Performance analysis of OFDM for 4G wireless systems under various fading channels

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Abstract: The era of entirely wireless, mobile communication is rapidly approaching.Increasingly; users are demanding versatile and convenient modes of communication along with high-speed broadband and technology in the premise of guaranteeing certain quality of communication without losing performance and efficiency. The challenges are to give users high-speed, high-performance in different channel conditions. So, Orthogonal Frequency Division multiplexing (OFDM) has been recognized as one of the most promising techniques to meet these challenges. Space Time block Coding (STBC) has drawn much attention in 4G wireless technologies just because of its decoding simplicity. This paper presents the performance evaluation of STBC-OFDM systems covering channel model and coding scheme, it includes Rayleigh fading channels by which it is observed that Bit Error Rate(BER) is reduced to achieve the high data rate.In this work, a performance criterion such as bit error rates for low SNR is analyzed. The BER for OFDM system over Rician fading channel is observed to be 0.1273.It has been reduced to 0.03919 over Rayleigh fading channel with Line of Sight (LOS) for the same Signal to noise ratio (SNR).

Keywords: Wireless Systems, OFDM, BER, STBC, MIMO, SNR.

I. INTRODUCTION

In a world of fast changing technology, there is a rising requirement for people to communicate and get connected with each other to have appropriate and timely access to information regardless of the location of the each individual. The increasing demands and requirements for wireless communication systems ubiquity have led to the need for the better fundamental issues in communication theory and their implications for the design of highly-capable wireless systems. The key challenge of future wireless communication systems is to provide high data rate wireless access at high quality of service. Since the availability of radio spectrum is limited and communication capacity needs cannot be met without a significant increase in communication spectral efficiency. The propagation conditions are hostile due to fading caused by destructive addition of multi-path components and interference from other users. Thus, it is required to radically increase spectral efficiency and to improve link reliability as a solution which can be achieved by MIMO wireless technology.

Multiple-Input Multiple-Output (MIMO) wireless technology seems to meet these demands by offering increased spectral efficiency. The MIMO system spreads the total transmitted power over the antennas which give us more spectral efficiency and link reliability which reduced fading without increasing transmitted power or bandwidth. Thus, high data throughput and link range can be achieved. MIMO technology plays an important role in modern wireless communication standards such as Long Term Evolution (LTE) developed by 3rd Generation Partnership Project (3GPP), 4G due to having these properties.

This paper is organized into five sections where in section I give introduction and MIMO-OFDM approach is dealt with in section II. Section III gives about the Space Time Block Coding and channel model that has been taken into consideration while results and discussion and conclusions are made in sections IV and V respectively.

A. *Literature Survey*

Although, the studies and system based on the concept of orthogonal frequency division multiple access have been publishing since 1958, the most of the application using current form of OFDMA developed during 1980s and 90s.There is a lot of research on increasing the data rate. Whereas this paper discusses how the BER can be reduces over various Fading channels.

The authors in [1] evaluated the performance of IEEE 802.16- 2004 and they found that the rate of data transmission is being increased.

The researchers in [3] analyzed the performance of two transmit antennas with more receive antennas is much better than that of the system with two transmit antenna and less receive antennas in term of BER due to the more diversity gain of Alamouti's code.

II. MIMO – OFDM SYSTEM

OFDM is an efficient technique for transmitting data over frequency selective channels. The main idea behind OFDM is to divide a broadband frequency channel in to a few narrowband sub-channels. Then, each sub-channel is a flat fading channel despite the frequency selective nature of the broadband channel. To generate these parallel sub-carriers in OFDM, an Inverse Fast Fourier transform (IFFT) is applied to a block of L data symbols. To avoid ISI due to the channel delay spread, a few "Cyclic Prefix" (CP) symbols are inserted in the block. The cyclic prefix samples are also called guard intervals. Basically, the last g samples of the block are duplicated in front of the block as the cyclic prefix. The number of these cyclic prefix samples, should be bigger than the length of the channel

impulse response. The effects of the cyclic prefix samples eliminate ISI and convert the convolution between the transmit symbols and the channel to a circular convolution. These cyclic prefix samples are removed at the receiver. Then, a Fast Fourier Transform (FFT) is utilized at the receiver to recover the block of *L* received symbols. The Fig.1 shows block diagram of a wireless communication system using OFDM over a SISO channel. This paper presents OFDM system designed for MIMO channels. This is usually called MIMO-OFDM.

Fig.1 Block diagram of SISO- OFDM system.

