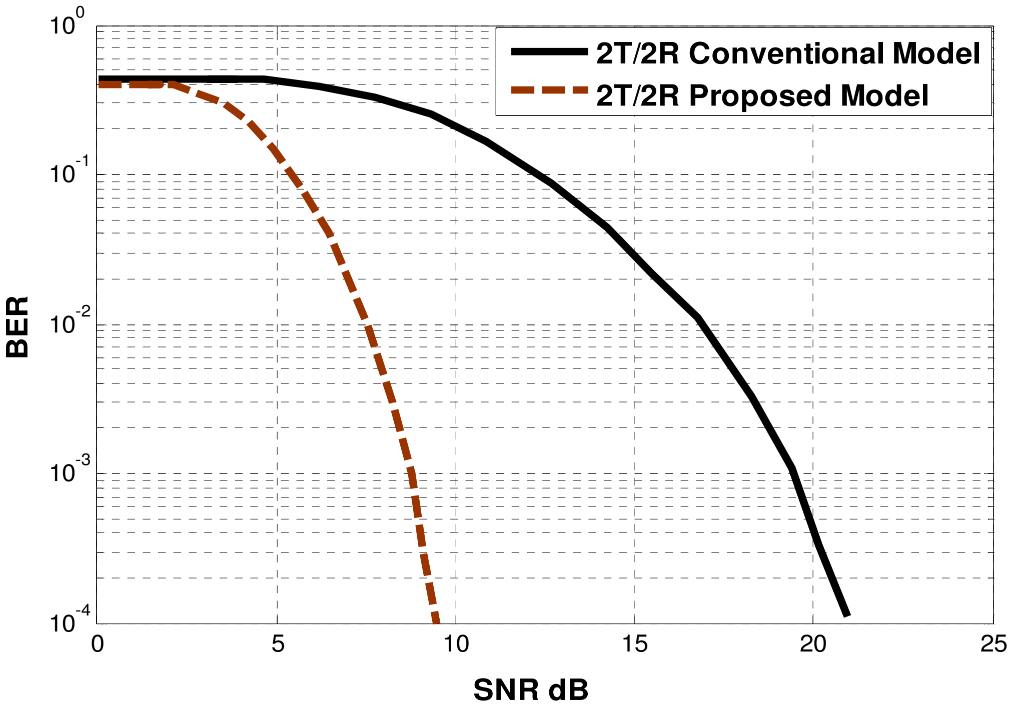

Figure.3 BER Performance of Proposed Model in Flat Fading Channel at Maximum Doppler Shift 10HZ

