one6G Summit 2025, Bologna

September 18, 2025, 14:45 – 16:00

Session 3: Industry Perspective on 6G

Toward 6G: Practical Pathways, Intelligent Networks, and Real-World Measurement Challenges

Dr. Taro Eichler

ROHDE&SCHWARZ

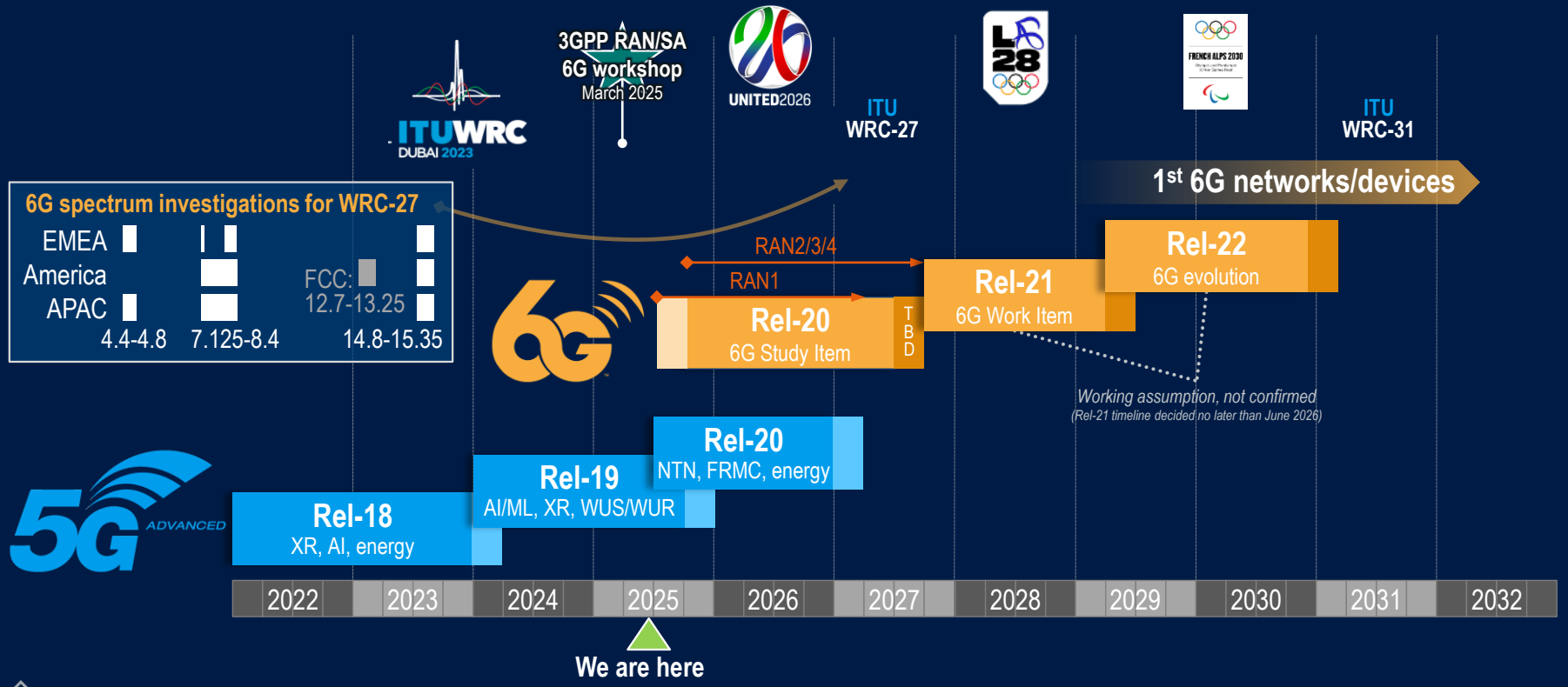
Make ideas real

Overview

- 6G Timeline & Standardization
  - Evolution from 5G Advanced → 6G (2030)
- AI as the Heart of 6G
  - AI in RAN (3GPP)
  - AI-native air interface
  - Neural receivers & digital twins
- Integrated Sensing & Communication (ISAC)
  - Object & motion sensing
  - Human-centric measurements
- THz & Photonics Frontiers
  - Channel measurements
  - Photonic demonstrators
- Take-aways

3GPP standardization and regulation

On the way towards planned 6G launch in 2030



3GPP Plenary June 2025, Prague: Rel-20 (6G Study Item)
Towards lean, streamlined and market-relevant specifications

Key values

3GPP aims to create lean and streamlined 6G standards

Focus areas include:

- Selecting an appropriate set of functionalities
- Minimizing multiple options for the same function
- Avoiding excessive configurations

Exceptions must be well justified.

