Design of Adaptive Equalizer For Frequency Selective Channels Using CSI

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Abstract*- Equalizer design is an extremely critical aspect for wireless networks. 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.*

Keywords- Multi Path Component (MPC), Inter Symbol Interference (ISI), Adaptive Equalizer, Channel State Information (CSI), 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 [1]:

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 [2].

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) [3]. The aforesaid condition can be understood as:

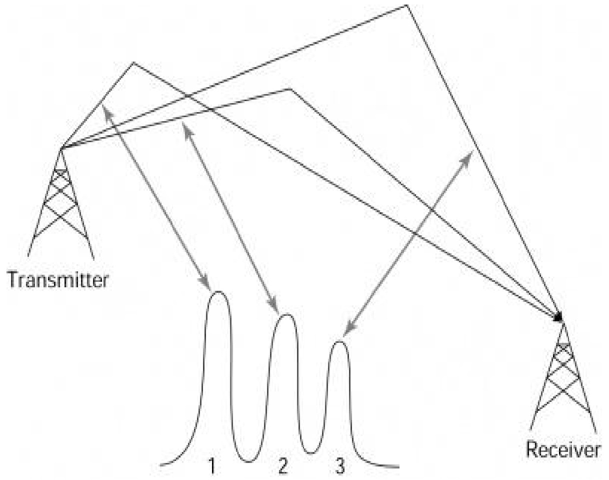

Fig.1. A Multipath Propagation Scenario

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 [4].

Considering x(t) be thetransmitted signal, If N coefficients are represented by A1,A2, A3, A4...ANand the strength of the reflections is a1, a2,a3,.. , aN then the weighted received signal y(t) is given by:

$$(t)=a1(t)+a2x(t-A1)+\ldots\ldots aNx(t-AN)(t) \qquad \text{--(1)}$$

Here,
n(t) represents additive interferences or noise effects.

Generally, the transmission channel is typically modeled digitally assuming a fixed sampling period Ts. Thus equation
can be approximated as:

$$(kTs)=a1(kTs)+a2u(k1Ts)+\cdots aNu(k-n)Ts+(kTs) \quad \text{--(2)}$$

Equation (2) assumes that the signal is sampled for every Tstime slot. The composite signal at the receiver needs to be separated in such a way that all users are detected with identical accuracy [5].

The variation of wireless channels are analytically modeled to evaluate their effects on transmitted signals that is required for radio resource management, capacity and coverage optimization. The metric which is generally considered to evaluate the performance of the system is the error rate. One of them a j or challenges which the multi user detection is 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 [6]. 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. It is profitable to obtain the without prior knowledge of the channel. The algorithms for equalizing unknown channels are alienated into the supervised mode in which a training or pilot sequence is transmitted that is known to receiver. Apparently training period uses portion of the available bandwidth and air time, and it might not be feasible and efficient in multi-user environments. In spite of resources wastage, supervised techniques are uncomplicated and assure success in convergence.

Based transmission faces is the reduction is power separation among signals due to fading and noise effects [7].

I. THE SUCCESSIVE SIGNAL DETECTION APPRAOCH

Frequency selective nature i.e. they behave differently for different frequencies. Moreover, the frequency selectivity is not fixed by also exhibits temporal variation [8]. This is depicted in figure2.

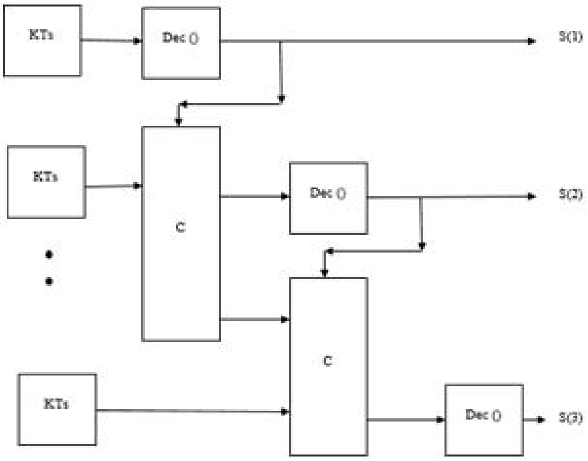

Fig.2.The conceptual model for successive signal detection

The figure contains the following blocks:
KTs: It is the sampling block which samples the signal every KTs seconds
C: It is the canceller block
Dec(c): It is the decoder block

