Ref. Ares(2022)6125480 - 05/09/2022

Horizon 2020 Grant Agreement no: 814523

Tera**h**ertz end-to-end wireless systems supp**o**rting ultra-high data **R**ate applications

ThoR

D7.14
Final dissemination and exploitation activity report

Coordinator (EU): Thomas Kürner
Organisation: Technische Universität Braunschweig

Coordinator (Japan): Tetsuya Kawansihi
Organisation: Waseda University

Start date of project: 01-Jul-2018

Date of issue: 02-Sep-2022
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Leader in charge of deliverable: Bruce Napier
Vivid Components

Project co-funded by the European Commission within the Horizon 2020 programme and the National Institute of Information and Communications Technology in Japan (NICT)		
Dissemination level		
PU	**Public**	**X**
PP	**Restricted to other programme participants (including the Commission Services)**	
RE	**Restricted to a group specified by the consortium (including the Commission Services)**	
CO	**Confidential, only for members of the consortium (including the Commission Services)**	

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Change register

Version	Date	Author	Organisation	Changes
A_DRAFT	01-Sep-2022	Bruce Napier	Vivid Components	Initial
A	02-Sep-2022	Bruce Napier	Vivid Components	Final; no changes following review; typos & formatting only

Reviewed by Prof. Thomas Kürner TU Braunschweig A_DRAFT 01-Sep-2022

1. Statement of independence

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

Confirmation by Authors: Bruce Napier Vivid Components

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2. Executive summary

This document summarises the dissemination and exploitation activities during the ThoR project. Although the COVID-19 restrictions had some impact on the events between approximately M21-36, the ThoR dissemination and communication activity has been broad and varied.

More info is available from the project website www.thorproject.eu

The headline items are as follows:

- The website has been maintained including an RSS news feed
- The project has been widely represented at international conferences, workshops and exhibitions
    - Two dedicated ThoR workshops hosted by the EU and Japanese coordinators:
        - Japan ThoR workshop held 20-Sep-2019 at Waseda University
        - EU ThoR final workshop and demo held 29-30 Jun-2022 at TU Braunschweig
            - Video showing demo produced
    - Three dedicated ThoR sessions at international workshops
    - 42 papers presented at 24 international conferences
        - Four further papers to be presented after the project period
    - Representation at four major trade shows and exhibitions
    - ~40 other presentations at various meetings, workshops and standards committees
        - ThoR contributions to standards has been highly influential: see D7.13.
- Three books on aspects of THz communications have been edited by the two ThoR coordinators
    - These each include several chapters from the consortium partners
- Twelve refereed journal papers were published during the project
    - This includes “Best Paper of the Year” prize winners from two different journals
- A range of dissemination resources have been prepared:
    - Six newsletters issued
    - Video on DEMO-1 filmed at Lille with several EU and Japanese partners
    - Follow up video with interviews with ThoR experts released
    - An array of information on the project for public use (business cards, posters, presentation *etc.*) and merchandise for distribution at exhibitions (post-it notes and coasters)
    - Mailing list of >100 THz comms industrial and academic researchers
- ThoR has been a leading member of the B5G Cluster:
    - Online booth at European Microwave Week Exhibition 2020
    - Two workshops on THz Communications (Brussels Mar-2019 and online Mar-2021)
    - Workshop at IEEE World Forum 2019 (Sep-2019)
    - Booth and Special Session at EUCNC 2019 (Jun-2019)
    - Booth at European Microwave Week (Sep-2018).

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Throughout the project, the consortium has maintained a register of new IPR and its exploitation. The details must remain confidential, but a list of this new IP is given below:

Result	**Title**
TUBS-01	Sharing Studies wrt WRC 19 AI 1.15
TUBS-02	Automatic planning and guidelines for 300 GHz backhaul/links
TUBS-03	Link-level simulator for THz backhaul/fronthaul links
DTAG-01	Operator and end-user requirements for 5G and B5G networks
DTAG-02	Scenario definition for 5G and B5G networks
IAF-01	MMIC to WR12 waveguide transition on quartz substrate
IAF-02	Broadband 300 GHz high power amplifier (>10 mW) MMIC/Module
IAF-03	Compact power amplifier cell designs
IAF-04	Broadband waveguide couplers
Siklu-01	E-band radio parallelization concept
ULIL-01	Photonic-based local oscillator
ULIL-02	Methods for system-level measurements/datacoms
ULIL-03	Methods for antenna measurements in the 300 GHz band
ULIL-04	Method for measurement of IP3 performance using photonic techniques
ULIL-05	Methods to conduct validation of THz link in the 300 GHz band
USTUTT-01	Superheterodyne architecture proof-of-concept
USTUTT-02	Superheterodyne 300 GHz transmitter and receiver design
USTUTT-03	Superheterodyne 300 GHz RX design with active down-converter
USTUTT-04	System-level simulation test bench
USTUTT-05	Automated test bench for back-to-back measurements
WUT-01	Studies on link budget under severe weather conditions
CIT-01	Building material properties model at 300 GHz
CIT-02	Antenna model at 300 GHz
GU-01	Visualization of THz wave propagation dynamics
GU-02	Antenna measurement system
NEC-01	Establishment of TWTA manufacturing method at 300 GHz
NEC-02	Study of wind effect on 300 GHz links
HRCP-01	IEEE 802.15.3e-2017 compliant 300 GHz chipset concept

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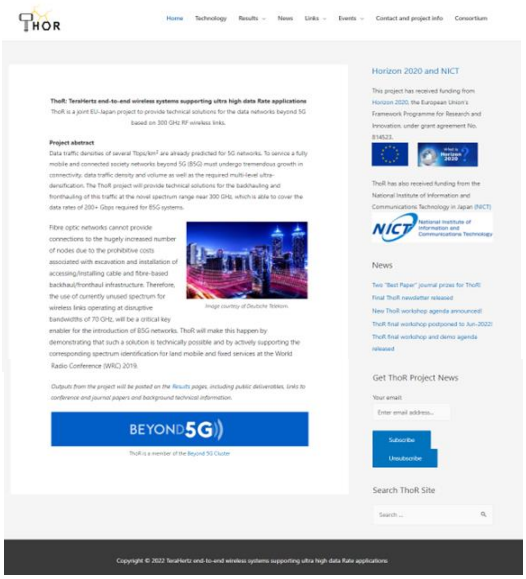
3. Dissemination activities at 45M

ThoR has been very active in its dissemination activity throughout the project. A range of dissemination material is available, and ThoR has been a key participant in many events relating to THz communications and B5G.

3.1. ThoR website

A website was established at https://thorproject.eu and this has been maintained throughout the project. This website includes all public ThoR documents, and is frequently updated with events, conference and journal papers as well as all the public deliverables. An RSS news feed is used to update on project progress and for announcements relating to ThoR activities. The page structure was updated during the project to improve the presentation of the results, and is as follows:

- Home
- Technology
- Results
  - Newsletters
  - Journal papers
  - Conference papers
  - Standards
  - Press coverage
  - Deliverables
- News
- Links
  - B5G Cluster
- Events
  - ThoR Final Workshop and Demo
  - 3rd Towards THz Comms Workshop (3TTCW)
  - ThoR Workshop 20-Sep-2019
- Contact and project info
- Consortium



The website had >17,000 visitors in 2021, consistently attracting >300/week (not including search engine robots). Throughout the third Period (from 01-Jul-2020), the average number of visitors per month is >1500, which is good for a niche technical project such as ThoR.

➔ **Plans M45+** The website will continue to be available for at least five years after the project.

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3.2. ThoR events

3.2.1. ThoR final workshop and demo D7.8 (Period 3: 29-30 Jun-2022)

[A more detailed description of the event is given in ThoR deliverable D7.8 *Final ThoR workshop (Europe)* and/or via the links listed below.]

The ThoR final workshop and demo was held in person (and also online) on 29-30 Jun-2022 hosted by EU Coordinator, TU Braunschweig. The event was co-located with a workshop led by the German national project METERACOM (28-Jun-2022), which has several partners in common with ThoR. In addition to the presentations and networking poster sessions, in person visitors were able to see a software demo and the ThoR hardware demo: a 2×20 Gbps bidirectional 300 GHz THz link over 160 m between campus buildings complying with standard IEEE 802.15.3d, which defines the new state-of-the-art.

Figure 1: *Showing the 160 record-breaking THz link over the TU Braunschweig campus 29-30 Jun-2022.*

Details and links to presentations are available from the ThoR website:
https://thorproject.eu/events/thor-final-workshop-and-demo/

Videos of the hardware and simulation demos are also available in the public domain:

https://www.youtube.com/watch?v=vEBfRHZGSyc Hardware demo

https://www.youtube.com/watch?v=2c07gXJLvgI Simulation demo

3.2.2. ThoR Japan workshop D7.6 (Period 2; 20-Sep-2019)

The first ThoR workshop was organised and hosted by Waseda University on FRI 20-Sep-2019. The workshop included three invited keynotes, presentations from the ThoR partners and a poster session. In addition, there was a small exhibition during the lunch and coffee breaks. Over seventy attendees were present, and the event was very well received.

