TU GRAZ SCIENCE FOR FUTURE

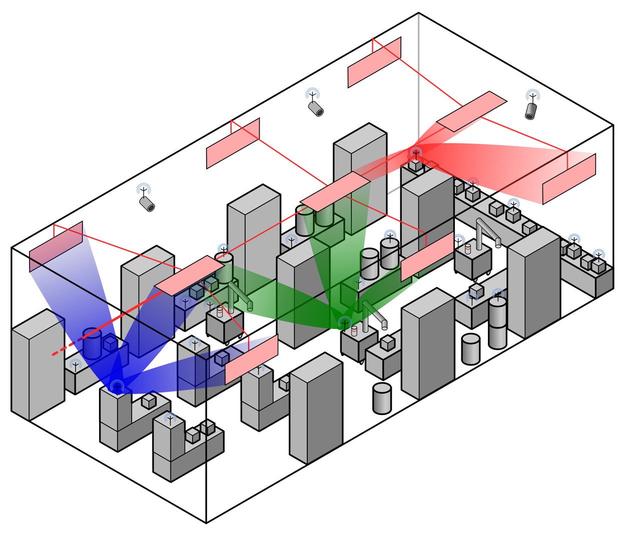
2022: DIGITAL VISIONS

RadioWeaves: Digitalization Use Cases Demanding a New 6G Wireless Infrastructure

Introduction

- 5G radio technologies promise to bring massive bandwidth to future wireless communication systems.
- Massive antenna arrays may be the enabling technology for future 6G use cases.
- RadioWeaves is a wireless infrastructure of distributed radio devices and computing resources featuring
  - ultra-reliable communication
  - precise positioning
  - wireless power transfer

  for use cases in the industry, healthcare, and public venues.



- Real-time and real-space applications are realized by shifting the computational burden to the infrastructure.
- Massive, yet sustainable deployments of batteryless energy neutral (EN) devices (e.g., sensors) map real-world use cases to the digital domain.

Application 1: Ultra-reliable Communication

- A large or distributed radio architecture allows to focus signals spatially.
- Both the line-of-sight (LoS) and specular multipath components (SMCs) are exploited for communication [1].
- Environment-awareness allows to predict channel vectors $\boldsymbol{h}$ (see Figure 6) geometrically [2] and leads to ultra-reliable communication.

