Techniques for Improving BER and SNR in MIMO Antenna for Optimum Performance

J. Prasanth Kumar[1] | R. Sowjanya[2] | P. Sameena[3] | P. MadhaviSankar Gowd[4]

[1]Assistant Professor, Department of ECE, Ramachandra College of Engineering, Eluru, India.
[2,3,4]B.Tech, Students, Department of ECE, Ramachandra College of Engineering, Eluru, India.

ABSTRACT

The use of multiple antennas for diversity, including MIMO (Multiple Input Multiple Output) is one of the most promising wireless technologies for broadband communication applications. This antenna system is a vital study in today's wireless communication system especially when the signal propagates through some corrupted environments. In our paper new techniques of improving bit error ratio and signal to noise ratio are discussed. Inter symbol interference is a major limitation of wireless communications. It degrades the performance significantly if the delay spread is comparable or higher than the symbol duration. To remove ISI, equalization needs to be included at the receiver end. This paper discusses the merits of the MIMO system and the techniques used for improving BER performance and SNR. In MIMO wireless communication, an equalizer is used to recover a signal that suffers from Inter symbol Interference (ISI) and the BER characteristics is improved and a good SNR can be obtained. Different equalization techniques are discussed in this paper.

KEYWORDS: *MIMO(Multiple input Multiple output), MRC(Maximum ratio combining equalizer), BER(Bit error rate), SNR(Signal to noise ratio), ISI(Inter symbol interference), OFDM(orthogonal frequency division multiplexing)*

I. Introduction

The use of multiple antenna technique has gained overwhelming interest throughout the last decade. The idea of using multiple antenna configurations instead of a single one has proven to be successful in enhancing data transfer rate, coverage, security and the overall performance of radio networks. In recent years high data rate techniques have gained considerable interests in communication systems. Signal –to-noise ratio (SNR) is defined as the ratio of the desired signal power to noise power. SNR indicates the reliability of link between the transmitter and receiver. The most meaningful criterion for evaluation of performance of communication systems is the bit error rate (BER). The development of next-generation wireless communication systems requires broadband and multiband devices formulti-functionality and faster data transfers, while maintaining good efficiency, low weight, low cost, and easy manufacturing.In this context, bit error rate and signal to noise ratio has become a real challenge for antenna designers. This paper discusses the merits of the MIMO system and the techniques used for improving BER performance and SNR. In MIMO wireless communication, an equalizer is used to recover a signal that suffers from Inter symbol Interference (ISI) and the BER characteristics is improved and a good SNR obtained. Different equalization techniques are discussed in this paper.

1.1 NEED OF MIMO:

Multiple-input multiple-output, or MIMO, is a radio communications technology or RF technology that is being mentioned and used in many new technologies these days.

Wi-Fi, LTE; Long Term Evolution, and many other radio, wireless and RF technologies are using the new MIMO wireless technology to provide increased link capacity and spectral efficiency combined with improved link reliability using what were previously seen as interference paths.

Even now many there are many MIMO wireless routers on the market, and as this RF technology is becoming more widespread, more MIMO routers and other items of wireless MIMO equipment will be seen.MIMO technology has attracted attention in wireless communications, since it offers significant increases data throughput and link range without additional bandwidth or transmit power. It achieves this by higher spectral efficiency (more bits per second per hertz of bandwidth) and link reliability or diversity (reduced fading). Because of these properties, MIMO is a current theme of international wireless research.Point-to-point (single user) MIMO communication promises large gains for both channel capacity and reliability, essentially via the use of space-time codes (diversity gain oriented) combined with stream multiplexed transmission (rate maximization oriented). Multiuser MIMO (MU-MIMO) information theory advocates for the use of spatial sharing of the channel by the users.

II. OFDM

The main limiting factors in high data rate transmission are noise, inter-symbol interference (ISI) and multipath effects. The effects of ISI on the transmission are negligible as long as the delay spread is significantly shorter than the duration of one transmitted symbol. At higher data rates this problem becomes very obvious. In order to mitigate the effects of ISI many techniques are suggested like equalization which can be used to suppress the echoes caused by the channel. Recently a new and more robust technique is suggested known as OFDM.

OFDM stands for Orthogonal Frequency Division Multiplexing. The basic idea is to divide the available spectrum into several sub-carriers transmitted in parallel to each other. This parallel transmission support high data rates with minimal amount of ISI. For high efficiency the OFDM sub-carriers must be overlapping and orthogonal. The orthogonality allows simultaneous transmission of lot sub-carriers in a tight frequency space without interference.

The spectrum of each sub-carrier has a “null” at the centre frequency of each of the other sub-carrier in the system.

