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Performance Evaluation of MIMO system over AWGN and Rayleigh Fading with Maximal Ratio Receiver Combining Diversity Scheme

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Abstract:

This paper indicates that antenna diversity method for the wireless multiple antenna system. In wireless communication fading accumulate in the channel is major apprehension .So the antenna diversity is used to mitigate the the effect of fading over the channel at the relatively less cost. The most commonly antenna diversity technique is space time block code (STBC) provides transmit diversity and maximum ratio combining (MRC) provides receiver diversity in wireless technology is case of multiple-input multiple-output (MIMO) systems. The most commonly employed antenna diversity is Maximal Ratio Receiver Combining (MRRC) in which several uncorrelated replica of the signals with weight values are combined at the receiver in order to achieve improved reconstructed signals. This paper presenting Maximal Ratio Receiver Combining (MRRC) receiver diversity technique to mitigate the effect of Rayleigh fading channel. The simulation result are based on BER performance for systems with single transmit antenna and multiple receiving antennas with (MRRC) diversity technique and result also shows that the two transmit antenna with multiple receiving antenna system. The analysis is carried out through comparison with MATLAB simulations.

Keywords: BER, MIMO, SNR, MRRC, Rayleigh

Introduction

MIMO is an abbreviation that stands for Multiple Input Multiple Output. It is an antenna technology that is used both in transmitter and receiver equipment for wireless communication. MIMO uses multiple antennas to send multiple parallel signals for transmission which exploit the multipath propagation in rich scattering environment. The matrix channel plays a pivotal role in the throughput of a MIMO link since the modulation, data rate, power allocation and antenna weights are dependent on the channel gain. Wireless communication technology has shown that when multiple antennas at both transmitter and receiver are employed it provides the possibility of higher data rates compared to single antenna systems [1] [2]. MIMO exploit the space dimension to improve wireless system capacity, range and reliability. In the never-ending search for increased Capacity in a wireless communication channel it has been shown that by using MIMO system architecture it is possible to increase that capacity substantially. Especially in broadband applications where Intersymbol interference is a critical factor. In an effort to reduce the receiver complexity of the mobile unit, substantial research efforts have been devoted to reprocessing the signal at the base station before transmission. These systems include the Maximum Ratio Combining (MRC) Receiver Diversity Coding techniques are used when there is no channel knowledge at the transmitter. The concept of space-time coding (STC) has arisen from diversity techniques using smart antennas and using data coding and signal processing in both side of the transmitter and receiver, space-time coding now is simpler than Traditional diversity techniques. Traditional diversity techniques are receiving diversities. Alamouti [1] proposed a simple but most effective transmit diversity technique which is called space-time coding because the source data are coded and transmitted through different antennas in different time slots. In some cases it is difficult to use receive diversity as a result of mobile units are purported to be little light-weight pocket communicators. Therefore, use of transmit diversity in base stations seems an attractive technique, as additional complicated base stations will be allowed [2] ~ [4]. Initial and straight forward samples of implementation of space-time coding got in [5], wherever two transmit antennas and two receive antennas were used. Tarokh, et al generalized the transmission theme to an arbitrary number of transmit antennas, which can achieve the full diversity promised by the transmit and receive antennas [6], [7]. From their papers, can find the key points of space-time coding. Firstly, the modulated symbols of source should be mapped into a transmit matrix of antennas and slots, or space and time, which has an orthogonal characteristic resulting in a simple method of detection. Secondly, the most probability detection algorithms will be utilized in the receiver to realize full gain of diversity. Thirdly, more than one antenna could be used in both sides of the transmitter and receiver. Capacity is maximum possible information that can be transmitted with available bandwidth and transmitted power [8].It implies that the radio links in space-time coding systems are multi-input multi-output (MIMO) radio channels that have higher characteristics in numerous propagation environments than traditional diversity techniques. In step with [9], the space-time coding techniques will be divided into three categories: space-time coding, reference system Trellis codes and space-time block codes. it's been shown that space-time block codes offer a much simple way of obtaining transmit diversity with none sacrifice in bandwidth and without requiring huge decoding complexity compared with the other two categories. Therefore, space-time block codes are investigated in our paper. It should be noted that the decoding of space time block codes requires knowledge of channels at the receiver. In diversity methods, a single stream (unlike multiple streams in spatial multiplexing) is transmitted, but the signal is coded using techniques called space-time coding [3][4]. The signal is emitted from each of the transmit antennas with full or near orthogonal coding.

