4.2 NON LINEAR EQUALIZATION

Linear equalizers do not perform well on channels which have deep spectral nulls in the pass band. In an attempt to compensate for the distortion, the linear equalizer places too much gain in the vicinity of the spectral null,there by enhancing the noise present in those frequencies.

Nonlinear equalizers are used in applications where the channel distortion is too severe for a linear equalizer to handle.

 Types of nonlinear equalizer.

Decision Feedback Equalization (DFE)

Maximum Likelihood Sequence Estimation (MLSE)

 Decision Feedback Equalization (DFE)

Basic idea: Once an information symbol s been detected, the ISI that it induces on future symbols can be estimated and subtracted out before detection of subsequent symbols.

DFE can be realized in either the direct transversal form or as a lattice filter.

The LTE form consists of a feed forward filter(FFF) and a feedback filter(FBF) as shown in figure 4.2.1.

The FBF is driven by decisions on the output of the detector, and its coefficients can be adjusted to cancel the ISI on the current symbol from past detected symbols.

The equalizer has $N1+ N2+ 1$ taps in FFF and $N3$ taps in FBF.

The output of DFE is

$$\hat{d}_k = \sum_{n=-N_1}^{N_2} c_n^* y_{k-n} + \sum_{i=1}^{N_3} F_i d_{k-i}$$

where c_n^*, and y_n, are tap gains and the inputs, respectively, to the forward filter, F_i^* are tap gains for the feedback filter, and d_i ($i < k$) is the previous decision made on the detected signal.

That is, once d_k is obtained using equation (above), d_k is decided from it. Then, d_k along with previous decisions d_k -1, d_{k-2} are fed back into the equalizer, and d_{k+1} is obtained using the above equation.
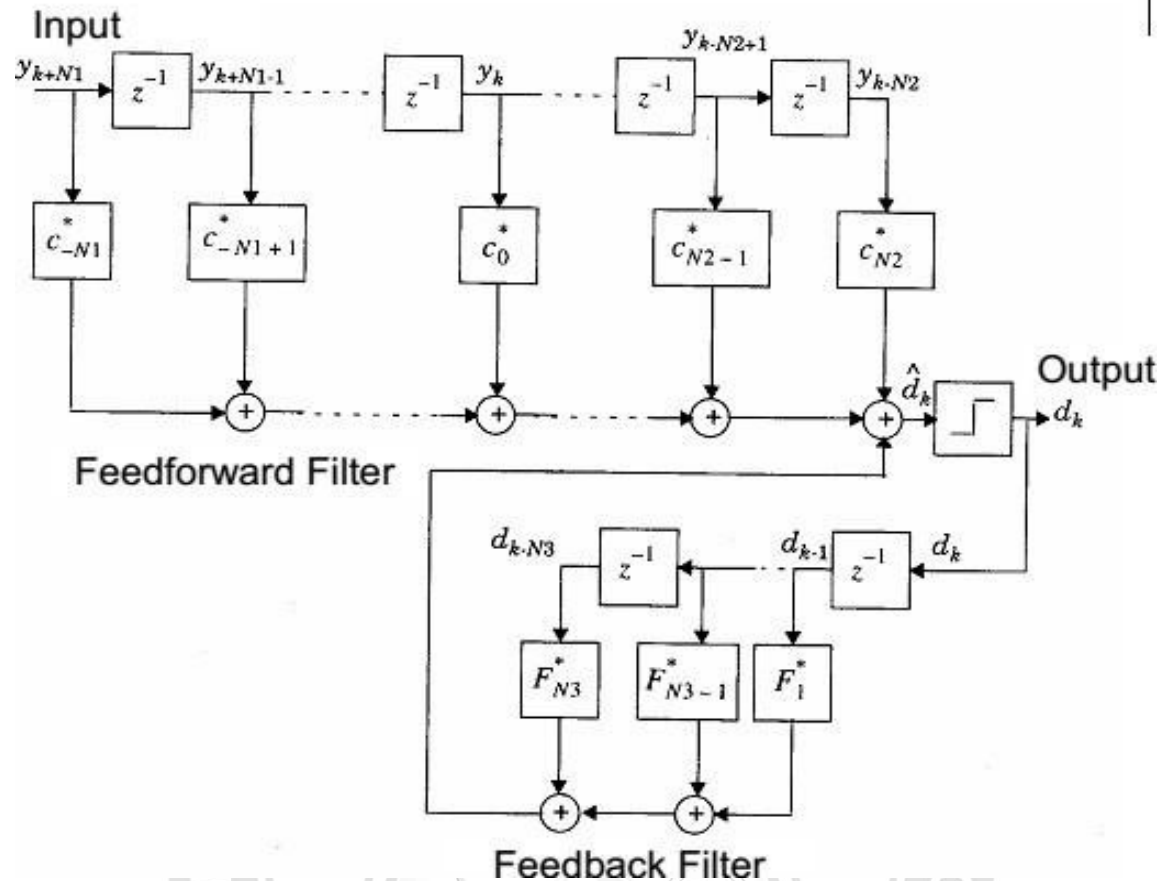
Fig4.2.1: Decision Feedback Equalizer

