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Performance Analysis of Linear and Non-Linear Equalizer in Rician Channel

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Abstract

In this paper, equalization algorithms applying soft–decision feedback, designed for quaternary phase–shift keying (QPSK) and 8PSK (phase–shift keying) transmission are introduced. The method employed is a minimum mean–squared error (MMSE) in which each iteration is done in order to refine the data estimates. The rule for generating soft decisions is adapted continuously to the current state of the algorithm. We show that standard Decision Feedback Equalization (DFE-Non linear Equaliser) methods are clearly outperformed the minimum mean–squared error (MMSE linear Equaliser). We use the MATLAB to show that the MMSE-DFE provide better performance with the increasing value of SNR in scattering environment.

Keywords— Equalization, Decision Feedback Equaliser, MMSE, Rician channel.

1. Introduction

The ultimate goal of digital communication [1][2] is the reliable transmission of information at the highest possible data rates. One major obstacle in achieving this goal is the inter symbol interference (ISI) and deep fades, increases with higher frequency selectivity, causing a corresponding increase in interference noise, imposed by the communication channel . The inter symbol interference[3] refers to the effect of neighbouring symbols on the current symbol and unless it is handled properly it can lead to high Bit Error Rates (BER) in the recovery of the transmitted sequence at the receiver. Decision feedback equalizers (DFE's) [4] can be used to combat the distortion of communication channels [5][6] because of their many advantages—even with severe and noisy channels, they can reach pretty good steady-state performance .Since the channels are unknown, the DFE must be implemented in an adaptive way.

There are various methods have been developed to increase the communications system performance by reducing the effects of the ISI. Linear equalization i.e. MMSE and Non-Linear i.e. DFE are the major

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attempts in this direction. A classical adaptive DFE receiver ‘learns’ the ISI, using minimum mean square equalizer (MMSE) [7][8] algorithm, to update the forward and backward filter coefficients.

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. A minimizes mean square error-linear equalizer (MMSE-LE) [9] minimizes the error between the received symbol and the transmitted symbol without enhancing the noise. Although MMSE-LE performs better, but its performance is not enough for channels with severe ISI. An obvious choice for channels with severe ISI is a non-linear equalizer

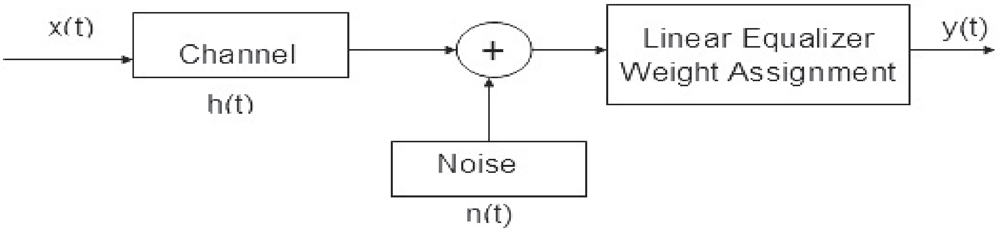

Fig.1. MMSE block diagram

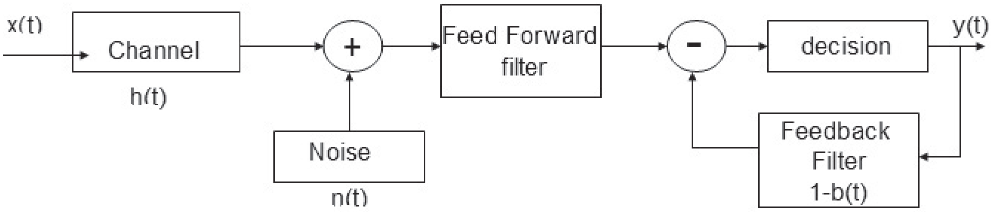

Fig.2. DFE block diagram

2. Minimum Mean Square Equalizer (MMSE)

The MMSE criterion minimizes the energy of the error at the decision point. The MMSE equalizer tries to minimize the mean squared error between its output and the appropriately delayed true symbol sequence. The advantage of using MMSE equalizers is the lower computation complexity compared with other equalizers only if the MMSE equalizer filter length[10] is smaller than the length of the channel impulse response. MMSE LE has the performance of the optimal bit error rate (BER) for long block lengths at high SNRs.

3. Decision Feedback Equaliser (DFE)

The Decision Feedback Equalizer (DFE) [11][12] (see Figure 2) consists of Feed forward Filters, Feedback Filters, and Decision Devices. Both the Feed forward and the Feedback Filters are usually realized as transversal finite impulse response (FIR) filters.

