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Malicious Reconfigurable Intelligent Surfaces: How Impactful can Destructive Beamforming be?

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Abstract-Reconfigurable intelligent surfaces (RISs) have demonstrated significant potential for enhancing communication system performance if properly configured. However, a RIS might also pose a risk to the network security. In this letter, we explore the impact of a malicious RIS on a multi-user multiple-input single-output (MISO) system when the system is unaware of the RIS's malicious intentions. The objective of the malicious RIS is to degrade the signal-to-noise ratio (SNR) of a specific user equipment (UE), with the option of preserving the SNR of the other UEs, making the attack harder to detect. To achieve this goal, we derive the optimal RIS phase-shift pattern, assuming perfect channel state information (CSI) at the hacker. We then relax this assumption by introducing CSI uncertainties and subsequently determine the RIS's phase-shift pattern using a robust optimization approach. Our simulations reveal a direct proportionality between the performance degradation caused by the malicious RIS and the number of reflective elements, along with resilience toward CSI uncertainties.

Index Terms—Reconfigurable intelligent surface (RIS), malicious RIS, imperfect CSI, SNR degradation

I. INTRODUCTION

Reconfigurable intelligent surfaces (RISs) provide intelligent control over radio propagation environments through the utilization of nearly passive integrated electronic circuits that manipulate incoming waves. Based on its significant potential to improve coverage, spectral and energy efficiency, as well as localization performance in cellular networks, RISs are acknowledged as a pivotal technology for sixth-generation (6G) networks [1]. However, the envisioned low-cost and easy deployment of RISs introduces the risk that these surfaces are exploited as malicious attackers that might degrade the communication performance of user equipments (UEs) [2]. This can be done without generating interfering signals, as in traditional jamming, which might make the attacks hard to detect. While much of the research on RIS has focused on its positive contributions, the massive and cost-effective deployment of RISs is anticipated to give rise to security issues when RIS functions as an untrusted component [3]. It is critically important to comprehend and analyze all the possible ways in which an RIS can be used to exploit the system vulnerabilities and what damages it can cause [4]. The consequence of this security threat posed by RISs is an

increasing interest in the development of techniques aimed at counteracting the action of a malicious RIS [5]. The common practice in wireless security analysis is to consider the worstcase scenario where the hacker has perfect channel state information (CSI) on all the channels. While this approach establishes the theoretical limits, it is of practical import to look into the effect that channel estimation errors (CEEs) have on the RIS's potential malicious actions.

RISs are usually envisioned to be deployed as an integral component of the network, enabling the deployment of defensive mechanisms against malicious entities, such as eavesdroppers or jammers. A comprehensive examination of strategies that enhance the physical layer security (PLS) can be found in [6]: the authors present different RIS-based design solutions with which the PLS of a 6G network can be increased. In [7], the authors consider a scenario with two RISs whereof only one is legitimate, as well as the presence of an eavesdropper amongst the receiving UEs. Their main objective is to maximize the secrecy rate by incorporating artificial noise into the transmitted waveform. On the other hand, in [2], they analyze the signal leakage towards a malicious RIS. Contrary to the usual approach, [3] optimizes the attack of a malicious active RIS, aimed at degrading the signal-to-noise ratio (SNR) of a single receiving device. Assuming perfect CSI, the RIS and base station (BS) beamforming vectors are obtained, both in the presence and absence of cooperation between these two parties.

A. Contributions

Contrary to the existing literature, where a RIS is used as a performance booster or as a tool to protect the network from eventual jammers, our work highlights how a RIS might be used as a silent attacker that causes harm without transmitting any signals—a feature that makes it hard to detect. We investigate the impact that the number of RIS reflective elements has on the malicious RIS's silent jamming action and how resilient this action is towards CEEs. We first assume perfect CSI at the hacker and derive the RIS phase-shift pattern that degrades the SNR of a designated UE, with the option of introducing minimum SNR constraints for the other UEs, making the silent attack even harder to detect as the channel quality of every UE, but one is preserved. We then introduce CEEs onto the static path, as the RIS never interacts with this channel. Adopting a bounded error model, we then recast the previously defined optimization problems into robust ones. To the best of the authors' knowledge, this is the first work characterizing

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Fig. 1: A RIS-aided communication system where a hacker has hacked into the RIS's control center.

the impact of CEEs onto a malicious RIS's SNR-minimizing action. We provide numerical results highlighting how the impact of the attack depends on the number of RIS elements. The impact of CEEs is then assessed by comparing the robust optimization solutions to their perfect-CSI counterparts.

