*International Journal of Innovative Research in Electronics and Communications (IJIREC)*
*Volume 1, Issue 2, May 2014, PP 40-46*
*ISSN 2349-4042 (Print) & ISSN 2349-4050 (Online)*
*www.arcjournals.org*

# Decision Feedback Equalizer – A Nobel Approch and a Comparitive Study with Decision Directed Equalizer

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**Abstract:** *Adaptive equalisation is a process through which noise distortion non-linearity introduced by unpredictable channel is equalized. In this paper the Decision Feedback Equalizer and Decision Directed Equalizer is illustrated and a comparative study between them is also implemented. The advantage and disadvantage of both process and various constraints are also discussed. The main aim of this paper is to illustrate various aspects of both processes in detail.*

**Keywords:** *Adaptive Equalizer, DDE, DFE, PAM, ISI*

## 1. Introduction

An equalizer is a filter, usually adjustable, chiefly meant to compensate for the unequal frequency response of some other signal processing circuit or system. A filter typically allows the user to adjust one or more parameters that determine the overall shape of the filter's transfer function. It is generally used to improve the fidelity of sound, to emphasize certain instruments, to remove undesired noises, or to create completely new and different sounds. The design objective of the equalizer is to undo the effects of the channel and to remove the interference. Conceptually the equalizer attempts to build a system that is a “delayed inverse” of the digital model of the transmission channel, removing the inter symbol interference while simultaneously rejecting the additive interferers uncorrelated to the source [1,2]

## 2. Problem Formulation

Any communication system faces many problems in the channel. The main problems are noise, inter symbol interference, bandwidth limitation, multipath propagation.

Now temperature, dust, weather change etc. affects the channel a lot and the channel characteristics changes unpredictably and non-linearly with the physical parameters. So,to prevent the message signal from these non-linear effects the equalizer will have to change its characteristics accordingly and hence the equalizer will have to be adaptive in nature.

An adaptive equalizer is such a device that can predict the channel to some extent by measuring the channel parameters at every instant with some effective algorithms.

Algorithms for the implementation of adaptive equalizer in MATLAB:

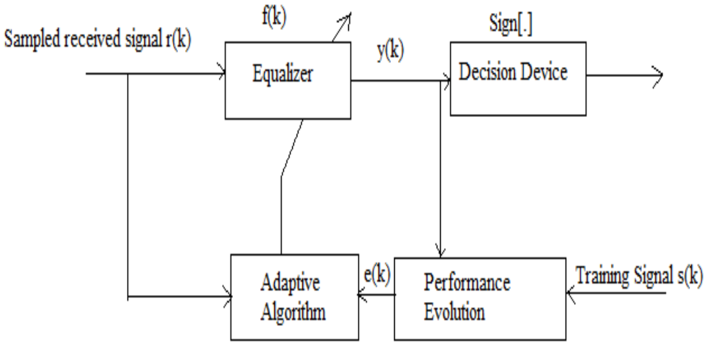


**Figure Error! No text of specified style in document.**.1 Trained Adaptive Linear Equalizer

## 3. DICISION DIRECTED LINEAR EQUALIZATION

During the training period, the communication system does not transmit any message data. Commonly, a block of training data is followed by a block of message data. The fraction of time devoted to training should be small, but can be up to 20% in practice. If it were possible to adapt the equalizer parameters without using the training data, then the message bearing (and revenue generating) capacity of the channel would be enhanced.

Consider the situation in which some procedure has produced an equalizer setting that opens the eye of the channel. Thus all decisions are perfect, but the equalizer parameters may not yet be at their optimal values. In such a case, the output of the decision device is an exact replica of the delayed source, i.e. it is as good as a training signal. For a binary + 1source and decision device that is a sign operator, the delayed source recovery error can be computed as sign {y[k]} –y[k] where y[k] is the equalizer output and sign{y[k]} equals s[k-δ ]. Thus, the trained adaptive equalizer of figure 1 can be replaced by the decision-directed error as shown in figure2. Thus the updated characteristics equation of adaptive equalizer is

