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Performance Analysis of Conventional Diversity Combining Schemes in Rayleigh and Rician Fading Channels

Medha Walia[1],Arvind Mahindru [2]
[1]PursuingM.Tech. GNDEC, Ludhiana,INDIA [2]M.Tech. NIT,Jalandhar,INDIA

Abstract: *Diversity is the powerful technique used in wireless communication system to improve the performance over a fading radio channel [1] [2]. Here receiver is provided with multiple copies of the same information signal which are transmitted over two or more real or virtual communication channels. Basic idea of diversity is repetition or redundancy of information. In virtually all the applications, the diversity decisions are made by the receiver and are unknown to the transmitter. This paper deals with the different diversity techniques like Maximal Ratio Combining (MRC), Equal Gain Combining (EGC) and Selection Diversity (SC) and their performance evaluation over Rayleigh and Rician Channel under Binary Phase Shift Keying (BPSK) modulation. The performance of MRC, EGC and SC is analysed in terms of Symbol Error Rate (SER) and Signal to Noise Ratio (SNR) by varying L diversity branches from 1 to 4.*
Keywords: *Diversity, MRC, EGC, SC, BPSK, SER, SNR.*

I. Introduction

System Description
1.1 Channel Model
In wireless system various channels like AWGN, Rayleigh and Rician are used for communication.
1.1.1 Rayleigh Fading
In mobile radio channels, the Rayleigh distribution is commonly used to describe the statistical time varying nature of the received envelope of a flat fading signal, or the envelope of an individual multipath component. It is well known that the envelope of the sum of two quadrature Gaussian noise signals obey a Rayleigh distribution. Rayleigh Fading is most applicable when there is no direct line of sight path exists between TX and RX [7] [6]. The Rayleigh distribution has a Probability Density Function (pdf) given by

$$p(r) = \frac{r}{\sigma^2} exp\left(-\frac{r^2}{2\sigma^2}\right) \qquad 0 \leq r \leq \infty \tag{1}$$

where σ is the rms value of the received voltage signal before envelope and σ^2 is the time average power of the received signal before envelope detection.
1.1.2 Rician Fading
The Rician distribution is observed where, in addition to the multipath components, there exist a direct path between the transmitter and the receiver. Amount of fading will be less than what is observed in Rayleigh fading due to presence of LOS component [8] [9].The envelope in this case has a probability density function is given by

$$f(r) = \frac{r}{\sigma^2} exp\left(-\frac{r^2+k_d^2}{2\sigma^2}\right) I_0\left(\frac{rk_d}{\sigma^2}\right) \qquad r \geq 0 \tag{2}$$

The Rician distribution is often described in terms of the Rician factor *K*, defined as the ratio between the signal power from the direct path and the signal power from the indirect paths. *K* is usually expressed in decibels as [2].

$$K_{(db)} = 10\log_{10}\left(\frac{a_0^2}{2\sigma^2}\right) \tag{3}$$

The quantity *K* is a measure of the strength of the LOS component, and when $K \to 0,$ we have Rayleigh fading. As *K* increases, the fading in the channel declines [4] [5].

II. Diversity Combining Techniques

2.1 Selection Diversity
From the number of antennas the branch that receives the signal with the largest signal-to-noise ratio is selected and connected to the demodulator. Larger the number of available branches, the higher the probability of having a larger signal-to-noise ratio (SNR) at the output.
The combined output is given by:

$$y(t) = Ae^{j\theta_i}s(t) + z(t)$$

$$A = max\{A_0, A_1, \ldots\ldots A_{M-1}\}$$

The received SNR is

$$\Gamma = \frac{A^2 E_b}{N_0} = max\{\Gamma_0, \Gamma_1, \ldots \ldots \ldots, \Gamma_{M-1}\}$$

The CDF of Γ is

$$P_\Gamma(\gamma) = \prod_{i=0}^{M-1} P_{\Gamma i}(\gamma)$$

The symbol error rate probability is given below [3].

$$P_e = \frac{1}{2}\sum_{k=0}^{N}(-1)^k \binom{N}{K}\left(1 + \frac{k}{(E_b/N_0)}\right)^{-1/2} \quad (4)$$

2.2 Maximal Ratio Combining

Both branches are weighted by their respective instantaneous voltage-to-noise ratios. The branches are then co-phased prior to summing in order to insure that all branches are added in phase for maximum diversity gain. The summed signals are then used as the received signal and connected to the demodulator.