6G Study Item for RAN and System architecture

- Overall 6G access architecture
- Migration and interworking: multi-radio spectrum sharing (5G/6G coexistence)
- Wireless AI
- Integrated RF sensing
- Efficient data framework
- Distributed computing: UL will become more important.
- NTN
- IoT
- Open interfaces incl. O-RAN
- Standalone 6G

AI in RAN

- Extensible AI framework, built on 5G-Advanced, and exploring new use cases.
- AI use cases include AI-enhanced receiver performance, AI-aided mobility measurements, AI-aided positioning etc.

Spectrum

- Both existing spectrum and new spectrum (e.g. ~ 7-15 GHz).
- Deployment of 6G on new spectrum using existing mid-band site grid is important.

Integrated sensing and communication (ISAC)

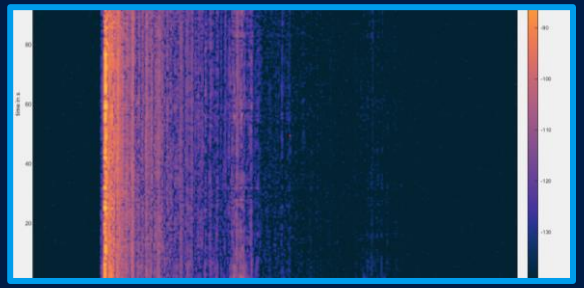
- Sensing-assisted communication
- Communications-assisted sensing.

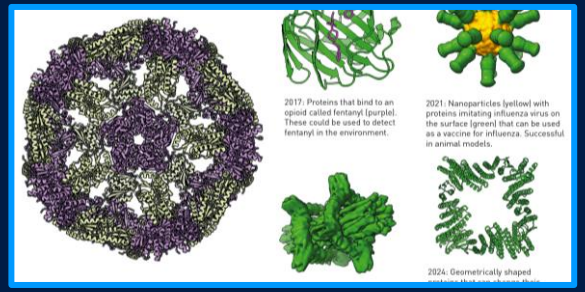
Sustainability and energy efficiency

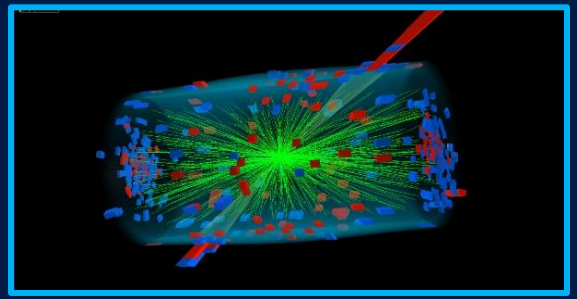
- Native and joint design to deliver network and device energy savings.

Why AI in 6G: Sparse data problem analogies across domains

AI/ML can fill in the gaps by learning hidden structures







Wireless Communication

- Sparse CSI feedback (few pilots)
- AI reconstructs hidden channel state

→ Better CSI, Higher throughput

Protein Folding

- Sparse structural data (few proteins known)
- AI predicts 3D fold (AlphaFold)

→ Reliable protein structure prediction

High-Energy Physics

- Sparse detector signals (rare particle events)
- AI reconstructs particle tracks

→ Better event reconstruction

Wireless communication channels, protein folding, and high-energy physics all deal with **complex systems where we only see partial, sparse data**. AI succeeds because it can capture hidden patterns and leverage physics-informed constraints to **reconstruct reality from incomplete information**.

