Project Report

This project successfully simulates an OFDMA (Orthogonal Frequency Division Multiple Access) system, which incorporates a system which transmits two OFDM (Orthogonal Frequency Division Multiplexing) symbols to two users simultaneously with an added feature of channel estimation. Out of the four given choices of modulation schemes I have chosen 16QAM (Quadrature Amplitude Modulation) for my system. The reason behind choosing 16QAM is the capability of sending more pilot symbols and also having the scope to use more bits as information bits. The bit to symbol allocation in for the 16QAM is as follows:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & = & -6 & +6i \\ 0 & 0 & 0 & 1 & = & -6 & +2i \\ 0 & 0 & 1 & 0 & = & -6 & -6i \\ 0 & 0 & 1 & 1 & = & -6 & -2i \\ 0 & 1 & 0 & 0 & = & -2 & +6i \\ 0 & 1 & 0 & 1 & = & -2 & +2i \\ 0 & 1 & 1 & 0 & = & -2 & -6i \\ 0 & 1 & 1 & 1 & = & -2 & -2i \end{bmatrix} \& \begin{bmatrix} 1 & 0 & 0 & 0 & = & 6 & +6i \\ 1 & 0 & 0 & 1 & = & 6 & +2i \\ 1 & 0 & 1 & 0 & = & 6 & -6i \\ 1 & 0 & 1 & 1 & = & 6 & -2i \\ 1 & 1 & 0 & 0 & = & 2 & +6i \\ 1 & 1 & 0 & 1 & = & 2 & +2i \\ 1 & 1 & 1 & 0 & = & 2 & -6i \\ 1 & 1 & 1 & 1 & = & 2 & -2i \end{bmatrix}$$

Figure 1: Bit allocation for 16

Here we get 16 symbols for each user. These 16 symbols are then allocated to 16 subcarriers, by interleaving the respective symbols of the two users (this is for the reference as further in the downlink the users get their specific bits interleaved from the received symbol stream). We then choose four pilot symbols for each OFDM symbol, optimally placed far apart from each other. It is necessary that the pilots are chosen far apart from each other for effective channel estimation. Then we apply IDFT (Inverse Discrete Fourier Transform) to the interleaved symbols stream. To this new symbol stream the cyclic prefix is added, i.e., the last three symbols are chosen and added to the start of the symbol stream. Because there are four channel taps, we choose three symbols as the cyclic prefix.

The symbol stream is convolved with the four channel taps and the noise is added. At the receiver, we remove the cyclic prefix, we can observe that because of this cyclic prefix feature, we were able to surpass ISI (Inter Symbol Interference). Then to get the data back to the frequency domain, we apply DFT (Discrete Fourier Transform). Here, since we do not know the channel information, we perform channel estimation by using the maximum likelihood function. The Z_{4x4} matrix is found by solving the matrix in *1.1.* To estimate the channel equation *1.2* was used. Once we have the estimated channel information, we find the G_k values by using the formula *1.3.*

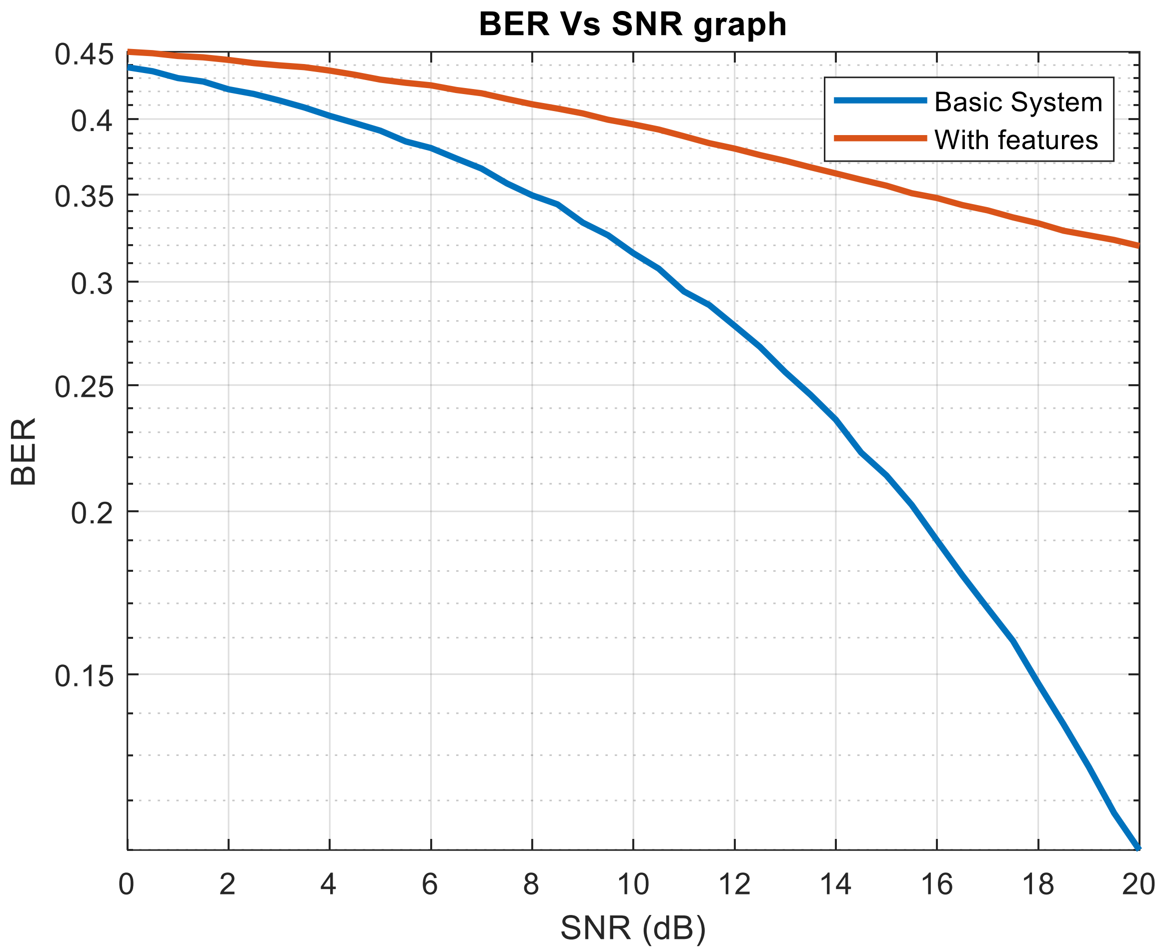
$$\begin{bmatrix} \mathrm{Uk}_{1x4}\mathrm{D1} \\ \mathrm{Uk}_{1x4}\mathrm{D2} \\ \mathrm{Uk}_{1x4}\mathrm{D3} \\ \mathrm{Uk}_{1x4}\mathrm{D4} \end{bmatrix} \quad \ldots 1.1$$

