Performance Evaluation of Adaptive Minimum Mean Square Error in WCDMA

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Abstract

Multiple user interference and inter-symbol interference as obstacles in the multi-path reception technique is a challenge in performance of Rake receivers in Wireless Communication. Several rake receivers has designed to collect many resolvable path. Many types of Rake receiver implementation structures have been proposed towards to reduce the complexity for getting better performances in multi-path receivers by reducing the bit error rate (BER). MMSE Rake receiver with conventional and Genetic Algorithm also compared for the research. Adaptive MMSE Rake Receivers which performed better to decrease probability error of bit reduce the system cost; minimize the number of correlators, and small in size. Simulated using MATLAB software to display the system performance by reducing the BER. The proposed Adaptive MMSE receiver gives best performance and suitable for the environment. We have analyzed the performance of Adaptive rake receiver for WCDMA.

Keywords: MMSE Rake Receiver, BER, Genetic Algorithm, Conventional Algorithm, Adaptive MMSE Rake receiver.
1. Introduction

RAKE receiver utilizes multiple correlators to separately detect strongest multi-path components. Each correlator detects a time-shifted version of the original transmission, and each finger correlates to a portion of the signal, which is delayed by at least one chip in time from the other fingers. The outputs of each correlator are weighted to provide better estimate of the transmitted signal than is provided by a single component. The Rake receiver needs a large number of fingers and the computational complexity of the Rake receiver becomes high [1]. In addition, the Rake receiver must estimate a large number of channel impulse responses, thus computational complexity of channel estimation is very high. Inter symbol interference (ISI) is the major reason for erroneous reception of information in high speed wireless broadband communications. The use of adaptive equalization can reduce the effect of ISI significantly [2]. Equalization virtually produces an ideal channel through which voice, data and video can pass through and can be received without error. A more effective receiver scheme is the minimum mean square error (MMSE) Rake receiver [3] which achieves a much improved performance for WCDMA system.

BER is a very simple concept—its definition is simply as follows:

\[ BER = \frac{Errors}{Total \ Number \ of \ Bits} \]

With a strong signal and an undisturbed signal path, this number is so small as to be inconsiderable. It becomes so considerable when wish to maintain a acceptable signal-to-noise ratio in the existence of undeveloped transmission through electronic circuitry (filters, amplifiers, mixers, and digital/analog converters) and the propagation medium (e.g. optical fiber and the radio path).[4]

2. MMSE RAKE RECEIVER

We provide a complete optimization theoretical framework for the finger selection problem for MMSE SRake receivers. First, we formulate the optimal MMSE SRake as a non-convex, integer-constrained optimization, in which the aim is to choose the finger locations of the receiver so as to maximize the overall SINR. While computing the optimal finger selection is NP-hard, we present several relaxation methods to turn the (approximate) problem into convex optimization problems that can be very efficiently solved by interior-point methods, which are polynomial-time in the worst case, and are very fast in practice.
These optimal finger selection relaxations produce significantly higher average SINR than the conventional one that ignores the correlations, and represent a numerically efficient way to strike a balance between SINR optimality and computational tractability. Moreover, we propose a genetic algorithm (GA) based scheme, which performs finger selection by iteratively evaluating the overall SINR expression. Using this technique, near-optimal solutions can also be obtained in many cases with a degree of complexity which is much lower than that of optimal search.

3. MMSE RAKE RECEIVER WITH CONVENTIONAL ALGORITHM

Instead of solving the problem in [5], the “conventional” finger selection algorithm chooses the $M$ paths with largest individual SINRs, where the SINR for the $l$th path can be expressed as

$$\text{SINR}_l = \frac{E_1(\alpha_l^{(1)})^2}{(s_l^{(\text{MAI})})^T A^2 s_l^{(\text{MAI})} + \sigma_n^2}$$

for $l = 1, \ldots, L$.

