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Performance Analysis of Rayleigh Fading Channel using the Hybrid Technique-MRC/EGC

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ABSTRACT: Fading is the most important issue for Wireless Communication .To remove adverse effect of fading in wireless channels a well-known scheme used is diversity combining technique. Transmitted signal is received through multiple numbers of independent fading paths in diversity receiver. These signals are combined to improve the signal-to-noise ratio (SNR) of the received signal. A new hybrid diversity scheme MRC/EGC for Rayleigh fading channel in which M number of branches carry out maximal ratio combining and L number of branches carry out equal gain combining is proposed in this paper. The effectiveness of this hybrid diversity scheme is evaluated by analysing the performance of the system in terms of Outage Probability and Average Bit Error Rate (ABER).

KEYWORDS: ABER, Equal gain combining, Hybrid MRC/EGC, Maximal ratio combining, Outage probability

I. INTRODUCTION

Fading is due to multipath propagation. Fading may lead to attenuating the signal power seen at the receiver. Diversity combining technique is used to overcome the effect of fading. The transmitted signals are received through multiple numbers of independent fading paths in receiver and are combined in such a way that the fading of the resultant signal is reduced. The diversity combining techniques used are selection combining (SC), maximal ratio combining (MRC) and equal gain combining (EGC). In selection combining, the signal with highest signal to noise ratio (SNR) is selected among all the signals in all the branches. In maximal ratio combining, the signals in all the branches are combined by multiplying with different weights. In equal gain combining, the signals in all the branches are combined by multiplying with equal weights. Maximal ratio combining is the most efficient combining technique in terms of performance improvement. By considering various aspects like low power consumption and higher diversity gain, hybrid combining techniques have been receiving great interest in recent days.

II. RELATED WORK

In [1] it was found that Rayleigh fading model is reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. Among selection combining, maximal ratio combining and equal gain combining used for Rayleigh fading channel, it is found that maximal ratio combining has best performance [2].

Hybrid diversity combining techniques have received considerable recognition considering aspects like low power consumption and higher diversity gain. The performance of Hybrid (SC/MRC) over Nakagami-m fading channel was evaluated in [3] and it was found that when fading increases the hybrid system has good performance. The comparative analysis of combination of selection combining and maximal ratio combining (SC/MRC) with the combination of selection combining and equal gain combining (SC/EGC) has been carried out [4]; the SC/MRC system outperforms the SC/EGC system. In [5] a dual hybrid diversity scheme over Rayleigh fading channel in which among the connected branches, the two branches with SNR greater than specified threshold SNR is switched and given to dual branch MRC system. The hybrid MRC/SC system for Rayleigh fading channel has been proposed in [6].Here the hybrid diversity scheme considered is having maximal ratio combining at the first stage and selection combining at the second. The M branches are combined using maximal ratio combining; out of L diversity branches the branch with the highest SNR is selected. The hybrid diversity scheme MRC/EGC over Rayleigh fading channel has not been found yet

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in all works considered. In this paper a new hybrid diversity scheme MRC/EGC over Rayleigh fading channel has been proposed. Here M number of branches carries out maximal ratio combining at the first stage and L number of branches carries out equal gain combining at the second stage.

The organization of this paper is as follows. The hybrid MRC/EGC system model has been discussed in Section III. In Section IV PDF and CDF of hybrid MRC/EGC combiner output SNR have been derived. The metrics used for performance of MRC/EGC Receiver are presented in the Section V. Section VI provides the simulation results. The conclusion and future work have been provided in the section VII.

III. HYBRID MRC/EGC SYSTEM MODEL

The hybrid MRC/SC system is depicted in Fig.1. The transmitted signals undergo Rayleigh fading after passing through Rayleigh fading channel. The signals get degraded. The M number of branches carries out maximal ratio combining at the first stage where signals in all the branches are combined by multiplying with different weights. The L number of branches carries out equal gain combining at the second stage where signals in all the branches are combined by multiplying with equal weights.