Figure 2: *Attendees of the first ThoR workshop at Waseda University Sep-2019.*

Based on this success, a follow-up event in Japan was planned (in addition to the EU workshop discussed above) but sadly this had to be abandoned due to the COVID-19 restrictions.

Further details on the workshop have been published in the public deliverable *D7.6 Mid-term ThoR Workshop (Japan)* and on the project website:

https://thorproject.eu/events/thor-workshop-sep-2019

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3.2.3. Dedicated ThoR workshop sessions

During the course of the project, in addition to the Japanese and EU ThoR workshops described above, there were three dedicated international workshop sessions in which ThoR was the sole or a major contributor.

- ISAP 2020
  - International Symposium on Antenna and Propagation
  - 25-28 Jan-2021; Osaka, Japan
    - Postponed due to COVID-19 restrictions
  - Special Session: 3G4: OS: MW Wave and Tera Hertz Propagation
    - This session consisted of five ThoR papers (details in §3.2.4)
- 3TTCW
  - 3rd THz Comms EC Workshop
  - 11-12 Mar-2021; Leuven, Belgium
  - B5G Cluster workshop (see §3.5)

- EuCAP 2021
  - European Conference on Antennas and Propagation
  - 22-26 Mar-2021 (planned for Düsseldorf, Germany but forced online)
  - Joint workshop with TERAPOD (H2020) and METERACOM (German national project)
  - SW03 Antennas and Propagation Aspects for THz Communications
  - Ten presentations including invited speakers plus a panel session (details in §3.2.4).

3.2.4. Conference papers

Due to the COVID-19 restrictions in 2020 and 2021, a number of events were cancelled, moved online (*e.g.* EUCAP 2020) or postponed (*e.g.* 3TTCW). Nevertheless, ThoR continued to have a strong presence at international conferences. To M48 in the project there have been 42 major conference papers at 24 events, with four papers planned after the project end. (In addition, there have been a number of presentations at smaller and less formal events: see §3.2.7.) These conferences are listed below in reverse chronological order. All these papers are either green or gold access: see ThoR website for details.

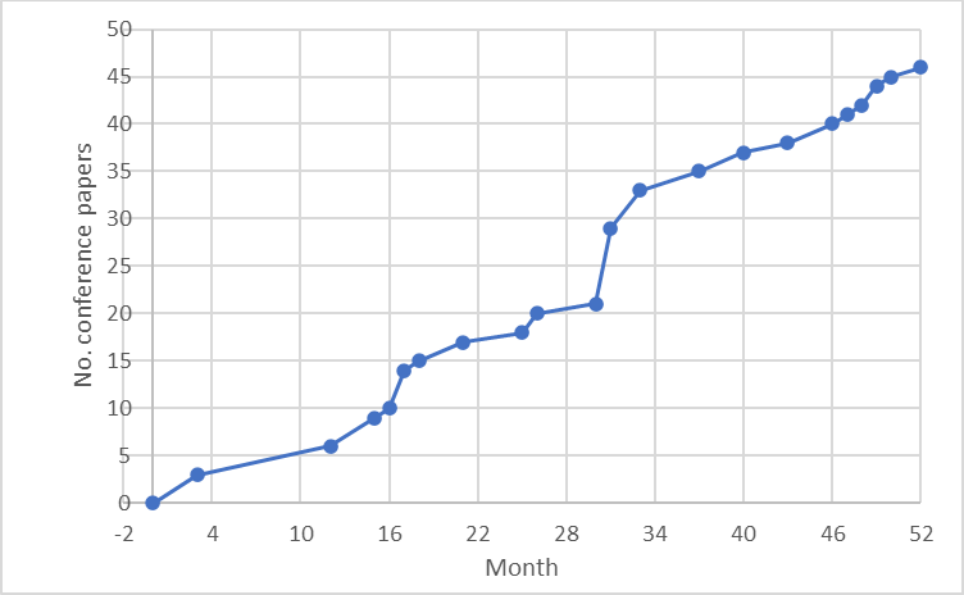

Figure 3: *Graph showing ThoR major conference papers during and planned after the project*

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After project end

ISAP 2022
2022 International Symposium on Antennas and Propagation
31-Oct to 03 Nov-202; Sydney, Australia

Performance Analysis of a Wireless Backhaul Network at Terahertz Frequencies
Johannes Eckhardt, Christoph Herold, Bo Kum Jung and Thomas Kürner
Accepted

IRMMW-THz 2022
47th International Conference on Infrared, Millimeter and Terahertz Waves
28-Aug to 02-Sep-2022; Delft, The Netherlands

Demonstrating 300 GHz Wireless Backhaul Links – The ThoR Approach
Thomas Kürner and Tetsuya Kawanishi
Invited

CLEO-PR 2022
15th Pacific Rim Conference on Lasers and Electro-Optics
31-Jul to 05-Aug-2022; Sapporo, Japan and online

THz and photonics convergence for future access links
Tetsuya Kawanishi
In press

Advanced Photonics Congress 2022
24-28 Jul-2022; Maastricht, The Netherlands and online

Terahertz Links for Future Mobile Networks
Tetsuya Kawanishi
In press

Period 3 (M25-M48; Jul-2020 to Jun-2022)

EUCNC 2022 and 6G Summit
European Conference on Networks and Communications and the 6G Summit
07-11 Jun-2022; Grenoble, France

Spectrum regulations for Terahertz communications: Trends and needs
Keynote by Prof. Thomas Kürner at TERAWAY project workshop “Photonic integration as a key enabling technology for 6G and beyond”
In press

URSI AT-AP-RASC 2022
URSI combined Atlantic / Asia-Pacific Radio Science Conference 2022
29-May to 03-Jun-2022; Gran Canaria, Spain

Performance Evaluation of Ray Tracing based Automatic Planning Algorithms for 300 GHz Backhaul Links (Invited)
Thomas Kuerner, Bo Kum Jung
In press

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EuMW 2021
European Microwave Week 2021
02-07 Apr-2022; London, UK (rescheduled from Feb-2022)

Short Range Wireless Transmission Using a 295-315 GHz Superheterodyne Link Targeting IEEE802.15.3d Applications
Dominik Wrana, Laurenz John, Benjamin Schoch, Sandrine Wagner, Ingmar Kallfass
https://doi.org/10.23919/EuMC50147.2022.9784217
https://opencms.uni-stuttgart.de/fak5/ilh/dokumente/PrePrint_Short-Range-Wireless-Transmission-Using-a-295315-GHz-Superheterodyne-Link-Targeting-IEEE802.15.3d-Applications.pdf

A Superheterodyne 300GHz Transmit Receive Chipset for Beyond 5G Network Integration
Iulia Dan; Christopher Grötsch; Laurenz John; Sandrine Wagner; Axel Tessmann; Ingmar Kallfass
https://doi.org/10.23919/EuMIC50153.2022.9783947
https://opencms.uni-stuttgart.de/fak5/ilh/dokumente/PrePrint_EuMW_Paper_idan_final.pdf

RWW 2022
IEEE Radio & Wireless Week 2022
16-19 Jan-2022; Las Vegas, NV, USA

Short-Range Full-Duplex Real-Time Wireless Link for IEEE
Dominik Wrana; Yigal Leiba; Laurenz John; Benjamin Schoch; Axel Tessmann; Ingmar Kallfass
http://doi.org/10.1109/RWS53089.2022.9719954
https://www.ilh.uni-stuttgart.de/dokumente/DW_Paper_RWW2022_PrePrint.pdf

ISAP 2021
26th International Symposium on Antennas and Propagation
19-22 Oct-2021; Taipei, Taiwan

Measurement of Far Field Radiation Pattern of 300 GHz band Cassegrain Antenna
Ken Watanabe, Akihiko Hirata, Issei Watanabe, Norihiko Sekine, and Akifumi Kasamatsu
https://thorproject.eu/wp-content/uploads/2021/11/Measurement-of-Far-Field-Radiation-Pattern-of-300GHz-band-Cassegrain-Antenna.pdf
https://doi.org/10.23919/ISAP47258.2021.9614528

Automatic Deployment Planning of 300-GHz-Band Wireless Fronthaul Link in Metropolitan Areas
Ryo Okumura, Akihiko Hirata
http://10.23919/ISAP47258.2021.9614556

URSI GASS 2021
XXXIVth General Assembly and Scientific Symposium of the International Union of Radio Science
28-Aug to 04-Sep-2021; online

Automatic Planning of NLOS Backhaul Links at 300 GHz arranged in Star Topology
Thomas Kürner; Bo Kum Jung
https://doi.org/10.23919/URSIGASS51995.2021.9560305
https://nbn-resolving.org/urn:nbn:de:gbv:084-2021120912441

Electrooptic technique to investigate the scattering phenomena in millimeter-wave band
Shintaro Hisatake
https://doi.org/10.23919/URSIGASS51995.2021.9560516
https://www.ursi.org/proceedings/procGA21/papers/URSIGASS2021-Tu-FIP-DA1-7.pdf

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EuCAP 2021
European Conference on Antennas and Propagation 2021
22-26-Mar-2021; online

ThoR EU Coordinator Prof. Thomas Kürner was General Chair of this important conference, which included a joint ThoR/METERACOM workshop with four ThoR papers.

