Reconfigurable Intelligent Surfaces: About Applications and Their Implementation

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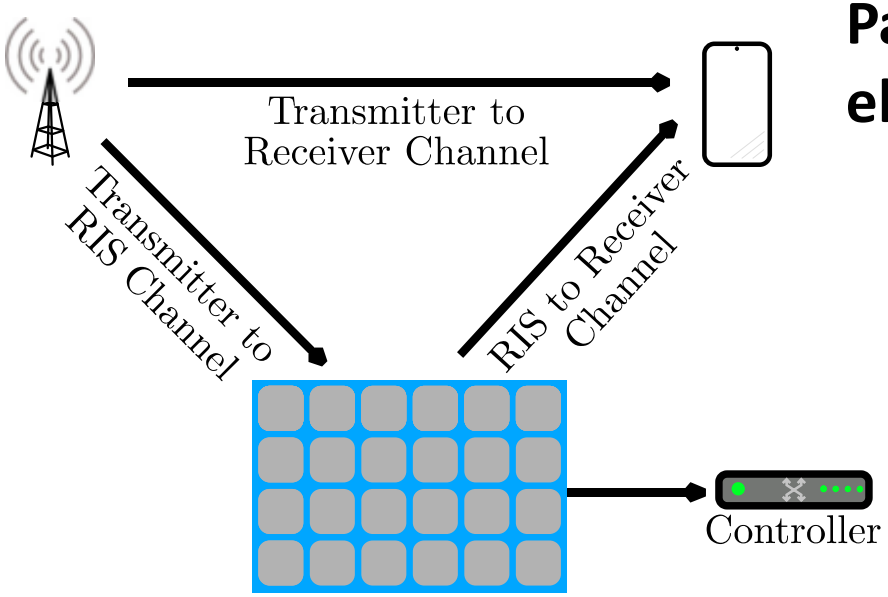
Introduction: RIS – Reconfigurable Intelligent Surface