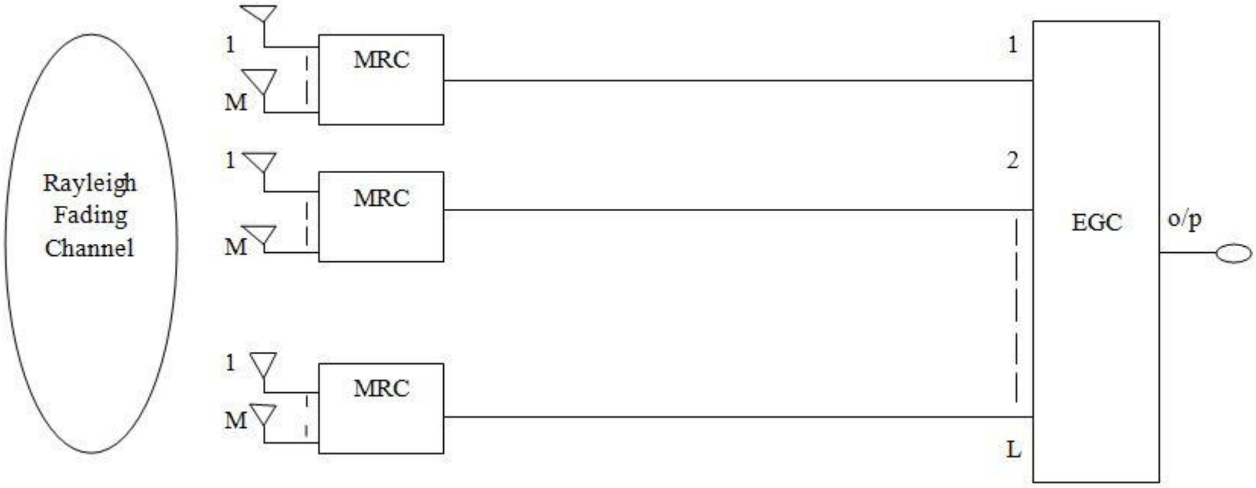

Fig. 1. Hybrid MRC/EGC System [10]

IV. PDF AND CDF OF HYBRID MEC/EGC COMBINER OUTPUT SNR

Considering Rayleigh fading channel, MRC having M branches the output SNR is given by eq. (1) [7]

$$f_{MRC}(\gamma) = \frac{\gamma^{M-1} e^{-\gamma/\bar{\gamma}}}{\bar{\gamma}^{M}\Gamma(M)} \quad \text{eq. (1)}$$

Where γ= instantaneous SNR

$\bar{\gamma}$= average SNR

Γ (M) = Gamma function

The inputs of EGC are MRC outputs. In EGC, the signals are equally weighted by their amplitudes. In other words, the branch weights are all set to unity [8]. By multiplying MRC outputs each with equal weights and then carrying L fold convolution of PDF of output SNR of MRC as in [4], PDF of hybrid MRC/EGC system can be obtained using eq. (2)

$$f_{MRC,EGC}(\gamma) = f_{1MRC}(\gamma) \otimes f_{2MRC}(\gamma) \otimes f_{3MRC} \cdots\cdots\cdots f_{LMRC} \quad \text{eq. (2)}$$

The CDF of hybrid MRC/EGC receiver can be obtained as in [6] using the eq. (3)

$$F_{MRC,EGC}(\gamma_0) = \int_0^{\gamma_0} f_{MRC,EGC}(\gamma)\, d\gamma \quad \text{eq. (3)}$$

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V. PERFORMANCE OF MRC/EGC RECEIVER

The metrics used for performance analysis are outage probability, Average BER using binary coherent and non-coherent modulation schemes.

A. Outage probability:

Outage probability is defined as the probability that output SNR falls below a certain specified threshold, γ_{th}. By referring [9] the outage probability can be obtained using eq. (4)

$$P_{out_{MRC,EGC}}(\gamma_{th}) = \int_0^{\gamma_{th}} f_{MRC,EGC}(\gamma)\, d\gamma \qquad \text{eq. (4)}$$

B. Average bit error rate:

An expression for ABER can be obtained by averaging the conditional bit error rate (BER), for the modulation scheme used, over the PDF of EGC output SNR [6]. Mathematically, it can be given as in [6] using eq. (5)

$$P_e(\bar{\gamma}) = \int_0^{\infty} p_e(\varepsilon/\gamma) f_{MRC,EGC}(\gamma)\, d\gamma \qquad \text{eq. (5)}$$

Where $p_e(\varepsilon/\gamma)$ = conditional bit error rate

$f_{MRC.EGC}(\gamma)$ = PDF of the output SNR of the hybrid MRC/EGC receiver

ABER expressions are obtained for both coherent and non-coherent modulation schemes.