Workshop SW03 Antennas and propagation aspects for THz communications
Chair Prof. Thomas Kürner (TUBS)

Introduction to H202 EU-Japan ThoR
T. Kawanishi

Automatic Planning Algorithm of 300 GHz Backhaul Links Using Ring Topology
Bo Kum Jung and Thomas Kürner
https://doi.org/10.23919/EuCAP51087.2021.9411010

Near-field Measurement and Far-field Characterization of a J-band Antenna in ThoR project
Shintaro Hisatake, Yusuke Tanaka, Cybelle Belem, Cyril Luxey, Frederic Gianesello, Guillaume Ducournau, Akihiko Hirata
https://doi.org/10.23919/EuCAP48036.2020.9135318

300 GHz transmission of E/V bands data-flows in the ThoR project
G. Ducournau, P. Szriftgiser, S. Hisatake, I. Kallfass, D. Wrana, L. John, R.P. Braun, Y. Leiba, K. Kondou, S. Sasaki, T. Kawanishi
https://hal.archives-ouvertes.fr/hal-03219144

IEICE General Conference 2021
09-12 Mar-2021; online

A perspective on radio-over-fiber and THz communications
Tetsuya Kawanishi
http://hdl.handle.net/2065/00074811

ISAP 2020
2020 International Symposium on Antennas and Propagation
25-28 Jan-2021; Osaka, Japan

Special Session: 3G4: OS: MW Wave and Tera Hertz Propagation
Chair: Prof. Akihiko Hirata (CIT)
This session consisted of five ThoR papers, and it is testament to the quality of the ThoR research that three of the papers were nominated for ISAP 2020 Best Paper Award, and Prof. Ducournau won the Award!

Link-Level and System-Level Simulation of 300 GHz wireless Backhaul Links
Bo Kum Jung, Christoph Herold, Johannes M. Eckhardt and Thomas Kürner
https://doi.org/10.23919/ISAP47053.2021.9391508
Nominated for best paper ISAP 2020!!

300 GHz link enabled by Yagi-Uda antenna
Guillaume Ducournau
https://doi.org/10.23919/ISAP47053.2021.9391489
https://thorproject.eu/wp-content/uploads/2021/11/Complex-Permittivity-Evaluation-of-Building-Materials-at-200-500-GHz-Using-THz-TDS.pdf
Winner of best paper ISAP 2020!!

Measurement of Glass Complex Permittivity at 200-500 GHz for THz Propagation Simulation
Akihiko Hirata; Koji Suizu; Norihiko Sekine; Issei Watanabe; Akifumi Kasamatsu
https://doi.org/10.23919/ISAP47053.2021.9391155
Nominated for best paper ISAP 2020!!

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THz links for future mobile systems
Tetsuya Kawanishi
https://doi.org/10.23919/ISAP47053.2021.9391239

Electrooptic sensing for antenna characterization and propagation investigation at THz band
Shintaro Hisatake
https://doi.org/10.23919/ISAP47053.2021.9391457

Other ThoR papers at ISAP 2020

Millimeter-wave and THz links under severe weather condition
Tetsuya Kawanishi
https://doi.org/10.23919/ISAP47053.2021.9391156
http://hdl.handle.net/2065/00074928

Complex Permittivity Evaluation of Building Materials at 200-500 GHz Using THz TDS
Masaaki Urahashi and Akihiko Hirata
https://doi.org/10.23919/ISAP47053.2021.9391390

Automatic Planning of 300-GHz-Band Wireless Fronthaul Link in Metropolitan Areas
https://thorproject.eu/wp-content/uploads/2021/11/Automatic-Deployment-Planning-of-300-GHz-Band.pdf
Ryo Okumura, Akihiko Hirata
https://doi.org/10.23919/ISAP47053.2021.9391385

ICOPS 2020
IEEE International Conference on Plasma Science
06-10 Dec-2020; online

THz Seamless Networks for Future Mobile Services
Tetsuya Kawanishi
https://doi.org/10.1109/ICOPS37625.2020.9717661
http://hdl.handle.net/2065/00088713

URSI GASS 2020
General Assembly and Scientific Symposium (GASS) of the Union Radio Scientifique Internationale (URSI)
Event cancelled but proceedings issued

Towards Propagation and Channel Models for the Simulation and Planning of 300 GHz Backhaul/Fronthaul Link
Kürner, Thomas; Hirata, Akihiko; Jung, Bo Kum; Sasaki, Eisaku; Jurcik, Petr; Kawanishi, Tetsuya
https://doi.org/10.24355/dbbs.084-202008031411-0

Near-field measurement and far-field characterization of a high-gain Cassegrain antenna at 300 GHz band base on a photonics technology
Yusuke Tanaka; Hana Arisesa; Atsushi Kanno; Norihiko Sekine; Junichi Nakajima; Shintaro Hisatake
https://doi.org/10.23919/URSIGASS49373.2020.9232141

IWMTS 2020
Third International Workshop on Mobile Terahertz Systems
02-03 Jul-2020; online

On the Impact of the Results of WRC 2019 on THz Communications
Kürner, Thomas; Hirata, Akihiko
https://doi.org/10.24355/dbbs.084-202008031403-0

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Period 2 (M13-M24; Jul-2019 to Jun-2020)

EUCAP 2020
14th European Conference on Antennas and Propagation
15-20 Mar-2020; Online event

Near-field measurement and far-field characterization of a J-band antenna based on an electrooptic sensing
Shintaro Hisatake, Yusuke Tanaka, Guillaume Ducournau, Akihiko Hirata
https://doi.org/10.23919/EuCAP48036.2020.9135318

GeMiC 2020
German Microwave Conference 2020
09-11 Mar-2020; Cottbus-Senftenberg, Germany

Considerations for Through-Substrate-Via Placement in InGaAs mHEMT THz Circuits Using Thin-Film Wiring
Laurenz John; Philipp Neininger; Axel Tessmann; Arnulf Leuther; Thomas Zwick
https://ieeexplore.ieee.org/document/9080211

Globecom 2019
IEEE Global Communications Conference 2019
09-13 Dec-2019; Waikoloa, Hawaii, USA

Terahertz and photonics seamless networks
Tetsuya Kawanishi
https://doi.org/10.1109/GCWkshps45667.2019.9024641

WPMC 2019
22nd International Symposium on Wireless Personal Multimedia Communications
24-27 Nov-2019; Lisbon, Portugal

THz Communications – A Candidate for a 6G Radio? [Invited]
Thomas Kürner
https://doi.org/10.24355/dbbs.084-202008031406-0

PEM 2019
3rd International Workshop on Photonics applied to Electromagnetic Measurement
18-19 Nov-2019; Ise, Mie, Japan

Evaluation of antenna radiation characteristics at terahertz frequency band based on an electrooptic near-field measurement
Yusuke Tanaka, Shintaro Hisatake

Characterisation of Terahertz Antenna for beyond 5G Systems
Akihiko Hirata, Katsumi Fujii, N. Sekine, I. Watanabe, A. Kasamatsu

Short-Focus Lens Design for Terahertz Ray
Keita Miyazawa, Atsushi Kanno, Shingo Saito, Keizo Inagaki and Tetsuya Kawanishi

ISAP 2019
International Symposium on Antennas and Propagation
27-30 Oct-2019; Xi'an, China

Measurement of Reflection and Transmission Characteristics of Glasses at 300 GHz
A. Hirata, N. Sekine, I. Watanabe, A. Kasamatsu
INSPEC Accession Number: 19284366

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EuMW 2019
European Microwave Week 2019
29-Sep to 04-Oct-2019; Paris, France

A Superheterodyne >300 GHz Wireless Link for Ultra-Fast Terahertz Communication System
Iulia Dan, Guillaume Ducournau, Shintaro Hisatake, Pascal Szriftgiser, Ralf-Peter Braun, Ingmar Kallfass
https://doi.org/10.23919/EuMC.2019.8910935

IRmmW-THz 2019
44th International Conference on Infrared, Millimeter, and Terahertz Waves
01-06 Sep-2019; Paris, France