The successive signal detection mechanism is an iterative algorithm for the separation of signals in the power domain. In this process, a multi-level comparison is made and the strongest signal is detected, stored and cancelled out from the composite signal. The detection starts with the strongest component and continues up-to the weakest component. Since different paths have different gains given by (g), the received

The noise effects are considered to be Gaussian with a constant two-sided power spectral density (psd) given by: Composite NOMA signal can be given by:

$$(t)= x1(t)g1+x2(t)g2+\cdots..(t)gn \qquad (3)$$

Here,
(t) is the received composite NOMA signal
(t) is the product of ‘nth’ transmitted signal with ‘nth’ path gain.

Typically the following cases would arise:

1) Near Users: The signals with the maximum path gains.
2) Average Users: The signals with intermediate or average path gains.
3) Far Users: The signals who have the least path gain.

Cancellation approach helps to detect the multiple signals separated in the power domain [11].

III. PROPOSED SYSTEM

The signals travelling through a wireless channel undergo the following detrimental effects:

1) *Multipath Propagation*
2) *Noise effects*

Multipath propagation makes the channel impulse response a weighted sum of impulses and also results in the interference effects at the receiving end [12]. The following composite impulse response can be considered for such a wireless channel:

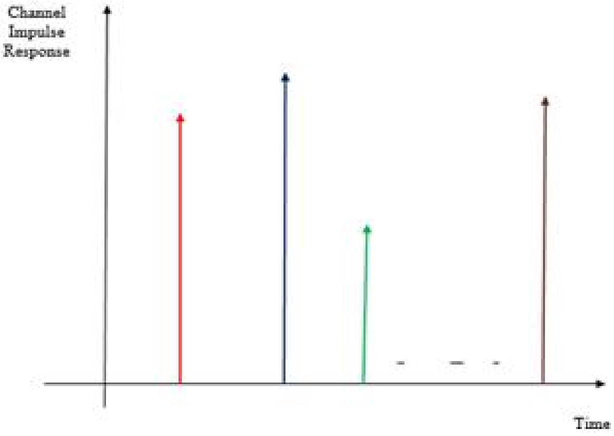

Fig.3.Weighted impulse response of the channel

Mathematically, the composite impulse response of the channel can be given by:

$$h(t)=\sum_{i=1}(t-irg_i) \qquad (4)$$

Here,
□(t)is the composite channel response
δ represents the impulse function
$gi$is the weight or gain of the ‘ith’ path
r is the delay in arrival of successive wave clusters due to multi-path propagation
N is the total number of impulses

Here,
psd
$noise$
$= \underline{N0}\,\nabla f{:}bandwidt$□ (5)
2

psd stands for the power spectral density
f stands for the frequency metric
N_0 is the one sided noise psd

The equalizer tries to nullify the effects of multi path propagation and noise effects. The equalization relies on the channel state information yielding the channel response (H).After obtaining the channel response (H), the inverse block is designed which is given by:

The different path gains actually arise out of the difference in

Here,
$E=\ 1$ _
H
(6) the path lengths of the different users located at different locations in the cellular network [9]-[10].The successive
E is the equalizer response
H is the sensed channel response

The decision feedback equalizer (DFE) is employed in this approach which is depicted in figure4.

It can be seen that without the proposed system, the BER of the strongest user falls steely while that for the average and far users fall slowly. This implies that the near users or the users with maximum path gain can be detected with maximum accuracy and the signal of the rest of the users would bear more errors. However, with the proposed approach, the BER curves of all the users coincide there by endering the condition of ideal error rate and reliability of detection for all user cases.

