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***Abstract* - A novel minimum bit-error rate (MBER) space–time-equalization (STE)-based multiuser detector (MUD) is proposed for multiple-receive-antenna-assisted space-division multiple-access systems. It is shown that the MBER-STE-aided MUD significantly outperforms the standard minimum mean-square error design in terms of the achievable bit-error rate (BER). Adaptive implementations of the MBER STE are considered, and both the block-data-based and sample-by-sample adaptive MBER algorithms are proposed. The latter, referred to as the least BER (LBER) algorithm, is compared with the most popular adaptive algorithm, known as the least mean square (LMS) algorithm. It is shown that in case of binary phase-shift keying, the computational complexity of the LBER-STE is about half of that required by the classic LMS-STE. Our simulation results demonstrate that the MBER ST-DFE assisted MUD is more robust to channel estimation errors as well as to potential error propagation imposed by decision feedback errors, compared to the MMSE ST-DFE assisted MUD.**

Index Terms— Decision feedback equalizer, minimum bit error rate, minimum mean square error, multiple antennas, multiple-input multiple-output, multiuser detection, space-division multiple access

I. INTRODUCTION

SMART-antenna-aided space–time processing is capable of substantially improving the achievable wireless system capacity, coverage, and quality by suppressing the effects of both intersymbol interference (ISI). . To interpret the multiuser supporting capability of such an SDMA system it is informative to compare it with classic code-division multiple-access (CDMA) multiuser systems.

In a CDMA system, each user is separated by a unique user-specific spreading code. By contrast, an SDMA system differentiates each user by the associated unique user-specific channel impulse response (CIR) encountered at the receiver antennas. In this analogy, the unique user-specific CIR plays the role of a user-specific CDMA signature. However, owing to the nonorthogonal nature of the CIRs, an effective multiuser detection (MUD) is required for separating the users in an SDMA system. In most situations, the wireless channel suffers attenuation due to destructive addition of multipath in the propagation media and to interference from other users.

The channel statistic is significantly often Rayleigh which makes it difficult for the receiver to reliably determine the transmitted signal unless some less attenuated replica of the signal is provided to the receiver. This technique is called diversity, which can be provided using temporal, frequency, polarization, and spatial resources. In many situations, however, the wireless channel is neither significantly time-variant nor highly frequency selective. This forces the system engineers to consider the possibility of deploying multiple antennas at both the transmitter and receiver to achieve spatial diversity.

The most popular SDMA receiver design is the minimum mean-square error (MMSE) MUD which leads to simple and effective adaptive implementation using the least mean square (LMS) algorithm. We consider an alternative design for the STE-aided MUD based on the minimum bit-error rate (MBER) criterion. Time-only processing, i.e., channel equalization, based on the MBER design has been considered before. Recently, we have also proposed the MBER design for space- only processing, i.e., the narrowband-beam forming-assisted receiver. In this paper, we extend the MBER design to the STE-aided MUD operated in a generic multiple antenna-aided SDMA system.

The contribution of this paper is two-fold. First, it is shown that the MBER STE-based MUD is superior in comparison with the MMSE design in terms of its achievable bit-error rate (BER).This is significant, since the MMSE design is often considered to be the state-of-the-art technique in multiple-antenna-assisted systems . Our study thus demonstrates that the system capacity can further be enhanced beyond that of the MMSE solution which is having low achievable bit error rate performance.

II. SYSTEM MODEL

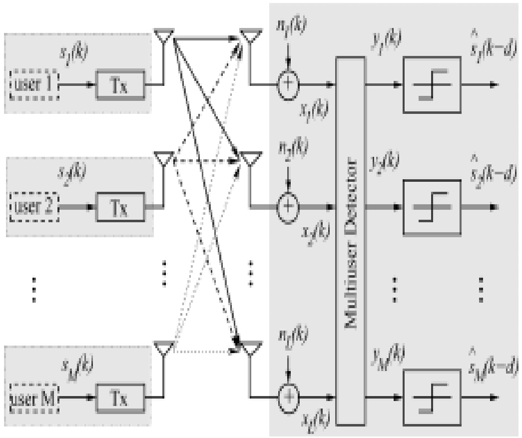

Fig.1. Schematic of an antenna-array-aided SDMA system, where each of the M users is equipped with a single transmit antenna, and the receiver is assisted by an L -element antenna array.

