用於分碼多重進接通信系統中之干擾阻隔耙狀接收器

An Interference-Blocking RAKE (IB-RAKE) Receiver for CDMA Communications Systems

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Abstract

In this paper, a space-time RAKE (ST-RAKE) receiver with enhanced interference rejection is proposed for a CDMA communications system over multipath channels. The scheme involves three stages. An interference-blocking (IB) transformation is first developed for suppressing the strong interference, while the other signals retained. Optimum beamforming is then performed based on the IB transformed data to produce reception of signals of interest (SOIs) and rejection of strong interference. Finally, RAKE receiver is used to constructively collect the SOI energy. Since strong interference has been removed, RAKE receiver can effectively combine the SOIs, leading to performance enhancement as compared with the conventional ST-RAKE receiver. Numerical results illustrate the efficacy of the proposed interference-blocking RAKE (IB-RAKE) receiver.

本論文中，吾人提出一用於分碼多重進接通信系統中之具有干擾抑制能力之時空耙狀接收器。其結構可分為三階層：首先建構一干擾阻隔轉換器用以壓抑強干擾並保留其他信號；接著根據轉換資料建構一最佳波束合成器藉以接收目標信號及抑制干擾；最後利用一耙狀接收器同調性地接收目標信號之能量。根據電腦模擬顯示，吾人提出之干擾阻隔耙狀接收器具有優於傳統時空耙狀接收器之效能。

Keywords: CDMA 分碼多重進接； Beamforming 波束合成法； Interference-Blocking 干擾阻隔； RAKE 耙狀接收器。

1. Introduction

A major challenge for wireless communications systems is the limited capacity due to sparse radio frequency spectrum. The capacity limit, in practice, is mainly determined by the interference rejection capability [1]. Spread-spectrum communications techniques, realized in the form of code division multiple access (CDMA), with the advantages such as robustness against narrow-band interference with moderate power as well as noise, have been strong candidates in the next generation of high capacity wireless communications systems [2]. In CDMA systems, signals from other users, termed as interference, can be significantly attenuated as a means of lower cross-correlation among users' spreading codes. However, strong narrow-band interference, possibly introduced due to the co-existence of non-CDMA systems, cannot be completely suppressed because of insufficient processing gain and will result in certain performance degradation. In addition to narrowband interference, multipaths introduced by the environment will deteriorate the performance. As a remedy, the RAKE receiver is proposed for the purpose of coherently combining of the multipath signals.

In this paper, a space-time RAKE (ST-RAKE) with an interference-blocking (IB) scheme is proposed for combating the strong interference in CDMA communications systems. Specifically, a scheme is developed firstly to construct an IB transformation for removing the strong interference, while other signals retained. From the fact that the power level of the signal is well below that of the strong interference, the interference term can be approximately expressed in terms of the dominate eigenvectors corresponding to the larger eigenvalues of the received data correlation matrix. The complementary (orthogonal) subspace, referred to IB subspace, can be utilized for suppressing the strong interference. An optimum beamforming is then performed based on the IB transformed data to produce effective reception of signals of interest (SOIs) and suppression of strong interference. Computer simulations demonstrate the efficacy of the proposed interference-blocking RAKE (IB-RAKE) receiver.

2. Algorithm Summary for Interference-Blocking RAKE (IB-RAKE) Receiver

In this section, a blind receiver suitable for the spread spectrum communications systems is developed with a three-stage scheme. First, a transformation for suppressing the strong interference is constructed based on the received data. Second, an optimal beamforming is performed on the transformed data consisting only of the SOIs and noise to produce maximum signal-to-noise ratio (MSNR). Finally, a RAKE receiver is used to constructively collect the SOI energy in the beamformer output.

The overall procedure of the proposed IB-RAKE receiver can be summarized as below:

1. Compute the data correlation matrix based on the received data.
2. Compute the IB subspace (transformation) by using eigenvalue decomposition technique.
3. Compute the transformed data, in which strong interference has been removed.
4. Compute the optimal beamforming weights, which perform suppression of interference and reception of the other signals.
5. Apply the RAKE technique to the beamformer outputs to produce constructive combining of multipaths in order to alleviate the degradation due to the effect of imperfect channel (multipath channel).
6. Obtain the estimated data by using a hard decision processor.

The corresponding schematic diagram of the proposed IB-RAKE receiver is depicted in Figure 1.

3. Computer Simulations

Computer simulations obtained via a third generation cellular system, a wideband-CDMA (WCDMA) system with band-width of 5 MHz, are conducted herein to demonstrate the efficacy of the proposed IB-RAKE scheme under a multipath fading channel. A four-element linear array with half-wavelength inter-element spacing, in which all elements are assumed to be identical and omni-directional with a unit gain, is employed. The carrier frequency of the impinging signals is centered at 1900 MHz. There are three paths in this simulation scenario: a direct path and two multipaths impinging at 0, 30, and –25 degrees with respect to the array board-side. The two multipaths are of the same power as the direct path and the associated delays are 976 (about 4 chips) and 20000 (about 77 chips) nano-seconds, respectively. The chip rate and sampling rate are both 3.84 MHz. In addition, a strong CW tone interferer at –55 degree has a power of 20 dB with respect to the direct path signal. Finally, the vehicle speed is 3 km/hr. Note that all the parameter settings are based on the multipath fading propagation conditions in the third Generation

Partnership Project (3 GPP) Technical Specification [3].