1. Binary Coherent Modulation:

The expression for the conditional BER of coherent modulation [6] can be given as $p_{e,ch}(\varepsilon/\gamma)$ = Q $(\sqrt{2a\gamma})$, where a=0.5 for coherent frequency shift-keying (CFSK) modulation. Putting $p_{e,ch}(\varepsilon/\gamma)$ and $f_{MRC,EGC}(\gamma)$ from eq. (2) together into eq. (5) the ABER of hybrid MRC/EGC system can be obtained.

2. Binary Non-coherent Modulation:

The expression for the conditional BER of non-coherent modulation [6] can be given as $p_{e,nch}(\varepsilon/\gamma)$ = $\frac{1}{2}$exp $(a\gamma)$, where a=0.5 for non-coherent frequency shift-keying (NCFSK) modulation. Putting $p_{e,nch}(\varepsilon/\gamma)$ and $f_{MRC,EGC}$ from eq. (2) together into eq. (5) the ABER of hybrid MRC/EGC system can be obtained.

VI. SIMULATION RESULTS

The Fig.2 shows the outage probability for Dual MRC/EGC receiver. The threshold value is set at 3 dB. The outage performance of Dual MRC/EGC receiver improves with the increase in the number of EGC branches, L. The outage performance of Dual MRC/ EGC receiver improves due to the fact that as the number of diversity branches increases, the probabilities of all the fading paths going to deep fade decreases [11].

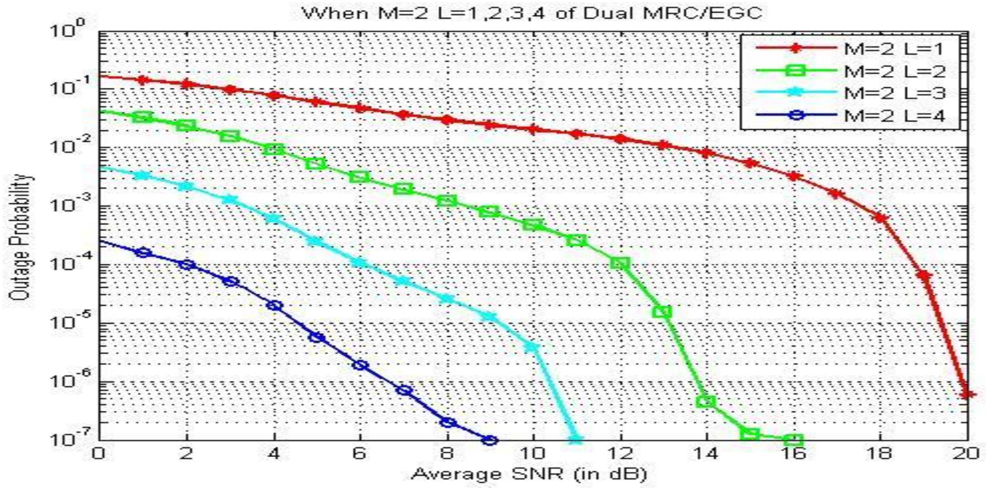

Fig. 2. Outage Probability of Dual MRC/ EGC receiver

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The Fig.3 shows the outage probability for MRC/Dual EGC receiver. The threshold value is set at 3 dB. The outage performance improves with the increase in the number of MRC branches, M. The outage performance of MRC/Dual EGC receiver improves due to the fact that as the number of diversity branches increases, the probabilities of all the fading paths going to deep fade decreases [11].