Notation: Boldface lowercase and uppercase letters denote vectors and matrices, with the symbols $(\cdot)^{\top}$ and $(\cdot)^{\mathsf{H}}$ representing the transpose and Hermitian transpose operators, respectively. The trace of the matrix **X** is denoted by $\operatorname{Tr}(\mathbf{X})$, while diag(**x**) represents the stacking of a vector **x** onto the main diagonal of a matrix. The symbols $|\cdot|$ and $||\cdot||$ denote the absolute value and Euclidean norm, respectively. The space of $M \times N$ complex matrices is denoted by $\mathbb{C}^{M \times N}$ and h(n) represents the *n*-th element of the vector **h**.

II. SYSTEM MODEL

We consider the RIS-assisted system shown in Fig. 1, where a BS with M antennas serves K single-antenna UEs. Unbeknownst to the transmitter, the RIS controller has been hacked with the goal of degrading the SNR of one UE, here assumed to be UE 1 without loss of generality. To keep its malicious intentions undetected, the RIS should simultaneously guarantee all other UEs a minimum SNR. The RIS is equipped with Npassive reflective elements, whose passive beamforming action is described by $\boldsymbol{\psi} = [\psi_1, \dots, \psi_N]^\top \in \mathbb{C}^N$, where $|\psi_n| = 1$, for $n = 1, \dots, N$. The static path between the BS and UE k is denoted by $\mathbf{h}_{s,k} \in \mathbb{C}^M$. The channel between the BS and RIS is described by $\mathbf{H}_t \in \mathbb{C}^{M \times N}$, while the channel between the RIS and UE k is $\mathbf{h}_{r,k} \in \mathbb{C}^N$. We adopt the cascaded channel model to define the overall channel between the BS and UE k as

$$\mathbf{h}_k = \mathbf{h}_{\mathrm{s},k} + \mathbf{H}_{\mathrm{t}} \mathbf{H}_{\mathrm{r},k} \boldsymbol{\psi},\tag{1}$$

where $\mathbf{H}_{\mathbf{r},k} = \operatorname{diag}(\mathbf{h}_{\mathbf{r},k}) \in \mathbb{C}^{N \times N}$ is a diagonal matrix. The BS applies a fixed precoding vector $\mathbf{p}_k \in \mathbb{C}^M$ to UE *k*'s data symbol. The effective end-to-end single-input single-output (SISO) channel to UE *k* then becomes

$$h_{k} = \mathbf{p}_{k}^{\top} \mathbf{h}_{k} = \underbrace{\mathbf{p}_{k}^{\top} \mathbf{h}_{\mathrm{s},k}}_{\triangleq h_{\mathrm{s},k}} + \underbrace{\mathbf{p}_{k}^{\top} \mathbf{H}_{\mathrm{t}} \mathbf{H}_{\mathrm{r},k}}_{\triangleq \check{\mathbf{h}}_{k}^{\mathsf{H}}} \boldsymbol{\psi} = h_{\mathrm{s},k} + \check{\mathbf{h}}_{k}^{\mathsf{H}} \boldsymbol{\psi}.$$
 (2)

The malicious RIS wants to compute its passive beamforming vector ψ with the aim of degrading the UE 1's SNR, defined

as $\text{SNR}_1 = |h_1|^2 / \sigma^2$, where σ^2 is the receiver noise variance. Similarly, the UE k's SNR is given as $\text{SNR}_k = |h_k|^2 / \sigma^2$. The reason for minimizing the SNR rather than the signal-tointerference-plus-noise ratio (SINR) is to give the impression to the UE that its channel is blocked, which can happen naturally.

