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Adaptive MMSE Rake Receiver for WCDMA

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---**ABSTRACT**---
Several types of Rake Receivers like A-Rake, S-Rake, P-Rake, Adaptive frequency Rake, Time frequency Rake, Conventional MMSE Rake and Adaptive MMSE rake are used for WCDMA. In this paper we observed that the BER performance of the Adoptive MMSE Rake receiver gives better result in WCDMA. The comparative analysis proved that the Adaptive MMSE Rake Receiver is much better than Conventional Rake Receiver. Both Genetic Algorithm (GA) and as well as Conventional algorithm are derived for WCDMA environment.

Key words: Adaptive MMSE Rake Receiver, Conventional Rake Receiver, Genetic Algorithm, Conventional Algorithm.

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1. Introduction

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 nonconvex, integer-constrained optimization, in which the aim is to choose the finger locations of the receiver so as to maximize the overall Signal-Plus-Interference-Noise-Ratio (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 be obtained in many cases with a degree of complexity that is much lower than that of optimal search.

2. MMSE Rake Receiver with Conventional Algorithm:

Instead of the solving the problem in [1], the "conventional" finger selection algorithm chooses the M paths with largest individual SINRs, where the SINR for the lth path can be expressed as

$$\mathrm{SINR}_l = \frac{E_1(\alpha_l^{(1)})^2}{(\mathbf{s}_l^{(\mathrm{MAI})})^T \mathbf{A}^2 \mathbf{s}_l^{(\mathrm{MAI})} + \sigma_n^2} \quad \text{…….. (1)}$$

for l = 1, . . . , 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 [2]. 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, paths. The correlation between the multipath components is the result of the MAI from the interfering users in the system.

3. MMSE Rake Receiver with Genetic Algorithm

The GA is an iterative technique for searching for the global optimum of a cost function [3]. The name comes from the fact that the algorithm models the natural selection and survival of the fittest [4]. We propose a GA (Genetic Algorithm) based approach to solve the finger selection problem, which directly uses the exact SINR expression and does not employ any relaxation technique in MMSE receiver. The GA is an iterative technique for searching for the global optimum of a cost function. The name comes from the fact that the algorithm models the natural selection and survival of the fittest. The GA has been applied to a variety of problems in different areas. Also, it has recently been employed in the multi-user detection problem. 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. In order to be able to employ the GA for the finger selection problem we need to consider how to represent the chromosomes, and how to implement the steps of the iterative optimization scheme in MMSE. By choosing the fitness function, the fittest chromosomes of the population correspond to the assignment vectors with the largest SINR values. Now, we can summarize our GA-based finger selection scheme as follows:

Generate Nipop different assignments randomly and select Npop of them with the largest SINR values.

1. Pairing: Pair Ngood of the finger assignments according to the weighted random scheme.
2. Mating: Generate two new assignments from each pair.
3. Mutation: Change the finger locations of some assignments randomly except for the best assignment.

The GA has been applied to a variety of problems in different areas [3] [5]. Also, it has recently been employed in the multi-user detection problem [6][7]. 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. Simulation Result 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 the 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 (M x L selection matrix X follows: M of columns of X is the unit vectors $e1 \ldots e_M$) increases since the channel is exponentially decaying and most of the significant multipath components are already combined by all the algorithms. M finger of MMSE Rake Receiver, $x_i = 1$ *i*th path is selected, and $x_i = 0$ otherwise;

$$\sum_{i=1}^{L} x_i = M \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

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 E1 = 1 and Ek = 10 k = 1, and all the parameters are as in the previous case. Then, as shown in Figure, 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.

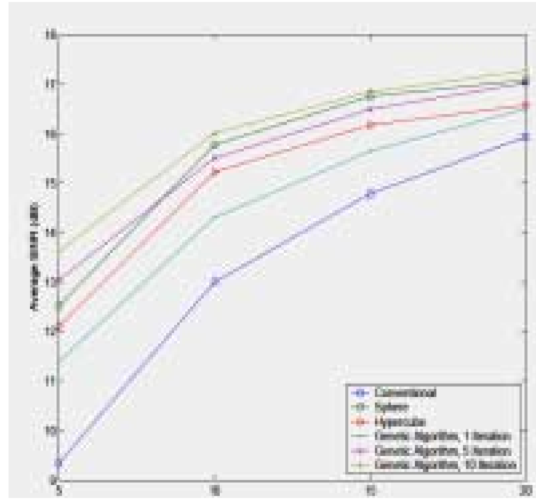

Fig 1: Number of Fingers

Fig 1: Average SINR versus number of fingers M . There are 10 users with each interferer having 10dB more power than the desired user.,where Eb is the bit energy. The channel has L = 15 multipath components and the taps are exponentially decay ing. The IR-UWB sy stem has Nc = 20 chips per frame and Nf = 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 [8] . 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) [9][10]**.** 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.

