BER Performance of OFDM with GI in SISO and MIMO System

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ABSTRACT
To overcome a multipath fading environment with low complexity and to achieve wireless broadband multimedia communication systems, orthogonal frequency division multiplexing (OFDM) transmission scheme is used. OFDM is one of the applications of a parallel data transmission scheme, which reduces the influence of multipath fading. The performance of OFDM can be improved further using concept of spatial diversity Multiple Input Multiple Output. The paper explains the performance of MIMO OFDM under the Rayleigh channel, also it uses different guard interval with modulation schemes as 4-QAM. It shows that by using OFDM with SISO and MIMO, remarkable performance is shown in terms of Bit Error Rate (BER).

Keywords
Enter Multiple Input Multiple Output (MIMO), orthogonal frequency division multiplexing (OFDM), Bit Error Rate (BER), Cyclic Prefix (CP), Guard Period, 4-QAM, Rayleigh channel.

1. INTRODUCTION
0rthogonal frequency division multiplexing (OFDM) is one of the most promising technologies for high data rate wireless communications. OFDM is treated as modulation multiplexing technique, where a high-rate serial data stream is split up into a set of low rate sub streams, each of which is modulated on a separate sc (fdm). OFDM is simply defined as a form of multi-carrier modulation where the carrier spacing is carefully selected so that each subcarrier is orthogonal to the other sub carriers. The multiple orthogonal subcarriers signals, which are overlapped in spectrum, can be produced by generalizing the single carrier Nyquist criteria into the multi carrier criterion. In practice, Discrete Fourier Transform (DFT) and inverse DFT process are useful for implementing these orthogonal signals. DFT and IDFT can be implemented efficiently by using fast fourier transform (FFT) and Inverse FFT (IFFT), respectively. As all subcarriers are of the finite duration T, the spectrum of the OFDM signals can be considered as the sum of the frequency-shifted sinc functions in the frequency domain, where the overlapped neighboring sinc functions are spaced by 1/T [1] [2].

In order to avoid ISI, OFDM play a vital role, which is usually introduced by frequency selective multipath fading in a wireless environment. Each sub-carrier is modulated at a very low symbol rate, making the symbols much longer than the channel impulse response. So ISI can be diminished and furthermore if a guard interval between consecutive OFDM symbol is inserted ISI can be completely remove. This guard interval in the time domain is called cyclic prefix (CP).

It has been acknowledge in recent year that the use of MIMO can potentially provide large spectral efficiency for wireless communication in the presence of multipath fading environments. MIMO is the use of multiple antennas at both the transmitter and receiver to improve communication performance because it offers significant increases in data throughput and link range without requiring additional bandwidth or transmitter power.

The paper focuses on the implementation of OFDM in SISO and MIMO system. The paper also explains the different way of adding guard interval to OFDM system and simulation result to demonstrate the same. The rest of the paper is organized as fallows. Section 2 introduces the system descriptions. Brief important theories were explained in section 3, 4 and 5. Performance is compared in various aspects in section 6. This paper concludes with the section 7.

2. SYSTEM DISCRIPTION
All The OFDM system typically consists of convolution encoder, modulation, and Inverse Fast Fourier Transform (IFFT), injection of guard interval (GI).

An OFDM signal consists of N orthogonal subcarriers modulated by N parallel data streams.

Each baseband subcarrier is of the form,

$$\Phi_k(t) = e^{j2\Pi f_k t} \tag{1.1}$$

Where, f_k is the frequency of the kth subcarrier. One baseband OFDM symbol multiplexes N modulated subcarriers.

$$S(t)= \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} x_k \Phi_k(t) \quad 0<t<NT, \tag{1.2}$$

Where x_k is the kth complex data symbol (typically taken from a QAM symbol constellation) and NT is the length of the OFDM symbol.

The subcarrier frequencies F_k are equally spaced.

$f_k = \frac{k}{NT}$,which makes the subcarriers $\Phi_k(t)$ on $0<t<NT$, orthogonal. The signal separates data symbols in frequency by overlapping subcarriers, thus using the available spectrum in an efficient way.