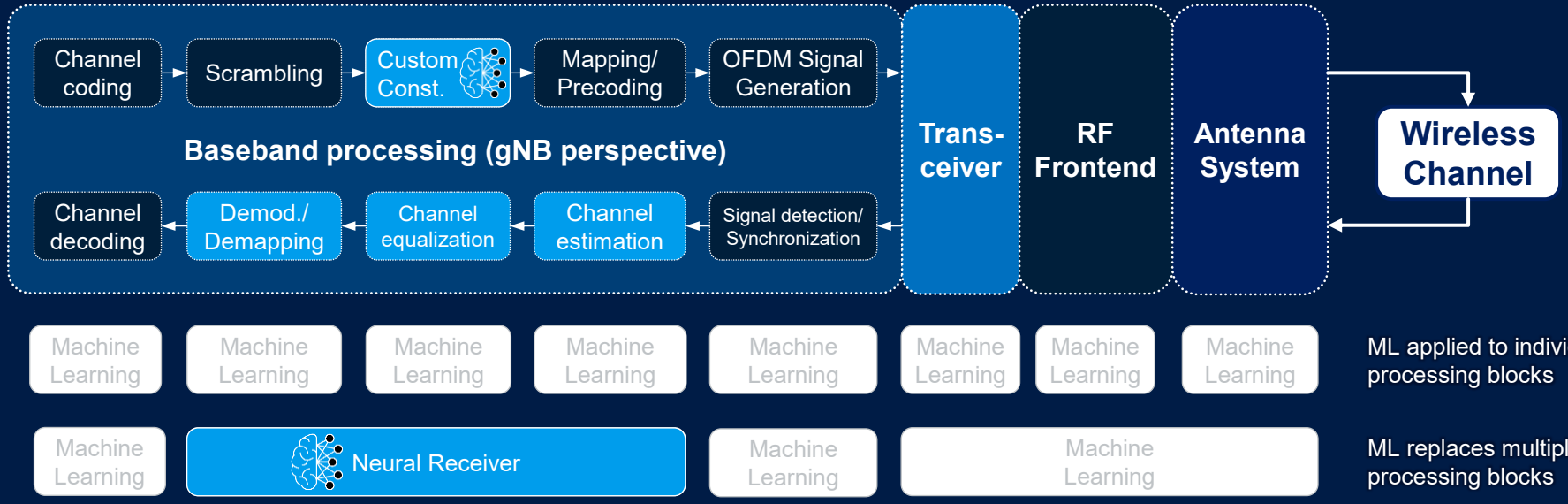
AI in RAN
AI/ML-based CSI Compression testing

ML-Enhanced CSI Feedback for 5G & 6G

- Demonstrates AI/ML-based **Channel State Information (CSI) feedback** to boost spectral efficiency and reduce overhead.
- **Essential for Massive MIMO**: enables precise beamforming and high-performance data transmission.
- **Two-sided AI models** (UE: encoder, CMX500: decoder) trained on reference models.
- **Cross-vendor demo (Qualcomm + R&S)** proves interoperability with ONNX models for 3GPP Rel-18/19 CSI Feedback Compression for prototype chipset implementation
- **Result:** Up to **+51% throughput** vs. standard CSI feedback.
- Studied in **3GPP Releases 18 & 19**, paving the way for **AI in 6G**.

- R&S®CMX500 5G One Box Signaling Tester allows the import of vendor-designed AI/ML models, e.g., proprietary decoder for ML-CSI feedback enhancement through the support of industry-standard ONNX interface

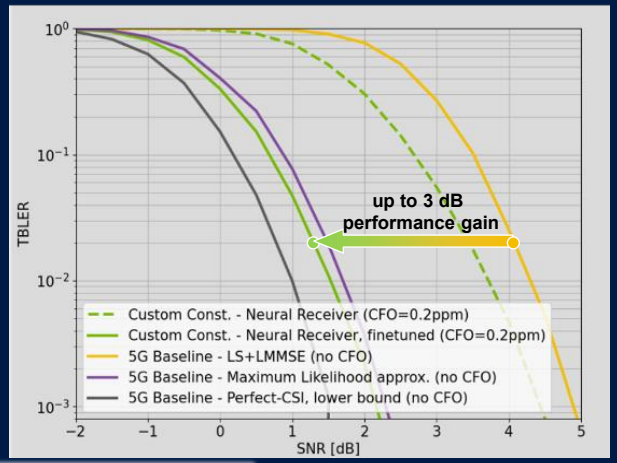
Towards an AI-native air interface for 6G
Neural receiver with custom constellation



Towards an AI-native air interface for 6G
Neural receiver with custom constellation

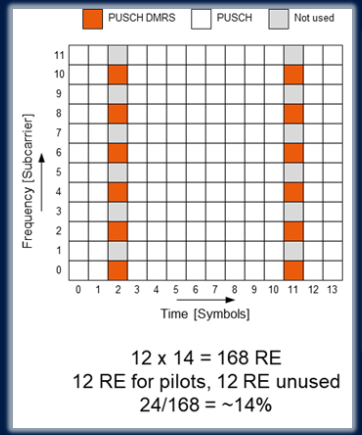
Benefits

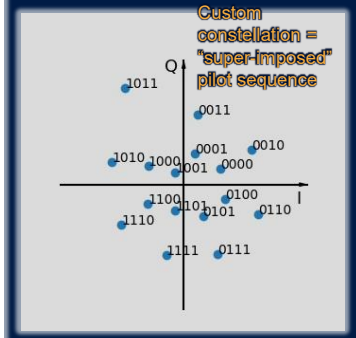
- Observed gains
  - based on learned pilot-/data-aided channel estimation and minimization of estimation and equalization errors compared to conventional algorithms
- Further improving spectral efficiency
  - Including custom constellation with asymmetric shape eliminates the need for pilot signals



No free lunch!