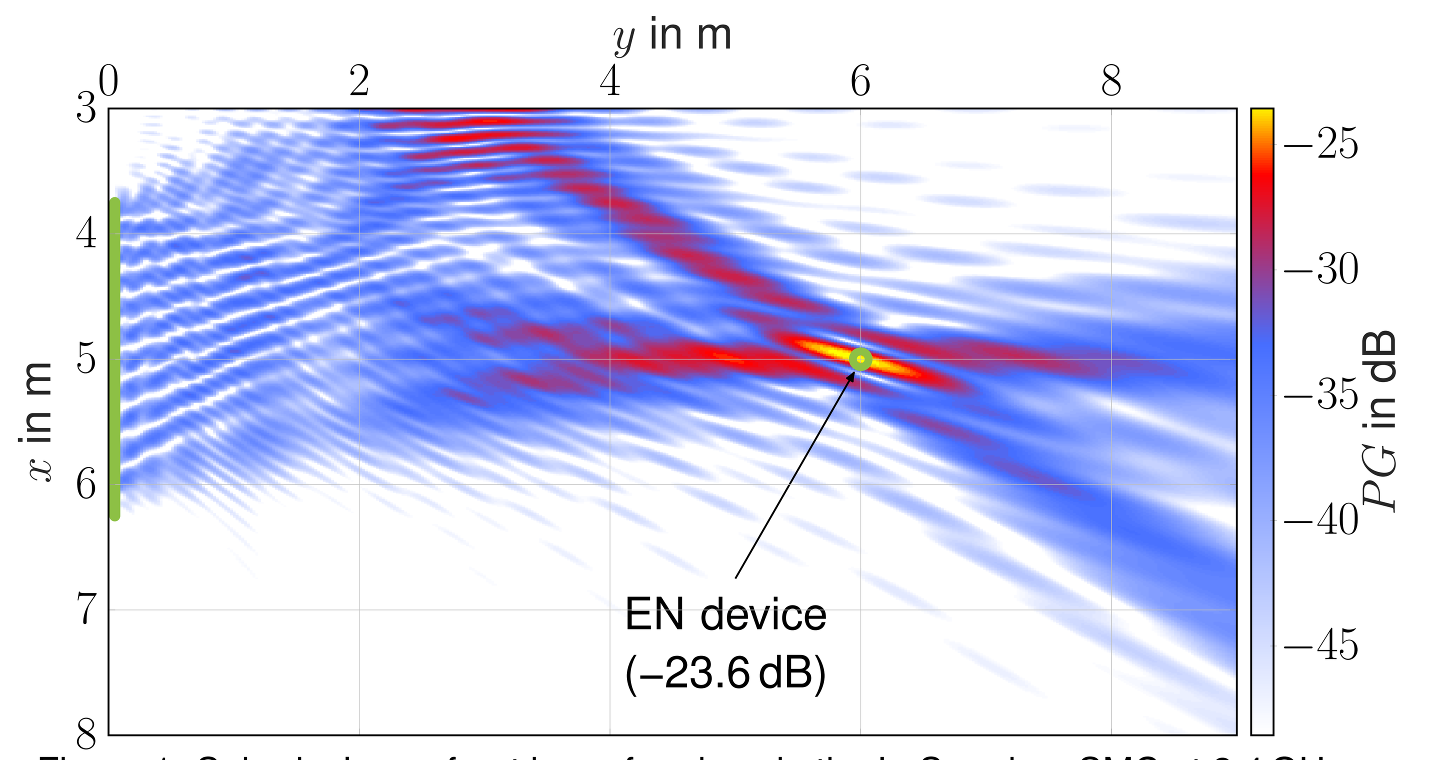


Figure 1: Spherical wavefront beamforming via the LoS and an SMC at 2.4 GHz.

Application 2: Positioning and Environment Learning

- Large apertures and spherical wavefront processing enable precise positioning despite limited bandwidth:
- Environment-learning facilitates resilient positioning, communication, and wireless power transfer (WPT).
- Non-stationarity needs to be accounted for in strong multipath environments (due to the large aperture and distribution).

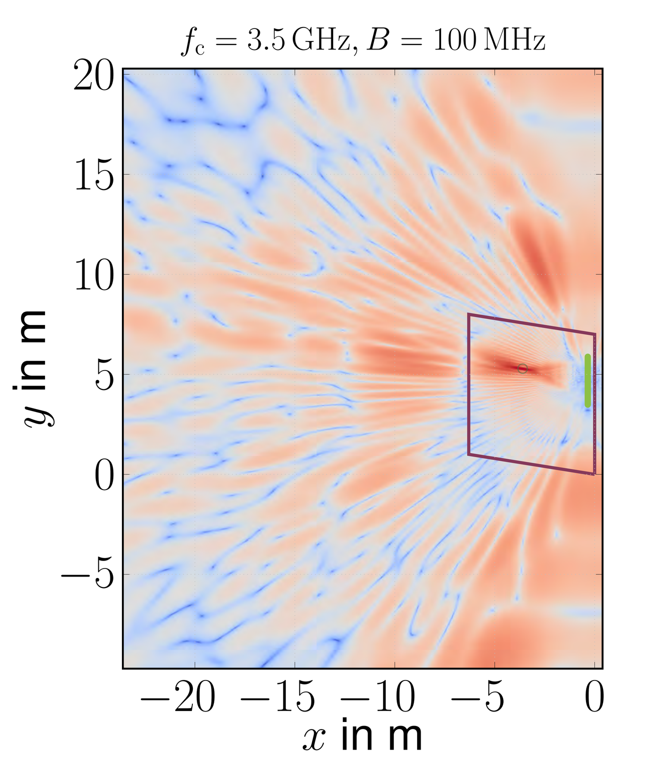


Figure 2: Large aperture, small bandwidth.