A decision feedback equalizer makes use of previous decisions [13] in attempting to estimate the current symbol. Any tailing ISI caused by a previous symbol is reconstructed and then subtracted. The DFE is inherently a non-linear device, but by assuming that all the previous decisions were correct, a linear analysis can be made. There are different variations of DFEs [14]. The choice of which type of DFE to use depends on the allowable computational complexity and required performance. The input to the feedback filter is the decision of the previous symbol (from the decision device).

4. Derivation of MMSE-DFE

Consider the development, where b_k and w_k are the feedback and feed forward filter coefficients derived in minimum-mean-square-sense, by making the error orthogonal to the received sequence. In Equation 1 represents the received signal as, y(t), the channel-input data symbols as, x_k, and the channel-impulse response as, h(t) where n(t) is additive-white Gaussian noise and T is the symbol duration

$$Y(t) = \sum (x_m.\ h(t-mT) + n(t)) \qquad (1)$$

$$Y_k = \sum (h_m.\ \ x_{k-} + n_k) \qquad (2)$$

The equalizer output error is expressed as

$$E_{\,k} = b^* x_{k,k-v} - w^* y_k + N_{f-1,k} \qquad (3)$$

Where v is expressed as channel memory

The w* feed forward filter taps are expressed as

$$W^* = [\, w^*_{-(Nf-1)}\ w^*_{-(Nf-2)}\ .....wo\ ] \qquad (4)$$

For a decision delay of Δ, the corresponding MMSE is expressed as

$$E\{|e_k|^2\} = E\{\, (x_{k-\,\Delta} - w\, Y_k + b\, x_{(k-1-\,\Delta)}) \,(x_{(k-\,\Delta)} - w\, Y_k + b\, x_{(k-\,\Delta\,-1)})^{\,*} \} \qquad (5)$$

where b is the vector of the coefficients for the feedback FIR filter and $x_{k-\Delta-1}$ is the vector of the data symbols in the feedback path.

Applying the orthogonal principle by making the error orthogonal to the output we get

$$E\{e_k.\ Y_k^*\} = 0 \qquad (6)$$

the optimum error sequence is uncorrelated with the observed data. This simplifies to Equation 7, which gives the relation between the DFE feedback and feed forward filter coefficients

$$B^* R_{xy} = w^* R_{yy} \qquad (7)$$

The FIR MMSE-DFE [15] autocorrelation matrix is expressed as

$$R_{yy} = (\, E\{\, Y_{(k+Nf-1,k)}\, Y^*_{(k+Nf-,\,k)} \}\,) = s_x\, H H^* + R_{nn} \qquad (8)$$

Where $R_{nn} = N_0 I_{Nf}$ and where N_0 is the noise power, and where I is an identity matrix, the input-output cross-correlation matrix, where S_x is the signal power as expressed

$$R_{xy} = E\,[\, x_{(k,k-v)}\, Y^*_{k+Nf-1,k}] = S_x\,[\, O_{(v+1)(Nf-1\,)} ....\ I_{(v+1)}]^{\,H} \qquad (9)$$

The mean-square error is expressed in

$$(\, R_{xx} - R_{xy} R_{yy}^{-1} R_{yx}\,) = S_x\,[\, O\, I_{v+1}]\,[\, I_{Nf+v} - H^*\,(\, H H^* + 1 / SNR\ I_{Nf+v})^{-1} H\,]\,[\, 0\ ;\ I_{v+1}] \qquad (10)$$

The matrix inversion lemma is given by

$$H^*\,(\, H H^* + (\, 1 / SNR\,)\, I_{NF})^{-1} H = (\, H H^* + (\, 1 / SNR\,)\, I_{NF}\,)^{-1} H^* H \qquad (11)$$

Simplifying Equation 10 by using the matrix inversion lemma results in

$$S_x\,[\,O\,I_{v+1}\,]\,[\,I_{Nf+v}- H^*(H\,H^* +1/\,SNR\,I_{Nf+v}\,)^{-1}\,H\,]\;0\;;\,I_{v+1}]=No[oI_{v+1}](\,{}^*+1/SNRI_{Nf+v})-1\;[0\;;I_{v+1}] \qquad (12)$$

The middle term in the right-hand side of Equation 13, is defined as a Cholesky factorization, where LDL' is the Lower-Diagonal-Upper.

