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論　文　要　旨

・論文の構成

Chapter 1 Introduction
Chapter 2 Covert Communication Performance under Imperfect CSI with FD
Chapter 3 Covert Communication Performance under Imperfect CSI with EE and FD
Chapter 4 Covert Communication Performance with Dynamic CSI Estimation
Chapter 5 Discussion
Chapter 6 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

Covert communications aim to hide the existence of wireless transmissions from adversaries, ensuring secure and confidential communication in wireless systems. However, in practical scenarios, the presence of imperfect channel state information (CSI) caused by estimation error (EE) and feedback delay (FD), significantly impacts covert communication performance. Despite its importance, no prior systematic study has been conducted to analyze covert communication performance under such practical imperfect CSI conditions. This dissertation addresses this research gap by providing a comprehensive analysis for and an enhancement on the covert communication performance under imperfect CSI in a two-hop relay system.

Initially, we consider a CSI scenario with FD alone and two typical transmission schemes

of power control (PC) and channel inversion power control (CIPC), and derive closed-form theoretical models the key performance metrics of detection error probability (DEP) and covert rate (CR). Next, we extend our study to a general two-hop relay system under imperfect CSI with both FD and EE. We develop corresponding closed-form theoretical models for DEP and CR, and formulate an optimization problem for CR maximization through the joint design of channel inversion power and data symbol length. We also propose an iterative alternating algorithm to efficiently solve this optimization problem. Finally, we explore covert communication performance enhancement under imperfect CSI by integrating two well-known CSI estimation techniques: minimum mean square error (MMSE) and maximum likelihood (ML). We first analyze EE and covert performance separately under MMSE and ML, and then propose a novel dynamic CSI estimation method that adaptively selects between MMSE and ML based on second-order channel statistics and signal-to-noise ratio (SNR). The proposed method minimizes EE, leading to an improved covert communication performance.

・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. This dissertation provides a comprehensive analysis of covert communication performance under practical imperfect CSI.
2. The findings of this dissertation can guide the design and implementation of future covert communication protocols, facilitating their practical deployment in real-world wireless environments.
3. From a broader perspective, the methodology and research approach developed in this dissertation are not limited to covert communication only, since they are also helpful for linking the general wireless communication theories with the engineering applications.

審 査 結 果 の 要 旨

This dissertation provides a comprehensive analysis of covert communication performance under practical imperfect channel state information (CSI). We begin with the covert communication performance analysis in a two-hop greedy relay system under imperfect CSI with solely feedback delay (FD), where the two typical transmission schemes of power control and channel inversion power control are considered. We then extend our study to a general two-hop relay system under imperfect CSl with both FD and estimation error (EE), and develop the corresponding theoretical models for covert communication performance analysis. Finally, we explore the covert communication

performance enhancement in a general two-hop relay system under imperfect CSI with both FD and EE. We consider two typical CSI estimation methods of the minimum mean square error (MMSE) and the maximum likelihood (ML), and further propose a dynamic CSI estimation method to dynamically select between MMSE and ML methods to minimize EE, leading to an improved covert communication performance.