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TERahertz ReconfigurAble METAsurfaces for ultra-high rate wireless communications

TERRAMETA

Deliverable D7.2
Report on Dissemination Standardisation and Exploitation Activities (initial)

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Organization: NKUA

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Organization: INESC TEC

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Exploitation Activities (initial)

Leader in charge of deliverable: Thomas Kürner, TUBS

Dissemination level		
PU	**Public – fully open**	**X**
SEN	**Sensitive – limited under the conditions of the Grant Agreement**	

Named Distribution Only

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Change register

Version	Date	Author	Organization	Changes
A	24-11-2023	Bo Kum Jung	TUBS	TOC
B	15-12-2023	Thomas Kürner	TUBS	Added sections on standardisation an exploitation
C	15-12-2023	Bo Kum Jung	TUBS	Formatting
D	24-12-2023	Bo Kum Jung	TUBS	Addressed review comments
E	30-12-2023	Luis Pessoa	INESC TEC	Minor corrections and formatting

1. <u>Statement of independence</u>

The work described in this document is genuinely a result of efforts pertaining to the TERRAMETA project: any external source is properly referenced.

Confirmation by Authors: Bo Kum Jung
Thomas Kürner
Kyriakos Stylianopoulos
George C. Alexandropoulos
Luis M. Pessoa

2. <u>Executive summary</u>

This deliverable summarizes the TERRAMETA's dissemination and standardisation activities in the period from M1 to M12 of the project. TERRAMETA partners have made great efforts on the dissemination, standardisation, and exploitation activities. The activity has been broad, extensive, and diverse.

The key points of this deliverable include the following:

- The official website has been opened.
    - available at: https://terrameta-project.eu/

- The LinkedIn account has been established and reached more than 190 registered followers.
    - available at: https://www.linkedin.com/company/terrameta/

- The X page (formerly Twitter) has been created.
    - available at: https://twitter.com/TERRAMETA_6GSNS

- Intensive participation in dissemination activities in a wide range of events all over the world.
    - 12 international conference presentations.
    - Organisation of workshop at EuCNC & 6G Summit workshop joint with RISE-6G, Meta Wireless, and ARIADNE including presentations and panel discussion.
    - Numerous other events including invited talks, lectureships, special sessions, and tutorials.
    - 9 referred journal papers.
    - 2 magazine papers.

- The first newsletter was published and distributed in diverse communication channels including email, website, LinkedIn, and X (formerly Twitter).

- The flyer was designed and distributed at the events where TERRAMETA either organised or participated in.

The key points of standardisation activities include the following:

- 2 contributions to IEEE 802.15 Standing Committee THz.

- 5 contributions to ETSI Industry Specification Group THz.

The key points of exploitation activities include the following:

- One patent has been filed.

- RIS capabilities have been incorporated in a system-level simulator.

- RIS hardware has been designed, which will be used in a joint measurement campaign with another SNS project.

3. <u>Dissemination Activities by M12</u>

TERRAMETA has been very actively engaged in the dissemination activity over the first 12 months of the project. This section underscores all dissemination activities that have been performed within this period.

3.1. TERRAMETA communication channels

To effectively reach and captivate our target audience, TERRAMETA has strategically utilised a wide range of communication channels. This ensures that our work resonates across multiple platforms, maximising TERRAMETA's outreach.

3.1.1. <u>TERRAMETA website</u>

A website has been launched and is available at: https://terrameta-project.eu/
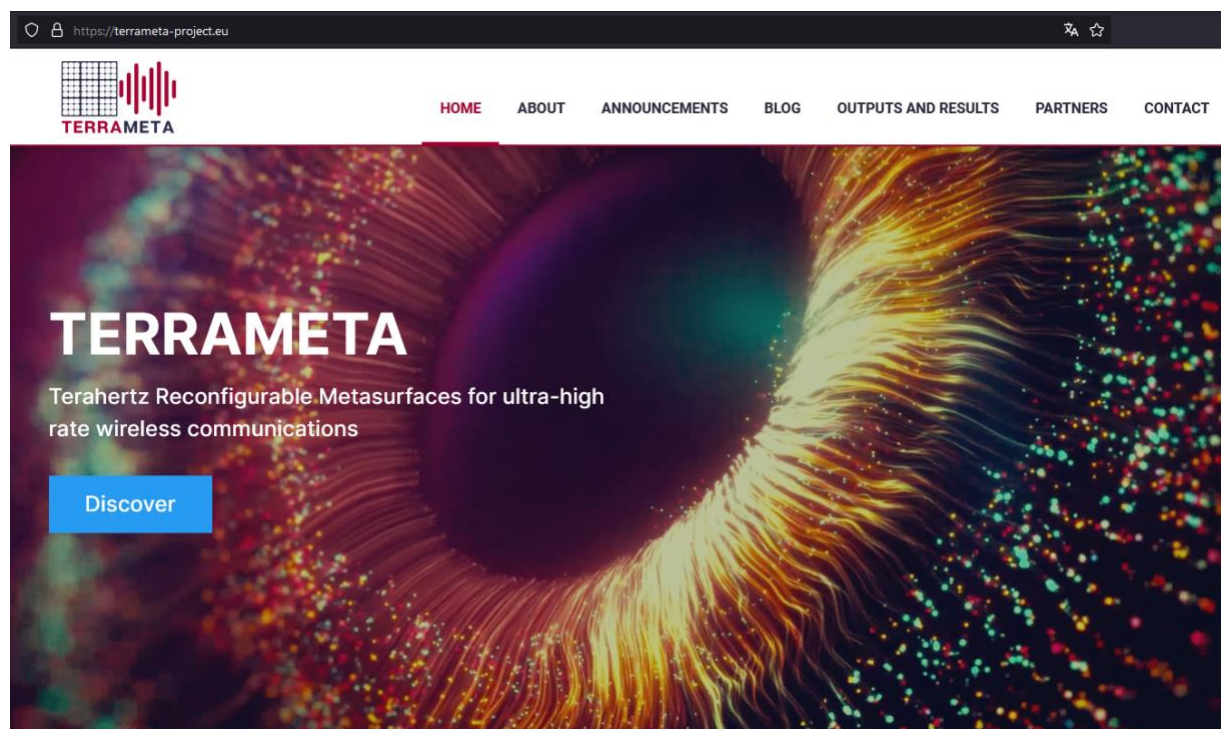
The website contains all relevant project details and presents an overview of the ongoing project including general project information, up-to-date news, and recent scientific findings and results.