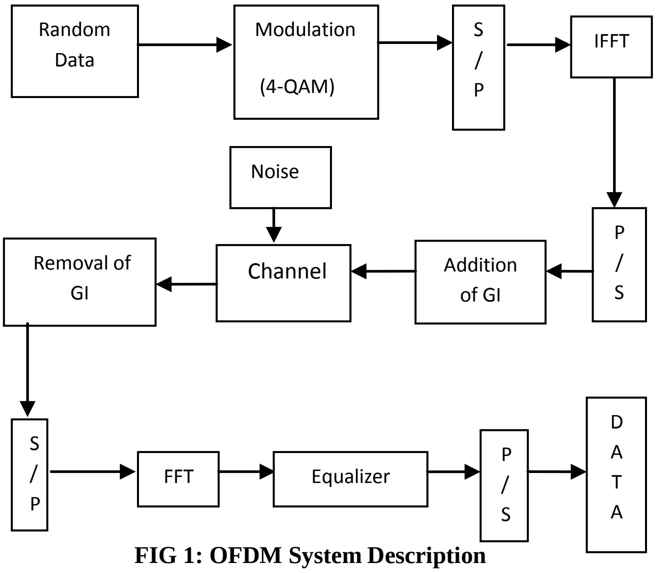

FIG 1: OFDM System Description

3. CYCLIC PREFIX

The main two difficulties when signal is transmitted over the dispersive channel are that channel dispersion destroys the orthogonality between subcarriers and cause inter-carrier interference (ICI). Furthermore system may transmit multiple OFDM symbols in a series so that a dispersive channel causes inter symbol interference (ISI) between successive OFDM symbols. The insertion of a silent guard period between successive OFDM symbols would avoid ISI in a dispersive environment but it doesn't avoid the loss of the subcarrier orthogonality. Peled and Ruiz (1980) solved this problem with the introduction of a cyclic prefix. The cyclic prefix both preserves the orthogonality of the subcarriers and prevents ISI between successive OFDM symbols. Therefore equalization at the receiver is very simple [4].

Let T_G be the length of Cyclic Prefix in the samples. By the insertion of CP OFDM symbol is extended to the duration $T_{sym}=T_{sub}+T_G$

The continuity of each delayed subcarrier has been warranted by the CP, its orthogonality with all other subcarriers is maintained over T_{sub} such that:

For the first OFDM signal that arrives with a delay of t_0, and

the signal expression is given as delay of $t_0 + T_s$ [5].

$$\frac{1}{Tsub}\int_0^{Tsub} e^{j2\Pi f_k(t-t0)} e^{j2\Pi f_i(t-t0-Ts)}dt = 0, k \neq i \qquad (1.4)$$

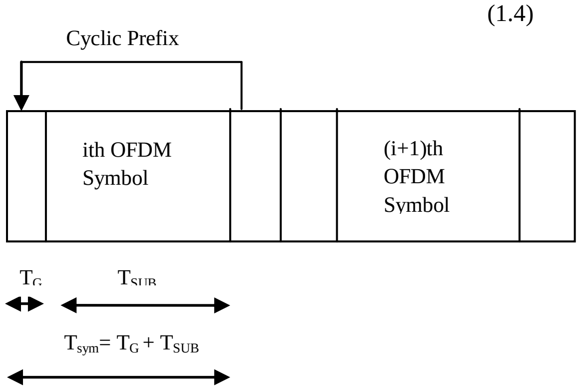

FIG 2: OFDM System Description

4. BER PERFORMANCE OVER REYLEIGH CHANNEL

Rayleigh fading is a statistical model for the effect of propagation environment on a radio signal. Rayleigh fading based on Rayleigh distribution given by

$$P_{Rayleigh}(r) = \left\{ \frac{r}{\sigma^2}\exp\left(-\frac{r^2}{2\sigma^2}\right) \right. \quad \begin{matrix} for \quad 0 \le r < \infty \\ for \quad r < \infty \end{matrix} \qquad (\mathbf{1}.5)$$

Rayleigh fading is viewed as a reasonable model for a troposphere and ionosphere signal propagation as well as the effect of heavily built up urban environments on radio signals. Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver

$$\frac{1}{Tsub}\int_0^{Tsub} e^{j2\Pi f_k(t-t0)} e^{j2\Pi f_i(t-t0)}dt = 0, k \neq i \qquad (1.3)$$

5. VBLAST TECHNIQUE

The layers are arranged horizontally across space and time for V-BLAST and the cycling operation is removed before transmission. At the receiver side, each receive antenna is a superposition of M faded symbols plus Additive White Gaussian Noise (AWGN).

