Newsletter #1

TERRAMETA

https://terrameta-project.eu/

Co-funded by the European Union

6G SNS

***TER**ahertz **R**econfigur**A**ble **META**surfaces for Ultra-high-rate wireless communications*

This project has received funding from Horizon Europe, the European Union's Framework Programme for Research and Innovation, under grant agreement 101097101. The project is supported by 6G SNS and its members (including top-up funding by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee)

- **Project Overview**
- **Release of the 1st Public Deliverable**
  - D2.1: Requirements, use cases, and scenario specifications available here
- **Planned Demos with THz Reconfigurable Intelligent Surfaces (RISs)**
  - Mobile manufacturing environments
  - Cellular network extension/improvement
- **THz RIS Unit Cell Designs**
  - GaN switches and continuous surface actuation
  - Software-based design solutions
- **THz Channel Measurement Setup with Multi-functional RISs**
- **THz Channel Modelling and Signal Processing**
- **Up-to-Date Scientific Contributions and Dissemination**
  - 12 journal/conference publications and 23 dissemination activities available here

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INESCTEC · National and Kapodistrian University of Athens, Established in 1827 · University of Oulu · instituto de telecomunicações · INTRACOM TELECOM · cea leti · uni.lu University of Luxembourg · DELL Technologies · Technische Universität Braunschweig · ACST THINK AHEAD · NOVA School of Science & Technology · University of Hertfordshire UH · BT

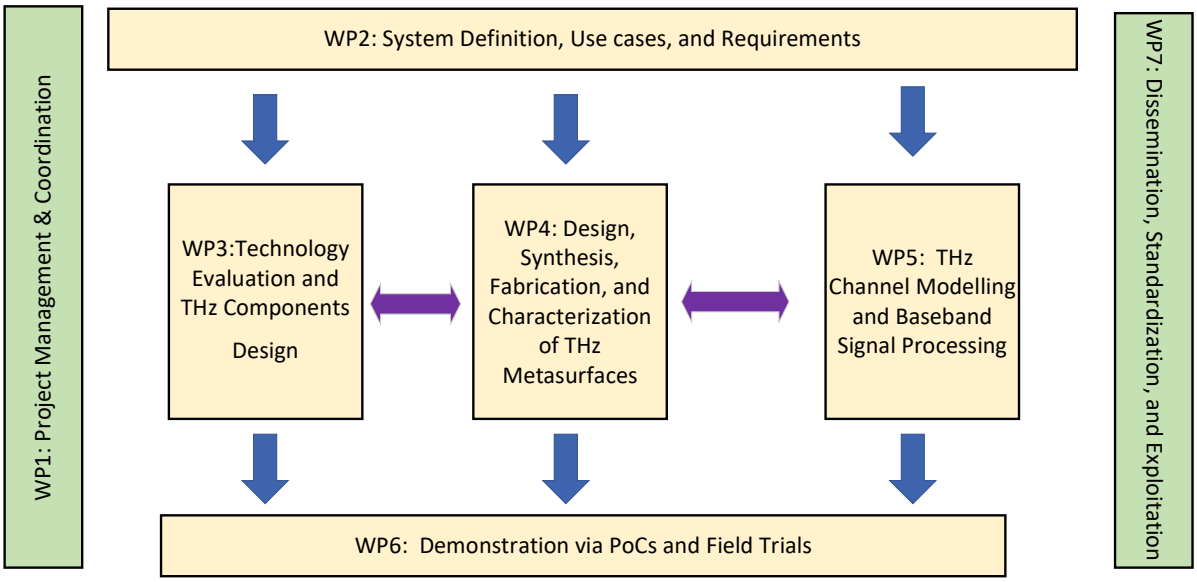
Introduction of the Project

TERRAMETA consortium comprises 13 institutions, including universities, research centers, and companies, with more than 50 researchers associated with its activities, all working in the area of wireless communications, reconfigurable intelligent surfaces (RISs), and metamaterial-based antenna arrays.