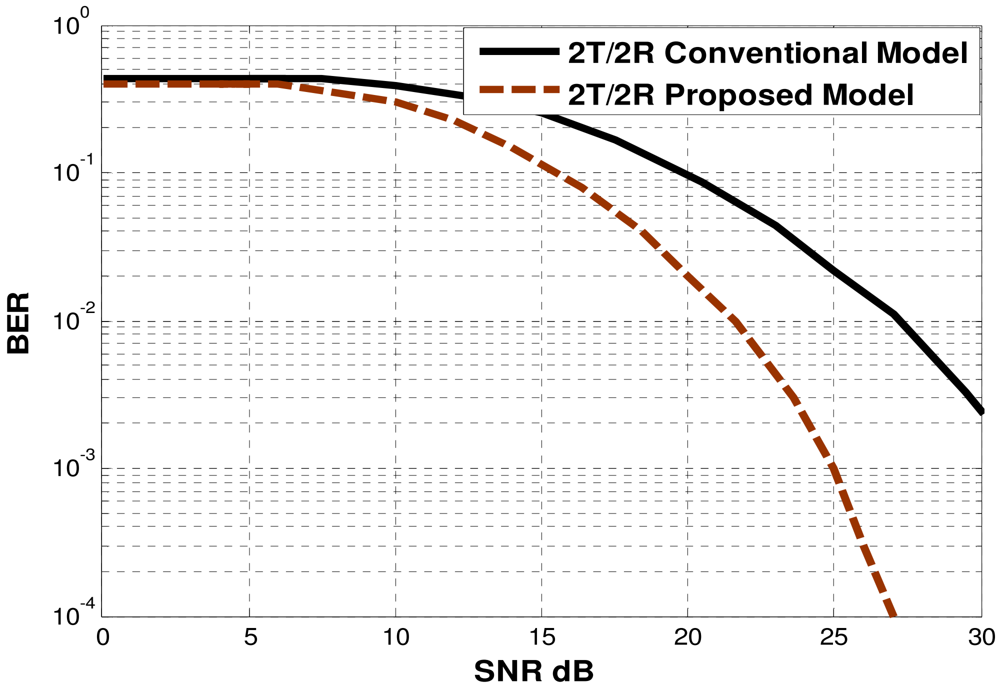

Figure.4 BER Performance of Proposed Model in Flat Fading Channel at Maximum Doppler Shift 100HZ

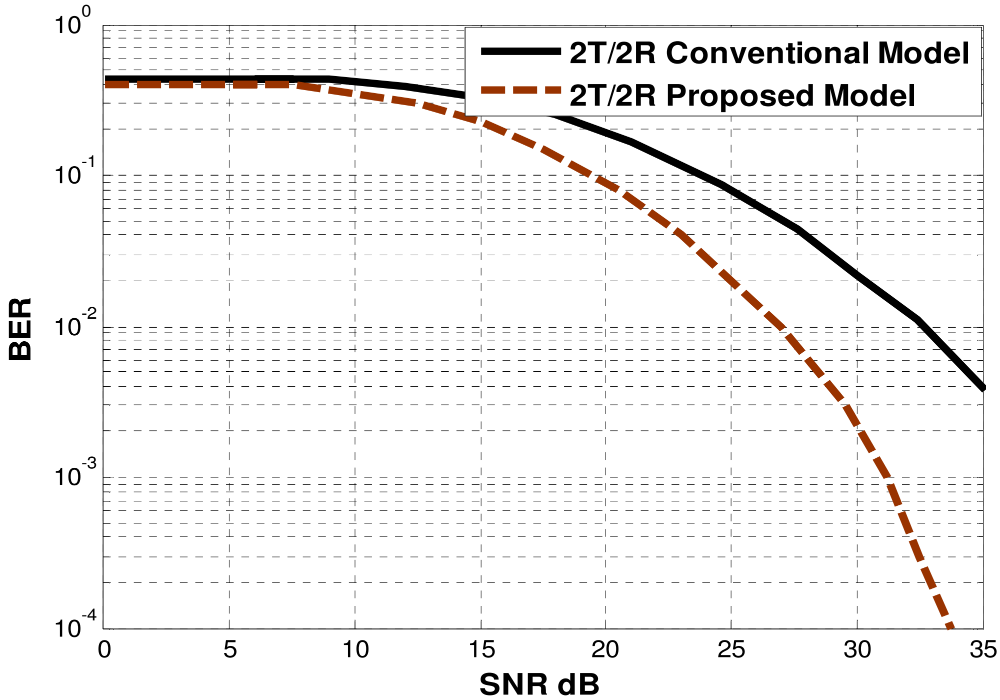

Figure.5 BER Performance of Proposed Model in Flat Fading Channel at Maximum Doppler Shift 500HZ

3.3 Performance of the Proposed STBC OFDM MC-CDMA with Phase Matrix in Selective Fading Channel

In this section, the channel model is assumed to be selective fading channel, where the parameters of the channel in this case corresponding to multipaths where two paths are chosen the LOS and second path the LOS path having Average Path Gain equal 0dB and Path Delay 0, where the second path has Average Path Gain -8dB and path Delay one sample as shown in Figiure.6 at Maximum Doppler shift 10Hz it is clear from this Figure, that BER performance of for STBC OFDM MC-CDMA with phase matrix is better also than the other systems. The STBC OFDM MC-CDMA with phase matrix has BER performance of 10^{-3}about 15dB has the same BER performance at 25 dB for STBC OFDM MC-CDMA without phase matrix. After that, the three systems are tested on other different parameter by changing first the Maximum Doppler Shift, setting the parameter to 100Hz and then to 500Hz, the values are shown in Figure.7 and Figure.8 for Doppler Shift parameter test, the STBC OFDM MC-CDMA with Phase Matrix is performing better than the conventional STBC OFDM MC-CDMA without Phase Matrix