- Model is only as good as the data set
- Retrain model for modulation schemes (constellation points) and subcarrier spacings as information is backed into weights during training process
- Computational complexity and power consumption

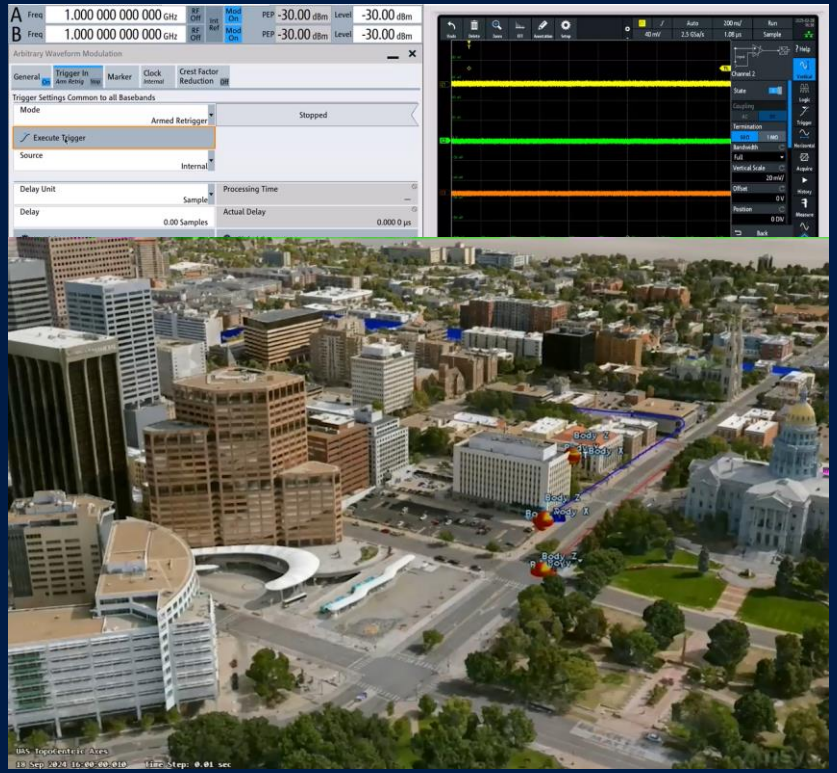




Depending on actual DMRS configuration (pilot signal) up to 14% gain in spectral efficiency

Digital Twin for AI-RAN

Synthetic channel emulation of realistic scenarios in conjunction with channel measurements



- Requirement to train and test AI/ML based communication systems with quasi-real-world (including site specific) scenarios
- Requirement for spatial consistency: e.g. ISAC, real-world GNSS near field simulation, AI/ML channel prediction, etc.
- Requirement for powerful tools to extend test coverage and reduce field test costs i.e. Field2Lab enablement

Digital Twin: RF channel Scenario

- Ansys Scenario: Denver City Vehicle Path
- Access Point on building, and moving subscriber on the ground and in the air
- CIR channel impulse response on oscilloscope trace 1 and 2 for respective vehicles
- Customized dynamic fading

AI-enhanced calibration of RF digital twins

Synthetic channel emulation of realistic scenarios in conjunction with channel measurements

Testing 6G ISAC through object emulation for future ISAC applications

- Integrated sensing and communication (ISAC) is a pillar of 6G. Combining two different yet similar worlds – communications and environmental sensing.
- Demonstration of object emulation in FR2 spectrum band for future 6G ISAC applications in cooperation w/ Nokia, providing the ISAC sensing node.
- The R&S®AREG800A automotive radar echo generator is a core element of research and development test solution.

In cooperation with NOKIA

R&S®AREG800A
Object (sensing target) emulator

R&S®FE44S
mm-wave front-end

Human motion sensing in FR3: NTT / DOCOMO 6G collaboration

Statistical evaluation of time variation of propagation channel at 7.9 GHz for sensing

- Wataru Yamada, Minoru Inomata, Nobuaki Kuno, Koshiro Kitao, Satoshi Suyama, et al. , Taro Eichler, and Wilhelm Keusgen, "Indoor Dynamic Channel Measurement for ISAC", accepted for ISAP 2025

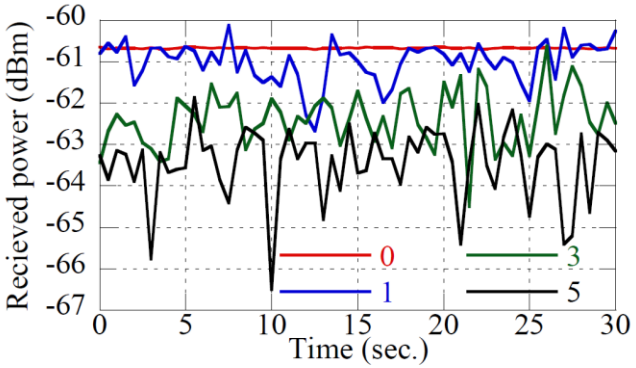


Fig. 2. Time variation of received power.

