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Hybrid Diversity Combining Techniques for Fading Channels

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ABSTRACT

Diversity combining is the effective to way to mitigate the effects of multipath fading. The independent signal paths have low probability of experiencing deep fades simultaneously is the fact exploited by diversity combining. In diversity combining the replicas of same information signal is combined together to obtain high SNR. The Hybrid Diversity combining techniques has been carried out to reduce the effects of fading owing to its good performance and low implementation complexity. Different Hybrid Diversity combining techniques are summarized in this paper.
Keywords: Diversity Combining, Equal Gain Combining, Maximal Ratio Combining, Selection Combining, SNR (Signal to Noise Ratio).

I. INTRODUCTION

The fading is due to multipath propagation. The transmitted signal will traverse through different paths due to presence of reflectors in the environment surrounding transmitter and receiver. The superposition of multiple copies of transmitted signal each traversing a different path will be obtained at receiver. The signal power drops significantly and it will have high BER, the channel is said to be in a fade.

Diversity combining is the powerful technique used to overcome multipath fading. It is used in receiver diversity, which has single transmitter antenna and multiple receiver antennas. The diversity combining techniques used are Selection Combining (SC), Maximal Ratio Combining (MRC), Equal Gain Combining (EGC) and Switch and Stay Combining (SSC). In Selection Combining, among the signals in all the branches the signal in the branch with highest SNR is selected. In Switch and Stay Combining, the signal in the branch is outputted whose SNR is above a given threshold SNR and the combiner switches to another branch if the SNR on the current branch falls below the threshold SNR. In Maximal Ratio Combining, the signals in all the branches are weighted by different weights and then the signals in all the branches are summed up. Here the branches with high SNR will be weighted more than the branches with low SNR. In Equal Gain Combining, it combines the signals in all the branches with equal weighting. The Co-phasing is carried out in Maximal Ratio Combining and Equal Gain Combining. The branch signals would not add up coherently in the combiner without co-phasing, thus the resulting signal could still exhibit fading due to constructive and destructive addition of the signals in all the branches. The Hybrid diversity combining techniques has received considerable recognition due to the ability to balance the effects of deep fades on wireless channels by gaining good compromise between the receiver performance and implementation complexity.

The different Hybrid diversity combining techniques i.e., Hybrid SEC/MRC, Hybrid SC/MRC and Hybrid MRC/SC are surveyed in this paper. The Hybrid Diversity Combining System Model is discussed in section II. The various Hybrid Diversity Combining Systems are explained in section III. In the section IV, the newly proposed Hybrid MRC/EGC system is explained. This paper is concluded by section V.

II. METHODS AND MATERIAL

A. Hybrid Diversity Combining System Model

In Fig.1 the Hybrid Diversity Combining System model for fading channel is depicted. There are M numbers of branches at each combiner's input. Among Selection

Combining (SC), Equal gain Combining (EGC), Maximal Ratio Combining (MRC) and Switch and Stay Combining (SSC), any one of diversity combining techniques will be carried out. The L numbers of branches obtained as output of first combiner are again combined using any one of above mentioned diversity combining techniques. For example: Consider Hybrid SC/EGC system. Here at first combiner the Selection Combining is carried out. Among signals in all the M number of branches, the signal with high SNR is selected. The outputs of first combining stage are given as input to second combining stage, where Equal Gain Combining is carried out. The signals in all the L number of branches are co-phased and then weighted by equal weights. The signals in all the L number of branches are summed up. Thus the Hybrid Diversity Combining is carried out.

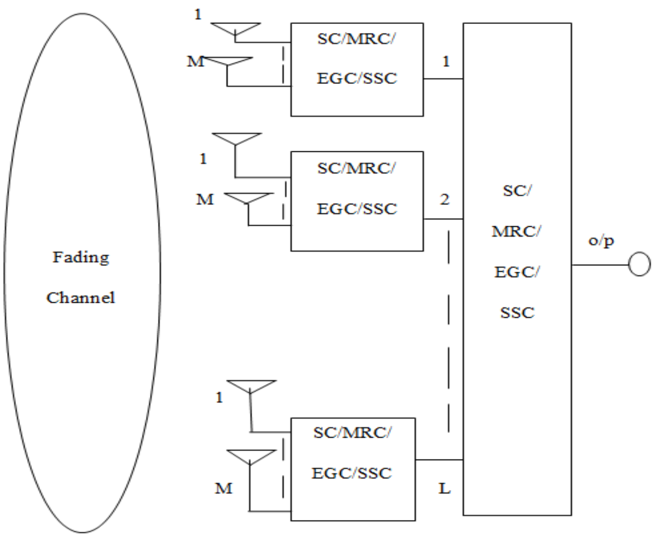

Figure 1: Hybrid Diversity Combining System model for fading channel

B. Hybrid Diversity Combining Systems

Hoyong Lee et.al has proposed a Hybrid SEC/MRC system as illustrated in Fig.2. The signals in all the M number of branches are Switched diversity combined. The signals in all the L number of branches are Maximal ratio combined to obtain the final output for Rayleigh fading channel. At the first combining stage, the two branches with SNR greater than threshold SNR chosen. The outputs of first combining stage are given as inputs to second combining stage. In second combining stage the dual Maximal ratio combining is carried out. The signals in two branches are co-phased and weighted by different weights. The signals are then summed up. The performance of this system is evaluated in terms of bit error rate (BER).