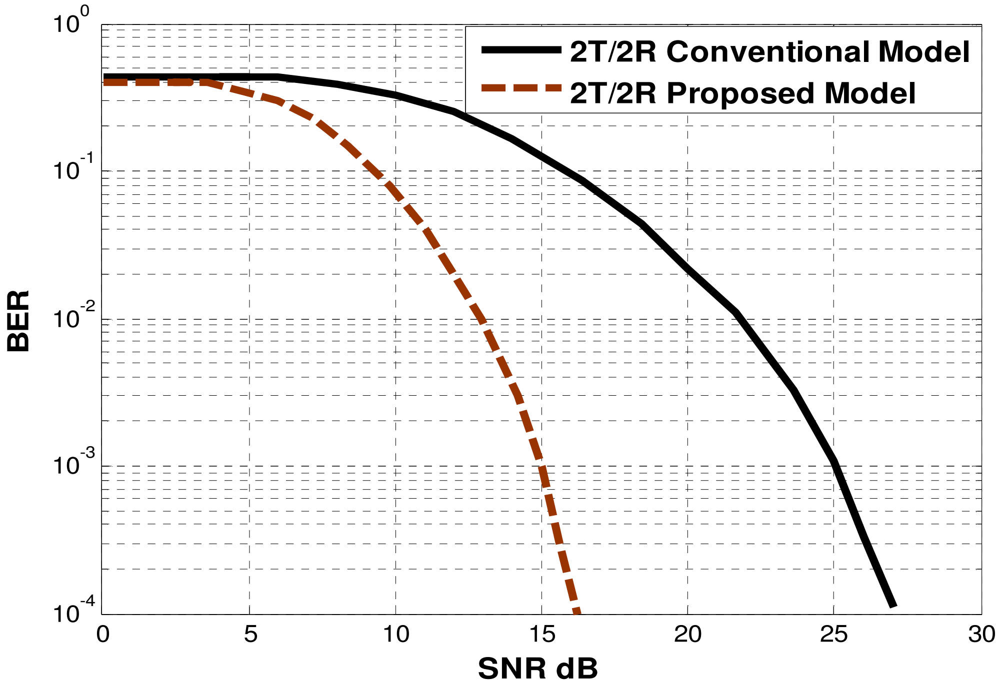

Figure.6 BER Performance of Proposed Model in Selective Fading Channel at Maximum Doppler Shift10HZ