$$f_i[k+1] = f_i[k] \pm \mu(\text{sign}(y[k]) - y[k])r[k-i]$$

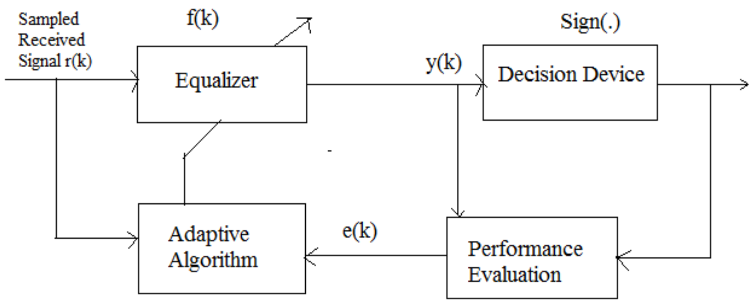


**Figure 2** *Decision-Directed Adaptive Linear Equalizer*

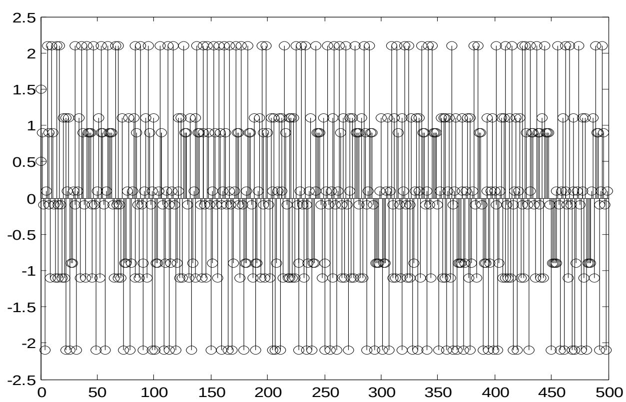


**Figure 3.** *Input Signal*

Thus, no training signal is required for its implementation and the decision-directed adaptive linear equalizer. So, it is also called a "blind" equalizer.The basic rule of thumb is that 5% (or so) decision errors can be tolerated before decision- directed LMS fails to converge properly.
The Matlab program DD equalizer has a familiar structure.The equalizer must begin with an open eye, f= 0 is a poor choice. The initialization used below starts all taps at zero except for one in the middle that begins at unity. This is called the "center-spike" initialization. If the channel eye is open, then the combination of the channel and equalizer will also have an open eye when initialized with the center spike.

### 3.1 DDE Algorithm

1. Generate 500 quantized numbers from 1 to 500 randomly and denote it as 'S'.
2. Pass it through channel whose transfer function is denoted as 'B' and let the channel output be 'R'.
3. Define step size and delay delta.
4. Define equalizer coefficient matrix.
5. Iterate the loop
   5.1. Generate the vector of the received Signal and denote it as 'RR' and then calculate error.
   5.2. Update equalizer coefficient.
6. Pass it through filter and generate Output 'Y'.
7. Quantize the output.

