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Analysis of Spatial Diversity in MIMO

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Abstract— ***In telecommunication 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 or co-channel interference and avoiding error bursts. This diversity scheme can be used in MIMO (Multiple input multiple output). By diversity schemes that uses two or more antennas to improve the quality and reliability of a wireless link. In this paper we are using different diversity i.e. MRC, EGC & SC schemes to analysis the BER performance of Multi antenna system (MIMO) system with the help of the MATLAB SOFTWARE***

Keywords- ***MIMO, Diversity Scheme, MRC, EGC, Alamouti codes, Minimum mean square error, Maximum likelihood estimation ,SISO ,MISO ,SIMO ,Bit error rate, SNR, Rayleigh channel, Modulation.***

INTRODUCTION

(Multiple Input Multiple Output) System

Multiple-input and multiple-output, or MIMO [1] (commonly pronounced my-moh or me-moh), is the use of multiple antennas at both the transmitter and receiver to improve communication performance. It is one of several forms of smart antenna technology. Note that the terms *input* and *output* refer to the radio channel carrying the signal, not to the devices having antennas.

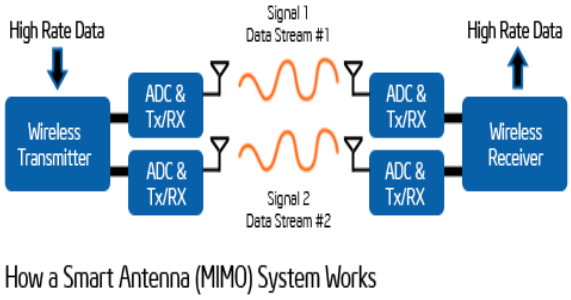


Fig 1-Multiple Input Multiple Outputs

MIMO can be sub-divided into three main categories, Precoding, spatial multiplexing SM, and diversity coding. Precoding [2] is multi-stream beamforming, in the narrowest definition. In more general terms, it is considered to be all spatial processing that occurs at the transmitter.

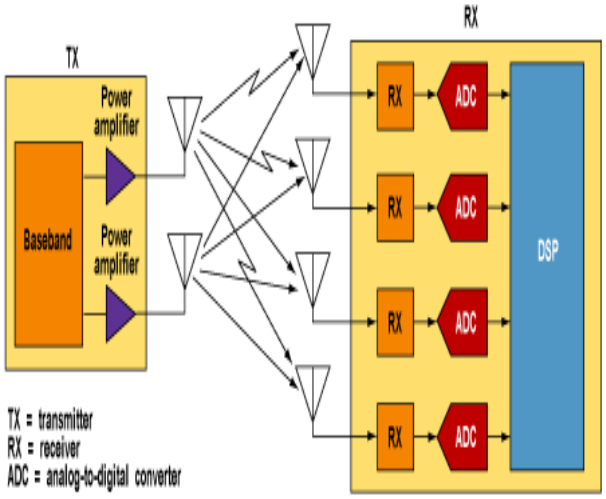
Spatial multiplexing [3] requires MIMO antenna configuration. In spatial multiplexing, a high rate signal is split into multiple lower rate streams and each stream is transmitted from a different transmit antenna in the same frequency channel. If these signals arrive at the receiver antenna array with sufficiently different spatial signatures, the receiver can separate these streams into (almost) parallel channels. Spatial multiplexing is a very powerful technique for increasing channel capacity at higher signal-to-noise ratios (SNR).

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.

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. 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 [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, receive diversity techniques which are also called antenna techniques for 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.

Transmit/Receive diversity uses two separate, collocated antennas for transmit and receive functions. Such a configuration eliminates the need for a duplexer and can protect sensitive receiver components from the high power used in transmit



4. In a typical MIMO arrangement, two transmitters simultaneously send data on the same channel while four antennas on the receiving end are set in a spatial diversity arrangement.

Fig 2-Spatial diversity system

Different type of combining techniques are used in receive diversity.In this paper We are using the maximal ratio combining because MRC is the best combining techniques for combating fading in smart antenna system.