The advantage is that improvements can be achieved with this configuration even when both branches are completely correlated. The disadvantage of maximal ratio is that it is complicated and requires accurate estimates of the instantaneous signal level and average noise power to achieve optimum performance with this combining scheme [3].

The combined output is given by:

$$y(t) = \sum_{i=0}^{M-1} w_i r_i(t)$$

The received SNR is

$$\Gamma = \frac{\sum_{i=0}^{M-1} E_b A_i^2}{N_0} = \sum_{i=0}^{M-1} \Gamma_i$$

The symbol error rate probability is given below [3] [4].

$$P_e = \int_0^\infty \frac{1}{2} erfc(\sqrt{\gamma}) p(\gamma) d\gamma$$

$$= \int_0^\infty \frac{1}{2} erfc(\Gamma) \frac{1}{(N-1)!(E_b/N_0)^N} \gamma^{N-1} e^{\frac{-\gamma}{(E_b/N_0)}} d\gamma \quad (5)$$

2.3 Equal Gain Combining

It is same as that of maximal ratio combining except that of equal gains. In this scheme, the gains of the branches are all set to a single value and are not changed. Both the branch signals are multiplied by the same branch gain (G), and the resulting signals are co-planed and summed. The resultant output signal is connected to the demodulator [3].

The combined output is given by:

$$y(t) = \sum_{i=1}^{M} e^{-j\theta_i} r_i(t)$$

The received SNR is

$$\Gamma = \left(\sum_{i=0}^{M-1} A_i\right)^2 \frac{E_b}{M N_0}$$

III. Simulation Results And Discussions

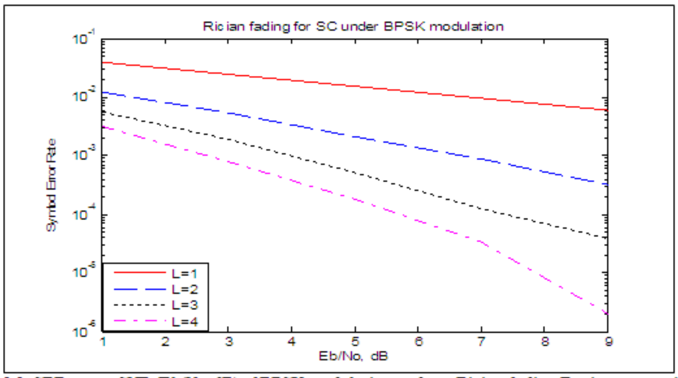
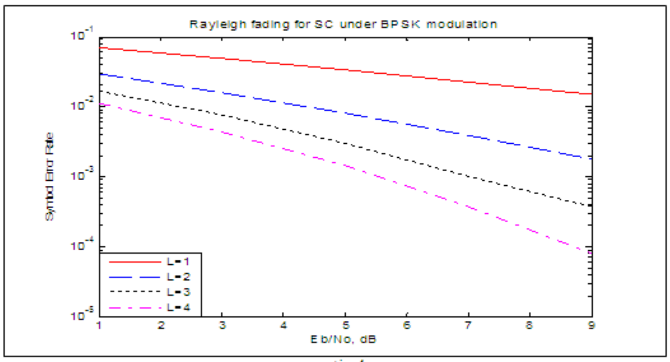


Fig 1.1: SER versus SNR (Eb/No, dB) of BPSK modulation under a Rician fading Environment with SC diversity channels varying from 1 to 4.

Depicts the SER variations with respect to the vary signal to noise ratio for wireless communication operating with signal encoding BPSK modulation under Rician fading environment for SC diversity. The simulation parameter for the plot are varying the value of L diversity branches results from the graph point out the drop in SER with SNR performance gains are achieved by using increase in number of branches. For SNR 5 dB we calculate 8.95E-02, 1.56E-02, 6.75E-03 and 4.33E-03 using L1, L2, L3 and L4 diversity branches



respectively.

Fig.1.2: SER versus SNR (Eb/No, dB) of BPSK modulation under a Rayleigh fading Environment with SC diversity channels varying from 1 to 4.

