Newsletter #3

TERRAMETA

Co-funded by the European Union

6G SNS

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)

TERahertz ReconfigurAble METAsurfaces for Ultra-high-rate wireless communications

Welcome to our 3rd Newsletter! TERRAMETA is now more than halfway through, and it has already achieved major milestones by M18, as noted during the project review in September 2024. The project has produced over 90 scientific publications, including 50 conference papers, 34 journal papers, and 5 magazine papers. It has also contributed to 5 patents and delivered 14 standardization contributions to IEEE and ETSI.

Read on to learn more about our scientific and dissemination activities and check the announcements at the end for upcoming events!

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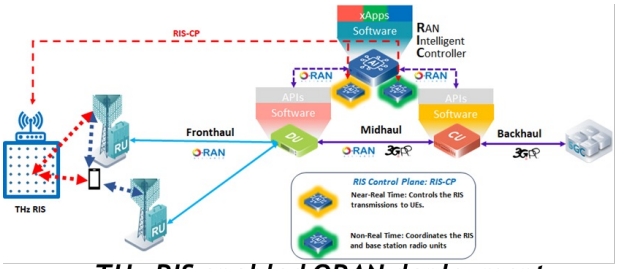
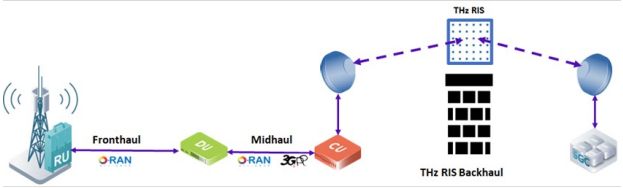
INESCTEC · BT · National and Kapodistrian University of Athens (Established in 1827) · University of Oulu · University of Luxembourg · INTRACOM TELECOM · Technische Universität Braunschweig · CST · University of Hertfordshire UH · DELL Technologies · instituto de telecomunicações · NOVA School of Science & Technology · cea leti

THz RIS Architectures and System Design



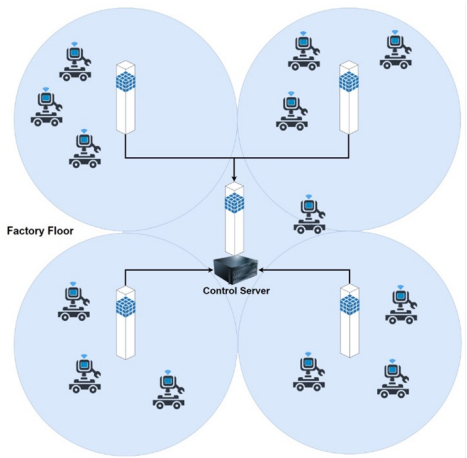
THz RIS enabled ORAN deployment



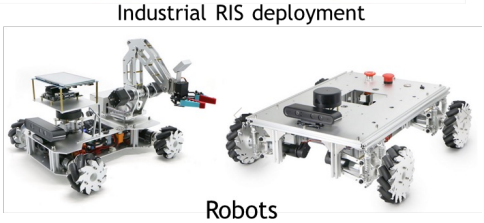
THz RIS backhaul

Modular THz RAN: This architecture adopts a disaggregated RAN approach leveraging ORAN for THz transport and mobile access.