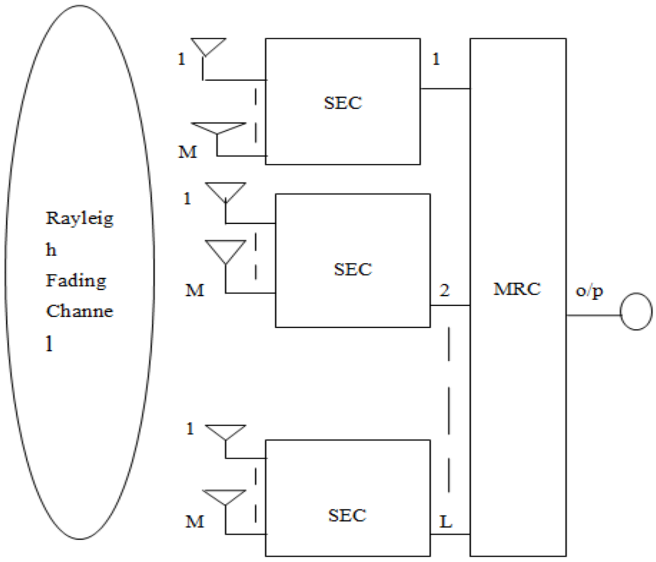

Figure 2: Hybrid SEC-MRC System

The SNR required for the Hybrid SEC/MRC System to keep BER equal to 10^{-4} is given in the Table I.

Table I: SNR required for the Hybrid SEC/MRC System to keep BER equal to 10^{-4} [2]

Hybrid SEC/MRC branches	SNR in db
3/2	12
4/2	10
5/2	9
6/2	8

From the above table it can be understood that for Hybrid SEC/MRC System performance improves with increase in the L number of branches.

Mohammed-Slim Alouini et.al has evaluated the performance of Hybrid SC/MRC System. This Hybrid SC/MRC System is depicted in Fig.3. For the Nakagami-m Fading Channels, the signals in all the M number of branches are Selection Combined. Then to obtain the final output, the signals in all the L number of branches are Maximal Ratio Combined. In the first combining stage out of the signals in all the M number of branches, the signal with high SNR is selected. These signals obtained from first combining stage are given as inputs to second combining stage. Here the signals in all the L number of branches are co-phased and weighted by different weights. Then the signals are summed up. The performance of system is evaluated in terms of BER.

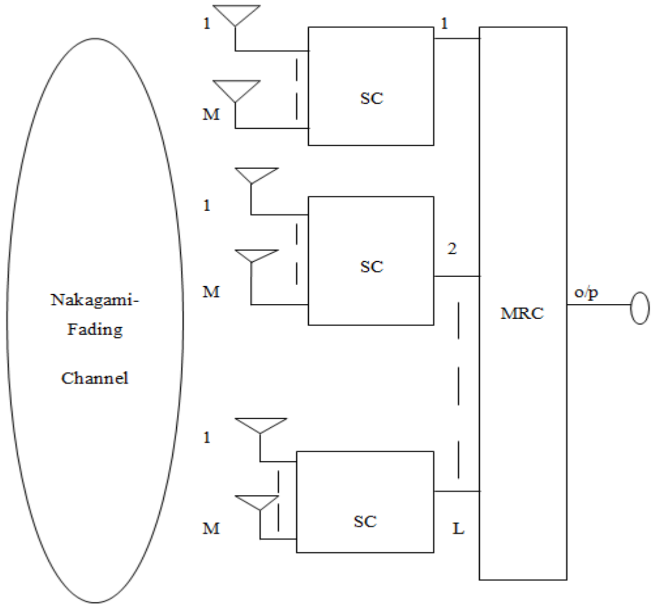

Figure 3: Hybrid SC/MRC System

The SNR required for Hybrid SC/MRC System to keep BER equal to 10^{-4} is given in the Table II. It can be noted that for constant value of M=2, the performance improves with increase in L number of branches for fading parameter m.