Passive elements

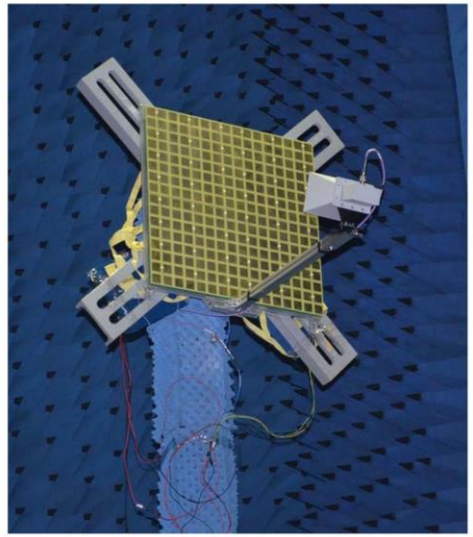
Element size in the range of λ/4

Controlled with smart Algorithm

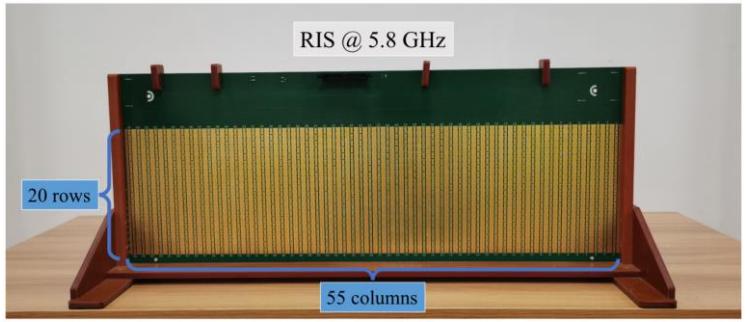
Manipulate reflective characteristics

→ **Beamforming**

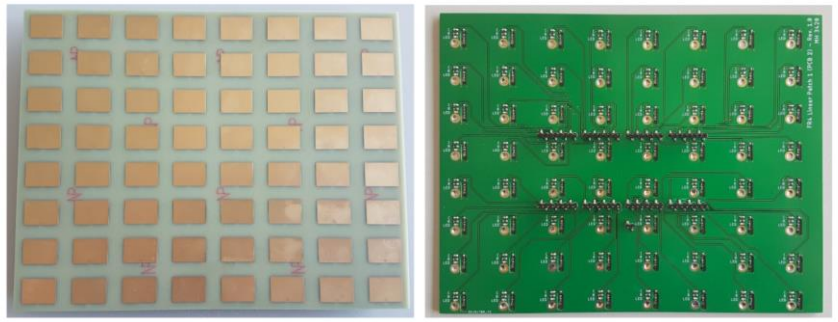
State of the art – antenna based



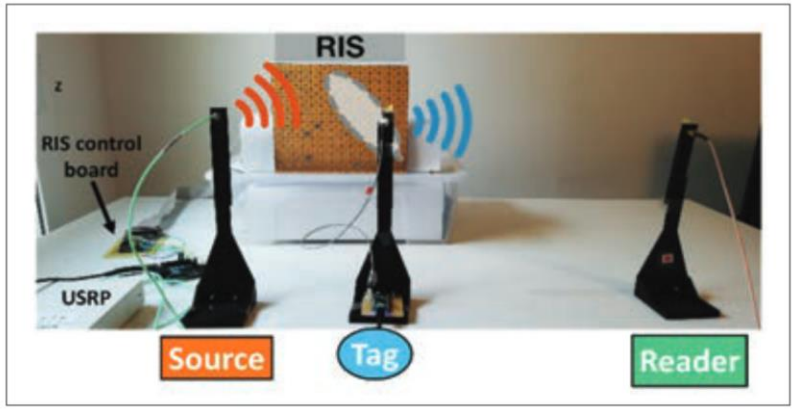
L. Dai *u. a.*, „Reconfigurable Intelligent Surface-Based Wireless Communications: Antenna Design, Prototyping, and Experimental Results“, *IEEE Access*, Bd. 8, S. 45913–45923, 2020



X. Pei *u. a.*, „RIS-Aided wireless communications: Prototyping, adaptive beamforming, and Indoor/Outdoor field trials“, *IEEE Transactions on Communications*, Bd. 69, Nr. 12, S. 8627–8640, 2021

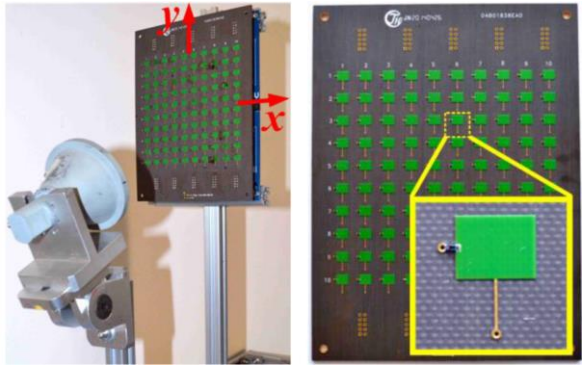


P. Staat, H. Elders-Boll, M. Heinrichs, C. Zenger, und C. Paar, „Mirror Mirror on the Wall: Wireless Environment Reconfiguration Attacks Based on Fast Software-Controlled Surfaces“, *arXiv:2107.01709 [cs]*, Aug. 2021



R. Fara, P. Ratajczak, D.-T. Phan-Huy, A. Ourir, M. Di Renzo, und J. de Rosny, „A Prototype of Reconfigurable Intelligent Surface with Continuous Control of the Reflection Phase“, *IEEE Wireless Commun.*, Bd. 29, Nr. 1, S. 70–77, Feb. 2022

V. Arun und H. Balakrishnan, „RFocus: Beamforming using thousands of passive antennas“, in *17th USENIX symposium on networked systems design and implementation (NSDI 20)*, Santa Clara, CA, Feb. 2020, S. 1047–1061.

