EE 413 Wireless Communications Project: A Simulation Study

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1 Problem Definition

Start with a Rayleigh fading simulator to model each branch, then implement diversity selection diversity and maximal ratio combining. Obtain their outage performance for different number of branches, M = 1, 2, 3, 4, 10, 20.

2 Method

Diversity is one of most important method to mitigate effects of multipath fading and shadowing. In our showcase, the multipath fading under rayleigh as microdiversity is investigated by Selection (SC) and Maximal Ratio Combining (MRC). We assume that we have independent fading paths in a wireless system with appropriate space diversity and antenna is set accordingly. I will model our independent paths under rayleigh fading within the system seen the Figure-I and then coherently combining them so that the effects of fading are mitigated.

As we know from the Goldsmith's textbook, SNR distribution under rayleigh fading is exponential distribution, however, this situation will changes in diversity cases. The distribution of the combiner output SNR can not be rayleigh within the diversity concepts.

My naive approach for simulation is the following[1]:

• First of all, I simulated M=1,2,3,4,10,20 separately; and for each experiment it generates Mth number of independent rayleigh faded path by using 'comm.RayleighChannel'[2] which is built-in function of MATLAB.
• For each path, it generates complex signal with white gaussian noise and then put it into the Rayleigh Channel, after that calculate SNR of output signal in dB unit.

[1] MATLAB codes are available in Appendix
[2] https://www.mathworks.com/help/comm/ref/comm.rayleighchannel-system-object.html

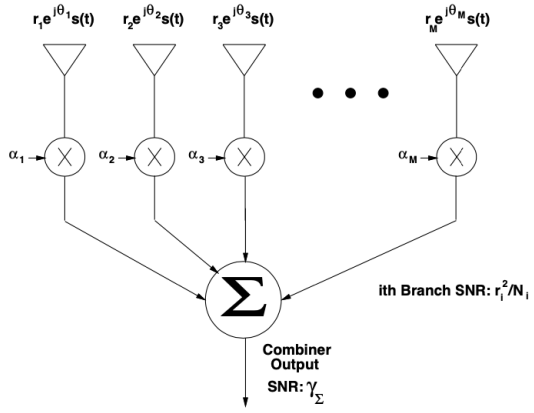

Figure 1: Overall model of the system: Linear Combiner, M-branch Diversity, Co-phasing.

• In SC, I just focused on the branch which has maximum SNR among all independent paths. That's why I took just maximum outcome among these SNRs after or before co-phasing.
• In MRC, I took the weighted sum of all branches unlike SC after co-phasing.
• After all these process, I check combined SNR is whether above or below the target SNR (γ_0) and update P_{out} accordingly.
• Just repeated all these process for every target SNR in t times and take them average.

At the end of the day, I used basic Monte Carlo sense to create this simulation environment. In a more rigorous way, let say we select m as diversity order, γ_0 is the target SNR and t as number of trials then the methodology for determining P_{out} as follows:

$$P^{M=m}_{out,\gamma_0,SC}=\frac{1}{t}\Sigma\mathbb{1}_{\gamma_{SC}<\gamma_0}=\mu^n_{m,SC} \qquad P^{M=m}_{out,\gamma_0,MRC}=\frac{1}{t}\Sigma\mathbb{1}_{\gamma_{MRC}<\gamma_0}=\mu^n_{m,MRC}$$

then P_{out} matrix for SC, when n is number of target SNRs and m is number of experiment, which is 6:

$$P_{out,SC,m\times n}=\begin{bmatrix} \mu_1^1 & \mu_1^2 & \mu_1^3 & . & . & \mu_1^n \\ \mu_2^1 & \mu_2^2 & \mu_2^3 & . & . & \mu_2^n \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ \mu_m^1 & \mu_m^2 & \mu_m^3 & . & . & \mu_m^n \end{bmatrix}$$

Actually, we have two matrix (SC and MRC) such that for the set of M = 1, 2, 3, 4, 10, 20. I obtained expected value for each case of scenario and then

convert them into the matrix seen above, so that the plotting in Figure-3 and Figure-7 can be sketched easily.

