5G Evolution and 6G
On the verge of 6G

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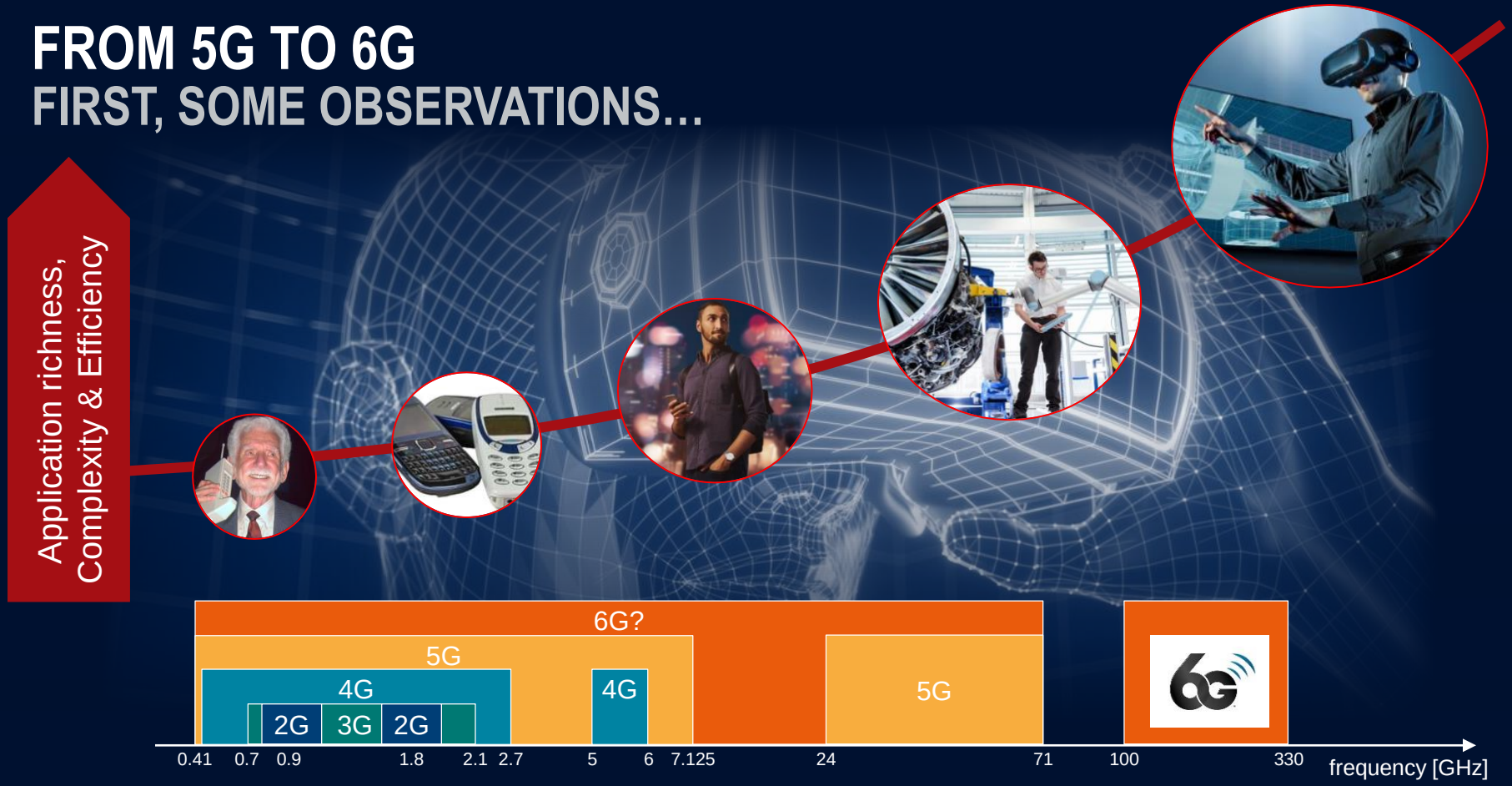
Wireless Communications - Manager
Rohde & Schwarz