$$R_{xx}^{-1}+ H * R_{nn}^{-1}\,H = (R_{xx}- R_{xy}\,R_{yy}^{-1}\,R_{yx})^{-1} = (1\,/\,SNR)\,I_{Nf+v} + H * H = LDL^* \qquad (13)$$

Where **L** is a lower-triangular monic matrix, **D** is a diagonal matrix. **L** is a monic matrix, its columns constitute a basis for the (N_{f+v}) dimensional vector space. When the feedback coefficients are located, the solution expressed in Equation 14, gives the optimal setting for **w**, the feed forward coefficient i.e.

$$w^*_{opt} = b^*_{opt}\,R_{xy}\,R_{yy}^{-1} \qquad (14)$$

5. Results

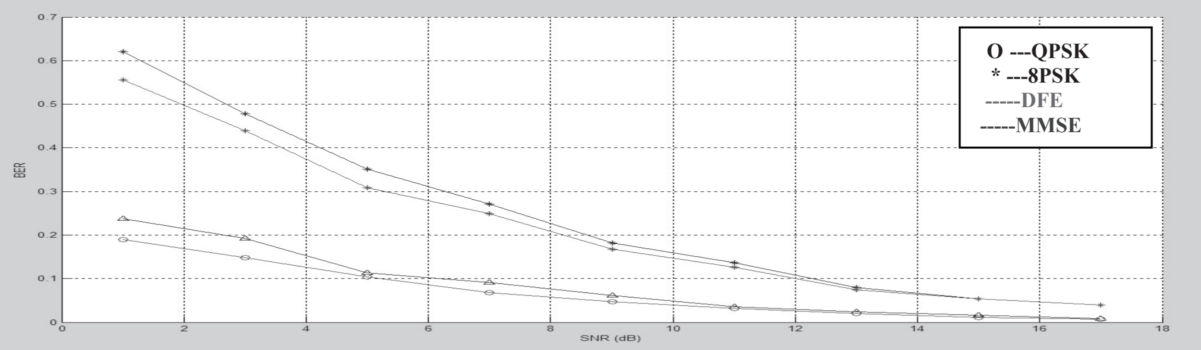

Fig.3. MMSE VS DFE FOR QPSK & 8PSK

Above figure shows the BER performance of Linear MMSE and MMSE-DFE. As in figure the QPSK modulation provide better performance with respect to 8-PSK digital modulation and also we find that at low SNR value MMSE-DFE provide much better BER performance in comparison to that of linear MMSE.

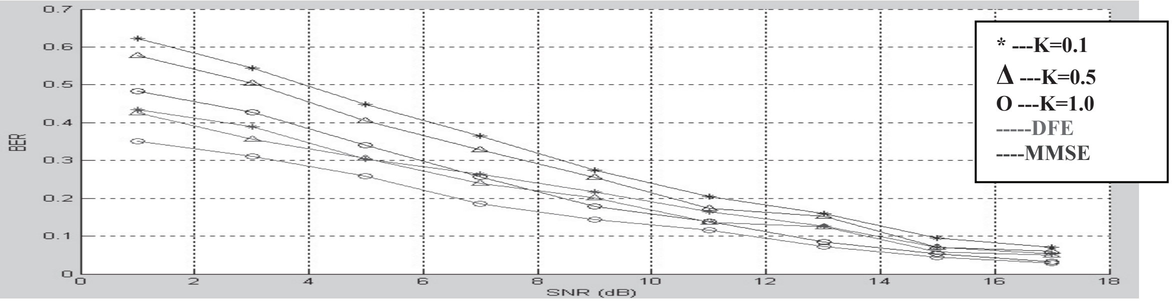

Fig.4: BER performance of MMSE and MMSE-DFE in Rician Channel.

Figure 4 depicts the performance analysis of MMSE-DFE and MMSE receiver in Rician channel condition. As we know that with the increase in fading parameter, k the channel condition becomes less destructive. Therefore as in figure 4 the BER performance of the receiver gets better in higher k. And also we find that MMSE-DFE provide better performance in comparison to that of MMSE receiver.

6. Conclusion

In wireless communication scenario design of proper receiver algorithm plays a vital role to enhance the system performance and also characterization of channel is very important for efficient receiver designing. In this paper, we have shown that MMSE based Non Linear equalizer (DFE) is better in comparison to that of the Linear equalizer (MMSE) (shown in **Fig.3, 4**) in different scattering environment. So Non-Linear equalizer (DFE) can be used for reducing BER and minimizing ISI in contrast to Linear Equalizer (MMSE LE).

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