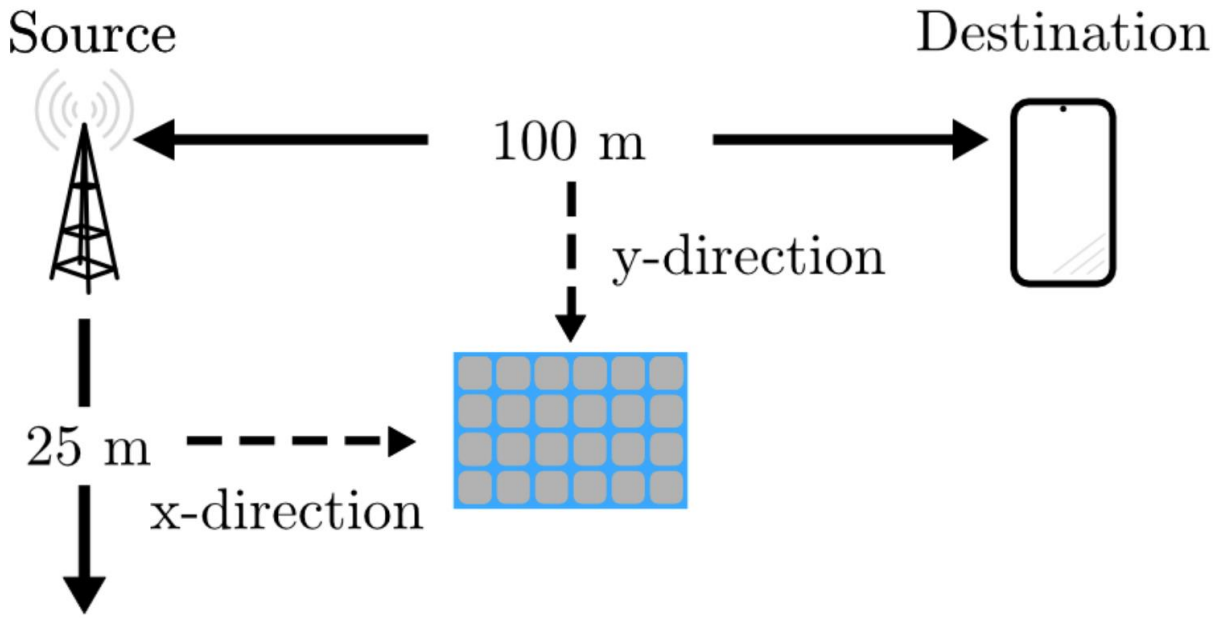


H. Yang *u. a.*, „A 1-Bit 10x10 Reconfigurable Reflectarray Antenna: Design, Optimization, and Experiment“, *IEEE Trans. Antennas Propagat.*, Bd. 64, Nr. 6, S. 2246–2254, Juni 2016

Overview

RIS Design	Use Cases	Phase-Quantization	Number of Elements	Operating Frequency /GHz	Reference
Patch-antennas – PIN diode based	Exploiting Constructive and Destructive Interference	2 states (On/ Off)	3200	2.4	*Arun et al.**
2D cross-design – PIN diode based	One of the first 2-bit phase shifting RIS-systems	4 states (90° each)	256 (16 × 16)	2.3 and 28.5	*Dai et al.**
Three layer system – varactor diode based	three layer system - varactor diode based & Energy efficient RIS-Prototype, based on *Dai et al.**	2 states (180°)	1100 (55 X 20)	5.8	*Pei et al.**
Patch-antennas – PIN diode based	Cost efficient RIS-System	2 states (180°)	100 (10 x 10)	11.75-13.25	*Yang et al.**, *Hum et al.**
2D layer system – varactor diode based	Assisting ambient back-scatter communication (AmBC) system	continuous phase tun-ing	196 (14 x 14)	5.15-5.75	*Fara et al.**
metallic patches – PIN diode based	Hall sensor for measuring magnetic fields	2 states (On/ Off)	64 (8 x 8)	2.4	*Ma et al.**
patch reflectors – PIN diode based	RIS as jamming attack device	2 states (180°)	128 (16 x 8)	5.37	*Staat et al.**

