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A DECISION FEEDBACK EQUALIZER DESIGN WITH SUCCESSIVE SIGNAL DETECTION

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ABSTRACT

A unique approach has been presented in this paper 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. Yet the irreversible nature of inter symbol interference proves to be a big challenge due to multi path propagation techniques in wireless channels. It is observed commonly that signals traversing a comparatively smaller path reach the receiver earlier and quicker compared to the multi-path component traversing a longer path. Assuming similar shadowing effects, it is observed that fading effects make it hard to receive long distance MPC in an accurate manner, thereby degrading the BER performance. It has been clearly shown that the proposed system achieves almost similar BER performance irrespective of the shadowing effect or run length of the MPCs.

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

INTRODUCTION

Multipath propagation in frequency selective channels result in enormous BER degradations due to the reasons underlined below:'

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

To handle the aforementioned challenges, it becomes crucial to design equalizers for wireless cannels. One of the most potent and effective techniques for equalizer design is the Decision Feedback Equalizer (DFE). The above mentioned condition can be understood as:

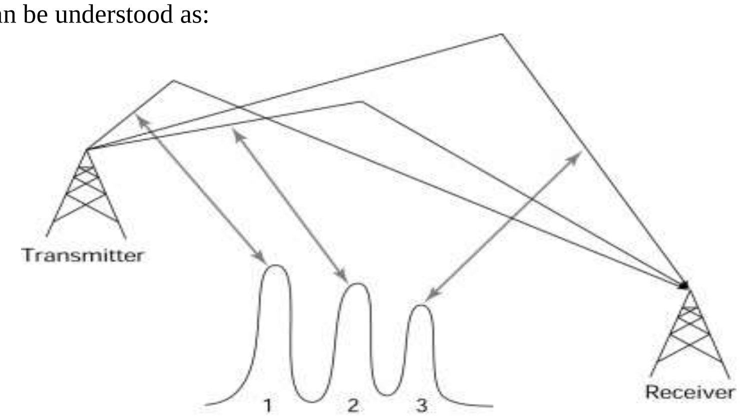

Fig.1 A Multipath Propagation Scenario

The principle challenge of communication is multipath and other additive interferers. The distortion caused due to analog wireless channel can be thought of as a combination of scaled and delayed reflections of the original

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transmitted signal. These reflections happen when there are various different paths from the transmitting antenna to the receiving antenna. The strength of the reflections is dependent on the physical properties of the reflecting objects, while the delay or lag of the reflections is chiefly 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 taken as a_1, a_2, a_3,.. , a_N then the received signal y(t) can be given by:

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

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 referred to as the delay spread of the physical medium.
This transmission channel is specifically modeled digitally assuming a fixed sampling period T_s. The above expression can be approximated as:

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

So it can be said that, 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 .As the delay is not a function of the symbol period T_s, smaller T_s needs more terms in the filter, i.e., larger n.

SYSTEM IMPLEMENTATION OF DECISION FEEDBACK EQUALIZER (DFE)

The implementation of a DFE is shown underneath.