The current structure of the website is organized as follows:
- Home
- About
- Announcements
- Blog
- Outputs and results
  - Scientific publications
  - Public deliverables
  - Dissemination & Communication
- Partners
- Contact

At the time of writing, the website has around 250 visits in total and it has appeared on search results 1500 times based on the statistic provided by google analytics.

The requirements, goals, and specifications of the website have been reported under D7.1.

3.1.2. TERRAMETA LinkedIn

A LinkedIn page has been launched and is available at:
https://www.linkedin.com/company/terrameta/
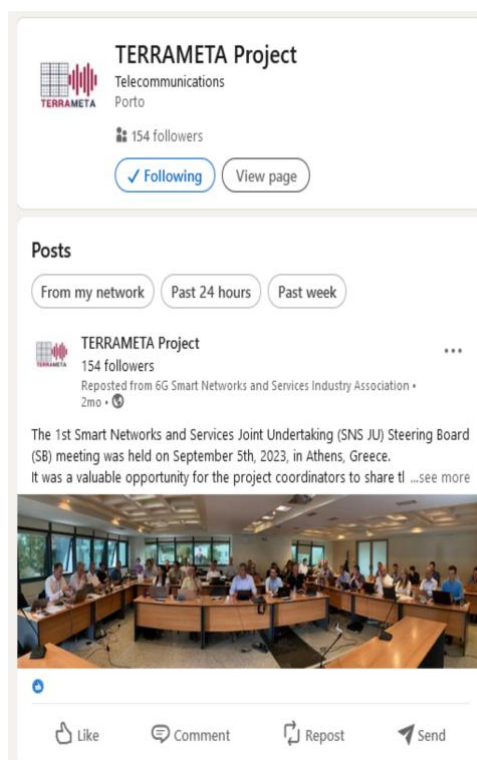
The LinkedIn page disseminates project-related news promptly and provides an opportunity to reach a wide variety of audience and to interact directly with them. The LinkedIn page already has more than 190 registered followers.

The LinkedIn page focuses on increasing TERRAMETA's reach by sharing important events such as the organization of special sessions and workshops, publishing newsletters, and any other relevant dissemination activities to attract the attention of other researchers in the same community and to look forward to the potential collaborations with them for synergy effects to make the TERRAMETA project a success.

The page already includes more than 10 posts at the time of writing, posted by 6 different accounts from involved Partners. The post about the first face-to-face meeting in Athens reached 47 likes which is the highest number at the time of writing.

### 3.1.3. TERRAMETA X (formerly Twitter)

A X page (formerly Twitter) has been launched and is available at:
https://twitter.com/TERRAMETA_6GSNS

The X page (formerly Twitter) facilitates the dissemination of project-related news promptly and provides an opportunity to engage with audiences from diverse backgrounds.

Capitalising on X's more direct and personal approach to posts, the content shared there is of a similar nature to LinkedIn, but phrased in a more friendly tone. Posts mainly include brief summaries of events (e.g., organizing workshops, meetings and publications of a newsletter) to keep interested stakeholders informed of the dissemination activities of TERRAMETA so that the project does not reach researchers from its own community only, but people from different fields can get also get information on the cutting-edge technologies tackled by TERRAMETA, such as sub-THz RIS technology.

At the time of writing, there are a total of five posts and two of which have over 40 views (related to the first kick-off meeting and the workshop session at EuCNC).
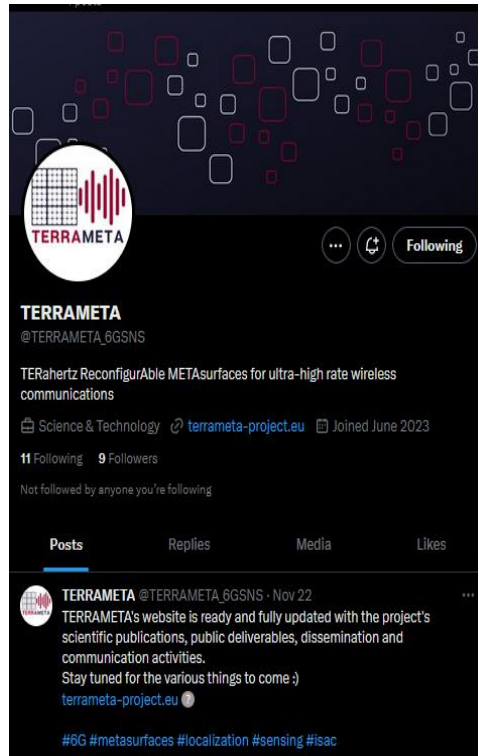
3.2. TERRAMETA events

It is self-evident to TERRAMETA partners that they were very active in disseminating TERRAMETA's results by organising and participating in numerous conferences, workshops, and any other types of events. In the first year of the project, more than 2000 participants attended the following events, in person, or virtually.

3.2.1. *Conference and Workshop presentations*

EuCAP 2023
17th European Conference on Antennas and Propagation, 26-31 March 2023, Florence, Italy (approximately 100 attendees).

- "Radio propagation characterizations and channel modelling for RIS and sub-THz channels" (presented by Qi Luo, UH)

ICEAA 2023
2023 International Conference on Electromagnetics in Advanced Applications, 09-13 October 2023, Venice, Italy (approximately 200 attendees).

- "Near-field Focusing with Transmitarrays: Impact of Phase Quantization" (presented by Antonio Clemente, CEA)

E-MRS
European material research society, 29 May - 02 June 2023, Strasbourg, France (approximately 500 attendees).