Maximal Ratio Combining - In maximal ratio combining (MRC), the signals from all of the *MR* branches are weighted according to their individual SNRs and then summed. Here the individual signals need to be brought into phase alignment before summing. This implies individual RF receiver tracts. The gain of each channel is made proportional to the rms signal level and inversely proportional to the mean square noise level in that channel.In maximal ratio combining different proportionality constants are used for each channel. It is also known as **ratio-squared combining** and **predetection combining**. Maximal-ratio-combining is the optimum combiner for independent AWGN channels.
where EGC is the same as MRC but with equal weighting for all branches. Hence, in this sense it is suboptimal. The performance is marginally inferior to MRC, but the complexities of implementation are much less.

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

$$f(x;\sigma) = \frac{x}{\sigma^2} e^{-x^2/2\sigma^2}, \quad x \geq 0,$$

for parameter $\sigma > 0$, and cumulative distribution function

for $F(x) = 1 - e^{-x^2/2\sigma^2}$

Modulation

Modulation is the process of conveying a message signal, for example a digital bit stream or an analog audio signal, inside another signal that can be physically transmitted. Modulation of a sine waveform is used to transform a baseband message signal into a pass band signal.

Here we are using M-ary PSK [7] for improvement of bit error rate of the MIMO system. Where M-ary PSK is a digital modulation scheme that conveys data by changing, or modulating, the phase of a reference signal .Any digital modulation scheme uses a finite number of distinct signals to represent digital data. PSK uses a finite number of phases; each assigned a unique pattern of binary digits. Usually, each phase encodes an equal number of bits. Each pattern of bits forms the symbol that is represented by the particular phase. The demodulator, which is designed specifically for the symbol-set used by the modulator, determines the phase of the received signal and maps it back to the symbol it represents, thus recovering the original data. This requires the receiver to be able to compare the phase of the received signal to a reference signal — such a system is termed coherent.

Detection Techniques

In this research work we used different detection techniques for the detection, like MMSE, MLE, Alamouti coding.

A minimum mean square error (MMSE) estimator describes the approach which minimizes the mean square error (MSE), which is a common measure of estimator [7] quality, where MLE is a method of estimating the parameters of a statistical model. When applied to a data set and given a statistical model, maximum-likelihood estimation provides estimates for the model's parameters.

Alamouti Coding or Space time coding

Now one of the other detection technique is Alamouti coding[8] which is a coding coding is a technique used in wireless communications to transmit 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. The fact that the transmit signal must traverse environment with scattering, reflection, refraction and so on and may then be further corrupted by thermal noise in the receiver means that some of the received copies of the data will be 'better' than others. This redundancy results in a higher chance of being able to use one or more of the received copies to correctly decode the received signal.

RESULT & CONCLUSION

Here we are showing the result of BER (Bit Error Rate) for BPSK modulation scheme with MRC, EGC &SC in fig 3. In this graph we plot curves between Bit error rate & Eb/No for

BPSK modulation scheme with SISO, MRC, EGC & SC.

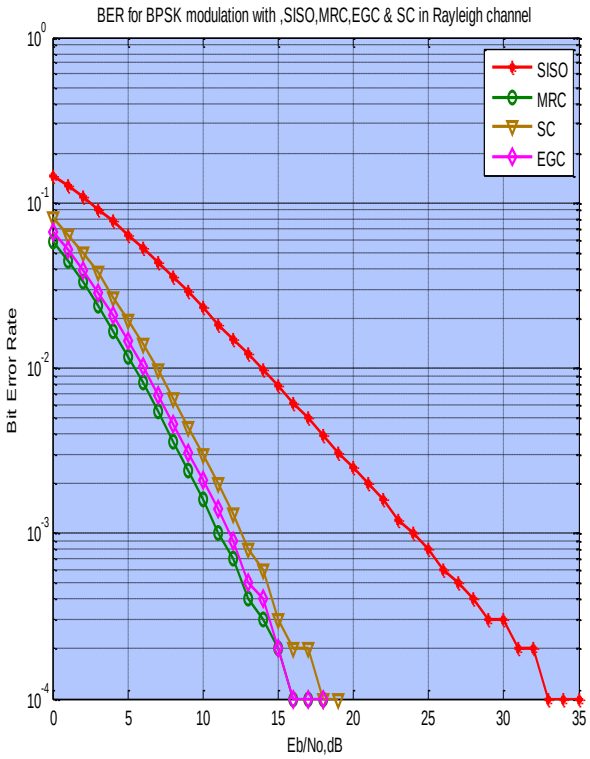


Fig 3-BER for BPSK modulation with MRC, EGC,SC & SISO

When we draw the BER curve for BPSK with different types of combining techniques i.e. MRC, EGC & SC. We find that the curve is showing that for the BPSK modulation with MRC givers better BER curve than the others. .

