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Analysis of MRC and OC with OFDM In Terms Of BER Using Different Modulation Techniques over Rayleigh Channel

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ABSTRACT: In wireless communication due to presence of multipath fading effects and noise, antenna diversity is an important technique to mitigate these effects. The antenna diversity is the most cost effective technique to improve system performance and to increase the channel capacity. Also in recent years the dire need of high speed and reliable digital wireless communication which includes not only cellular phones but devices such as wireless modems, high definition television (HDTV) and digital radios. The need of high speed data transfer is catered by the orthogonal frequency division multiplexing (OFDM) and the performance of the system which is dictated by random fluctuations in the amplitude of the received signal is enhanced by using maximal ratio combining (MRC) and optimal combining(OC) diversity combining technique. Here is explanation of system performance having receiver antenna diversity along with OFDM in Rayleigh fading environment. The performance of system is evaluated in terms of signal to noise ratio (SNR) and bit error rate (BER) probability. The simulation result shows that the performance of OFDM system in Rayleigh fading in terms of SNR can be improved by using MRC and OC.

KEYWORDS: OFDM, MRC, OC, HTV, HDTV, SNR, BER.

I. INTRODUCTION

In a mobile communication channel while transmitting signal from a transmitter end to a receiver end through a channel, the signal not only confront noise and distortion but the presence of multipath propagation also dictates the propagation. In analog communication this multipath propagation results in echoes (in Audio communication) and shadows (in case of Visual communication), which can be tolerated by our ears and eyes respectively. But in case of digital communication these multipath propagations leads to linear channel distortion which manifest as inter symbol interference (ISI). This is because multipath leads to multiple copies of same signal reflected from various obstacles lying within the path while travelling through the channel. These multiple copies arrive at the receiver with different time delays. Thus one symbol pulse delayed affects one or more adjacent symbols causing ISI. To combat the effect of ISI, two highly effective tools are equalization and OFDM [1]. Fast fading frequency selective channels are the most serious challenges to mobile wireless communications, because firstly they introduce ISI and secondly the channel characteristics are also time varying. However to combat the ISI time domain equalization techniques can be applied but they need training data to either the channel parameters or estimate equalizer parameters. Since the parameter estimation of channels or equalizers cannot work properly and effectively unless the parameters stay constant between successive training periods. As a result these kinds of equalizers are unable to confront such channels having fast fading response. Now OFDM can convert a frequency-selective channel into a parallel group of flat channels and hence converting a fast fading and frequency selective channel into a parallel bank of fast flat-fading channel [2].

The receiver diversity is a very effective tool to mitigate the effect of this fast flat-fading. The receiver diversity can be achieved by transmitting the same data over more than one path in order to nullify the effect of fading. Here is description of BER two most popular diversity techniques MRC and OC. The motive behind using OFDM along with MRC is to divide a broadband frequency channel into a number of narrowband sub-channels.MRC is preferred over

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other linear combiners due to its best performance amongst the others [6,7]. Then these sub-channels experience flat fading instead of frequency selective fading, as it is found in case of broadband channels and to mitigate the effect of flat fading we can use diversity or equalization techniques can be easily applied [5]. While in case of presence of interferers OC is best amongst all other diversity combiners [9]. Among the advanced wireless standards such as Wi-Fi(IEEE 802.11n), WiMAX (IEEE 802.16e) and cellular LTE (long-term evolution) these all have adopted OFDM and MIMO technologies to achieve much higher data rates and better coverage area.

II. OFDM MODEL

Orthogonal Frequency Division Multiplexing (OFDM) is a modulation technique which is suited for high-data-rate transmission in delay-dispersive environments. This modulation technique converts a high-rate data stream into a number of low rate data stream over narrow band, parallel channels. These narrowband parallel channels are easily equalized [3].OFDM splits the information into N parallel streams, these are transmitted by modulating N distinct carriers which are orthogonal to each other.