- "Application of memristor switches" (presented by Asal Kiazadeh, NOVA ID)

Euro Nano Forum
Euro Nano Forum 2023, 11-13 June 2023, Lund, Sweden (approximately 200 attendees).

- "Overview on memristor technology in power-efficient processing" (presented by Asal Kiazadeh, NOVA ID)
- "Sustainable printing methods of Memristor technology" (presented by Jonas Deuermeier, NOVA ID)

ETSI Research Conference
ETSI Research Conference: Maximizing the Impact of European 6G Research through Standardization, 6-8 February 2023, Sophia Antipolis, France (approximately 100 attendees).

- "Project overview and standardisation plans" (presented by George C. Alexandropoulos, Luis M. Pessoa)

NANOARCH 2023
18th ACM International Symposium on Nanoscale Architectures Association for computing machinery, NANOARCH, 18-20 December 2023, Dresden, Germany

- "Concept paper on novel radio frequency resistive switches" (presented by Asal Kiazadeh, NOVA ID)

EUSIPCO 2023
31st European Signal Processing Conference, 04-08 September 2023, Helsinki, Finland

- "Full Duplex Holographic MIMO for Near-Field Integrated Sensing and Communications" (presented by Ioannis Gavras, NKUA)
- "Full-Duplex-Enabled Joint Communications and Sensing with Reconfigurable Intelligent Surfaces" (presented by Chandan Kumar Sheemar, Uni.Lu)

URSI GASS 2023
International Union of Radio Science General Assembly and Scientific Symposium, 19-26 August 2023, Sapporo, Japan.

- "On the Requirements on Reflective Intelligent Surfaces in THz NLOS Backhaul" (presented by Thomas Kürner, TUBS)

IEEE International Conference on Communications
IEEE International Conference on Communications, 28 May - 1 June 2023, Rome, Italy (approximately 200 attendees).

- "Channel modeling and multi-user precoding for tri-polarized holographic MIMO communications" (presented by Li Wei).
- Tutorial "Leveraging smart wireless environments for beyond 5G localization and sensing" (delivered by George C. Alexandropoulos, NKUA).

IEEE ICASSP
IEEE International Conference on Acoustics, Speech, and Signal Processing, 4 June 2023, Rhodes, Greece (approximately 200 attendees).

- Tutorial "Machine learning for smart wireless environments" (delivered by George C. Alexandropoulos, NKUA)

EuCNC & 6G Summit Workshop
EuCNC & 6G Summit workshop joint with RISE-6G, Meta Wireless, and ARIADNE, 06 June 2023, Gothenburg, Sweden (approximately 100 attendees).

- "Reconfigurable Intelligent Surfaces from sub-6GHz to THz: Recent Advances and Open Challenges" (organizer: George C. Alexandropoulos)
- "Reconfigurable technologies for integrating RIS elements at THz: New approaches and challenges" (presented by Luis M. Pessoa, INESC TEC)
- THz RIS for ultra-high rate wireless communications: element design and synthesis (presented by Sergio Matos, IT)
- "Simulation scenarios for the assessment of reflective intelligent surfaces in THz backhaul applications" (presented by Bo Kum Jung, TUBS)
- "The RIS technology status, trends, and road to standardization" (discussion panel: Luis M. Pessoa)
- "Through the development of reconfigurable electromagnetic surfaces at sub-THz: Actual technology and future challenges" (presented by Antonio Clemente, CEA)

IEEE GLOBECOM Workshop
IEEE GLOBECOM Workshop on Reconfigurable Intelligent Surfaces-Empowered 3CLS for 6G and Beyond Communications (approximately 20 attendees).

- "Enhancing NLoS RIS-Aided Localization with Optimization and Machine Learning" (presented by Luis M. Pessoa, INESC TEC)

3.2.2. *Other events*

Spanish URSI Symposium 2023
URSI 2023 - XXXVIII Simposio Nacional de la Unión Científica Internacional de Radio, 13-15 September 2023, Caceres, Spain (approximately 20 attendees).

- "Reconfigurable intelligent surfaces for communications and sensing" (presented by Luis M. Pessoa, INESC TEC)

SNS lunchtime webinar
Stream B2 & B3 projects addressing: Wireless Communications and Signal Processing & Communication Infrastructure and Devices, 06 March 2023, online (approximately 90 attendees).

- "Project overview presentation" (presented by Luis M. Pessoa, INESC TEC)

IEEE P802.15 meeting
IEEE P802.15 Working Group for Wireless Speciality Networks (WSN), 13 March 2023, Atlanta, USA.

- "Overview on the Horizon Europe 6G SNS Project TERRAMETA" (presented by Thomas Kürner, TUBS)

Symat COST Action Meeting
COST Action CA18223 - SYMAT - Future Communications with higher symmetric engineered artificial materials, 04 May 2023, Lisbon, Portugal (approximately 50 attendees).

- "Overview of INESC TEC research activities including an overview of TERRAMETA Project" (presented by Luis M. Pessoa, INESC TEC)

RFIC
Radio Frequency Integrated Circuits Symposium, 11-13 June 2023, San Diego, USA.

- "Transmitarrays and in-package antenna solutions for future communication systems at millimeter wave and sub-THz frequencies" (presented by Antonio Clemente, CEA)

IEEE CSCN 2023
IEEE Conference on Standards for Communications and Networking, 11 August 2023, Munich, Germany (approximately 40 attendees).

- Special session: "Key challenges for enabling high-performance short-range communications in extreme propagation environments" (Organizer: Luis M. Pessoa, Panel participation: Sean Ahearne (EISI), George C. Alexandropoulos (NKUA))
- Invited Talk: "TERRAMETA – THz Reconfigurable Intelligent Surfaces for next generation communications and sensing" (presented by Sean Ahearne, EISI)

School of Advanced Studies
The Lake Como School of Advanced Studies, 4 July 2023, Lake Como, Italy (approximately 20 attendees).