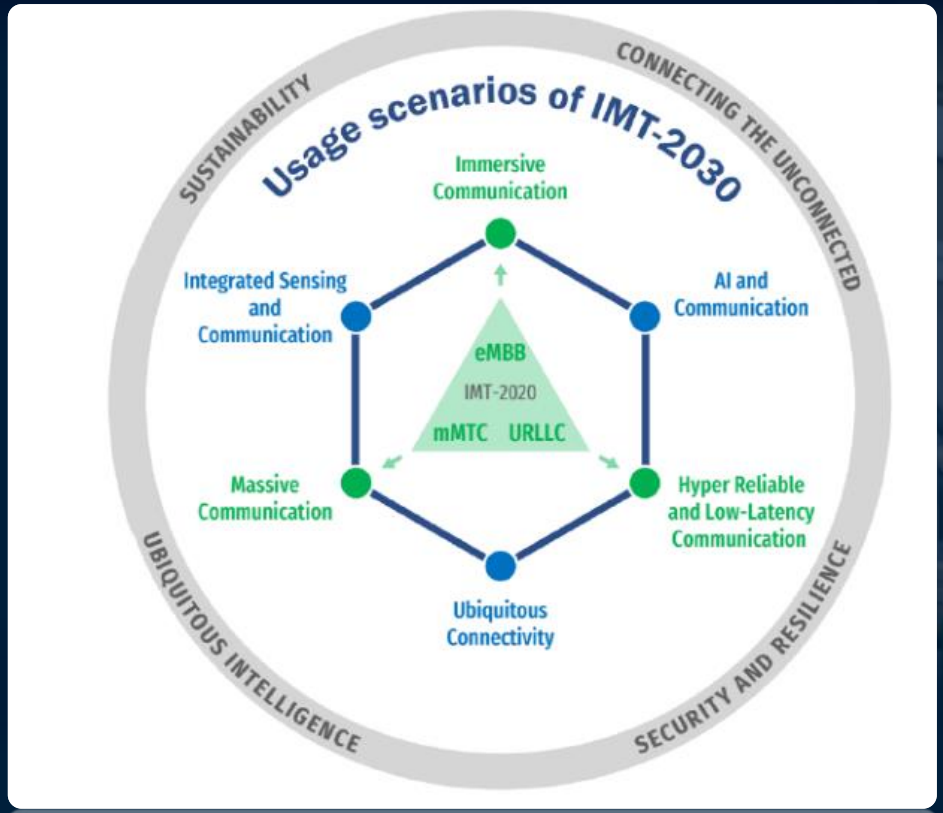
ROHDE&SCHWARZ
Make ideas real

BHARAT 6G 2024
2ND INTERNATIONAL CONFERENCE & EXHIBITION
15TH MAY 2024 ◇ LE MERIDIEN, NEW DELHI
5G & BEYOND: CONNECTIVITY FOR A DIGITAL WORLD