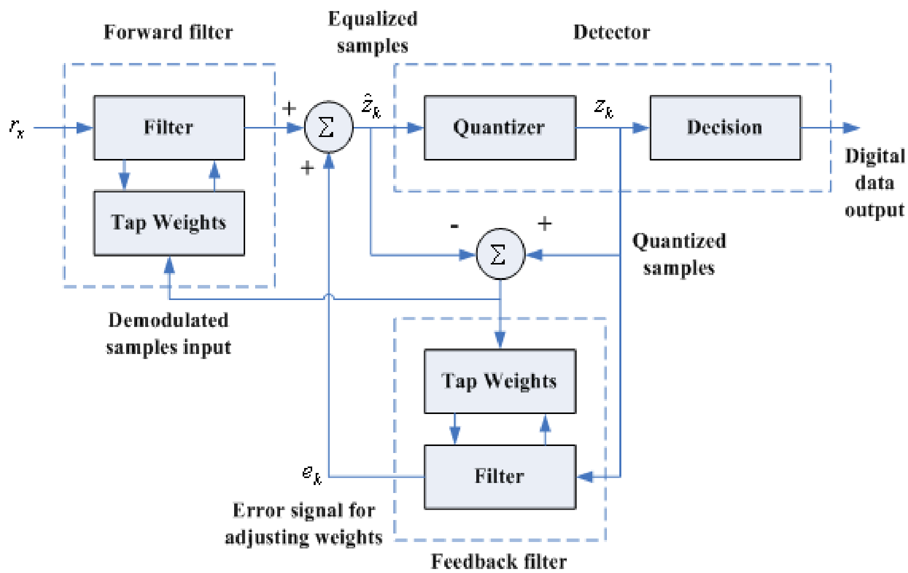

Fig.2 Block Diagram of a Decision Feedback Equalizer (DFE)

The aforementioned approach above makes use of decision feedback to cancel the interference from symbols which have been detected already. The equalized signal is the sum of the outputs of the forward and feedback parts of the equalizer. The forward part is akin to 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 have no part to play 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 relatively less sensitive to the sampler phase.

THE SUCCESSIVE SIGNAL DETECTION APPROACH

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

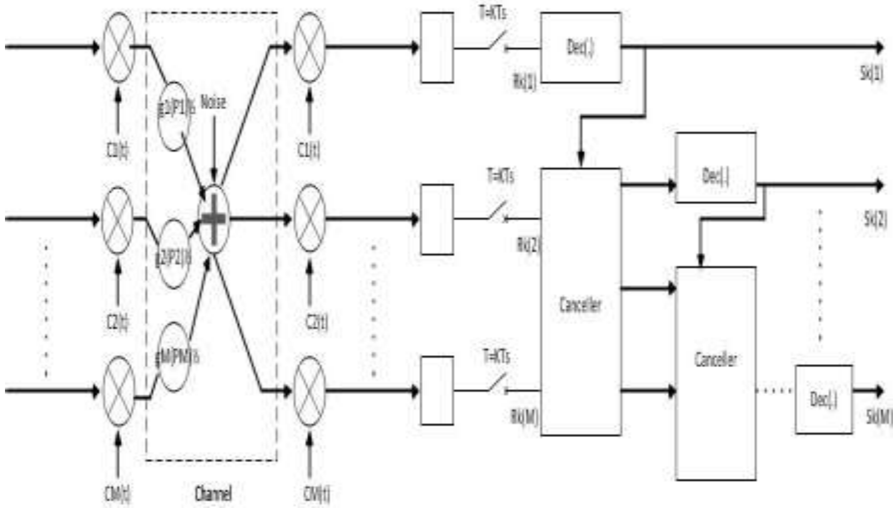

Fig.3 Successive Signal Detection Approach

This approach makes use of the fact that it is the easiest method to detect the signal with the least run-length or the maximum power in comparison 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 repeatedly. It tries to emulate a single signal scenario among the multi-path scenario of different MPCs.

MATHEMATICAL MODELLING OF PROPOSED APPROACH

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

The successive DFE equalization approach is an efficient and effective method 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 requires the following computations:

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

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

Where S stands for i^{th} MPC power,

'g' is taken as gain of the i^{th} path

P is 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. $n_i(k)$

Therefore the various MPCscorresponding to paths can be mathematically equated as:

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

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

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

The proposed algorithm can be elucidated 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 multiplied with the corresponding channel gain where the channel gain for different MPCs varies due to frequency selectivity of the channel.

If we take into consideration that we have the information about the signal strengths given by equation ,then

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

We then decide accordingly the strongest amidst the entire received user MPCs.

2. The k^{th}strongest MPC among all the signals using the following equation is detected and given by:

$$S_k = dec(P_i G_i)^M$$

3. the first strongest MPC interference is cancelled at the receiver end according to the equation underneath:

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

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

4. Then considering let k=1, and the process mentioned above is repeated for all the received signals up to k=M

Hence the BER performance is plotted successfully for the proposed system for the following cases:

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

The system is said to show equalizing effects only if the MPC governed BER performance matches to a great extent without multi path communication and therefore it results in no multi path propagation.