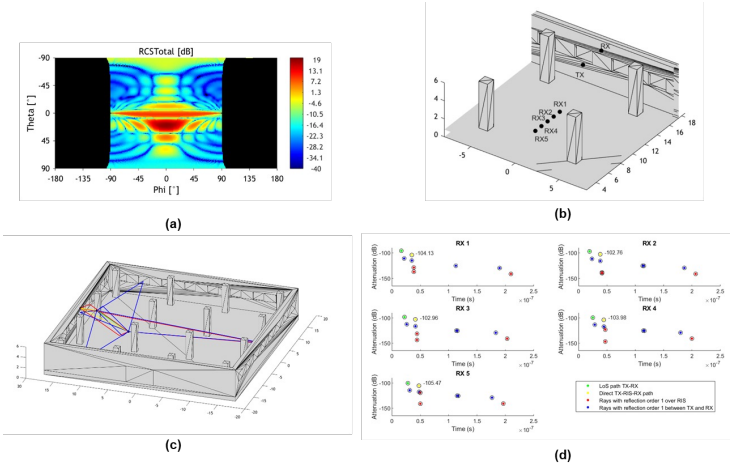
Factory Floor: Isometric representation of RIS deployment strategy and network architecture whereas each pillar is a THz RIS enabled AP. The robots depicted are to be involved in the integration.



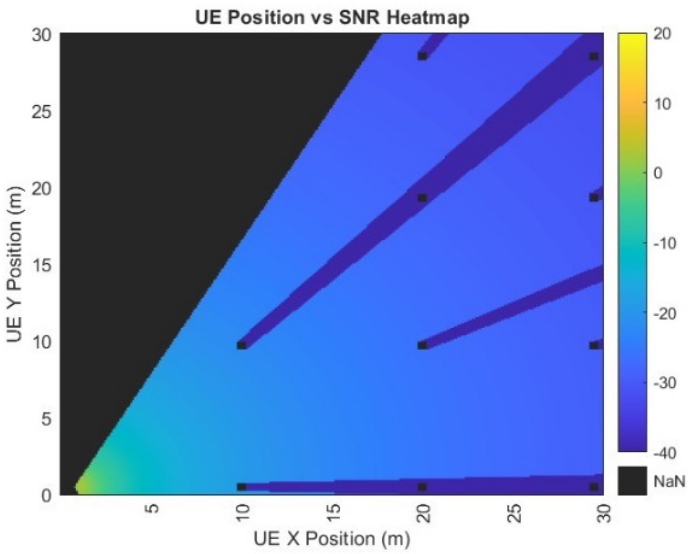
Industrial RIS deployment



Robots



(a) illustrates RIS diagram with a reflection radiated beam pattern rotated to the ground; (b) demonstrates a plot of the antenna and RIS positions; (c) raytracing analysis is represented by a 3D; (d) shows the CIR's at the different reviver positions.



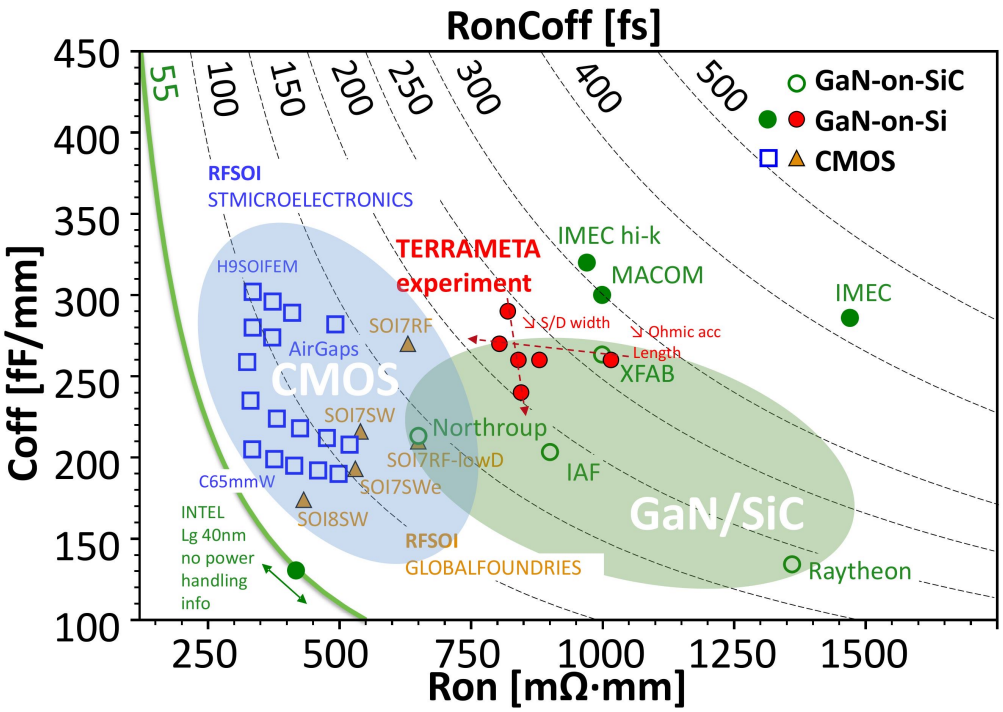
A plot of the SNR heatmap in the factory use case. In the calculation, the RIS is placed at (0,0) and its reflection a configured beam. The black squares represents the pillars of the factory.