Simulation and Automatic Planning of 300 GHz Backhaul Links [Keynote]
Bo Kum Jung, Nils Dreyer, Johannes M. Eckhardt and Thomas Kürner
https://doi.org/10.24355/dbbs.084-201908211532-0
https://publikationsserver.tu-braunschweig.de/receive/dbbs_mods_00066857

Towards super-heterodyne THz links pumped by photonic local oscillators
Iulia Dan; Shintaro Hisatake; Pascal Szriftgiser; Ralf-Peter Braun; Ingmar Kallfass; Guillaume Ducournau
https://doi.org/10.1109/IRMMW-THz.2019.8873762

Period 1 (M1-M12; Jul-2018 to Jun-2019)

EUCNC 2019
European Conference on Networks and Communications
18-21 Jun-2019; Valencia, Spain

ICT Beyond 5G Cluster: Seven H2020 for Future 5G
Paoloni, Claudio; Alexiou, Angeliki; Bouchet, Oliver; Davy, Alan; Ermolov, Vladimir; Kürner, Thomas; Napier, Bruce; Sahin, Onur
https://doi.org/10.24355/dbbs.084-201908211514-0
https://publikationsserver.tu-braunschweig.de/receive/dbbs_mods_00066854

Regulatory Aspects of THz Communications and Related Activities Towards WRC 2019
Thomas Kuerner
https://doi.org/10.24355/dbbs.084-201908211524-0
https://publikationsserver.tu-braunschweig.de/receive/dbbs_mods_00066855

IMS 2019
International Microwave Symposium
02-07 Jun-2019; Boston, USA

300 GHz broadband power amplifier with 508 GHz gain-bandwidth product and 8 dBm output power
Benjamin Schoch, Axel Tessmann, Arnulf Leuther, Sandrine Wagner, Ingmar Kallfass
https://doi.org/10.1109/MWSYM.2019.8700754
https://www.ilh.uni-stuttgart.de/institut/team/Schoch-00003/

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IRmmW-THz 2018
43rd International Conference on Infrared, mm-wave and THz waves
09-14 Sep-2018; Nagoya, Japan

Compact Antennas Pattern Measurement Setup at 240 GHz
C. Belem Goncalves ; E. Lacombe ; Carlos del Rio ; F. Gianesello ; C. Luxey ; G. Ducournau
http://doi.org/10.1109/IRMMW-THz.2018.8509996

Considerations on Local Oscillator Isolation in a Terahertz Wireless Link Used for Future Communication Systems
Iulia Dan; Christopher M. Grotsch; Shoichi Shiba; Ingmar Kallfass
http://doi.org/10.1109/IRMMW-THz.2018.8510497

[Keynote] Turning THz Communications into Reality: Status on Technology, Standardization and Regulation
Thomas Kuerner
http://doi.org/10.1109/IRMMW-THz.2018.8510153

3.2.5. Trade shows and exhibitions

ThoR has participated in several trade shows and exhibitions, including:

Period 3

- EuMW 2020
  - 10-15 Jan-2021 (planned for Utrecht, The Netherlands but forced online due to COVID-19 restrictions)
  - European Microwave Week Exhibition
  - Joint online booth with TERAPOD to represent B5G Cluster (see §3.5)

- EuCAP 2021
  - 22-26 Mar-2021 (planned for Düsseldorf, Germany but forced online due to COVID-19 restrictions)
  - Joint booth with TERAPOD (H2020) and METERACOM (German national project)
  - Various ThoR material available
    - PDF documents
    - Videos
    - Links to webpage and open access papers
  - Live networking platform
  - Booths looked good and were well-supported by the IT provider
  - ThoR was 8th most popular booth (of 20) with ~350 visits
  - NB There was also a joint workshop with TERAPOD and METERACOM at this event (details in §3.2.4).

Period 2

- ThoR Workshop exhibition (see D7.6 and §3.2.2)
  - FRI 20-Sep-2019; Waseda University
  - The first ThoR workshop included a small 12 booth exhibition

- IRmmW-THz 2019 conference and exhibition
  - 44th International Conference on Infrared, Millimeter, and Terahertz Waves
  - 02-Sep-2019; Paris, France
  - Booth 31 (PSL-University of Paris) showed ThoR merchandise

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    - Guillaume Ducournau (Lille)
- B5G Cluster booth at EUCNC 2019: see §3.5.

Two further exhibitions were planned in Period 2, but had to be cancelled due to COVID-19:

- NGMN Industry Conference & Exhibition 2020
    - 08-10 Sep-2020; Paris, France
    - This event was postponed from Mar-2020 to Sep-2020 and finally cancelled due to COVID-19 concerns.
- European Conference on Networks and Communications (EUCNC 2020)
    - 15-18 Jun-2020 (online)
    - This event was due to be held in Dubrovnik, Croatia, and ThoR was to participate in a B5G Cluster booth at the exhibition
    - Unfortunately, the conference was held online and the exhibition was cancelled.

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3.2.6. Summary of main ThoR events

The schematic in Figure 4 summarises the major events during the ThoR project. The consortium is pleased to have been able to participate in so many important industrial and academic events. Unfortunately, in the period from approximately M21-36, a number of events were cancelled or restricted to online activity due to the COVID-19 precautions.

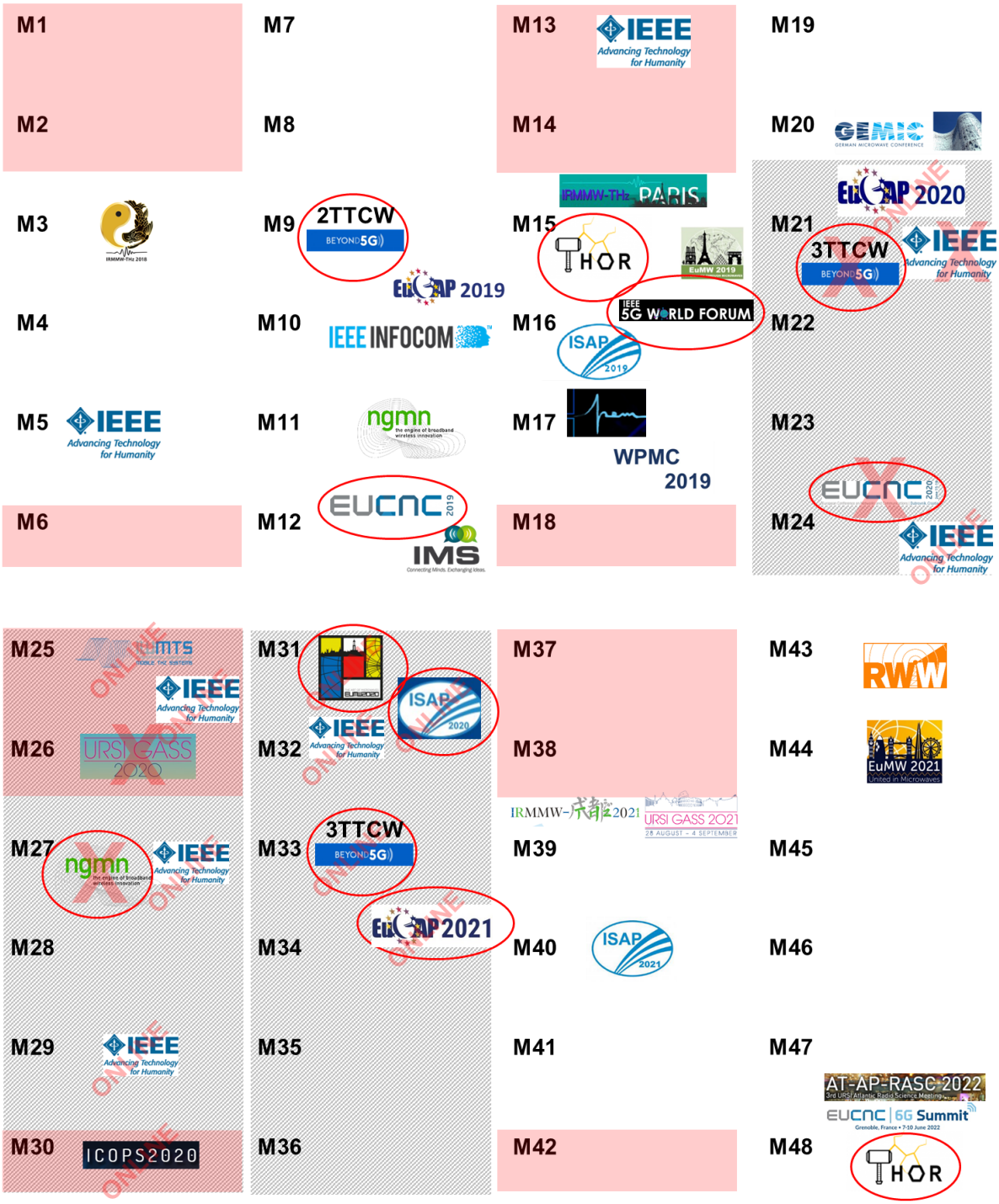

Figure 4: *Schematic showing the major ThoR events. Red rings indicate events of particular importance for the project (e.g. ThoR booths or workshops). Red shading indicates periods of traditionally limited activity in EU and Japan: Jul/Aug (summer holidays) and Dec (Christmas). Grey shading shows the period of COVID-19 lockdown restrictions, when many events were cancelled or forced online.*

