Comparative Study of Rayleigh Fading Multiple Antenna System with MRC

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ABSTRACT- We consider multiple-input multiple-output (MIMO) transmit space time coded systems with maximum ratio combining (MRC) receivers. The operating environment is multipath Rayleigh fading with *both* transmit and receive spatial correlation. We present exact expressions for the probability density function (p.d.f.) of the output signal-to-noise ratio (SNR), as well as the system probability error function. The results are based on BER performance . For systems with one antennas at either the transmitter or N number of receiver, we also derive exact closed-form expressions for the symbol error rate (SER). The new expressions are used to prove that MIMO-MRC achieves the maximum available spatial diversity order,and to demonstrate the effect of spatial correlation. The analysis is lidated through comparison with MATLAB simulations.

Keywords:- BER, MIMO system, signal to noise ratio (SNR), Diversity Methods, Rayleigh .

MIMO is an acronym that stands for Multiple Input Multiple Output. It is an antenna technology that is used both in transmitter and receiver equipment for wireless radio 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) transmit scheme 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 [3][4]. The signal is emitted from each of the transmit antennas with full or near orthogonal coding.

2 Channel Model

In this paper we are using Rayleigh Distribution because the signals do not ravel 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

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

3 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.

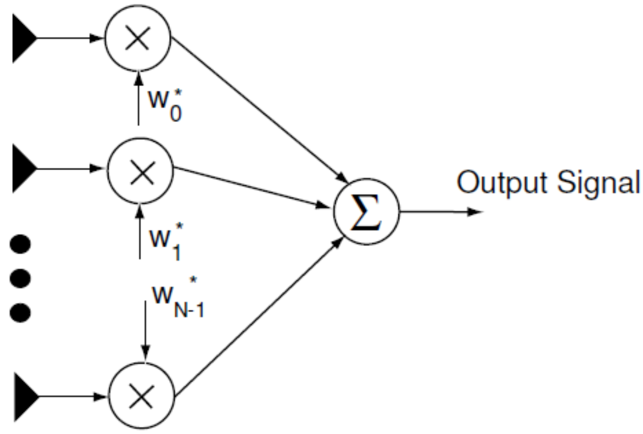

Fig1.The receiver in the diversity combining system

4 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.

5 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-gain* *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.

6 Maximal Ratio Combining (MRC)

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 $\mu_{h_i}=0$and variance $\sigma^2_{h_i}=\frac{1}{2}$.
4. The channel experience by each receive antenna is independent from the channel experienced by other receive antennas.
5. On each receive antenna, the noise n has the 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 $\sigma^2=\frac{N_0}{2}$.
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.
7. In the presence of channel h_i, the instantaneous bit energy to noise ratio at i^{th}receive antenna is $\frac{|h_i|^2E_b}{N_0}$.

For notational convenience, let us define,

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

On the i^{th}receive antenna, the received signal is,

$$y_i=h_ix+n_i$$

where

$y_i$is the received symbol on the i^{th}receive antenna,
$h_i$is the channel on the i^{th}receive antenna,
x is the transmitted symbol and
$n_i$is the noise on i^{th}receive antenna.

Expressing it in matrix form, the received signal is,

$\boldsymbol{y}=\boldsymbol{h}x+\boldsymbol{n}$, where

$\boldsymbol{y}=[y_1y_2\cdot\cdot y_N]^T$ is the received symbol from all the receive antenna

$\boldsymbol{h}=[h_1h_2\cdot\cdot h_N]^T$ 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,

$$h^H h = \sum_{i=1}^{N} |h_i|^2$$

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

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

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

$$\gamma = \sum_{i=1}^{N} \frac{|h_i|^2 E_b}{N_0} = N\gamma_i .$$

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

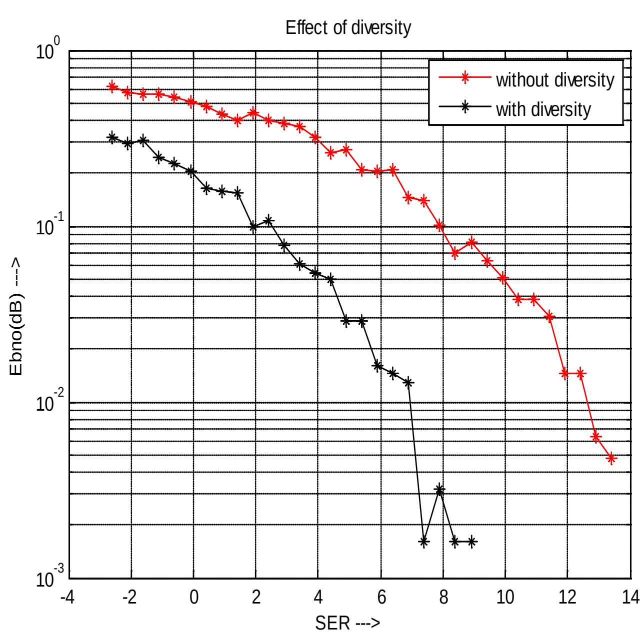

Fig.2 Performance of diversity on Rayleigh fading channel

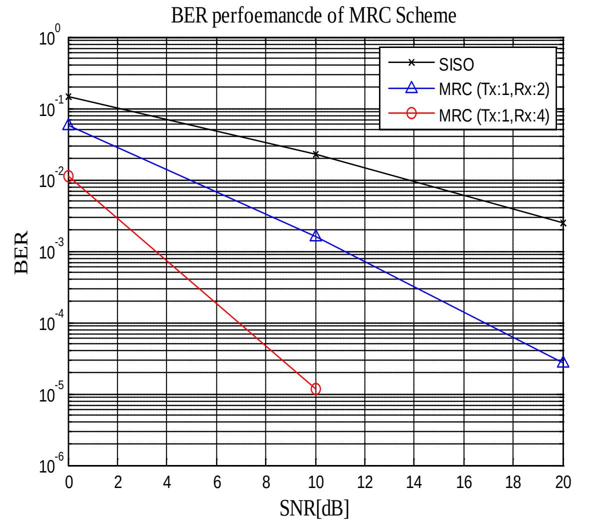

Fig. 3. Performance of MRC receiver diversity technique for 2 receives and 4 receive antenna.

6 Results and Discussion

The BER measurement for the simulation model is done using MATLAB simulation. In this method, the differences between input and output bits are calculated to measurable values. We evaluate the performance of diversity on Rayleigh fading channel and then evaluate the performance of maximal ratio combining (MRC) receiver diversity using multiple antenna systems that is one transmit and one receive antenna, one transmitter and two transmit antenna and one transmit and four receive antenna. The performance of the receiver diversity scheme realizations obtained by simulations of Rayleigh fading channels is shown in Fig. 3.

The simulation studies have been carried out using the MATLAB software. In Fig. 2 shows the plot between Eb/N_0 v/s SER that is the performance of SISO systems. The BER values have been computed and plotted as a function of SNR for 1x1, 1x2 and 1x4 MIMO systems using receiver diversity technique shown in Fig. 3and comparison is carried out.

7 Conclusions

The simulations were carried out. Now let us consider the simulation analysis of diversity with Rayleigh fading channel SER rapid ally decreases when 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 shown the comparison between MRC receiver diversity technique for wireless

Rayleigh fading channel with one transmit and one receive antenna , one transmit and two receive antenna system and one transmit and four receive antenna system and it is clearly mentioned in the figure that the BER deceases as the receiver antenna increases.

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