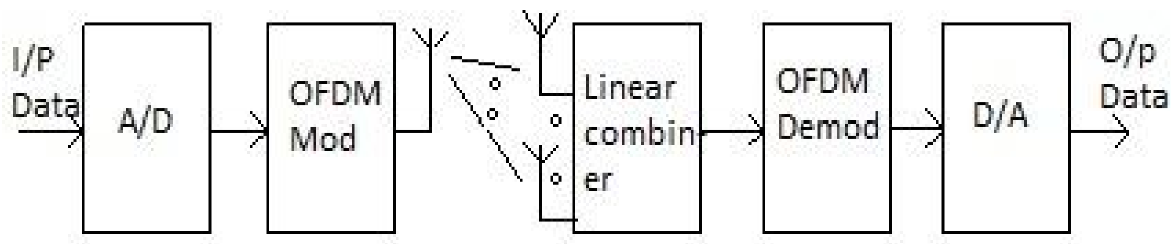

Fig. 1 OFDM Linear Combiner

As described in fig.1 the input data is firstly converted from analogue to digital by A/D converter, then these serial data streams are converted to parallel data stream by using P/S(parallel to serial converter). The serial data stream of L length is now grouped into N number of blocks of parallel data streams having length of M bits each. Each of these M bit blocks are then fed to a N point Inverse Fast Fourier Transformer (IFFT) block. This block provides N number of sub-carriers which are providing N number of sub channels having different carrier frequencies as equivalent to N number of different local oscillators in analog signal. These sub channels are also orthogonal to each other in order to minimize the interference between them and to utilize the available bandwidth in the best possible way. After the division and applying IFFT to the blocks of signal a cyclic prefix (CP) is added to each of the block at both ends. This CP consists of nearly one fourth bits of the block itself and is added to each of the blocks both at the starting end and at the last end of each block, this addition of extra bits leads to minimizing the effects of inter-symbol-interference (ISI). It also converts the linear convolution between channel and transmitter data to the circular conversion which is easier to implement. After the addition of CP to the blocks of parallel data stream, it is again converted to serial data stream. The serial data is again converted to analog signal and transmitted through single antenna. Now the data is transmitted over the channel, where it faces noise, attenuation and channel delay spread due to which multipath propagation occurs.
At the receiver end the signal is received by using receiver diversity in which the same signal is transmitted over a number of paths in order to get a number of copies of same signal, these multiple copies of signal are the weighted and combined by linear combiners. Here is a discussion about two of the appropriate techniques.

1. MRC: The signals from all the Rn branches are weighted as per their individual signal voltage to noise power ratios and then added with each other. The individual signals must be co-phased before the summing process. Thus MRC produces an output SNR which is sum of individual SNRs of each branch. This provides advantage of having an output with an acceptable SNR even when no individual branch has required SNR [4].
2. OC: In following technique the signals received by antennas are weighted and combined to maximize the output signal to interference plus noise ratio (SNIR). Thus besides considering the noise power as in MRC, in OC the power of interfering signal is also taken into account.

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After combining with desired combiner the signal is fed to analog to digital converter which gives us the digital format of received data which is in serial form, parallel to serial converter gives back parallel blocks and feed it to CP remover where additional cyclic prefix is removed. After then data is fed to FFT block to get the original data bits from each carrier. The parallel data is again converted back to serial bitstream and hence original data bits are obtained at the output.

III. RECIEVER DIVERSITY

This section describes the receiver diversity of the system. An Rn branch receive diversity consists of single transmitting antenna and Rn number of receiver antennas. Each of these receiver antennas now detect the N number of replicas of the same signal which are approaching towards these via independent (assumed) multipath. These replicas are then weighted suitably and linearly combined to get maximum SNR at the receiver. The effectiveness of receiver can be enhanced by increasing the number of receiver antennas. Assuming a single transmitting antenna as in single input multi output (SIMO) channel, the channel can be depicted as follows:

$$h = [h_1, h_2, \dots \dots \dots \dots . h_{R_n}] \quad (1)$$

Given is expression for Rn independent Raleigh fading channel. Let x is transmitted signal having unit variance in the SIMO channel. The received signal $y \in \mathbb{C}^{R_n * 1}$ can be expressed as:

$$y_i = \sqrt{\frac{E_b}{N_O}} * h_i x + N_i \quad (2)$$

Where Rn is receiver antenna and N_i is the noise (AWGN) which is additive in nature. By using receiver diversity.

Rayleigh Channel:
In wireless channel the signal has to traverse a path which can be most suitably depicted by Rayleigh model. In Rayleigh model the statistical time varying behavior of received signal of a flat fading signal or the envelope of individual multipath component. The envelope of a Rayleigh distributed signal can be assumed to be sum of two quadrature Gaussian noise signals. The probability density function of Rayleigh distribution is given by

$$p(r) = \begin{cases} \frac{r}{\sigma^2} exp\left(-\frac{r^2}{2\sigma^2}\right), & 0 \le x \le \infty \\ 0 & , 0 < x \end{cases} \quad (3)$$

Where σ is defined as the rms value of the received signal before envelope detection, and σ^2 is time average power of the received signal [2].
Now the received signal traversing through the Rayleigh channel can be written as

$$y = hx + n \quad (4)$$

Where y is the received signal, h is the channel response having Rayleigh fading distribution, x is the transmitted signal and n is the AWGN noise. As the channel is randomly varying with respect to time thus the transmitted signal gets multiplied by randomly changing complex number h. As the h is modeled as following the Rayleigh distribution, the real and imaginary parts of Gaussian distributed having mean 0 and variance ½.

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IV. BER DETERMINATION

The Bit-error probability for MRC can be given by the following equation [10].

$$P_e^{MRC} = \frac{1}{2}\left(1 - \sqrt{\frac{\Gamma}{\Gamma+1}}\right) \tag{5}$$

Where Γ is defined as SNR of the signal and P_e^{MRC} is the Bit-error probability of MRC combining technique.
Now for Optimal Combining technique the Bit-error probability can be determined by following equation [8].