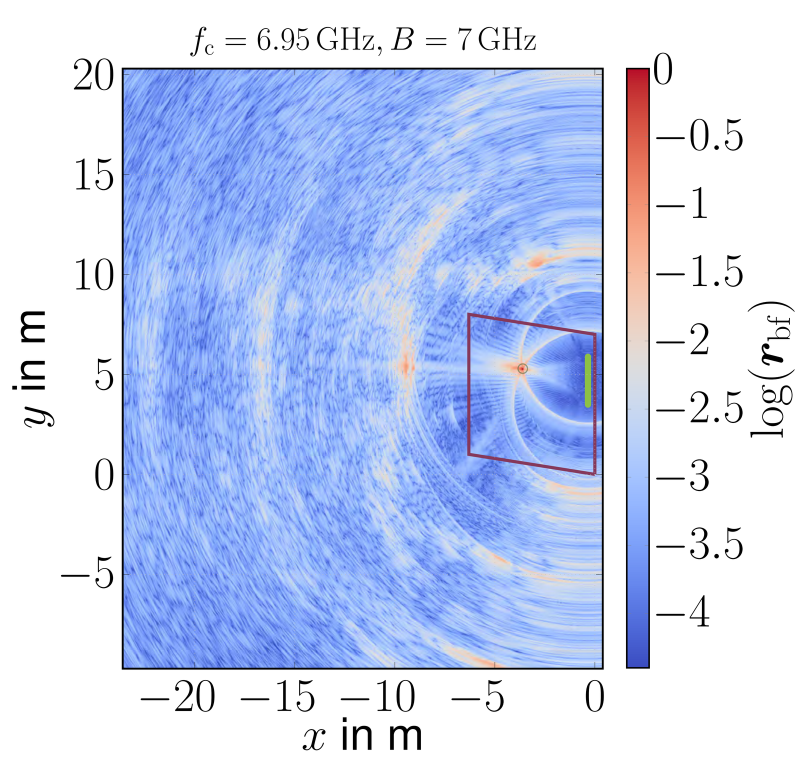


Figure 3: Large aperture, large bandwidth.

Application 3: Efficient Wireless Power Transfer

- Massive apertures allow efficient WPT exploiting a high array gain.
- Distributed architectures enable radiation-safe power transmission.
- A geometry-based channel model supports location-based beamforming.
- Synthetic aperture measurements validate the achievable gains [2]:

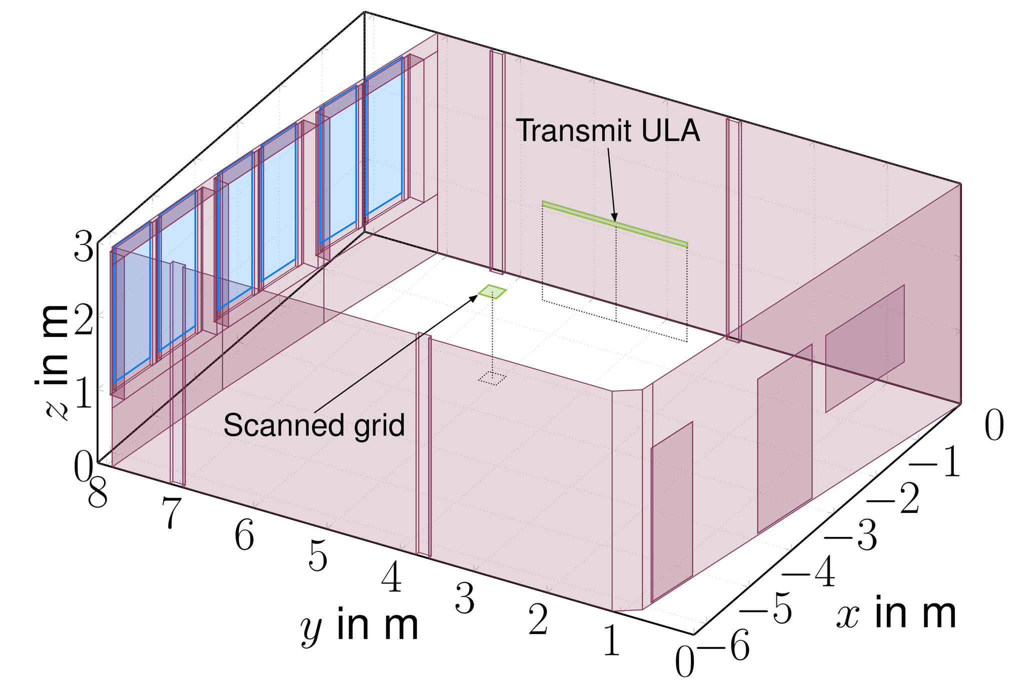


Figure 4: Synthetic aperture measurements: A $\frac{\lambda}{2}$-uniform linear array (ULA) transmits power wirelessly to a hypothetical EN device at 3.8 GHz [2].