Depicts the SER variations with respect to the vary signal to noise ratio for wireless communication operating with signal encoding BPSK modulation under Rayleigh fading environment for SC diversity. The simulation parameter for the plot are varying the value of L diversity branches results from the graph point out the drop in SER with SNR performance gains are achieved by using increase in number of branches. For SNR 5 dB we calculate 8.97E-02, 7.65E-03, 3.25E-03and 9.88E-04 using L1, L2, L3 and L4 diversity branches respectively

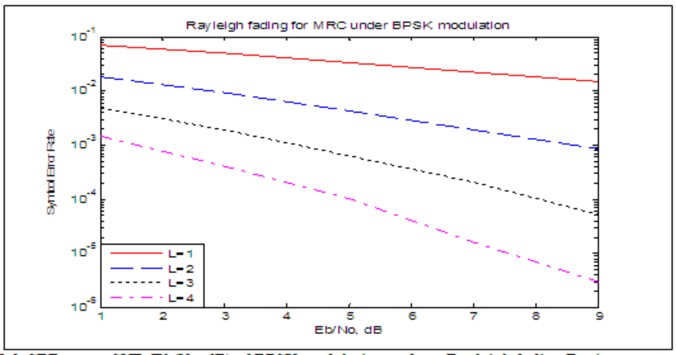


Fig.1.3: SER versus SNR (Eb/No, dB) of BPSK modulation under a Rayleigh fading Environment with MRC diversity channels varying from 1 to 4.

Depicts the SER variations with respect to the vary signal to noise ratio for wireless communication operating with signal encoding BPSK modulation under Rayleigh fading environment for MRC diversity. The simulation parameter for the plot are varying the value of L diversity branches results from the graph point out the drop in SER with SNR performance gains are achieved by using increase in number of branches. For SNR 5 dB we calculate is 8.00E-02, 9.83E-03, 9.10E -04 and 1.05E-05 using one, two, three and four diversity branches respectively.

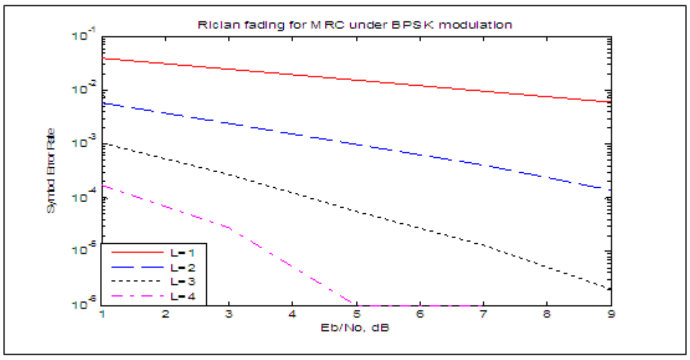


Fig.1.4: SER versus SNR (Eb/No, dB) of BPSK modulation under a Rician fading Environment with MRC diversity channels varying from 1 to 4.

Depicts the SER variations with respect to the vary signal to noise ratio for wireless communication operating with signal encoding BPSK modulation under Rician fading environment for MRC diversity. The simulation parameter for the plot are varying the value of L diversity branches results from the graph point out the drop in SER with SNR performance gains are achieved by using increase in number of branches. Reduction in SER is observed by employing MRC diversity in Rician faded channel. At SNR of 5dB, SER is 7.00E-02, 1.83E-04, 1.08E-05 and 9.05E-06 using one, two, three and four branches respectively.

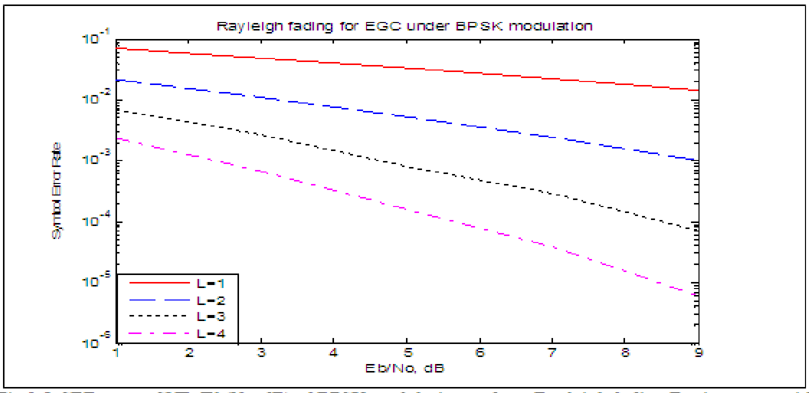


Fig.1.5: SER versus SNR (Eb/No, dB) of BPSK modulation under a Rayleigh fading Environment with EGC diversity channels varying from 1 to 4.

