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Research Article

Performance Analysis of Beam-Former Rake receiver and Adaptive Rake receiver for WCDMA

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Abstract

Direct-sequence code-division multiple-access (DSCDMA) cellular systems, such as Wideband CDMA (WCDMA), are limited in performance by interference. 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. A Beam former-Rake receiver can be an effective solution to provide the receivers enhanced capabilities needed to achieve the required performance of a WCDMA system. Beam former-Rake receivers for WCDMA uplink employ three Eigen-Beam forming techniques which based on the Maximum Signal to Noise Ratio (MSNR) and Maximum Signal to Interference and Noise Ratio (MSINR) criteria. In this paper, we have analyzed the performance of Beam-former rake receiver and Adaptive rake receiver for WCDMA.

Keywords: *Adaptive MMSE Rake Receiver, Beam former-Rake receiver, Genetic Algorithm, Conventional Algorithm, Maximum Signal to Noise Ratio (MSNR).*

1. Introduction

In mobile radio environment the signal arrive at the receiver via various paths. In order to make use of this path diversity Rake receiver is employed to coherently combine the energies in the multipath to improve system performance. To resolve multipath, wider-band DSSS technique is used .The path are resolvable if the adjacent paths are separated by at least the spreading sequence bit(chip) duration T_c. Rake receiver is worked as a tapped delay line filter. Optimum performance from Rake receiver is achieved if the tap weight of the Rake represents the impulse response of the channel. When impulse response of the channel is time-varying, adaptive scheme is needed to keep track of these variations. MMSE S Rake receivers provide a complete optimization theoretical framework for avoiding finger selection problem. First, formulate the optimal MMSE S-Rake 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 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.

A Beam-former-Rake (A. F. Naguib *et al*, 1996) receiver is a concatenation of a beam-former (J. Litva *et al*, 1996) and a Rake receiver (T.S. Rappaport *et al*, 1996).This provides a higher degree of freedom since the signal can be processed in both the temporal and the spatial domains. The signal processing of the Beam-former-Rake combats against the Multiple Access Interference (MAI) and mitigates fading. Wireless service providers throughout the world are working to introduce the third generation (3G) (Malcom *et al*, 1999) cellular service that will provide higher data rates and better spectral efficiency. Wideband Code Division Multiple Access (WCDMA), has been widely accepted as one of the air interfaces for 3G. A Beam-former-Rake receiver can be an effective solution to provide the receivers enhanced capabilities needed to achieve the required performance of a WCDMA system. One of the objectives of this research is to develop and study different Beam-former-Rake receiver structures that are suitable for WCDMA systems and investigate their performance under different operating conditions. The majority of the Beam-forming techniques employed for performing the spatial processing at the Beam-former-Rake receiver in this work are based on solving the Eigen value Problem (G. H. Golub *et al*, 1989). The key objective of this dissertation is to investigate different computationally simple algorithms for solving the Eigen value problem and at the same time propose and develop additional low- complexity

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innovative techniques. Orthogonal Frequency Division Multiplexing (OFDM) (R. V. Nee *et al*, 1998) is a multi-carrier technique that has recently received considerable attention for high speed wireless communication.

2. System Design Model

2.1 MMSE Rake Receiver with Conventional

Algorithm

Instead of the solving the problem in (Fishler. E *et al*, 2005), 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

$$\mathrm{SINR}_t = \frac{E_t(\alpha_t^{(l)})2}{(S_t^{(MAI)})^T A^2 S_t^{(MAI)} + \sigma_n^2}$$

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 (Lin Zhiwei *et al*, 2005). 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.

2.2 MMSE Rake Receiver with Genetic Algorithm

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. A GA (Genetic Algorithm) based approach is propos 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.

2.3 Beam forming Rake receiver Criteria

There are three different techniques that can be applied for beam-forming in a CDMA based cellular environment and an OFDM system. Maximum Signal to Noise Ratio (MSNR), the Maximum signal to Interference and Noise Ratio (MSINR) and the Minimum Mean Square Error (MMSE).MSNR beam-forming is intended to maximize the Signal to Noise Ratio (SNR) at the output of the beam-former. In the literature, it is often termed as the conventional beam-former. The weight vector that maximizes the SNR is the principal eigenvector of the covariance matrix of the desired signal. If the interference and noise is spatially white, this is the optimum beam-forming.

In MSINR, if interference is white, MSNR weight is the optimum weight vector. But if the interference is not white, the eigenvector corresponding to the maximum Eigen-value of the received signal does not correspond to the MSNR weight vector. However this is a moot point since the spatial structure of the interference requires to be taken into account and the optimum weigh vector will be the weight that maximizes the Signal to Interference and Noise Ratio (SINR).

Minimum Mean Squared Error (MMSE) criterion intends to find a weight vector that will minimize the Mean Squared Error (MSE) between the combined signal and some desired (or reference) signal.

3. Simulation Results

Fig 1 shows the BER graph of proposed scheme and C-Rake receiver. From the graph if the number of user for channel model 1 is 16, then BER for Adaptive MMSE Rake receiver is less than 10^{-10} whereas for C-Rake receiver is greater than 10^{-10} .Hence BER performance of proposed Adaptive MMSE Rake receiver for CM1 is good as compared c-Rake receiver.