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3.2.7. Other events

ThoR researchers have presented on the project at (at least) 38 other conferences, meetings and workshops including 15 in Period 3. These are listed below in chronological order:

Period 3

- IEEE 802.15 meeting (online)
  - 15-Jul-2020; online
  - Thomas Kürner (TUBS) chair
- Invited technical report to IEICE meeting
  - 20-Jul-2020; online
  - *Optical fiber transmission for future seamless networks*
  - Available from WUT repository: http://hdl.handle.net/2065/00074812
- Invited technical report to IEICE
  - 25-Aug-2020; online
  - *Transmission distance extension and interference mitigation in THz high-speed communication systems* SRW2020-22
  - Available from WUT repository: http://hdl.handle.net/2065/00074813
- ETTCOM 2020
  - W02: Workshop on Enabling Technologies for Terahertz Communications
  - 31-Aug-2020; online
  - Part of IEEE International Symposium on Personal, Indoor and Mobile Radio Communications
  - *THz fixed links for high-speed access*
    - Tetsuya Kawanishi presentation (WUT)
- IEEE 802.15 meeting (online)
  - 17-Sep-2020; online
  - Thomas Kürner (TUBS) chair
- WORTECS final workshop
  - 15-Oct-2020 (online)
  - ThoR posters included in poster session
- Invited technical report to IEICE
  - 22-Oct-2020; online
  - *Transmission distance extension in THz radio systems for mobile networks* RCS2020-101
  - Available from WUT repository: http://hdl.handle.net/2065/00074814
- Asia Communications and Photonics Conference (ACP) 2020
  - 25-Oct-2020; Beijing, China
  - *Photonics in 5G and beyond [Invited]*
    - Tetsuya Kawanishi presentation (WUT)
- IEEE 802.15 meeting (online)
  - 10-Nov-2020; online
  - Thomas Kürner (TUBS) chair
  - *Link-Level and System-Level Simulation of 300 GHz Wireless Backhaul Links (21/046)*
    - Bo Kum Jung presentation (TUBS)
- 41st AGM Laser Society Japan
  - 18-Jan-2021; online
  - *Optoelectronics for millimeter-wave and THz-wave communications*
    - Tetsuya Kawanishi presentation (WUT)
- APT Wireless Group AWG-27
  - 22-30 Mar-2021; Japan
  - NEC attended and represented ThoR

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- ICEP 2021 (12-14 May-2021)
  - 2021 IEEE International Conference on Electronics Packaging
  - Prof. Tetsuya Kawanishi (WUT) invited paper (#FC1)
    - *High-Speed, Wireless & Components: Wired and wireless seamless networks for beyond 5G*
- IWMTS 2021 (07-Jul-2021; online)
  - IEEE International Workshop on Mobile Terahertz Systems
  - Thomas Kürner (TUBS) presentation (Session 5 – THz Research in Europe)
  - *THz end-to-end wireless systems supporting ultra high data Rate applications (ThoR)*
- IEEE 802.15 meeting (online)
  - 20-Jul-2021
  - Thomas Kürner (TUBS) chair
  - *Extension of Interframe space for supporting long distance transmission*
    - Keitarou Kondou (HRCP) presentation
  - *Next steps for IEEE 802.15.3*
    - Thomas Kürner (TUBS) presentation
- URSI AT-AP-RASC 2022 (Gran Canaria, Spain; 29-May to 03-Jun-2022)
  - URSI combined Atlantic / Asia-Pacific Radio Science Conference 2022
  - Prof. Kawanishi (WUT) and Prof. Kürner (TUBS) were hosts for session D07: Electronic and photonic components for THz Communications

Period 2

- Asian Wireless Group (AWG) meeting
  - 01-Jul-2019; Tangerang, Indonesia
  - Liaison from ITU-R antenna measurements
  - Tetsuya Kawanishi (WUT)
- IEEE 802.15 THZ IG
  - 16-Jul-2019; Vienna, Austria
  - *Simulation and Automatic Planning of 300 GHz Backhaul Links -First Results from H2020-ThoR*
  - Bo Kum Yung (TUBS)
- OSA Advanced Photonics Congress
  - Symposium: A Light in Digital Darkness: Optical Wireless Communications to Connect the Unconnected
  - 30-Jul-2019; San Francisco, USA
  - *THz and Photonic Seamless Networks for Easy-deployable High-speed Access*
  - Tetsuya Kawanishi (WUT)
- Terahertz Systems Application Symposium (IEICE)
  - 06-Aug-2019; Osaka, Japan
  - *Photonics for millimeter/THz-wave networks*
  - Tetsuya Kawanishi (WUT)
- 44th International Conference on Infrared, Millimetre and Terahertz Waves (IRmmW-THz 2019)
  - 01-06 Sep-2019; Paris, France
  - Conference and exhibition
  - In addition to two ThoR papers (see §3.2.4), ULILLE represented ThoR at booth 31 (PSL-University of Paris) and showed ThoR merchandise
- International Conference on Radar, Antenna, Materials, Electronics and Telecoms (ICRAMET 2019)
  - *23-24 Oct-2019; Tangerang, Indonesia*
  - *Near-field visualization of millimeter-wave and THz wave based on photonics: principle and applications [Invited]*

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    - Shintaro Hisatake (Gifu)
- IET Antennas and Propagation Conference
    - 18-Nov-2019 (Birmingham, UK)
    - Invited Keynote
    - *THz Communications – A Candidate for a 6G Radio?*
    - Thomas Kürner (TUBS)
- Workshop WS-13 THz Communications
    - 09-Dec-2019; Puako, Hawaii, USA
    - Part of Globecom 2019
    - *Terahertz and photonics seamless networks 1570573789*
    - Tetsuya Kawanishi (WUT)
- IEEE 802.15 meeting (online)
    - 07-Jun-2020; online
    - Presentation on ThoR results
    - *Results of WRC 2019 AI 1.15 and its Impact on THz Communications*
    - Thomas Kürner (TUBS)
- Wireless World Research Forum Meeting 44 (WWRF44)
    - 29-Jun-2020; online
    - Presentation on ThoR results
    - *Towards THz Backhaul/Fronthaul Links –Approach and first Results from the ThoR Project*
    - Thomas Kürner (TUBS)

Period 1

- Invited lecture on ThoR
    - 12-Oct-2018; Aalto University, Espoo, Finland
    - Thomas Kürner (TUBS)
- Internal THz workshop
    - 13-Oct-2018; University of Lille
- Tutorial at IEEE 802.15 meeting
    - 12-Nov-2018; Bangkok, Thailand
    - *THz Communications: An overview and options for IEEE 802 standardisation*
    - Thomas Kürner (TUBS)
- Presentation at IEEE 802.15 THz Interest Group
    - 14-Nov-2018; Bangkok, Thailand
    - *Introduction to the H2020 EU-Japan project ThoR*
    - Thomas Kuerner (TUBS) & Tetsuya Kawanishi (WUT)
- 8th EU-Japan Digital Strategies workshop
    - 04-Dec-2018; Vienna, Austria
    - Presentation on ThoR
    - Thomas Kürner (TUBS)
- IEEE 802.15 THZ IG
    - 11-Mar-2019; Vancouver, Canada
    - *ThoR: Initial Results on Sharing Studies*
    - Thomas Kürner (TUBS)
- Meeting of German National Preparatory Group for WRC 19
    - 13-Mar-2019; Mainz, Germany
    - Presentation of initial results on sharing studies
    - Sebastian Rey (TUBS)
- Terahertz System Application Promotion Council Meeting
    - 25-Mar-2019; online

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- H2020 ThoR Initial results on sharing studies
- Thomas Kürner (TUBS)

- INFOCOM THz Workshop
  - 29-Apr-2019; Paris, France
  - Keynote address including ThoR
  - Thomas Kürner (TUBS)
- Next Generation Mobile Networks (NGMN) Forum
  - 14-May-2019; Berlin, Germany
  - Presentation on ThoR
  - Thomas Kürner (TUBS)
- 42nd Meeting of the Wireless World Research Forum
  - 16-May-2019; Tokyo, Japan
  - Presentation on ThoR
  - Tetsuya Kawanishi (WUT)
- Compound Semiconductor Week 2019
  - 19-May-2019; Nara, Japan
  - *THz Frequency HEMTs: Future Trends and Applications [WeE2-1 Invited]*
  - Arnulf Leuther (IAF)
- Wireless Technology Park 2019 (exhibition)
  - 29-May-2019; Tokyo, Japan
  - Presentation on ThoR (in Japanese)
  - Tetsuya Kawanishi (WUT)