- Received power decreases as number of people walking increases.
- Fluctuation of power increases as number of people walking increases.
- Next step:
  - Use AI for faster eval.
  - Use phase and wideband info

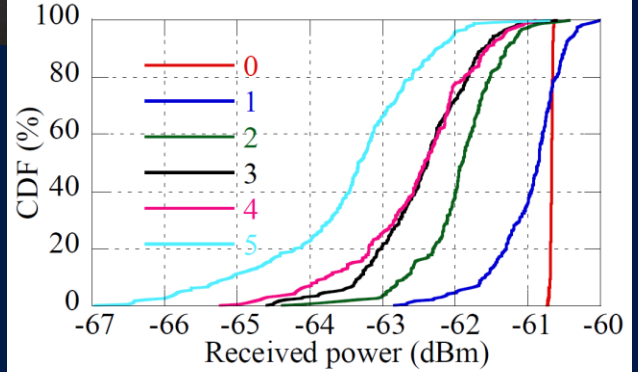
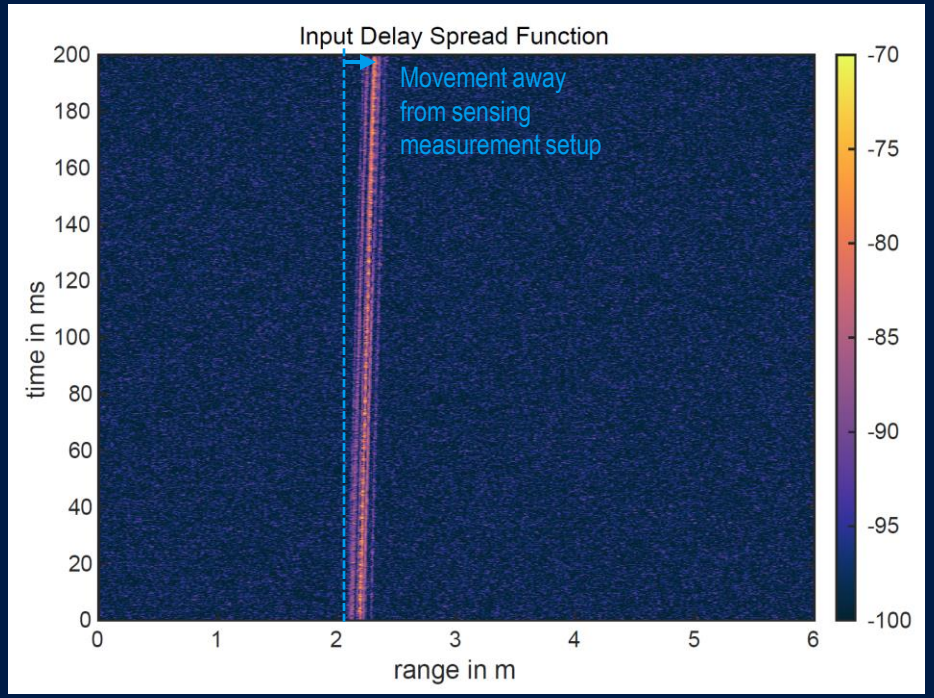


Fig.3. CDF of received power.

THz drone sensing
Time-domain Channel impulse response evolution at 300 GHz

W. Keusgen and T. Eichler, "Outdoor THz channel measurements at 300 GHz with observed multipath components beyond 1 km," 2024 IEEE 100th Vehicular Technology Conference (VTC2024-Fall), Washington, DC, USA, 2024, pp. 1-5



Ultra-high time resolution 0.125 ns
(8 GHz modulation bandwidth)