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5. Comparison of Adaptive (Proposed) MMSE Rake Receiver with Conventional Rake

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[11] [12] [13], for DS-CDMA can be extended to UWB communication, but the major drawback of these techniques is the very high computational complexity.

We choose the IEEE UWB channel parameters to get the simulation result

Parameter	CM1	CM2	CM3
Cluster arrival rate, Λ (1/ns)	0.0233	0.4	0.0667
Ray arrival rate, λ (1/ns)	2.5	0.5	2.1
Cluster decay factor, Γ	7.1	5.5	1.4
Ray decay factor, ϒ	4.3	6.7	7.9
Std. dev. of cluster, σζs (dB)	3.3941	3.3941	3.3941
Std. dev. of ray, s σξ (dB)	3.3941	3.3941	3.3941
Std. dev. of total MP, σg (dB)	3	3	3

Table 1: IEEE UWB channel parameters.

6. 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 [14] are used. Channel model parameters are listed in table. 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. μ = 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. Eb /N0 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 *d*B) 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 *d*B at 10^{-2} BER, and substantial improvement for BER < 10^{-3}

Fig shows simulation results for bit error probability vs. number of users with E*b* /N*o* = 20 *d*B 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

BER		10^{-2}	10^{-3}	10^{-4}
CM1	Proposed	17	11	9
	C-Rake	8	5	2
CM2	Proposed	17	11	9
	C-Rake	7	4	2
CM3	Proposed	14	10	8
	C-Rake	7	4	2

Table 2: Number of users supported for Eb /N0 = 20 dB.

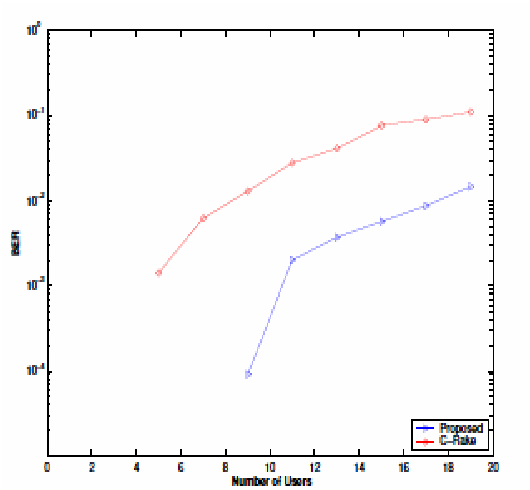

Fig 2: BER vs. No. of users for CM1 with E*b* /N*o* = 20 *d*B

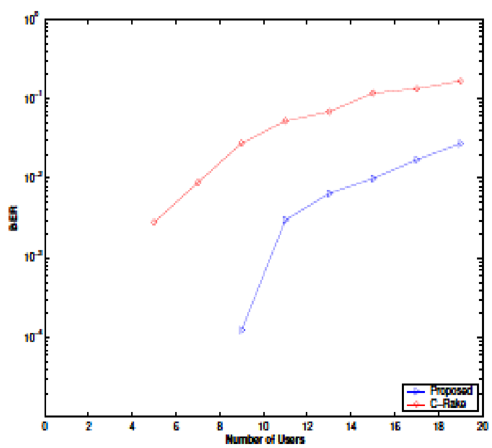

Fig 3: BER vs. No. of users for CM2 with E*b* /N*o* = 20 *d*B

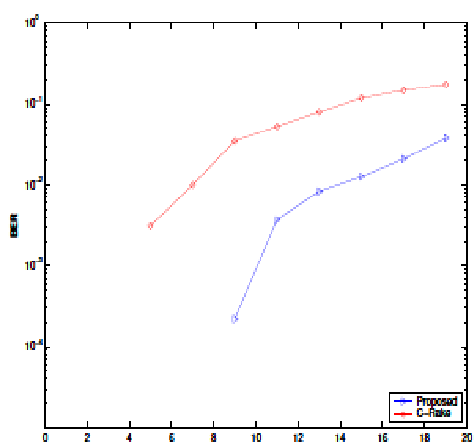

Fig 4: BER vs. No. of users for CM3 with E*b* /N*o* = 20 *d*B

7. Conclusion

We have derived that the Adaptive MMSE Rake receiver for WCDMA UWB multipath channels and studied its BER performance in multiuser environment with AWGN**.** It is observed 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 *d*B 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* /N*o* = 20 *d*B is two times that of the conventional Rake receiver with the same computational complexity.

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Authors Biography

Dr. J. Jeya A Celin has finished her Ph.D at Manonmaniam Sundaranar University, Tirunelveli. She has published / presented few research papers in National journals/conferences. Her main research area is developing Data mining algorithms for clustering databases. She is also interested in networking research activities. Previously she worked in St.Xavier's college, Palayamkottai for more than 7 years and at present, she is working as a lecturer in Eritrea Institute of Technolgy, State of Eritrea. She is a member of IAENG (International Association of Engineers), Technical Committee Member of JEMS Journals, Brazil.

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