Project: IEEE P802.15 Working Group for Wireless Speciality Networks (WSN)

Submission Title: Overview on the Horizon Europe 6G SNS Project TERRAMETA

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Source: Thomas Kürner, TU Braunschweig
Address Schleinitzstr. 22, D-38092 Braunschweig, Germany
Voice:+495313912416, FAX: +495313915192, E-Mail: t.kuerner@tu-braunschweig.de

Re: n/a

Abstract: This document provides information on the Horizon Europe 6G SNS Project TERRAMETA (TERahertz ReconfigurAble METAsurfaces for ultra-high rate wireless communications)

Purpose: Information of IEEE 802.15 SC THz

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TERRAMETA
TERahertz ReconfigurAble METAsurfaces for ultra-high rate wireless communications

Project Overview
Presented to IEEE 802.15 SC THz
Thomas Kürner - TU Braunschweig
Luis Pessoa - INESC TEC

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Views and opinions expressed are however those of the authors only and do not necessarily reflect those of the European Union, 6G SNS or UKRI. The European Union, 6G SNS or UKRI cannot be held responsible for them.
Funding Framework

- A total of 35 Research and Innovation (R&I) projects have been selected following the evaluation of proposals submitted under the first call of the EU’s Smart Networks and Services Joint Undertaking (SNS JU).

- TERRAMETA is one of those funded projects in Stream-B, see https://smart-networks.europa.eu/stream-b-research-for-revolutionary-technology-advancement-towards-6g/

- Project run-time: 1 January 2023 - 31 December 2025
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<th>Partner</th>
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<tr>
<td>Research Center</td>
<td>INESC TEC</td>
<td>THz antennas; switch modelling; IC design.</td>
<td>Project coordinator, Task leader</td>
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<tr>
<td>University</td>
<td>University of Athens (NKUA)</td>
<td>Signal processing; multi-element transceiver hardware architectures; reconfigurable metasurfaces.</td>
<td>Technical coordinator, WP leader</td>
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<td>University</td>
<td>University of Hertfordshire</td>
<td>Reflectarrays and transmitarrays; beam-forming algorithms; localization and sensing.</td>
<td>Task leader</td>
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<tr>
<td>University</td>
<td>University of Oulu</td>
<td>THz antennas and measurement; micro-fluidics.</td>
<td>Task leader</td>
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<tr>
<td>Research Center</td>
<td>Instituto de Telecomunicações</td>
<td>Reflectarrays and transmitarrays; antenna characterization.</td>
<td>WP leader</td>
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<tr>
<td>Large Industrial</td>
<td>Intracom</td>
<td>Baseband unit; signal processing.</td>
<td>Task leader</td>
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<td>Research Center</td>
<td>CEA-Leti</td>
<td>Reflectarrays and transmitarrays; array and metasurface modelling, design and characterization; IC design.</td>
<td>WP leader</td>
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<td>University</td>
<td>University of Luxembourg</td>
<td>Network design and optimization; metasurfaces.</td>
<td>Task leader</td>
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<td>Large Industrial</td>
<td>Dell EMC Research</td>
<td>Industrial operations and management.</td>
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<td>University</td>
<td>Technische Universität Braunschweig</td>
<td>THz characterization and propagation modelling; standardization.</td>
<td>WP leader</td>
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<td>SME</td>
<td>ACST GMBH</td>
<td>THz transmitter and receiver.</td>
<td>Task leader</td>
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<tr>
<td>University</td>
<td>NOVA.ID.FCT</td>
<td>Memristor design and fabrication.</td>
<td>Task leader</td>
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<td>Large Industrial</td>
<td>British Telecom</td>
<td>System architecture; Exploitation of application scenarios.</td>
<td>WP leader</td>
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TERRAMETA in a nutshell

- Investigation of ground-breaking technologies for 6G, demonstrating the feasibility of ultra-high data rate wireless communications leveraging THz metasurfaces (140 GHz and 300 GHz).
  - Novel high-performance THz hardware will be developed, including low-power consumption wideband switches, RISs, and TXs/RXs.
  - Using the designed THz components, advanced network analysis/optimization techniques will be investigated.

