



Performance Analysis of Combining Techniques Used In MIMO Wireless Communication System Using MATLAB

¹Prabhat Kumar, ²Manisha Manoj Chahande

Amity Institute of Telecom Engineering and Management
Amity University, sector-125, Noida-201301, (U.P), INDIA

Abstract: In wireless communication diversity techniques are very powerful to mitigate the fading impairment. In presence of receiver side how do we use effectively the information from the entire antenna to demodulate the data? This paper presents the equal gain combining and maximal ratio combining techniques used in MIMO wireless communication system. The analysis of the SNR and BER after these two combining techniques is made in Rayleigh fading channels and modulation which is taking into count is BPSK modulation.

Keywords: Maximal ratio combining, Equal gain combining, Effective E_b/N_0 , Bit Error Rate.

I. Introduction

Transmit/receive diversity can improve the performance of mobile radio system by weighting and combining the receiving signals strength from all branches of antenna to minimize the fading and co-channel interference (CCI) [1]. Receive diversity are including the algorithm maximal ratio combining and equal gain combining [2]. In equal gain combining, the signals from all the branches are first co-phased then equally weighted by their amplitudes. In other words the branch weights are set to unity. The possibility of producing acceptable signals from number of unacceptable signals input is still retained. The equal gain combining has optimal performance close to maximal ratio combining but its implementations are very simple. This paper focuses the impact of fading and co-channel interference on equal gain combining, since these are the major factor in wireless communication. In maximal ratio combining the signal from each branch is first co-phased and then phase distributions are canceled out, the signals in each branch is weighted by weighting factor proportional to the ratio of career amplitude to the noise power of i^{th} branch [7]. In particular, we focus on the outage probability of unacceptable repetition in the proposed coverage area [3].

II. Maximal Ratio Combining

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

$$y_i = h_i x + n_i$$

Where, y_i is the received signal strength at i^{th} received antenna.

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

x is the transmitted symbol

n_i is the i^{th} received antenna

Received signal in matrix form is represented by,

$$y = h_x + n$$

$y = [y_1 \ y_2 \ y_3 \ \dots \ y_N]^T$ is the received symbol from all the received antenna

$h = [h_1 \ h_2 \ h_3 \ \dots \ h_N]^T$ channel on all the received antenna

x is the transmitted symbol

$n = [n_1 \ n_2 \ n_3 \ \dots \ n_N]^T$ is noise on all the receive antenna

The equalized symbol is,

$$\hat{x} = \frac{h^H y}{h^H h} = \frac{h^H h x}{h^H h} + \frac{h^H n}{h^H h} = x + \frac{h^H n}{h^H h}$$

It is intuitive to note that the term,

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

i.e. sum of channel power at receive antenna.

A. Effective E_b/N_0 with maximal ratio combining

In presence of channel h_i , the signal-to-noise ratio at any time instant at i^{th} received antenna is

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

Since we are equalizing the channel h^H with N receive antenna. So the effective bit energy to noise ratio is

$$\begin{aligned}\gamma &= \sum_{i=1}^N \frac{|h_i|^2 E_b}{N_0} \\ &= N \gamma_i\end{aligned}$$

In case of N receive antenna effective bit energy to noise ratio is N times the bit energy to noise ratio for single antenna case.

B. Error rate with maximal ratio combining

In chi-square random variable, we know that if, h_i is the rayleigh distributed random variable, then h_i^2 is the chi-squared random variable with two degrees of freedom. The probability density function of γ_i is

$$p(\gamma_i) = \frac{1}{(E_b/N_0)} e^{\frac{-\gamma_i}{(E_b/N_0)}}$$

Effective bit energy to noise ratio γ is the sum of N random variables, then the probability density function of γ is chi-random variable with $2N$ degrees of freedom. The pdf γ is defined as

$$p(\gamma) = \frac{1}{(N-1)!(E_b/N_0)^N} \gamma^{N-1} e^{\frac{-\gamma}{(E_b/N_0)}}, \quad \gamma \geq 0$$

Effective bit energy to noise ratio with MRC is γ , total bit error rate is the integral of the conditional BER integrated over all possible values of γ [4].

$$\begin{aligned}P_e &= \int_0^{\infty} \frac{1}{2} \operatorname{erfc}(\sqrt{\gamma}) p(\gamma) d\gamma \\ &= \int_0^{\infty} \frac{1}{2} \operatorname{erfc}(\sqrt{\gamma}) \frac{1}{(N-1)!(E_b/N_0)^N} \gamma^{N-1} e^{\frac{-\gamma}{(E_b/N_0)}} d\gamma\end{aligned}$$

The equation reduces as [5]

$$\begin{aligned}P_e &= p^N \sum_{k=0}^{N-1} \binom{N-1+k}{k} (1-p)^k \\ p &= \frac{1}{2} - \frac{1}{2} \left(1 + \frac{1}{E_b/N_0} \right)^{-1/2}\end{aligned}$$