New approach to RF switching

- The development of sub-THz Reconfigurable Intelligent Surfaces (RIS) demands significant progress in both materials and device designs. For example, while the AlGaAs PiN flip-chip diode has been the RF switch of choice for electronically controlled unit cells, it faces limitations in physical size and static power consumption, prompting researchers to seek alternatives.

- Various solutions at different stages of maturity have been proposed and evaluated. Among the most "mature" options, CEA-Leti has explored the use of High Electron Mobility Transistors (HEMTs) based on Gallium Nitride (GaN) on high-resistivity silicon. Originally developed for power amplifiers, this technology has been adapted for RF switching applications. Dedicated test structures were created to assess its performance as a switch, and the results will be presented at IEDM 2024 in San Francisco (https://www.ieee-iedm.org/), a premier conference for device innovations.

- TERRAMETA results show that the R_{on} × C_{off} figure of merit for GaN HEMTs is still behind that of both AlGaAs PiN diodes and commercial CMOS solutions. However, GaN HEMTs excel in power handling, making them highly attractive for high-power applications. Currently, this technology may not be the best fit for RIS unit cells, where unit cell power requirements are relatively low. Nevertheless, as highlighted in the accompanying figure, scaled versions of similar GaN-based technologies have demonstrated competitive R_{on}× C_{off} values, even though power-handling data is not yet available. With further optimization and scaling, GaN-based HEMTs could still emerge as a viable option for future RIS unit cells.

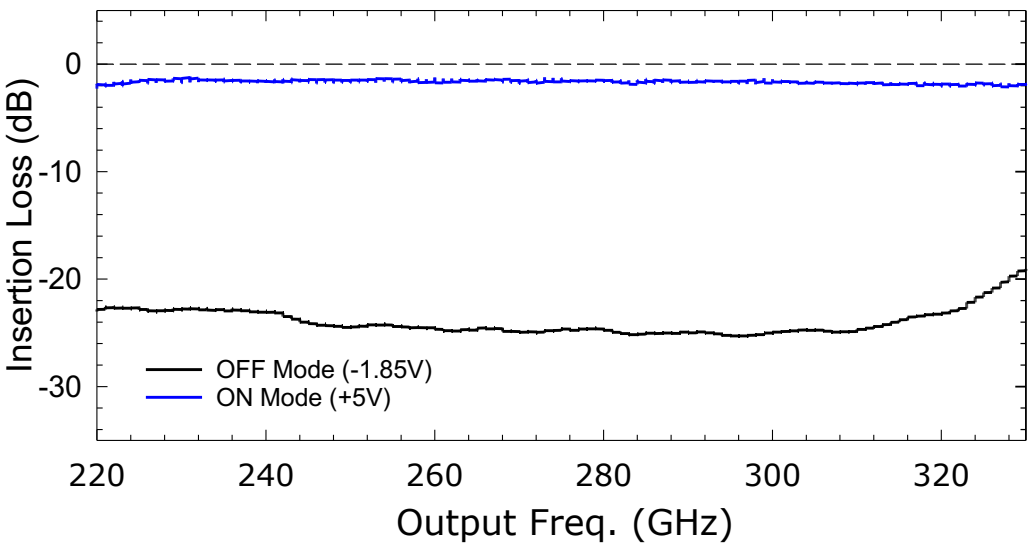


R_{on} × C_{off} for the new approach compared to other solutions.