This algorithm is not optimal because it ignores the correlation of the noise components of different paths. Therefore, it does not always maximize the overall SINR of the system given in [6]. For example, the contribution of two highly correlated strong paths to the overall SINR might be worse than the contribution of one strong and one relatively weaker, but uncorrelated, path. The correlation between the multipath components is the result of the MAI from the interfering users in the system.

4. MMSE RAKE RECEIVER WITH GENETIC ALGORITHM

The GA is an iterative technique for searching of the global optimum of a cost function [7]. The name comes from the fact, that these algorithm models display the natural selection and survival of the fittest [8]. The GA starts with a population of chromosomes, where each chromosome is represented by a binary string. Let $N_{\text{pop}}$ denote the number of chromosomes in this population. Then, the fittest $N_{\text{pop}}$ of these chromosomes are selected, according to a fitness function. After that, the fittest $N_{\text{good}}$ chromosomes, which are also called the “parents”, are selected and paired among themselves (pairing step), from each 5.
Although we consider only the binary GA, continuous parameters GAs are also available [7].

From all the chromosome pairs, two new chromosomes are generated; this is called the mating step. In other words, the new population consists of Ngood parent chromosomes and Ngood children generated from the parents by mating. After the mating step, the mutation stage follows, where some chromosomes (the fittest one in the population can be excluded) are chosen randomly and are slightly modified; that is, some bits in the selected binary string are flipped. After that, the pairing, mating and mutation steps are repeated until a threshold criterion is met. The GA has been applied to a variety of problems in different areas [7], [9]. Also, it has recently been employed in the multiuser detection problem [10],[11]. The main characteristics of the GA algorithm are that it can get close to the optimal solution with low complexity, if the steps of the algorithm are designed appropriately.

4.1 SIMULATION RESULTS OF MMSE RAKE RECEIVER WITH GENETIC ALGORITHM

We plot the SINR of the proposed suboptimal and conventional techniques for different numbers of fingers, where there are 50 multipath components and Eb/N0 = 20. The number of chips per frame, Nc, is set to 75, and all other parameters are kept same as before. In this case, the optimal algorithm takes a very long time to simulate since it needs to perform exhaustive search over many different finger combinations and therefore it was not implemented. The improvement using convex relaxations of optimal finger selection over the conventional technique decreases as M increases since the channel is exponentially decaying and most of the significant multipath components are already combined by all the algorithms. Also, the GA based scheme performs very close to the suboptimal schemes using convex relaxations after 10 iterations with Nipop = 128, Npop = 64, Ngood = 32, and 32 mutations.
Finally, we consider an MAI-limited scenario, in which there are 10 users with $E_1 = 1$ and $E_k = 10$ for $k = 1$, and all the parameters are as in the previous case. Then, as shown in Figure 3.4, the improvement by using the suboptimal finger selection algorithms increase significantly. The main reason for this is that the suboptimal algorithms consider (approximately) the correlation caused by MAI whereas the conventional scheme simply ignores it.

Fig 1 shows that an Average SINR versus number of fingers $M$. There are 10 users with each interferer having 10dB more power than the desired user, where $E_b$ is the bit energy. The channel has $L = 15$ multipath components and the taps are exponentially decaying. The IR-UWB system has $N_c = 20$ chips per frame and $N_f = 1$ frame per symbol. There are 5 equal energy users in the system and random TH and polarity codes are used.