III.   STBC FOR OFDM SYSTEM AND CHANNEL MODELS

A.   Space Time Block Codes

In this paper, space-time block codes are presented and the performance of MIMO fading channels is evaluated by Simulations. The Alamouti code is one of the block codes, which is a simple two branch transmit diversity scheme. The key features of the scheme is orthogonally between the sequences generated by two transmit antennas.

The space-time block codes can achieve the full transmit diversity specified by the number of the transmit antennas n_T, while allowing a very simple maximum-likelihood decoding algorithm, based only on linear processing of the received signals.

The Fig.2 shows an encoder structure for STBC. In general, a space-time block code is defined by a $n_{TX}p$ transmission matrix X. Here n_T represents the number of transmit antennas and p represents the number of time periods for transmission of one block of coded symbols.
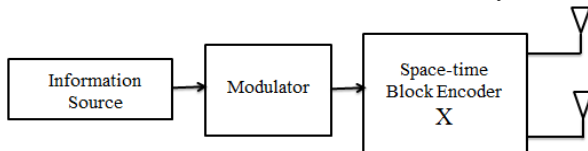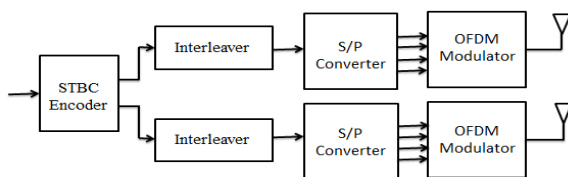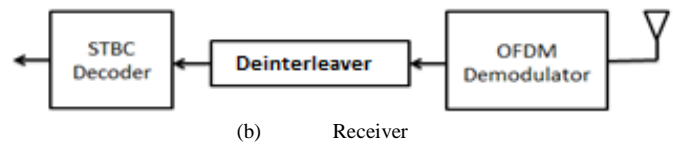

Fig. 2 Encoder for STBC

B.   Space Time Block Code used in OFDM System

The Space Time Block codes are used in MIMO-OFDM because of its decoding simplicity. In this paper, two transmit antennas and one receive antenna is considered. Fig.3 (a) and (b) shows the transmitter & Receiver of STBC-OFDM System including Space Time Block encoder and decoder.

(a)   Transmitter

(b)   Receiver

Fig.3 An STBC-OFDM system block diagram

C.   MIMO Channel Model

In wireless communications, multipath propagation occurs because of reflection, diffraction, scattering and shadowing of the transmitted signals due to surrounding objects as a result the transmitted signals arrive at the receiver with different amplitude, different phase angles and at different time intervals. The amplitude fluctuation of the received signal is called signal fading and we assume the fading process follows a Rayleigh probability distribution function. In time domain, the channel response from the ith Transmit antenna to the jth receive antenna can be given as

$$h_{i,j}(t) = \sum_{l=0}^{L-1} \alpha_{i,j}(l)\delta(t - \tau_l) \qquad (1)$$

Where $\alpha_{i,j}(l)$ is the multi-path gain coefficient, L denotes the number of resolvable paths, and τ_l represents the path delay time of lth multi-path component. The frequency response of the channel is given by

$$h_{i,j}^k(f) = \sum_{l=0}^{L-1} \alpha_{i,j}^k(l)e^{-j2\pi f\tau_l} \qquad (2)$$

Since, two transmit antennas and one receive antenna are considered, the values of *i* are 1, 2 and, j is 1.

D.   Statistical Models for Fading Channels

Because of the multiplicity of factors involved in propagation in a cellular mobile environment, it is convenient to apply statistical techniques to describe signal variations. In a narrowband system, the transmitted signals usually occupy a bandwidth smaller than the channel's coherence bandwidth, which is defined as the frequency range over which the channel fading process is correlated. That is, all spectral components of the transmitted signal are subject to the same fading attenuation. This type of fading is referred to as frequency nonselective or frequency flat. In this section Rayleigh and Rician fading models are introduced to describe signal variations in a narrowband multipath environment.

1)   *Rayleigh Fading:* The transmission of a single tone with constant amplitude is considered. In a typical land mobile radio channel, it is assumed that the direct wave is obstructed and the mobile unit receives only reflected waves. When the number of reflected waves is large, according to the central limit theorem, two quadrature components of the received signal are uncorrelated Gaussian random processes with a zero mean and variance σ_s^2 . As a result, the envelope of the received

signal at any time instant undergoes a Rayleigh probability distribution and its phase obeys a uniform distribution between −π and π. The probability density function (PDF) of the Rayleigh distribution is given by

$$p(a) = \begin{cases} \dfrac{a}{\sigma_s^2} \cdot e^{-a^2/2\sigma_s^2} & a \geq 0 \\ 0 & a < 0 \end{cases} \quad (3)$$