3 Results

Selection Combining Case:

As expected for SC, the average SNR gain increases with M, but not linearly as seen the figures of SC in Appendix clearly. However, again, I can say that the P_{out} is going down as M increases. One of our ultimate goal for this study is to obtain the figure which overlaps with the Figure 7.2 in Andrea Goldsmith's textbook and as we expected, the graphs generated by MATLAB are overlapping with that. In the Appendix, there can be seen some perturbance in plots due to number of trials, which is 500 for my experiment. There are also some regression of plots with degree-7 to see behaviour of curves more clearly. However, we can expect more smooth curves by increasing the number of trials in this Monte Carlo approach.

Maximal Ratio Combining Case:

Unlike SC, the average combiner SNR increases linearly with M. This is because we sum up all the SNR of path for combined SNR. As a remarkable point, MRC works better than SC especially for highest M, diversity order, and SNR values. It achieves full diversity order. Thus performance of MRC case is higher than SC. In high diversity order and SNRs, MRC can starts below 1 directly which is important to reduce P_{out} quickly. Additionally, the table for $\bar{P}_{out}$, average values, are available below to facilitate comparison.

M	$\bar{P}_{out}$ for SC	$\bar{P}_{out}$ for MRC
1	0.8544	0.8643
2	0.8220	0.8192
3	0.7885	0.7641
4	0.7575	0.7071
10	0.6580	0.4332
20	0.5577	0.1733

4 References

• Goldsmith, A. (2005). Wireless communications. Cambridge university press.