Successive Interference Cancellation (SIC) is incorporated with V-BLAST architecture for both ZF and MMSE detection algorithm so as to improve the performance of detection algorithm. The detection process consists of two main operations [5].

a. Interference Suppression (nulling): The interference is null out by projecting the received vector onto the null subspace (perpendicular subspace) of the subspace by the interfering signals. After that, normal detection of the first symbol performed [5].

b. Interference Cancellation (Subtraction): The contribution of the detection is subtracted from the receiver [7]

5.1 V-BLAST MMSE

This paper has taken VBLAST MMSE as the detection algorithm for MIMO technology. It is found from the various researches that VBLAST MMSE has superior performance over conventional ZF, MMSE and less complexity over ML detection algorithm. The MMSE receiver suppresses both the interference and noise components, whereas the ZF Receiver removes only the interference components. This implies that the mean square error between the transmitted symbols and the estimate of the receiver is minimized. Hence, MMSE has better performance over ZF in the presence of noise. Some of the important characteristics of MMSE detector are simple linear receiver, superior performance to ZF and at Low SNR, MMSE becomes matched filter. Also at high SNR, MMSE becomes ZF. MMSE receiver gives a solution of

$$\hat{x} = (\frac{1}{SNR} I_{NR} + H^{H} x) H^{H} x \quad (1.6)$$

Where, SNR is the signal to noise ratio and H^H is the Hermitian transpose. $\hat{x}$ is the estimated signal [7] [8]

6. PERFORMANCE ANALYSIS

6.1 System Parameter

This paper OFDM system parameters used in the simulation are indicated in Table 1. The guard interval to be greater than the maximum delay spread is chosen in order to avoid inter-symbol-interference. Simulation is carried out for different signal to noise ratio. The simulation parameters to achieve those results are shown in table 1.

Table 1: Simulation Parameter

PARAMETER	SPECIFICATION
FFT Size	64
Number of carrier in OFDM symbol	52
Channel	RAYLEIGH
Guard period	16 samples
Signal constellation	4-QAM
MIMO System	2×2, 3×3 and 4×4

Note: These parameters are taken for the experimental purpose. There are not any specific reasons to use these parameters.

6.2 Diversity Order

As the number of transmitting as well as receiving antenna is increased, the performance of the system increased in terms of BER. Hence it shows the significance of the implementation of MIMO technology. The computational complexity arises in MIMO system as the numbers of transmitting as well as receiving antennas are increased.

6.3 Simulation Results

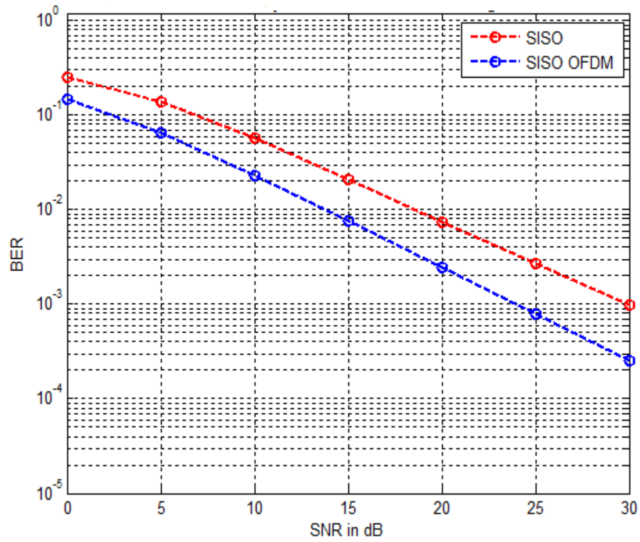

Figure 3: BER analysis of SISO VS SISO-OFDM (with GI =16) using 4-QAM under Rayleigh channel.