Depicts the SER variations with respect to the vary signal to noise ratio for wireless communication operating with signal encoding BPSK modulation under Rayleigh fading environment for EGC diversity. The simulation parameter for the plot are varying the value of L diversity branches results from the graph point out the drop in SER with SNR performance gains are achieved by using increase in number of branches. For SNR 5 dB we calculate is 8.90E-02, 9.99E-03, 9.89E -04 and 1.95E-05 using one, two, three and four diversity branches respectively.

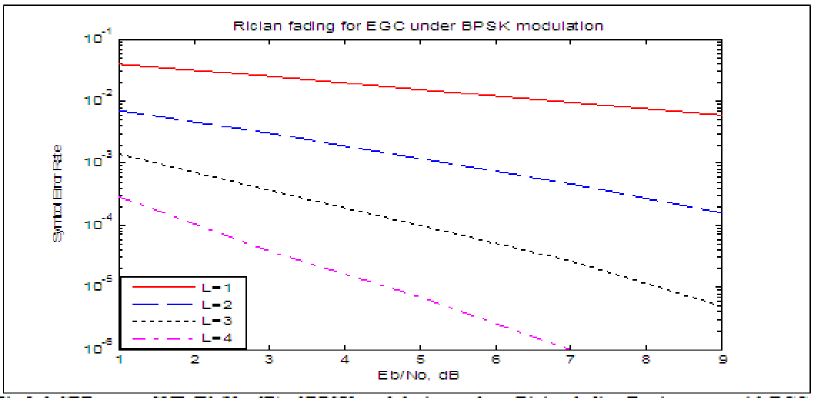


Fig.1.6: SER versus SNR (Eb/No, dB) of BPSK modulation under a Rician fading Environment with EGC diversity channels varying from 1 to 4.

Depicts the SER variations with respect to the vary signal to noise ratio for wireless communication operating with signal encoding BPSK modulation under Rician fading environment for MRC diversity. The simulation parameter for the plot are varying the value of L diversity branches results from the graph point out the drop in SER with SNR performance gains are achieved by using increase in number of branches. Reduction in SER is observed by employing MRC diversity in Rician faded channel. At SNR of 5dB, SER is 7.89E-02, 1.99E-04, 1.98E-05 and 9.95E-06 using one, two, three and four branches respectively.

IV. The Overall Summary Of The Result Are Listed In Table 1.1, 1.2.

Table 1.1 Shows the results for different diversity branches L under MRC, SC and EGC in Rayleigh channel under BPSK modulation.

Result Summary for Rayleigh Channel.			
Sr. No.	**SC**	**ECG**	**MRC**
L1	8.95E-02	8.90E-02	8.00E-02
L2	1.56E-02	9.99E-03	9.83E-03
L3	6.75E-03	9.89E -04	9.10E -04
L4	4.33E-03	1.95E-05	1.05E-05

Table 1.2 Shows the results for different diversity branches L under MRC, SC and EGC in Rician channel under BPSK modulation.

Result Summary for Rician Channel.			
Sr. No.	**SC**	**ECG**	**MRC**
L1	8.97E-02	7.89E-02	7.00E-02
L2	7.65E-03	1.99E-04	1.83E-04
L3	3.25E-03	1.98E-05	1.08E-05
L4	9.88E-04	9.95E-06	9.05E-06

V. Conclusion

For the receiver, we used three diversity techniques; selection combining, maximal ratio combining and equal gain combining are used over BPSK modulation under Rayleigh and Rician channel for checking the performance. We calculated the error rate at 5db is 0.9 % high in case of Equal gain combining and 0.95% in case of selection combining than that of maximal ratio combining under Rayleigh fading and in case of Rician fading error rate is 0.89% is more in case of equal gain combining and 1.97% is more in case of selection combining than that of maximal ratio combining. So we conclude that the performance of the maximal ratio combining is better as compare to selection combining and equal gain combining.

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