III. DESTRUCTIVE BEAMFORMING WITH PERFECT CSI

This section is dedicated to the retrieval of the optimal SNR-degrading ψ under the assumption of perfect CSI at the hacker. The achieved SNR degradation is intended as a benchmark to assess the RIS's SNR-degradation capabilities and the impact of CEE. The SNR-degrading ψ acts as a destructive beamforming vector and will be obtained in two scenarios: a single-UE scenario, where the RIS degrades UE 1's SNR disregarding the possible presence of other UEs, and a multiple-UE scenario, where additional constraints are imposed to guarantee a minimum SNR level to the other UEs. In the single-UE scenario, the most SNR-degrading ψ is found by solving the following optimization problem:

$$\underset{\hat{\psi}}{\text{ninimize}} \quad \hat{\psi}^{\mathsf{H}} \mathbf{R}_{1} \hat{\psi} \tag{3a}$$

subject to
$$|\hat{\psi}_n| = 1, \ n = 1, ..., N,$$
 (3b)

$$\hat{\psi}_{N+1} = 1, \tag{3c}$$

where

$$\hat{\boldsymbol{\psi}} = \begin{bmatrix} \boldsymbol{\psi}^{\top}, 1 \end{bmatrix}^{\top}, \quad \mathbf{R}_1 = \begin{bmatrix} \mathbf{\check{h}}_1 \mathbf{\check{h}}_1^{\mathsf{H}} & \mathbf{\check{h}}_1 h_{\mathrm{s},1} \\ h_{\mathrm{s},1}^* \mathbf{\check{h}}_1^{\mathsf{H}} & |h_{\mathrm{s},1}|^2 \end{bmatrix}.$$
(4)

This problem is non-convex due to the unit modulus constraints in (3b). Rather than employing a semi-definite relaxation (SDR)-based approach, we apply a penalty-based convex concave procedure (CCP) approach [8] due to its lower computational complexity. First, unit modulus constraints can be decoupled into a chain of inequalities such as $1 \leq |\hat{\psi}_n|^2 \leq 1$, $n = 1, \ldots, N$. Then, the leftmost inequality is convexified by substituting $|\hat{\psi}_n|^2$ with its first-order Taylor expansion around the local point $\hat{\psi}_n^{(r)}$, which is the solution found at iteration r. Finally, we define a penalty variable $\mathbf{d} = [d_1, \ldots, d_{2N}]^{\mathsf{T}}$ and introduce it into the previously defined inequalities. Finally, the constraint (3b) can be redefined as

$$\left|\hat{\psi}_{n}\right|^{2} \le 1 + d_{n} , \ n = 1, \dots, N$$
 (5a)

$$\left|\hat{\psi}_{n}^{(r)}\right|^{2} - 2\Re\left(\hat{\psi}_{n}^{*}\hat{\psi}_{n}^{(r)}\right) \leq d_{N+n} - 1 , \ n = 1, \dots, N.$$
 (5b)

Problem (3) can then be recast into the convex problem

P1: minimize
$$\hat{\psi}^{\mathsf{H}} \mathbf{R}_1 \hat{\psi} + \lambda^{(r)} ||\mathbf{d}||$$
 (6a)

subject to
$$(5a)$$
, $(5b)$, $(6b)$

$$\hat{\psi}_{N+1} = 1, \tag{6c}$$

$$d_n \ge 0, \quad n = 1, \dots, 2N, \tag{6d}$$

where $\lambda^{(r)}$ is a multiplying factor, adjusting the impact of the penalty term onto the objective function, at iteration r.

The multiple-UE optimization problem follows the same rationale but has K - 1 additional minimum-SNR constraints:

minimize
$$\hat{\psi}^{\mathsf{H}} \mathbf{R}_1 \hat{\psi}$$
 (7a)

subject to
$$\hat{\psi}^{\mathsf{H}} \mathbf{R}_k \hat{\psi} \ge \gamma_k \sigma^2, \ k = 2, \dots, K,$$
 (7b)

$$\left| \hat{\psi}_n \right| = 1, \ n = 1, \dots, N,$$
 (7c)

$$\hat{\psi}_{N+1} = 1, \tag{7d}$$

where \mathbf{R}_k is defined as in (4) but with a different index and γ_k is the minimum SNR requirement for UE k. This problem is non-convex due to the presence of the constraints in (7b). However, it can be convexified by substituting $\hat{\psi}^{\mathsf{H}} \mathbf{R}_k \hat{\psi}$ with its first-order Taylor expansion around $\hat{\psi}^{(r)}$:

$$\hat{\boldsymbol{\psi}}^{(r)\mathsf{H}}\mathbf{R}_{k}\hat{\boldsymbol{\psi}}^{(r)} - 2\Re\left(\boldsymbol{\psi}^{(r)\mathsf{H}}\mathbf{R}_{k}\hat{\boldsymbol{\psi}}\right) \le t_{k} - \gamma_{k}\sigma^{2}, \quad (8)$$

where t_k is the penalty term for this constraint. Problem (7) can then be rewritten as