1. Channel Model

In this paper we are using Rayleigh Distribution because the signals do not travel in Line of sight. Rayleigh distribution is a continuous probability distribution. A Rayleigh distribution is often observed when the overall magnitude of a vector is related to its directional components .The Rayleigh probability density function is The Rayleigh distribution is the most widely used distribution to describe the received envelope value. The Rayleigh flat fading channel model assumes that all the components that make up the resultant received signal are reflected or scattered and there is no direct path from the transmitter to the receiver. The Rayleigh distributed envelope of a received signal is given by

$$P_X(x) = \begin{cases} \frac{x}{\sigma^2} \; exp\left(\frac{x^2}{2\sigma^2}\right) & 0 \le x \le \infty \\ 0 & \end{cases}$$

Diversity Techniques

A diversity scheme refers to a method for improving the reliability of a message signal by using two or more communication channels with different characteristics. Diversity plays an important role in combating fading and co channel interference and avoiding error bursts. Diversity Coding techniques are used when there is no channel knowledge at the transmitter. In diversity methods, a single stream (unlike multiple streams in spatial multiplexing) is transmitted, but the signal is coded using techniques called space-time coding [4]. The signal is emitted from each of the transmit antennas with full or near orthogonal coding. Antenna diversity is especially effective at mitigating these multipath situations. This is because multiple antennas offer a receiver several observations of the same signal. Each antenna will experience a different interference environment. Antenna diversity [2] [5] can be realized in several ways. Depending on the environment and the expected interference, designers can employ one or more of these methods to improve signal quality. Here we are using spatial diversity, transmit diversity, and receive diversity techniques which are also called antenna techniques for diversity.

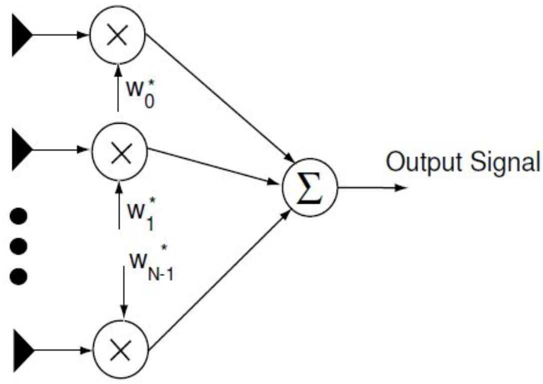

Figure1.The receiver in the diversity combining system

Spatial Diversity

In this spatial diversity [5] employs multiple antennas, usually with the same characteristics, that are physically separated from one another. Depending upon the expected incidence of the incoming signal, sometimes a space on the order of a wavelength is sufficient. Other times much larger distances are needed. Often, especially in urban and indoor environments, there is no clear line-of sight (LOS) between transmitter and receiver. Instead the signal is reflected along multiple paths before finally being received. Each of these bounces can introduce phase shifts, time delays, attenuations, and distortions that can destructively interfere with one another at the aperture of the receiving antenna. Cellularization or sectorization, for example, is a spatial diversity scheme that can have antennas or base stations miles apart. This is especially beneficial for the mobile communication industry since it allows multiple users to share a limited communication spectrum and avoid co-channel interference.

Receiver Diversity

It can be used in channels with multiple antennas at the receive side. The receive signals are assumed to fade independently and are combined at the receiver so that the resulting signal shows significantly reduced fading. Receive diversity is characterized by the number of independent fading branches and it is at most equal to the number of receive antennas. The key feature of all diversity methods is a low probability of simultaneous deep fades in the various diversity channels. In general the system performance with diversity techniques depends on how many signal replicas are combined at the receiver to increase the overall SNR. There exist four main types of signal combining methods at the receiver: *selection combining, switched combining, equal-gai combining* and *maximum ratio combining* (MRC).For all three, the goal is to find a set of weights w, More information about combining methods can be found in Depending on surrounding environment, a transmitted radio signal propagates through several different paths. This phenomenon is often referred as multipath propagation [3]. The signal received by the receiver antenna consists of the superposition of various multipath. If there are Non-Line of Sight components between the transmitter and receiver, the attenuation coefficients corresponding to different paths are assumed to be independent and identically distributed. In which case the central limit theorem applies and the resulting path can be modeled as a complex Gaussian random variable. In this paper, the channel is said to be Rayleigh. Signal power in a wireless system fluctuates. When this signal power drops significantly, the channel is said to be in fade. Diversity is used in wireless channels to combat the fading. Receive diversity and transmit diversity mitigate fading and significantly improve link quality. The receive antennas see independently faded versions of the same signals. The receiver combines these signals so that the resultant signal exhibits considerably reduced amplitude fading. In most scattering environments, antenna diversity is a practical, effective and, hence, a widely applied technique for reducing the effect of multipath fading . The classical approach is to use multiple antennas at the receiver and perform combining or selection and switching in order to improve the quality of the received signal. The major problem with using the receive diversity approach is the cost, size, and power of the remote units. The use of multiple antennas and radio frequency (RF) chains makes the remote units larger and more expensive. As a result, diversity techniques have almost exclusively been applied to base stations to improve their reception quality. A base station often serves hundreds to thousands of remote units. It is therefore more economical to add equipment to base stations rather than the remote units. For this reason, transmit diversity schemes are very attractive.