[Source : "Wireless communications" by Theodore S. Rappaport,Page-314]

The minimum mean square error of DFE

$$E\left[\left|e(n)\right|^2\right]_{min} = \exp\left\{\frac{T}{2\pi}\int_{-\pi/T}^{\pi/T} \ln\left[\frac{N_0}{\left|F(e^{j\omega T})\right|^2 + N_0}\right]d\omega\right\}$$

It can be seen that the minimum MSE for a DFE is always smaller than that of an LTE.

An LTE is well behaved when the channel spectrum is comparatively flat. A DFE is more appropriate for severely distorted wireless channels.If the channel is severely distorted or exhibits nulls in the spectrum, the performance of an LTE deteriorates and the mean squared error of a DFE is much better than a LTE.

Also, an LTE has difficulty in equalizing a non minimum phase channel ,where the strongest energy arrives after the first arriving signal component.Thus, a DFE is more appropriate for severely distorted wireless channels.

Another type of DFE proposed by Belfiore and Park is called a predictive DFE, and is shown in Figure 4.2.2 .
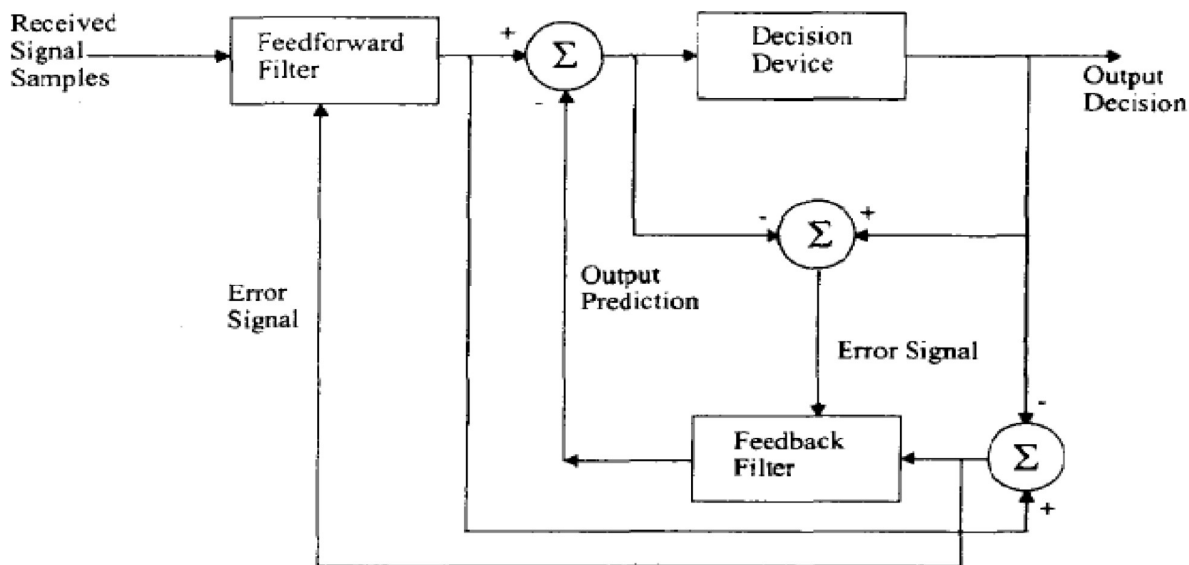

Fig4.2.2: Predictive Equalizer
[Source : "Wireless communications" by Theodore S. Rappaport,Page-315]

It consists of a **feed forward filter (FFF) as in the DFE.**

Here, the feedback filter (FBF) is driven by an input sequence formed by the difference of the output of the detector and the output of the feed forward filter. Hence, the FBF here is called a noise predictor because it predicts the noise and the residual contained in the signal at the FFF output and subtracts from it the detector output after some feedback delay.