P2: minimize
$$\hat{\psi}^{\mathsf{H}} \mathbf{R}_1 \hat{\psi} + \lambda^{(r)} ||\mathbf{d}|| + \omega^{(r)} ||\mathbf{t}||$$
 (9a)
 $\hat{\psi}_{,\mathbf{d},\mathbf{t}}$

subject to (8),
$$k = 2, ..., K$$
, (9b)

$$(5a), (5b), (6d)$$
 (9c)

$$\hat{\psi}_{N+1} = 1,\tag{9d}$$

$$t_k \ge 0, \quad k = 2, \dots, K, \tag{9e}$$

where $\mathbf{t} = [t_2, \ldots, t_K]^{\top}$ and $\omega^{(r)}$ is the multiplying factor associated with the penalty term $||\mathbf{t}||$. Choosing a fixed value of γ_k would undermine the fairness of the performance comparison across different values of N: a certain minimum SNR is easy to ensure when N is large, but it would be hard or impossible to guarantee said SNR when N is low. We then define γ_k as a fixed percentage of the maximum SNR achievable by each UE: its value is retrieved by solving the following problem

$$\gamma_k = c \text{ maximize } \operatorname{Tr}\left(\mathbf{R}_k \hat{\Psi}\right)$$
 (10a)

subject to
$$\hat{\Psi}_{n,n} = 1, \ n = 1, ..., N + 1,$$
 (10b)

$$\hat{\boldsymbol{\Psi}} \succeq 0, \ \operatorname{rank}\left(\hat{\boldsymbol{\Psi}}\right) = 1,$$
 (10c)

where $\hat{\Psi} = \hat{\psi}\hat{\psi}^{\mathsf{H}}$ and $0 < c \leq 1$. By relaxing the rank-one constraint, this problem becomes convex and can be directly solved by general-purpose convex optimization solvers.

We now assume that the RIS has a constant-magnitude channel (e.g., line-of-sight (LoS)) to both the AP and UE 1: The reflected path can then be denoted as $\check{\mathbf{h}}_1 = \rho_r [e^{j \angle \check{h}_1(1)}, \ldots, e^{j \angle \check{h}_1(N)}]^{\top}$, where ρ_r is the channel magnitude. The cascaded channel in (2) can now be written as

$$h_{s,1} + \breve{\mathbf{h}}_{1}^{\mathsf{H}} \boldsymbol{\psi} = |h_{s,1}| e^{j \angle h_{s,1}} + \rho_{\mathsf{r}} \sum_{n=1}^{N} e^{-j \angle \breve{h}_{1}(n)} e^{\angle \psi_{n}}.$$
 (11)

Under these assumptions, problem (3) can be solved in closed form, as stated in the following lemma.

Lemma 1. Let the RIS choose $\xi \in [0, 2\pi)$ and let the *n*-th RIS phase-shift be $\angle \psi_n = \angle h_{s,1} + \angle h_1(n) + (n - \frac{N+1}{2})\xi + \pi$. Then, the cascaded channel magnitude becomes

$$\left|h_{s,1} + \breve{\mathbf{h}}_{1}^{\mathsf{H}}\boldsymbol{\psi}\right| = \left||h_{s,1}| - \rho_{\mathsf{r}}\frac{\sin(N\xi/2)}{\sin(\xi/2)}\right|.$$
 (12)

If $|h_{s,1}| \ge N\rho_r$, then problem (3) outcome is $SNR_1 = (|h_{s,1}| - N\rho_r)^2 / \sigma^2$, obtained for $\xi = 0$. If $|h_{s,1}| \le N\rho_r$, SNR_1 can be nullified for some ξ .

Proof: The summation $\sum_{n=1}^{N} e^{-j \angle \check{h}_1(n)} e^{\angle \psi_n}$ in (11) can be rewritten as $\rho_r \sin(N\xi/2)/\sin(\xi/2)$, thanks to the geometric series formula and Euler's formula. The latter has peaks around $\xi = 0$ with a maximum equal to $N\rho_r$. If $|h_{s,1}|$ is higher than this peak value, the best the RIS can do is to choose $\xi = 0$: on the other hand, if $|h_{s,1}|$ is lower than the peak, the RIS can choose a ξ such that SNR₁ = 0.