The project aims to investigate ground-breaking technologies for 6G wireless broadband networks and demonstrate the feasibility of ultra-high data rate wireless connectivity leveraging on THz RISs. TERRAMETA's objectives are summarised as follows:

- **Novel hardware development for 6G THz communications.**
- **Design of THz-tailored network architectures based on realistic models.**
- **Development of signal processing techniques for THz communications, localisation, sensing, and their integration with state-of-the-art multi-functional RISs and dynamic metasurface antennas.**
- **Demonstration of two THz networking use cases via the project's fabricated RISs and transceivers: an industrial edge environment and an outdoor telecom scenario.**
- **Influence 6G and THz communications standardisation and regulation.**

The main pillars of TERRAMETA (THz multi-functional RISs and transceiver components, THz channel characterisation and modelling, THz signal processing and networking, and THz-tailored network architectures) define the project's workplan:



For more information, visit TERRAMETA's website: https://terrameta-project.eu

Kick-off Meeting @INESC TEC in Porto, Portugal

On 10 January 2023, the TERRAMETA project team met face to face for the first time at INESC TEC (project coordinator) in Porto, Portugal. This productive and successful hybrid kick-off meeting provided all partners with a clear understanding of the project's objectives, scope and expectations, and laid a strong foundation for the project execution.

Half-Y1 Meeting @NKUA in Athens, Greece

A two-day hybrid meeting for the first half of Y1 of the project took place on 26 and 27 June 2023 at the National and Kapodistrian University of Athens (NKUA) (technical coordinator) in Greece, Athens. The meeting underscored the great synergy among the project partners, the fruitful discussions, and the promising prospects for the project's success.

Dissemination Activity

The first 11 months of the project, TERRAMETA team has been very active in research and respective dissemination, contributing **12 scientific journal/conference publications** in the communities of wireless communications and antennas and propagation, and diligently organising/participating in **23 international dissemination activities**.

One of the prominent activities of the project was the co-organisation of the 2023 EuCNC & 6G Summit workshop “Reconfigurable Intelligent Surfaces from sub-6GHz to THz: Recent Advances and Open Challenges,” by George Alexandropoulos (TERRAMETA’s technical coordinator), Halid Hrasnica, and Stefano Buzzi (jointly with the projects RISE-6G, MetaWireless, and ARIADNE) to highlight the latest research and development advances of the RIS technology and discuss future challenges.

TERRAMETA’s contributions to the workshop: “Reconfigurable technologies for integrating RIS elements at THz: New approaches and challenges,” “THz RIS for ultra-high rate wireless communications: Element design and synthesis,” and “Simulation scenarios for the assessment of reflective intelligent surfaces in THz backhaul applications”. Luis M. Pessoa (TERRAMETA’s project coordinator) participated in the workshop’s panel discussion.

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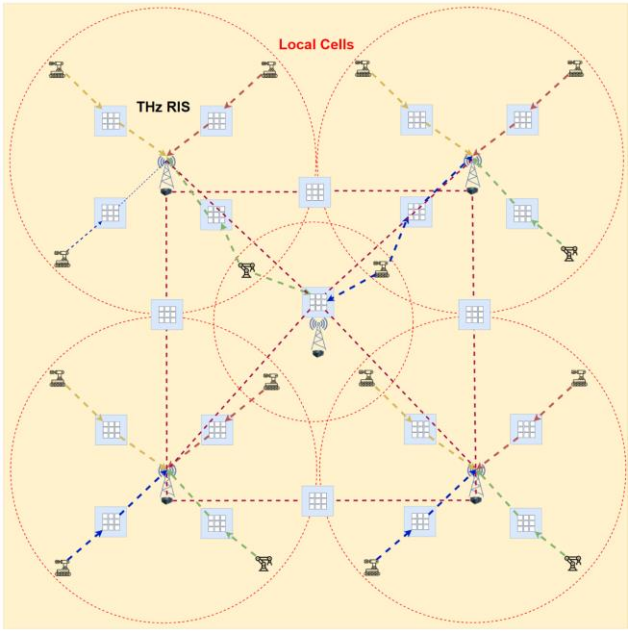
RIS-Empowered THz Communications for Manufacturing



As factories usher in an era of heightened mobility and sensor sophistication, the demand for a wireless network that transcends the limitations of traditional WiFi and 5G technologies is becoming imperative.

