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Multi-receiver Physical Layer Security using Reconfigurable Intelligent Surfaces

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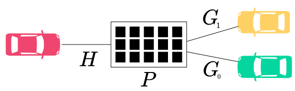
- Physical Layer Security (PLS) techniques can leverage random wireless channel realizations for security and privacy
- Via Reconfigurable Intelligent Surfaces (RISs), we can
  - enhance signal quality at an intended receiver, even without line of sight
  - while generating disrupting interference towards potential eavesdroppers
- Existing approaches consider single receiver / single RIS scenarios
- We extend the existing model to work with multiple receivers and multiple RISs, and evaluate the spatial coverage of the privacy feature
- Using a Ray Tracer like Sionna helps us validate the model using realistic simulations

Problem

Enable legitimate receivers to decode an SSK signal while making it incomprehensible to eavesdroppers.

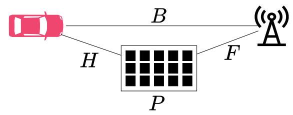
System model

Car to car communication using RISs



$$y = GPHx = \begin{bmatrix} \alpha_{11} & 0 & \cdots & 0 \\ 0 & \alpha_{22} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \alpha_{KK} \end{bmatrix} \begin{bmatrix} 1 \\ 0 \\ \vdots \\ 0 \end{bmatrix} = \begin{bmatrix} \alpha_{11} \\ 0 \\ \vdots \\ 0 \end{bmatrix}$$

Car to eavesdropper communication disrupted



$$y = Bx + FPHx$$

Solution

Choose RIS configuration so that the overall channel matrix for intended receivers is diagonal.

$$||G_j PH - [G_j PH]_{diag}||^2 = 0, \quad \forall j \in \{1, \dots, J\}$$

Solve $p^\dagger W p = 0$ with $W = \left[W_1^\intercal, \dots, W_J^\intercal\right]^\intercal$

$$W_j = \sum_{i=1}^{K} \sum_{k=1, i \neq k}^{K} (g_{jk,*} \odot h_{*,i}^\intercal)^\dagger (g_{jk,*} \odot h_{*,i}^\intercal) \in \mathbb{C}^{N \times N}$$

Compute the singular value decomposition

$$W = R \Sigma V^\dagger \in \mathbb{C}^{JN \times N}$$

Take the last $N - J(K^2 - K)$ rows of $V^\dagger \in \mathbb{C}^{N \times N}$ as U_1

Define $U = U_1^\dagger \in \mathbb{C}^{N \times N - J(K^2 - K)}$ and take

$p = \frac{\eta}{||Uq||_\infty} Uq$ with $q \neq 0$ a random complex vector

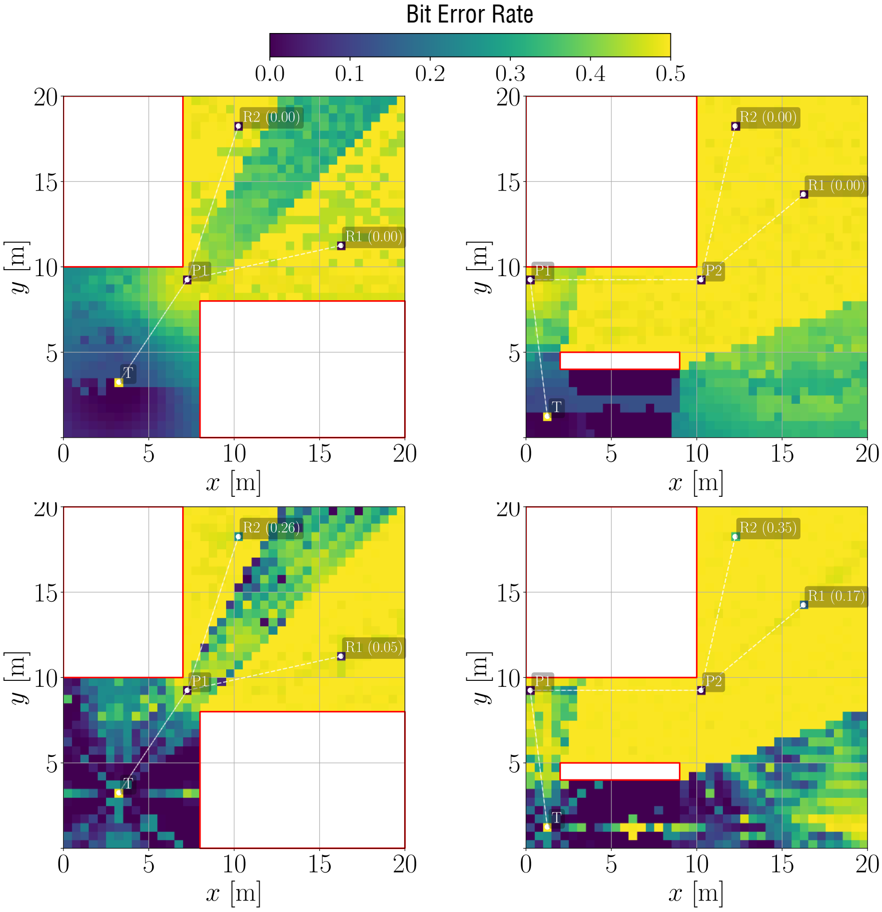
The RIS configuration is $P = \mathrm{diag}(p) \in \mathbb{C}^{N \times N}$

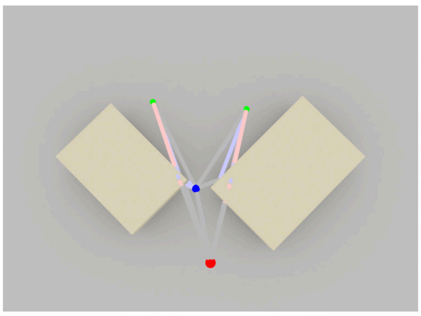
If we have multiple RISs in series, define

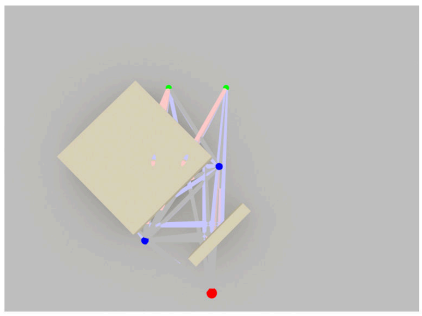
$$||GP_1C_1 \dots P_M H - [GP_1C_1 \dots P_M H]_{diag}||^2 = 0$$

$$G' = GP_1C_1 \dots P_{M-1}C_{M-1} \in \mathbb{C}^{K \times N}$$

and solve as before.







References

J. Luo et al., "Reconfigurable Intelligent Surface: Reflection Design Against Passive Eavesdropping," IEEE Trans. on Wireless Communications, May 2021

J. Jeganathan et al., "Space shift keying modulation for MIMO channels," IEEE Trans. on Wireless Communications, July 2009

S. Marrocco, P. Casari and M. Segata, "Exploiting Reconfigurable Intelligent Surfaces to Achieve Multi-Receiver Physical Layer Security," 2025 IEEE 31st International Symposium on On-Line Testing and Robust System Design (IOLTS), July 2025

S. Marrocco, P. Casari, and M. Segata, "RIS-Based Physical Layer Security: Realistic Evaluation and Challenges Ahead," 2025 IEEE 20th Wireless On-demand Network systems and Service (WONS), March 2026

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