IV. IMPERFECT CSI: ROBUST OPTIMIZATION

We will now relax the perfect CSI assumption by introducing CEE onto the static path. This choice is motivated by the fact that this path is the hardest one to estimate from the hacker's point of view. We can denote the cascaded channel in (2) as $h_k = \hat{h}_{s,k} + \Delta h_{s,k} + \breve{\mathbf{h}}_k^{\mathsf{H}} \psi$, where $\Delta h_{s,k}$ denotes the CEE. We adopt a bounded error model [9], where the error can be anything satisfying $|\Delta h_{s,k}| \leq \epsilon_{s,k}, k = 1, \dots, K$, and the upper limit $\epsilon_{s,k}$ is assumed to be known by the hacker. Under these assumptions, problem (3) becomes

$$\underset{\boldsymbol{\psi}}{\text{minimize}} \quad \max_{|\Delta h_{s,1}| \le \epsilon_{s,1}} \left| \hat{h}_{s,1} + \Delta h_{s,1} + \breve{\mathbf{h}}_{1}^{\mathsf{H}} \boldsymbol{\psi} \right|^{2}$$
(13a)

subject to
$$|\psi_n| = 1, \ n = 1, ..., N.$$
 (13b)

As usual, when dealing with min-max problems, we define an auxiliary variable a and recast the problem in epigraph form:

$$\begin{array}{c} \underset{\psi,a}{\text{minimize}} a \tag{14a} \end{array}$$

subject to
$$\left|\hat{h}_{s,1} + \Delta h_{s,1} + \breve{\mathbf{h}}_{1}^{\mathsf{H}} \boldsymbol{\psi}\right|^{2} \leq a, \ \forall \ |\Delta h_{s,1}| \leq \epsilon_{s,1},$$
(14b)

$$|\psi_n| = 1, \ n = 1, \dots, N,$$
 (14c)

$$a \ge 0. \tag{14d}$$

The presence of CSI uncertainties makes (14b) a constraint of infinite cardinality, as $\Delta h_{s,1}$ can take an infinite number of values. To address this issue, we use the Schur complement [10] to rewrite the constraint in (14b) as

$$\begin{bmatrix} a & x \\ x^* & 1 \end{bmatrix} \succeq 0, \quad \forall \ |\Delta h_{s,1}| \le \epsilon_{s,1}, \tag{15}$$

where $x = \hat{h}_{s,1} + \Delta h_{s,1} + \breve{h}_1^{\mathsf{H}} \psi$. We then apply Nemirovski's lemma to equivalently express the constraint as [11]

$$\begin{bmatrix} a-\xi & \hat{x} \\ \hat{x}^* & 1 \end{bmatrix} \succeq 0, \ \begin{bmatrix} \xi & \epsilon_{s,1} \\ \epsilon_{s,1} & 1 \end{bmatrix} \succeq 0,$$
(16)

where $\hat{x} = \hat{h}_{s,1} + \check{\mathbf{h}}_1^{\mathsf{H}} \boldsymbol{\psi}$ and $\xi \ge 0$ is an auxiliary variable. Finally, we define the robust version of problem P1 as

P1': minimize
$$a + \lambda^{(r)} ||\mathbf{d}||$$
 (17a)

The multi-user scenario optimization problem can be defined by adding K - 1 minimum SNR constraints to P1'.¹ We then obtain the problem

$$\underset{\boldsymbol{\psi}, \boldsymbol{a}, \boldsymbol{\varepsilon}, \mathbf{d}}{\text{minimize}} \quad \boldsymbol{a} + \lambda^{(r)} ||\mathbf{d}||$$
(18a)

$$\left|\hat{h}_{\mathrm{s},k} + \Delta h_{\mathrm{s},k} + \breve{\mathbf{h}}_{k}^{\mathsf{H}} \boldsymbol{\psi}\right|^{2} \ge \gamma_{k} \sigma^{2}, \qquad (18c)$$

$$\forall \ |\Delta h_{\mathbf{s},k}| \le \epsilon_{\mathbf{s},k}, \ k = 2, \dots, K.$$

The constraint (18c) is once again non-convex and of infinite cardinality. Hence, we first approximate $|h_k|^2$ with a local lower bound.

