Design And Implementation Of Decision Feedback Equalizers For Frequency Selective Channes

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Abstract- *This paper presents an approach combining the decision feedback mechanism and successive signal detection to equalize frequency selective channel effects for signals traversing different run-lengths. In this approach, the errors on comparison between the transmitted signal and received signal are fed to the equalizer to adjust the tap weights. Still the irreversible nature of inter symbol interference is a huge challenge due to multi path propagation mechanisms in wireless channels. It is a common observation that signals traversing a smaller path reach the receiver earlier compared to the multi-path component traversing a longer path. Assuming similar shadowing effects, it is seen that fading effects make it difficult to accurately receive long distance MPCs, thereby degrading the BER performance. It has been shown that the proposed system attains almost similar BER performance irrespective of the shadowing effect or run length of the MPCs. An analysis of outage probability with respect to SNR has also been shown.*

Keywords- Multi Path Component (MPC), Inter Symbol Interference (ISI), Decision Feedback Equalizer, Successive Signal detection, Bit Error Rate (BER), Probability of Error.

I. INTRODUCTION

Multipath propagation in frequency selective channels result in severe BER degradations due to the following reasons:

a) Non-Uniform signal strength of the received signal due to small scale fading
b) Inter Symbol Interference (ISI) due to reception of multiple copies of the transmitted signal at the receiver
c) Frequency Selective Nature of practical wireless channels.
d) Doppler Shifts corresponding to movement of transmitter or receiver or both.

To mitigate the above mentioned challenges, it is necessary to design equalizers for wireless cannels. One of the most potent and effective techniques for equalizer design is the Decision Feedback Equalizer (DFE).

The aforesaid condition can be understood as:

The main challenge of communication is multipath and other additive interferers. The distortion caused by an analog wireless channel can be thought of as a combination of scaled and delayed reflections of the original transmitted signal. These reflections occur when there are different paths from the transmitting antenna to the receiving antenna. The strength of the reflections depends on the physical properties of the reflecting objects, while the delay of the reflections is primarily determined by the length of the transmission path.

Let u(t) be the transmitted signal. If N delays are represented by A_1, A_2, A_3, A4...A_N and the strength of the reflections is a_1, a_2, a_3, a_4,a_N then the received signal y(t) is given by:

$$y(t) = a1u(t-A1)+ a2u(t-A2)+ \ldots\ldots\ldots+ aNu(t-A_N)+n(t) \quad (1)$$

Where n(t) represents additive interferences. This model of the transmission channel has the form of a finite impulse response filter, and the total length of time AN - A1 over which the impulse

Response is nonzero is called the delay spread of the physical medium.

This transmission channel is typically modeled digitally assuming a fixed
sampling period T_s. The above expression can be approximated as:

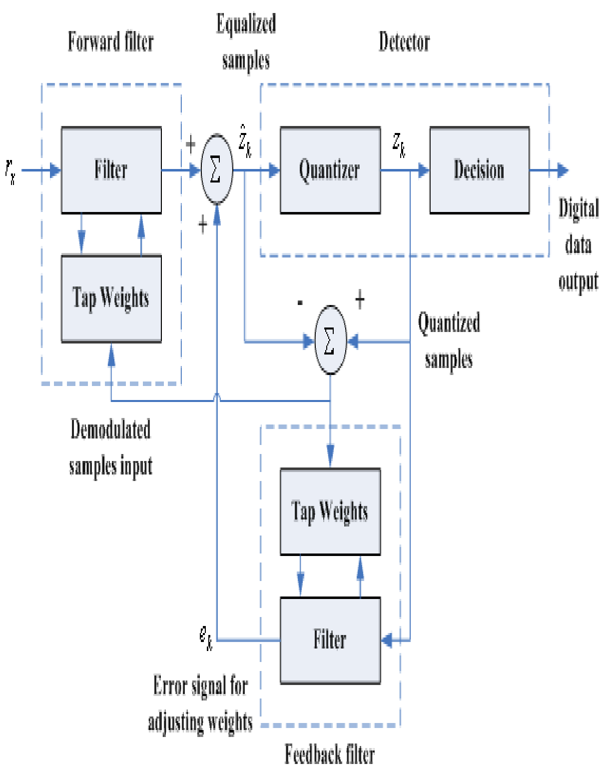
$$y(kTs)=a1u(kTs)+a2u((k-1)Ts)+\ldots\ldots+aNu((k-n)Ts)+n(kTs) \quad \ldots\ldots\ldots(2)$$

The total time over which the impulse response is nonzero (the time pT_s) must be at least as large as the maximum delay A_N .Since the delay is not a function of the symbol period T_s, smaller T_s require more terms in the filter, i.e., larger n.