III. Equal Gain Combining

Equalization is performed at the receiver on the i^{th} receive antenna by dividing the received symbol y_i by the apriori known phase of h_i [4]. The h_i is represented in polar form as:

$$|h_i| e^{j\theta_i}$$

The decoded symbol is the sum of the phase compensated channel from all the received antenna.

$$\begin{aligned}\hat{y} &= \sum_i \frac{y_i}{e^{j\theta_i}} \\ &= \sum_i \frac{|h_i| e^{j\theta_i} x + n_i}{e^{j\theta_i}} \\ &= \sum_i |h_i| x + \tilde{n}_i\end{aligned}$$

Where,

$$\tilde{n}_i = \frac{n_i}{e^{j\theta_i}}$$

is the additive noise scaled by the phase of the channel coefficient. For demodulation, we use classical definition i.e.

$$\hat{y} \leq 0 \rightarrow 0 \text{ and } \hat{y} > 0 \rightarrow 1$$

A. Effective E_b/N_0 with Equal gain combining

In 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 the notational convenience, we can define it as:

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

The effective E_b/N_0 with equal gain combining is the channel power accumulated over all receive chains, i.e.

$$\begin{aligned} E(\gamma_i) &= \frac{E_b}{N_0} \frac{1}{N} \left(\sum_{i=1}^N |h_i|^2 \right) \\ &= \frac{E_b}{N_0} \frac{1}{N} \left(\sum_{i=1}^N \sum_{k=1}^N |h_i| |h_k| \right) \\ &= \frac{E_b}{N_0} \frac{1}{N} \left(\sum_{i=1}^N |h_i|^2 + \sum_{i=1}^N \sum_{k=1, k \neq i}^N |h_i| |h_k| \right) \end{aligned}$$

The first term is chi-square random variable with $2N$ degrees of freedom having mean value of $2N\sigma_{h_i}^2$. Hence the first term reduces and written as:

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

The second term is the product of two Rayleigh random variables. The mean of Rayleigh random variable with variance $\sigma_{h_i}^2$ is $\sigma_{h_i} \sqrt{\frac{\pi}{2}}$. Hence the second term is,

$$\sum_{i=1}^N \sum_{k=1, k \neq i}^N |h_i| |h_k| = N \sqrt{\frac{\pi}{4}} (N-1) \sqrt{\frac{\pi}{4}} = N(N-1) \frac{\pi}{4}$$

Simplifying, the effective E_b/N_0 with equal gain combining is,

$$\begin{aligned} E(\gamma_i) &= \frac{E_b}{N_0} \frac{1}{N} \left[N + N(N-1) \frac{\pi}{4} \right] \\ &= \frac{E_b}{N_0} \left[1 + (N-1) \frac{\pi}{4} \right] \end{aligned}$$

B. Bit Error Rate with Equal Gain Combining

With two receive antennas, BER with equal gain combining is [6],

$$P_e = \frac{1}{2} \left[1 - \frac{\sqrt{E_b/N_0(E_b/N_0+2)}}{E_b/N_0+1} \right]$$

IV. Simulation and Results

We are using MATLAB to simulate these combining techniques. Here the channel is flat Rayleigh and modulation is BPSK. Here we have taken three parameters SNR, BER and No. of receive antenna for simulation. In figure-1 and 3 we have plot the graph between number of receive antenna and SNR with Maximal Ratio Combining. We analysis that if, we are increasing the number of antenna than SNR is improved. So if SNR will be high then BER will be less. In figure-2 and 4 we have plot the graph between SNR and BER with Equal Gain Combining. Here in this case we see that if SNR is high then BER got reduced.

