Analysis of Code Aided MMSE Receiver for Transceiver Impairments and Multiple Access Interference in CDMA Systems over Rayleigh Fading Channels

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Abstract: ***This paper deals with the method to study and improve the interference due to transceiver impairments which occurs due to the some impairments at transmitter and receiver end and other interference such as Multiple access interference sharing of resources like narrow bandwidth and spectral bandwidth in Rayleigh fading channels. Fading is major source of impairment in wireless communications because of the propagation environment. There are various techniques to mitigate these types of interferences, here the CODE AIDED MMSE detector is considered as this technique results in better interference rejection than linear MMSE detector.***

Keywords: CDMA (Code division multiple access), MMSE (Minimum mean square error), MAI (multiple access interference), QPSK (quadrature phase shift keying), QAM (quadrature amplitude modulation), SIR (signal to interference ratio), Rayleigh fading channels, Transreceiver impairments.

1. Introduction

Communications is one of the most active areas of research for technology enhancement of current times. Videos, images, text and data can be transmitted with its development. As a result of its progress, the demand for transmitted power and bandwidth is increasing. But these two resources are severely limited in the deployment of modern wireless networks. Recently, it was shown that transceiver hardware impairments also have a detrimental impact on the performance of communication systems especially for high–rate systems. So current effort in recent years is aimed at developing new wireless capacity through the deployment of greater intelligence in wireless networks.

To obtain maximal benefit from these transmission techniques, advanced receiver signal processing techniques such as channel equalization, and multi-user detection to mitigate multiple access interference are deployed. Here, rejection of interference by CODE AIDED MMSE criterion is used. It is applied to fading channels and is found to suppress narrowband and multiple access interference.

And why the approach has been shifted to CODE AIDED MMSE receiver will always be a concern this is because when previous research has been studied and analysed which analysed the performance of convolutionally coded CDMA system with MMSE receiver for interference suppression showed that lower rate codes are not always the best choice on Rayleigh fading channels. CODE AIDED MMSE receiver has also been a better option to avoid the interference due to hardware present in the communication systems.

2. Block Diagram

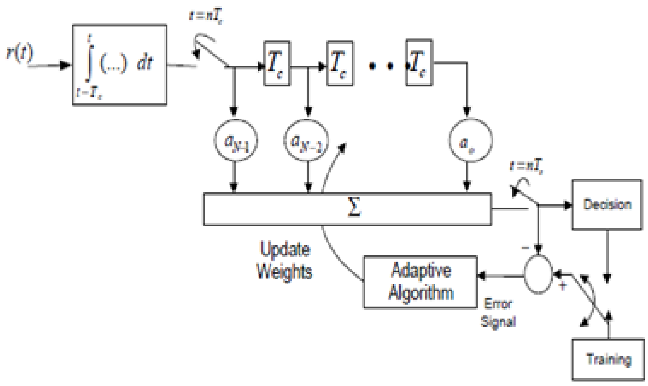

Figure 1: The MMSE receiver structure

Traditionally, higher level modulation has been used to achieve higher bandwidth efficiency. To understand the advantages of the MMSE receiver, we need to describe briefly how it works. The received signal which consists of the desired user's signal, MAI, and Gaussian noise is fed at the chip rate into the equalizer until the N-tap delay line becomes full. After one symbol time, the equalizer content are correlated with the tap weights, **a**, and the result of this correlation is used to make a decision about which symbol was sent. These tap weights are updated every symbol interval to minimize the mean square error between the output of the filter and the desired output. In practice, the filter is trained for a reasonable period of time by a known training sequence to reach a tap weight vector that is close to the optimum weights.

3. Mathematical Analysis

The MMSE linear detector under the effect of interfering data signals has a bank of filters matched to the pulse shape of all users followed by symbol-rate samplers and IIR digital filter as shown in Fig.2.

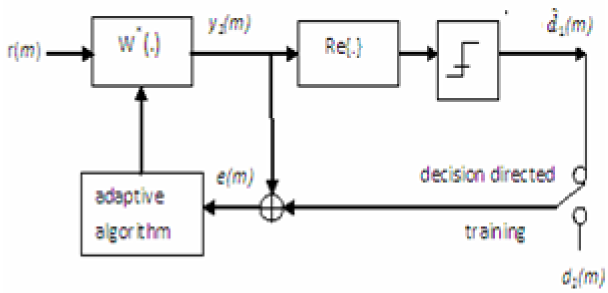

Figure 2: Block Diagram of MMSE Receiver.

The channel output is sampled at the chip rate, and an *N*_tap adaptive FIR filter is used to minimize the mean squared error (MSE) between the transmitted and detected symbol. The detector can be implemented as an infinite-length fractionally spaced tapped-delay line. Even in the chip- and symbol-asynchronous situation, the *N*_tap MMSE detector has a far better performance than the matched filter.
There are three parameters, which are measures of the performance of the linear MMSE detector. These are Mean Square Error (MSE), Signal to Interference Ratio (SIR) and error probability. Factor γ has been introduced for analysis of the effect of fading on the system performance.

$$\alpha = \gamma\sqrt{\frac{Eb}{N}} \quad (1)$$

The code aided MMSE receiver is based on the decomposition of the linear detector as

$$c = s + x \quad (2)$$

$$\text{and } w = c + x \quad (3)$$

where s is the signature sequence of the user and the other is the orthogonal and adaptive component.
It is under the condition

$$s^T x = 0 \quad (4)$$

$$\text{SIR} = [1 - \tfrac{1}{N}]\,\frac{\gamma^2 P_S}{\sigma^2} \quad (5)$$

equation (5) gives the SIR for MAI only when transreciever impairements are not being considered.

