The International Journal Of Engineering And Science (IJES)
|| Volume || 5 || Issue || 5 || Pages || PP -63-68 || 2016 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Performance Analysis of a SIMO-OFDM System Using Different Diversity Combining Techniques and Their Comparison

Sahil Dhingra[1],Sovanjyoti Giri
[1]*Department Of Electronics And Communication, Dehradun Institute Of Technology*
[2]*Department Of Electronics And Electrical Communication Engineering, IIT Kharagpur*

--ABSTRACT--
The motive of any wireless communication system is to reduce BER for the corresponding SNR. Through this OFDM based receiver diversity system we analyze BER for different diversity combining techniques such as EGC, MRC, SC in a rayliegh faded environment. This model serves two benefits: first noise limited system performance is improved by combating ISI through OFDM and second use of diversity combining which helps combat multipath fading. We also try to achieve an optimum trade-off between BER improvement and increase in number of receiver antennas. This is just to make less-complex receiver as it requires only one DFT processor.

KEYWORDS: *BER, EGC, MRC, OFDM, Pre-DFT combining, SC, SNR.*

Date of Submission: 19 April 2016 Date of Accepted: 10 May 2016

I. Introduction

Though BER can be reduced by increasing SNR of a system but most wireless equipments are power limited i.e. we cannot go on indefinitely increasing the signal power as the power source will dry out fast rather we need to find ways to reduce BER at low SNR values also For that we use OFDM and receiver Diversity combining in this paper.

OFDM is a technique used for high speed data transmission. In OFDM high speed data streams are broken into multiple low speed data streams to be carried over by different sub-carriers which are orthogonal to each other. OFDM converts independent frequency selective fading channels into frequency flat fading channels. Use of OFDM today is in digital data transmission and WLANs.

OFDM performs better than other techniques because it can transmit data at high rate even when channel bandwidth is low. OFDM along with diversity combining helps in further enhancing the system performance as the frequency flat fading problem is solved by using diversity combining techniques.

The process is to first transmit the modulated data by using OFDM technique through a wireless rayliegh channel. At the receiver end the data received is first equalized using diversity techniques i.e. weighted sum of each link is added to produce optimum SNR. Then the data is de-multiplexed and at last demodulated.
The idea behind diversity is to send data on independent fading paths. The combination of these paths is such that fading of the resultant signal is reduced**.**

Most combining techniques are linear: the output of the combiner is just a weighted sum of the different fading paths or branches, when more than one branch is non-zero the combiner first removes the phase of each branch coherently by technique called co-phasing. In post-DFT combining all the receiver chains have a separate DFT processor while in pre-DFT there is only one DFT processor for all receiver chains though in performance post-DFT is better but it is at the cost of system complexity, increased hardware and increased size. By using post-DFT the performance is only slightly improved[1].

The use of pre-DFT combining to reduce computational complexity as seen in the works of Minoru okada in space diversity assisted COFDM[1], the work of H. Hamazumi on application of OFDM to create a OFDM and diversity assisted technique for wideband mobile radio reception[5],

The work of S. Hara, M. Mouri, M. Okada, and N. Morinaga on Transmission performance analysis of multi-carrier modulation in frequency selective fast Rayleigh fading channel[4] . all these works have inspired me to develop this system which performs better even at low SNR values and has reduced system complexity due to the innovative use of pre-DFT combining which requires only one DFT processor at receiver end. The goal of wireless system design is to reduce BER on this principle this whole paper is centered. Rest of the paper is sequentially organized as:
Section-II describes the block diagram of the system and functions of each block.

Section-III simulation includes system parameters and various graphical results obtained for each combining technique plus an approach on receiver optimization.
Section-IV is conclusion where we discuss the best technique of all and its implementation.