- "Reconfigurable intelligent surfaces: From programmable wireless propagation to holographic MIMO" (presented by George C. Alexandropoulos, NKUA)

IEEE Signal Processing Society Summer School

The Summer School on Integrated Sensing and Communication sponsored by the IEEE Signal Processing Society, IEEE Aerospace and Electronic Systems Society, and EURASIP, 28 June 2023, Baiona, Spain (approximately 20 attendees).

- "Beamforming for joint radar and communication with self-interference cancellation constraints" (presented by George C. Alexandropoulos, NKUA)
- "RIS-aided joint radar and communication" (presented by George C. Alexandropoulos, NKUA)
- "Reconfigurable intelligent surfaces: From programmable wireless propagation to holographic MIMO" (presented by George C. Alexandropoulos, NKUA)

UK-Taiwan Joint Webinar

The UK-Taiwan Joint Webinar on Next Generation Multiple Access and AI for 6G, 1 May 2023, Online (approximately 15 attendees).

- Invited talk "Integrated sensing and communications with multi-functional reconfigurable metasurfaces" (presented by George C. Alexandropoulos, NKUA)

IEEE ComSoc Distinguished Lectureships

- IEEE ComSoc Distinguished Lectureship at the University of Glasgow, 30 March 2023, Glasgow, Scotland (approximately 20 attendees).

    o Lectureship "Reconfigurable metasurfaces for 6G wireless: Hardware architectures, modeling, optimization, and applications" (presented by George C. Alexandropoulos, NKUA)

- IEEE ComSoc Distinguished Lectureship at the Department of Electrical and Computer Engineering University of Illinois at Chicago, 10 March 2023, Chicago, USA (approximately 30 attendees).

    o Lectureship "Hybrid reconfigurable intelligent Surfaces: From channel estimation improvement to self-optimization" (presented by George C. Alexandropoulos, NKUA)

- IEEE ComSoc Distinguished Lectureship at EURECOM, 09 February 2023, Nice, France (approximately 20 attendees).

    o Lectureship "Integrated sensing and communications with multi-functional reconfigurable metasurfaces" (presented by George C. Alexandropoulos, NKUA)

- IEEE ComSoc Distinguished Lectureship at the School of Physics, Engineering, and Computer Science, 14-15 September 2023, University of Hertfordshire, Cambridge, UK (approximately 15 attendees).

- Lectureship "Hybrid reconfigurable intelligent surfaces: From conventional optimization to autonomous learning" (presented by George C. Alexandropoulos, NKUA)
  "Reconfigurable intelligent surfaces: From programmable wireless propagation to holographic MIMO" (presented by George C. Alexandropoulos, NKUA)

- IEEE ComSoc Distinguished Lectureship at the Institute of Radiocommunications, Faculty of Computing and Telecommunications, 16 November 2023, Poznan University of Technology, Poznan, Poland (approximately 20 attendees).

  - Lecture "Joint sensing and communications with full duplex radios and reconfigurable metasurfaces" (presented by George C. Alexandropoulos, NKUA).

Lancaster University
Invited talk at School of Engineering - Lancaster University, 09 June 2023, Lancaster, UK.

- "Intelligent Reflective Surfaces in the Era of 6G" (presented by Henrique M. Salgado, INESC TEC)

National Conference on Communications
National Conference on Communications, Indian Institute of Technology Guwahati, 23 – 25 February 2023, Guwahati, India (approximately 40 attendees).

- Tutorial "Reconfigurable intelligent surfaces and holographic MIMO transceivers: Current status and future directions" (presented by George C. Alexandropoulos, NKUA)
- "Hybrid reconfigurable intelligent Surfaces: From channel estimation improvement to self-optimization" (presented by George C. Alexandropoulos, NKUA)

IEEE PIMRC Workshop
IEEE International Symposium on Personal, Indoor and Mobile Radio Communications Workshop 6G Envisioned Reconfigurable Intelligent and Holographic Surfaces, 05 September 2023, Toronto, ON, Canada (approximately 30 attendees).

- "Integrated sensing and communications with multi-functional reconfigurable metasurfaces" (presented by George C. Alexandropoulos, NKUA)

CMD30 FisMat 2023
CMD30 FisMat 2023, Minicolloquia, 04-08 September 2023, Milano, Italy (approximately 60 attendees).

- Invited lecture "New Insights on Emerging Materials and Concepts for Neuromorphic Computing" (presented by Asal Kiazadeh, NOVA ID)

E-MRS Spring
E-MRS Spring, 29 May – 02 June 2023, Strasbourg, France (approximately 500 attendees).

- Lecture "Sustainable Zinc tin oxide artificial synapses towards energy-efficient in-memory computation architecture" (presented by Asal Kiazadeh, NOVA ID)

- Lecture "Sustainable solution-processed oxide memristors: Approaches to interface analysis by XPS" (presented Jonas Deuermeier, NOVA ID)

Annual Conference on Global Nanotechnology
2nd Annual Conference on Global Nanotechnology, Instituto De Ciencia De Materiales De Madrid (ICMM-CSIC), 19-21 June 2023, Madrid, Spain (approximately 100 attendees).

- Invited lecture "Sustainable and viable processes to produce metal oxide devices in large scale manufacturing" (presented by Emanuel Carlos, NOVA ID)

International Conference on Memristive Materials, Devices & Systems
6th International Conference on Memristive Materials, Devices & Systems, 05-09 November 2023, Torino, Italy (approximately 500 attendees).

- Lecture "Cost-effective Solution-based metal oxide memristors" (presented by Raquel A. Martins, NOVA ID)
- Lecture "ZTO memristor devices and applications" (presented by Carlos Silva NOVA ID)

Congress of the Portuguese Committee of the URSI
17th Congress of the Portuguese Committee of the URSI, 24 November 2023, ANACOM's head office, Lisbon (approximately 40 attendees).

- Invited talk and panel session on "Smart materials for radioscience" (Asal Kiazadeh (NOVA ID) and Luis M. Pessoa (INESC TEC))

TED talk
Portuguese TED talk organized by Escola 42 Lisboa, 15 November 2023 (approximately 50 attendees on site).