TERRAMETA harnesses the transformative power of THz communications to achieve far greater bandwidths and bitrates.

As device densities escalate within factories, RISs, acting as dynamic reflectors, can ensure optimal signal quality and integrity, mitigating interference and enhancing connectivity. Hence, THz connectivity coupled with RISs promises a next generation wireless network for immersive enterprise applications.

For more information, contact Sean Ahearne: Sean.Ahearne@dell.com

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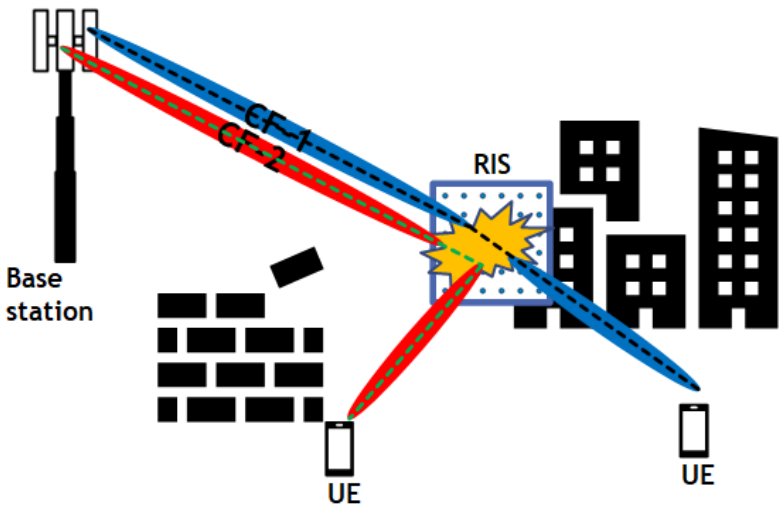
RIS-Empowered THz Coverage for 6G Mobile Networks

In the ever-evolving landscape of telecommunications, the battle against network black spots and non-line of sight coverage at higher frequencies persists. Recognising this, TERRAMETA delves into the potential of the RIS technology for outdoor telecommunication scenarios.

These innovative adaptive surfaces are set to redefine how we deploy and utilise our urban telecoms infrastructure.

By strategically integrating RISs on city buildings and light poles, we will be able to dynamically shape and direct electromagnetic waves around black spots and obstacles, providing a significant boost to signal quality and coverage.

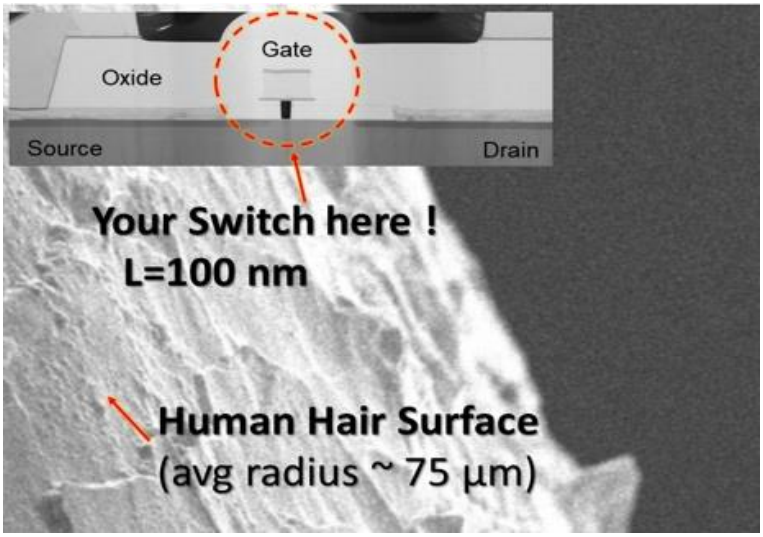


For telcos, the integration of RIS heralds a new era of infrastructure efficiency and customer satisfaction, paving the way for a more connected and accessible urban future.