Optimal and suboptimal finger selection algorithms for MMSE-SRake receivers in an IR-UWB system have been considered. Since UWB systems have large numbers of multipath components, only a subset of those components can be used due to complexity constraints. Therefore, the selection of the optimal subset of multipath components is important for the performance of the receiver. We have shown that the optimal solution to this finger selection problem requires exhaustive search which becomes prohibitive for UWB systems. Moreover, we have proposed a GA based iterative finger selection scheme, which depends on the direct evaluation of the objective function.
A feasible implementation of multipath diversity combining can be obtained by a selective-Rake (SRake) receiver, which combines the M best, out of L, multipath components [12]. Those M best components are determined by a finger selection algorithm. For a maximal ratio combining (MRC) Rake receiver, the paths with highest signal-to-noise ratios (SNRs) are selected, which is an optimal scheme in the absence of interfering users and inter-symbol interference (ISI) [13], [14]. For a minimum mean square error (MMSE) Rake receiver, the “conventional” finger selection algorithm can be defined as choosing the paths with highest signal- to-interference-plus-noise ratios (SINRs). This conventional scheme is not necessarily optimal since it ignores the correlation of the noise terms at different multipath components. The finger selection problem is also studied in the context of WCDMA downlink equalization.

5. ADAPTIVE (PROPOSED) MMSE RAKE RECEIVER

In this session we are comparing the Adaptive MMSE Rake receiver with Conventional Rake. Ultra wideband (UWB) is a new technology that has the potential to revolutionize wireless communication by delivering high data rates with very low power densities. Multiuser DS-CDMA detectors proposed in [15], for DS-CDMA can be extended to UWB communication, but the major drawback of these techniques is the very high computational complexity.

![MMSE Adaptive Algorithm receiver Block diagram](image-url)
We choose the IEEE UWB channel parameters to get the simulation result.

IEEE UWB channel parameters.

Table 1: IEEE UWB channel parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CM1</th>
<th>CM2</th>
<th>CM3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ray arrival rate, $\lambda$ (1/ns)</td>
<td>2.5</td>
<td>0.5</td>
<td>2.1</td>
</tr>
<tr>
<td>Cluster decay factor, $\Gamma$</td>
<td>7.1</td>
<td>5.5</td>
<td>14</td>
</tr>
<tr>
<td>Ray decay factor, $\Upsilon$</td>
<td>4.3</td>
<td>6.7</td>
<td>7.9</td>
</tr>
<tr>
<td>Std. dev. of cluster, $\sigma\zeta_s$ (dB)</td>
<td>3.3941</td>
<td>3.3941</td>
<td>3.3941</td>
</tr>
<tr>
<td>Std. dev. of ray, $s\sigma\xi_s$ (dB)</td>
<td>3.3941</td>
<td>3.3941</td>
<td>3.3941</td>
</tr>
<tr>
<td>Std. dev. of total MP, $\sigma g$ (dB)</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

5.1 SIMULATION RESULT OF ADAPTIVE (PROPOSED) MMSE RAKE RECEIVER WITH CONVENTIONAL RAKE

Simulations were carried out to evaluate and compare the bit error probability performance of the proposed adaptive MMSE Rake receiver in multipath channels with AWGN. The system for simulations considered in this paper is, synchronous WCDMA UWB with the following specifications. All users have equal power with gold sequence of spreading gain 31 as spreading code. Binary phase shift keying with sampling frequency of 50 GHz, chip time of 0.5 nsec and second derivative of Gaussian pulse of width 0.5 nsec used. Random binary data is generated for each user, the data is spread with the respective spreading code followed by modulation with second derivative of the Gaussian pulse. Each user undergoes a different UWB channel. Channel models CM1, CM2 and CM3 from IEEE P802.15 [16] are used. Channel model parameters are listed in the table 3.3. The number of multipaths is selected in such a way that 90 percent of the transmitted energy is captured. Proposed adaptive MMSE Rake receiver and conventional adaptive MMSE Rake (C-Rake) receiver use training signals of 500 bits followed by decision directed operation. Proposed MMSE Rake receiver does not require spreading code of any user, where as, it is assumed that C –Rake receiver knows spreading code of the user of interest.

Bit error probability is averaged over 500 realizations for each user with 2000 bits/channel. Initial value of $w = [0, 0, 0,...0]^T$ and $r = [0, 0, 0,...0]^T$. $\mu = 0.01$, and 0.001
gives best performance for C-Rake and proposed adaptive MMSE Rake receiver respectively.