3.2.8. Other communication activity

Books

- *Wired and Wireless Seamless Access System for Public Infrastructure (2020)*
  - Tetsuya Kawanishi
  - Publisher: Artech House
  - Pages: 330
  - ISBN: 9781630817404
- *THz Communications: Paving the Way Towards Wireless Tbps (2022)*
  - Editors: Thomas Kürner, Daniel M. Mittleman, Tadao Nagatsuma
  - https://doi.org/10.1007/978-3-030-73738-2
  - Publisher: Springer Cham
  - Pages: 531
  - Hardcover ISBN: 978-3-030-73737-5
  - eBook ISBN: 978-3-030-73738-2
- *Handbook of Radio and Optical Networks Convergence [In press]*
  - Editors: Tetsuya Kawanishi *et al.*
  - Online Springer handbook
  - Several chapters from ThoR partners
  - Scheduled completion Q4 2022

Best paper awards

- Best paper of 2020 award from the International Journal of Microwave and Wireless Technologies
  - *A superheterodyne 300 GHz wireless link for ultra-fast terahertz communication systems* by Iulia Da *et al.* (see §3.3 for details)
  - https://www.eumwa.org/en/publications/international-journal/b.html
- Best paper of 2022 award from the IEEE Transactions on Terahertz Science and Technology.

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    - *Broadband 300-GHz Power Amplifier MMICs in InGaAs mHEMT Technology* by Laurenz John *et al.* (see §3.3 for details)
    - https://mtt.org/2022-ieee-mtts-awards/
- Three ThoR best paper nominations at 2020 International Symposium on Antennas and Propagation (ISAP 2020) (see §3.2.4 for details)
    - *300 GHz link enabled by Yagi-Uda antenna* by Guillaume Ducournau
        - Best paper award
    - *Link-Level and System-Level Simulation of 300 GHz wireless Backhaul Links* by Bo Kum Jung *et al.*
        - Nominated for best paper award
    - *Measurement of Glass Complex Permittivity at 200-500 GHz for THz Propagation Simulation* by Akihiko Hirata *et al.*
        - Nominated for best paper award
    - https://www.ieice.org/cs/isap/2020/files2/BPA_SPA_Award_ceremony.pdf

Other

- Press release (29-Jun-2022)
    - Issued simultaneously in EU in both English and German (by TUBS) & Japan (by WUT)
    - Well covered by many outlets
    - See D7.9 and the links from the ThoR website:
        - https://thorproject.eu/thor-closing-press-release
- IEEE Future Networks Tech Focus **3**, Issue 3 (Nov-2019)
    - Article: *Seamless Networks for Beyond 5G*
    - Tetsuya Kawanishi
- Press release (29-Oct-2018)
    - Issued simultaneously in EU (by TUBS) & Japan (by WUT)
    - Well covered by many outlets
- Article in Nikkei (Japanese national newspaper) (25-Mar-2019)
    - Collaboration of Japan and Europe for Post-5G
    - [In Japanese]
- TV Tokyo reported on the Nikkei article (25-Mar-2019)
- Asia Nikkei version (28-Mar-2019)
    - Japan-Europe project to challenge China for post-5G supremacy
    - [In English].

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3.3. Journal publications

Twelve journal papers published were published on the ThoR results during the project, including two prize winners.

Automatic Planning Algorithms for 300 GHz Wireless Backhaul Links
B. K. Jung and T. Kürner
IEICE Transactions on Communications **E105.B** 685-693 (2022).
https://doi.org/10.1587/transcom.2021ISI0002 [Gold link]

Sensitivity Analysis of a 280-312 GHz Superheterodyne Terahertz Link Targeting IEEE802.15.3d Applications
Dominik Wrana; Laurenz John; Benjamin Schoch; Sandrine Wagner; Ingmar Kallfass
IEEE Transactions on Terahertz Science and Technology **12**, 325-333 (2022).
https://doi.org/10.1109/TTHZ.2022.3172008
Green link: https://opencms.uni-stuttgart.de/fak5/ilh/dokumente/PrePrint_Sensitivity-Analysis-of-a-280---312-GHz-Superheterodyne-Terahertz-Link-Targeting-IEEE802_15_3.pdf

Modular Link Level Simulator for the Physical Layer of Beyond 5G Wireless Communication Systems
Christoph Herold, Bo Kum Jung, Nils Dreyer and Thomas Kürner
Radio Science **57**, e2021RS007395 (2022).
https://doi.org/10.1029/2021RS007395 [Gold link]

Short-Range Wireless Transmission in the 300 GHz Band Using Low-Profile Wavelength-Scaled Dielectric Cuboid Antennas
Kazuki Yamada, Yuto Samura, Oleg V. Minin, Atsushi Kanno, Norihiko Sekine, Junichi Nakajima, Igor V. Minin and Shintaro Hisatake
Frontiers in Communications and Networks **2** (2021).
https://doi.org/10.3389/frcmn.2021.702968 [Gold link]

Performance Analysis of 300 GHz Backhaul Links Using Historic Weather Data
Thomas Kuerner and Bo Kum Yung
Advances in Radio Science **19**, 153–163 (2021).
https://doi.org/10.5194/ars-19-153-2021 [Gold link]

Photonics-Based Near-Field Measurement and Far-Field Characterization for 300-GHz Band Antenna Testing
Yusuke Tanaka, Guillaume Ducournau, Cybelle Belem-Goncalves, Frederic Gianesello, Cyril Luxey, Issei Watanabe, Akihiko Hirata, Norihiko Sekine, Akifumi Kasamatsu, and Shintaro Hisatake
IEEE Open Journal of Antennas and Propagation **3**, 24-31 (2021).
https://doi.org/10.1109/OJAP.2021.3133470 [Gold link]

Millimeter-Wave and Terahertz Fixed Wireless Link Budget Evaluation for Extreme Weather Conditions
Zu-Kai Weng; Atsushi Kanno; Pham Tien Dat; Keizo Inagaki; Kosuke Tanabe; Eisaku Sasaki; Thomas Kürner; Bo Kum Jung; Tetsuya Kawanishi
IEEE Access **9**, p. 63476-163491 (2021).
https://doi.org/10.1109/ACCESS.2021.3132097 [Gold link]

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Terahertz and Photonics Seamless Short-Distance Links for Future Mobile Networks [Invited]
T. Kawanishi, K. Inagaki, A. Kanno, N. Yamamoto, T. Aiba, H. Yasuda, T. Wakabayashi
Radio Science **56**, p. e2020RS007156 (2021).
https://doi.org/10.1029/2020RS007156
Green link: http://hdl.handle.net/2065/00082456

A superheterodyne 300 GHz wireless link for ultra-fast terahertz communication systems
Dan, I., Ducournau, G., Hisatake, S., Szriftgiser, P., Braun, R., & Kallfass, I.
International Journal of Microwave and Wireless Technologies **12**, 578-587 (2020). https://doi.org//10.1017/S1759078720000495 [Gold link]
Winner of IJMWT Best Paper Award 2020!

Broadband 300-GHz Power Amplifier MMICs in InGaAs mHEMT Technology
L. John, A. Tessmann, A. Leuther, P. Neininger, T. Merkle and T. Zwick
IEEE Transactions on Terahertz Science and Technology, **10**, p. 309-320 (2020).
https://doi.org/10.1109/TTHZ.2020.2965808 [Gold link]
Winner of T-TST Best Paper Award 2022!

A Terahertz Wireless Communication Link Using a Superheterodyne Approach
Iulia Dan ; Guillaume Ducournau ; Shintaro Hisatake ; Pascal Szriftgiser ; Ralf-Peter Braun ; Ingmar Kallfass
IEEE Transactions on Terahertz Science and Technology **10**, p. 32-43 (2020).
https://doi.org/10.1109/TTHZ.2019.2953647
Green link: https://www.ilh.uni-stuttgart.de/dokumente/A-Terahertz-Wireless-Communication-Link-Using-a-Superheterodyne-Approach_Iulia-Dan.pdf

IRACON propagation measurements and channel models for 5G and beyond
Sana Salous, Fredrik Tufvesson, Kenan Turbic, Luis M. Correia, Thomas Kürner, Diego Dupleich, Christian Schneider, Daniel Czaniera, Belen Montenegro Villacieros
ICT Discoveries **2**, Special Issue 1 (2019).
http://handle.itu.int/11.1002/pub/814397b3-en [Gold link]

3.4. Other ThoR dissemination activity

3.4.1. Newsletters

Six ThoR newsletters have been released and are available to download from the project website: https://thorproject.eu/results/newsletters/

Figure 5: *Examples of ThoR newsletter front pages.*

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Further info is given in D7.10 (Summary of newsletters). The main topics are as follows:

- **ThoR Newsletter #6 (May-2022)**
- Flexible waveguide for millimetre and THz systems
- Deutsche Telekom comments on future implementations of ThoR
- Development of E-band modems in ThoR by Siklu
- Travelling wave tube amplifier advances at NEC and Waseda
- Near-field measurement for antenna testing at Gifu University
- Superheterodyne H-band frontend from University of Stuttgart
- 300 GHz mHEMT high power amplifiers from Fraunhofer IAF
- System-level testing of the ThoR frontends by University of Lille
- Update on the ThoR final workshop and demonstration.