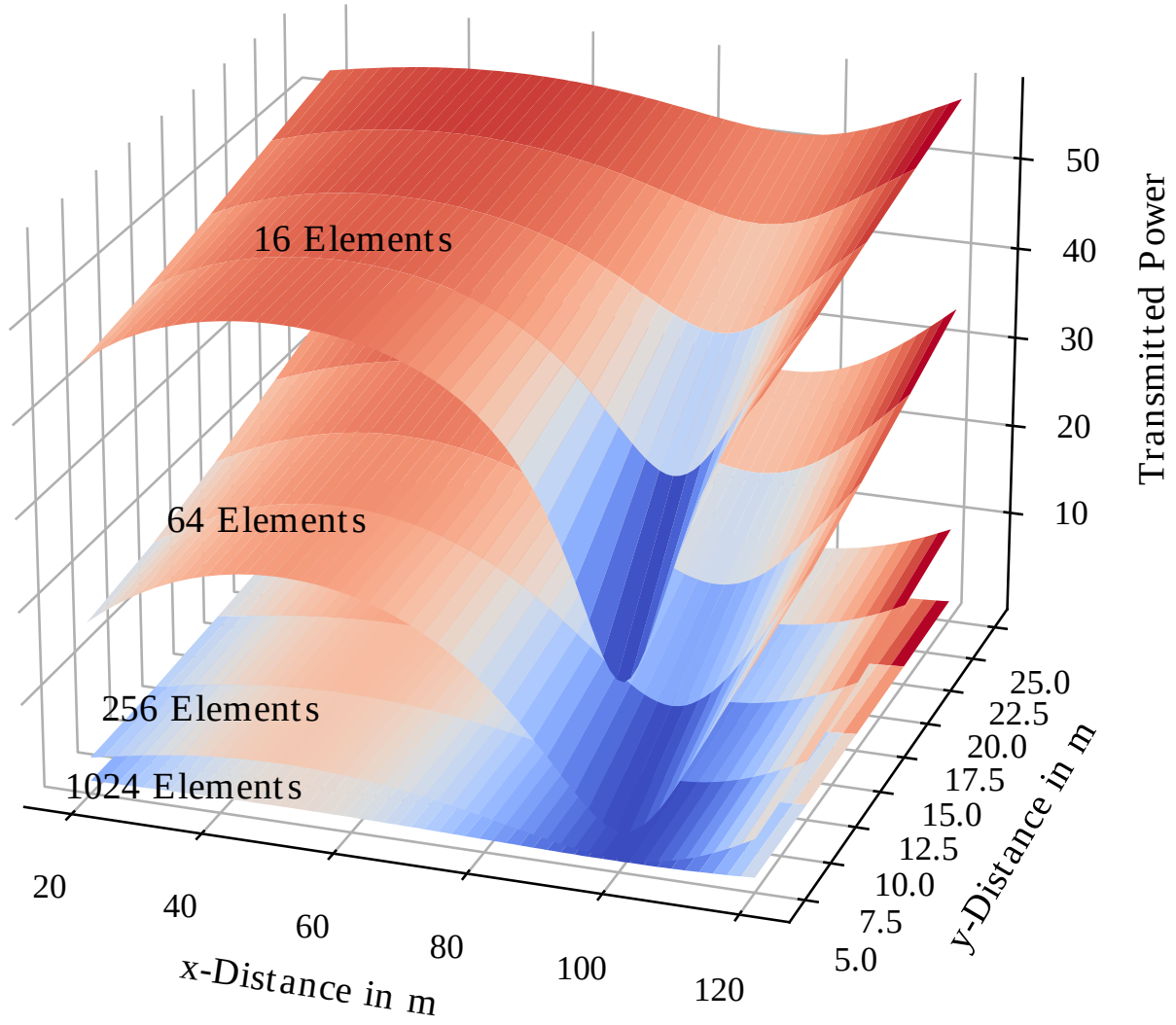
Simulation of different RIS positions



- Varying x- and y- position of RIS-System
- Model provided from *Björnson et al.**
- Urban micro model *(Non-Line-of-Sight)*
- Simulation of 4x4, 8x8, 16x16, 32x32-Element-RIS

E. Björnson, Ö. Özdogan, and E. G. Larsson, “Intelligent Reflecting Surface vs. Decode-and-Forward: How Large Surfaces Are Needed to Beat Relaying?” IEEE Wireless Communications Letters, vol. 9, no. 2, pp. 244–248, Feb. 2020. DOI: 10 . 1109 / LWC . 2019 . 2950624.

Simulations



Colorscaled: achieve a certain data rate of 4 bits/ s

Limited position selection: close to transmitter or receiver

Gain/ element-ratio: 8 times higher for 1024-elements compared to 16 considering costs

Difficulties and Feasibilities

❌ Not user-selective right now

❌ Unwanted Interference due to RIS-Systems

❌ Insertion Loss through RIS has to be considered

⚠ Security aspekts have to be evaluated: RIS influences hole radio environment, eavesdropping may become a risk

- Energy efficiency: Deployment without fixed energy source?
- Flexibility: Easy deployment
- Cost efficiency: Solution for blind spots
- Higher frequencies: possible solution

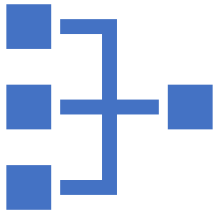
Fundamental Design Choices I

a) What is the experimental setup the RIS should be designated for?

b) 2-state elements or elaborated phase control?

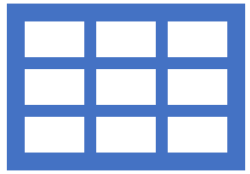
c) Linear antenna design or 2D elements?

Fundamental Design Choices II



d) How to tune the antenna element?

e) What frequency should be used

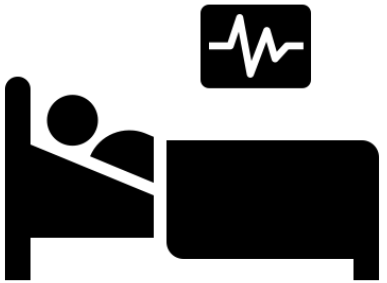


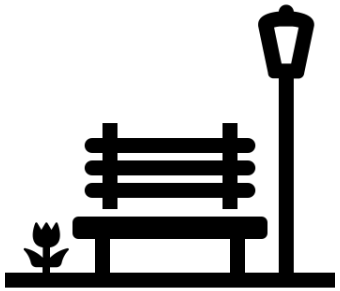
f) What size of RIS and what number of elements should be used?

What is a feasable use case?

Stationary systems:

- Portable user equipment localized for a certain time frame
- Optimized state stable without reoptimization
- RIS as passive system
- park, campus, hospital





Summary

- Highlighted fundamental design choices in the scope of the feasibility of RIS
- Discussed challenges on RIS positioning and element number based on provided simulations
- Narrowed down the use cases for state-of-the-art systems

THANK YOU

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