Let's consider we are calculating Eb/No dB for MRC, EGC & SC, by which we will, came to know the difference between these three techniques. If we consider BER at 10^{-3} and Compare all three systems at same point we got different results for each one. Now we find the dB performances for given 10^{-3} BER we got MRC gives 11 dB Eb/No performance and EGC gives 12 dB at same point. Hence MRC gives 1 dB better performance than EGC. At same point of measurement, MRC gives 2 dB better results than SC. We find MRC gives better Eb/No then the SC. In curve we also find the result for SISO which gives worst result.

Hence from observations we observed that MRC gives better Eb/No dB result than EGC & SC for given BER. However we know that MRC is complex diversity combining technique than the EGC in employing, but beside its complexity it gives best result than EGC & SC.

The second result is shown for the SNR (Signal to Noise Ratio) improvement for BPSK with different combining techniques. In this we plot a graph which is showing curves between the Numbers of receiving antennas

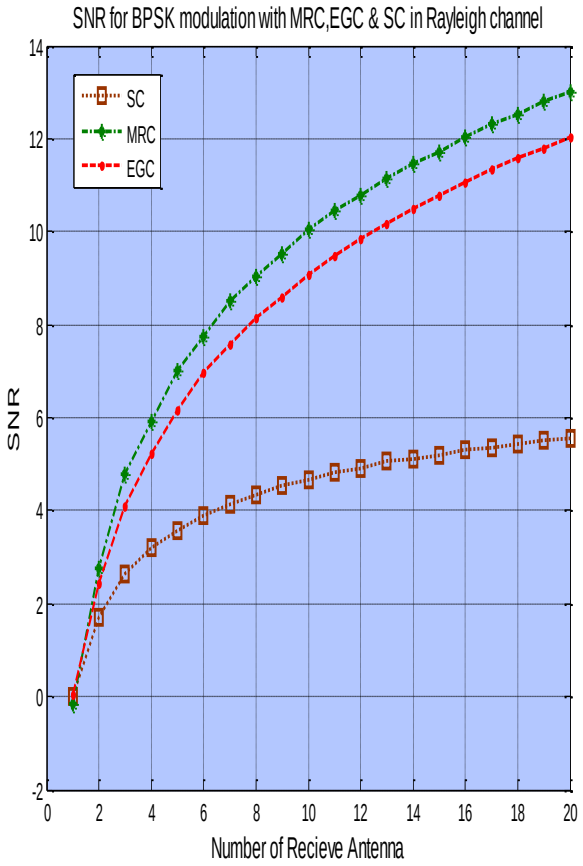


Fig 4- SNR for BPSK modulation with MRC,EGC & SC in Rayleigh Channel.

From the second graph we come to see that as the numbers of receiving antenna increase the SNR also improves. We know that as the numbers of receive antenna are more in MRC than EGC & SC. Now if we consider the number of receiving antennas are 8 and compare the SNR for different techniques, we find that the MRC gives SNR value 9 and EGC gives 8 and so on SC gives near about 4.Hence from above result of graph we concluded that MRC gives better SNR performance than the EGC & SC.

CONCLUSION

From the above given graphs and results we concluded that between different diversity combining technique i.e. MRC, EGC and SC, MRC is best combining techniques for achieving better BER & SNR results. Here we come to know that receive diversity in Multiantenna system gives better performance than the Transmit diversity,however MRC is complex combining technique than other combining techniques but it gives better result for BER & SNR.

Thus we analysis the different diversity combining techniques and find that Maximal ratio combining(receive diversity) is better than other types of combining techniques.

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