Maximal Ratio Receiver Combining (MRRC)

To eliminate the effect of multipath fading antenna diversity is practical, effective and commonly used technique. MRRC is classical receive diversity technique, which uses the multiple antenna at the receiver and performs combining or selection and switching to improve the quality of received signal. Since the cost, size and power are the important factors to be considered, MRRC uses selection and switching circuit in the receiver which makes it larger in size and costly. Due to this reason transmit diversity schemes are found more attractive than the receive diversity In this systems, the signals from the received antenna elements are weighted with the weights being proportional to the power in each branch such that the signal-to-noise ratio (SNR) of their sum is maximized. However, with MRC, most of the system complexity concentrates at the receiver side[8][9]. To achieve a high diversity order, a large number of receive antennas with the same number of RF chains have to be deployed at the small size mobile set, which is normally impractical. Analysis of MRC for one transmit and N receive antenna system-

1. We have N receive antennas and one transmit antenna.
2. The channel is Rayleigh fading – In simple terms, it means that the multipath channel has only one tap. So, the convolution operation reduces to a simple multiplication [10][11].
3. The channel experienced by each receive antenna is randomly varying in time. For the i^{th} receive antenna, each transmitted symbol gets multiplied by a randomly varying complex number h_i. As the channel under consideration is a Rayleigh channel, the real and imaginary parts of h_i are Gaussian distributed having mean μ_{h_i} =0 and Variance $\sigma_{h_i}^2$ =1/2

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4. The channel experience by each receive antenna is independent from the channel experienced by other receive antennas.

5. On each receive antenna, the n noise , Gaussian probability density function with

$$p(n)=\frac{1}{\sqrt{2\pi\sigma^2}}e^{\frac{-(n-\mu)^2}{2\sigma^2}}$$

with $\mu=0$ and $\sigma^2=\frac{N_0}{2}$. (2)

The noise on each receive antenna is independent from the noise on the other receive antennas.

6. At each receive antenna, the channel h_i is known at the receiver.

$$\gamma_i=\frac{|h_i|^2 E_b}{N_0}$$

i^{th}

In the presence of channel h_i, the instantaneous bit energy to noise ratio at i^{th} receive antenna is $\frac{|h_i|^2 E_b}{N_0}$.

For notational convenience, let us define,

$$\gamma_i=\frac{|h_i|^2 E_b}{N_0}$$

i^{th}

On the y_i receive antenna, the received signal is

$$y_i=h_i x+n_i$$

Where

y_i is the received symbol on i^{th} receive antenna.

h_i is the channel on i^{th} receive antenna

x is the received symbol on i^{th} receive antenna

n_i is the noise on i^{th} receive antenna.

Expressing it in matrix form, the received signal is,

$$y_i=h_i x+n_i \quad (5)$$

where

$y_i=[y_1 y_2 ....y_N]^T$ is the received symbol from all the receive antenna

$h_i=[h_1 h_2 ....h_N]^T$ is the channel on all the receive antenna x is the transmitted symbol and

$n=[n_1 n_2 ....n_N]^T$ is the noise on all the receive antenna.The equalized symbol is,It is intuitive to note that the term,

$$h^H=\sum_{i=1}^{N}|h_i|^2$$ i.e sum of the channel powers across all the receive antennas.

