Equalisation in a communication receiver

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Introduction:

Intersymbol interference (ISI) in telecommunications is the distortion of signal pulses in the time domain, which results in partial or whole symbols being received outside of their intended time interval, resulting in bit errors at the receiver. The effect of ISI is similar to that of noise, but occurs primarily as a result of heavy filtering at the transmitter and receiver and a phenomenon called multipath propagation. Multipath propagation occurs when a signal (primarily wireless) can travel through several different pathways and arrive at the receiver with varying amounts of delay. Heavy filtering of the transmitted signal has the effect of spreading the signal symbols out in the time domain, and it is the combination of this symbol spreading with multipath delays that results in intersymbol interference.There are several ways to attempt to mitigate ISI, one such method being equalisation. Equalisation works to directly oppose the influence of channel distortion on the signal, and can do this in a variety of ways. This project will focus on the comparison between a Linear Equaliser (LE) and a Decision Feedback Equaliser (DFE), both using the Least Mean Square (LMS) algorithm. The DFE operates in a similar way to the LE, but includes feedback from previous symbols to attempt to improve performance, particularly in signals with a low Signal - Noise Ratio (SNR).

Method:

The primary goal of this project was to explore and compare the performance of two forms of equalisation (linear and decision-feedback) at varying SNR values and to discuss the advantages and disadvantages of DFE over LE. This comparison was made through the use of Matlab simulations.A random binary signal was first generated . This signal was then modulated using Binary Phase Shift Keying (BPSK) to provide maximum phase separation, helping to mitigate the effect of ISI. Channel distortion was then simulated on the signal by applying Additive White Gaussian Noise (AWGN) at various SNR values.

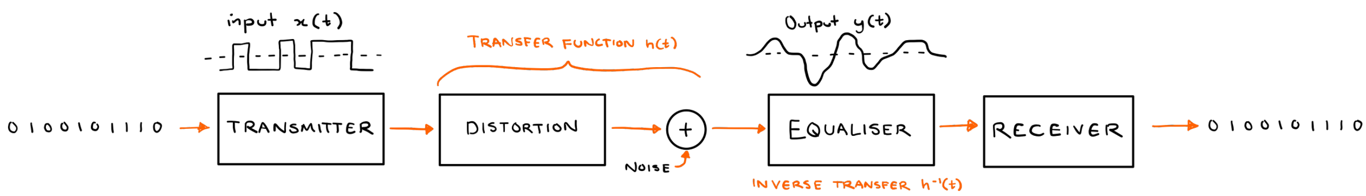

Figure 1: Block diagram of a model telecommunications system with ISI and equalisation

The resulting digitally modulated, noisy signal was then equalised using both a linear equaliser and a decision feedback equaliser. The equalised signals were then displayed on a constellation diagram for easy visualisation. The un-equalised signal and the two equalised signals (LE and DFE) were then demodulated, and the Bit Error Rates (BER) of each signal were calculated.

Results & Discussion:

The constellation diagrams for the simulations carried out at SNR values of 12, 16 and 20 are shown below in figures 3, 4 and 5 respectively. From these constellation diagrams it can be seen that the effectiveness of the equalisers are heavily dependent on the SNR of the simulated distorted signal, with performance being severely limited at low SNR. Furthermore, contrary to what was expected it can be seen from these results that there is little difference between the effectiveness of the LE and the DFE. Referring to the plot of BER against SNR below in figure 2, it can be seen that the LE actually results in fewer bit errors at most of the SNR values in our data range.

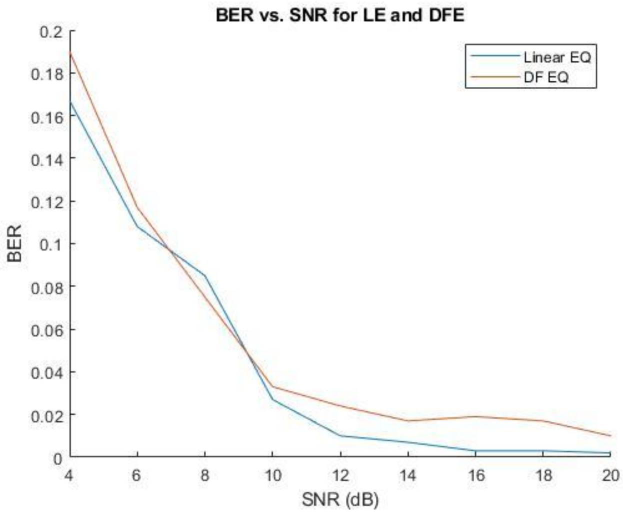

Figure 2: Plot of Bit Error Rate against Signal-Noise Ratio for the Linear Equaliser and Decision-Feedback Equaliser

From the data obtained with these simulations it would be logical to draw the conclusion that the LE is more effective at mitigating ISI than the DFE. However, this contradicts expected theoretical results as well as findings in well established research papers. The DFE is expected to improve on the effectiveness of the LE by utilising feedback from previously filtered symbols, which should result in a smaller BER. This effect should have been even clearer at low SNR values, as one of the weaknesses of linear equalisation is its poor performance with high noise.