Amplitude modulator via Schottky diodes

Based on our high-power Schottky Diodes, ACST has developed an ultra-fast low-loss 300 GHz Direct Amplitude Modulator featuring:

- Full-Band WR-3.4 Frequency Band (220-330 GHz)
- 1.3 dB Insertion Loss in ON Model
- More than 20 dB Attenuation in OFF Mode
- Switching or Modulating Speed up to 40 GHz through a K-Connector
- High Power Handling Capabilities



Insertion loss of amplitude modulator over the output frequency for ON and OFF mode.

Channel measurement campaign

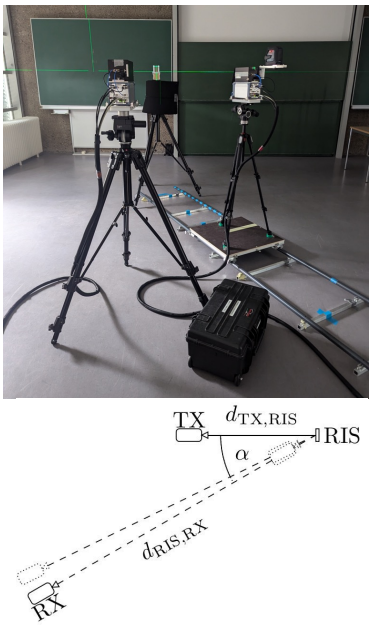
Objective and setup

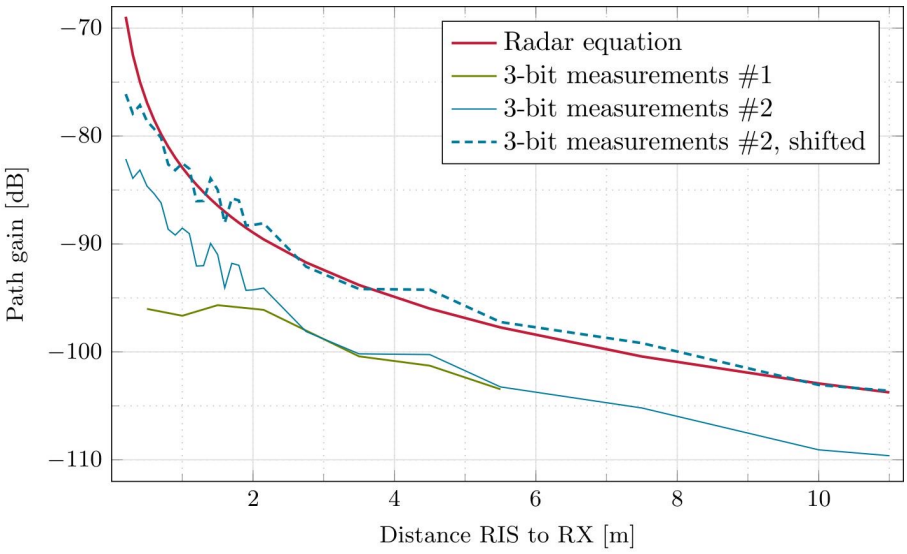
- The first conducted channel measurement campaign at Technische Universität Braunschweig involving passive 300 GHz Reconfigurable Intelligent Surfaces (RIS) observed a constant offset between path gain measurement and expectation according to the radar equation (1) for most of the examined distances between RIS and receiver (RX). For smaller distances, a deviation of the qualitative curve progressions of path gain and prediction was observed. Both these points motivated a follow-up measurement campaign investigating the path gain more thoroughly.
- The 3-bit RIS was used with perpendicular incidence from the transmitter (TX) at a distance of 2.15 m. RX was positioned at 30°. The range as well as the resolution of the distance between RIS and RX was increased, such that measurements between 20 cm and 11 m (above Fraunhofer distance of RIS) were conducted. For reproducibility, a rail system and alignment laser were used.