II. System Description

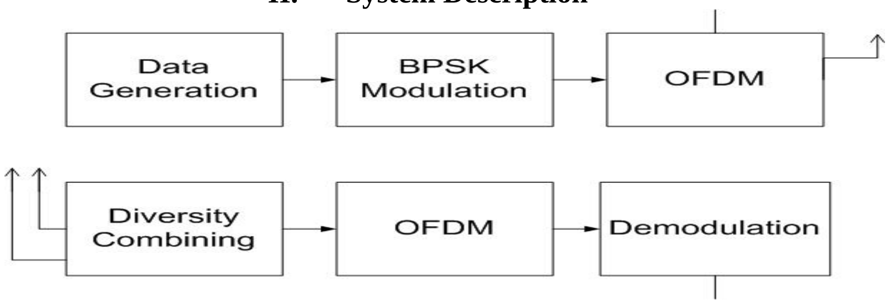

Fig1: Block Diagram of system

In the above figure Data generation is in the form of bits 1's and 0's. These data bits are modulated using binary phase shift keying where the signal output corresponding to 1's and 0's is 180 degree apart. These modulated bits are then converted serial to parallel for assignment to the orthogonal carriers generated by IFFT operation. These data streams are then concatenated with cyclic prefix added after each stream.

Data is transmitted through a rayliegh channel and same copies of data are sent to multiple receivers. The pre-DFT processor then by using diversity combining techniques which can be selection combining, equal gain combining, maximal ratio combining generates an optimum SNR signal.

Further, FFT(Fast Fourier Transform) of the data stream is taken and cyclic prefix is removed. After demodulation the data generated at output is compared with the input data to calculate the number of errors. These errors are then further used in evaluation of BER. The BER corresponding to different number of receiver antennas is plotted on a BER vs SNR plot.

1. Orthogonal Frequency Division Multiplexing:

- High speed Data streams broken into low speed data streams.
- Each stream assigned a sub-carrier which is orthogonal to other sub-carriers.
- Cyclic prefix added to avoid interference and data loss.
- IFFT,FFT, cyclic prefix addition, serial to parallel conversion, concatenation of multiple parallel streams for data transmission and the reverse process on receiver side combined make the OFDM block

2. Receiver Diversity:

Multiple antennas at the receiver end employed as the probability of a single link to go into deep fade is high than probability of multiple links. Different combining techniques ensure better optimization of all the receiver chains.

2.1 Selection Combining:

in this approach the link with the maximum SNR is chosen at the combiner output. This is the most simplified method and is least efficient.

$$E = \frac{E_b}{N_o}\sum_{i=1}^{N}\frac{1}{i}$$

Where i is the ith receiver chain and N is the total number of receiver chains, E is the average bit energy to noise ratio, Eb is bit energy and No noise.

2.2 Equal Gain Combining:

A simpler technique which co-phases the signals on each branch and then combines them with equal weight. The SNR of the combiner output, assuming equal noise power N in each branch.

$$E = \frac{E_b}{N_o}\frac{1}{N}\left(\sum_{i=1}^{N}|h_i|^2\right)$$

E is the effective (Eb/No) after combination of all receiver chains, N is the number of antennas, h is the channel complex number, I is the ith receiver antenna.

2.3 Maximal Ratio Combining:

The output is a weighted sum of all branches. the signals are cophased ,$\alpha = ae^{-j\theta}$, where Θ is the phase of the incoming signal on the ith branch.

$$E = \sum_{i=1}^{N} \frac{|h_i|^2}{N_o} E_b$$

E is the effective (Eb/No) after combination of all receiver chains, N is the number of antennas, h is the channel complex number, i is the ith receiver antenna.

III. Simulation

To start with simulation we define number of antennas as a variable and see how BER changes with increase in SNR and number of antennas for all the diversity techniques SC, EGC, MRC. As the system also uses OFDM we also check how system responds with and without diversity combining.

3.1. System Parameters:

These include various variables that define the system as modulation order, number of bits, size of FFT etc.

