Efficient Designing of Communication Link with PSK Modulation using Adaptive Equalization

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Abstract: *In the era of revolution of communication, bandwidth is definitely one of the scarier thing. So the pressure is to reduce the requirement of bandwidth while reduction in bandwidth may result in Inter Symbol Interference. One of the ways to reduce Inter Symbol Interference is to use equalization and in this paper, we have proposed decision feedback equalizer with adaptive equalization for reducing inter-symbol interference and from the depicted results it it quite obvious that the ISI reduces drastically by using adaptive equalization.*

Keywords: PSK modulation, Equalization, Inter-symbol Interference (ISI), Adaptive Equalization, Frequency-Flat Fading

1. Introduction

This Inter Symbol Interference will be one of the common and most effective noise source when we will receive the signal at receiver and in case of a digital signal this will produce lots of error. The reason behind this ever increasing Inter-symbol Interference (ISI) is that, if want to reduce bandwidth of signal beyond a limit channel will definitely become unable to carry information. To minimize this effect, we have to increase time per bit but then this will reduce data speed or the next bit will affect the previous one and create Inter Symbol Interference. Even if we manage these problems there are other sources of Inter Symbol Interference and those are beyond control as these occurs during transmission of signal through channel like multipath time we can negotiate at the receiver minimize their effect but cannot eliminate them. This multipath time occurs because of propagation of a signal through different propagation paths. These paths may vary in length and medium and because of these variations same signal may arrive at a receiver at different time intervals and may be added to the original signal and create Inter Symbol Interference. The ISI may be reduced by using equalization and there are many methods of equalization.

2. Types of Equalization

There are two types of equalizer

2.1 Linear Equalizer

Linear Equalizers can be used where noise from neighboring channels cannot affect channel and costing is of primary importance

a) Mean Square error equalizer
b) Zero Forcing Equalizer

The Zero-Forcing Equalizer are designed on the basis of maximum distortion at the start of session and this cannot be changed. It can not include the effect of positive additive Gaussian noise effect in the channel. In such type of equalizer problem of noise at high frequency will be more if at the time of designing ISI and channel noise is not considered

The Minimum Mean Square error equalizer overcomes this drawback by the equalizer characteristics such that the combined power in the ISI and the additive noise at the equalizer output is minimized

2.2 Non Linear Equalizers

These equalizers are very useful in the cases like wireless channels where inter symbol interference is very much possible from neighboring channels and it is varying continuously changing so we cannot design it at the start of session so we have to make changes continuously.

2.2.1 Adaptive Equalizers
As in any Feedback System in a adaptive equalizer has two parts one is Forward path and another is Feedback path. The Feedback path provides the output data to a equalizer so that it can compare the output and input. Figure 1 shows the equalizer without feedback. Figure 2 contains a weighted and cascaded Decision along with feedback filters.

2.2.2 Weighted Equalization
There are two types of weighted equalizers

a) **Fixed Weight Equalizers-** These equalizer normally used for the cases where frequency response of the channel is constant. In such type of system once the weights fixed it cannot be changed.
b) **Adaptive Weight Equalizers-** These systems are used where frequency response vary with time. In these systems the output of the system is compared with the reference sequence and output varied time to time. Figure 3 shows adaptive fixed equalizer.

Adaptive equalizers works in two methods either the receiver information is used to generate error signal or a reference training bits are used which is compared to a known transmission bit sequence and thus if there is any change in timing of bit it can be corrected by calculating the difference between the initial time calculated by training bit. Adaptive equalizer initially produces some error because equalizers try to get used to it.
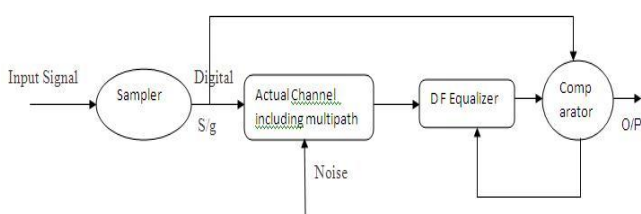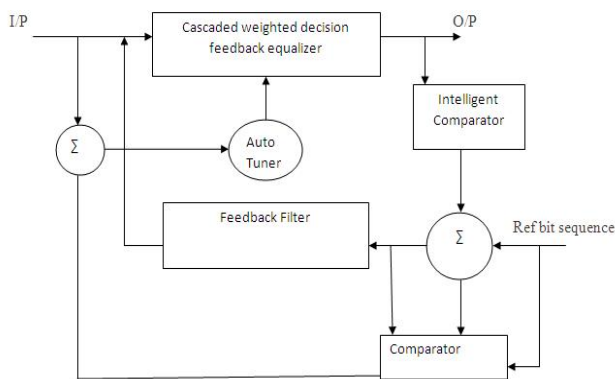
Figure 1: Equalizer without feedback

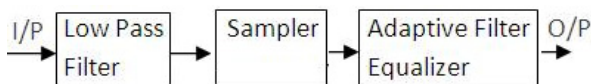**Figure 2:** Equalizer with feedback filter

Figure 3: Adaptive weight Equalizer

3. Results & Discussion

The PSK modulation has been used for a communication link for simulation purposes. The different parameters have been adjusted for setting simulation parameters and creating equalizer objects.