$$PG = \frac{\sigma\,\lambda^2}{(4\pi)^3 \cdot d_{TX-RIS}^2 \cdot d_{RIS-RX}^2} \quad (1)$$

Results

- The previous results for 2 m onwards are confirmed. The offset is believed to stem from a combination of misalignment, beamsquint, fabrication errors and the measurement setup.
- The unexpected behavior below 2 m could not be reproduced. Instead, the qualitative curve progressions indicate that the path gain can be modeled adequately by the radar equation for distances as low as a tenth of the Fraunhofer distance of the RIS.
- Below 1 m the radar equation overestimates the path gain even further, i.e., the discrepancy is no longer constant but increasing.

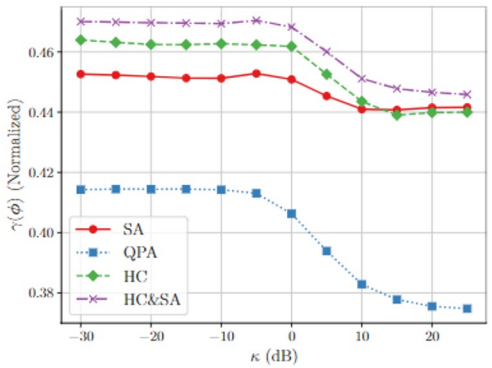




Measured path gain for 3-bit RIS in first and second measurement together with expected path gain according to radar equation

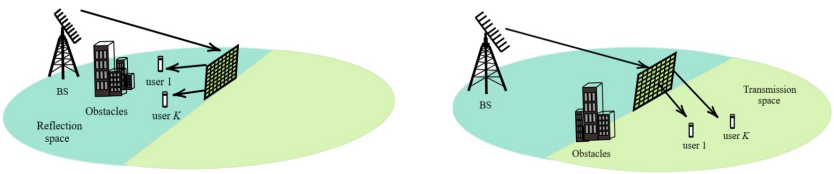
Signal Processing for THz Multi-Functional RISs

- The elements of most RIS prototypes have quantised responses and low-complexity configuration algorithms with performance guarantees are missing.
- A closed-form configuration for RISs with 1-bit phase resolution elements in SISO systems targeting SNR maximisation has been derived.
- Performance lower bounds for the instantaneous and expected achievable SNR are growing asymptotically with the squared number of RIS elements.



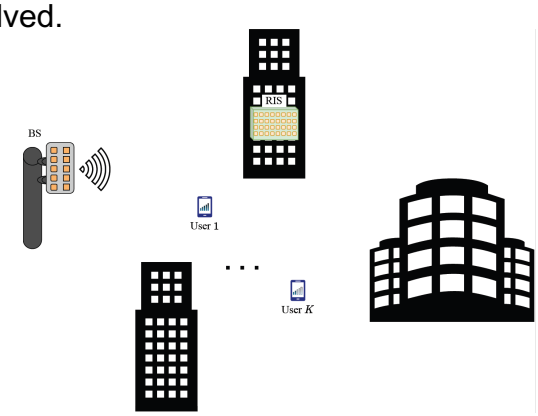
Proposed algorithm (SA), quantization of the continuous optimal (QPA), hill climbing algorithm (HC), and hill climbing initialized via SA (HC&SA).

- Physically compliant modelling of reflective and transmissive RISs.
- Proposed an offline optimisation of RIS's mutual coupling based on the environment of deployment.
- Two-layered problem: the inner one focuses on jointly optimizing the RIS phase profiles and the BS active precoding, while the outer one involves optimising mutual coupling based on the scattering parameters.