FROM 5G TO 6G
FIRST, SOME OBSERVATIONS…



IMT-2030 capabilities and usage scenarios



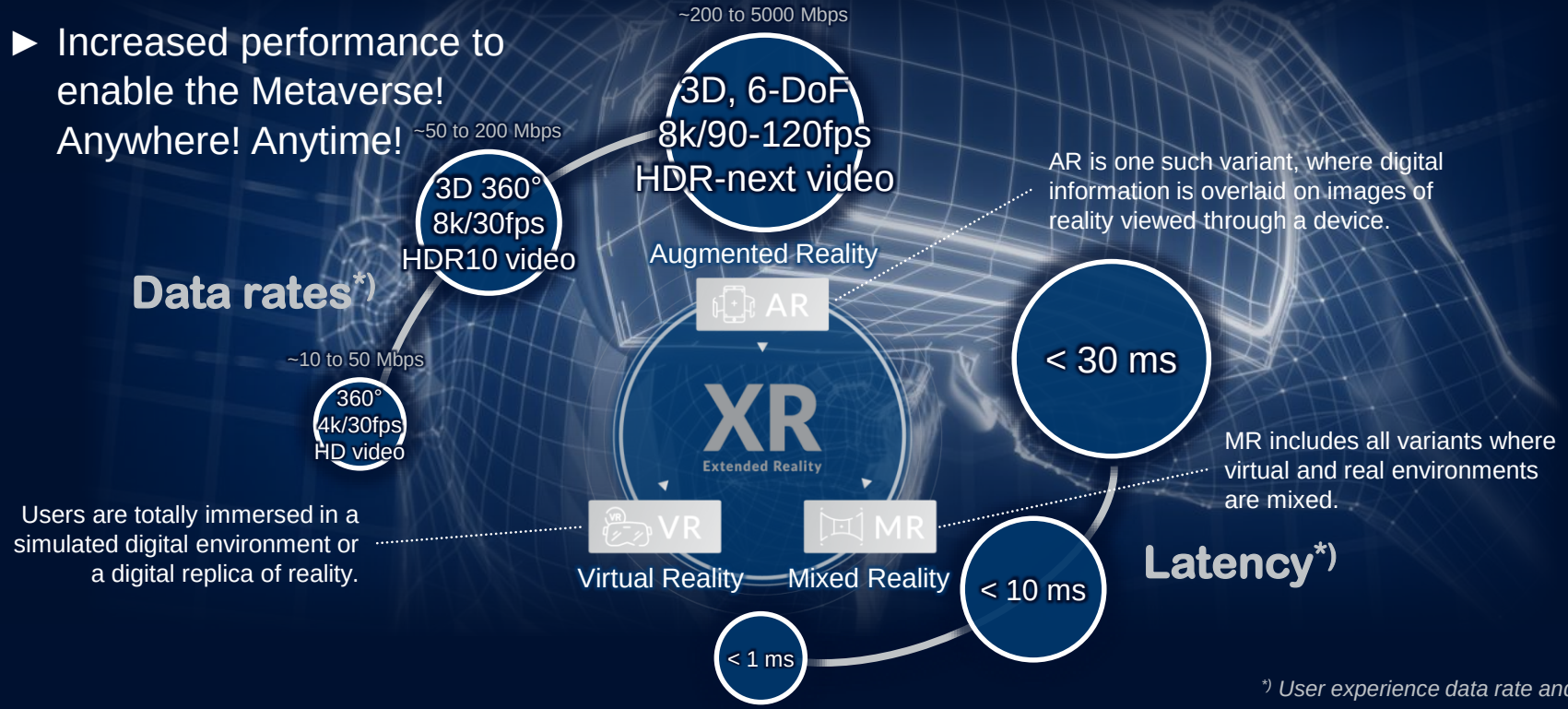
IMMERSIVE COMMUNICATIONS
WHAT DO WE NEED? NEW TYPE OF DEVICE?!?

“A hologram display over a mobile device (one micrometer pixel size on a 6.7-inch display, i.e., 11.1 Gigapixel) form-factor requires at least 0.58 Tbps.”

Source: [Samsung 6G White Paper]

CONTINUING THE THOUGHT EXPERIMENT: WHAT KPI'S ?

- Increased performance to enable the Metaverse! Anywhere! Anytime!