These are enlisted in the following table

S.No.	Parameter	value
1.	Modulation Type	BPSK
2.	FFT size	64
3.	Number of subcarriers	52
4.	Number of symbols	10^4
5.	Number of bits/symbol	52
6.	SNR range(dB)	0-20
7.	Number of receiver antennas	Variable (1-4)

Table 1: System Parameters

3.2. Selection Combining Simulation:

The logic of selection combining is to choose the best signal out of all the receiver chains i.e. the chain with the maximum SNR.

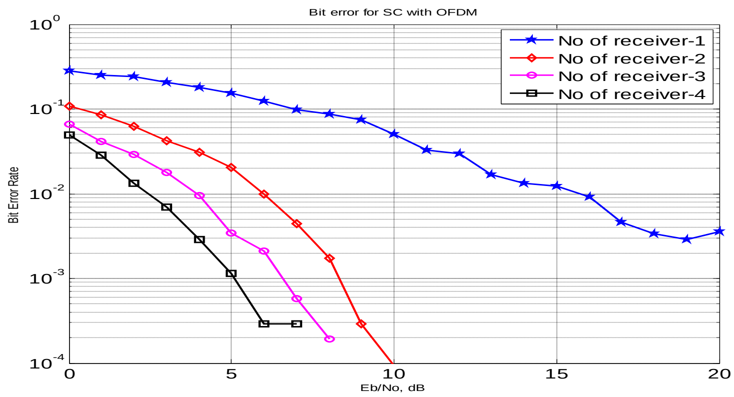

Fig 2: BER vs. SNR plot for selection combining

The blue line indicates that number of receiver antenna is equal to one which means that there is no diversity logic used the system behaves purely as OFDM implemented. But as it is evidently clear that with use of space diversity or multiple antennas the BER for a particular SNR goes on decreasing with increase in number of antennas.

SNR value	No. Of antenna	BER
5 dB	1	0.1750
5 dB	2	0.0200
5 dB	3	0.0036
5 dB	4	0.0012

Table 2: values of BER for different number of antennas (SC).

3.3. Equal Gain Combining:

It is a sub-optimal technique in which only co-phasing is required. In this all the branches are given equal weight.

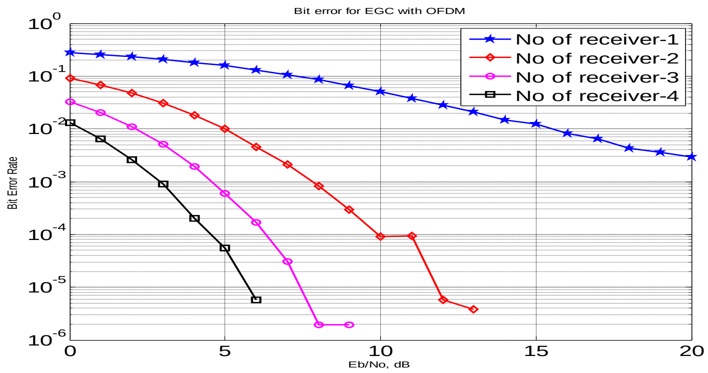

Fig 3: BER vs. SNR plot for Equal Gain Combining.

The EGC logic further enhances the system performance following the same trend of decrease in BER for a particular SNR with increase in number of antennas

.

SNR value	No. Of antennas	BER
5 dB	1	0.17500
5 dB	2	0.01000
5 dB	3	0.00060
5 dB	4	0.00006

Table 3: values of BER for different number of antennas (EGC).

3.4. Maximal Ratio Combining:

It is the most optimum technique of the three. It considers all the receiver chains in both amplitude and phase and after co-phasing assigns different weights to different chains to produce the best SNR at combiner output.

