



## Performance Analysis of Diversity Combining Techniques in Cooperative Communication System under Fading Environment

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**Abstract**—Diversity is a powerful communication receiver technique that provides wireless link improvement at relatively low cost. A general framework for diversity combining techniques in cooperative wireless communication system is provided in this paper. Performance analysis of different diversity combining techniques i.e. Selection Diversity, Equal Gain Combining and Maximal Ratio Combining is calculated over Rayleigh fading. Monte Carlo simulations resulting in graphs showing the bit error rate v/s signal to noise ratio are provided to verify the results.

**Keywords**—Diversity, fading, Rayleigh channel, Path loss, EGC, MRC, SC.

### I. INTRODUCTION

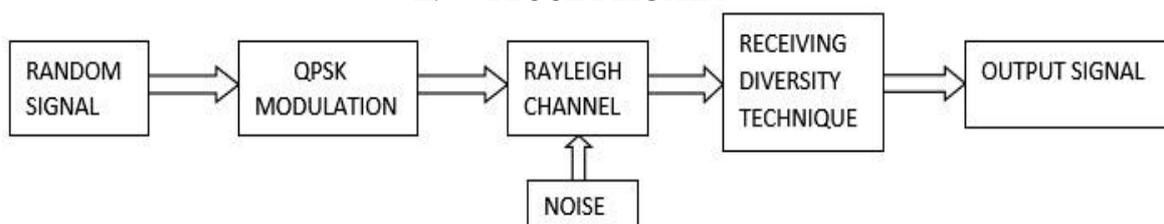
In wireless broadband networks cooperative communication emerged as an upgrade to single hop cellular architecture. Diversity is very powerful technique to provide robustness against channel fading. The use of diversity at receiver needs combining the outputs of statistically independent fading channels in accordance with a criterion that leads to improved receiver performance. It is assumed that the wireless communication channel is described by a frequency-flat, slow-fading Rayleigh channel. It implies that all the frequency components constituting the transmitted signal are characterized by the same random attenuation and phase shift. The fading remains essentially unchanged during the transmission of each symbol. A variety of combining techniques are available for reception of the space or antenna diversity signals. Diversity combining is used to mitigate the effect of fading which consist of receiving redundancy of the same information over two or more fading channels. Diversity combine these multiple replicas at the receiver to increase the overall received SNR. The intuition behind this concept is to exploit the low probability of occurrence of deep fades in all the diversity channels to lower the probability of error and of outage. In this paper, we have taken the following conditions for analysis:

- There are N antennas at the receiver end and one antenna for transmitting the data.
- The channel is flat fading – In simple terms, it means that the multipath channel has only one tap. So, the convolution operation reduces to a simple multiplication.
- The channel experienced by each receiving antenna is randomly varying in time. For any receiving antenna, each transmitted symbol gets multiplied by a randomly varying complex number  $h_i$  which is the channel tap coefficient at point i. As the channel under consideration is a Rayleigh channel, the real and imaginary parts of  $h_i$  are Gaussian distributed having mean 0 and variance 1/2.
- The channel experience by each receiving antenna is independent from the channel experienced by other receiving antennas.
- On each receiving antenna, the noise  $n$  has the Gaussian probability density function with

$$p(n) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(n-\mu)^2}{2\sigma^2}} \text{ with } \mu = 0 \text{ and } \sigma^2 = \frac{N_0}{2}$$

Where  $\mu$  is the mean and  $\sigma^2$  is the variance for Gaussian pdf. There are number of techniques for combining statistically independent faded signal components available at output of the coherent demodulators for transmitted symbol detection by the decision device. The diversity branches are summed up linearly in the linear combining method. Linear combining techniques include selective combining, equal gain and maximal ratio combining.

### II. BLOCK DIAGRAM



### III. SELECTION COMBINING

With selective diversity, one best signal is chosen based on the received signal strengths from the set of diversity branches. The receiver monitors the SNR value of each diversity branch and selects the one with the maximum SNR value for signal detection.