- "AI hardware of future" (presented by Asal Kiazadeh, NOVA ID)
  - https://www.youtube.com/watch?v=4SPi8zzbEbk

ICT-52 and Hexa-X Workshop on 6G
Radio and sensing for 6G session of the ICT-52 and Hexa-X Workshop on 6G, 18 January 2023, online (approximately 50 attendees).

- Invited talk "Localization, sensing, and their integration with reconfigurable intelligent surfaces" (presented by George C. Alexandropoulos, NKUA)

RISE-6G Training Workshop
RISE-6G Training Workshop, 12 December 2023, online (104 attendees).

- Tutorial "The RIS technology: Today's key pillars and open challenges" (presented by George C. Alexandropoulos, NKUA)

Expert Seminar on 6G
Expert Seminar on 6G: New PHY-layer solutions and spectrum, jointly organized by the Directorate-General for Research and Innovation of the European Commission and the National Science and Technology Council of Taiwan, 14 December 2023, online (approximately 50 attendees).

- Seminar "Multi-functional RISs, holographic MIMO, integrated sensing and communications, cell-free smart wireless environments" (presented by George C. Alexandropoulos, NKUA)

National SME Meeting Telecommunications

National SME Meeting Telecommunications, XXVII National SME Meeting in the sector of Telecommunications, 30 November 2023, Lisbon, Portugal (approximately 40 attendees).

- "The path towards 6G" (presented by Luis M. Pessoa, INESC TEC)

3.3. Journal publications

9 journal papers have been published acknowledging TERRAMETA. Only the accepted journal papers appear here.

[1] B. Smida, A. Sabharwal, G. Fodor, G. C. Alexandropoulos, H. A. Suraweera, and C.–B. Chae, "Full-duplex wireless for 6G: Progress brings new opportunities and challenges," *IEEE Transactions on Wireless Communications*, vol. 41, no. 9, pp. 2729–2750, September 2023.

[2] J. An, C. Xu, D. W. K. Ng, G. C. Alexandropoulos, C. Huang, C. Yuen, and L. Hanzo, "Stacked intelligent metasurfaces enabling efficient holographic MIMO communications for 6G," *IEEE Journal on Selected Areas in Communications*, vol. 41, no. 8, pp. 2380–2396, August 2023.

[3] M. Perreira, P. barquinha, E. Fortunato, R. Matins, and A. Kiazadeh, "Recent progress in optoelectronic memristors for neuromorphic and in-memory computation," *Journal of Neuromorphic Computing and Engineering*, vol. 3, no. 2, pp. 2634-4386, May 2023.

[4] L. Wei, C. Huang, G. C. Alexandropoulos, Z. Yang, J. Yang, W. E. I. Sha, Z. Zhang, M. Debbah, and C. Yuen, "Tri-polarized holographic MIMO surface in near-field: Channel modeling and precoding design," *IEEE Transactions on Wireless Communications*, 2023.

[5] H. Kim, H. Chen, M. F. Keskin, Y. Ge, K. Keykhosravi, G. C. Alexandropoulous, S. Kim, and H. Wymeersch, "RIS-Enabled and Access-Point-Free Simultaneous Radio Localization and Mapping," *IEEE Transactions on Wireless Communications*, 2023.

[6] A. Papazafeiropoulos, P. Kourtessis and S. Chatzinotas, "Max-Min SINR Analysis of STAR-RIS Assisted Massive MIMO Systems with Hardware Impairments," *IEEE Transactions on Wireless Communications*.

[7] C. Silva, J. Deuermeier, W. Zhang, E. Carlos, P. Barquinha, R. Martins, A. Kiazadeh, "Perspective: Zinc-Tin Oxide based Memristors for Sustainable and Flexible In-memory computing edge devices," *Advanced Electronic Materials (2023)*, pp. 1-16.

[8] T. Gong, P. Gavriilidis, R. Ji, C. Huang, G. C. Alexandropoulos, L. Wei, M. Debbah, H. V. Poor, and C. Yuen, "Holographic MIMO communications: Theoretical foundations, enabling technologies, and future directions," *IEEE Communications Surveys & Tutorials*, to appear, 2023.

[9] S. Gharbieh, J. Milbrandt, B. Reig, D. Mercier, M. Allain, and A. Clemente, "Design of a binary programmable transmitarray based on phase change material for beam steering applications in D-Band", *Scientific Reports,* to appear, 2023.

3.4. Magazine publications

Two magazine papers have been published acknowledging TERRAMETA.

[1] G. C. Alexandropoulos, N. Shlezinger, I. Alamzadeh, M. F. Imani, H. Zhang, and Y. C. Eldar, "Hybrid reconfigurable intelligent metasurfaces: Enabling simultaneous tunable reflections and sensing for 6G wireless communications," *IEEE Vehicular Technology Magazine*, early access, 2023.

[2] A. Masaracchia, D. V. Huynh, G. C. Alexandropoulos, B. Canberk, O. A. Dobre, and T. Q. Duong, "Towards the metaverse realization in 6G: Orchestration of RIS-enabled smart wireless environments via digital twins," *IEEE Internet of Things Magazine*, 2023.

3.5. Interactions with other projects

As illustrated by the actions listed above, TERRAMETA has actively pursued collaborations and synergies with other ICT-52, H2020, and Horizon Europe SNS JU projects.

- The presence of TERRAMETA representatives in EuCNC & 6G Summit 2023 provided an excellent opportunity with face to face interactions with related projects. In particular, a workshop has been co-organised in the venue alongside ICT-52 projects RISE-6G and ARIADNE as well as the European Training Network project Meta Wireless.
- TERRAMETA partners were involved with the ICT-52 project RISE-6G Training Workshop by giving a tutorial speech on RIS technology and participating on a panel discussion on RIS commercialisation.
- TERRAMETA partnered with the SNS JU projects 6G-SHINE and TIMES to organize a special session on "Key challenges for enabling high-performance short-range communications in extreme propagation environments" at IEEE Conference on Standards for Communications and Networking (CSCN 2023).
- TERRAMETA partnered with the Horizon Europe CONVERGE project to propose one workshop at the IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP) in Seoul, South Korea, entitled "Super-resolution integrated communications, localization, vision and radio mapping (SUPER-CLAM)". The workshop has been accepted and is currently open for paper submissions.