2)   *Rician Fading:* In some propagation scenarios, such as satellite or microcellular mobile radio channels, there are essentially no obstacles on the line-of-sight path. The received signal consists of a direct wave and a number of reflected waves. The direct wave is a stationary nonfading signal with constant amplitude. The reflected waves are independent random signals. Their sum is called the *scattered component* of the received signal. The sum of a constant amplitude direct signal and a Rayleigh distributed scattered signal results in a signal with a Rician envelope distribution. The PDF of the Rician distribution is given by

$$p(a) = \begin{cases} \dfrac{a}{\sigma_s^2} \cdot e^{\frac{-(a^2+b^2)}{2\sigma_s^2}} I_0 \left(\dfrac{aD}{\sigma_s^2} \right) & a \geq 0 \\ 0 & a < 0 \end{cases} \quad (4)$$

IV.   SIMULATION RESULTS

Simulation results are presented to evaluate the performance of OFDM system with two transmit antennas and one receive antenna. Fig.4 shows the performance analysis of OFDM system with STBC on Rician channel and performance analysis of OFDM system with STBC under Rayleigh fading channel with LOS is shown in the Fig.5.

A.   Performance Analysis of OFDM system with STBC under Rician channel

In the Fig.4, simulation results for the performance of OFDM system without STBC under Rician fading channel are shown. The performance of the system is analyzed with various low SNR values ranging from 0dB to 20dB.
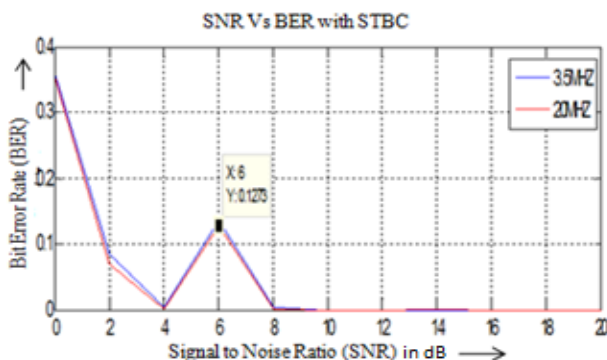

Fig.4.BER performance of OFDM System with STBC under Rician channel

The Simulation model employs various modulation schemes based on Rate_Id, indicating the modulation technique used and the modulation rate. the values of Rate_Id are 0 for BPSK1/2,1 for QPSK1/2,2 for QPSK3/4,3 for 16-QAM1/2 ,4 for 16-QAM3/4,5 for 64-QAM2/3 and 6 for 64-QAM3/4.

In Fig.4, it is observed that the value of BER at SNR of 6dB is 0.1273for the channel bandwidth of 3.5MHZ and 20MHZ.

B.   Performance Analysis of OFDM system with STBC under Rayleigh fading channel

In this fig.5, simulation results for the performance of STBC on Rayleigh fading Channels with low SNR values ranging from 0dB to 20dB are shown. It is observed that the value of BER at SNR of 6dB is 0.03919for the channel bandwidth of 20MHZ and 0 for 3.5MHZ.
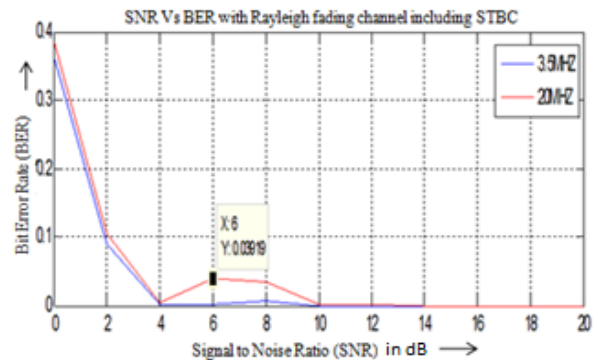

Fig.5. BER performance of OFDM System with STBC under Rayleigh fading channel

In both the simulation results provided above, we observe that in fig.4 the value of BER is 0.1273 for SNR of 6dB whereas in fig.5 the value of BER reduces to 0.03919 for same SNR. Thus reduction of BER imposes that number of bits that are being transmitted increased, indicating high bit rate. Hence, performance of OFDM system increases under Rayleigh fading channel than the performance under Rician fading channel alone.

V.   CONCLUSION

In this paper, the performance of the MIMO-OFDM system under various fading channels is evaluated. It is observed that for low SNR values ranging from 0dB to 20dB, the BER for OFDM system over Rician fading channel is 0.1273 and is reduced to 0.03919 over Rayleigh fading channel and LOS for the signal to noise ratio(SNR) of 6dB Rate. As BER is reduced, the number of bits transmitted to receiver are increased which implies that high bit rate is achieved.

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