Consider N number of independent fading signals received by multiple receiver antennas. There are N-branch receiver antennas. There are N-branch receivers comprising of coherent demodulators. The output of demodulators is presented to a logic circuit which selects the particular branch receiver output having the largest SNR value of received signal. The antenna chooses the best SNR among the received signals. In the figure 1 s, the receiver selects the signal having maximum SNR. In selection diversity, we will assume that the channel is a flat fading Rayleigh multipath channel and the modulation is QPSK. As each element is an independent sample of the fading process, the element with the greatest SNR is chosen for further processing. In selection combining therefore

$$w_k = \begin{cases} 1 & \gamma_k = \max_n \{\gamma_n\} \\ 0 & \text{otherwise} \end{cases}$$

Where  $w_k$  is weight of signal and  $\gamma_k$  is Signal to Noise Ratio. The overall SNR of the system is given by equation  $\gamma = \max_n \{\gamma_n\}$

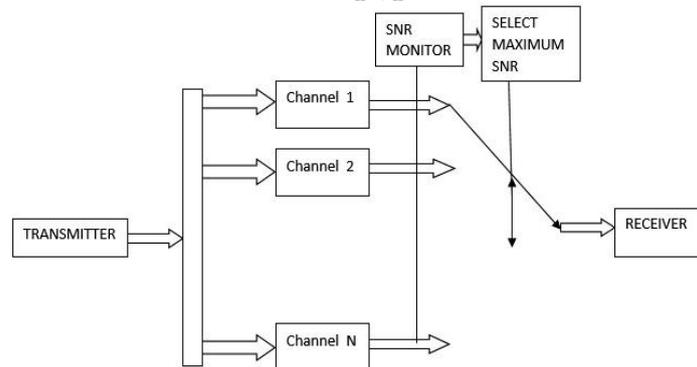


Fig 1. Selection Diversity

### IV. EQUAL GAIN COMBINING

In this type of combining technique, all the signals are weighted equally after coherent demodulation which removes the phase distortion. All the weighting parameters have their phase angle set opposite to those of their respective multipath branches and their magnitudes are set equal to some constant value. The coherently detected signals from all the M branches are simply added and applied to the decision device. As the receiver does not need to estimate the amplitude fading, the receiver design is not complex. Due to hardware limitations or physical separation of the diversity receivers, it is difficult to implement it practically. The performance of an equal-gain combiner is only marginally inferior to a maximal-ratio combiner and superior to a selection diversity combiner. Among the three linear combining techniques, maximal-ratio combining offers the best performance, followed by equal gain combining.

Various techniques are known to combine the signals from multiple diversity branches. In Equal Gain Combining, each signal branch weighted with the same factor, irrespective of the signal amplitude. However, co-phasing of all signal is needed to avoid signal cancellation. Thus, Equal Gain Combining is simpler to implement than Maximum Ratio Combining. The adaptively controller amplifiers / attenuators are not needed. Moreover, no channel amplitude estimation is needed. Maximal Ratio Combining technique requires the weights to vary with the fading signals, the magnitude of which may fluctuate over several 10s of dB. The equal gain combiner sidesteps this problem by setting unit gain at each element. In the equal gain combiner, the weights and SNR are given by equations below:

$$w_n = e^{j\angle h_n}$$

$$\gamma = \frac{[\sum_{n=0}^{N-1} |h_n|]^2}{N\sigma^2}$$

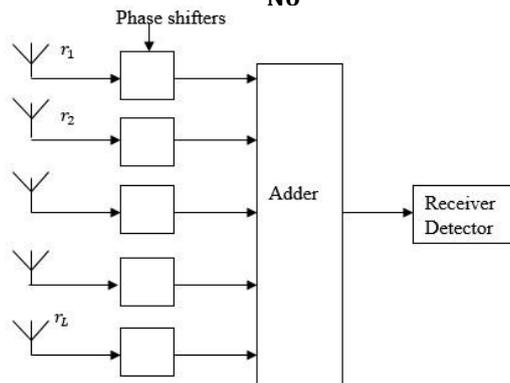


Figure: 2- branch Equal Gain Combining antenna diversity receiver (L = 5).

### V. MAXIMUM RATIO COMBINING

It is considered to be the optimum technique of combining in which the diversity branches are weighted prior to summing them, each weight being proportional to the signal strength of the received branch. This technique assumes that the receiver is able to accurately estimate the amplitude fading and carrier-phase distortion for each diversity channel. The receiver coherently demodulates the received signal from each branch. After removing the phase distortion, the coherently detected signal is then weighted by the corresponding amplitude gain. The weighted received signals from all L branches are then summed together and applied to the decision device.