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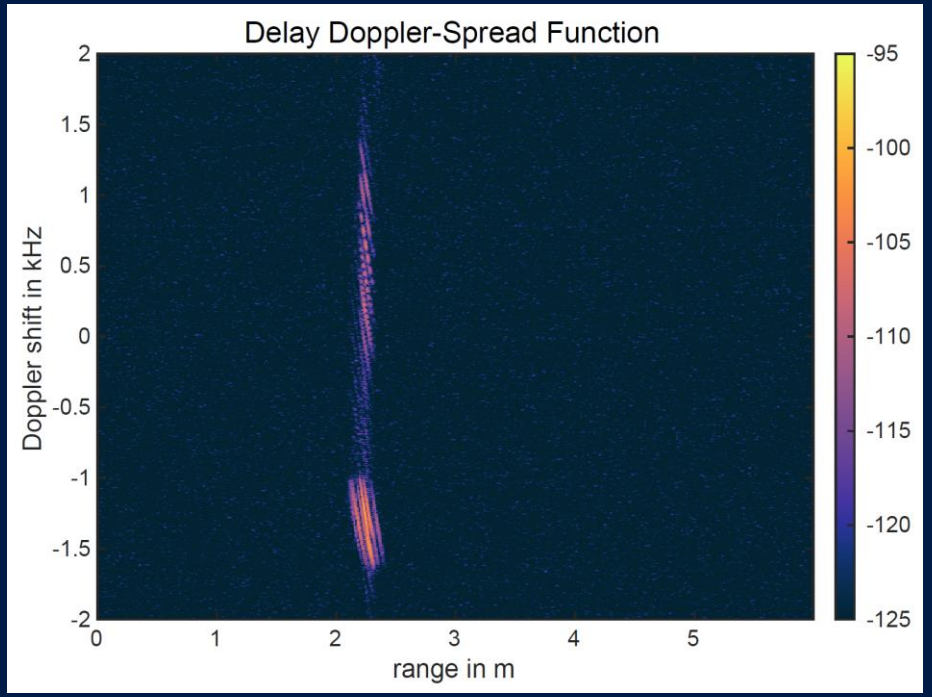
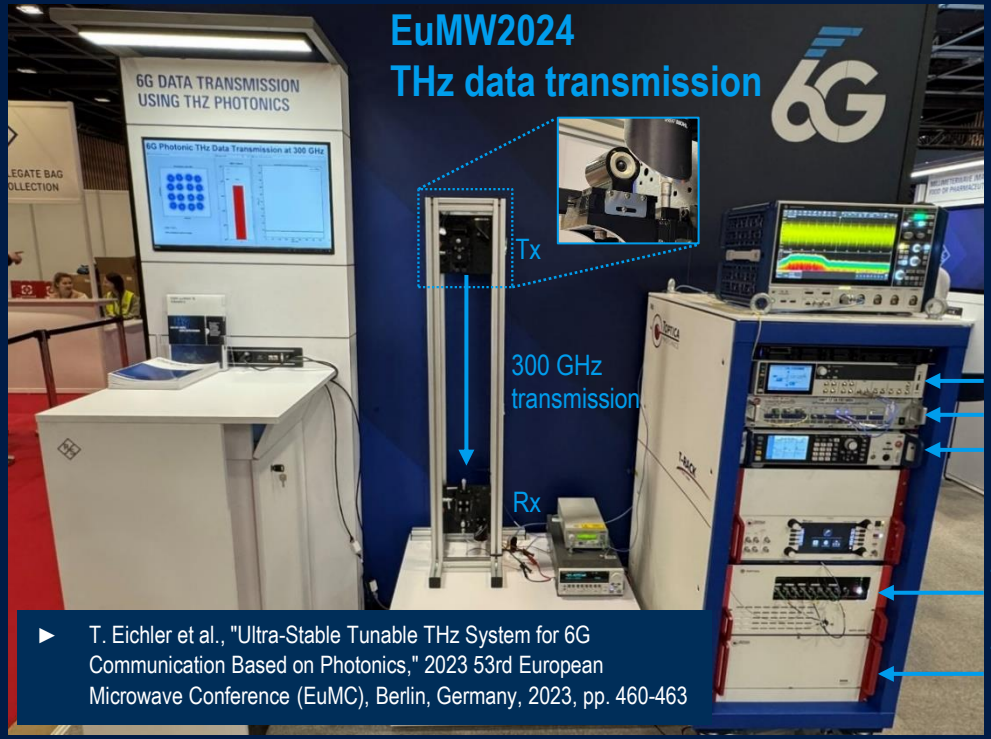


Ultra-high time resolution 0.125 ns
(8 GHz modulation bandwidth)

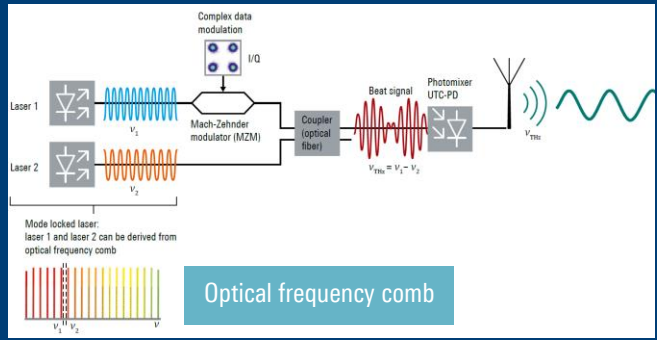
6G Data Transmission by THz Photonics
EuMW2024 6G-ADLANTIK Demonstrator