3.6. Other dissemination activity

3.6.1. TERRAMETA newsletter

The first TERRAMETA newsletter has been published and disseminated across the various media platforms mentioned above. The newsletter showcases the TERRAMETA project, novel scientific findings, results, and research plans encompassing from software simulation to hardware manufacture.

The focus of the newsletter is as follows:

- Project overview
- Demonstration plan
- THz RIS design
- THz channel measurement plan
- THz channel modelling and signal processing

The first newsletter briefly introduces the project outlining the aim and vision of the project and its impact on the society in the same field to capture the potential subscribers. In the newsletter, we seized the opportunity to give a strong impression of the project by providing a summary of TERRAMETA's dissemination activities such as number of publications and

the successful organisation of the workshop at EuCNC & 6G Summit where we gave four presentations and also participated in the panel discussion. Besides, we have focused on providing the clear goal of the project "RIS" ranging all aspects from identifying use cases of RIS, hardware developments, and software-based design solution to channel modelling and channel measurement.

Newsletter #1

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.

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

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Newsletter #1

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.
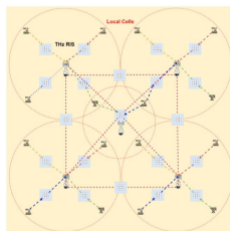

For more information, visit TERRAMETA's website : https://terrameta-project.eu

4

Newsletter #1

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

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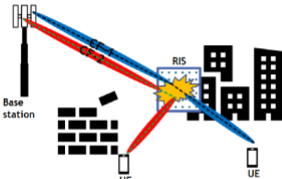
For telcos, the integration of RIS heralds a new era of infrastructure efficiency and customer satisfaction, paving the way for a more connected and accessible urban future.

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

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Newsletter #1

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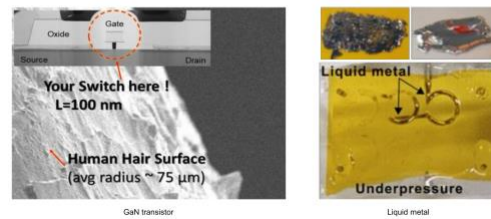
TERRAMETA investigates new hardware approaches for RISs at sub-THz (140 GHz), such as Gallium-Nitride (GaN) switches and continuous surface actuation by injecting liquid metal (LM) into microfluidic structures.

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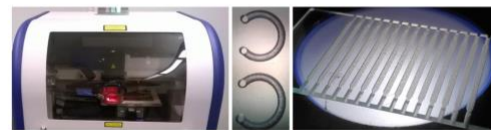
Laser micromachining device (left) used to fabricate C-shaped (midle), and straight (right) microchannels.

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

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Newsletter #1

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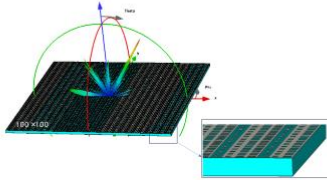
Full-wave evaluation of a large RIS design (100x100 unit cells) for 300 GHz.

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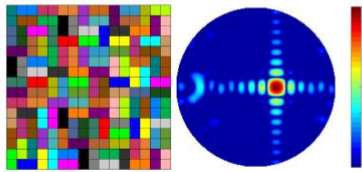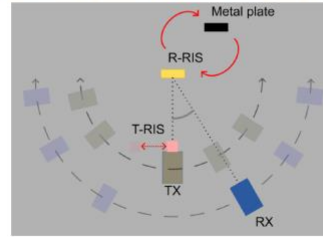
Modelling a large metasurface and optimisation of the side lobes' level of beam steering through a sub-array tiling approach.

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Newsletter #1

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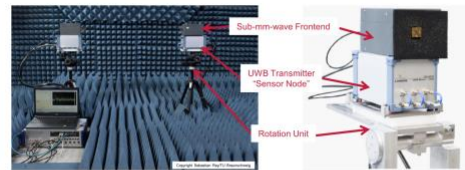
THz channel sounding equipment at IfN, TU Braunschweig (video available here).

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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Newsletter #1