Branches with strong signal are further amplified, while weak signals are attenuated. Maximal Ratio Combining obtains the weights that maximizes the output SNR, i.e., it is optimal in terms of SNR. The output SNR is the sum of the SNR at each element.

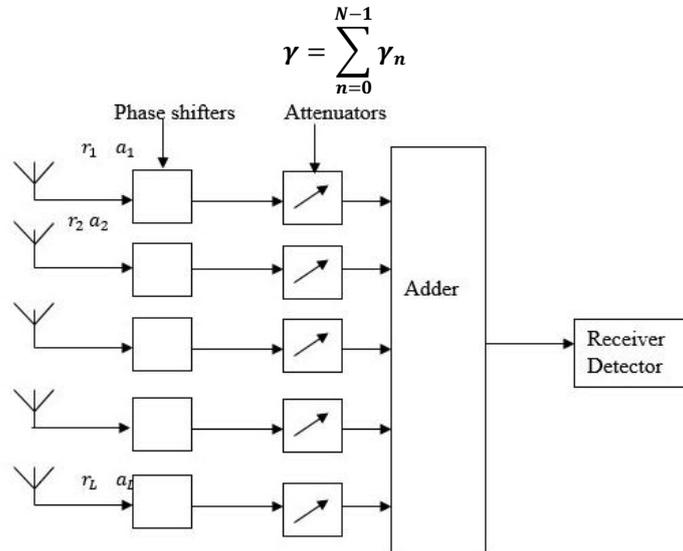


Figure: 3-branch antenna diversity receiver (L = 5). With MRC, the attenuation/amplification factor is proportional to the signal amplitude  $a_i = r_i$  for each channel i.

### VI. RESULTS

In the figures below, plot of the BER with the  $E_b/N_0$  for all the three techniques have been shown. This clearly shows that BER in case of MRC is much better than that of Equal Gain combining and selection diversity. The modulation technique chosen is QPSK i.e. Quadrature Phase Shift Keying to represent the message signal. Results reveal that as the no. of receiver increases BER improves. Some numerical values of BER and SNR are presented in table 2, 3,4 and 5 for analysis purpose. A table showing the methodology used to implement the different combining techniques and their performance analysis is given below

Table 1: system parameters for simulation

Contents	Parameters
Channel type	AWGN, Rayleigh
No. of receiving antennas	1,2,3 and 4
Modulation	QPSK
$E_b/N_0$ (dB)	0 to 15