We utilize the Dedicated Physical Control Channel (DPCCH) data with spreading factor 256 to verify the efficacy of the proposed algorithm. In each of the following simulation results, bit-error rate (BER) statistics are obtained from a period of 3000 frames (4.5×10^5 bits), and the optimal beamformer is constructed within the observation period of 10 bits. A simulation is performed to examine the effect of input signal-to-noise ratio (SNR) Ec/No, with Ec and No denoting the signal energy associated with the direct path and spatially white Gaussian noise density contained within a chip (Watt/chip), respectively. In this case, the value of Ec/No is varied from –20 to –10 dB. The corresponding BERs are plotted in Figure 2(a). For comparison, the simulation results obtained by the time-domain RAKE (T-RAKE) and conventional space-time RAKE (ST-RAKE) with Fourier beamforming employed, are also included. The plots indicate that the proposed IB-RAKE receiver outperforms the conventional RAKE receivers, especially for high signal-to-noise ratio. This is because that the proposed algorithm is constructed only on the interference-suppressed data such that the RAKE receiver can effectively combine the SOIs. On the contrary, both conventional methods fail due to the large leakage interference in the inputs of RAKE receivers. It is noteworthy that the proposed receiver performs well for high SNR. This confirms that the proposed scheme is effectively in reception of the SOIs and suppression of interference. On the other hand, both T-RAKE and ST-RAKE receivers exhibit a certain degradation in performance because of weakness in interference suppression. To gain more insights, the beam patterns obtained for SNR=-10 dB are depicted in Figure 2(b). Clearly, the proposed beamformer is successful in canceling the strong interference. Moreover, the proposed beamformer is able to produce multiple mean-beams for extracting the signals of interest. These simulation results confirm that the performance of the proposed IB-RAKE receiver is quite reliable in suppressing strong interference and coherently combing the SOIs.

4. Conclusion

In this paper, an interference-blocking RAKE (IB-RAKE) receiver for combating strong interference and constructively combining the SOIs is proposed. The development of the proposed scheme involves a three-stage procedure. An interference-blocking (IB) transformation is first constructed for removing the strong interference. Optimum beamforming is then performed based on the IB transformed data to produce maximum output SINR. Finally, a conventional RAKE receiver is utilized to coherently collect the SOI energy of the beamformer output. Numerical results demonstrate that the proposed IB-RAKE receiver exhibits robustness against strong interference and a significant performance enhancement as compared with the conventional RAKE receivers.

Acknowledgement

The author would like to express my sincerest appreciation to Dr. C. P. Li for useful discussions that make a significant contribution to the effort.

5. References

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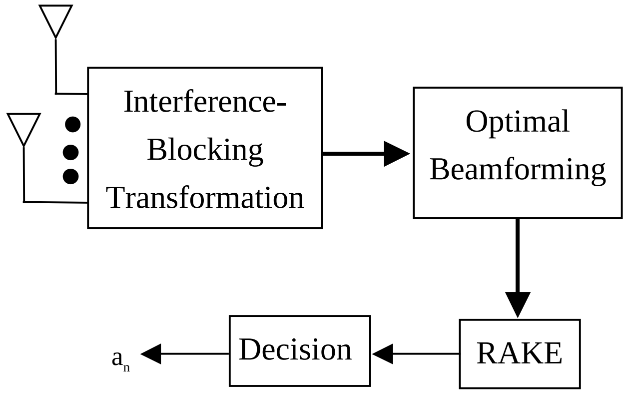

Figure 1: Schematic diagram of proposed IB-RAKE receiver for a CDMA system.

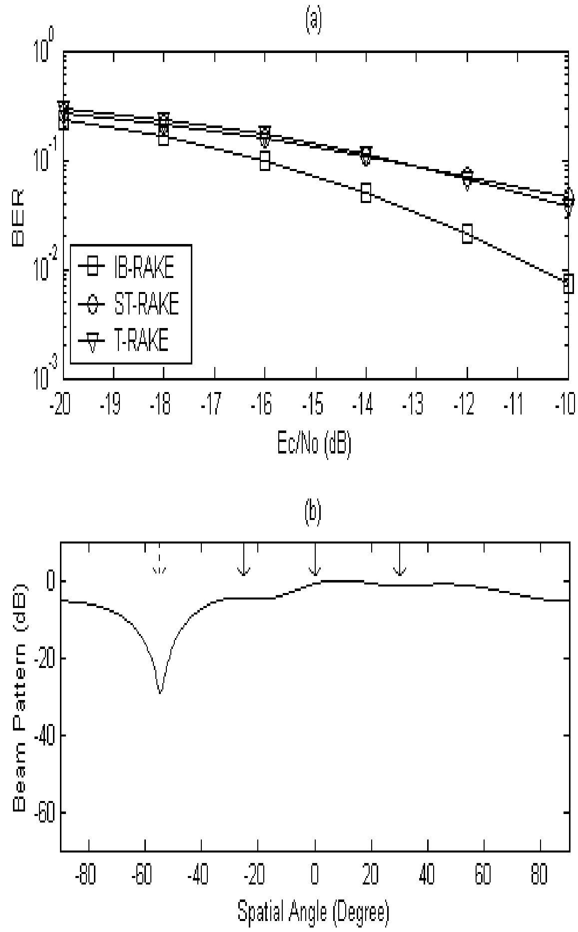

Figure 2. Performance evaluation of proposed IB-RAKE receiver. SOIs at 0, -25, and 30 degree. Interference at –55 degree. (a) BER versus Ec/No. (b) Pattern obtained for Ec/No=-10 dB.