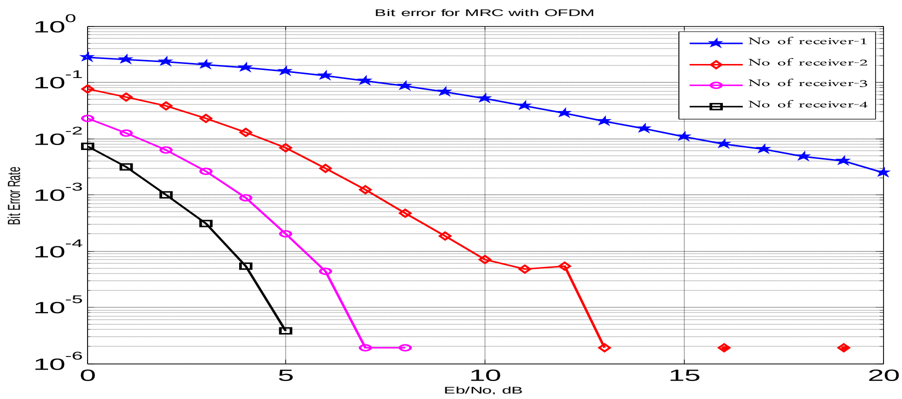

Fig 4: BER vs. SNR plot for Maximal Ratio Combining

As seen in the graph the OFDM and MRC combination has reduced BER to a considerably low level even at low SNR. BER is reaching around 10^{-6} at SNR value just above 5 dB.

SNR value	No. Of antennas	BER
5 dB	1	0.175000
5 dB	2	0.008000
5 dB	3	0.000200
5 dB	4	0.000004

Table 4: values of BER for different number of antennas (MRC).

It is evident from the graph that slope of MRC logic is very steep that is with increase in number of antennas the fall in BER is very high.

3.5. Comparative Study:

In this section we compare all the three techniques to find the best suitable technique for use in wireless communication.

Taking the values from the above three tables:

SNR	antennas	SC	EGC	MRC
5 dB	4	0.00120	0.000060	0.0000040
6 dB	4	0.00030	0.000005	0.0000010

Table 5: Comparative Study of SC,EGC,MRC.

With single unit rise in SNR the values for each technique change drastically and the table clearly shows that OFDM with MRC produces the best result. For further evaluation we will use MRC as the most optimum technique.

3.6. Number of Receiver antenna optimization:

The last part of simulation is the trade-off between BER reduction and number of antennas that can be put to use.

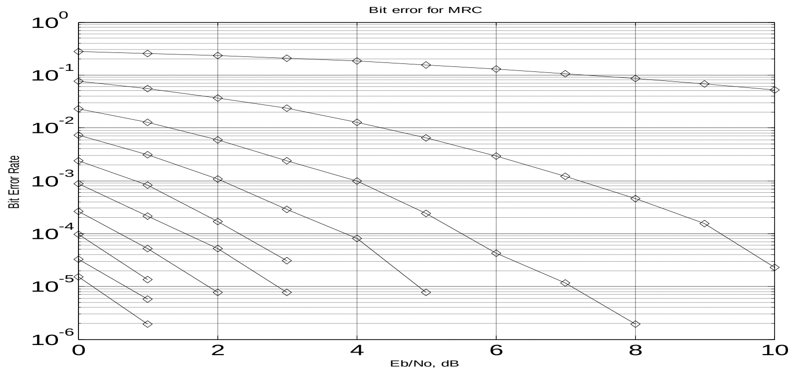

Fig 5: Receiver optimization

In the graph we can see that slope goes on decreasing with increase in number of antennas. Using the above data, systems that work on very low SNR values to have BER performance of around 10^{-6} need to increase the number of receiver antennas considerably. At 1 dB if a system requires BER of $10^{-5.9}$ there need to be around 10 receiver antennas. Factors of cost, hardware, complexity, size all come into picture in trade-off with system performance. If the system can work at 8-10dB range then only 3 receiver antennas can give a BER of $10^{-5.9}$. so, optimization of number of receiver antennas is very application specific or system requirement dependent.

