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論　文　要　旨

・論文の構成

Chapter 1 Introduction

Chapter 2 Preliminaries and Related Works

Chapter 3 Covert MIMO Communication in One-hop Systems

Chapter 4 Covert MIMO Communication in Two-hop Relay Systems

Chapter 5 Covert MIMO Communication in RIS-assisted Two-hop Relay System

Chapter 6 Discussion

Chapter 7 Conclusion

・研究目的の妥当性，　従来の手法との比較においての有意性，　および理論　・実験手法の新規性

This dissertation focuses on the beamforming design and related performance optimization for covert MIMO communications in wireless communication systems.

This dissertation first explores the beamforming design for covert MIMO communication in one-hop wireless systems. Existing works primarily focus on the analysis of the fundamental theoretical performance limits of covert MIMO communication, but the related exact modeling and analysis on the impact of beamforming on covert performance remain some open issues. To address these issues, we propose a one-hop beamforming scheme for covert transmission, and develop theoretical framework for the exact covert performance modeling in terms of detection error probability (DEP) and covert capacity.

We also explore the optimization of beam forming matrices for covert capacity maximization in the system.

This dissertation then investigates the beamforming design for the covert MIMO communication in two-hop wireless relay systems. While current research indicates that wireless relay networks can effectively implement covert communications, integrating MIMO technique into relay systems to enhance covert communication is a critical but unexplored issue. To address this issue, we consider both the NB and WB scenarios, devise corresponding covert transmission schemes for the two-hop covert MIMO communication system, and also develop related theoretical models for performance analysis under each scheme. Based on these models, we explore the optimization of the target rate and transmit power in the NB scenario for covert capacity maximization, as well as the optimization of beamforming matrices at source/relay in the WB scenario for covert capacity maximization.

This dissertation further investigates the beamforming design for covert MIMO communication in a RIS-assisted two-hop wireless relay system. We first jointly apply the RJS and optimal beamforming to develop a beamforming scheme for covert transmission in the considered system, and develop theoretical models to depict the inherent relationship among the source/relay beamforming matrices, the RIS phase matrix, and covert performance of the system in terms of DEP and covert capacity. We then explore the optimization of beam forming matrices at source/relay and the phase matrix at RIS for covert capacity maximization. To reduce computational complexity, we further apply various theoretical methods to develop a sub-optimal framework to identify the optimal settings of the beamforming matrices at source/relay and the phase matrix at RIS for covert capacity maximization.

・得られた知見のシステム情報科学の分野における意義

The results of this thesis provide the following valuable insights.

1. The beamforming schemes designed in this thesis offer promising solutions for various covert MIMO systems.
2. The corresponding theoretical models developed in this thesis could be helpful for the modeling of covert MIMO communication performance in various wireless systems as well.
3. It is expected that the work in this thesis can shed light on performance enhancement in future covert wireless communications.

審 査 結 果 の 要 旨

This dissertation focuses on the beamforming design and related performance optimization for covert multiple-input and multiple-output (MIMO) communications in wireless communication systems. Firstly, for a one-hop wireless system, we propose beamforming scheme for covert transmission, develop theoretical frameworks for the covert performance modeling, and explore the optimization of beamforming matrices for covert capacity maximization of the system. Then, we consider a two-hop relay system with no beamforming (NB) or with beamforming (WB). We devise corresponding covert transmission schemes, develop related theoretical models for performance analysis, and explore the optimization problem for covert capacity under the two scenarios. Finally, we consider a reconfigurable intelligent surface (RIS)-assisted two-hop wireless relay system. We propose a beamforming scheme for covert transmission in the system, establish theoretical models for covert performance, and explore both the optimal and sub-optimal frameworks to jointly optimize the beam forming matrices and the RIS phase matrix for covert capacity maximization.