*) *User experience data rate and latency*

6G RESEARCH AREAS FROM A T&M PERSPECTIVE

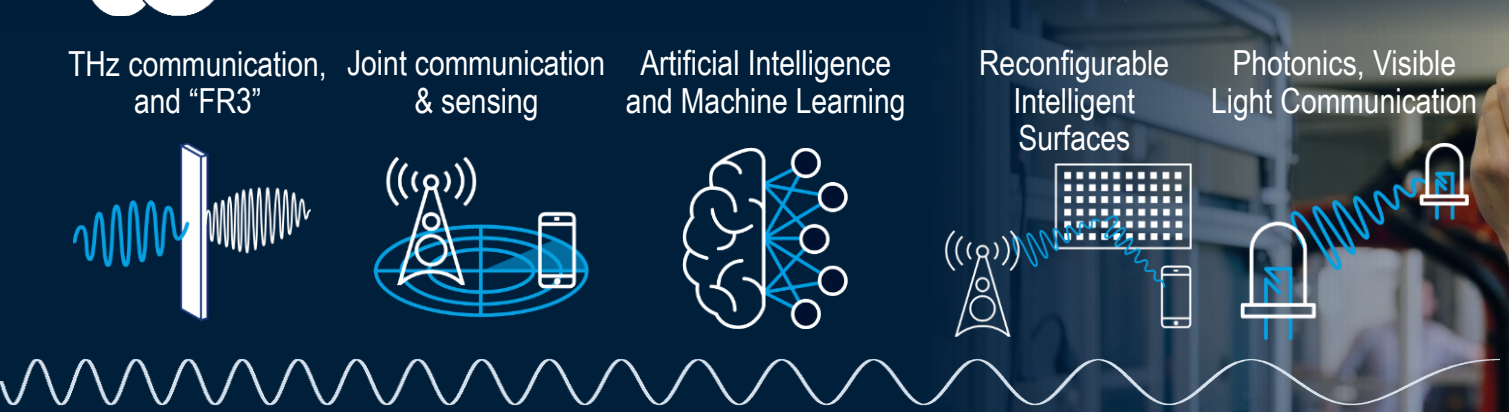
THz communication, and “FR3”

Joint communication & sensing

Artificial Intelligence and Machine Learning

Reconfigurable Intelligent Surfaces

Photonics, Visible Light Communication



Multiple access, new waveforms, channel coding

Ultra-massive MIMO

New network topologies, distributed computing

Full-duplex communication

Security & Trustworthiness

A high-level overview on all these research areas is provided in one of our #THINKSIX video. Don’t miss it!

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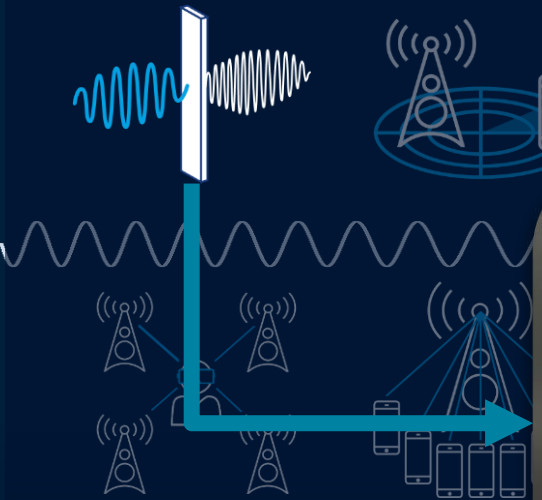

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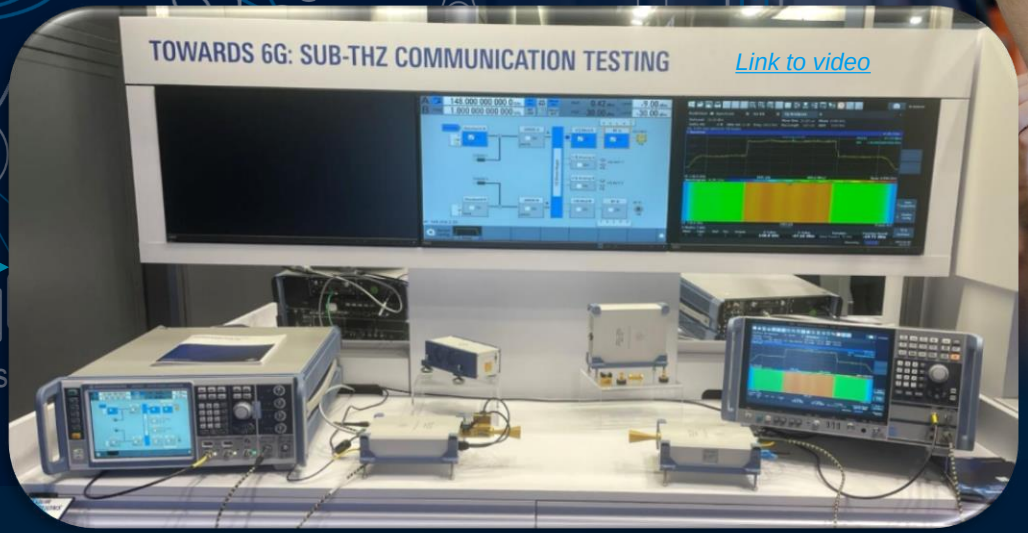