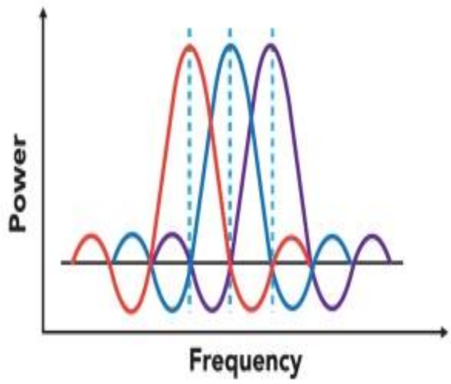

Fig.1 orthogonality of sub-carriers

OFDM is a wideband system with many narrowband sub-carriers. The mathematical MIMO channel model is based on a narrow band non-frequency selective channel. The latter is supported by OFDM as well. Fading effects in wideband systems normally occur only at particular frequencies and interfere with few sub-carriers. The data is spread over all carriers, so that only a small amount of bits get lost, and these can be repaired by forward error correction (FEC).

.Each subcarrier is modulated using varying levels of QAM modulation, e.g. QPSK, QAM, 64QAM or possibly higher orders depending on signal quality. Each OFDM symbol is therefore a linear combination of the instantaneous signals on each of the sub carriers in the channel. Because data is transmitted in parallel rather than serially, OFDM symbols are generally MUCH longer than symbols on single carrier systems of equivalent data rate.

III. EQUALIZATION TECHNIQUES

In wireless communication, an equalizer in general is implemented in the receiver side in order to recover the signal very efficiently from the Inter symbol interference problems . This implementation of equalizers improves the Bit Error Rate and hence provides good Signal to Noise ratio. These equalization techniques are also called as combining techniques as the signals from various paths are combined together. The Equalization techniques are as follows:

A. Maximal Ratio Combining (MRC):

In this MRC technique, each of the signals is multiplied with a weight function which is proportional to the signal amplitude. Hence the diversity branch which has strong signals is amplified further and the branches with weak signals are further attenuated. In this diversity

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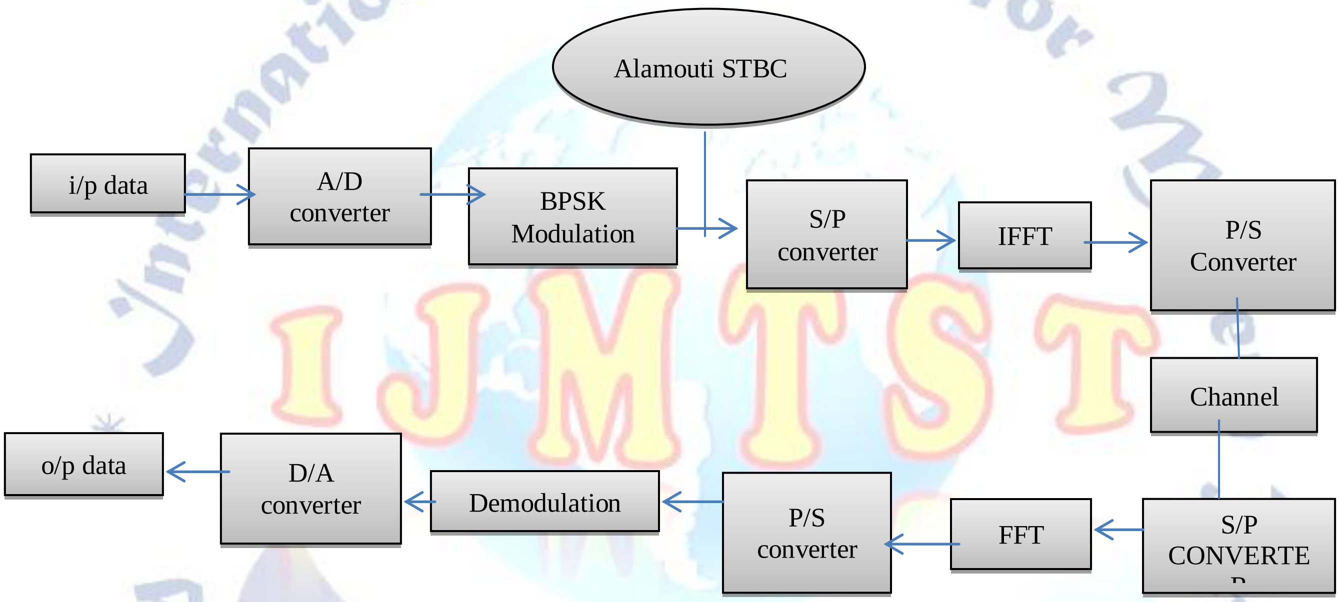
combining technique, signals from various channels are added together and the gain of each channel is proportional to the RMS value of the signal and is inversely proportional to the mean square noise level of that particular channel. This is also called as pre-detection combining or ratio-squared technique and is well suited for independent AWGN channels.

