Comparison of Two Branch Transmit Diversity and MRRC Schemes

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***Abstract*—The objective was to implement and compare classical Maximal-Ratio Receive Combining (MMRC) schemes with the new transmit diversity scheme from Alamouti's paper. The schemes that were used were MMRC schemes with 1 transmitter and 1,2,and 4 receivers and new transmit diversity schemes with 2 transmitters and 1 and 2 receivers. These schemes were tested by implementing a Rayleigh fading channel. The bit error rates of the each schemes were computed with signal to noise ratios (SNR) from 0 to 50.**

***Index Terms*—MMRC, Transmit Diversity, Rayleigh**

I. Rayleigh Fading

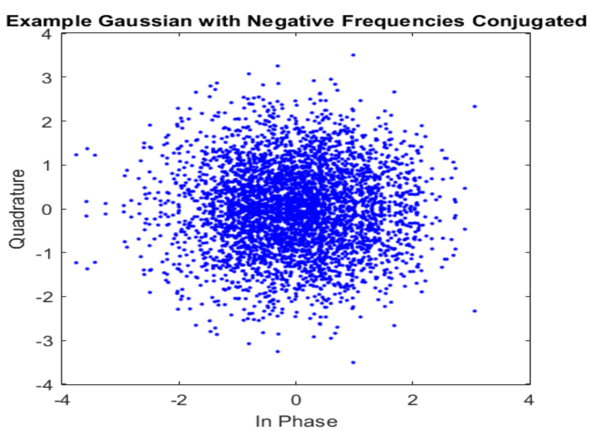

Fig. 1. Example Gaussian Distribution

In order to make a Rayleigh Fading channel, a Gaussian distribution from -fm to fm had to be made first. The resulting Gaussian can be seen in Figure 1This distribution was made by using the 'randn' function on MATLAB, and although this was shifted positively by a factor of fm due to MATLAB's indexes, care was taken in the following parts in order to keep this from being an issue. Once this Gaussian distribution was made, a Doppler spectrum was made by using the formula from Figure 2.

Because the Doppler spectrum is being centered at baseband, fc is equal to 0. Fm is the same as what was used to make the Gaussian distribution. The result can be seen in Figure 3.

$$S_{E_z}(f) = \frac{1.5}{\pi f_m \sqrt{1-\left(\frac{f-f_c}{f_m}\right)^2}}$$

Fig. 2. Doppler Spectrum formula

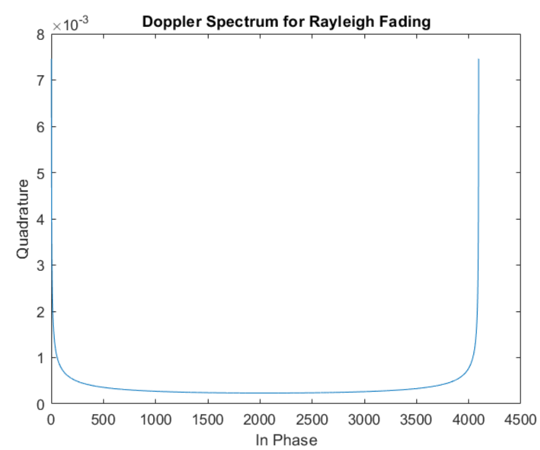

Fig. 3. Doppler Spectrum

With the Gaussian distribution and the Doppler spectrum complete, they were then multiplied together and an inverse fast Fourier transform of the product was taken. The process of making a Gaussian distribution and a Doppler spectrum before taking an inverse fast Fourier transform was then repeated again, so that the two outputs can be squared,summed and square rooted.The output of this is finally the Rayleigh fading channel, and 4 channels were created this way in order to make enough channels for the maximum cases present of 1 transmitter and 4 receivers and 2 transmitters with 2 receivers. An example Rayleigh Channel can be seen in Figure 4

II. MRRC

For each scheme, the transmitted signal was a BPSK modulated binary signal. An example of this can be seen in Figure 5. MRRC consists of using 1 transmitter with multiple receivers to implement diversity and redundancy that can