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Integrated sensing and communication | Artificial Intelligence | Reconfigurable Intelligent Surfaces | Photonics, Visible Light Communication | The Metaverse and eXtended Reality (XR)

5G-enabled AR-animated call

Rendered on Cloud XR server

Cloud XR Server

IP connection

R&S®CMX500
5G One Box Signaling Tester

5G connection to Motorola Edge smartphone

R&S®ATS1800C
RF shield box

USB-C connection

XR Client App

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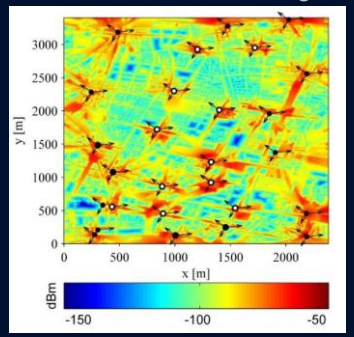
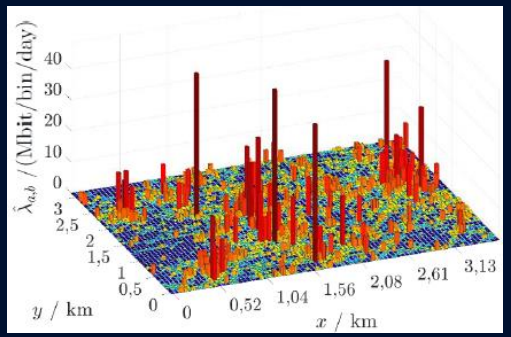
Continuing the thought experiment: Enabling the metaverse! Anywhere, anytime! – but How?

- We need a more adaptive Physical layer! And why is that required?

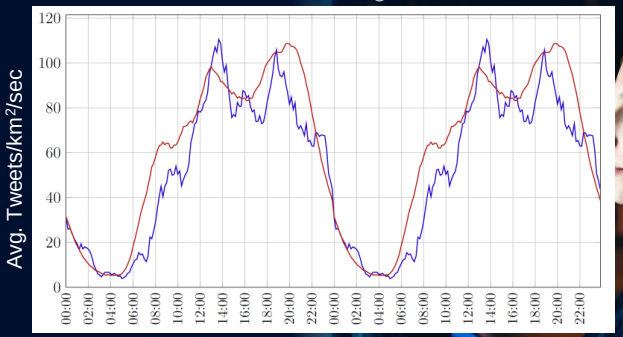
Non-uniform cell coverage*)



Non-uniform user distribution*)



Non-uniform data usage over time*)