IV. MIMO

A. History of MIMO

ArogyaswamiPaulraj and Thomas Kailath proposed the concept of Spatial Multiplexing using MIMO in 1993. Their US Patent No. 5,345,599 issued in 1994 on Spatial Multiplexing emphasized applications to wireless broadcast. In 1996, Greg Raleigh and Gerard J. Foschinirefine new approaches to MIMO technology, which considers configurations where multiple transmit antennas are co-located at one transmitter to improve the linkthroughput effectively. Bell Labs was the first to demonstrate a laboratory prototype of spatial multiplexing(SM) in 1998, where spatial multiplexing is a principal technology to improve the performance of MIMO communication systems,

Block Diagram of MIMO



Additive White Gaussian Noise (AWGN)

As a last step, we include additive noise in our input/output model. We make the standard assumption that w(t) is zero-mean additive white Gaussian noise (AWGN) with power . The assumption of AWGN essentially means that we are assuming that the primary source of the noise is at the receiver or is radiation impinging on the receiver that is independent of the paths over which the signal is being received. This is normally a very good assumption for most communication situations.

The system was initially tested under AWGN channel conditions using BPSK modulation scheme. Next, tests were conducted under Rayleigh fading channel conditions. Under these conditions, the system performance degraded enormously making it imperative to come up with a solution. The Rayleigh fading channel and the solutions to minimize the effect of channel will be discussed in detail in the next chapter.

B. Alamouti STBC:

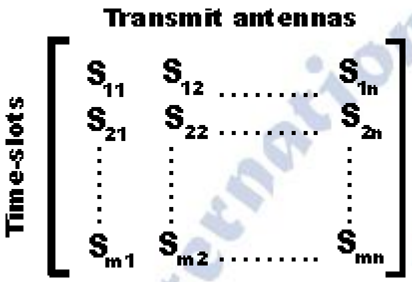
Space-time block codes are used for MIMO systems to enable the transmission of multiple copies of a data stream across a number of antennas and to exploit the various received versions of the data to improve the reliability of data-transfer. Space-time coding combines all the copies of the received signal in an optimal way to extract as much information from each of them as possible.

Space time block coding uses both spatial and temporal diversity and in this way enables significant gains to be made.

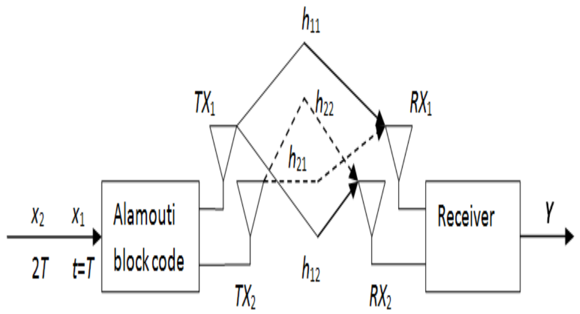
Space-time coding involves the transmission of multiple copies of the data. This helps to compensate for the channel problems such as f

When using space-time block coding, the data stream is encoded in blocks prior to transmission. These data blocks are then distributed among the multiple antennas (which are spaced apart to decorrelate the transmission paths) and the data is also spaced across time.

A space time block code is usually represented by a matrix. Each row represents a time slot and each column represents one antenna's transmissions over time. ading and thermal noise. Although there is redundancy in the data some copies may arrive less corrupted at the receiver.



Within this matrix, Sij is the modulated symbol to be transmitted in time slot i from antenna j. There are to be Ttime slots and nT transmit antennas as well as nR receive antennas. This block is usually considered to be of 'length' T.



Since the transmission is done over two periods of time, the decoding will also be done over two periods of time. At the receiver, the received vector $\boldsymbol{Y}$ can be represented by the following equation:

$$\boldsymbol{Y} = \begin{bmatrix} y_1^1 \\ y_2^1 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1^1 \\ n_2^1 \end{bmatrix}$$