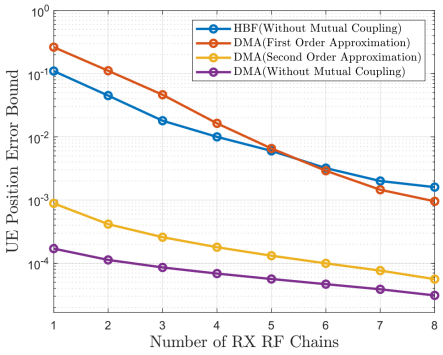
Multi-user MIMO assisted by either a reflective or a transmissive RIS.

- Introduced a novel wideband channel model incorporating RISs as well as non-reconfigurable stationary surfaces.
- The model shows how RIS phase configurations within a single channel interval in OFDM systems induce frequency selectivity.
- A novel RIS activity detection problem as an online sequential change point detection problem was presented and solved.



A system with RISs and stationary reflectors.

- Near-field localization with a metasurface-based receiver via electromagnetics-compliant modelling incorporating mutual coupling.
- Closed-form solutions for the position estimation error minimization by taking the first- and second-order Taylor approximations of the considered model to tackle the non-convex structure of the objective function.



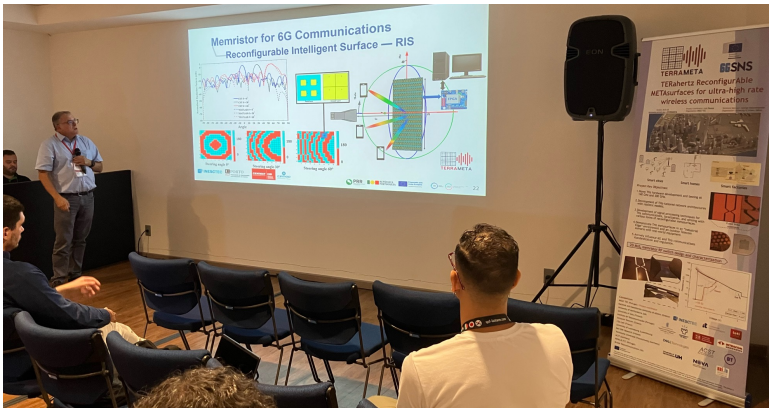
Position error bound for different modelling approaches.

B-MRS 2024 memristor symposium

NOVA SCHOOL OF SCIENCE & TECHNOLOGY

TERRAMETA organized the symposium "Memristor devices from theory to system level integration for next generation of computation and communication" at the B-MRS Meeting 2024, in Santos, Brazil (https://www.sbpmat.org.br/22encontro/symposia/). High-level invited presentations were given by Valeria Bragalia (IBM Zürich, Switzerland), Stephan Menzel (Forchungszentrum Jülich, Germany), Hannes Raebiger (Yokohama National University, Japan) and Vítor Tavares (INESC TEC Porto, Portugal). The symposium was moderated by Dr. Jonas Deuermeier from NOVA University Lisbon and results from the TERRAMETA project were presented by Prof. Vítor Tavares.

SANTOS
B-MRS Meeting 2024
XXII
September 29th to October 3rd



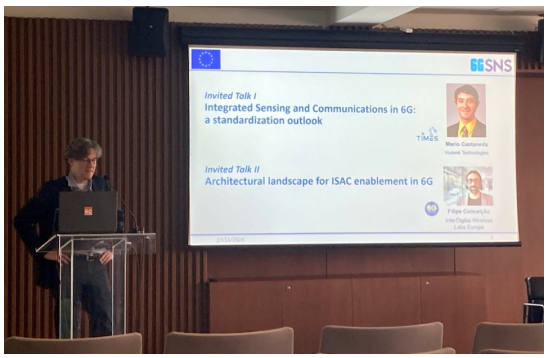
Special Session co-organized at IEEE CSCN 2024

Special Session on Key Enablers for Integrated Sensing and Communications in Industrial Environments - IEEE CSCN 2024 | 25–27 November | Belgrade, Serbia
The Special Session on "Key Enablers for Integrated Sensing and Communications in Industrial Environments," jointly organized by TERRAMETA, TIMES, and 6G-SHINE, was a highlight at the IEEE Conference on Standards for Communications and Networking (CSCN) 2024. This session brought together experts from academia, industry, and standardization, focusing on shared topics across the three SNS JU Phase I projects.