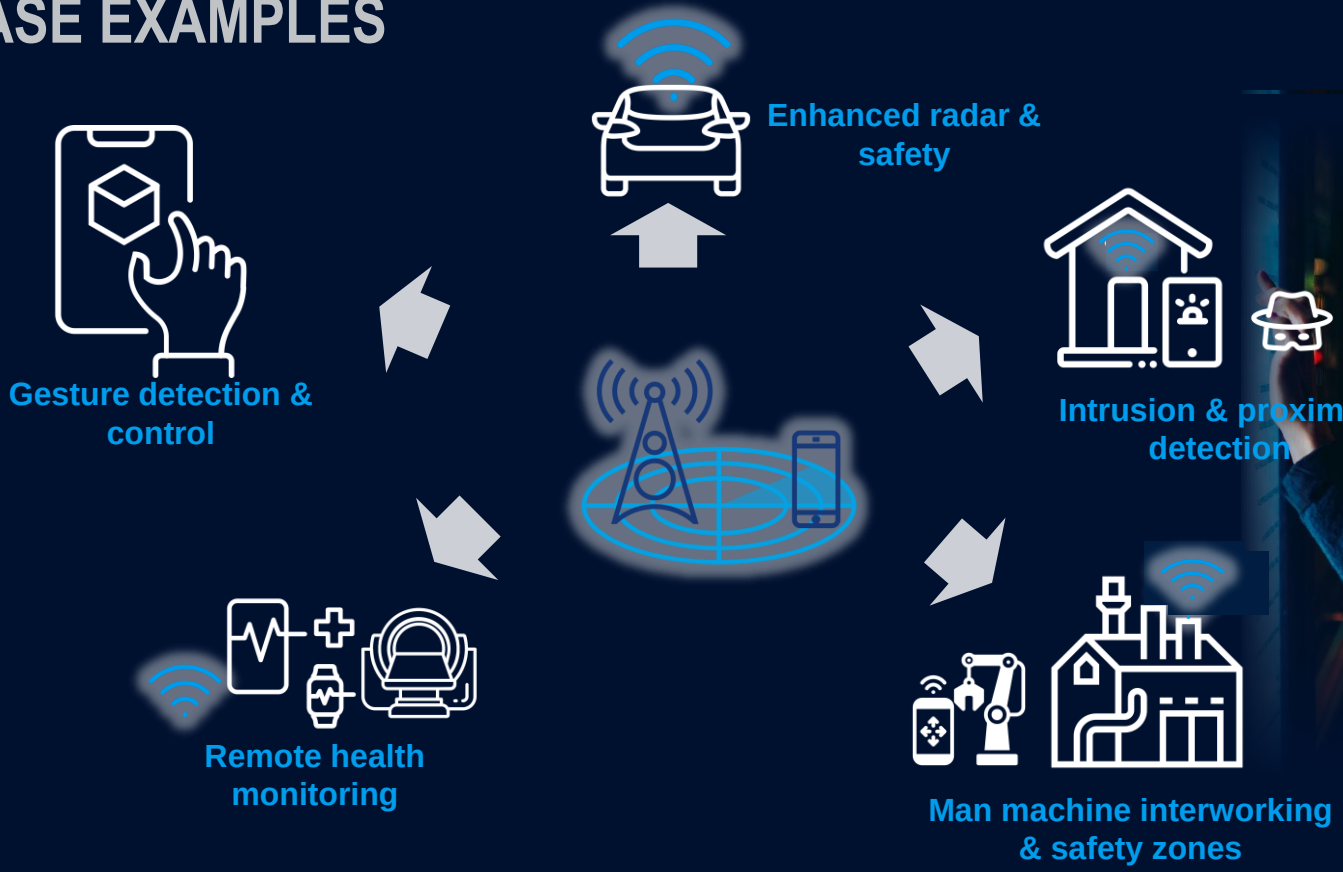


- The change of access scheme goes along with another observation when switching “G’s” – We typically change the PHY from an odd to an even “G”:
  - 1G to 2G → analog to digital
  - 3G to 4G → TDMA/FDMA/CDMA to OFDMA
  - 5G to 6G → OFDMA to ???