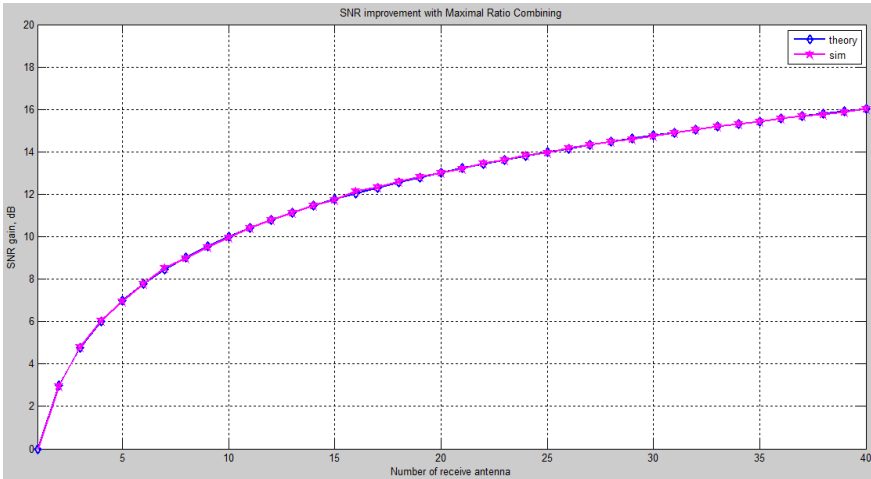


Figure 1: SNR improvement with MRC

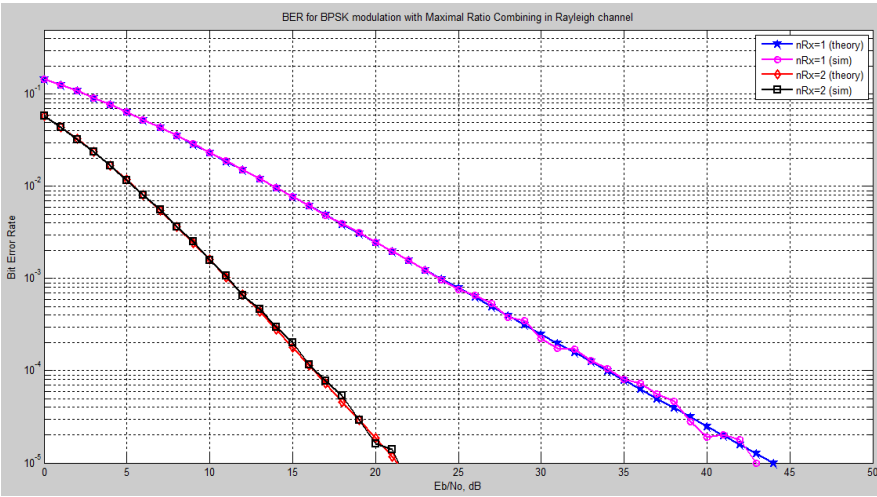


Figure 2: BER plot for BPSK in Rayleigh channel with MRC

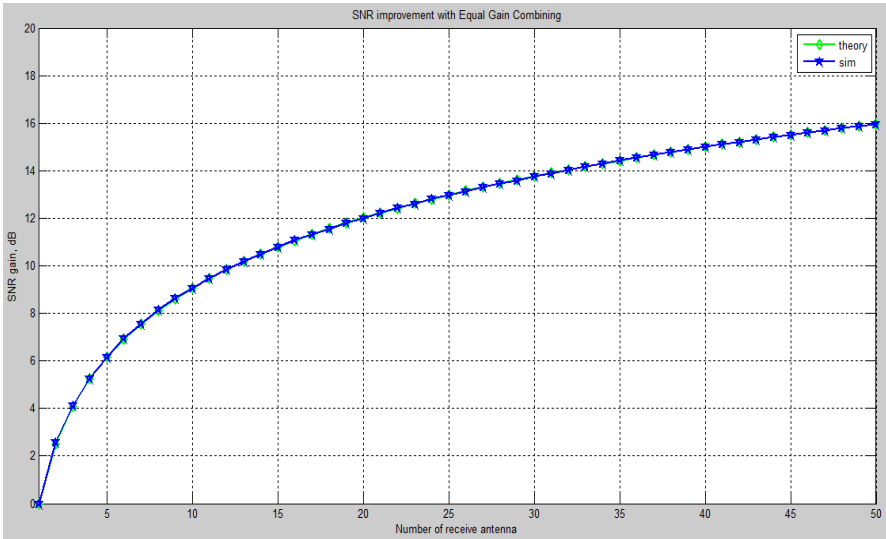


Figure 3: SNR improvement with EGC

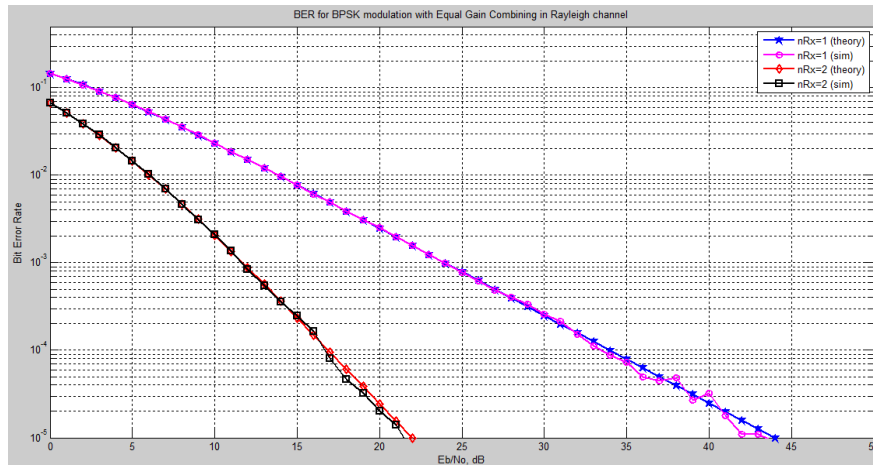


Figure 4: BER plot for BPSK in Rayleigh channel with MRC

V. Conclusions

MIMO systems are high in demand because of their versatility features. They offer high data rates, throughput, different frequency of operability as per demand and many more. In case of EGC $n_{Rx}=1$ gives better theoretical result and $n_{Rx}=2$ simulated result is fluctuated after 16 dB of SNR. In case of MRC $n_{Rx}=1$, theoretical result is better than simulated result. While $n_{Rx}=2$ theoretical result is good but simulated result is fluctuated after 20dB of SNR. so, Maximal Ratio combining techniques performs better in all above cases.

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