II. SYSTEM IMPLEMENTATION OF DECISION FEEDBACK EQUALIZER (DFE)

The implementation of a DFE is shown below.

The above cited approach uses decision feedback to cancel the interference from symbols which have already have been detected. The equalized signal is the sum of the outputs of the forward and feedback parts of the equalizer. The forward part is like the linear transversal equalizer. Decisions made on the equalized signal are fed back via a second transversal filter. The basic idea is that if the values of the symbols already detected are known (past decisions are assumed correct), Then the ISI contributed by these symbols can be canceled exactly, by subtracting past symbol values with appropriate weighting from the equalizer output. Since the output of the feedback section of the DFE is a weighted sum of noise- free past decisions, the Feedback coefficients play no part in determining the noise power at the equalizer output. However, the DFE can compensate for amplitude distortion without as much noise enhancement as a linear equalizer. The DFE performance is also less sensitive to the sampler phase.

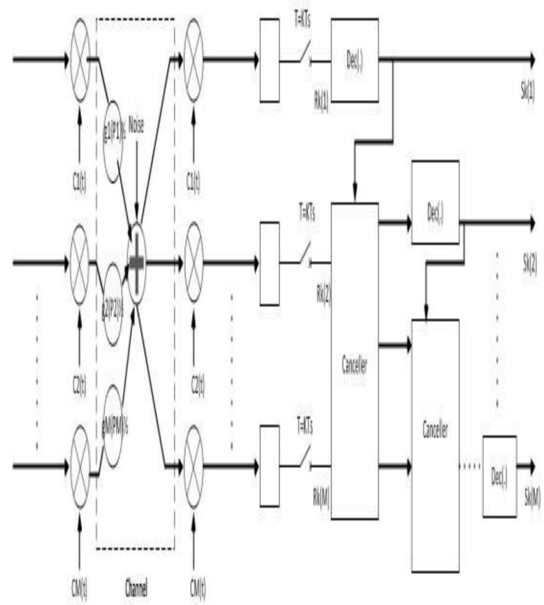


III. THE SUCCESSIVE SIGNAL DETECT- ION APPROACH

The successive signal detection approach can be understood by the diagram shown below:

This approach utilizes the fact that it is the easiest to detect the signal with the least run-length or the maximum power compared to all the signals arriving at the receiver. Hence the approach detects the signal with the maximum strength, saves it and cancels it from the composite signal arriving at the receiver.

This process is performed iteratively. It tries to emulate a single signal scenario among the multi-path scenario of different MPCs.



MATHEMATICAL MODELLING OF PROPOSED APPROACH

In light of the explained approach, it is necessary to derive its mathematical formulation which is given below:

The successive DFE equalization approach is an efficient technique of equalizing the received signal power and is capable of detecting different multi-path components

(MPCs) under varying signal strengths or BER conditions. The approach needs the following computations:

a) Individual signal strength of each MPC be given by:

$$S_i = g_i\sqrt{P_i} \qquad (3)$$

Where, S represents i^{th} MPC power,
'g' represents gain of the i^{th} path
P represents the power of the i^{th} MPC

b) The cross correlation of the spreading function applied on the data stream:

$$\text{Spreading Function} = R_i, j(k)$$

(c) The noise statistics for the k^{th}sample
i.e. $n_i(k)$

Thus the different MPCscorresponding to paths can be mathematically written as:

$$r_k = R_k . D . S_k + n_k \quad (4)$$

Where D represents the signal strength matrix corresponding to different MPCs given by:

$$S_i = g_i \sqrt{P_i} \quad (5)$$

The proposed algorithm can be explained as: Let the various MPC strengths be:

$S_1.G_1,\ S_2.G_2,\ S_3.G_3$................. $S_n.G_n$

It can be observed that the signal power of transmitter is zultiplied with the corresponding channel gain where the channel gain for different MPCs varies due to frequency selectivity of the channel.

Considering that we have the information about the signal strengths given by equation

$$P_1 {g_1}^2 > P_2 {g_2}^2 > \dots\dots\dots\dots\dots\dots\dots P_M {g_M}^2 \quad (6)$$

We decide the strongest among all the received user MPCs.