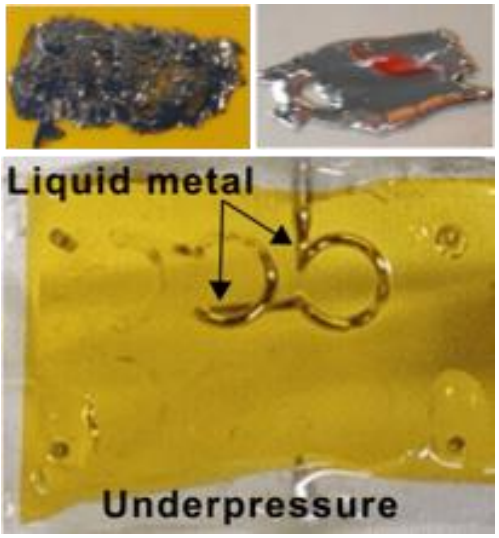
For more information, contact Ryan Husbands: ryan.husbands@bt.com

Hardware Development Approaches for Sub-THz RISs

Implementing RISs at sub-THz and THz frequency bands faces fundamental hardware challenges in terms of suitable switching mechanisms (e.g., GaAs PiN diodes are unproven above 80 GHz and there exist issues with PiN physical dimensions for 100+ GHz operation).



GaN transistor



Liquid metal

TERRAMETA investigates new hardware approaches for RISs at sub-THz (140 GHz), such as Gallium-Nitride (GaN) switches and continuous surface actuation by injecting liquid metal (LM) into microfluidic structures.

Electromagnetic simulation, designing of microfluidic structures, and actuation principles for controlling of the fluid is closely coupled and tested as all these aspects are interrelated having influence among each other.

In TERRAMETA, the microfluid structures are machined using proper equipment to understand the effect of LM behaviors under the continuous actuation.

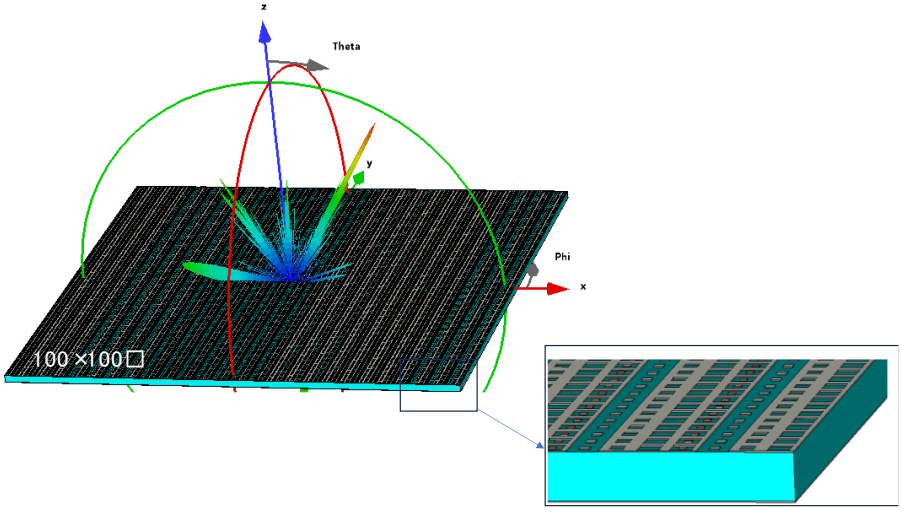
Laser micromachining device (left) used to fabricate C-shaped (midle), and straight (right) microchannels.