### 3.2 Simulation Results

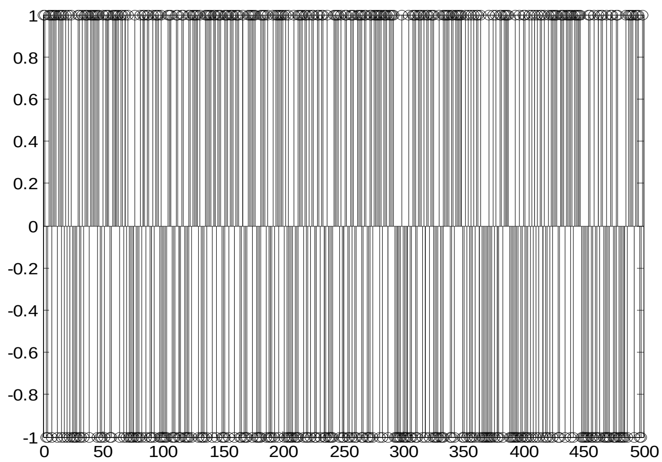


**Figure 4.** *Channel Output*

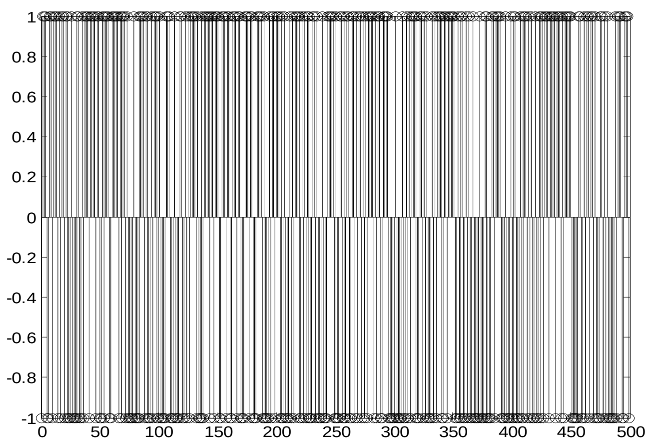


**Figure 5.** *Equalizer Output*

## 4. Decision Feedback Equalizer

An adaptive decision feedback equalizer to detect digital information transmitted by pulse-amplitude modulation (PAM) through a noisy dispersive linear channel is described, and its performance through several channels is evaluated by means ofanalysis, computer simulation, and hardware simulation. For the channels considered, the performance of both the fixed and the adaptive decision feedback equalizers are found to be notably better than that obtained with a similar linear equalizer. The fixed equalizer, which may be used when the channel characteristics are

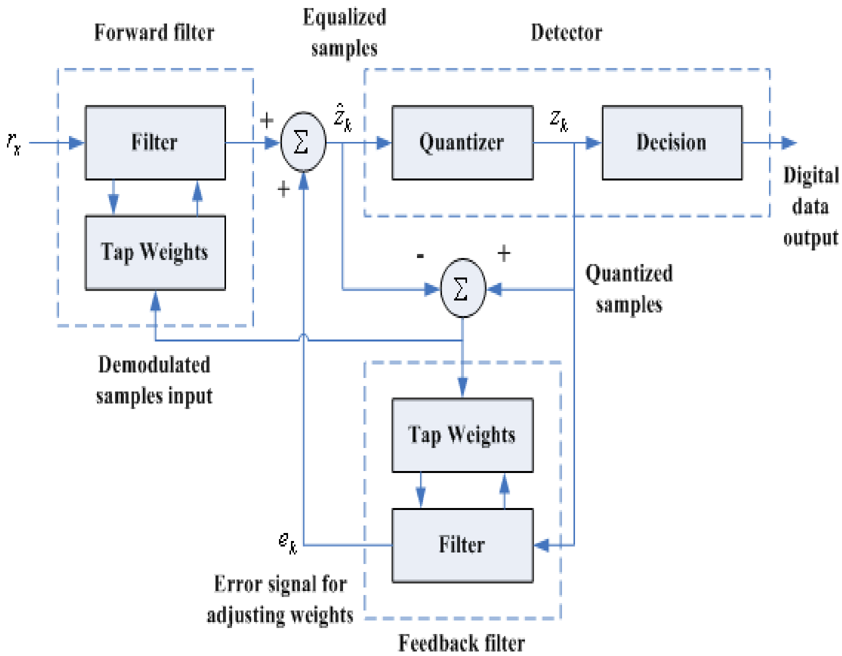


**Figure 6.** *Decision Feedback Equalization*

known, exhibits performance which is close to that of the optimum, but impractical, Bayesian receiver and is considerably superior to that of the linear equalizer. The adaptive decision feedback equalizer, which is used when the channel impulse response is unknown or time varying, has a better transient and steady-state performance than the adaptive linear equalizer. The sensitivity of the receiver structure to adjustment and quantization errors is not pronounced.

Here, in this algorithm the adaptive filter transfer function is modified in each step by calculating the quantisation error. Here the formula for calculating the adaptive filter transfer function remains the same as Decision Directed algorithm, but here the error is calculated separately in each step.