3.1 Modulation and Transmission Block

Parameters related to PSK modulation and the transmission blocks have been adjusted. The block consists of 3 parts; One of them is to train the sequence and thereafter pay-loading & tailing the sequence. Each uses the similar PSK scheme. The function of training and tail sequences is equalization. We have taken
Symbol period = 1e-6
Number of bits per PSK symbol = 2
Number of modulation levels = 2
Number of payload symbols = 800
Number of training symbols = 200
Number of tail symbols = 40

3.2 Transmit/Receive Filters

Structures have been created which contain information regarding transmission and reception of filters. Each filter is having a square-root raised cosine frequency response which is implemented with an FIR structure. The transmission and reception of filters include up-sampling and down-sampling, respectively, and both use an efficient poly-phase. These multi-rate filters retain state from one transmission block to the next, like the channel object. The peak value of the impulse response of the filter cascade is 1. The transmit filter uses a scale factor to ensure unit transmitted power. To construct the pulse filter structures, this algorithm uses an auxiliary function.

Filter parameters are:
Number of symbol periods spanned by each filter = 8;
Oversampling factor for filter = 4;
Roll-off factor = 0.25;

3.3 Frequency-Flat Fading Channel

Begin with single-path, frequency-flat fading. For this channel, the receiver uses a simple 1-tap LMS (least mean square) equalizer, which implements automatic gain and phase control. We have taken ratio of symbol energy to noise power spectral density (dB) = 20. Before the first run, the script displays the initial properties of the channel and equalizer objects. For each run, a MATLAB figure shows signal processing visualizations. The red circles in the signal constellation plots correspond to symbol errors. In the "Weights" plot, blue and magenta lines correspond to real and imaginary parts, respectively. Figure 4 shows the response of frequency flat fading channel.
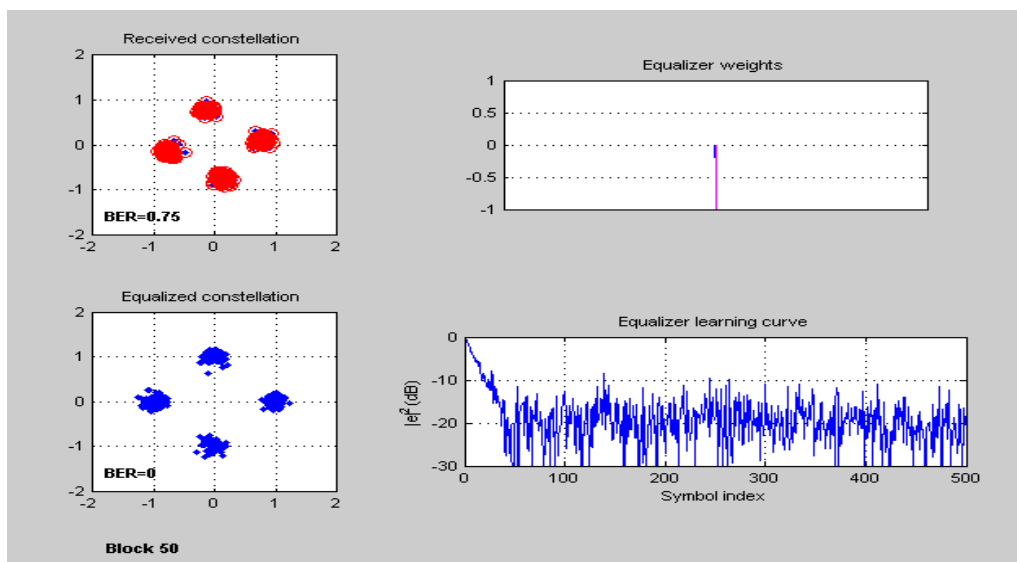