Consider the multiple antenna aided SDMA system supporting users, as depicted in Fig. 1, where each of the M users is equipped with a single transmit antenna and the receiver is assisted by an L -element antenna array.

$$x_l(k) = \sum_{m=1}^{M} \sum_{i=0}^{n_C-1} c_{i,l,m} s_m(k-i) + n_l(k) = \bar{x}_l(k) + n_l(k)$$

where n1(k) is an independently identically distributed complex-valued Gaussian white noise process, E[n_l(k)^2]=2σ_n^2.

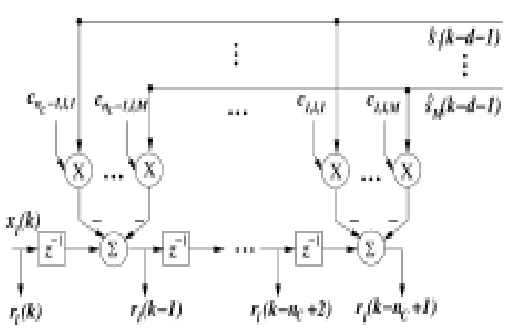

Fig. 2. Schematic of the observation space translation.

A schematic of this space translation is illustrated in Fig. 2. It is important to emphasize that using the detector structure with the space translation is exactly the same as using the original DFE structure. The feedback coefficient vector does not simply "disappear." It has in fact been set to its "optimal value," Thus, in an adaptive implementation, one has to estimate the coefficient of the CIRs rather than estimating the coefficients of the feedback filters, when adopting the detector structure. Moreover, when the MMSE solution, is used in the detector the feedback filter coefficient vector is automatically set to its MMSE solution.

An adaptive implementation of the MMSE solution can be realized, for example, using the LMS algorithm. The main contribution of this paper is to derive the MBER solution for the weight vectors of the ST-DFEs and develop an adaptive MBER multiuser detector for the SDMA systems.

III. ADAPTIVE MINIMUM BIT ERROR RATE IMPLEMENTATION

The evaluation of the error probability requires the knowledge of the pdf of the ST-DFE's output signal. Hence, some form of pdf estimation is required for supporting the adaptive implementation of the MBER ST-DFE assisted MUD.

A. Block-Data Based Gradient Adaptive MBER ST-DFE

The Parzen window method constitutes an efficient means of estimating a pdf. Specifically, the Parzen window method estimates a pdf using a window or block of the ST-DFE output signal by placing a symmetric unimodal kernel function centered on each sample and averaging over all the data points. This density estimation technique is capable of producing reliable pdf estimates with the aid of short data records and is natural when dealing with Gaussian mixtures.

B. Stochastic Gradient-Based Adaptive MBER ST-DFE

Our aim is to develop a sample-by-sample adaptive implementation of the MBER ST-DFE. In the Parzen window estimate the kernel width explicitly depends on the detector's weight vector . However, the BER is invariant to and a constant kernel width may also be adopted in the density estimate. An advantage of using a constant kernel width , rather than , in the density estimate is that the gradient of the resultant estimated BER has a simpler form, which leads to a considerable computational complexity reduction. This approximation is an adequate one, provided that the width is chosen appropriately.

It can readily be shown that for the BPSK case, the LBER ST-DFE is computationally simpler than the LMS ST-DFE, imposing about half the computational complexity required by the LMS algorithm. It can also be shown that for QPSK modulation, the LBER ST-DFE has a similar computational complexity as the LMS ST-DFE.