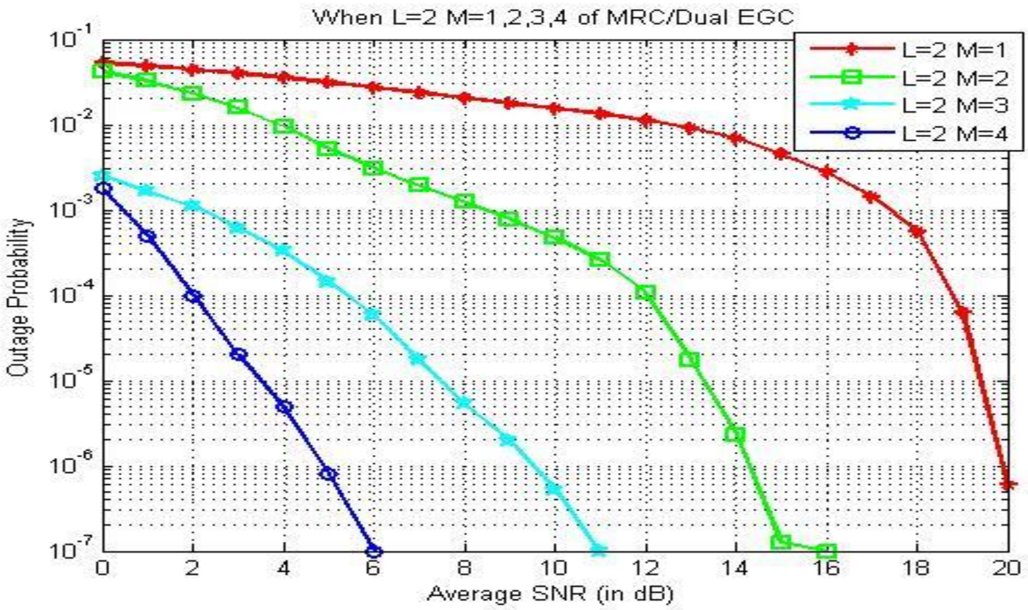

Fig.3. Outage Probability of MRC/Dual EGC receiver

In Fig.4, ABER of coherent modulation for Hybrid MRC/EGC system has been plotted against average SNR. The performance improves with increase in number of diversity branches. Here the SNR required for having an acceptable level of performance (Average BER of 10^{-4}) decreases with increase in the number of MRC diversity branches [6].

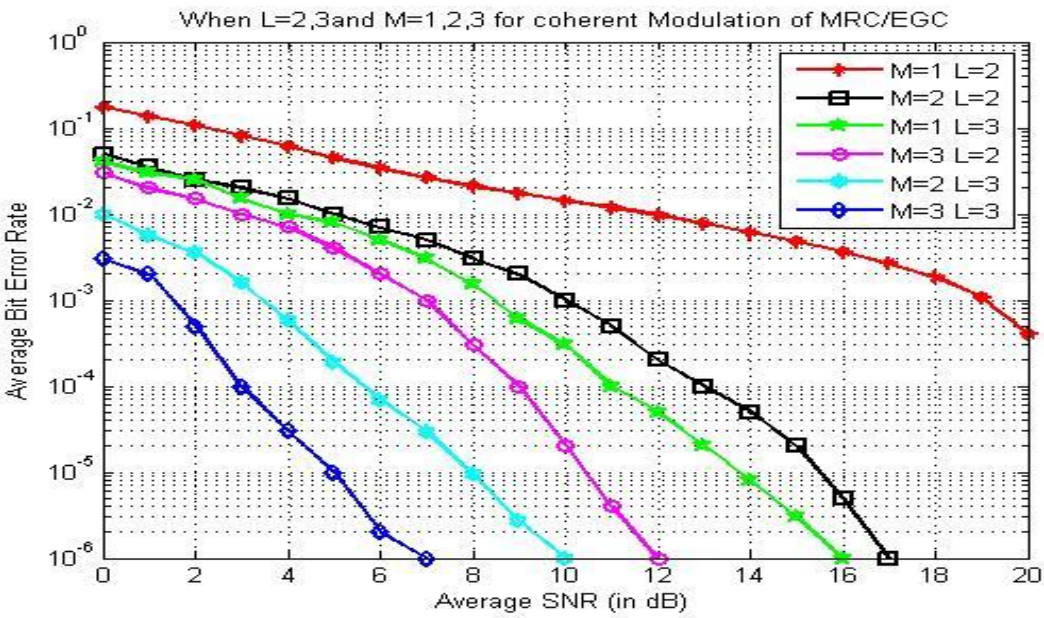

Fig.4. ABER of Coherent Modulation

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In Table 1 the SNR required for maintaining the ABER equal to 10^{-4} for coherent modulation for Hybrid MRC/EGC system is given. The SNR requirement to maintain ABER equal to 10^{-4} reduces with increase in the order of diversity of Hybrid system [6].