Lemma 2. Let $\psi^{(r)}$ be a feasible point for problem (18) at iteration r. In that case, $|h_k|^2$ can be lower bounded as

$$|h_k|^2 \ge h_{\mathbf{s},k}^* h_{\mathbf{s},k} + h_{\mathbf{s},k}^* \mathbf{\breve{h}}_k^{\mathsf{H}} \boldsymbol{\psi} + \boldsymbol{\psi}^{\mathsf{H}} \mathbf{\breve{h}}_k h_{\mathbf{s},k} + c_k, \qquad (19)$$

where $c_k = \psi^{(r)\mathsf{H}}\breve{\mathbf{h}}_k\breve{\mathbf{h}}_k^\mathsf{H}\psi + \psi^\mathsf{H}\breve{\mathbf{h}}_k\breve{\mathbf{h}}_k^\mathsf{H}\psi^{(r)} - \psi^{(r)\mathsf{H}}\breve{\mathbf{h}}_k\breve{\mathbf{h}}_k^\mathsf{H}\psi^{(r)}.$

Proof: Any complex scalar variable δ can be lower bounded as [8] $|\delta|^2 \geq \delta^{(r)*}\delta + \delta^*\delta^{(r)} - \delta^{(r)*}\delta^{(r)}$ for any $\delta^{(r)}$. By choosing $\delta = h_{s,k} + \mathbf{\check{h}}_k^{\mathsf{H}} \psi$ and $\delta^{(r)} = h_{s,k} + \mathbf{\check{h}}_k^{\mathsf{H}} \psi^{(r)}$ we obtain (19).

Given that $h_{s,k} = \hat{h}_{s,k} + \Delta h_{s,k}$, (18c) can be reformulated as

$$\Delta h_{s,k}^* \Delta h_{s,k} + 2\Re \left(\left(\breve{\mathbf{h}}_k^{\mathsf{H}} \boldsymbol{\psi} + \hat{h}_{s,k} \right)^* \Delta h_{s,k} \right) + f_k \ge \gamma_k \sigma^2, \forall \ |\Delta h_{s,k}| \le \epsilon_{s,k},$$
(20)

where $f_k = \hat{h}_{s,k}^* \hat{h}_{s,k} + \hat{h}_{s,k}^* \mathbf{H}_k^{\mathsf{H}} \boldsymbol{\psi} + \boldsymbol{\psi}^{\mathsf{H}} \mathbf{H}_k \hat{h}_{s,k} + c_k$. We are now able to get rid of $\Delta h_{s,k}$ by applying the S-procedure [12]. If we define the auxiliary variable α , (20) can be equivalently expressed as

$$\begin{bmatrix} 1 + \alpha & \breve{\mathbf{h}}_{k}^{\mathsf{H}}\boldsymbol{\psi} + \hat{h}_{\mathsf{s},k} \\ \left(\breve{\mathbf{h}}_{k}^{\mathsf{H}}\boldsymbol{\psi} + \hat{h}_{\mathsf{s},k} \right)^{*} & f_{k} - \gamma_{k}\sigma^{2} - \alpha\epsilon_{\mathsf{s},k}^{2} \end{bmatrix} \succeq 0.$$
(21)

Finally, we are able to rewrite problem (18) as

P2': minimize
$$a + \lambda^{(r)} ||\mathbf{d}||$$
 (22a)

subject to
$$(5a)$$
, $(5b)$, $(6d)$, (16) , (21) , $(22b)$

$$\alpha \ge 0. \tag{22c}$$

All the problems presented in the last two sections are solved by Algorithm 1, where $\mathcal{P} = \{P1, P2, P1', P2'\}$.

Algorithm 1: CCP based algorithm for RIS destructive beamforming optimization

1: Initialize: $\psi^{(0)}, \omega^{(0)}, \lambda^{(0)}$, set r = 02: if $P_p \neq P2$ then 3: $\mathbf{t}=\mathbf{0}$ 4: end if 5: repeat Compute $\psi^{(r+1)}$ by solving $P_p \in \mathcal{P}, r \leftarrow r+1$ 6: $\lambda^{(r)} = \min\left(\mu\lambda^{(r-1)}, \lambda_{\max}\right),$ 7: if $P_p=P2$ then 8: $\hat{\omega}^{(r)} = \min\left(\mu\omega^{(r-1)}, \omega_{\max}\right)$ 9: end if 10: 11: **until** $||\mathbf{d}|| \le \nu$, $\|\boldsymbol{\psi}^{(r)} - \boldsymbol{\psi}^{(r-1)}\| \le \nu$, $||\mathbf{t}|| \le \nu$ 12: Output: ψ_{opt}



Fig. 2: SNR degradation analysis with perfect CSI.