The predictive DFE performs as well as the conventional DFE as the limit

in the number of taps in the FFF and the FBF approach infinity. The FBF in the predictive DFE can be realized as a lattice structure . The RLS lattice algorithm can be used in this case to yield fast convergence.

Maximum Likelihood Sequence Estimation (MLSE)Equalizer

The MSE-based linear equalizers are optimum with respect to the criterion of minimum probability of symbol error when the channel does not introduce any amplitude distortion.

This is precisely the condition in which an equalizer is needed for a mobile communications link.

MLSE uses various forms of the classical maximum likelihood receiver structure.

The MLSE tests all possible data sequences (rather than decoding each received symbol by itself), and chooses the data sequence with the maximum probability as the output.A channel impulse response simulator is used within the algorithm.

Drawback: An MLSE usually has a large computational Requirement especially when the delay spread of the channel is large.
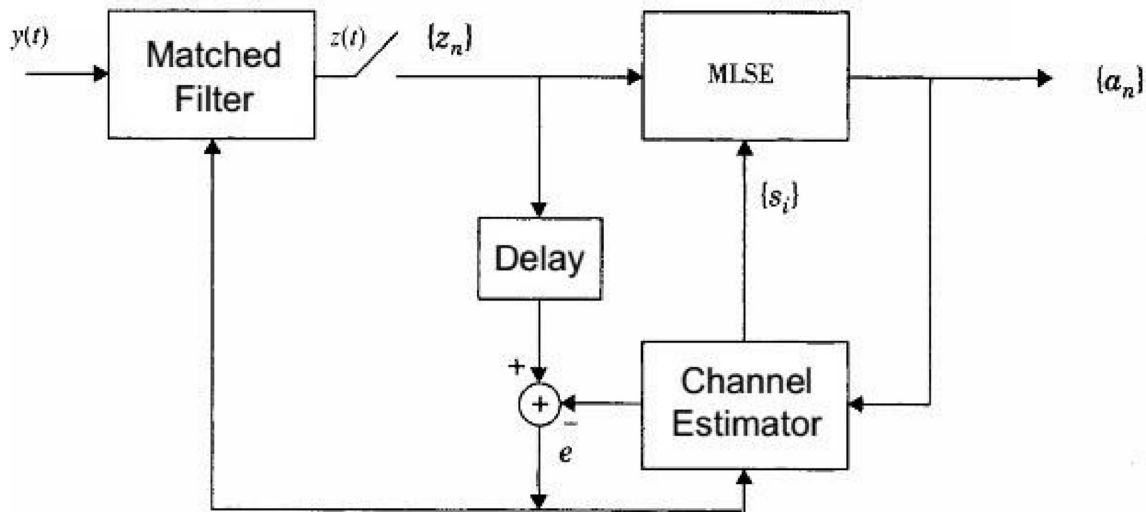

Fig 4.2.3:MLSE Structure

[Source : "Wireless communications" by Theodore S. Rappaport,Page-316]

The MLSE can be viewed as a problem in estimating the state of a discrete time finite state machine The channel has ML states, where M is the size of the symbol alphabet of the modulation. An ML trellis is used by the receiver to model the channel over time.

The Viterbi algorithm then tracks the state of the channel by the paths through the trellis.

The block diagram of a MLSE receiver based on the DFE is shown in Figure 316.

The MLSE is optimal in the sense that it minimizes the probability of a sequence error. The MLSE requires knowledge of the channel characteristics in order to compute the metrics for making decisions.

The MLSE also requires knowledge of the statistical distribution of the noise corrupting the signal. Thus, the probability distribution of the noise determines the form of the metric for optimum demodulation of the received signal. The matched filter operates on the continuous time signal, whereas the MLSE and channel estimator rely on discretized (nonlinear) samples.

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