1. Detect the k^{th}strongest MPC among all the signals using the following equation:
S_k=dec$(P_i G_i)^M$

2. Cancel the first strongest MPC interference at the receiver end according to the equation:

$$y_{e+1}^{(i)} = y_e^{(i)} \_ g_e \sqrt{P_e} R_i, e(k) \hat{S}_k^{(e)} \quad (7)$$

Here we subtract the interference from the strongest interfering signal from each signal received at the receiver using the Decision Feedback actuating Signal $e(k)S_k^{(e)}$

3. let k=1, and repeat the above process for all the received signals up to k=M

Plot the BER performance for the proposed system for the following cases:

a) When there is only one signal travelling from transmitter to receiver
b) When a multi-path model has many MPCs with different run lengths and hence different phase shifts
c) MPC governed BER without proposed system
d) MPC governed BER with proposed system.

The system is said to exhibit equalizing effects only if the MPC governed BER performance matches to a large extent the one without multi path communication and hence no multi path propagation.

IV. RESULTS

The results obtained are shown below. Firstly, the BER performance of MPCs without the proposed mechanism is shown. Subsequently, the results employing the proposed mechanism are shown.

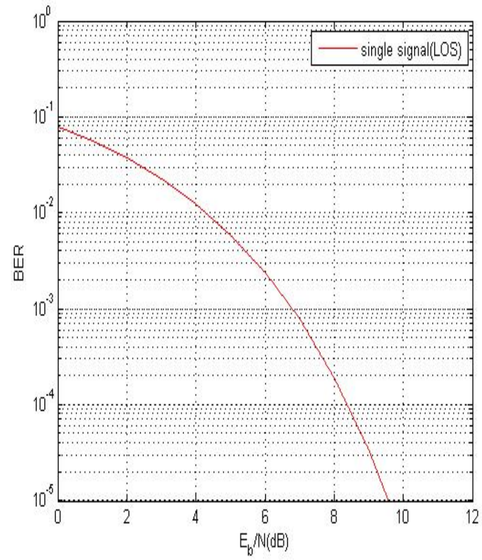


Fig.4 LOS BER condition

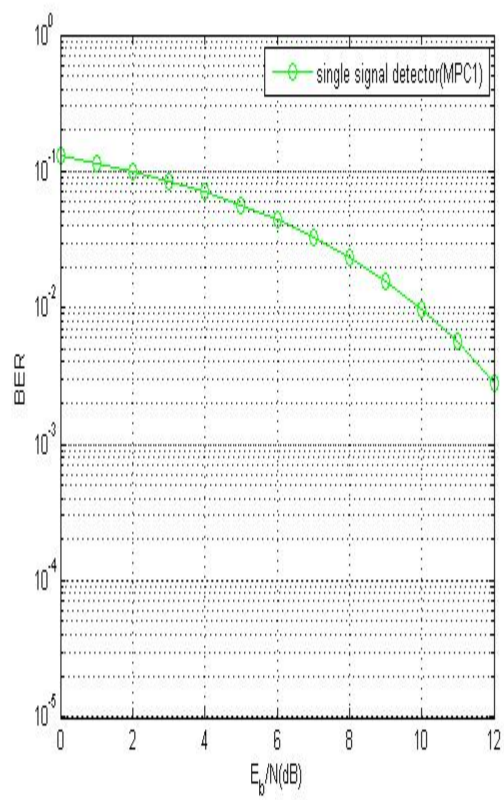


Fig.5 BER for MPC.1 without equalization

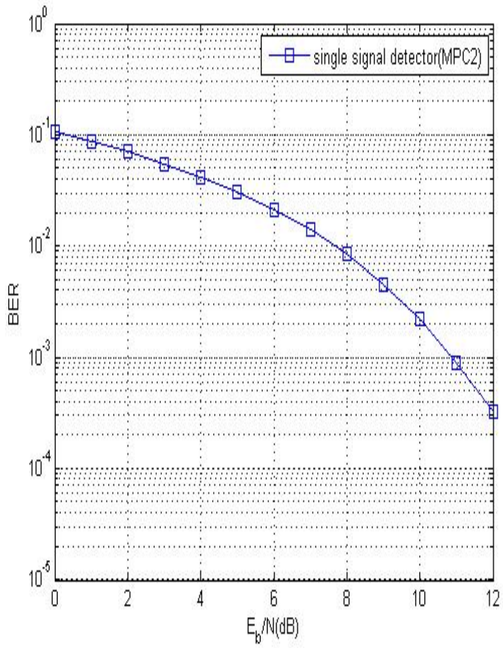