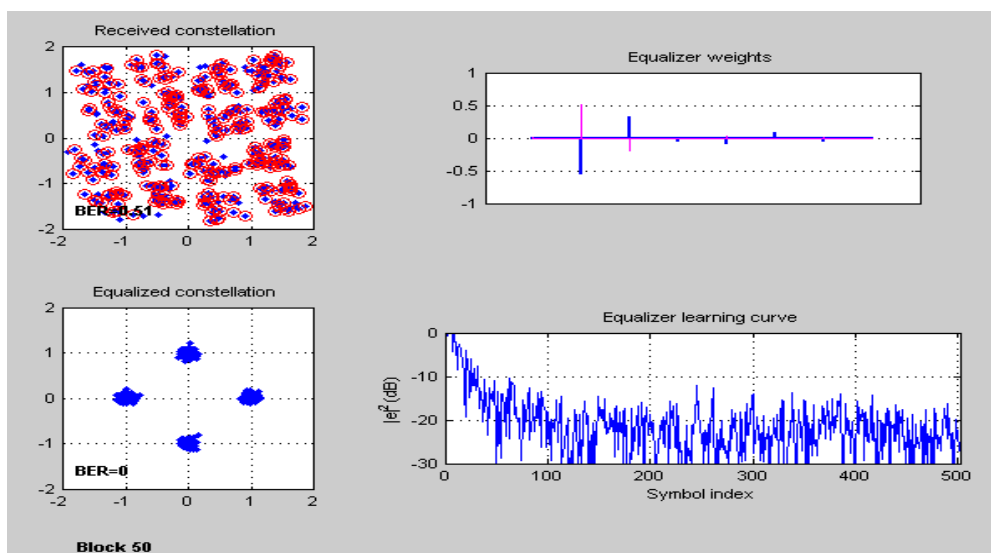**Figure 4:** Response of Frequency Flat Fading Channel

Figure 5: Response of Frequency-Selective Fading Channel and Linear Equalizer
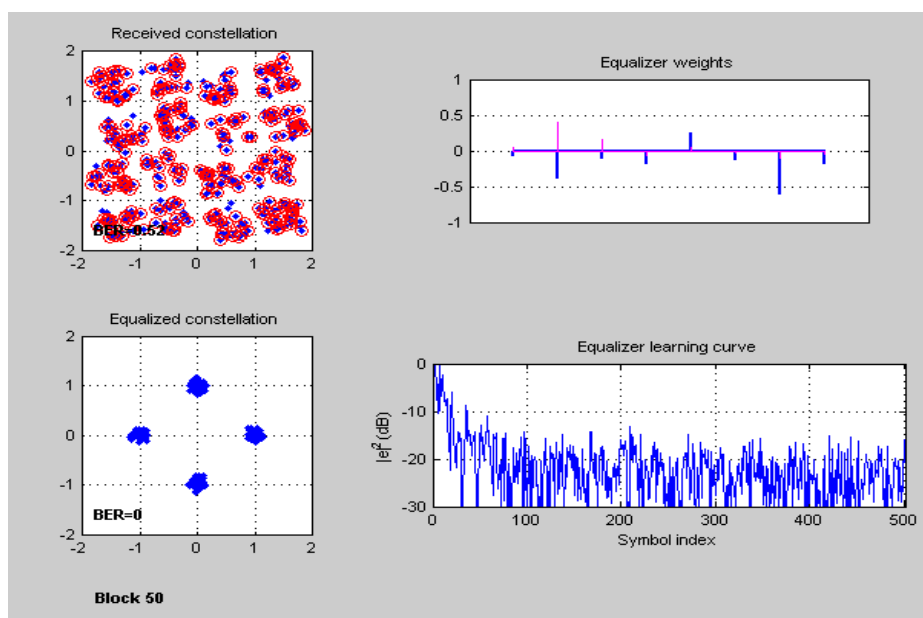

Figure 6: Response of Decision Feedback Equalizer (DFE)

3.4 Frequencies-Selective Fading Channel and Linear Equalizer

The receiver uses an 8-tap linear RLS (recursive least squares) equalizer with symbol-spaced taps. The simulation uses the channel object from Simulation 1, but with modified properties.

Linear equalization parameters are
No. of weights = 8;
RLS algorithm forgetting factor = 0.99;
Figure 5 shows the response of frequency selective fading channel and linear equalizer.

3.5 Adaptive Equalizer

The receiver uses a adaptive equalizer with a six-tap fractionally spaced forward filter (two samples per symbol) and two feedback weights. The DFE uses the same RLS algorithm as in 3.4. The receive filter structure is reconstructed to account for the increased number of samples per symbol. This simulation uses the same channel object as in 3.4.

Adaptive equalization parameters are:
Number of feed forward equalizer weights = 6
Number of feedback filter weights = 2
Figure 6 shows the response of adaptive equalizer.

4. Conclusion

From the results it is clear that the receive filter structure for adaptive equalization is reconstructed to account for the increased number of samples per symbol with the same channel object as in linear equalization. Therefore, we can say that the equalization using adaptive Equalizer increases the efficiency of the communication system.

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