The session featured two insightful invited talks:

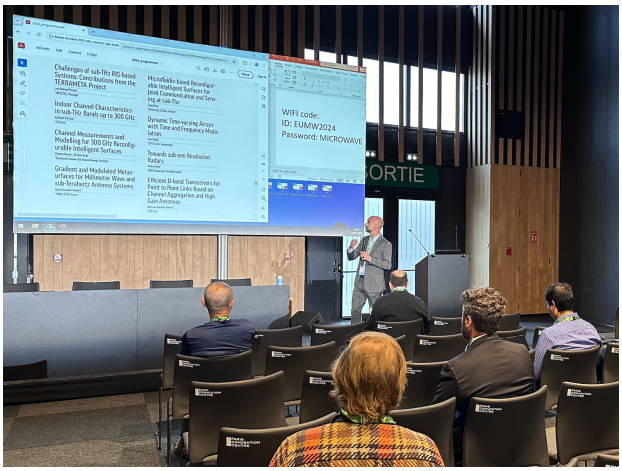
- **"Integrated Sensing and Communications in 6G: A Standardization Outlook"** by *Mario Castaneda* (Huawei, Germany).
- **"Architectural Landscape for ISAC Enablement in 6G"** by *Filipe Conceição* (InterDigital, UK).

A dynamic panel discussion moderated by *Malte Schellmann* (Huawei, Germany) further enriched the session, with contributions from *Praveen Naidu Vummadisetty* (University of Luxembourg, Luxembourg) and *Konstantinos Manolakis* (Nokia, Germany).
The session fostered engaging dialogue, offering unique insights and perspectives on integrated sensing and communications (ISAC) in industrial environments. The diverse audience actively participated, posing thought-provoking questions and enhancing the depth of discussions.
This collaborative effort successfully showcased the synergy between research, industry, and standardization efforts, highlighting the pivotal role of ISAC technologies in the evolution of 6G.



Workshop organization at EuMW 2024

TERRAMETA organized the workshop "*Disruptive sub-THz antenna and transceiver systems for future sensing, localization and communication*", at the European Microwave Conference 2024, in Paris, France, on 22 September 2024.



The workshop organizers were Antonio Clemente (Chair) and José-Luis González-Jiménez (Co-Chair). The workshop spanned a full day with a total of 8 presentations, including the following TERRAMETA presentations:

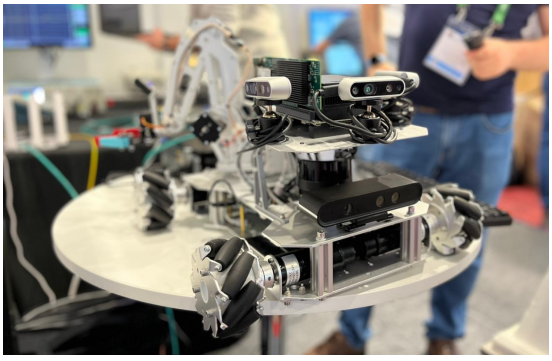
- *Challenges of sub-THz RIS-based Systems: Contributions from the TERRAMETA Project*, presented by Luis M. Pessoa (INESC TEC)
- *Channel Measurements and Modelling for 300 GHz Reconfigurable Intelligent Surfaces*, presented by Bo Kum Jung (Technische Universität Braunschweig)
- *Microfluidic-based Reconfigurable Intelligent Surfaces for Joint Communication and Sensing at sub-THz*, presented by Tung Phan (University of Oulu)
- *Efficient D-band Transceivers for Point to Point Links Based on Channel Aggregation and High Gain Antennas*, presented by José Luis González Jiménez (CEA-Leti)