Table II: SNR required for Hybrid SC/MRC System to keep BER equal to 10^{-4} [3]

	SC/MRC-2/3	**SC/MRC-2/4**
SNR in db for m=1/2	20	14.2
SNR in db for m=1	11.2	8.2
SNR in db for m=2	7.8	6.2
SNR in db for m=4	7	5.8

A Dinamani et.al has proposed a new Hybrid MRC/SC System depicted in Fig.4. For Rayleigh Fading channel, the signals in all the M number of branches are Maximal Ratio Combined. Then the signals in all the L number of branches are Selection Combined to obtain final output. In first combining stage, the signals in all the M number of branches are co-phased and weighted by different weights. Then the signals are summed up. These signals obtained from first combining stage are given as inputs to second combining stage. Among the signals in L number of branches, the signal with high SNR is selected. The performance of this system is evaluated in terms of Average Bit Error Rate (ABER). ABER can be obtained by averaging the conditional bit error rate for modulation scheme used, over the PDF of the SC output SNR [4].

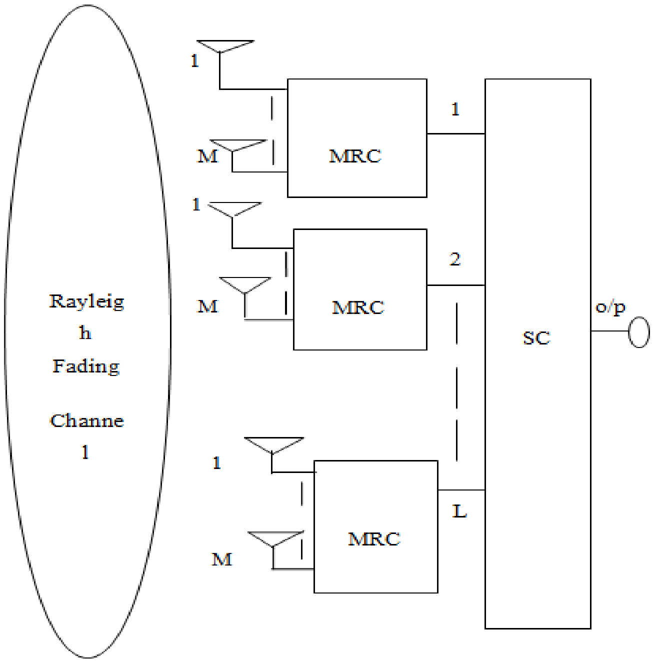

Figure 4: Hybrid MRC/SC System [4]

The SNR required for Hybrid MRC/SC System to keep ABER equal to 10^{-4} is given in Table III. The performance improves with increase in M number of branches and L number of branches.

Table III: SNR required for Hybrid MRC/SC System to keep ABER equal to 10^{-4} [4]

Hybrid MRC/SC	**SNR in db**
1/2	20
2/2	12
3/2	9
1/3	11.8
2/3	6.2
3/3	4.4

By summarizing all the above mentioned Hybrid Diversity Combining Systems, the SNR required for Hybrid Diversity Combining System-2/3 to keep ABER equal to 10^{-4} is given in Table IV.

Table IV: SNR required for Hybrid Diversity Combining Systems to keep ABER equal to 10^{-4} [2-4]

Hybrid Diversity Combining Systems	SNR in db
Hybrid SEC/MRC	12
Hybrid SC/MRC for m=1/2	20
Hybrid SC/MRC for m=1	11.2
Hybrid SC/MRC for m=2	7.8
Hybrid SC/MRC for m=4	7
Hybrid MRC/SC	6.2

C. Hybrid MRC/EGC System

In all Hybrid Diversity Combining Systems considered, all the available branches are not used. Thus there will be SNR penalty. To overcome this new Hybrid MRC/EGC system is proposed which is depicted in Fig.5. The signals in all the M number of branches are Maximal Ratio Combined. Then the signals in all the N number of branches are Equal Gain Combined. The Rayleigh fading channel is considered. In first combining stage, the signals in all the M number of branches are co-phased and weighted by different weights. Then signals are summed up. These signals obtained from first combining stage are given as inputs to second combining stage. The signals in all L number of branches are weighted by equal weights and then summed up.

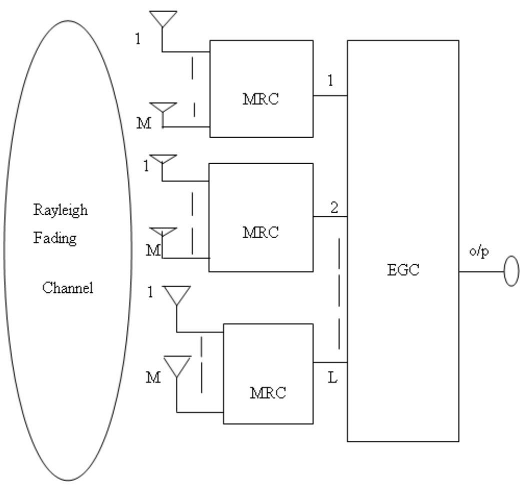

Figure 5: Hybrid MRC/EGC System

III. CONCLUSION

Various Hybrid Diversity Combining systems are summarized in this paper. All the available branches are not used in these systems. Thus a new Hybrid MRC/EGC system is proposed. In this newly proposed system all the available branches are used as Maximal Ratio Combining and Equal Gain Combining are used. Thus the system performance can be improved.

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