V. NUMERICAL RESULTS

We now demonstrate the destructive beamforming that a malicious RIS can perform in different situations. The Monte-Carlo simulations are obtained using 200 independent channel realizations. The transmitter is located at (10, 0) m whereas the RIS center is located at (50, 100) m. There are K = 2UEs located at (300, 0) m and (300, 50) m. The static paths $\mathbf{h}_{s,k}$ are modeled as Ricean fading, with a K-factor equal to 10, \mathbf{H}_t is assumed to be a LoS channel whereas $\mathbf{h}_{r,k}$ is Rayleigh fading, The large-scale shadowing coefficient is $\beta_k = -30 - 20 \log_{10}(d_k/d_0)$, where d_k is the distance between the transmitter, either the BS or the RIS, and UE k and $d_0 = 1$ m. The noise power at all the UEs is -70 dB. The performances of our algorithm are compared against a maximumratio transmission (MRT) benchmark, where the RIS phaseshifts are defined as $\psi_n = \check{h}_2(n)/|\check{h}_2(n)|, n = 1, \dots, N.$ This approach leverages the large channel dimensionality (i.e., favorable propagation) to divert the signal away from UE 1. The CEE bounds are defined as $\epsilon_{s,k} = \eta |h_{s,k}|, k = 1, \dots, K$, where $0 \le \eta \le 1$. The parameters , λ_{\max} and ω_{\max} are equal to 10^4 , $\mu = 1.5$, and $\nu = 10^{-3}$

A. Perfect CSI

The impact of the malicious RIS is directly dependent on the static path strength relative to $\check{\mathbf{h}}_k$. As N grows, the magnitude of the reflected path grows as well and the malicious

¹To obtain a fair comparison, this robust approach uses the same minimum SNR γ_k as its perfect CSI counterpart.



Fig. 3: SNR degradation analysis under imperfect CSI.

RIS' silent attack can become more powerful. This trend is showcased in Fig. 2, where SNR_1 is shown as a function of the number of RIS elements, N. We compare our algorithm with two low complexity approaches, namely the previously mentioned MRT and a random approach, where each phaseshift ψ_n takes a random value in $[0, 2\pi)$. The first feature that we can observe is that our algorithm drastically outperforms the other approaches, first and foremost the random approach, since we know that a user SNR in the presence of random RIS phase-shifts grows linearly with N [13]. Secondly, the MRT approach, albeit being slightly better than the random one, still does not give a SNR reduction, as we see that said SNR is still always above the "no RIS" curve, equal to $|h_{s,1}|^2/\sigma^2$. As for our proposed algorithm, the presence of a minimum SNR requirement has a sizable impact on the overall performance. If the presence of other UE is disregarded, we see that 5 reflective elements are enough to obtain a 20 dB SNR reduction, whereas if the presence of other UE is taken into account, the RIS needs at least 30 elements to replicate the same SNR reduction.

B. Imperfect CSI

We will now investigate the impact of channel uncertainties on the RIS' SNR-degrading action, using the results presented in the previous section as a benchmark. Fig. 3 shows the effect of CEEs as a function of N for different values of $\epsilon_{s,k}$. The presence of CEEs does not alter the inverse proportionality between SNR 1 and N, however, a larger CEE magnitude obviously leads to worse performance. In Fig. 3, we can observe how the destructive beamforming performance in the single-user case is robust against CEEs. CEEs have a nonnegligible impact, even when $\eta = 1$ only 15 reflective elements are sufficient to obtain a 40 dB reduction. This can be ascribed to the fact that in P1 and P1', the most important thing is to phase-align the destructive paths rather than knowing the static one. The same cannot be said about the multiuser cases. Indeed, Fig. 3(b) shows that even relatively small errors can severely hinder the RIS's destructive capability. This is partially explained by the very stringent minimum SNR introduced.

VI. CONCLUSIONS

We investigated a novel scenario where a hacker takes control of a RIS with the intention of degrading the SNR of a specific UE while preserving the SNR of all other UEs. Assuming perfect CSI, the RIS phase-shift vector design strategy is presented, with a closed-form solution for LoS channels. We then devised a robust optimization approach. Our simulations demonstrate that our algorithms can dramatically reduce a UE SNR and how minimum SNR constraints limit this action, especially in the presence of CEEs.

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