With funding from the:
Federal Ministry of Research, Technology and Space



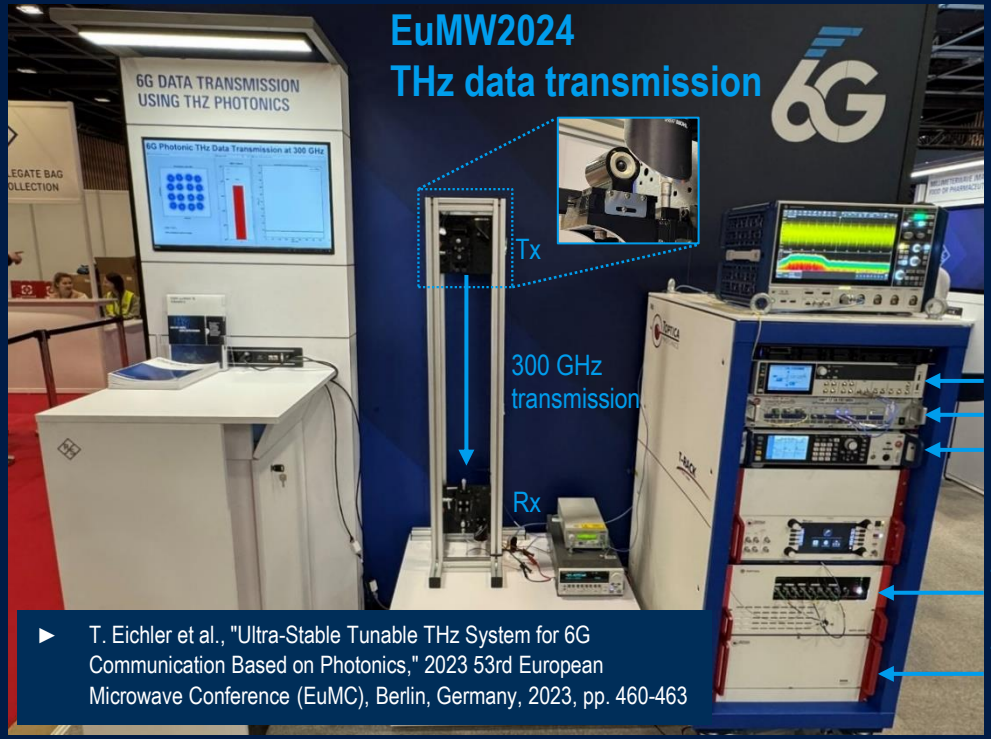
► T. Eichler et al., "Ultra-Stable Tunable THz System for 6G Communication Based on Photonics," 2023 53rd European Microwave Conference (EuMC), Berlin, Germany, 2023, pp. 460-463

Down-conversion: Optoelectronic THz Generation
Photomixer: unitraveling carrier photodiode (UTC-PD)



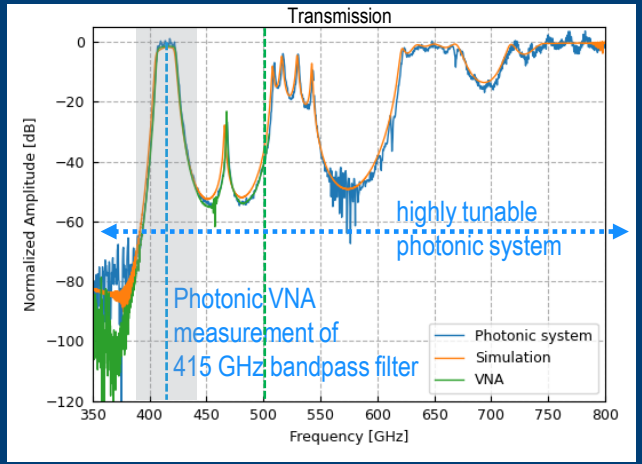
Reference: „Advances in terahertz communications accelerated by photonics“, T. Nagatsuma, G. Ducournau & C. Renaud
Nature Photonics volume 10, pages 371–379 (2016)

THz Photonics VNA measurement
EuMW2025 6G-ADLANTIK Demonstrator



► T. Eichler et al., "Ultra-Stable Tunable THz System for 6G Communication Based on Photonics," 2023 53rd European Microwave Conference (EuMC), Berlin, Germany, 2023, pp. 460-463

VNA-type 415 GHz bandpass filter meas.