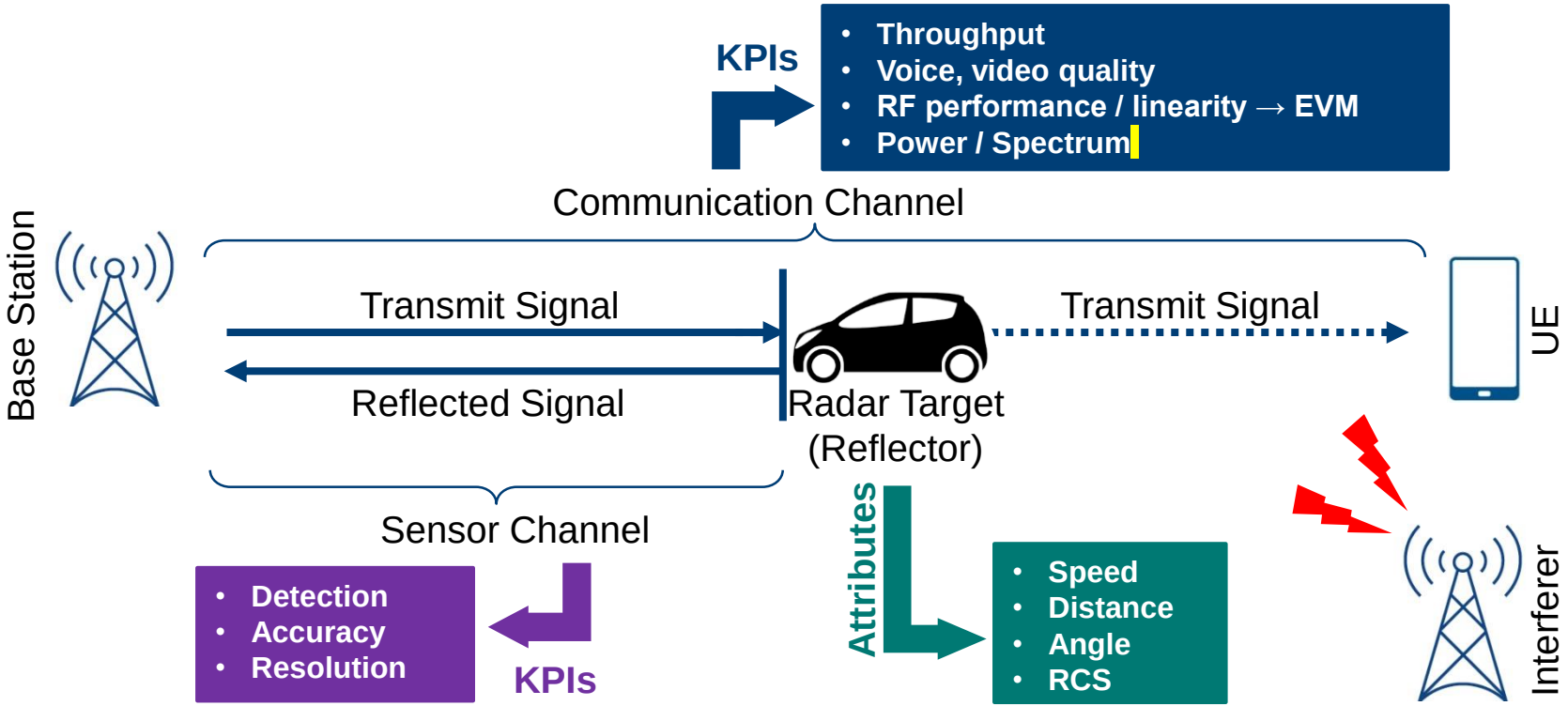
*) *6G-ANNA research project, Ahmad Nimr, et all, “Gearbox PHY – Flexible HW/SW architecture*


COMMUNICATION
Towards the **immersive** experience delivered by the **metaverse**?
THINGS
SENSOR
DATA
HUMAN
WORLD
PHYSICAL WORLD
DATA
ACTION
DIGITAL WORLD
DATA
ML/AI
ACTION