Effective Eb/No with Maximal Ratio Combining (MRC).In the presence of channel h_i the instantaneous bit energy to noise ratio at i^{th} receive antenna is

$$\Upsilon_i=\frac{|h_i|^2 E_b}{N_o} \quad (6)$$

Given that we are equalizing the channel with h^H, with the N receive antenna case, the effective bit energy to noise ratio is,

$$\gamma=\sum_{i=1}^{N}\frac{|h_i^2|E_b}{N_0} \quad (7)$$

$$=N\gamma_i \quad (8)$$

Effective bit energy to noise ratio in a N receive antenna case is N times the bit energy to noise ratio for single antenna case.

Two Transmit antennas with one receiver

Let us assume a signal x1 and x2 are transmitted by antenna 1 and antenna 2 respectively at time t. At next time t+T signal. $-x_2^*$ is transmitted from antenna 1 and signal $x_1^*$is transmitted from antenna 2 where (*) is the complex conjugate operation [12].

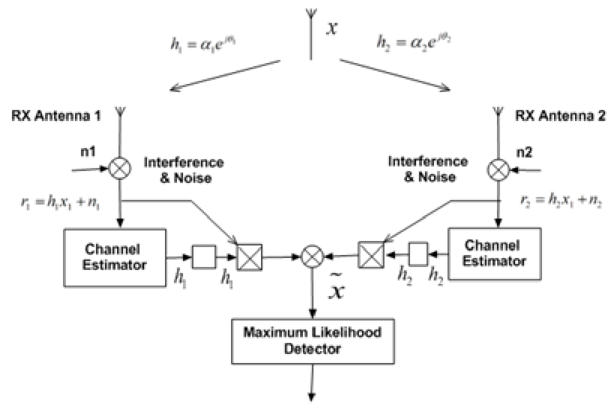

Figure 2: One Transmitter and two receiver Antenna system

Table1. Encoding and transmission sequence for 2x1 Alamouti scheme

Time	Antenna 1	Antenna 2

t	x_1	x_2
t+T	$-x_2^*$	$-x_1$

Let h1 and h2 be the channel response for antenna 1 and antenna 2. Assume α_1 and α_2 be the respective path gains from transmit antenna 1 and 2 to the receive antenna as given as given by equation (9).

$$h_1 = \alpha_1 e^{j\theta_1}$$
$$h_2 = \alpha_1 e^{j\theta_2} \quad (9)$$

Let r1 and r2 be receiving signal at a receiver in time t and t+T respectively

$$r_1 = r(t) = h_1 x_1 + h_2 x_2 + n_1 \quad (10)$$

$$r_2 = r(t+T) = -h_1 x_2^* + h_2 x_1^* + n_2 \quad (11)$$

Where n1 and n2 are variable representing noise (AWGN, fast fading).

The combiner combines the two signals as shown in above Here,

$$\tilde{x}_1 = h^*_1 r_1 + h^*_2 r_2$$
$$\tilde{x}_2 = h^*_2 r_1 + h^*_1 r_2 \quad (12)$$

Now by substituting above two equations in combiner equation, the result is

$$\tilde{x}_1 = (\alpha_1^2 + \alpha_2^2) s_1 + h_1^* n_1 + h_2 n_2^*$$
$$\tilde{x}_2 = (\alpha_1^2 + \alpha_2^2) s_2 + h_1 n_2^* + h_2^* n_1 \quad (13)$$

At the receiver end these signals are combined and finally send to the maximum likelihood equalizer which makes a decision parameter for each of transmitted signals.

Results and Discussion:

In this section we evaluate BER performance analysis using MATLAB simulation. We compare the results of MRRC receiver diversity technique with Alamouti scheme with different antenna system.