This is for the first time period. For the second time period, the equation is as follows:

$$\boldsymbol{Y} = \begin{bmatrix} y_1^2 \\ y_2^2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} -x_2^* \\ x_1^* \end{bmatrix} + \begin{bmatrix} n_1^2 \\ n_2^2 \end{bmatrix}$$

where $\begin{bmatrix} y_1^1 \\ y_2^1 \end{bmatrix}$ represents the received OFDM symbol at the first time period, for antennas 1 and 2, respectively, and where $\begin{bmatrix} y_1^2 \\ y_2^2 \end{bmatrix}$ represents the received OFDM symbol at the second time period for antennas 1 and 2, respectively. Both equations can easily be combined and arranged to produce the following result:

$$\boldsymbol{Y} = \begin{bmatrix} y_1^1 \\ y_2^1 \\ y_1^{2*} \\ y_2^{2*} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \\ h_{12}^* & -h_{11}^* \\ h_{22}^* & -h_{21}^* \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1^1 \\ n_2^1 \\ n_1^{2*} \\ n_2^{2*} \end{bmatrix}$$

The next step is to find a way to isolate the transmitted symbols, x_1 and x_2. One way to reduce the number of unknowns is by using a channel estimator to estimate the channel coefficients. In Nutaq's OFDM reference design, channel estimation OFDM symbols are sent with each transmitted packet to enable estimating those channel coefficients at the receiver. Given the following matrix:

$$\boldsymbol{H} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \\ h_{12}^* & -h_{11}^* \\ h_{22}^* & -h_{21}^* \end{bmatrix}$$

we can isolate x_1 and $x_2$by simply multiplying the matrix $\boldsymbol{Y}$ by the inverse of $\boldsymbol{H}$. However, since this matrix is not square, we need to use the Moore-Penrose pseudo-inverse $\boldsymbol{H}^+$ to solve our equations:

$$\boldsymbol{H}^+ = \left(\boldsymbol{H}^H \boldsymbol{H}\right)^{-1} \boldsymbol{H}^H$$

Using this inverse matrix expression, the noisy estimated transmitted symbols can be found using the following expression:

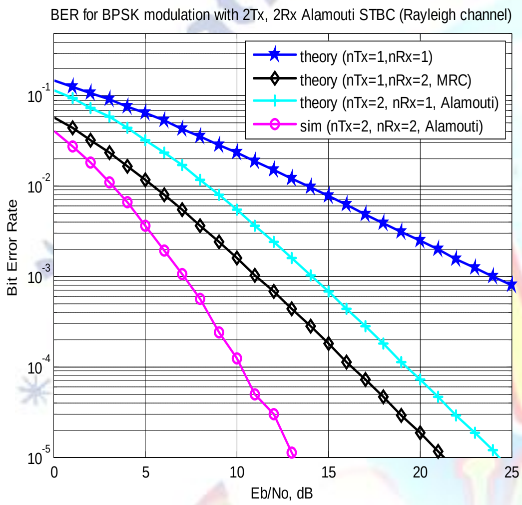
$$\begin{bmatrix} \widehat{x_1} \\ x_2 \end{bmatrix} = \left(\boldsymbol{H}^H \boldsymbol{H}\right)^{-1} \boldsymbol{H}^H \begin{bmatrix} y_1^1 \\ y_2^1 \\ y_1^{2*} \\ y_2^{2*} \end{bmatrix}$$

The last step would be to make a final decision on the transmitted symbols. In Nutaq's OFDM reference design, the decision is made based on the minimum squared Euclidian distance criterion. In the next figure, we can see that the addition of diversity to the system brings a significant performance gain in terms of BER in simulation.

C. Advantages

- Higher data rates in wireless access
- Improves reliability and coverage.
- capacity scales linearly with number of antennas
- Larger spectral efficiency
- Larger number of users
- Better interference suppression.

V. Simulation Results



It isobserved that the Bit Error Rate of alamouti equalizer based receiver is less as compared to maximum ratio combining . The BER for Theoretical MRC is 0.0581, Simulated ALMOUTI is 0.0402 . This shows that alamouti has lower BER as compared to MRC in every case

VI. Conclusion

To conclude this paper provides the complete knowledge of the key issues in the field of mobile communication. When data is transmitted at high bit rates over mobile radio channels, the channel impulse response can extend over many symbol periods which leads to intersymbol Interference. The ultimate goal is to provide universal personal and multimedia communication without regard to mobility or location with a high data rates. To achieve such an objective a strong equalization technique is taken. The receiver scheme is based on Almouti STBC. Bit Error Rate performance for MIMO-STBC in correlated Rayleigh flat fading channel is better than Maximum ratio combining Equalizer. The performance iscompared with the two types of equalizer based receiver namely MRC, STBCAs the number of transmitters is less and more increasing in number and BER decreases for a particular value of Eb/No value. BER performance of STBC Equalizer is superior then MRC Equalizer. The BER values from fig.1 are 0.0581 for MRC and 0.0402 for Almouti STBC. It is inferred that theSTBC equalizer is the best of the other equalizextend upto orthogonal MIMO-STBC,Integer MIMO-STBC.

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