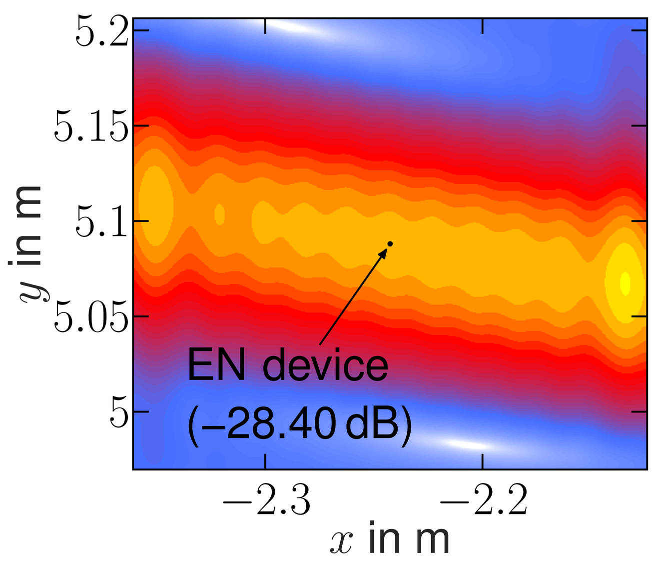


Figure 5: Simulated path gain
$\boldsymbol{w} \leftarrow f(\boldsymbol{h}_{\text{model}})$
$PG \leftarrow f(\boldsymbol{h}_{\text{model}})$.

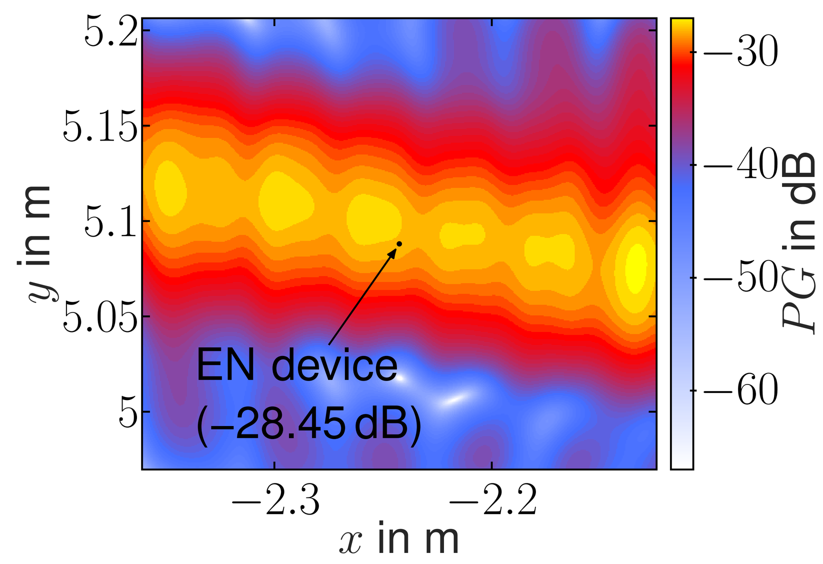


Figure 6: Measured path gain
$\boldsymbol{w} \leftarrow f(\boldsymbol{h}_{\text{model}})$
$PG \leftarrow f(\boldsymbol{h}_{\text{meas}})$.

6G Use Cases

A RadioWeaves architecture supports novel 6G use cases:

- Real-time inventory tracking supports future supply chain management in warehouses, sales floors and hospitals.
- Electronic shelf labels will be positioned, supplied with power wirelessly, and information dynamically updated.
- Providing resilient, ultra-low latency communication, and WPT, RadioWeaves off-loads demanding video-processing to the edge computing infrastrucutre and makes EN augmented reality feasible.

Figure 7: Inventory tracking.

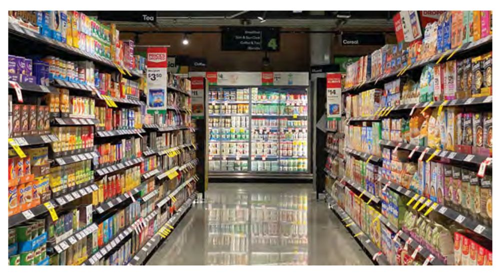


Figure 8: Electronic labeling.

Figure 9: Augmented reality.

Summary and Outlook

Advantages of a distributed RadioWeaves infrastructure are manifold:

- Ultra-robust communication enables (wire-like) resilience, and imperceptible latency (1 ms) enabling future Industry 4.0 use cases.
- Centimeter-level accuracy real-time positioning and tracking maps real-world inventory, industrial processes, and autonomous robots to the digital domain, thus generating digital twins.
- Unprecedented WPT power budgets (mW-level) allow the operation of massive deployments of battery-less Internet of Things (IoT) devices with unparalleled computational and functional capabilities.

Literature

[1] Benjamin J. B. Deutschmann et al. "Location-based Initial Access for Wireless Power Transfer with Physically Large Arrays". In: *WS08 IEEE ICC 2022 Workshop on Synergies of communication, localization, and sensing towards 6G (WS08 ICC'22 Workshop - ComLS-6G)*. Seoul, Korea (South), May 2022.

[2] Chesney Buyle et al. *System design study for energy-neutral devices interacting with the RadioWeaves infrastructure*. Deliverable ICT-52-2020 / D4.1. REINDEER project, 2022.

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