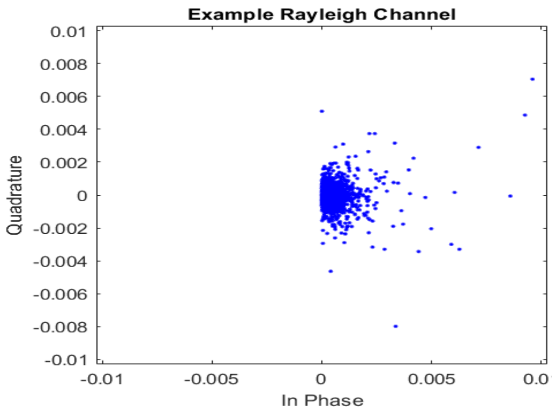

Fig. 4. Example Rayleigh Channel

correct any errors in the received signal among the multiple receivers.The received signal at each receiver was computed as a sum of each of the channels multiplied by the signal with additional white Gaussian noise. After using the conjugate of the channel and the receivers to cancel out some of the noise, a Maximum likelihood detector was used to recreate the transmitted signal. This maximum likelihood detector takes the Euclidean distance between the approximate signal and the known signal. The output of the maximum likelihood detector was then demodulated and compared to the original signal with the bit error rate. This was done with 1, 2, and 4 receivers, where multiple receivers meant that more signals could be combined before being put into the maximum likelihood detector.

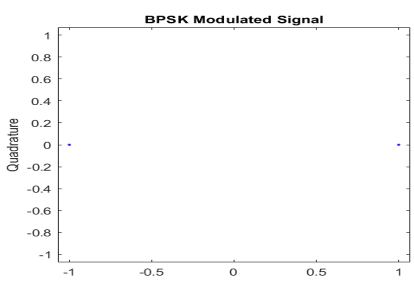

Fig. 5. BPSK Modulated Symbols

III. Two Branch Transmit Diversity

Two branch transmit diversity consists of using 2 transmitters with multiple receivers to implement diversity and redundancy that can correct any errors in the received signal among the multiple receivers.The received signal at each receiver was computed as a sum of each of the channels multiplied by the signal with additional white Gaussian noise, but the difference here is that each receiver now observes two different channels and two different signals as a result of having two receivers. Once again, after using the conjugate of the channel and the receivers to cancel out some of the noise, a Maximum likelihood detector was used to recreate the transmitted signal. The output of the maximum likelihood detector was again demodulated and compared to the original signal with the bit error rate. This was done with 1 and 2 receivers.

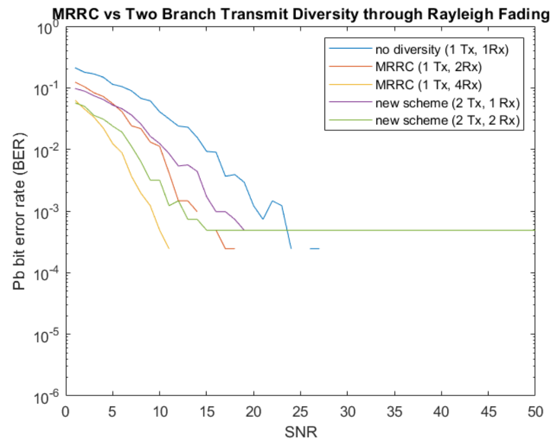

Fig. 6. MRRC vs Two Branch Transmit Diversity

IV. Analysis

In Alamouti's paper, MRRC with 4 receivers performed the best with two branch transmit diversity with two receivers following shortly after. MRRC with 2 receivers is next, followed by two branch transmit diversity with 1 receiver. Lastly, no diversity has the worst bit error rate. The graph from Figure 6 follows the same behavior but limitations in time and the power of the computer meant that the bit error rate could only be simulated with 4096 bits. This only allows for minimum bit error rates between 1/1000 and 1/10000. Furthermore, SNR was simulated until 50dB but in large intervals of 1dB, contributing more to the jagged nature of the resulting graph. Regardless, even with a smaller sample size, it can be seen that the new scheme is comparable to MRRC, approximating MRRC if the power of the transmitters were equal.

V. Improvements

As mentioned in the Analysis section, the jagged curve was a result of a low sample size and a large interval between different SNR values. The results could be further verified by overnight simulations with a much larger number of bits in the magnitude of 1000000. With this amount of bits, a bit error rate on the order of 1/1000000 is possible again. Another workaround would be to closely study the behaviour of the BER at lower SNR values. By plotting the same amount of SNR values with a much lower maximum SNR, a much smoother graph would be available.

Acknowledgments

I would like to thank Sophie Jaro for reexplaining some of the concepts to me.

REFERENCES

[1] S. Alamouti, "A Simple Transmit Diversity Technique for Wireless Communications," IEEE Journal On Select Areas In Communications, vol. 16, NO.8, October 1998.