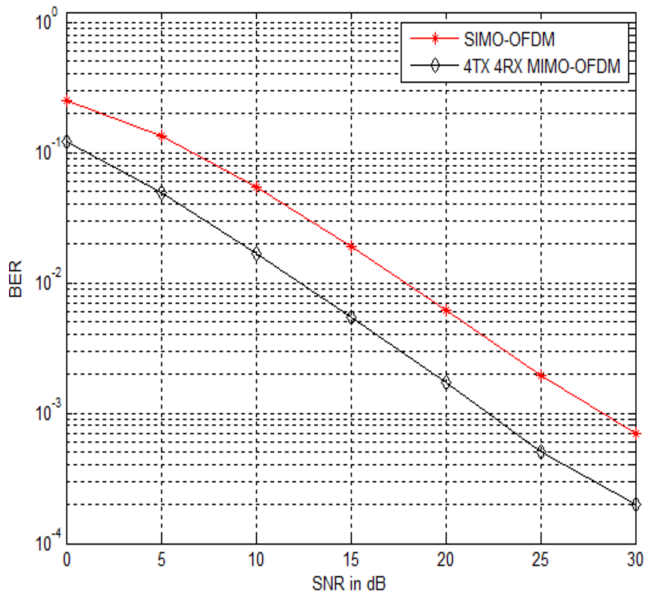

Figure 4: BER analysis of SISO-OFDM VS MIMO-OFDM using 4-QAM under Rayleigh channel with Guard Interval Insertion (GI=16)

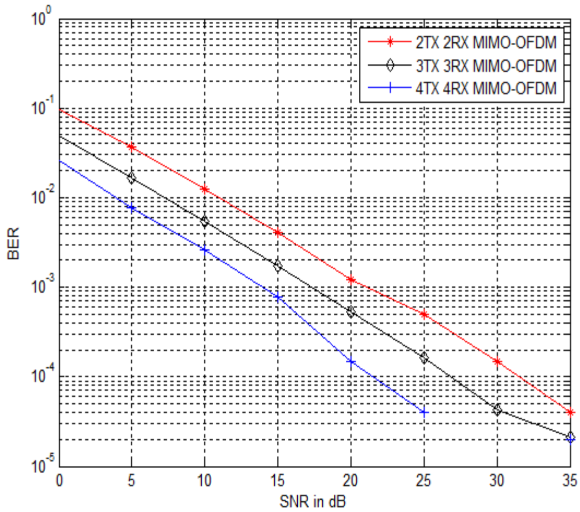

Figure 5: Variation of MIMO in TX as well as RX antenna using 4-QAM under Rayleigh channel with Guard Interval Insertion (GI=16)

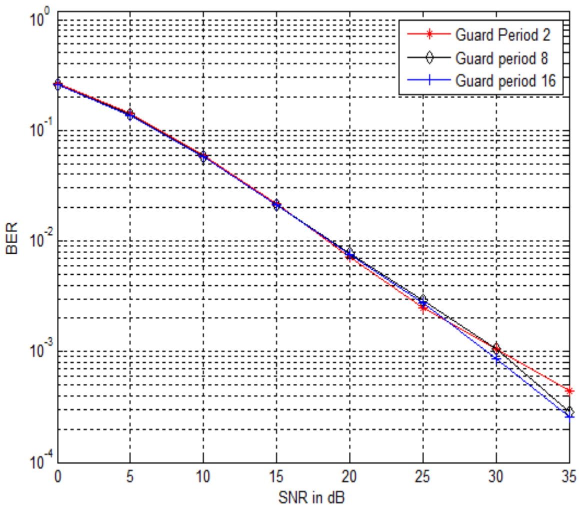

Figure 6: Variation of GI value antenna using 4-QAM under Rayleigh channel

7. CONCLUSION

In this paper, SISO-OFDM, MIMO-OFDM with various Guard Intervals have been studied, analyzed and compared. OFDM is a key principle used here which shows a significance performance when compared SISO and SISO-OFDM as shown in figure 3. Similarly, SISO-OFDM and MIMO-OFDM is compared under Rayleigh channel distribution using 4-QAM as a modulation scheme. It is found that MIMO-OFDM has better performance over SISO-OFDM. Further, it is found that as the number of antenna at TX as well as RX antenna is increased, the performance of the system also increased. The above study also explains the fact that cyclic prefix is used as GI and if properly taken, can optimize the inter-symbol interference. In this Paper, 16 samples as a guard prefix are used and hence it showed the significant improvement in BER. The OFDM system is subjected to a flat fading channel as long as guard interval is large enough. The effect of ISI on the multipath Rayleigh fading channel can be seen on the variation of GI. As in figure 6, it is explained that whenever the value of GI decreased it eventually lead to an error.

8. REFERENCES

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