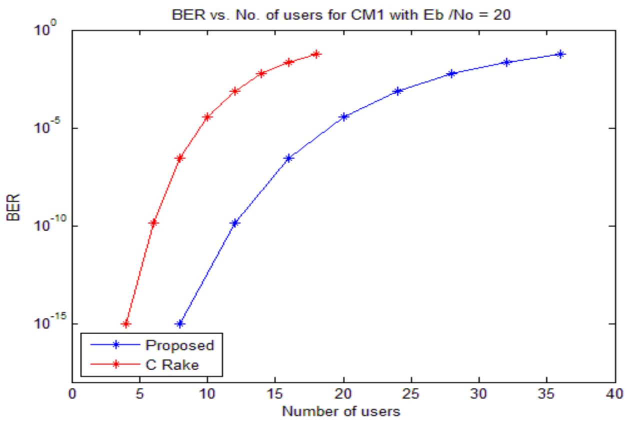

Fig 1: BER vs. No. of users for CM1 with Eb /No = 40 dB

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 0.001gives best performance for C-Rake and proposed adaptive MMSE Rake receiver respectively.

To verify and investigate receiver performance bit error probability vs. E_b /N0 for K = 5, L = 10, 15 and 20 is considered. Simulation results in fig..2 for channel model 2 shows that the proposed detectors BER performance is better than that of C-Rake receiver. It is observed that proposed detector gives better BER performance even for small number of Rake fingers (L = 10), whereas 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 < $10^{-3.}$

From fig.2 if number of user for channel model 2 is 8, then BER for Adaptive MMSE Rake receiver is approx less than 10^{-15} whereas for C-Rake receiver is greater than 10^{-5} .Hence BER performance of proposed Adaptive MMSE Rake receiver for channel model 2 is better than model 1.

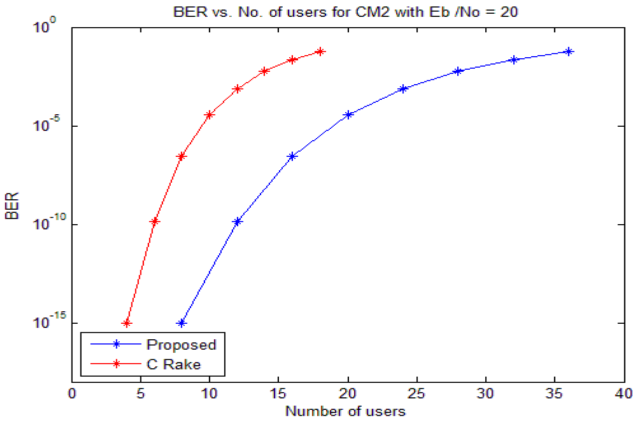

Fig 2: BER vs. No. of users for CM2 with E_b/No=40

Simulation results for bit error probability vs. number of users with E_b/N*o* = 40 *d*B for channel mode 3 is shown in fig. 3. 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. From the graph BER performance of CM3 is approximately same as CM2 for less number of users. But for large number of user BER performance of channel model 3 is better than both CM1 and CM2.

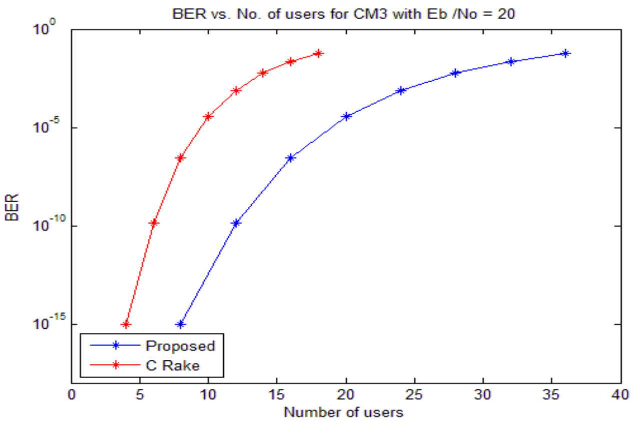

Fig 3: BER vs. No. of users for CM3 with E_b/No=40

3.1 Simulation Result of Adaptive MMSE Rake Receiver with beam-former 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.

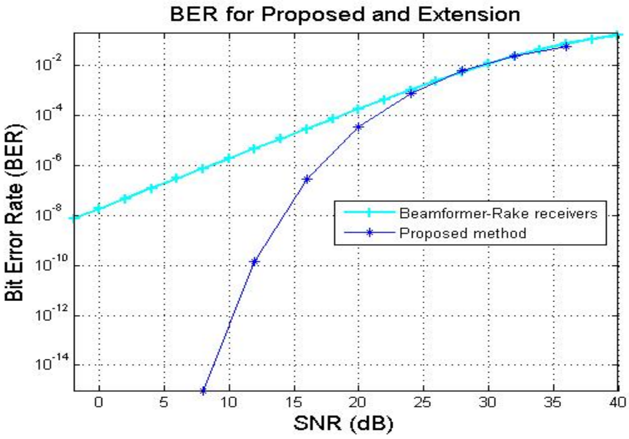

Fig 4: BER vs. No. of users with Eb /No = 20 dB for beam-former and adaptive rake receiver.

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 n-sec and second derivative of Gaussian pulse of width 0.5 n-sec 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

Conclusion

In this paper it has been that BER performance of Adaptive MMSE Rake receiver and Beam-former Rake receiver for WCDMA UWB multipath channels in multiuser environment with AWGN**.** 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. BER of Further, it offers significant improvement in MAI cancellation in multipath channels. Furthermore simulation results shown that the number of users supported by the beam-former rake receiver is two times that of the adaptive Rake receiver with the same computational complexity. Hence BER performance of Adaptive MMSE Rake receiver is most efficient and reliable for improving BER performance for WCDMA UWB multipath channels in multiuser environment with AWGN as compared to Beam-forming Rake receiver.

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