2x2 Mimo OFDM System

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***Abstract*—The goal of the project was split up into the parts. The first goal was to set up a working 2x2 MIMO system through different Rayleigh channels and additive white noise before being equalized with 3 different methods: Zero Forcing, MMSE, and Precoding. By comparing the 3, we can compare the viability of each and the throughput. The second goal is to set up a working OFDM modulator and demodulator. The OFDM symbols would be passed through a Rayleigh channel and additive white noise before being demodulated. Like the first goal, the three different equalization types are tested and compared. Lastly the two are combine to create a full 2x2 MIMO OFDM system with one of the prior equalization types. The type chosen for the final part was Zero Forcing and Bit error rates of 10e-6 were achieved with each equalization type. 16 QAM modulation was done for each part, but could be varied for future iterations.**

I. MIMO

DopplerShift	zero_forcing	precoding	MMSE
5	0.0033983	0.0035241	0.0036632
50	0.033824	0.02973	0.03627
500	0.14226	0.10611	0.15311

Fig. 1. Equalization comparison for MIMO with different doppler shifts

For 2x2 MIMO, 2 different binary data sets were created as outputs for each of the transmitters. A 2x2 Rayleigh channel matrix was created using by first using 2 Quadrature Gaussian distributions, multiplying them by a fading spectrum based on a chosen Doppler shift, taking the IFFT of each, and then taking the square root of the sum of their squares. This process was used 4 times to create each of the coefficients for the 2x2 Rayleigh matrix before being applied to the 2xn matrix of the signal with matrix multiplication. After adding a 2xn Gaussian noise sample with a predetermined SNR, the output transmitted signal was created.

The effect of the channel was undone with each of the different equalization types. For this section and any later section, the equalization was done with full knowledge of the channel. This is typically impossible practically and channel estimation is usually done, but because the purpose was to demonstrate the functionality of MIMO and OFDM, this was overlooked.

Zero Forcing is the simplest method of the 3 equalization types. The reasoning for it is simple; if multiplication with with the channel is distorting the data, then multiplying the received signal with the inverse of the channel matrix should undo this effect. Error occurs because the noise that is added in also gets amplified when undoing the effects of the channel.

Precoding requires taking the Singular Value Decomposition (SVD) of the channel matrix. By precoding and multiplying the matrix with V before the channel is applied, the channel can be undone by then multiplying the received signal by the conjugate transpose of U before multiplying the resulting matrix by the inverse of S.

MMSE requires taking the Hermitian transpose of the channel matrix, it can be used in tandem with the known variance of the noise in order to undo the effect of both the channel and the noise.

MMSE seems to perform the worst between the 3 equalization types. Zero forcing performs better at low Doppler shifts, while the opposite is true for Precoding. Overall, the error is higher for higher Doppler shifts regardless of the type of equalization. BER of around 3e-3 were achieved with and SNR of 20.

II. OFDM

eqtype	Bit_Error_Rate
'Zero Forcing'	5.722e-06
'Precoding'	1.9073e-06
'MMSE'	0.49904

Fig. 2. Equalization comparison for OFDM

The process behind OFDM begins with bit creation before choosing a modulation method. The method chosen for this project was 16 QAM. The signal is then taken from the frequency into the time domain through an IFFT before a cyclic prefix is added. Once this is done, it is ready for transmitting, the Rayleigh channel can be applied and noise can be added. It is then received and demodulated.

Once again each equalization type was tested,and although MMSE was not working, I was able to get reasonable bit error rates for zero forcing and Precoding with an SNR of

20. As seen in Figure 2, it is very clear that the BER for Precoding is the best among the three and that with the same BER, Precoding would allow for more throughput.

III. MIMO AND OFDM COMBINED

DopplerShift	zero_forcing_final
5	0.028823
50	0.18669
500	0.37361

Fig. 3. Equalization comparison for OFDM

Once two individual parts were complete (MIMO and OFDM), it was time to combine them. Because MIMO and Zero Forcing are only regarding equalization as well as transmitting and receiving, it was very easy to isolate the MIMO and OFDM portions to integrate them together. The zero forcing was done before the cyclic prefix was removed. This had to be done with a higher SNR of 50, as the channel had amplified the noise to a great extent. Even so, it is still clear that higher Doppler shifts with Zero Forcing Equalization still cause a greater bit error rate, as it did in the MIMO section.

IV. CONCLUSION

It seems that with these simulations, Precoding performs best under MIMO and OFDM. Although it was not tested, it should also provide a higher throughput than Zero forcing because of the lower noise gain from using the SVD. Also, MMSE seems to have the lowest throughput from its MIMO simulations.

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