Impact of a Rogue RIS on Cellular Dynamics: RIS with destructive interference

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Abstract

In this letter, we introduce a rogue reflective intelligent surface (RRIS) employed to disrupt RIS-aided communication. By jointly adjusting the reflective coefficient and phase shifts, the rogue RIS aims to minimize the received signal at the receiver. To tackle the resulting non-convex optimization problems, we employ Block Coordinate Descent, Semidefinite Relaxation, and Gaussian Randomization techniques. Simulation results highlight the significant impact of the rogue RIS, demonstrating its ability to severely degrade communication between the base station and the user.

Ⅰ. Introduction

Reconfigurable intelligent surfaces (RIS) are proposed for beyond fifth generation (5G) and sixth generation (6G) wireless networks, transforming them into smart radio environments through power and cost-efficient services combined with high data rates [1] using low-cost reflective components that intelligently adjust the amplitudes and phase shifts of incident signals [2]. Consequently, RIS can precisely control the strength and direction of reflected electromagnetic waves, significantly enhancing the signal power received by target devices by adjusting the phase shifts of all elements simultaneously. However, RIS deployment can also inadvertently interfere with essential wireless communications, an aspect that remains underexplored. A few recent studies have examined scenarios where RIS is used maliciously [3],[4].

This study discusses a downlink communication system enhanced by a legitimate RIS (LRIS) to compensate for a blocked direct link from the base station to the legitimate user in the presence of a RRIS. The LRIS modifies the phase shift and amplitude of the reflected signal, using the ideal phase shift to maximize signal reception [5]. Meanwhile, the RRIS aims to disrupt communication by redirecting the reflected signal by strategically optimizing the magnitudes of reflection coefficients and discrete phase shifts to achieve the minimum total received signal power possible.

We address the non-convex optimization of reflection coefficients and phase shifts using block coordinate descent (BCD) [3]. BCD alternates between solving sub-problems for each parameter, initially converting discrete phase shifts to continuous forms. We employ semidefinite relaxation (SDR) with Gaussian randomization for the relaxed sub-problem, finalizing the solution through quantization. For the second sub-problem, we efficiently utilize the CVX tool.

Ⅱ. System Model

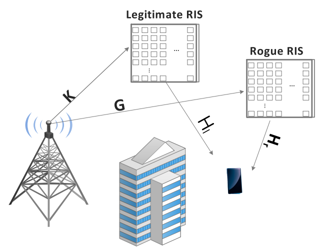

Fig. 1. System Model of MISO-RIS Transmission

The system model illustrated in Fig.1 represents a downlink single-user configuration comprising one base station (BS) equipped with M antennas and one user equipped with a single antenna. Positioned between the base station and the user is a LRIS designed to compensate for the blocked direct downlink from the BS to the user. Additionally, an attacker with RRIS is present. Both LRIS and RRIS consist of N passive reflective elements capable of adjusting their amplitude and phase shifts. It is assumed that the attacker possesses adequate computational capabilities to perform essential tasks.

We consider a linear beamforming at the transmitter $p \in \mathbb{C}^{Mx1}$ satisfying $\|p\|^2=P_t$, where P_t is the transmit power. Furthermore, we solely account for signals that are reflected by the RISs for the first time at the LR, and the rest of the signals are ignored due to the substantial pathloss [3]. Under these conditions the received signal at the user is:

$$y = (H_l^H \Omega K + H_r^H \theta G) ps + n$$

Notations: $H_l^H \in \mathbb{C}^{1xN}$, $H_r^H \in \mathbb{C}^{1xN}$, $K \in \mathbb{C}^{NxM}, G \in \mathbb{C}^{NxM}$ represent respectively the channels LRIS to the user, RRIS to the user, BS to the LRIS and BS to the RRIS where the subscript H represent the Hermitian transpose operation and $\mathbb{C}$ is the space i x j complex values matrices. Ω represent the ideal phase shift [5]of the LRIS. $\theta = diag(\beta_1 e^{j\theta 1}, \ldots, \beta_N e^{j\theta_N})$ represent the RRIS diagonal matrix where $\beta_n \in [0,1]$ and $\Theta_n \in [0,2\pi)$ are the magnitude of the reflection coefficient and the phase shifts on the cascaded signal. We consider that the phase shift for each element is discretized (eq (1) in [3]) and constrained to the interval[0,2π). Finally, s and z represent the information-symbol intended for the user with unit power and the additive white Gaussian noise (AWGN) at the receiver with zero mean and variance σ^2respectively. The received signal at the user can be reformulated as:

$$y = (H_l^H \Omega K + H_r^H \Gamma \overline{\theta} G) p s + n$$

where $\Gamma = diag(\beta_1, \ldots, \beta_N)$ and$\overline{\theta} = diag(e^{j\theta 1}, \ldots, e^{j\theta_N})$.

