Performance of EGC Diversity Technique with Multiple Antennas on Limited Space

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1. Abstract

In this paper, Equal Gain Combining (EGC) technique is considered because it provides performance comparable to the optimal Maximal ratio combining (MRC) technique but with greater simplicity. Although, performance evaluation of EGC diversity is a much more difficult task in comparison with other classical techniques but it has been presented several times in literature. However, the problem concerning multiple antennas on limited space has never been presented. This is because the correlation between multiple antennas can be neglected if the antenna spacing is large enough. In practice, the dimension of user terminal is fixed with the trend of small in size. Therefore, it is impossible to avoid the effect of antenna correlation due to limited space. In this paper, the performance investigation of EGC diversity technique is presented by considering the problem of multiple antennas on limited space. The simulation results reveal the significant differences observed if neglecting the antenna correlation.

2. Introduction

Space diversity with multiple antennas is a well known technique to improve performance in fading channel for wireless systems. This technique includes maximal ratio combining (MRC), equal gain combining (EGC), and selection diversity [1]. The EGC receiver is generally known to have a performance close to a MRC receiver while at the same time being less complex from the implementation point of view. Hence, the performance analysis of this receiver is of interest.

In literature on EGC performance, there is surprisingly limited works in comparing with popular diversity combining methods. Most of them evaluate the EGC performance with the assumption of neglecting the antenna correlation. However, this assumption cannot be accepted in practice because the size of user terminal is so small that multiple antennas on this limited space are unavoidably correlated. The literature on correlated diversity branches is quite a few and all of them studied on dual antenna diversity. In [2], the problem of correlated fading for a two branch selection combining scheme was considered. Amongst the initial works of gain combining schemes, Pierce and Stein [3] studied the performance of MRC and EGC in a correlated Rayleigh fading channel and showed that an increase in correlation had adverse effects on the system performance. In [4-6], practical implementations of spatial diversity at the mobile handsets are usually restricted to second order diversity with closely spaced antennas that result in correlation between the diversity branches. As explained in [7], the correlation between the branch envelopes in spatial diversity systems is a function of the spacing between the antennas. The general trend is that correlation decreases with increasing antenna spacing. The authors in [8] consider a procedure for generating two equal power Rayleigh-fading envelopes with any desired cross-correlation coefficient. These works in literature have been useful in analyze of the correlated signals to ground the basis formula in this paper. However, the problem of multiple antennas on limited space has never been addressed before. In this paper, the EGC performance is investigated by changing the number of antennas on a limited space. Both uncorrelated and correlated signals for EGC diversity with multiple branches in presence of Rayleigh fading and AWGN fading are considered.

3. EGC diversity and antenna correlation

3.1 EGC model

EGC techniques are known to combine the signals from multiple diversity branches. The signal output of the combiner is the direct sum of the received signals, which co-phase the signals on each branch and then combines them with equal weighting g_k in each branch of receivers. The signal plus noise in each branch is then multiplied by a voltage gain factor g_k and then added in a linear combiner which is subsequently demodulated through receiver. Thus the predetection diversity signal output equal gain system can be written as

$$\mathbf{r}(t) = \sum_{k=1}^{M} g_k \{r_k(t) + n_k(t)\} \qquad , k = 1,2,..., M \tag{1}$$

Where $g_k = e^{-j\phi_k}$

The EGC receiver performance is superior to other diversity performance and only marginally inferior compared to MRC. EGC is often used in practice because of its reduced complexity relative to the optimum MRC scheme.

3.2 Antenna correlation on limited space

Figure 1 shows the multiple antennas on limited space. The linear array with *M* antenna elements is configured on a fixed length *D*.

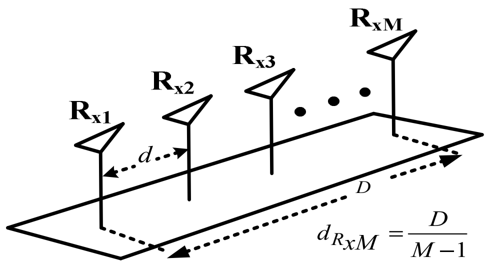

Figure 1: Configuration of multiple antennas

The relation between power correlation coefficient ρ and antenna separation d derived by Clarke [9] can be expressed by

$$\rho = J_0^2\left(\frac{2\pi d}{\lambda}\right) \tag{2}$$

Where $J_0(.)$ is the zero order Bessel function of first kind, and λ is the carrier wavelength. This relationship is used to determine the correlation properties of the signal on each branch which is expressed as

$$p_n(\gamma) - \rho = 0 \tag{3}$$

Where $p_n(\gamma)$ is the least squares n degree polynomial given in [8]. The parameter γ has been useful in analyze of the correlation signals. In [9], the authors found the special case of the correlation matrix given by

$$\mathbf{L} = \begin{bmatrix} \sigma_x & 0 \\ \frac{1}{\sqrt{2}}\gamma\sigma_x(1+j) & \sigma_x\sqrt{1-\gamma^2} \end{bmatrix} \tag{4}$$

Where σ_x is an absolute desired signal power. Now, the correlated signals between two branches can be easily generated. Figure 2 shows the uncorrelated and correlated signals in a Rayleigh fading channel. For the correlated signals, the power correlation coefficient is 0.9. Figure 2(a) and 2(b) present the uncorrelated and correlated signals for two branches while Figure 2(c) and 2(d) present for four branches. It is clearly noticed the difference between correlated and uncorrelated signals.