For more information, contact Sérgio Matos: Sergio.Matos@iscte-iul.pt

Software-Based Design Solutions of THz RISs

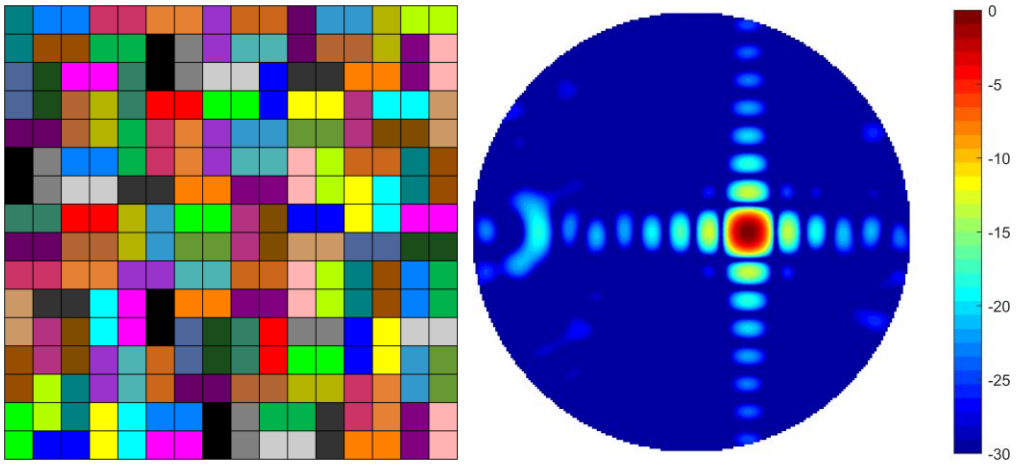
Experimental work has been initiated for liquid-metal operation by finding feasible substrate materials, their optimal processing parameters, and design variables. The aim is to understand the liquid-metal behavior under continuous actuation. In addition, the influence of surface treatments and possible accompanying carrier liquids have been investigated.

An efficient use of RISs is fundamental for the TERRAMETA's vision. Proper modelling tools capable of capturing the physics of the problem are fundamental for the RIS design. The project partners are joining efforts to provide efficient ways of assessing the performance of large RISs for allowing fast optimisation cycles.



Full-wave evaluation of a large RIS design (100x100 unit cells) for 300 GHz.

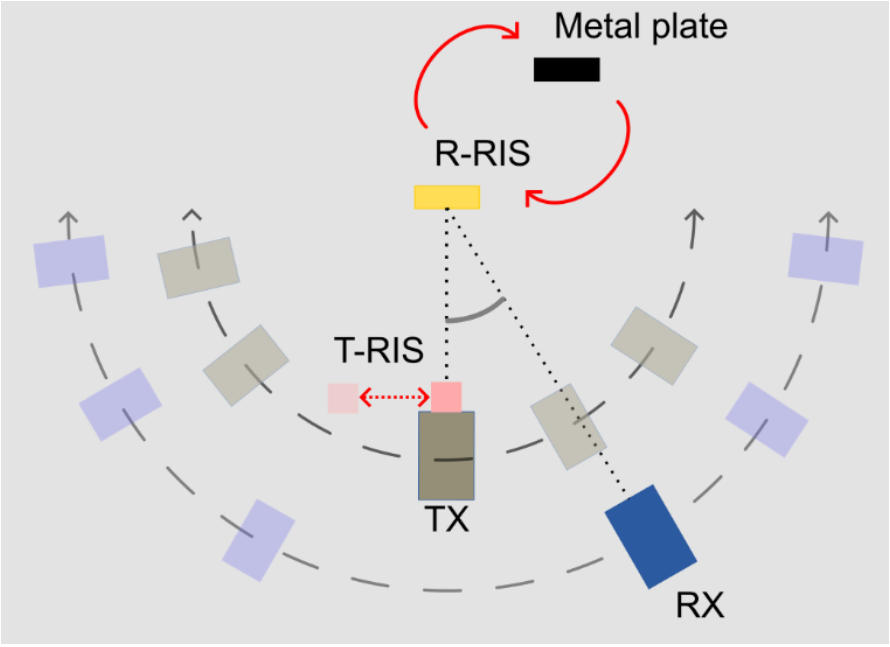
Optimisation of RIS codebooks is also being developed. An algorithm for tiling the subarrays in order to improve the side-lobe levels of the RIS, when reflecting the incident wave to different angles, has been designed. It has been showcased that an irregular array with gathered elements has the potential to obtain a balance between the beam-steering capability of the RIS and a cost-effective design.