Fig.6 BER for MPC.2 without equalization

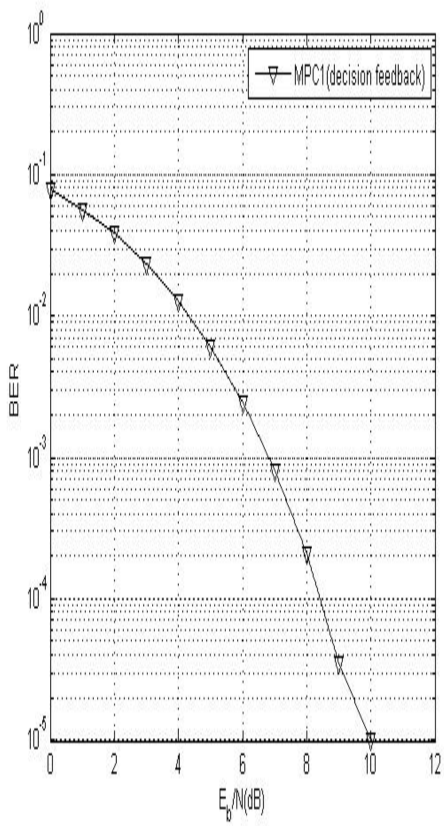


Fig.7 BER for MPC.1 with equalization

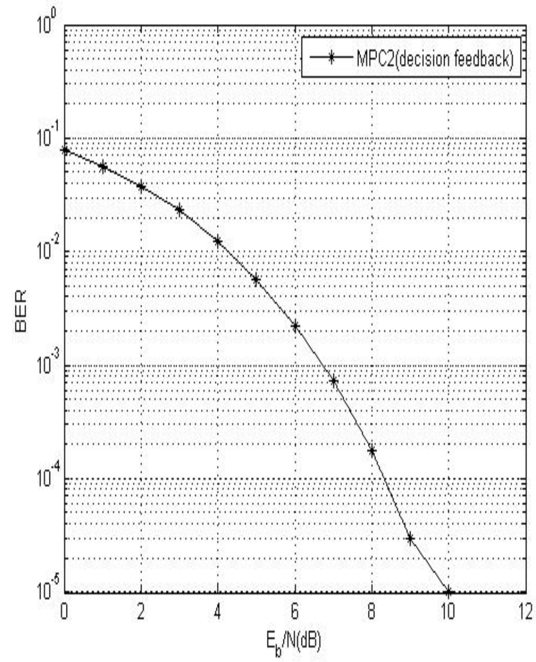


Fig.8 BER for MPC.2 with equalization

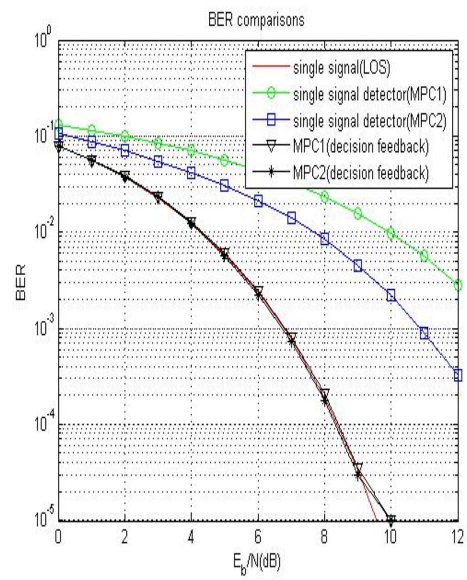


Fig.9 Comparative BER analysis

User Analysis	**BER**	**SNR required**
MPC1 with conventional Detection	10^{-2}	10dB
MPC1 with Proposed Algorithm	10^{-2}	4dB

MPC2 with conventional Detection	10^{-2}	7dB
MPC2 with Proposed Algorithm	10^{-2}	4dB
LOS	10^{-2}	4dB

Table 5.1 Comparative BER tabulation

V. CONCLUSION

It can be clearly seen from the graphs that different received signals corresponding to different users have different BER conditions. Table.1 renders insight into the working of the proposed technique. It can be seen that the BER falls much more steeply for MPCs 1 and 2 in case of the proposed DFE receiver compared to singular detection of the same signals. Therefore the proposed technique would need much less SNR boiling down to lower Signal Power to achieve same BER performance compared to conventional techniques. Conversely, the same SNR would result in much improved BER performance for the proposed technique compared to the conventional technique. Also it can be seen that the proposed technique achieves results almost similar to LOS scenario. It can also be seen that the outage probability decreases with increasing SNR for the system.

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