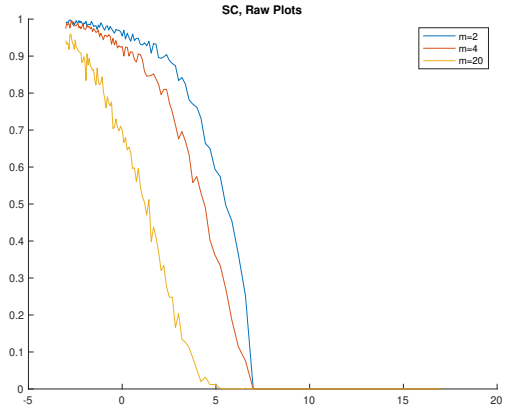

Figure 2: SC, y-axis: P_{out} and x-axis: $10log\frac{\gamma}{\gamma_0}$

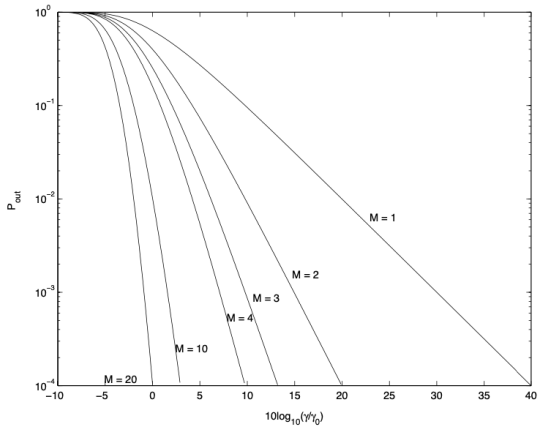

Figure 3: SC, The Original Plotting from textbook

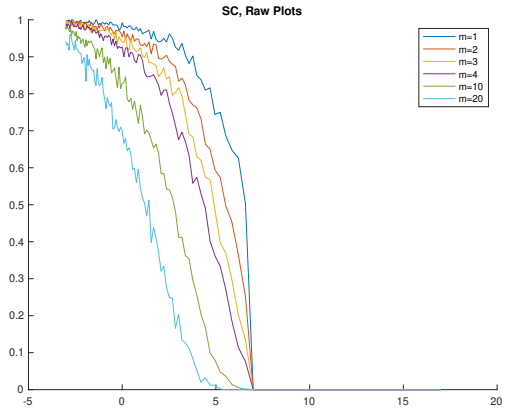

Figure 4: SC with all M trials

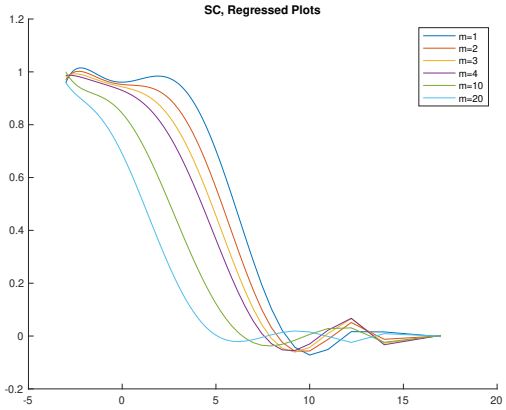

Figure 5: SC Regressed Version

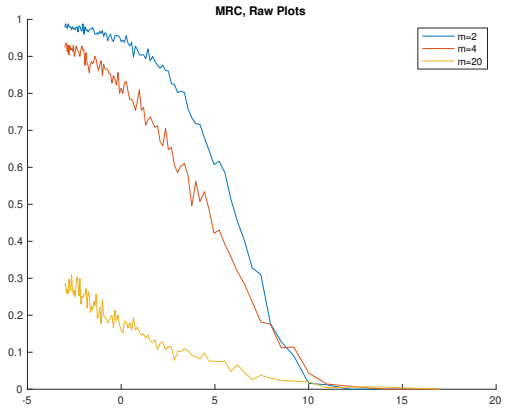

Figure 6: MRC, y-axis: P_{out} and x-axis: $10log\frac{\gamma}{\gamma_0}$

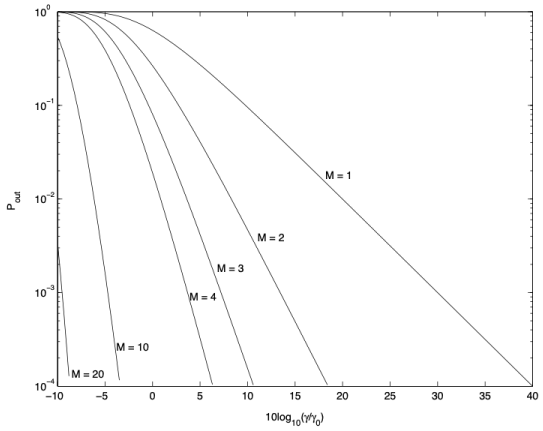

Figure 7: MRC, The Original Plotting from textbook

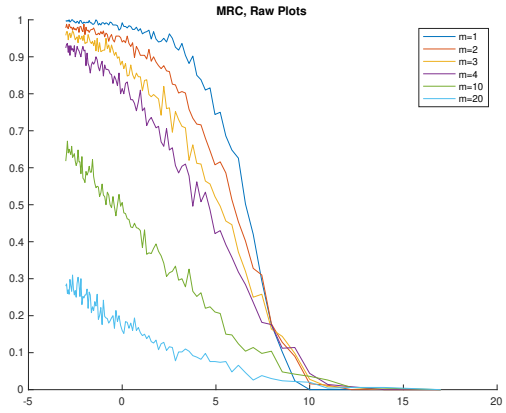

Figure 8: MRC with all M trials

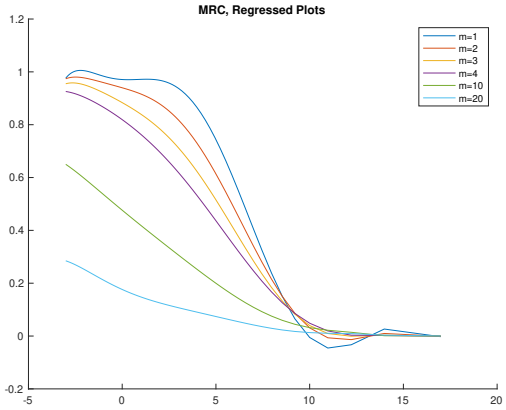

Figure 9: MRC Regressed Version