To verify and investigate receiver performance bit error probability vs. $\frac{E_b}{N_0}$ for $K = 5$, $L = 10, 15$ and 20 is considered. Simulation results for CM1, CM2 and CM3 respectively. It shows that the proposed detectors BER performance is better than that of C-Rake receiver in all three channel models. It is observed that proposed detector gives better BER performance even for small number of Rake fingers ($L = 10$), where as for C-Rake receiver even for $L = 20$ BER performance is still inferior to proposed receiver. It is also observed that, for higher SNR ($> 6 \, \text{dB}$) proposed detector BER performance is much better than C-Rake receiver indicating that proposed detector has better MAI and multipath effect cancellation capability. Proposed detector gives an improvement of $2 \, \text{dB}$ at $10^{-2}$ BER, and substantial improvement for BER $< 10^{-3}$.

Fig 3.5, 3.6 and 3.7 shows simulation results for bit error probability vs. number of users with $\frac{E_b}{N_0} = 20 \, \text{dB}$ for CM1, CM2 and CM3 respectively. It is observed that the proposed detector performs much better than C-RAKE even for large number of users. This improved performance is once again attributed to the better MAI cancellation capability in multipath environment. The number of users supported by the above discussed detectors is summarized in Table 2.

<table>
<thead>
<tr>
<th>BER</th>
<th>$10^{-2}$</th>
<th>$10^{-3}$</th>
<th>$10^{-4}$</th>
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<tbody>
<tr>
<td>CM1</td>
<td>Proposed</td>
<td>17</td>
<td>11</td>
</tr>
<tr>
<td>C-Rake</td>
<td></td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>CM2</td>
<td>Proposed</td>
<td>17</td>
<td>11</td>
</tr>
<tr>
<td>C-Rake</td>
<td></td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>CM3</td>
<td>Proposed</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>C-Rake</td>
<td></td>
<td>7</td>
<td>4</td>
</tr>
</tbody>
</table>
In this session we have derived that the Adaptive MMSE Rake receiver for WCDMA UWB multipath channels and studied its BER performance in multiuser environment with AWGN. Simulation result shows that the BER performance of the Adoptive MMSE Rake receiver is much better in comparison with conventional MMSE Rake receiver. Proposed receiver given as improvement of 2 dB at BER of $10^{-2}$ and substantial improvement for BER $< 10^{-3}$ in all three channel models (CM1-CM3). Further, it offers significant improvement in MAI cancellation in multi-path channels. We have shown by simulation results that the number of users supported by the proposed receiver at BER of $10^{-3}$ with $E_b/No = 20$ dB is two times that of the conventional Rake receiver with the same computational complexity.

Finally the comparative analysis of the different types of rake receivers and the simulation result proved that the Adaptive MMSE Rake Receiver gives better environment for WCDMA. In this thesis we selected to develop the algorithm for Adaptive MMSE Rake Receivers.
6. Conclusion

MMSE adaptive algorithm is more efficient and powerful because of its ability and features of adaptation to the substantial changes in the UWB multipath wireless communication channel model proposed by the IEEE 802.15.3a. We have analyzed Adaptive MMSE Receivers and proved that the Adaptive MMSE Rake Receiver is suitable to develop the new algorithm for the environment. The Adaptive MMSE Rake Receiver gives better environment for WCDMA. The simulation Result also shows that Adaptive MMSE Rake receiver is much better in comparison with conventional MMSE Rake receiver. Hence we choose the same for the developing. In this paper it has been that BER performance of Adaptive MMSE Rake receiver for WCDMA UWB multipath channels in multiuser environment. After observing the result it is concluded that BER performance of the Adaptive MMSE Rake receiver is much better in comparison with conventional MMSE Rake receiver. Hence BER performance of Adaptive MMSE Rake receiver is most efficient and reliable for improving BER performance for WCDMA UWB multipath channels.

Reference


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