- Developments driven by 6G usage scenario requirements.
- Indoor, outdoor, and indoor-to-outdoor scenarios will be demonstrated in a real factory setting and a telecom testing field.
Objective 1

- Novel hardware development for 6G THz wireless communications and its integration:
  - At switch level, novel reconfigurable approaches based on **memristors and microfluidics** will be addressed for the first time in THz, as well as the performance of lower risk approaches, namely **CMOS-based switches**, will be advanced.
  - **TXs and RXs** capable of handling **high-power modulated THz signals** will be developed and optimized for the considered applications of RIS-enabled THz networks.
  - **Multi-functional RISs - T-RIS, R-RIS, hybrid RISs with sensing capability** - integrating different switch technologies will be designed and experimentally tested.
Objective 2

- Development of THz-tailored network architectures based on realistic models:
  - THz network design based on the hardware developments of the project.
  - Assessment of Large active antenna arrays (massive/ultra-massive MIMO) under
    - power-limited and low-resolution hardware
    - accurate THz channel models,
    - centralized and cell-free network architectures.
  - The placement of RISs will be optimized to provide extra degree of freedoms and enhance the network coverage, connectivity, and rate performance.
  - The sharing of RISs between different nodes and the effects of wideband processing on the network performance will be studied as well.
  - The obtained theoretical and simulation-based results will be further tested through lab emulations to demonstrate the performance of realistic THz networks.
Objective 3

- Development of signal processing techniques for THz communications, localization, and sensing with various forms of reconfigurable metasurfaces:
  - Signal processing algorithms and techniques for ultra-massive THz systems, considering:
    - transceivers and wireless environment equipped with RIS
    - the actual hardware specifications and operational capabilities of metasurfaces.
  - Development of THz channel models profiting from a dedicated channel sounding activity.
  - The designed algorithms will focus on the selected use cases and target ultra-high data rate wireless communications, localization, and sensing.
Objective 4

- Demonstrate the feasibility of applying THz RISs in an “Industrial Edge” environment and an outdoor Telecom scenario with real-world equipment.

Factory Floor - Industrial Edge environment

Telecom scenario

TERRAMETA presentation IEEE 802.15 SC THz  13 March 2023
Objective 5

- Actively influence 6G and THz communications standardization and regulation:
  - Standardization process at various standards bodies (3GPP, ETSI, and IEEE 802).
    - RIS hardware reconfigurability methods
    - RIS based THz channel models
    - RIS based network architectures
  - The project will also work on proposals for interfacing RISs into THz communication systems.
  - Influence the preparation of the World Radio Conference (WRC) 2027, where the THz spectrum is likely to be on the agenda.
TERRAMETA’s Focus (1/3)

- Development of THz RIS technology (both transmissive and reflective use-cases):
  - Materials and electronics components that can support the THz operation frequency with appropriate performance, cost-efficient fabrication and low power consumption will be investigated.
  - Two types of THz RIS, reflective-RIS and transmissive-RIS, will be developed by exploring multiple THz capable reconfigurable micro-electronics technologies: memristors, BiCMOS/GaN and microfluidics.
  - Signal processing techniques for THz RIS communications, localisation, and sensing, including channel modelling, channel estimation, beam management, baseband processing and THz-tailored network architectures including Ultra-Massive MIMO techniques will be developed.
TERRAMETA’s Focus (2/3)

- Two frequency bands being currently under strong research focus at device level and expected to play a key role as part of 6G (enabling ultra-high data rates):
  - 140GHz (D-band: 110-170 GHz): around 30GHz spectrum available especially for backhaul/fronthaul applications
  - 300GHz (253-322GHz band; IEEE 802.15.3d): almost 70GHz spectrum considered in IEEE 802 Std 15.3d-2017 with most of it allocated to fixed and mobile services.
TERRAMETA’s Focus (3/3)

- **R-RIS design target:**
  - Different reconfiguration technologies: **memristor switches**, **BiCMOS/GaN switches**, and **microfluidic** with piezoelectric actuation, striving to improve technologies that have been shown to work at lower frequencies in order to demonstrate their viability in the 140 GHz band.

- **T-RIS design target:**
  - Demonstrate the first such device operating in the D-band and at 300GHz, using more advanced **RF-SOI-based CMOS processes**. The switch architecture will be co-designed with the RIS elements to achieve the best trade-off between Ron, Coff, power dissipation, insertion loss, and bandwidth.
Work Plan

WP1: Project Management & Coordination

WP2: System Definition, Use cases, and Requirements

WP3: Technology Evaluation and THz Components Design

WP4: Design, Synthesis, Fabrication, and Characterization of THz Metasurfaces

WP5: THz Channel Modelling and Baseband Signal Processing

WP6: Demonstration via PoCs and Field Trials

WP7: Dissemination, Standardization, and Exploitation
TERRAMETA’s Standardisation Plans

- **Standardization plans / objectives:**
  - Standardization is seen as a means to dissemination the project’s results as pre-normative input to standardization.

- **Project activities / technologies that may lead to standardization:**
  - Definition of scenarios and use cases;
  - THz channel measurements and modelling in scenarios with RISs; and
  - RF impairment modeling of RISs.

- **Potential targeted standardization bodies / groups:**
  - IEEE 802 SC;
  - ETSI ISG THz;
  - THzETSI ISG RIS; and
Thank you for your attention!