The discrepancy between our results and the expected results could be due to several different factors such as equalisation algorithm choice, simple data set choice that may not reflect real world data, and the use of binary phase shift keying instead of quadrature phase shift keying and other higher degrees of modulation.

Conclusion:

This project explored some of the differences between linear and decision-feedback equalisation, but was unable to clearly demonstrate the expected improvements of a DFE over the simpler LE. Other studies show that linear equalisers, while being simple and easier to implement, have poor performance in systems with a low SNR value, as they tend to amplify high frequency noise. Ideally the simulated results would have shown that the performance of the DFE was significantly better as the SNR decreased.

References:

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Appendices:

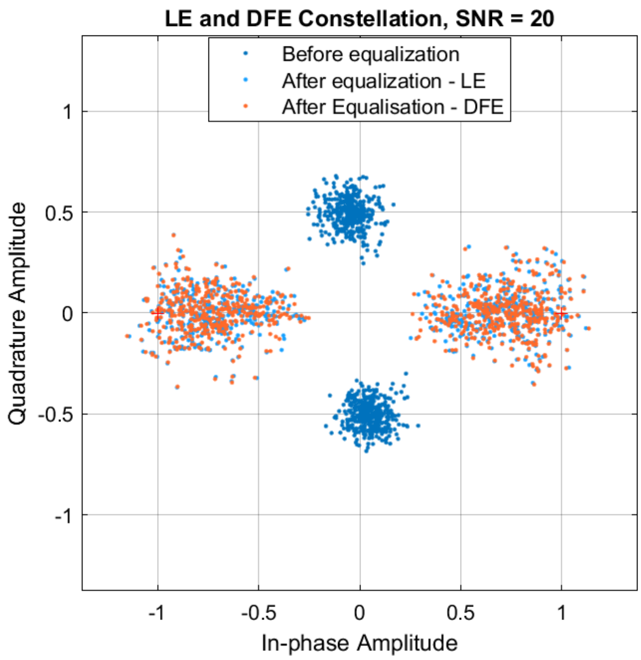

Figure 3: Constellation diagram for SNR value of 20.

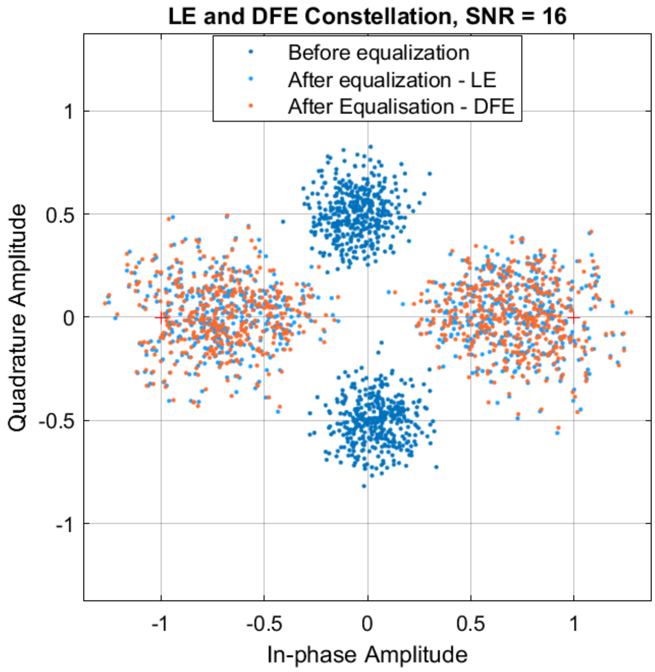

Figure 4: Constellation diagram for SNR value of 16

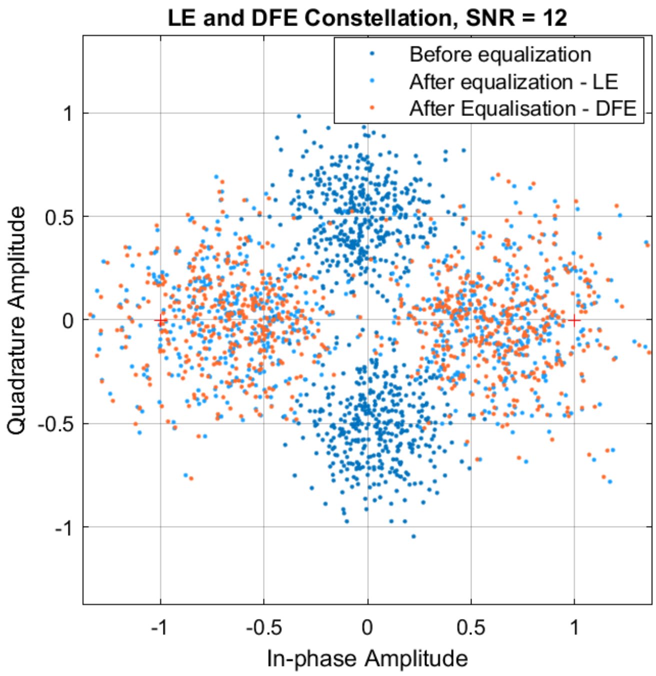

Figure 5: Constellation diagram for SNR value of 12.