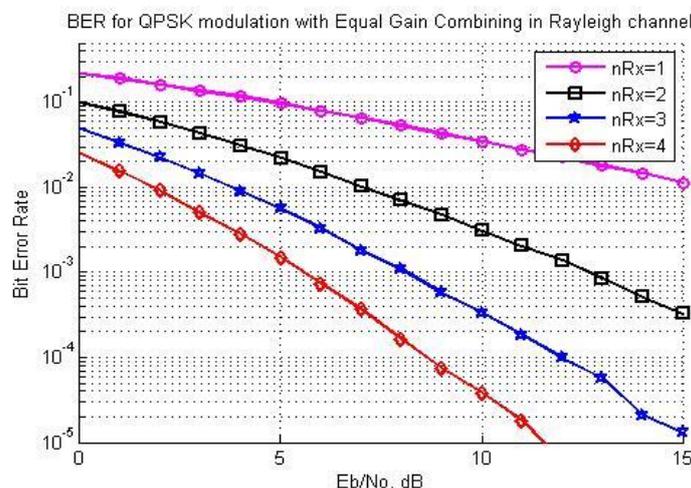


Fig 4: BER v/s SNR for Equal Gain Combining

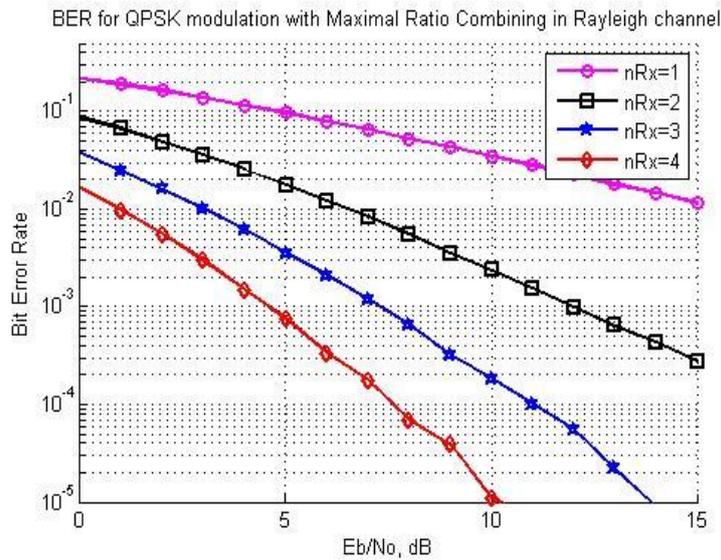


Fig 5: BER v/s SNR for MRC

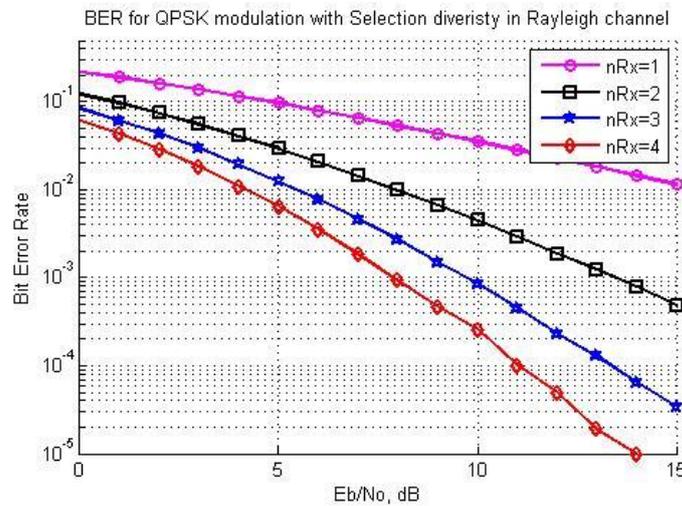


Fig 6: BER v/s SNR for Selection Diversity

Table 2: BER for different combining techniques with 1 antenna

Number of antennas	SNR(in dB)	BER for MRC	BER for SC	BER for EGC
1	0	0.2193	0.2196	0.2193
1	2	0.1625	0.1628	0.1625
1	4	0.1158	0.1159	0.1160
1	6	0.0793	0.0801	0.0791
1	8	0.0532	0.0534	0.0535
1	10	0.0349	0.0349	0.0350

Table3: BER for different combining techniques with 2 antennas

Number of antennas	SNR	BER for MRC	BER for SC	BER for EGC
2	0	0.0870	0.1229	0.1003
2	2	0.0493	0.0741	0.0585
2	4	0.0256	0.0411	0.0312
2	6	0.0121	0.0209	0.0151
2	8	0.0055	0.0099	0.0071
2	10	0.0024	0.0044	0.0030

Table 4: BER for different combining techniques with 3 antennas

Number of antennas	SNR	BER for MRC	BER for SC	BER for EGC
3	0	0.0374	0.0827	0.0496
3	2	0.0161	0.0430	0.0228

3	4	0.0060	0.0197	0.0091
3	6	0.0021	0.0078	0.0032
3	8	0.0006	0.0027	0.0011
3	10	0.0002	0.0008	0.0004

Table 5: BER for different combining techniques with 4 antennas

Number of antennas	SNR	BER for MRC	BER for SC	BER for EGC
4	0	0.0167	0.0619	0.0251
4	2	0.0056	0.0287	0.0091
4	4	0.0015	0.0112	0.0028
4	6	0.0004	0.0035	0.0007
4	8	0.0001	0.0010	0.0002
4	10	0.0000	0.0002	0.0000

## VII. CONCLUSION

As given in the literature, we have different diversity techniques for the receiver diversity. Out of these techniques, we used three techniques selection diversity, maximal ratio combining and equal gain combining for our work. In the beginning  $10^6$  bits are generated. Two random data bits D1 and D2 each of length N are formed from  $10^6$  bits. A QPSK modulated signal is generated using D1 and D2 data bits which is in the form of  $Q1+jQ2$ .

Where  $Q1=2D1-1$  and  $Q2=2D2-1$ . This QPSK modulated signal passes through Rayleigh channel. Noise gets added in the channel and degrades the signal. We observed that with different number of antennas, the bit error rate for maximal ratio combining has lesser value as compare to the equal gain combining and selection diversity. Therefore performance of maximal ratio combining is better than equal gain combining and selection diversity. To verify the results, BER v/s SNR graphs are plotted for each case.

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