- **ThoR Newsletter #5 (Mar-2021)**
- 3TTCW and EuCAP 2021
- Automatic planning algorithms for THz comms by TU Braunschweig
- 300 GHz link design and interference study by Waseda University
- Three upcoming books or journals on THz comms
- 300 GHz sold state power amplifier development at Fraunhofer IAF
- Characterisation of ThoR demo modules by University of Stuttgart.

- **ThoR Newsletter #4 (Aug-2020)**
- New date for the 3rd Towards THz Comms Workshop (3TTCW)
- Photonic LO progress at University of Lille
- Modem bank parallelisation in ThoR by Siklu
- Implications of WRC 19 AI 1.15 for THz comms (TUBS/CIT).

- **ThoR newsletter #3 Dec-2019**
- ThoR workshop in Japan (20-Sep-2019; University of Waseda)
- Save the date! 3rd Towards THz Comms Workshop 12-13 Mar-2020 at IMEC
- Overview of 5G/beyond 5G requirements wireless transport links from Deutsche Telekom
- Review of the ThoR parallelisation of 70/80 GHz transceiver modules from Siklu
- An update on measurement of 300 GHz band high-gain antennas at CIT.

- **ThoR newsletter #2 Jun-2019**
- Near-field measurements and antenna characterisation at 300 GHz by Gifu University
- 300 GHz front end development by Fraunhofer IAF and Univ. Stuttgart
- ThoR DEMO-1 and circuit design by the project team
- Development of a high power TWTA at 300 GHz band by NEC.

- **ThoR newsletter #1 Dec-2018**
- A brief overview of the project and its objectives
- An outline of the ICT-09-2017 Cluster of related projects
- Information on an EC THz communications workshop on 07-Mar-2019
- Results from spectrum sharing studies relevant to WRC 2019
- World first experimental demonstration of a superheterodyne 300 GHz wireless link!

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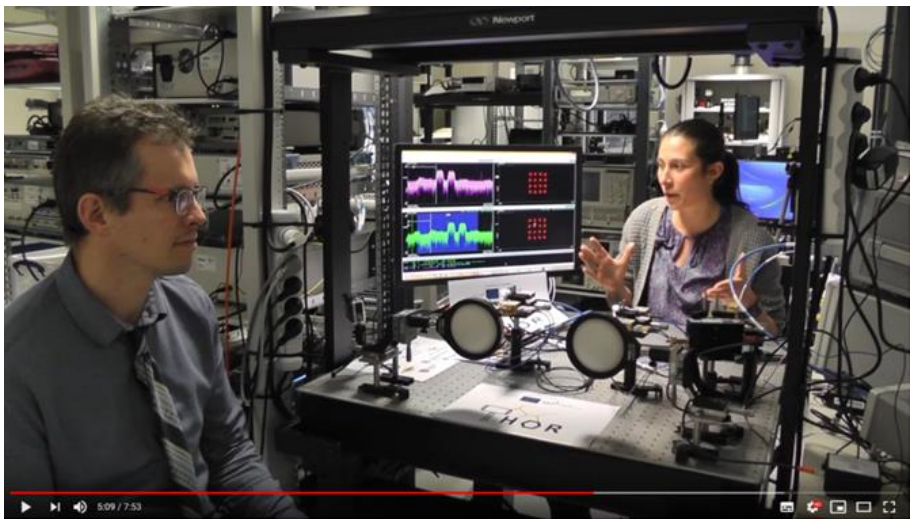
3.4.2. ThoR videos

The first video (*c.* 8 min) of the ThoR DEMO-1 was recorded on 28-Nov-2018 at University of Lille/ IEMN CNRS (France). The experimental work was performed by University of Lille, University of Stuttgart, Gifu University and Deutsche Telekom. The video was recorded and edited by Vivid and has been approved for release by the ThoR consortium. This represents the first ever superheterodyne wireless link at 300 GHz and demonstrates the proof-of-principle for the project.



The journal publication was in progress at the time of writing (see §3.3), so no details were provided, but the video gives an overview of the laboratory set-up, and was put on the project website on 21-Dec-2018: https://thorproject.eu/results

The video is also available directly from YouTube: https://www.youtube.com/watch?v=U1zatU6Gfbk

On 02-Mar-2020 a second video was put on the website, which consists of a series of short pieces to camera by several of the ThoR experts. The interviews explain the background to the project, an overview of the ThoR approach and how it offers a new route forward for THz communications.

This video (~8 min) was put online and is also available directly from YouTube.

https://youtu.be/T-VvUow_W18

As mentioned in §3.2.1, videos of the hardware and simulation demos from the final workshop (29-30 Jun-2022) are also available in the public domain:

https://www.youtube.com/watch?v=vEBfRHZGSyc Hardware demo

https://www.youtube.com/watch?v=2c07gXJLvgI Simulation demo

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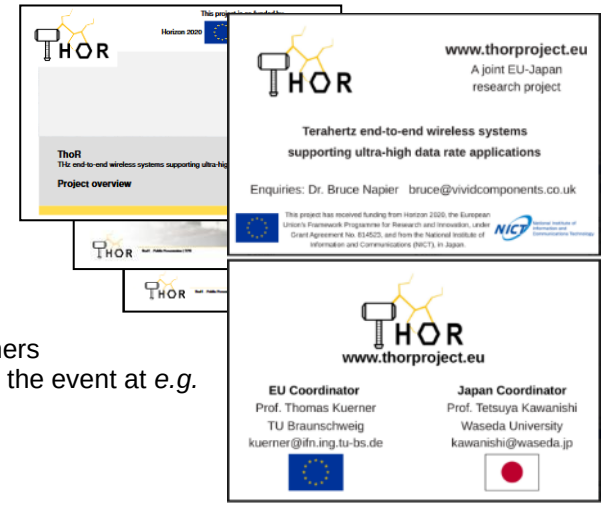
3.4.3. Dissemination material

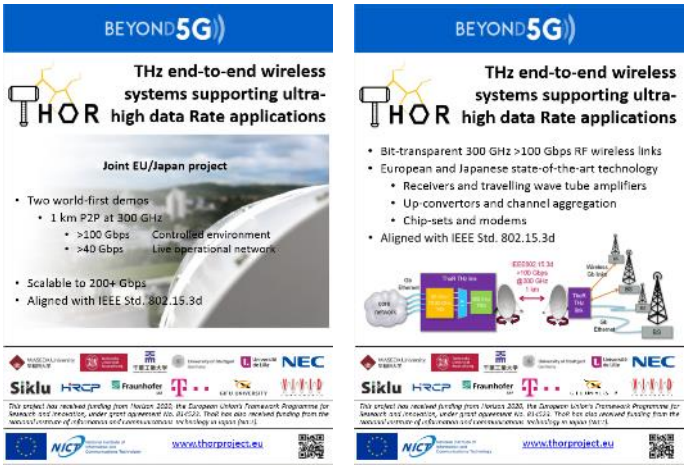
- Business cards
  - Business cards were produced with the project contact info
  - These are very useful for passing on info to contacts at *e.g.* exhibitions, conferences *etc.*
- Save the date cards (EC THz Communications Workshop (07-Mar-2019)
  - These were sent to all B5G Cluster project Coordinators and all ThoR partners
  - These proved very useful for promoting the event at *e.g.* EuMW 2018 *etc.*



- Merchandise
  - Coasters (*i.e.* drinks mats) and post-it notes
  - For promotion at exhibitions, *e.g.* EUCNC 2019.

Figure 6: *ThoR promotional coasters and post-it notes*

- Posters and pop-ups
  - Poster version with common format and Beyond 5G logo produced and used
  - E.*g.* at EUCNC 2019 (Valencia, Jun-2019)



- Project presentation
  - Available online
  - First version issued 15-Nov-2018
    - Used as basic structure for many ThoR external presentations (see §3.2.7)
    - Several updates during the project.