$c_{l,m}(z$	m=1	m=2	m=3	m=4
l=1	(0.6+j0.7)+(0.8+j0.5) z^{-1} +(0.3+j0.4) z^{-2}	(-0.1-j0.2)+(0.4+j0.5) z^{-1} + (0 z^{-2}	(0.7+j0.5)+(0.6+j0.4) z^{-1}+(0.5+j0.5) z^{-2}	(0.8-j0.4)+(-0.6+j0.5) z^{-1} + (0.3+j0.3) z^{-2}
l=2	(0.1+j0.2)+(0.4+j0.3) z^{-1} +(0.5+j0.4) z^{-2}	(0.9+j0.2)+(0.3+j0.7)z^{-1}+(0.2+j0.2)z^{-2}	(-0.3-j0.3)+(0.4+j0.2)z^{-1} +(-0.2+j0.4) z^{-2}	(0.3+j0.3)+(0.4+j0.4)z^{-1}+ (0.5+j0.5)z^{-2}
l=3	(-0.1+j0.3) +(0.6-j0.5) z^{-1} +(0.2+j0.4) z^{-2}	(0.5+j0.6)+(-0.3-j0.4)z^{-1}+ (0.2+j0.4) z^{-2}	(0.2-j0.3)+(0.4-j0.5)z^{-1}+ (0.6+j0.3) z^{-2}	(0.1+j0.8)+(0.7+j0.6)z^{-1}+ (0.8+j0.5)z^{-2}
l=4	(0.8+j0.9)+(0.6+j0.5) z^{-1} +(0.5+j0.3) z^{-2}	(0.4+j0.4)+(0.4+j0.4)+(0.4+j0.4)z^{-2}	(0.1+j0.2)+(-0.3-j0.4)z^{-1}+ (0.3+j0.2) z^{-2}	(0.4+j0.6)+(0.5+j0.3)z^{-1}+ (0.2+j0.3)z^{-2}

Table 1: System's CIRs for a four –antenna four user Time invariant SDMA system

IV. SIMULATION STUDY

In our simulation investigations, unless otherwise stated, perfect channel estimates are assumed in performing the translation. Hence our attention is focused of the performance

of the adaptive MBER and MMSE designs In order to avoid obfuscating the prevalent MBER/MMSE performance trends by asynchronous transmissions, we assumed synchronous communications and an identical CIR dispersion for all users.

The system used in our simulations supported users with the aid of receiver antennas. All the four users had an equal transmit power. The resultant 16 CIRs are listed in Table I. It can be seen that for all four users, the MBER ST-DFE-MUD provided a better BER performance than the MMSE ST-DFE-MUD. In reality, the ST-DFE-MUD may produce

Erroneous symbol feedback. For the sake of investigating the effects of decision feedback induced error propagation, the BERs of the MMSE and MBER ST-DFE-MUDs were also calculated using simulations with the error-prone detected symbols being fed back.

It is interesting to see that the BER performance degradation owing to DFE-induced error propagation is less serious for the MBER ST-DFE-MUD than for the MMSE ST-DFE-MUD.

MBER ST-DFE-MUD appears to be significantly more robust to error propagation. The effect of imperfect channel estimates to the performance of a ST-DFE-MUD was next investigated.

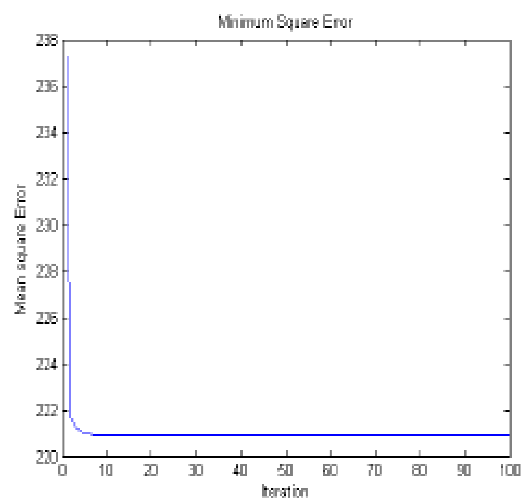

Fig.3. Bit error rate performance of MMSE

The effect of imperfect channel estimates to the performance of a ST-DFE –MUD was next investigated. We added the Gaussian white noise with standard deviation 0.1 to each tap of the CIRs to represent channel estimation errors. The resultant estimated CIRs were then used to perform the space translation as well as to calculate the MMSE and MBER solutions .