$$\hat{h}_{4x1} = \left(Z^*_{4x4} Z_{4x4}\right)^2 Z^*_{4x4} Y_{4x1} \qquad \ldots\ldots 1.2$$

$$\hat{G}_k = \sum_n^{L-1} e^{-j2\pi\frac{kn}{N}} \hat{h}_n \qquad \ldots\ldots 1.3$$

Now, by using this estimated channel information the estimated symbol stream is calculated using the minimum distance decoding algorithm. The estimated symbols are again mapped back to their respective symbols, and we calculate the BER (Bit Error Rate) by comparing the estimated bits to the original bits. To show the results, a BER vs SNR curve is plotted.

Simulation and results:



Note: In the above graph the basic system is simulated with a higher noise variance.

Discussion:

The above graph shows the BER vs SNR curve for both a basic system and a system with added features. In the basic system, we have the modulation scheme BPSK (Binary Phase Shift Keying) sending two OFDM symbols to one user with the added knowledge of the channel at the receiver. Thus, the simulation shows us the best possible curve.

My system, as described in the previous page, does the best possible estimation of the channel, and then calculated the error rate with that information. Because we do not have the exact channel information, the BER is higher than of the basic system. We could get more optimized BER values that are closer to that of the basic system if we choose more pilot symbols. But that would be at a cost of information bits and that will reduce the spectral efficiency,

Supplement Information

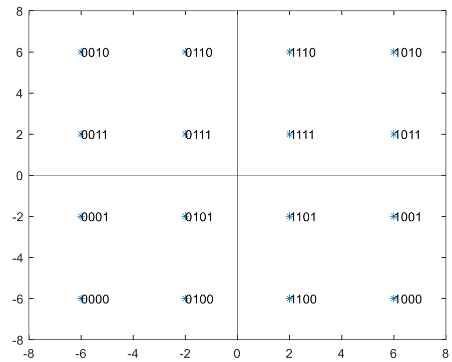
Spectral Efficiency:

$$SE = \frac{Channel\ throughput}{Channel\ utilization} \times number\ of\ bits\ per\ symbol$$

$$SE = \frac{24\ information\ symbols}{6 cyclic\ prefix + 8 pilot\ symbols + 24 information\ symbols} \times 4$$

$$SE = \frac{24}{38} \times 4 = 2.5 b/s/H$$

Constellation Diagram and Bit allocation:



Subcarrier Allocation:

	OFDM1	**OFDM2**
Subcarrier 1	P	UE1S9
Subcarrier 2	UE2S1	P
Subcarrier 3	UE1S2	UE1S10
Subcarrier 4	UE2S2	UE2S10
Subcarrier 5	P	UE1S11
Subcarrier 6	UE2S3	P
Subcarrier 7	UE1S4	UE1S12
Subcarrier 8	UE2S4	UE2S12
Subcarrier 9	P	UE1S13
Subcarrier 10	UE2S5	P
Subcarrier 11	UE1S6	UE1S14
Subcarrier 12	UE2S6	UE2S14
Subcarrier 13	UE1S7	UE1S15
Subcarrier 14	UE2S7	UE2S15
Subcarrier 15	P	UE1S16
Subcarrier 16	UE2S8	P