Modelling a large metasurface and optimisation of the side lobes' level of beam steering through a sub-array tilling approach.

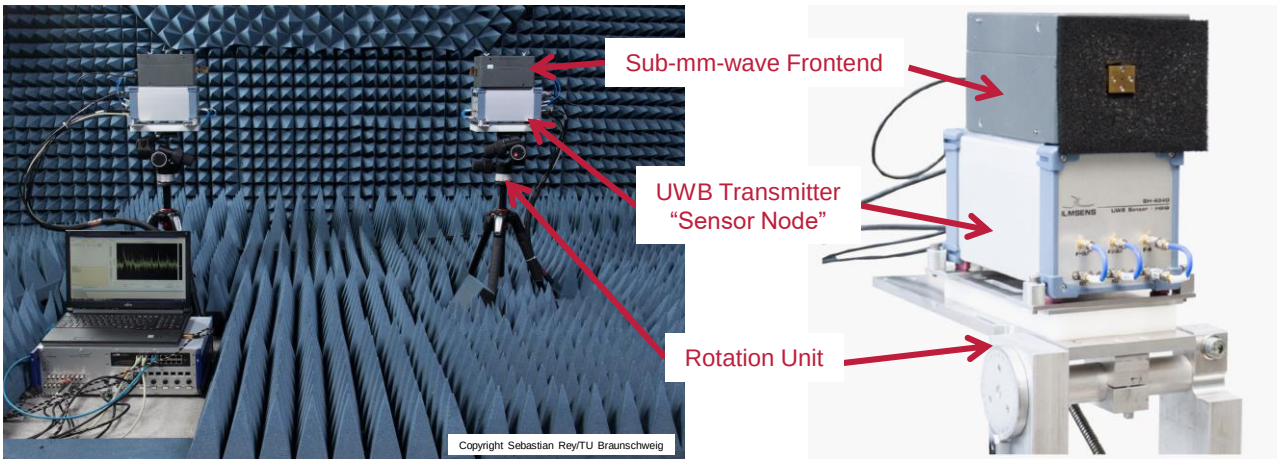
For more information, contact Sérgio Matos: Sergio.Matos@iscte-iul.pt

THz Channel Measurement Setup with Multi-Functional RISs



TERRAMETA's channel sounding plan for far- and near-field T/R-RIS-enabled wireless links at 300 GHz.

TERRAMETA's first measurement campaign will be performed using a 300 GHz channel sounder to characterise both fabricated RISs (a Transmissive RIS (T-RIS) as the transmitter and a Reflective RIS (R-RIS)), and the wireless channel including the RISs as well as a metal plate as a dummy reflector.



THz channel sounding equipment at IfN, TU Braunschweig (video available here).

The channel sounding results will be used as a basis for developing new THz channel models. Furthermore, we aim to design innovative algorithms at THz for channel estimation and beamforming, novel strategies for near- and far-field beam management, and new localization, and joint communications and sensing schemes for RIS-empowered and ultra-massive MIMO systems.