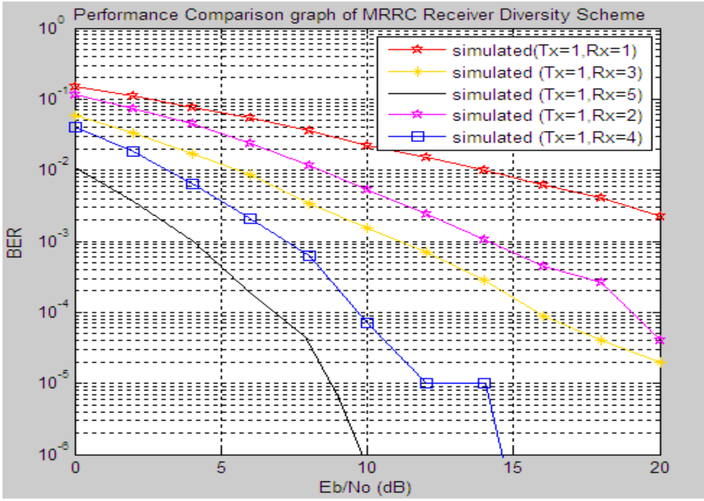

Figure3. Performance comparison of Receiver diversity

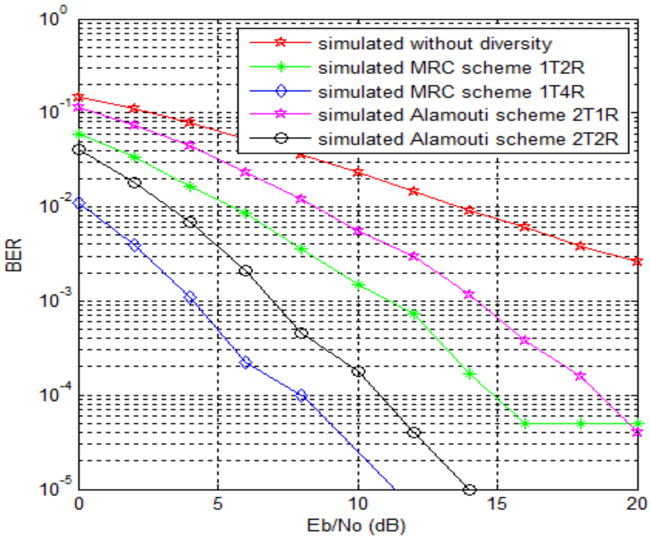

Figure 3. Performance comparison of MRC and alamouti scheme

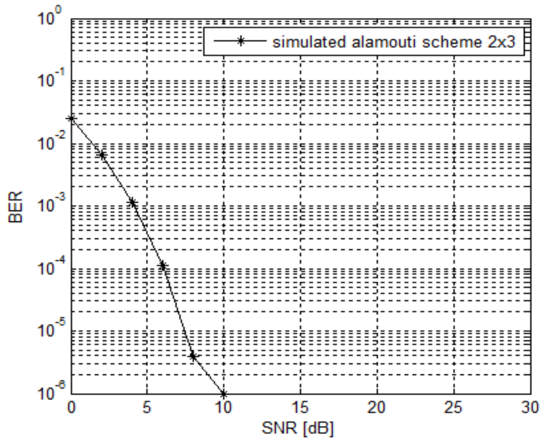

Figure4. Performance MRC with Alamouti scheme

2. Result and Discussion

The BER performance evaluation is done using MATLAB simulation. We evaluate the performance of receiver diversity with Rayleigh fading channel for multiple antenna systems that is one transmit and multiple receiving antennas. Figure 2 shows that BER Vs. SNR graph for multiple receiving antennas system at 10^{-6} BER is achieved at less than 10 dB of SNR , the same BER can be achieved against the less than 15dB of SNR for 1x4 antenna system or BER at 10^{-5}can be achieved against the 12dB of SNR for 1X4 antenna system. So from the simulation BER improvement can be achieved by paying 2dB of extra SNR for 1x4 antennas System. The graph shows that the performance of 1x2, 1x3, 1x4, 1x5 antenna system. Figure 3 shows that performance comparison graph which compares the performance of Alamouti scheme with the MRRC receiver diversity technique. From the graph At 10^{-5} BER can be achieved against 11dB of SNR for MRC scheme with 1x4 antenna system and for the same BER achieved against the 14dB SNR for 2x2 Alamouti scheme having same diversity. Figure 4 shows that the performance of 2x3 Antenna System which can achieve BER at 10^{-6} against the 10dB of SNR that shows the better result than the other antenna system.

3. Conclusion

The simulations were carried out. Now let us consider the simulation analysis of diversity with Rayleigh fading channel BER rapidly decreases when SNR(Eb/N_0) ratio increases as the diversity technique is applied on Rayleigh fading channel shown in figure 2.Also comparison between different antenna system has been done in Figure no.3. Figure. Which shows that comparison

between two diversity technique Alamouti and MRRC receiver diversity technique for wireless Rayleigh fading channel where LOS is not available. It is clearly mentioned in the figure that the BER deceases as the receiver antenna increases. If the antenna diversity is same but the performance of MRRC diversity technique gives better result as compare with alamouti scheme or Alamouti scheme required as compared to the receiving diversity (MRRC).

9. Acknowledgements

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