TABLE 1. SNR required for maintaining ABER of coherent modulation equal to 10^{-4}

Hybrid Technique	M=1L=2	M=2L=2	M=1L=3	M=3L=2	M=2L=3	M=3L=3
MRC/EGC SNR(in dB)	>20	12.8	10.8	9	5.7	3

In Fig.5, ABER of non-coherent modulation for Hybrid MRC/EGC system has been plotted against average SNR. The performance improves with increase in number of diversity branches. Here the SNR required for having an acceptable level of performance (Average BER of 10^{-4}) decreases with increase in the number of EGC diversity branches.

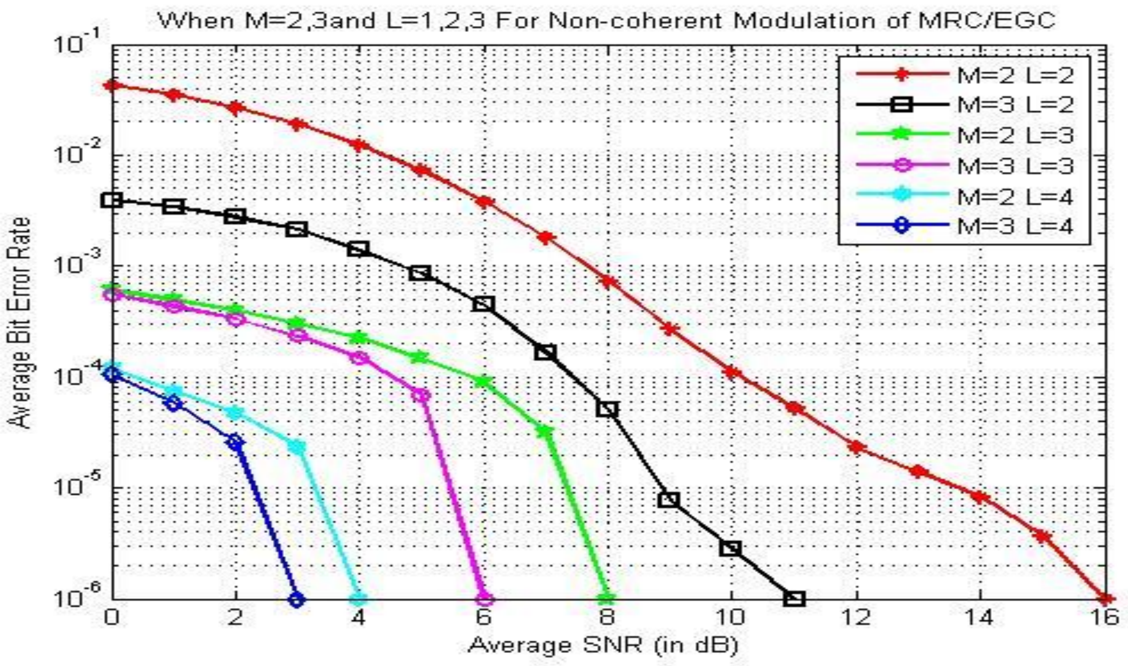

Fig.5. ABER of Non-coherent Modulation

In Table 2 the SNR required for maintaining the ABER equal to 10^{-4} for non-coherent modulation for Hybrid MRC/EGC system is given. The SNR requirement to maintain ABER equal to 10^{-4} reduces with increase in the order of diversity of Hybrid system [6].

TABLE 2. SNR required for maintain ABER of Non-coherent modulation equal to 10^{-4}

Hybrid Technique	M=2L=2	M=3L=2	M=2L=3	M=3L=3	M=2 L=4	M=3L=4
MRC/EGC SNR(in dB)	10.2	7.2	5.8	4.4	0.4	0.1

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VII. CONCLUSION AND FUTURE WORK

The performance of newly proposed hybrid MRC/EGC system is analysed in this paper. The PDF of hybrid receiver is obtained by carrying L fold convolution using MATLAB. Using the PDF and conditional bit error rate; the Average Bit Error Rate is calculated for coherent and non-coherent modulation schemes. The CDF of hybrid receiver is obtained by integrating the PDF of hybrid receiver. The outage probability with 3 dB threshold is calculated. The hybrid MRC/EGC system has good performance for both metrics Outage Probability and Average Bit Error Rate. In regard to the Hybrid MRC/EGC system outage probability performance has been presented for dual diversity systems in this paper. In future the outage probability performance can be further determined for increase in number of diversity branches and the performance of Hybrid MRC/EGC system can be evaluated for other fading channels.

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BIOGRAPHY

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