Hence, the received signal power can be computed as:

$$\gamma = |(H_l^H \Omega K + H_r^H \Gamma \overline{\theta} G) p|^2 .$$

Ⅲ. Received signal minimization.

To minimize the received signal, we optimize both the magnitude of the reflection coefficients and the phase shifts concurrently. the resulting optimization problem is given by:

$$min_{(\beta,\theta)} |(H_l^H \Omega K + H_r^H \Gamma \overline{\theta} G) p|^2$$

$$\text{s.t } 0 \leq \beta_n \leq 1 \ \forall n = \{1,..,N\}$$
$$\Theta_n \in \mathcal{B} \ \forall n = \{1,...,N\}$$

To solve this, we use an algorithm based on BCD method to optimize β and Θ alternatively. in the first step we first optimize the phase shift Θ for a given β:

$$min_{\theta} |(H_l^H \Omega K + H_r^H \Gamma \overline{\theta} G) p|^2$$

$$\text{s.t } 0 \leq \Theta_n \leq 2\pi \ \forall n = \{1,..,N\}$$

Through substitution and semidefinite Relaxation [3], the previous problem can be reformulated as:

$$min_V \ \text{Tr (RV)} + |\Psi|^2$$

$$\text{s.t. } V_{n,n} = 1, \ \forall n \text{ and } V \geq 0.$$

The previous problem can be solved by CVX tool supplemented by the Gaussian Randomization technique [3]. This approach effectively handles the tendency of CVX solutions to deviate from rank-one solutions.

in the following step we optimize β for an already optimized θ:

$$min_{\beta} |(H_l^H \Omega K + H_r^H \Gamma \overline{\theta} G) p|^2$$

$$\text{s.t } 0 \leq \beta_n \leq 1 \ \forall n = \{1,..,N\}$$

Which can also be solved using CVX tool.

IV. Simulation results

To illustrate the effect of tunning the phase shifts and magnitude we compare two received signals, one without the jammer and another in the presence of the jammer. The parameters for simulation are as follow: M=8, N=150, xt= (0,0), x_{user}=(10,0), x_{LRIS}=(5,5), x_{RRIS}=(7,3) and the pathloss exponent α=3.5.

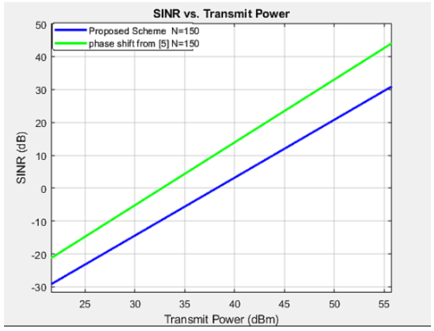

Fig. 2. SINR vs Transmit power.

Fig.2. illustrates that the proposed scheme reduces the SINR across different transmit power. It can be seen that the proposed phase shift can degrade the system by approximately 10dbm compared to the safe system.

V. Conclusion

In this study, we effectively utilized an RIS to disrupt legitimate communication by dynamically adjusting both the reflection coefficient and phase shift. Our future endeavors will revolve around proposing mitigation techniques aimed at neutralizing the impact of such disruptions.

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References

[1] F. Naeem, M. Ali, G. Kaddoum, C. Huang and C. Yuen, "Security and Privacy for Reconfigurable Intelligent Surface in 6G: A Review of Prospective Applications and Challenges," {IEEE Open Journal of the Communications Society, vol. 4, pp. 1196-1217, 2023,

[2] Q. Wu and R. Zhang, "Intelligent Reflecting Surface Enhanced Wireless Network via Joint Active and Passive Beamforming," IEEE Transactions on Wireless Communications, vol. 18, no. 11, pp. 5394-5409, Nov. 2019,

[3] B. Lyu, D. T. Hoang, S. Gong, D. Niyato and D. I. Kim, "IRS-Based Wireless Jamming Attacks: When Jammers Can Attack Without Power," in ₩textit {IEEE Wireless Communications Letters}, vol. 9, no. 10, pp. 1663-1667, Oct. 2020,

[4] A. S. de Sena, J. Kibiłda, N. H. Mahmood, A. Gomes and M. Latva-Aho, "Malicious RIS Versus Massive MIMO: Securing Multiple Access Against RIS-Based Jamming Attacks," {IEEE Wireless Communications Letters}, vol. 13, no. 4, pp. 989-993, April 2024.

[5] E. Basar, "Reconfigurable Intelligent Surface-Based Index Modulation: A New Beyond MIMO Paradigm for 6G," in IEEE Transactions on Communications, vol. 68, no. 5, pp. 3187-3196, May 2020