$$P_e^{OC} = \frac{1}{2} - \frac{\Gamma\left(N+\frac{1}{2}\right)P_s^{N+\left(\frac{1}{2}\right)}}{\sqrt{\pi}\sigma^2\Gamma(N)h^N}\frac{1}{\Gamma(N)P_I^N}\int_{\sigma^2}^{\infty}\frac{\lambda_1}{(\lambda_1+P_s)^{N+\frac{1}{2}}}(\lambda_1-\sigma^2)^{N-1}e^{-\left(\frac{(\lambda_1-\sigma^2)}{P_I}\right)} \times F_2\left(N+\frac{1}{2},1,N-1;\frac{3}{2},N;\frac{P_s}{\lambda_1+P_s},\frac{\lambda_1-\sigma^2}{\lambda_1+P_s}\right)d\lambda_1 \tag{6}$$

Where P_e^{OC} is the Bit-error probability, $P_s^{N+\left(\frac{1}{2}\right)}$ is mean signal power per antenna, λ_1 is the Eigen value of covariance matrix, $F_2(.)$ is Appell's hypergeometric function and σ^2 is defined as the noise power.

V. SIMULATION RESULTS

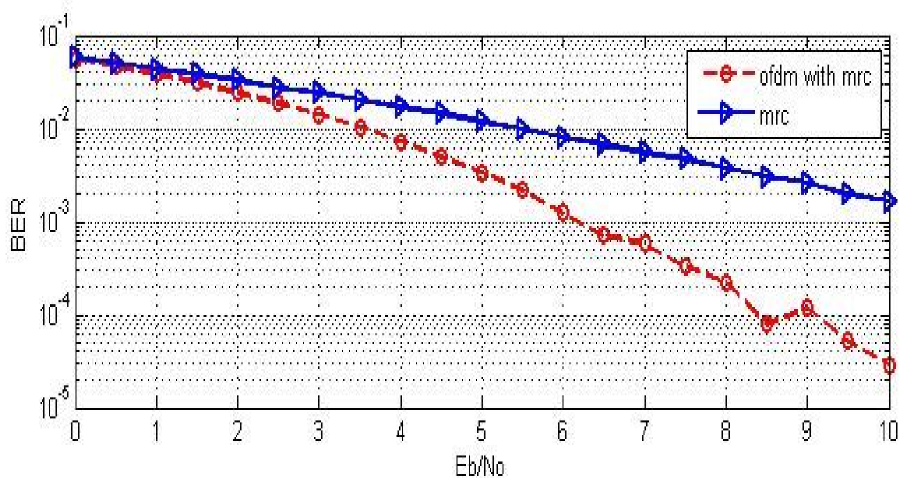

Fig. 2 BER curve for BPSK using OFDM MRC

The following Fig.2 shows the performance of a maximal-ratio combining diversity receiver for various digital modulation schemes. As shown in MATLAB simulation the BER rate goes on decreasing with deployment of OFDM and MRC both. Here 1×2 are used to show the advantages in terms of BER. SNR v/s BER plots for BPSK over Rayleigh fading channel for SIMO-OFDM .

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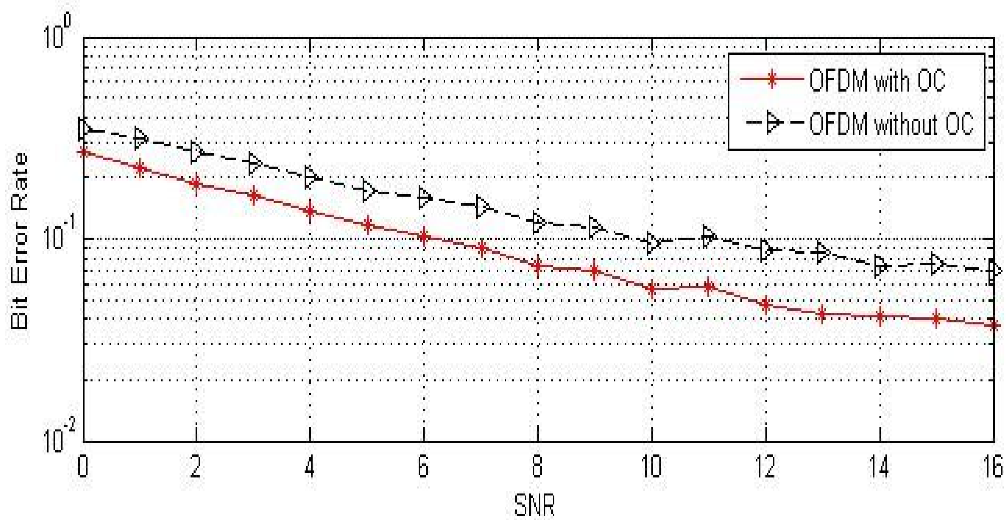

Fig. 3 BER curve for OFDM with OC

Following Fig.3 shows the results of BER with respect to increasing SNR, for OFDM-OC modulation. Here is observed that with increasing by SNR the BER performance is better in OFDM-OC model as comparative to MRC only.

VI. CONCLUSIONS

This paper explores the performance analysis of SIMO-OFDM system using different diversity techniques. It has been analyzed that both the powerful techniques MRC and OFDM can perform well when employed with each other, these results are helpful in designing high data rate systems which are working in wireless communication environment with least possible error rate. While in case of presence of number of interferers as it occurs in modern communication channels the OFDM-OC is the best suitable solution for optimal performance.

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