IV. Conclusion

To achieve a BER of (0.0001) with use of 3 antennas the SNR values for each technique vary as SC achieves it at SNR of around 10 dB, EGC at around 7 dB and MRC at around 6dB. We can see the SNR improvement with improvement in diversity combining logic. In each of the graphs the blue line is the system performance only with OFDM and no use of diversity. But, we see that with use of diversity system performance drastically improves. Out of all the three diversity combining MRC technique gave the least BER at a particular SNR level. Further the use of OFDM-MRC in optimizing the number of receivers displayed that trade-off between system performance at low SNR and cost, hardware usage were system requirement dependent. Achieving 1 bit error in every 10^6 bits sent is very useful in wireless communication as with the advent of new technologies every device is becoming wireless and there is an exponential increase in the number of smartphone users. Data efficient technologies find application in military, high speed internet, satellite D2H connections..

References

[1]. Minoru Okada, Shozo Komaki, Pre-DFT Combining Space Diversity Assisted COFDM, IEEE Transaction on vehicular technology, Vol. 50 NO. 2,MARCH 2001.

[2]. Anis Charrada, Abdelaziz Samet ,SIMO-OFDM Channel Estimation based on Nonlinear Complex LS-SVM, IJCA(0975-8887) VOLUME42-NO.3,MARCH 2012.

[3]. Ripan Kumar Roy, Tushar Kanti Roy ,BER analysis of MIMO-OFDM system using Alamouti STBC and MRC Diversity scheme over Rayleigh multipath channel, GJRE Vol. 13 Issue 13 Print ISSN-0975-5861

[4]. S. Hara, M. Mouri, M. Okada, and N. Morinaga, Transmission performance analysis of multi-carrier modulation in frequency selective fast Rayleigh fading channel, Wireless Personal Commun. Vol.2 no. 4, pp 335-356,1996

[5]. H. Hamazumi, Y. Ito and H. Miyazawa, Performance of frequency domain sub-band diversity combination technique for wideband mobile radio reception-an application to OFDM ,Trans. IEICE, vol. J80-B-II, no.-6, pp. 466-474, june1997.

[6]. M.Mŭnster, T. Keller, and L.Hanzo, Co-channel interference suppression assisted adaptive OFDM in interference limited environments.,In Proc. 50th Vehicular Technology Conf(VTC 1000, vol. 1, Amsterdam, the Netherlands, Sept. 1999 pp. 284-288.

[7]. Andrea Goldsmith, Wireless Communications (Cambridge University Press,2005)

[8]. R. W. Chang and R. A. Gibby, A theoretical study of performance of an orthogonal multiplexing data transmission scheme, IEEE Trans. Commun. Vol. COM-16, pp. 529-540, Aug. 1968.

[9]. http://www.dsplog.com/2008/09/28/maximal-ratio-combining/,Krishna Sankar , Sept 28,2008.
[10]. Yong Soo Cho, Jaekwon Kim, Won Young Yang and Chung-Gu Kang, MIMO-OFDM Wireless Communications with MATLAB. (Wiley publications, IEEE press, 2010)

Biographies and Photographs

Sahil Dhingra pursuing B.Tech from Dehradun Institute of Technology, Dehradun in Electronics and Communication engineering. His areas of interest include work on SIMO systems, fixed wing UAV design and control.

Sovanjyoti Giri received the B.Tech degree in Electronics and Communication Engineering from Kalyani Government Engineering College (W.B.U.T.), Kalyani, India, in 2012. He received his M.Tech. degree in Communication Systems from M.N.N.I.T. Allahabad, Allahabad, India, in 2014. He worked as an assistant professor in the Department of Electronics and Communication Engineering at D.I.T. University, Dehradun, India from July 2014 to June 2015. Since July 2015, he is a Ph.D. research scholar in the Department of Electronics and Electrical Communication Engineering, IIT Kharagpur, Kharagpur India. His research areas include relayed and co-operative communication, turbo code performance over fading channels, MIMO-OFDM systems, system network coding, complex communication networks.