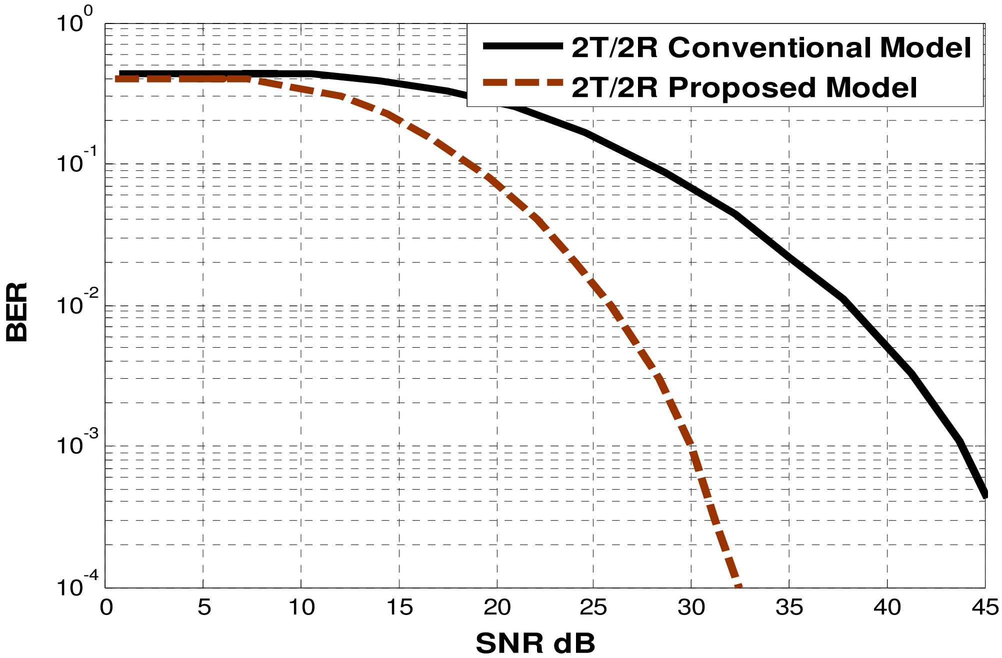

Figure.7 BER Performance of Proposed Model in Selective Fading Channel at Maximum Doppler Shift100HZ

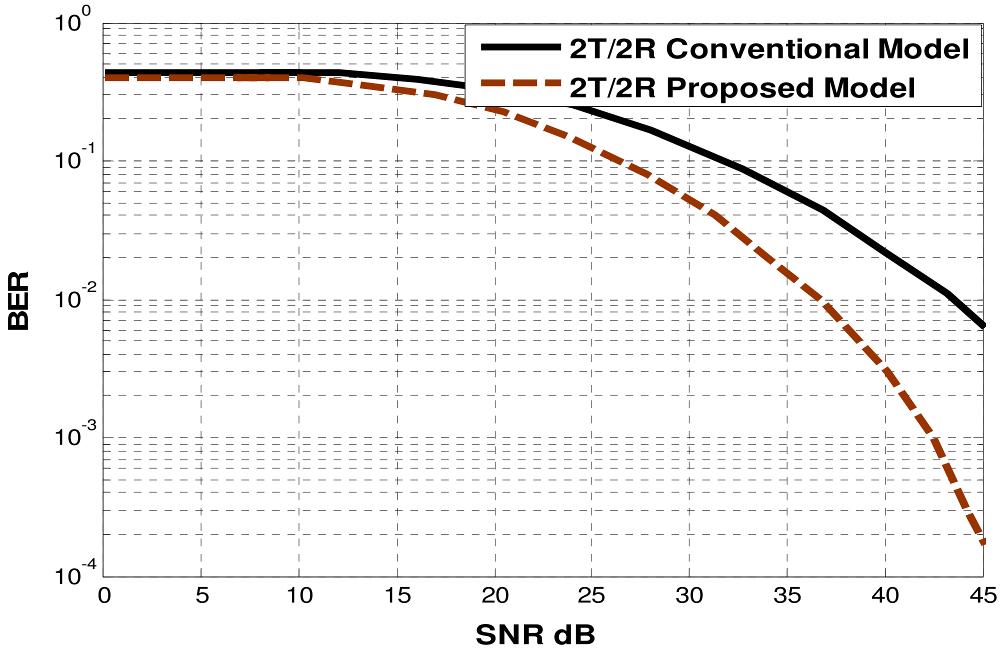

Figure.8 BER Performance of Proposed Model in Selective Fading Channel at Maximum Doppler Shift500HZ

4. Conclusion

This paper validated the different design criteria for STBC OFDM MC-CDMA in the presence of channel fading model. The simulation of the proposed and conventional STBC OFDM-CDMA systems has been accomplished. It has been shown that the a new STBC OFDM MC-CDMA with phase matrix is further active to work under some different channel conditions. The proposed model is less affected by changing the path gain and the path delay and much lower bit error rates and counteractive for multipath channels

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