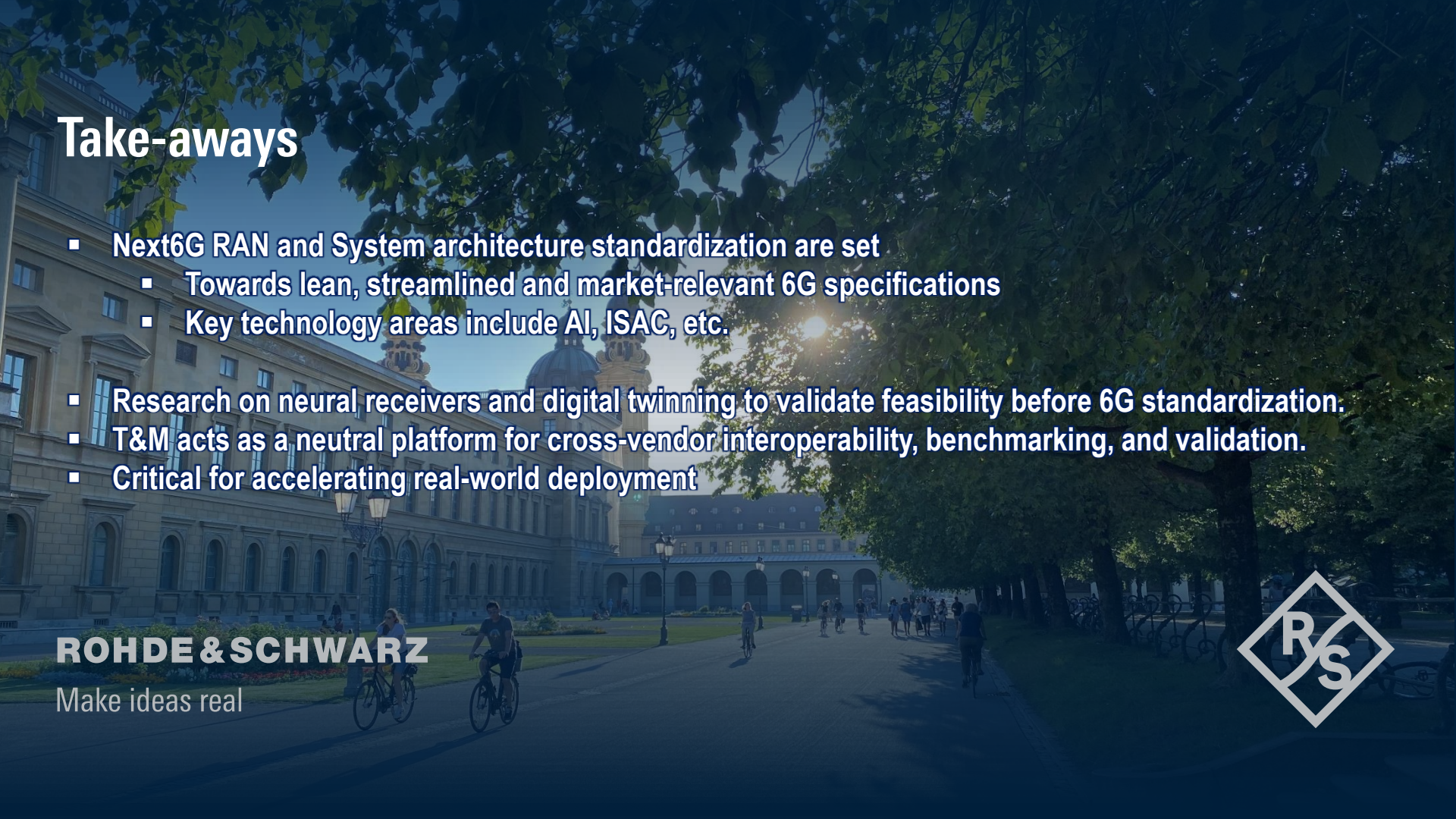


► S. Müller, T. Puppe, T. Noack, M. Wittmann, G. Hechtfischer and N. Vieweg, "Design, Fabrication and Broadband High-Resolution Characterization of a 415 GHz Rectangular Waveguide Bandpass Filter," 2024 54th European Microwave Conference (EuMC), Paris, France, 2024, pp. 632-635

Take-aways

- Next6G RAN and System architecture standardization are set
  - Towards lean, streamlined and market-relevant 6G specifications
  - Key technology areas include AI, ISAC, etc.

- Research on neural receivers and digital twinning to validate feasibility before 6G standardization.
- T&M acts as a neutral platform for cross-vendor interoperability, benchmarking, and validation.
- Critical for accelerating real-world deployment



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