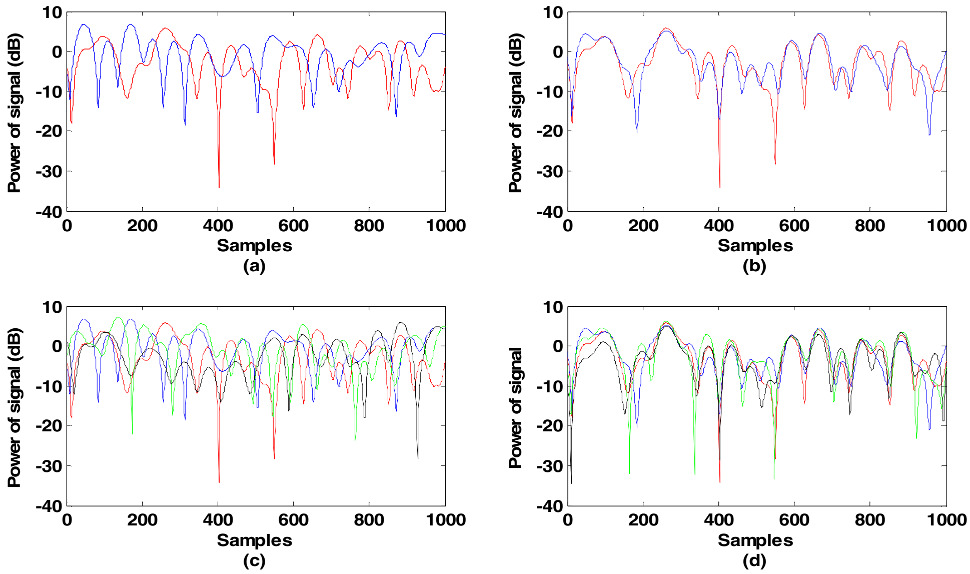

Figure 2: The uncorrelated and correlated signals in a Rayleigh fading channel, (a) two uncorrelated signals, (b) two correlated signals, (c) four uncorrelated signals and (d) four correlated signals.

For the problem on limited space, the total length *D* is a fixed distance and the correlation coefficient is changed by number of antennas with an equal spacing.

4. Simulation Results

For sake of saving space in the paper, only output SNR performance of EGC diversity technique is presented here. This is because BER performance is simply predicted as a direct proportional function of SNR. The comparison between probability density function of the uncorrelated and correlated signals is provided. For all simulations, the limited distance *D* is set to 30 cm as the average length of notebook.

Figure 3 shows the output SNR of EGC diversity technique as a function of number of antennas in Rayleigh and AWGN fading channels. The results show that the increase of output SNR depends on the number of antennas. The significant differences between uncorrelated and correlated signals are noticed in AWGN fading but this finding is not pronounced for Rayleigh fading. This is because under a rich multipath the fluctuation of signals due to fading plays a major role on EGC performance whether antenna correlation is existed or not.

Figure 4 shows the probability density function of output SNR for uncorrelated and correlated signals in Rayleigh and AWGN fading channels. It can be noticed that the variance of signal is smaller when applying more antennas. In addition, the probability density functions of uncorrelated and correlated signals are more diverse if the number of antennas increase.

From all simulation results, the effect of correlated signals due to limited space is seriously significant in AWGN channel but not Rayleigh channel. However, the real propagation channel is in between AWGN and Rayleigh. Thus, these results are helpful for any researchers using EGC diversity technique to design the available margin due to antenna correlations in practice.

5. Conclusion

In this paper, the performance investigation of EGC diversity technique is presented by considering the problem of multiple antennas on limited space. The simulation results reveal the significant differences observed if neglecting or including the antenna correlations. In future work, the measurement of EGC diversity technique will be undertaken to verify the simulation results in this paper.