### 4.1 DFE Algorithm

1. Generate 500 quantized numbers from 1 to 500 randomly and denote it as ‘S’.
2. Pass it through channel whose transfer function is denoted by ‘B’ and let the channel output be ‘T’ and then quantize ‘T’ and the quantized output is denoted by ‘R’
3. Define step size and delay delta.
4. Define equalizer coefficient matrix.
5. Iterate the loop
    a. Generate the vector of the received Signal and denote it as ‘RR’ and then calculate error.
    b. Update equalizer coefficient.
    c. Pass it through filter and generate output ‘Y’.

d. Let ‘T1’ be the difference between ‘T’ and ‘Y’.

6. Quantize the output.

### 4.2 Simulation Results

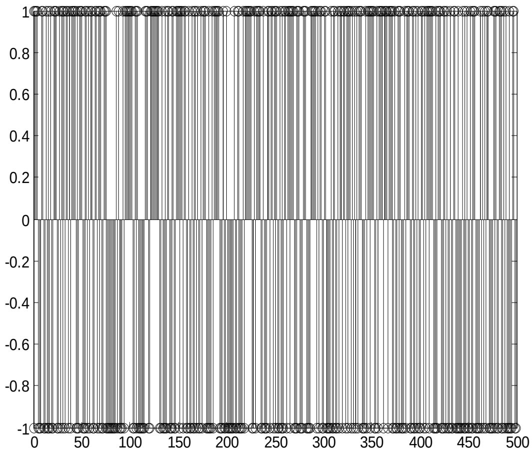


**Figure 7**. *Input Signal*

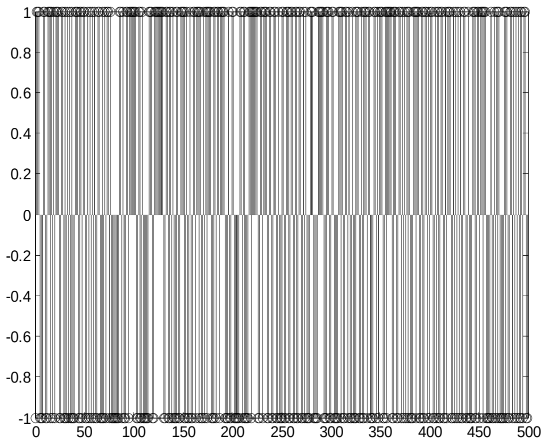


**Figure 8.** *Channel Output*

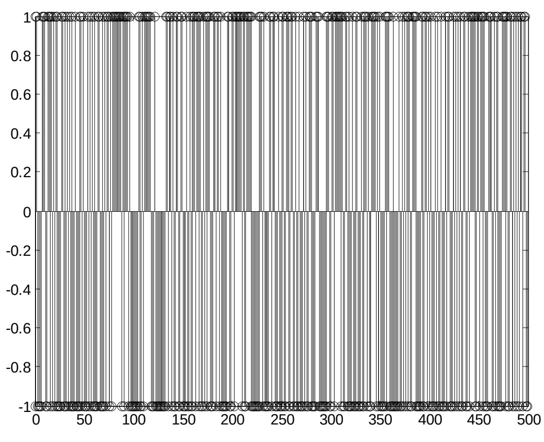


**Figure 9.** *Equalizer Output*

## 5. COMPARISON

Channel equalizers are either linear or non-linear. Non-linear equalization is needed when the channel distortion is too severe for the linear equalizer to mitigate the channel impairments. An example of a linear equalizer is a zero-forcing equalizer (ZFE), and, as the name implies, it forces

ISI to become zero for every symbol decision. A zero-forcing equalizer enhances noise and results in performance degradation. On the other hand, a minimises mean square error-linear equalizer (MMSE-LE) minimizes the error between the received symbol and the transmitted symbol without enhancing the noise. Although MMSE-LE performs better than ZFE, its performance is not enough for channels with severe ISI. An obvious choice for channels with severe ISI is a non-linear equalizer.

Decision directed equalizer (DDE) is a linear equalizer and Decision feedback equalizer (DFE) is a non-linear one. DFE checks its quantisation error in each step of iteration and hence minimises that by a feedback method.

So, DFE is a bit slower than DDE, but DFE can reconstruct the message signal more accurately.

## 6. Conclusion

In this paper the various features of Decision Directed Equalizer (DDE) and Decision Feedback Equalizer (DFE) are shown.DDE and DFE are discussed in detail and a comparative study between them is given.

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