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3.5. Beyond 5G Cluster

The ICT-09-2017 Cluster was initiated by the TERAPOD project (by Bruce Napier; Vivid Components) to gather the resources of the six projects funded in the H2020 call ICT-09-2017 “Networking research beyond 5G.” Following discussions within the group, the ThoR project was invited to join the Cluster in Q3 2018. The Cluster agreed on a more succinct name, the Beyond 5G Cluster, and a common logo which was used to improve the visibility of the group in the various dissemination activities. In 2019 the Car2TERA H2020 project joined the Cluster. Thus, the final B5G Cluster membership is as follows:

Car2TERA	*Terahertz sensors and networks for next generation smart automotive electronic systems*	
DREAM	*D-band Radio solution Enabling up to 100 Gbps reconfigurable Approach for Meshed beyond 5G networks*	
EPIC	*Enabling Practical Wireless Tb/s Communications with Next Generation Channel Coding*	
TERAPOD	*Terahertz-based ultra-high bandwidth wireless access networks*	
TERRANOVA	*Terabit/s Wireless Connectivity by TeraHertz innovative technologies to deliver Optical Network Quality of Experience in Systems beyond 5G*	
THOR	*TeraHertz end-to-end wireless systems supporting ultra high data Rate applications*	
ULTRAWAVE	*Ultra capacity wireless layer beyond 100 GHz based on millimeter wave Traveling Wave Tubes*	
WORTECS	*Wireless Optical/Radio TErabit CommunicationS*	

B5G Cluster activities (since ThoR membership Q3 2018)

Period 3

- EuMW 2020
  - European Microwave Week Exhibition 2020
  - 12-14 Jan-2021 (planned for Utrecht, The Netherlands but forced online due to COVID-19 restrictions)
  - B5G Cluster online booth

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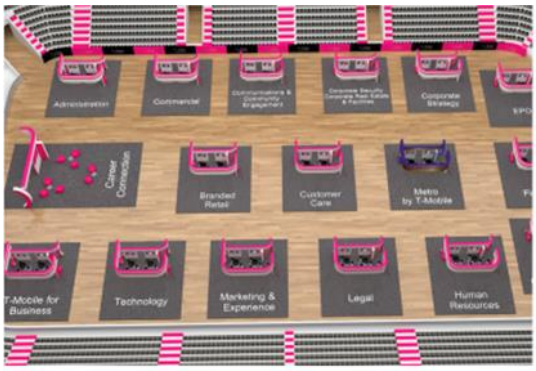

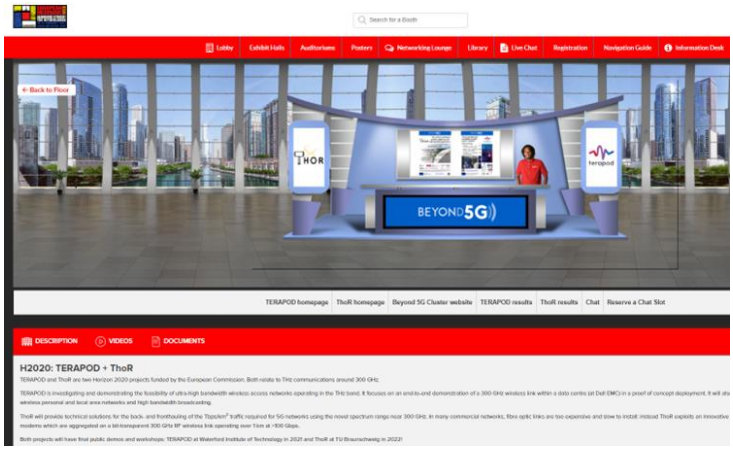

- Material presented on virtual booth
  - All existing videos etc.
  - Updated presentation
  - Other relevant material
  - Company literature
  - Academic results
  - *Etc.*

- 3TTCW (12-Mar-2021; online)
  - Third Towards Terahertz Communications Workshop
  - This event was originally planned for Mar-2020 at IMEC (Leuven), but had to be postponed due to COVID-19
  - The 2021 event was held online, and was a major success for the Cluster
  - >200 attendees attended the workshop
  - Full agenda including presentations from B5G Cluster partners
  - Guest speakers included:
    - Prof. Piet Wambacq — IMEC
    - Dr. Muhsin Ali — Universidad Carlos III de Madrid
    - Dr. Akshay Jain — Universitat Politecnica de Catalunya
    - Prof. Matti Latva-aho — University of Oulu
    - Dr. Volker Ziegler — Nokia
    - Eric Mercier — CEA-Leti
  - Panel discussion

Period 2

- EUCNC 2020 (15-18 Jun-2020)
  - A booth and workshop special session were planned but unfortunately the face-to-face event was cancelled and these two activities could not take place.

- IEEE World Forum 2019 (30-Sep-2019; Dresden, Germany)
  - The B5G Cluster organised a workshop entitled: *From Evolution to Revolution, a Roadmap for Beyond 5G*
  - The workshop included several presentations and a panel discussion session
  - Prof. Thomas Kürner (TUBS) presented on ThoR
  - Further info from a webpage produced by the ULTRAWAVE partner University of Lancaster: http://wp.lancs.ac.uk/wf5gworkshopb5g/

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- European Conference on Networks and Communications (18-21 Jun-2019; Valencia, Spain); EUCNC 2019
  - Cluster booth #60
  - This is a major EU event (750 attendees) co-financed by the EC
  - The Cluster also held a Special Session
    - Special Session #2: Advanced THz technologies towards terabit/s wireless communications
    - https://www.eucnc.eu/special-sessions/special-session-2

- Second Towards Terahertz Communications Workshop (07-Mar-2019; Brussels)
  - Held in the EC facilities at Albert Borschette Congress Centre (CCAB)
  - EC, B5G and high profile international invited speakers, including:
    - Prof. Tadao Nagatsuma; Osaka University, Japan
    - Prof. Daniel Mittleman; Brown University, USA
    - Dr. Wolfgang Templ; Nokia Bell Labs, German
  - Full agenda and public presentations available from the TERAPOD website (hosted on behalf of the Cluster
    - https://terapod-project.eu/events/ec-thz-workshop

- Cluster calls: Regular calls led by Bruce Napier (Vivid) are held to plan events and coordinate activities:
  - Period 3
    - Conference call (03-Nov-2020)
    - Conference call (30-Jun-2020)
  - Period 2
    - Conference call (03-Sep-2019)
    - Conference call (26-Nov-2019)
    - Conference call (12-Dec-2019)
    - Conference call (21-Jan-2020)
  - Period 1
    - Conference call (05-Oct-2018)
    - Conference call (25-Oct-2018)
    - Conference call (11-Jan-2019)
    - Conference call (08-Feb-2019)
    - Conference call (22-May-2019)
- Minutes were taken and circulated by Vivid
- A Cluster actions register is kept and maintained by Vivid

3.6. ThoR mailing list

A mailing list of 107 experts has been compiled and these contacts have been kept up-to-date with project progress.

NB In line with General Data Protection Regulation (GDPR), all these members have explicitly agreed that they wish to be included on the mailing list. For confidentiality reasons, the names and contact info are not provided here.

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4. ThoR exploitable results

The consortium has maintained a register of new IPR generated through the project which is described through a detailed set of tables providing information on the development and plans for exploitation. The details must remain confidential, but a list of this new IP is given below:

Result	Title
TUBS-01	Sharing Studies wrt WRC 19 AI 1.15
TUBS-02	Automatic planning and guidelines for 300 GHz backhaul/links
TUBS-03	Link-level simulator for THz backhaul/fronthaul links
DTAG-01	Operator and end-user requirements for 5G and B5G networks
DTAG-02	Scenario definition for 5G and B5G networks
IAF-01	MMIC to WR12 waveguide transition on quartz substrate
IAF-02	Broadband 300 GHz high power amplifier (>10 mW) MMIC/Module
IAF-03	Compact power amplifier cell designs
IAF-04	Broadband waveguide couplers
Siklu-01	E-band radio parallelization concept
ULIL-01	Photonic-based local oscillator
ULIL-02	Methods for system-level measurements/datacoms
ULIL-03	Methods for antenna measurements in the 300 GHz band
ULIL-04	Method for measurement of IP3 performance using photonic techniques
ULIL-05	Methods to conduct validation of THz link in the 300 GHz band
USTUTT-01	Superheterodyne architecture proof-of-concept
USTUTT-02	Superheterodyne 300 GHz transmitter and receiver design
USTUTT-03	Superheterodyne 300 GHz RX design with active down-converter
USTUTT-04	System-level simulation test bench
USTUTT-05	Automated test bench for back-to-back measurements
WUT-01	Studies on link budget under severe weather conditions
CIT-01	Building material properties model at 300 GHz
CIT-02	Antenna model at 300 GHz
GU-01	Visualization of THz wave propagation dynamics
GU-02	Antenna measurement system
NEC-01	Establishment of TWTA manufacturing method at 300 GHz
NEC-02	Study of wind effect on 300 GHz links
HRCP-01	IEEE 802.15.3e-2017 compliant 300 GHz chipset concept

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