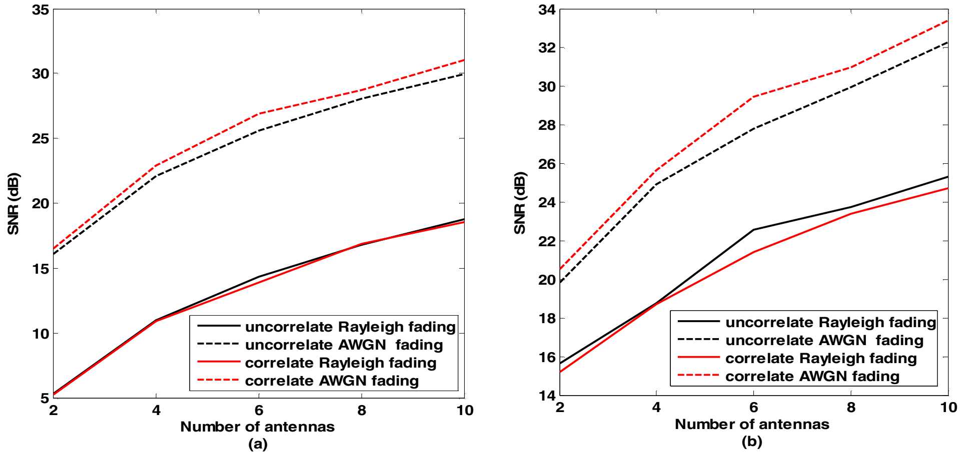

Figure 3: Output SNR of EGC diversity technique as a function of number of antennas in Rayleigh and AWGN fading, (a) Average SNR, (b) Peak SNR

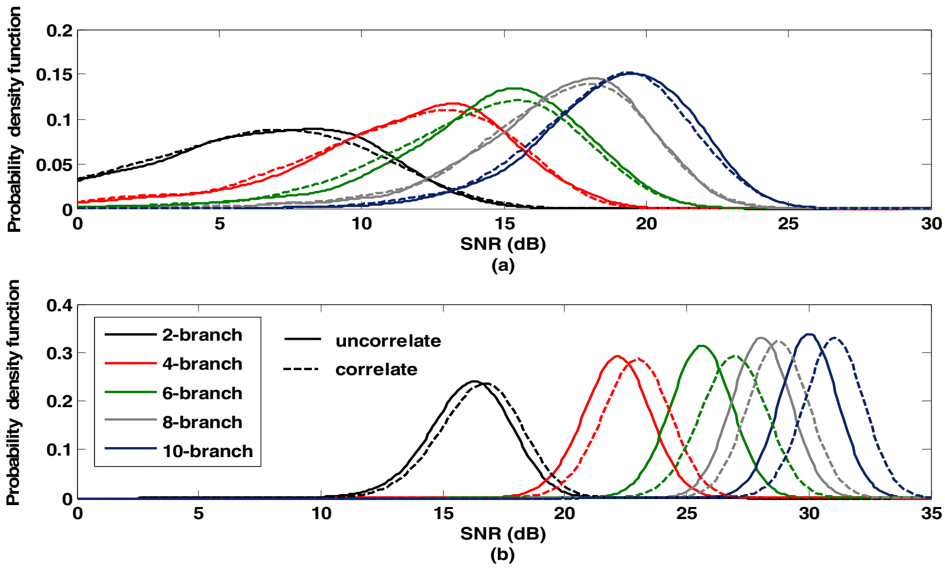

Figure 4: Probability density function of uncorrelated and correlated signals in fading channels (a)Rayleigh fading (b)AWGN fading

References

[1] M. Yacoub, *Fundations of Mobile Radio Engineering*. CRC Press, Boco Raton, 1993.

[2] D. G. Brennan. *Linear Diversity Combining Techniques*. In Proc. IRE, pp. 1075-1102, 1959.

[3] J. N. Pierce and S. Stien. *Multiple Diversity with Non-Independent Fading*. In Proc. IRE, pp. 89-104, 1960.

[4] M. Lefevre, M. A. Jensen, and M. D. Rice, “Indoor measurement of handset dual antenna diversity performance,” in *VTC* ’97, pp. 1763-1767, 1989.

[5] M. G. Douglas, M. Okoniewski, and M. A. Stuchly, “A planar diversity antenna for handheld PCS devices,” IEEE Trans. On Vehicular Technology, Vol. 47, pp. 747-754, 1998.

[6] C. N. Zhang, W. K. Lam, and C. C. Ling, “A low-complexity antenna diversity receiver suitable for TDMA handset implementation”, in *VTC’97,* pp. 1753-1757, 1997.

[7] C. B. Dietrich, Jr., K. Dietze, J. R. Nealy, and W. L.Stutzman, “Spatial, Polarization, and Pattern Diversity for Wireless Handheld Terminals,” IEEE Transactions on Antennas and Propagation, Vol. 49, (9), pp. 1271-1281, 2001.

[8] Richard B. Ertel and Jeffrey H. Reed, “Generation of Two Equal Power Correlated Rayleigh Fading Envelopes,” IEEE COMMUNICATIONS LETTERS*,* vol.2, no. 10, pp. 276-278, 1998.

[9] R. H. Clarke, “A Statistical Theory of Mobile-Radio Reception”, The Bell System Technical Journal, Vol. 47, No. 6, pp. 957-1000, 1968.