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.
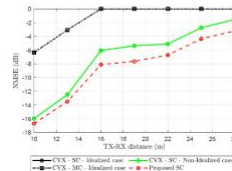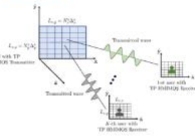
XL MIMO channel estimation in THz considering the presence of propagation delays across the entire array apertures, which leads to frequency selectivity, a problem known as *beam squint*. Designed a novel time-domain channel estimation technique for single-carrier modulation. The beam-squint effect is 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.
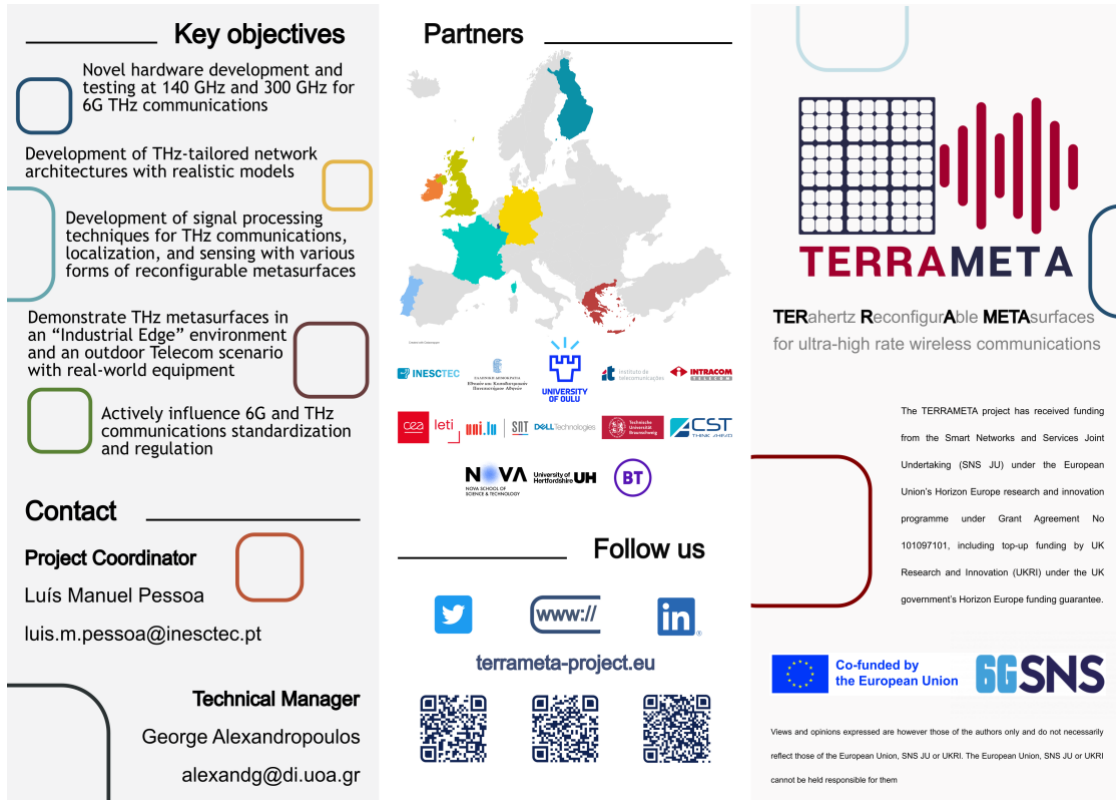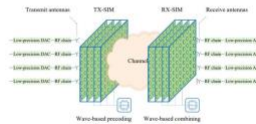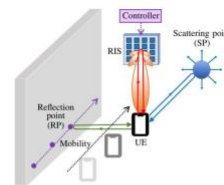
Low-complexity fully digital beamforming transceivers aided by stacked transmissive RISs that realise wave-based analog beamforming. Devised efficient algorithms for optimizing the unit cells of the RISs and derived capacity scaling laws.

For more information, contact George Alexandropoulos: alexandg@di.uoa.gr

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3.6.2. *TERRAMETA flyer*

The TERRAMETA flyer has been designed and printed in a trifold format for distribution. The targeted events for the distribution of the flyer are all forms of face-to-face events either organised by TERRAMETA or in which TERRAMETA participated such as in EuMW2023 and IRMMW-THz 2023 conferences.

For the upcoming year, we expect more opportunities to raise awareness of TERRAMETA by distributing flyers at workshops, conferences, and any other opportunities.

3.6.1. *Organisation of the special sessions*

In the first 12 months of the project, TERRAMETA co-organized two special sessions at the 2023 EuCNC & 6G Summit workshop and IEEE Conference on Standards for Communications and Networking.

Jointly with RISE-6G, MetaWireless, and ARIADNE, TERRAMETA co-organized a special session entitled "Reconfigurable Intelligent Surfaces from sub-6GHz to THz: Recent Advances and Open Challenges" at the 2023 EuCNC & 6G Summit workshop in Gothenburg, Sweden. A total of three presentations took place about the design and synthesis of RIS, new approaches and challenges for integrating RIS, and potential application scenarios of RIS in THz backhaul links. In addition, TERRAMETA coordinator participated in the discussion panel: "The RIS technology status, trends, and road to standardization".

TERRAMETA partnered with the 6G-SHINE and TIMES to organize a special session on "Key challenges for enabling high-performance short-range communications in extreme propagation environments" at IEEE Conference on Standards for Communications and Networking (CSCN 2023). This Special Session held in Munich, Germany and covered the overlapping topics researched within the context of three SNS JU Phase I projects. It brought together experts from diverse backgrounds to share the perspectives on enabling

high-performance communication in high frequencies and with reconfigurable intelligent surfaces. In addition to discussing the research challenges, the session also explored pathways for transferring the outputs of research projects to standards, which is essential for the commercialization of these technologies.

4. <u>Standardisation Activities by M12</u>

TERRAMETA has been actively contributing to two standardisation groups at IEEE 802 (IEEE 802.15 SC THz) and ETSI (ISG THz), which are both working towards pre-standardisation of THz communication systems. In addition, NKUA, INESC TEC and TUBS have participated in ETSI ISG RIS on reflective intelligent surfaces and ETSI ISG on Integrated Sensing And Communication (ISAC).

4.1. Contributions to IEEE 802.15 Standing Committee THz (IEEE 802.15 SC THz)

The IEEE 802.15 Standing Committee Terahertz is chartered to explore the feasibility of Terahertz for wireless communications (https://www.ieee802.org/15/pub/SCTHz.html). TERRAMETA partner TUBS is participating in this group and Prof. Kürner is the chair of the group. In 2023, TERRAMETA has made two contributions, which provided an overview on the TERRAMETA project and introduced the simulation scenarios for the enhancement of THz backhaul links by Reconfigurable Intelligent Surfaces:

- T. Kürner, L. Pessoa; Overview on the Horizon Europe 6G SNS Project TERRAMETA, IEEE 802.15 doc.: 15-23-0132-01-0thz, IEEE 802 Plenary, Atlanta, 13 March 2023; https://mentor.ieee.org/802.15/dcn/23/15-23-0132-01-0thz-overview-on-the-horizon-europe-6g-sns-project-terrameta.pdf

- B. K. Jung, T. Kürner; Simulation Scenarios for the Assessment of Reflective Intelligent Surfaces in THz Backhaul, IEEE 802.15 doc.: 15-23-0342-00-0thz, IEEE 802 Plenary, Berlin, 9 July 2023, https://mentor.ieee.org/802.15/dcn/23/15-23-0342-00-0thz-simulation-scenarios-for-the-assessment-of-reflective-intelligent-surfaces-in-thz-backhaul-applications.pptx