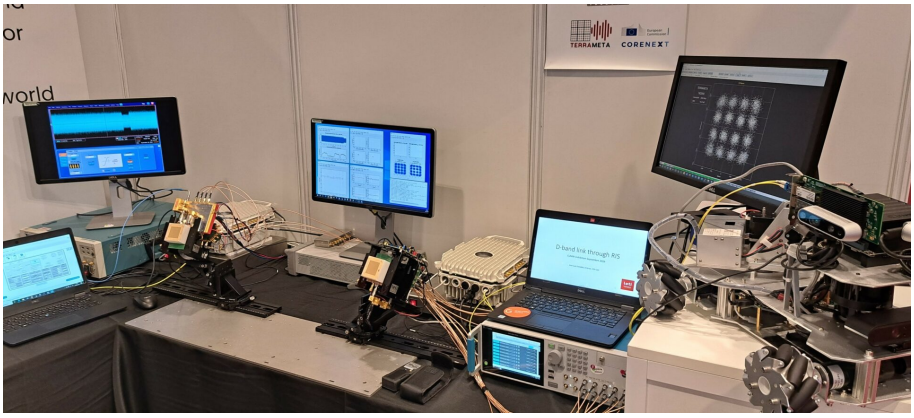
TERRAMETA demonstrator at EuMW 2024

At the European Microwave Conference 2024, in Paris, France, in September 2024, CEA-Leti, Intracom Telecom, and DELL Technologies organized a demonstrator that showcased an advanced scenario tailored for mobile robots in factory environments, featuring real-time 3D reconstruction of surroundings. This cutting-edge setup included:

- A baseband unit developed by *Intracom Telecom* with a 2 GHz baseband bandwidth.
- A D-band transceiver operating at 145 GHz, supporting bandwidths up to 17 GHz.
- Active RISs (developed by *CEA-Leti*), enabling seamless communication in NLOS scenarios.

These components, among others, highlighted the potential of TERRAMETA's innovations in tackling complex industrial use cases. The demo may be watched at https://terrameta-project.eu/terrameta-demonstrator-at-eumw-2024/.





TERRAMETA participated in a Panel at Hannover Messe

TERRAMETA was invited to a 6G industry panel at Hannover Messe in Germany, back in April 2024. The panel "Is Industry waiting for 6G?" counted with Luis Pessoa, representing INESC TEC and the TERRAMETA Project, Frank Burkhardt from Fraunhofer IIS, representing 6G-SHINE project, Thomas Kürner from Technische Universität Braunschweig, representing TIMES 6G, Dr.-Ing. Christian Bauer from Belden Inc., Dr. Eike Lyczkowski from SEW Eurodrive, Andreas Mueller from Bosch, and Miriam Solera Ureña from VDMA as moderator.
A vivid discussion was held around topics such as "Why are industries missing the 5G Boat?", "Why should industries adopt 5G now?", "What should we expect from 6G?".

Announcements:

EuCAP 2025: Scientific Workshop and Convened Session

TERRAMETA will co-organise two activities at EuCAP 2025, to be held in Stockholm, between 30th March and 4th April 2025.

- Scientific Workshop “Sub-THz Reconfigurable Intelligent Surfaces, RF Front-Ends, and Channels for 6G Networks” will also count with the participation of additional 6G-SNS projects, namely TIMES, Tera6G, 6GTandem, and TeraGreen.
- Convened Session on "Extremely Large or Distributed Antenna Systems in Near-Field Environments’’.

ICC 2025: co-organisation of two workshops

Together with other projects, TERRAMETA will co-organise two activities at IEEE ICC 2025:

- "3rd Workshop on Near-Field Communications, Localization, and Sensing”
- "4th Workshop on Synergies of Communication, Localization, and Sensing towards 6G"

Up-to-date scientific contributions:

- 90 journal/conference publications and 70 dissemination activities available on the website

https://terrameta-project.eu