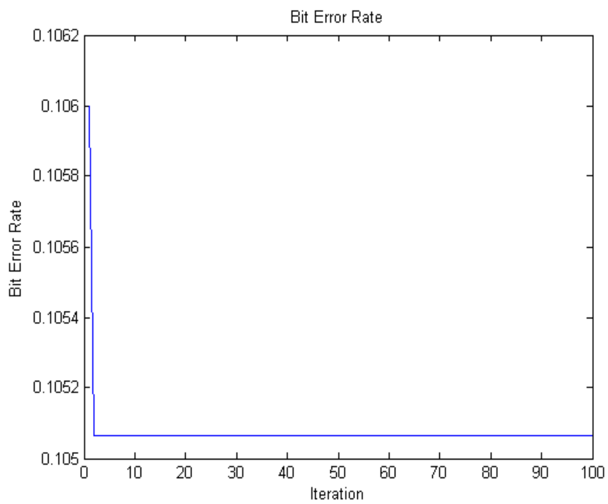

Fig.4. Bit error rate performance of MBER

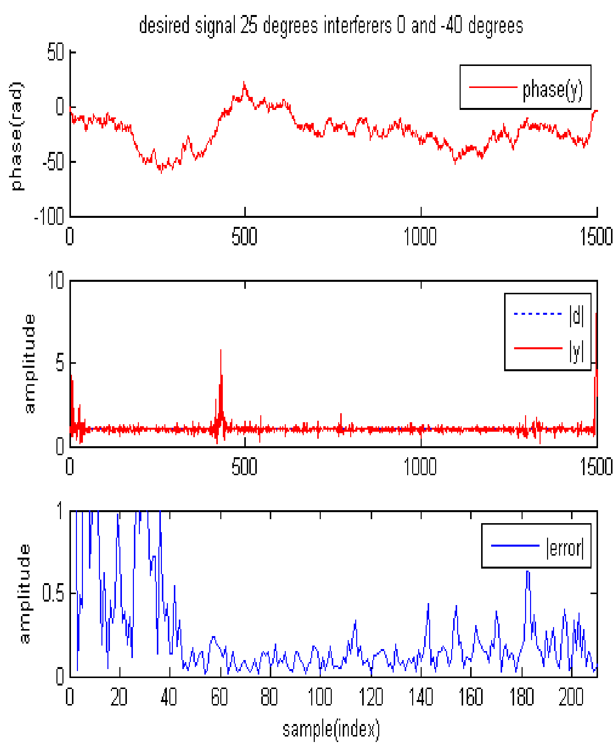

Fig.5. Desired signal 25 degrees interferes 0 and -40 degrees.

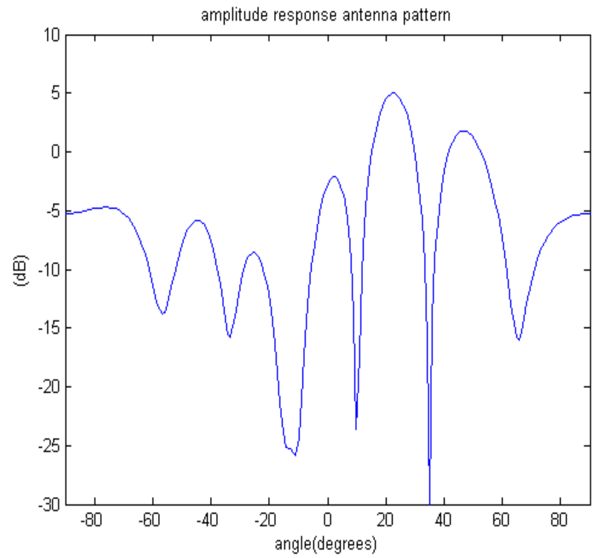

Fig.6. Amplitude response pattern.

V. CONCLUSIONS

A novel minimum bit error rate design has been proposed for the space-time decision feedback equalization assisted multiuser detector employed in multiple antenna aided space-division multiple-access systems. It has been demonstrated that this MBER design is capable of achieving better performance and hence of improving the attainable system capacity, compared to the classic MMSE design. MBER ST-DFE-MUD is significantly more robust against the error propagation caused by error-prone detected symbols used in the MUD's feedback loop, in comparison to the standard MMSE ST-DFE-MUD.

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