4.2. Contributions to ETSI Industry Specification group THz (ETSI ISG THz)

ETSI ISG THz performs pre-standards work currently covering four work items (WI), see https://www.etsi.org/committee/2124-thz and https://www.etsi.org/newsroom/blogs/blog-thz.
The four work items are:

- WI#1: Identification of use cases for THz communication systems
- WI#2: Identification of frequency bands of interests for THz communication systems
- WI#3: Channel measurements and modelling in THz bands
- WI#4: RF Hardware Modelling

TERRAMETA partners TUBS, INESC TEC, EISI, CEA, NKUA and IT are participating in this group and Prof. Kürner (TUBS) is the chair of the group. A total of five TERRAMETA contributions have been made with respect to WI#1 and WI#4:

- THz(23)000109 - *Use cases for RIS-based THz communications and sensing*
  Contribution to WI#1 presenting 4 potential use cases for reconfigurable intelligent surface based THz communications and sensing, which have been defined in the context of the TERRAMETA project.

- THz(23)000201 - *Use case on Ultra-high throughput for indoor users*
  Contribution to WI#1 to the Enabling Technologies section of the group report GR001, with a description regarding the use of Transmissive reconfigurable intelligent surfaces within this use case.

- THz(23)000159 - *Use case on cooperative mobile robots*
  Contributed to WI#1 under the Enabling Technologies section of GR001, with a description on the use of THz RIS for directional THz communication links within this use case.

- THz(23)000110 - *Use case for Wireless Links in Data Centers*
  Contributed to WI#1 under the Enabling Technologies section of GR001, with a description on the usage of RIS to improve wireless communications within Data Centre environments.

- THz(23)000187 - *Input to Section 5 of GR 004*
  Contributed to WI#4 with a text proposal for a section entitled "Beam squinting for Reconfigurable Intelligent Surfaces", analysing the effects of beam squinting considering the use of Reconfigurable Intelligent Surfaces at 140 GHz, to be included in GR004.

5. Exploitation Activities by M12

Although exploitation activities typically don't take-off during the first twelve months of the project, many partners already have worked towards exploitation and achieved the following key points:

- **NKUA** has capitalized on the developed algorithmic approaches of the project, mainly under WP5, as well as the proposed deployment scenarios and use-cases for RISs in THz communications to enrich its portfolio, brand name, and expertise as leading academic experts on the field. The portfolio to be built by the end of the project is planned to be exploited for the pursue of further research grants and funded projects (national, European, or from the private sector) and enhance the quality of the education offered by the University by incorporating advancements and knowledge from TERRAMETA onto the educational material. So far, developments from TERRAMETA have contributed to the commencement of two relevant research projects, 6G-DISAC (SNS JU phase 2 project) and PRISM (funded under ESA-NAVSIP programme).
- An ongoing exploitation activity initiated by **IT** is the design of a collection of passive R-RIS panels to be used in a joint measurement campaign with the SNS project TIMES at **TUBS** enabling further cross-exploitation among the two projects.
- **EISI** continues its engagement with Advanced Wireless Technologies business unit (BU), who are now investigating THz RIS themselves as well as its engagement with the Manufacturing BU and the Smart edge EU project. Initial tests with robots have proven that WiFi is indeed unsuitable for their application. A higher speed wireless network is needed.
- **INESC TEC** and **CEA** have filed a European Patent Application with the title: "Cell for transmit array or reflect array, transmit array or reflect array, and system", which protects the concept of using memristors for controlling unit-cells from transmit and reflect array antennas.
- **UH** had no exploitation activities in the first year, but is planning to create an RF short course and some outcomes of TERRAMETA will be included in this short course. The targeted audiences are postgraduates and apprentices from the industry.
- **TUBS** has incorporated RIS-related simulations into his Simulator o Mobile Networks (SiMoNe).
- **NOVA ID** plans to file a patent in year 2.
- **ACST GMBH** was present in EuMW2023 and IRMMW-THz with the company booth and the flyers from the project, doing advertisement.

6. <u>Conclusion</u>

In this deliverable, the dissemination, standardisation, and exploitation activities of the project over the first 12 months have been presented. In this period, TERRAMETA was very actively engaged in dissemination including 12 conference papers, 9 journal papers, 2 magazine papers, and numerous other activities in diverse fields. The activities are spread across the three communication channels of the website, LinkedIn, and X (formerly Twitter) to increase the TERRAMETA's reach to the society in various backgrounds. Furthermore, TERRAMETA was very active in collaborating with other projects investigating overlapping topics to generate synergy for the success of TERRAMETA.

TERRAMETA has actively pursued collaborations and synergies with other ICTS-52, H2020, and Horizon Europe SNS JU projects such as co-organisation of a workshop session at EuCNC & 6G Summit 2023 with the RISE-6G, Meta Wireless, and ARIADNE projects, a special session at IEEE Conference on Standards for Communications and Networking (CSCN 2023) with the 6G-SHINE and TIMES projects, and a workshop at IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP) with the CONVERGE project.

In terms of standardisation activities, TERRAMETA contributed passionately to IEEE 802.15 SC THz and ETSI ISG THz. Especially for ETSI ISG THz, TERRAMETA achieved significant contributions. Six partners from TERRAMETA (TUBS, INESC TEC, DELL, CEA LETI, NKUA and IT) are participating in this group and Prof. Kürner (TUBS) is the chair of the group. Here, a total of five TERRAMETA contributions have been already made.

For the exploitation activities, TERRAMETA showed outstanding results. The exploitation activities do typically not take-off during the initial phase of the project. Nonetheless, many partners already have worked towards exploitation.

In addition, TERRAMETA will be kept strongly engaged in dissemination, standardisation and exploitation activities in the second year of the project (M13 - M24). As an example, TERRAMETA has carried out work which resulted in 9 publications currently under the revision process for four peer-reviewed journals and five conferences. Additionally TERRAMETA is co-organising one workshop at the IEEE ICASSP in Seoul, South Korea and three workshops at IEEE International Conference on Communications (ICC) in Denver, USA.