Where

α is the SNR of received signal
γ is the fading parameter
E_b is the bit energy
P_s is the signal power
N is the processing gain
σ is the covariance of noise

on the same above lines if we consider the transciever impairments in analysis of Code Aided MMSE receiver

$$\text{SIR} = [1 - \tfrac{k}{N}]\,\frac{\gamma^2(P_S + N/K_j + \sigma)}{\sigma^2} \quad (6)$$

where
k is the transciever impairment factor

4. Results

Figure 3 shows the plot between Signal To Interference Ratio (SIR) Vs Signal Power (Ps) for different values of Fading Parameter γ**.** According to equation 5 as the N (processing gain) increases SIR decreases and the interfering energy almost suppresses. And as signal power P_S increases the SIR increases. And SIR is also directly proportional to Fading Parameter γ. Higher the value of γ more is the SIR. For 3 values of γ i.e. 0.8, 0.6 and 0.4, γ = 0.8 has highest value of SIR than γ = 0.6 and γ =0.4 respectively.

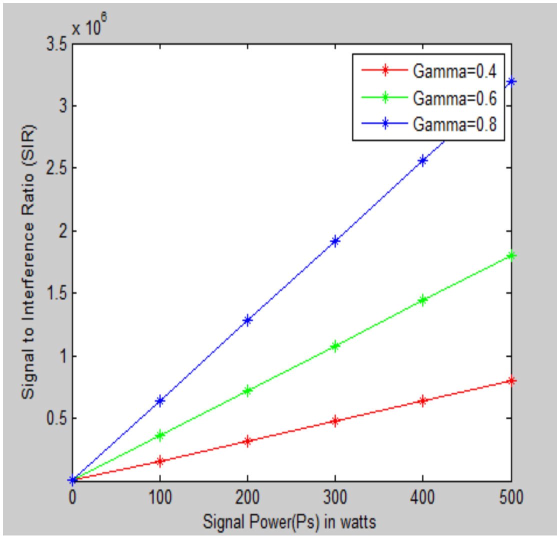

Figure 3: Signal To Interference Ratio (SIR) Vs Signal Power (Ps) for different values of Fading Parameter γ for MAI

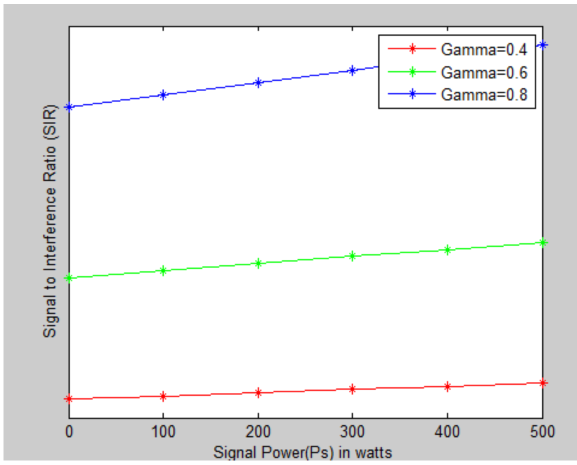

Figure 4: Signal To Interference Ratio (SIR) Vs Signal Power (Ps) for different values of Fading Parameter γ with k the transceiver impairment factor

Figure 4 shows the plot between Signals to Interference Ratio (SIR) Vs Signal Power (Ps) for different values of Fading Parameter γ with transceiver impairment factor k. According to equation 6 k is directly proportional to SIR.

5. Conclusion

Due to transceiver impairment factor the Sir which is to be 0 beyond 0 has some value beyond 0 also, these interferences are not advisable for the wireless communication systems so linear Code Aided MMSE receiver are the better option to mitigate all these type of interferences. For code aided MMSE receiver, there is an improvement in rejection of interference up to the extent of 10% this is because as the N (processing gain) increases SIR decreases and the interfering energy almost suppresses.

Suppose a code aided MMSE based CDMA system is operating using a modulation format such as QPSK. As the loading of the system increases, at some point, the MMSE receiver eventually becomes interference limited. This threshold in the number of users is reached because of imperfect suppression of the multiple access interference (MAI) due to the fact that the processing gain does not provide the MMSE receiver with enough dimensions to suppress all the interfering signals. Since the receiver now is in the interference-limited region, SINR cannot be improved by simply increasing the transmitter power. This limitation can be overcome by increasing the processing gain (number of chips per symbols) by going to a higher order modulation format such as 16QAM. Doing so will move the code aided MMSE receiver from the interference-limited region and will allow the receiver to suppress the multiuser interference and hence will increase the capacity of the system.

Since the 16QAM modulation format needs a higher SINR to operate effectively, one can take advantage of the restored interference suppression capability of the code aided MMSE receiver and increase the transmitted power to achieve a desirable performance.

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