The BER performance of the proposed system has been listed in table I.

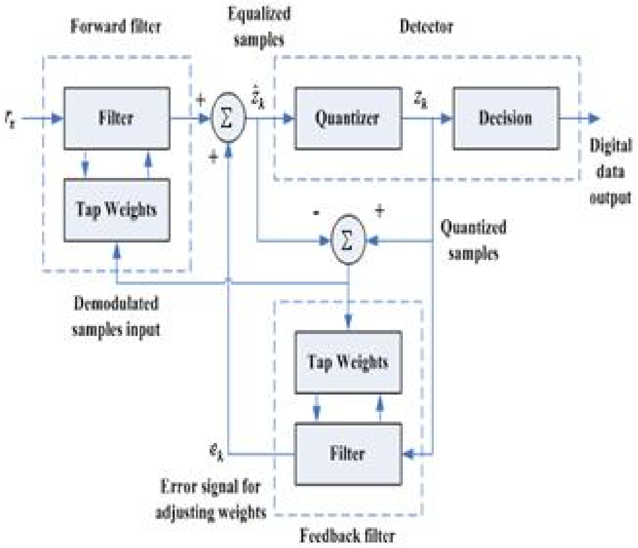

Fig.4.Blockdiagramofdecisionfeedbackequalizer

The decision feedback equalizer adjusts the tap weights of the filter based on the actuating or error signal that is generated on comparing the dummy data transmitted and its copy received at the receiving end. The filter weights are updated every Ts seconds. In general, the sampling time of the receiver employing successive signal detection and that of the decision feedback equalizer are kept identical.

Finally, the detection of the signals at the receiving end is done based on the following conditions:

TABLE-I

PERFORMANCE ANALYSIS OF DIFFERENT BER FORDIFFERENTCONDITIONS

S.No.	BER	SNR	Case
1	10^{-1}	0dB	Strongest User
2	10^{-1}	0dB	Weakest User without Proposed System
3	10^{-1}	0dB	Weakest User with Proposed System
4	10^{-1}	0dB	Average User without Proposed System
5	10^{-1}	0dB	Average User with Proposed System
6	10^{-2}	4dB	Strongest User
7	10^{-2}	10dB	Weakest User without Proposed System
8	10^{-2}	4dB	Weakest User with Proposed System
9	10^{-2}	8dB	Average User without Proposed System
10	10^{-2}	4dB	Average User with Proposed System
11	10^{-3}	7dB	Strongest User
12	10^{-3}	N.A.	Weakest User without Proposed System
13	10^{-3}	7dB	Weakest User with Proposed System
14	10^{-3}	11dB	Average User without Proposed System
15	10^{-3}	7dB	Average User with Proposed System
16	10^{-4}	8.2dB	Strongest User
17	10^{-4}	N.A.	Weakest User without Proposed System
18	10^{-4}	8.4dB	Weakest User with Proposed System
19	10^{-4}	N.A.	Average User without Proposed System
20	10^{-4}	8.2dB	Average User with Proposed System
21	10^{-5}	8.7dB	Strongest User
22	10^{-5}	N.A.	Weakest User without Proposed System
23	10^{-5}	10dB	Weakest User with Proposed System
24	10^{-5}	N.A.	Average User without Proposed System
25	10^{-5}	10dB	Average User with Proposed System

Here,

$(Ts)=\sum i=1(Ts)$

(7)

Yn is the composite received signal.

Xnrepresents the individual signals.

$Ts$is the sampling time

The signals are detected from strongest to weakest as:

yk= max $((Ts)$ (8)

Thus, y k

is the strongest signal detected. It is stored and cancelled from the composite signal.

$y^1 = (Ts) - yk$ (9)

Here,

y^1 denotes the cancellation of the strongest after the first iteration. This process is continued iteratively till all the signals are detected.

