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Space-Time-Frequency Coding for MIMO Relay System Based on Tensor Decomposition

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Abstract—Space-time-frequency (STF) coding can obtain the diversity gain from three dimensions (space, time and frequency) to effectively improve the transmission performance of the multi-input multi-output (MIMO) relay system. In this study, a MIMO one-way two-hop amplify-and-forward (AF) relay communication system is presented by means of triple Khatri–Rao space-time-frequency (KRSTF) coding, which forms a five-dimensional tensor at the destination node that satisfies a new multi-dimensional tensor decomposition approach called asymmetric nested PARAFAC decomposition (ANPD). Then based on this model, a semi-blind receiver is derived to perform the joint channel and symbol estimation in terms of three-step alternating least squares (ALS) algorithm. Compared with the existing two-hop symmetry methods, the proposed scheme uses an asymmetric nested model to obtain additional frequency coding diversity, which significantly improves the performance of the system in parameter estimation accuracy as demonstrated by simulation results.

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1. INTRODUCTION

In recent time, the relay technology has attracted a significant interest because of its capability in solving the problems of blind and edge area coverage in wireless communication systems in harsh environments such as shadow fading and large path loss [1, 2].

Several works have pointed out that the amplify-and-forward (AF) relay protocol can amplify forward symbols directly and retain the soft information of the transmitted signal effectively, with simple operation and short signal delay time [3–5].

Compared with traditional relay systems, multiple input multiple output (MIMO) relay systems can achieve greater coverage, higher transmission rates and better stability. These systems have become a key technology in the field of wireless communications [6]. In MIMO relay system, it is of great significance to learn the channel status information (CSI) for optimizing a target transmitter and detecting symbols.

Processing of multi-dimensional signaling by using a multi-dimensional algebraic model can benefit from multiple signal diversities, such as time, space, and frequency diversities [7–9]. A tensor model is very effective for processing of multidimensional data.

The channel estimation methods in MIMO AF relay system based on tensor model have been proposed in [10–13] in previous work. Different from the conventional matrix-based methods, tensor-based channel estimation approaches can estimate multiple channels jointly so that cooperative diversity can be fully utilized, whereas the authors of paper [10] propose a tensor-based channel estimation (TENCE) scheme, which is applied to an arbitrary antenna configuration.

In [11], utilizing the structured least squares (SLS) technique to optimize the solution of the TENCE [10], the iterative of SLS refinement is optional. An approach for estimating channel of AF MIMO relay systems is proposed based on two-hops [12], while the algorithm of [13] focuses on three-hops. All of the above methods require training sequences to obtain CSI that results in inefficient spectrum of the system.

Recently, several semi-blind receivers with joint signal and channel estimation have been proposed in MIMO two-hop AF relay systems [14–18]. Most of them are based on a tensor model called PARAFAC, whose uniqueness has the characteristics that allow joint channel and symbol estimation compared to matrix estimation approach under more relax identification conditions.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ADDITIONAL INFORMATION

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