RESULTS

The results obtained are represented and shown below. Firstly, the BER performance of MPCs without the proposed mechanism is shown. Furthermore, the results implementing the proposed mechanism are shown.

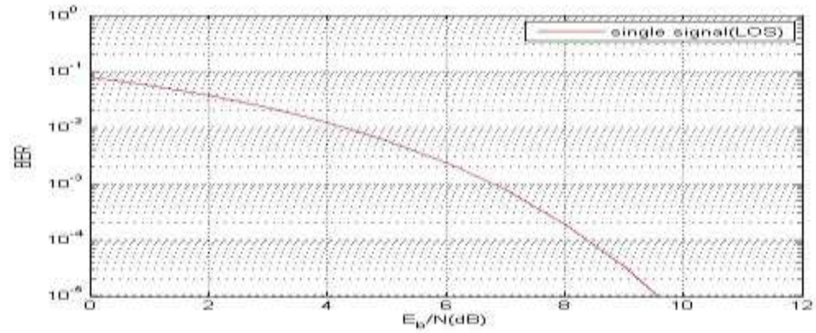

Fig.4 LOS BER condition

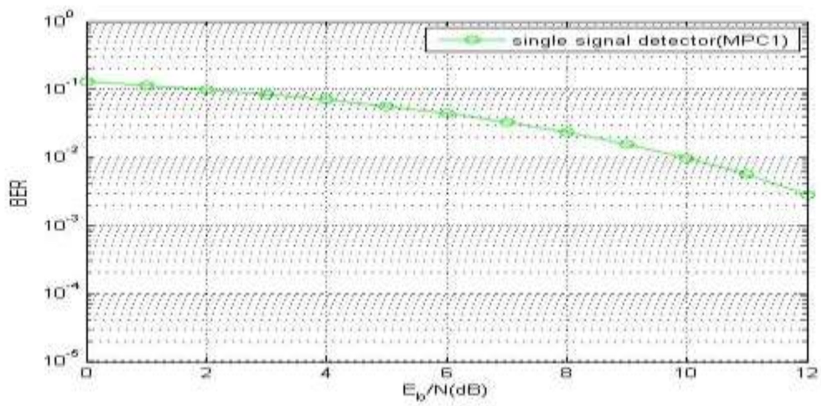

Fig.5 BER for MPC.1 without equalization

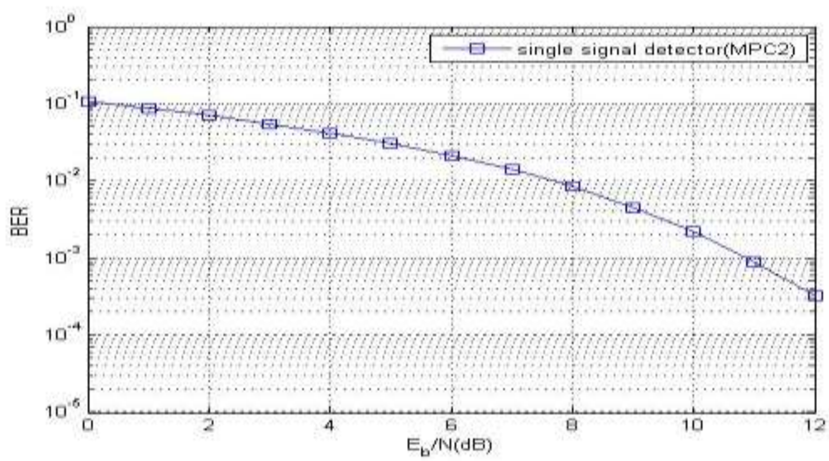

Fig.6 BER for MPC.2 without equalization

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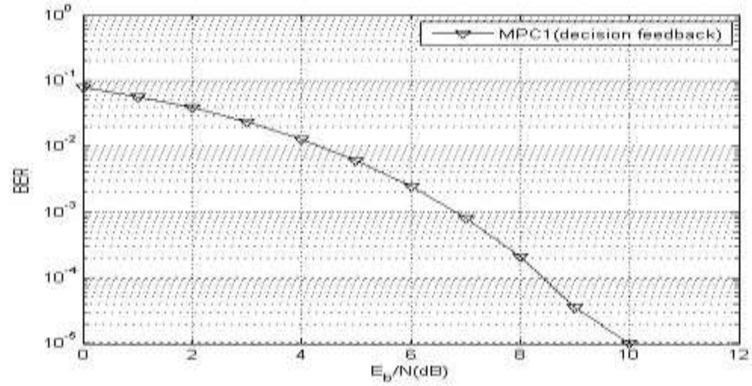

Fig.7 BER for MPC.1 with equalization

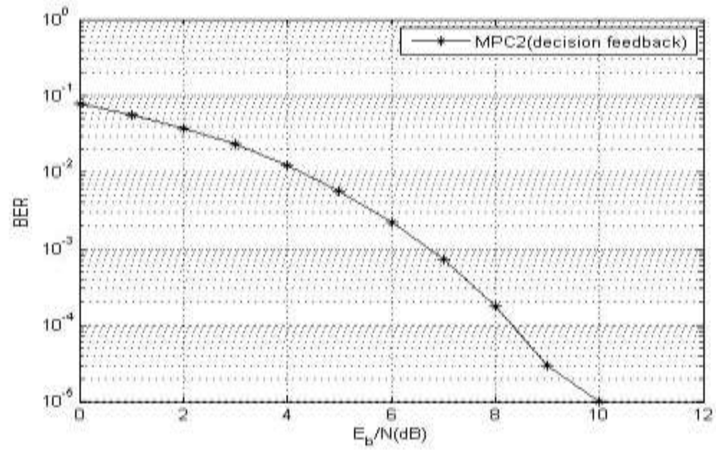

Fig.8 BER for MPC.2 with equalization

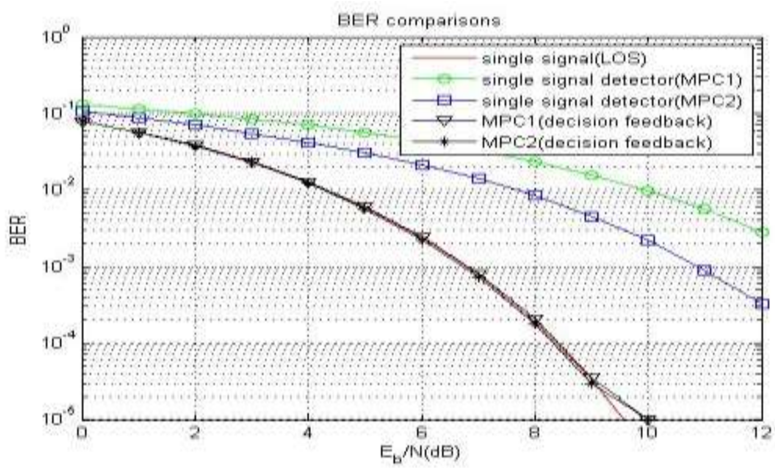

Fig.9 Comparative BER analysis

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 1 Comparative BER tabulation

CONCLUSION

Hence it can be clearly observed from the graphs that different received signals corresponding to different users have different BER conditions. Table.1 gives a useful insight into the working methodology of the proposed technique. It can be seen that the BER falls steeper for MPCs 1 and 2 in case of the proposed DFE receiver compared to singular detection of the same signals. So the proposed technique would require much less SNR boiling down to reduce Signal Power to obtain same BER performance with respect to conventional and existing techniques. On the contrary, the same SNR would result in a lot more improved BER performance for the proposed technique compared to the conventional method. Also it can be seen that the proposed technique acquires results almost similar to LOS scenario. So the proposed model proves be efficient and effective in all ways.

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