IV. SIMULATION RESULTS

The simulations are carried out for three cases:

1) Strongest User without t proposed system
2) Average User without proposed system
3) Average User with t proposed system
4) Weak User without proposed system
5) Weak User with proposed system

The BER curves for the different conditions are shown:

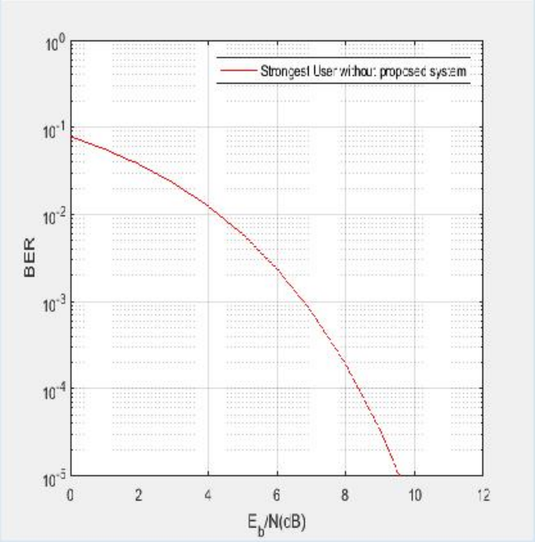

Fig.5. Strongest user without proposed system

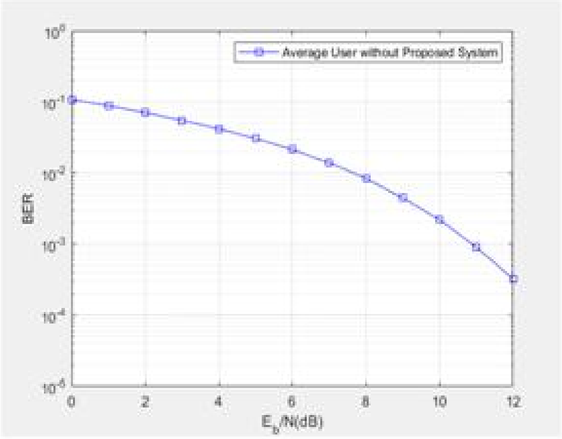

Fig.6. BER Analysis for Average User without proposed system.

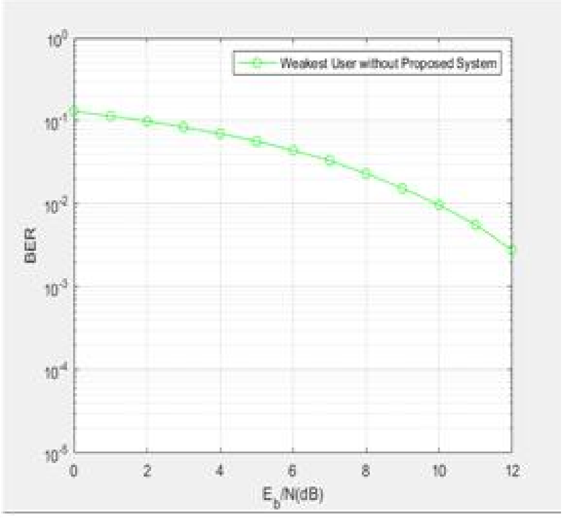

Fig.7. BER Analysis of Weakest User without proposed system.

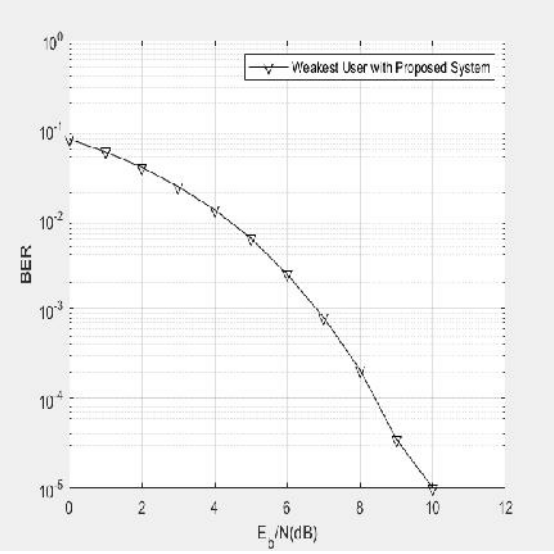

Fig.8. BER Analysis of Weakest User with proposed system.