For more information, contact Bo Kum Jung: bo.jung@tu-braunschweig.de

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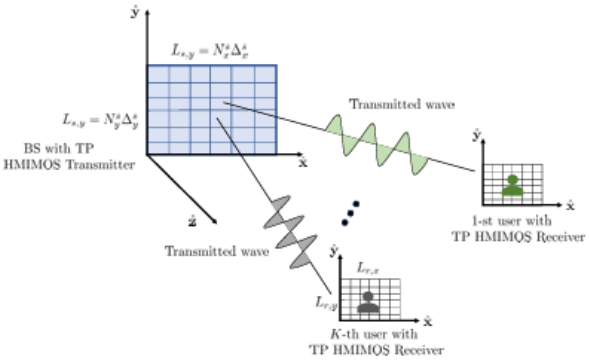
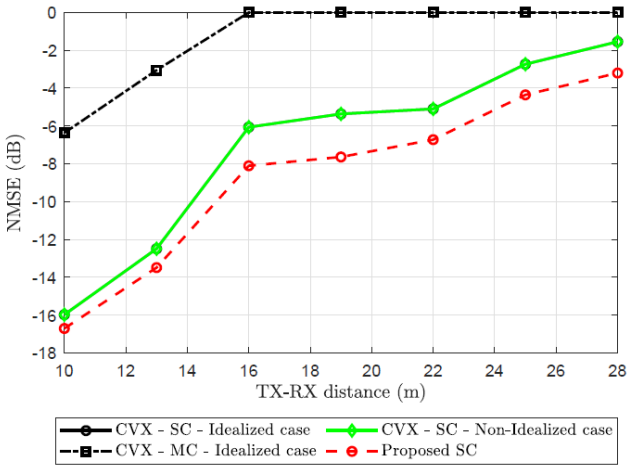
THz Channel Modelling and Signal Processing

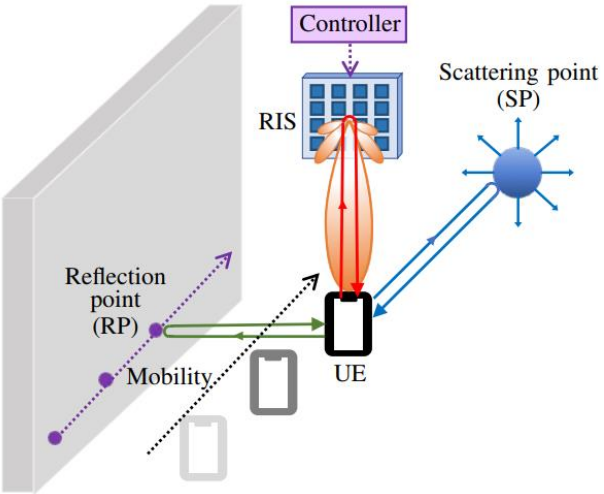
Novel multi-user near-field channel modelling with holographic MIMO transceivers (e.g., metasurface-based antenna panels) and triple polarization. A two-layered precoder is also developed for mitigating cross-polarisation and inter-user interference, which outperforms and dual-polarised holographic MIMO.

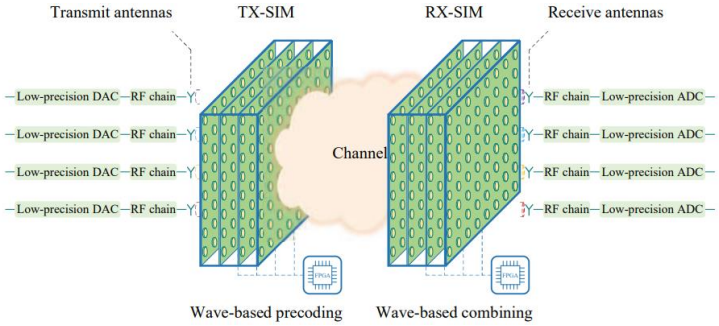




XL MIMO channel estimation in THz considering the presence of propagation delays across the entire array apertures, which leads to frequency selectivity, a problem known as *beam squint*. Designed a novel time-domain channel estimation technique for single-carrier modulation. The beam-squint effect is incorporated in a sparse vector recovery problem that is solved via sparse optimisation tools.

RIS-enabled simultaneous localization and RF mapping without the intervention of access points. Designed RIS phase profiles leveraging prior information for the user equipment (UE); a novel estimation approach for the UE state and landmarks; and analysed the theoretical bounds on the estimators for the channel parameters and the UE state.





Low-complexity fully digital beamforming transceivers aided by stacked transmissive RISs that realise wave-based analog beamforming. Devised efficient algorithms for optimizing the unit cells of the RISs and derived capacity scaling laws.

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