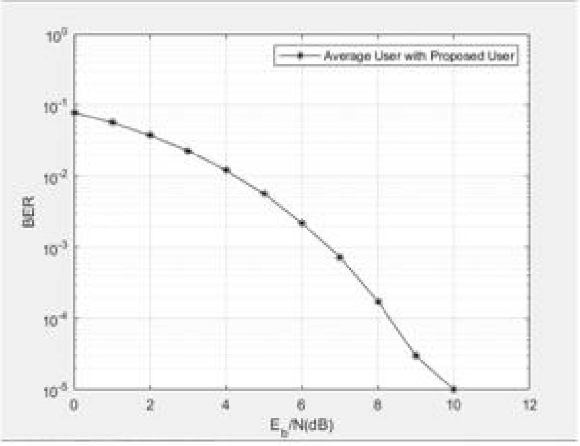

Fig.9. BER Analysis of Average User with proposed system.

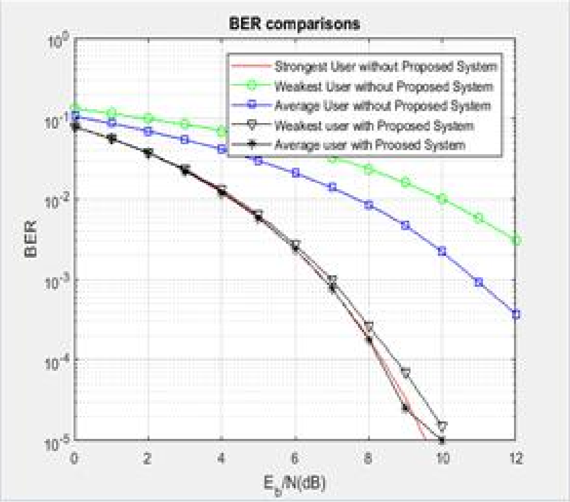

Fig.10.Comparative BER Analysis of Proposed System for all user cases.

The comprehensive evaluation of the BER for the various cases and conditions has been analyzed. The simulation of BER has been operated for 10-1 to 10-5. The analysis could be obtained only for up-to 10-5 as surpassing that value yielded relatively lower standards of communication quality in accordance with the Shannon's limit. It limits usually takes into account the errors for a BER range of 10^{-5} to 10^{-6} as negligible. The range of SNR has been selected as (0-12) dB attributing to the fact that there is convergence of the BER at around 10dB. The term N.A here refers to not applicable and is generally refers to the case where it can't reach the particular BER value in the specified range of SNR. A comparative analysis based on graphical and tabular representation also represents an evaluation of the proposed system that legibly illustrates that after the implementation of the system proposed; the BER obtained for average and weak receivers is almost similar with respect the strong user's at SNR ranges which are identical. That infers achieving better and improved Quality of Service for the NOMA systems that have been deployed.

V. CONCLUSION

The can be distinctly observed from the graphical illustrations that different signals at the receiving end users carry different BER conditions. Table-1 enlists the BER values and corresponding SNR requirements for the different cases. It is well observed that the BER fall is steeper for MPCs 1 and 2 considering the proposed receiver signal in comparison to the identical signals with singular type detection. Henceforth theintended technique required lesser SNR that infers reduced Signal Power to attain same BER performance metric compared to the conventional methods. Contrarily, the similar SNR value would give a lot more improved performance of BER for the technique proposed in comparison to the traditional mechanisms. It can also be seen that for the proposed method the probability of outage considerably lessens within crease in the SNR value suggesting better performance.

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