JOINT COMMUNICATION AND SENSING (JCAS)
USE CASE EXAMPLES



JOINT COMMUNICATION AND SENSING
DIFFERENCES IN PERFORMANCE INDICATION



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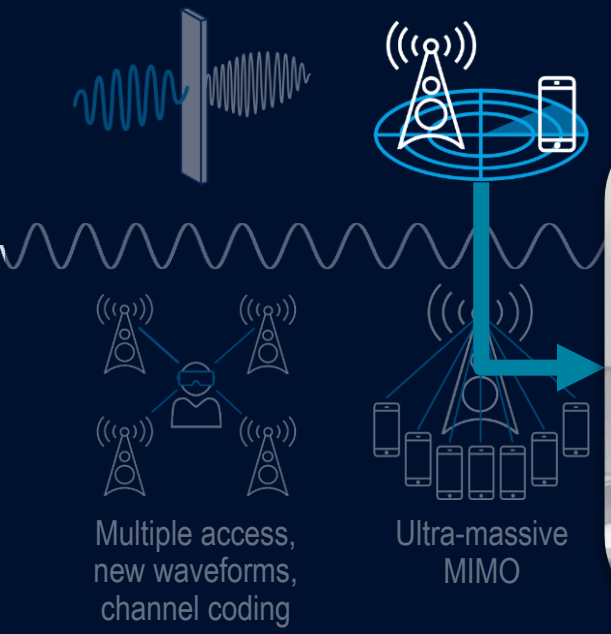

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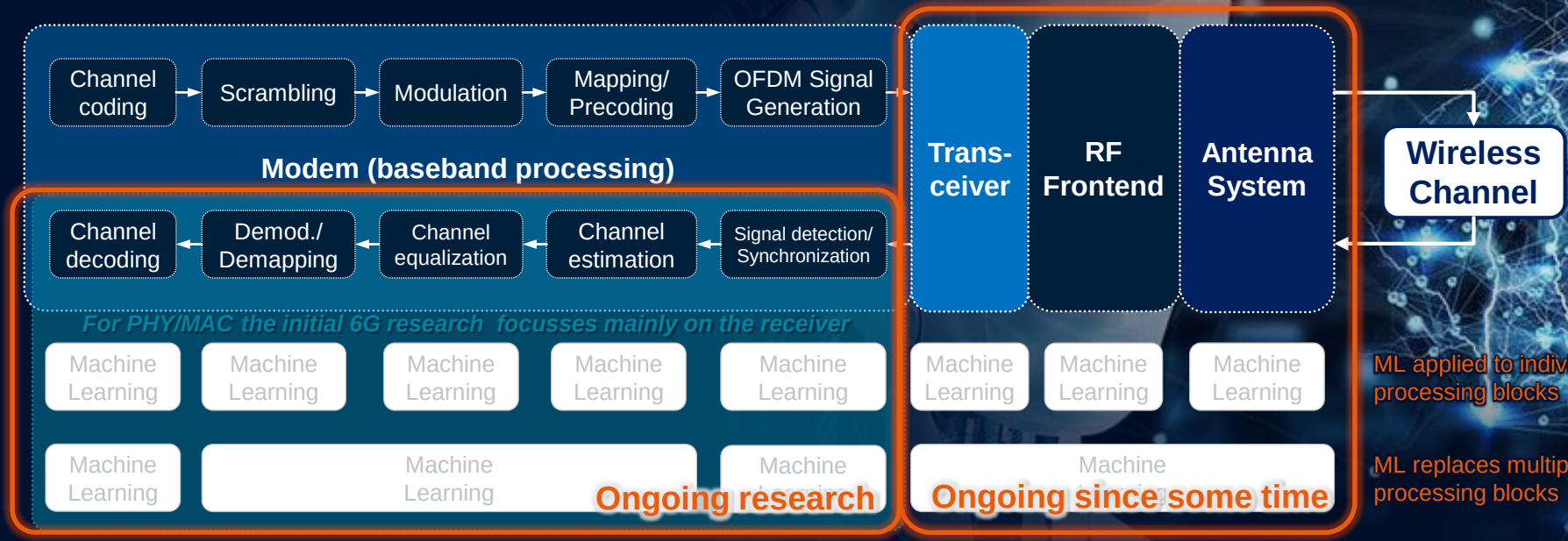
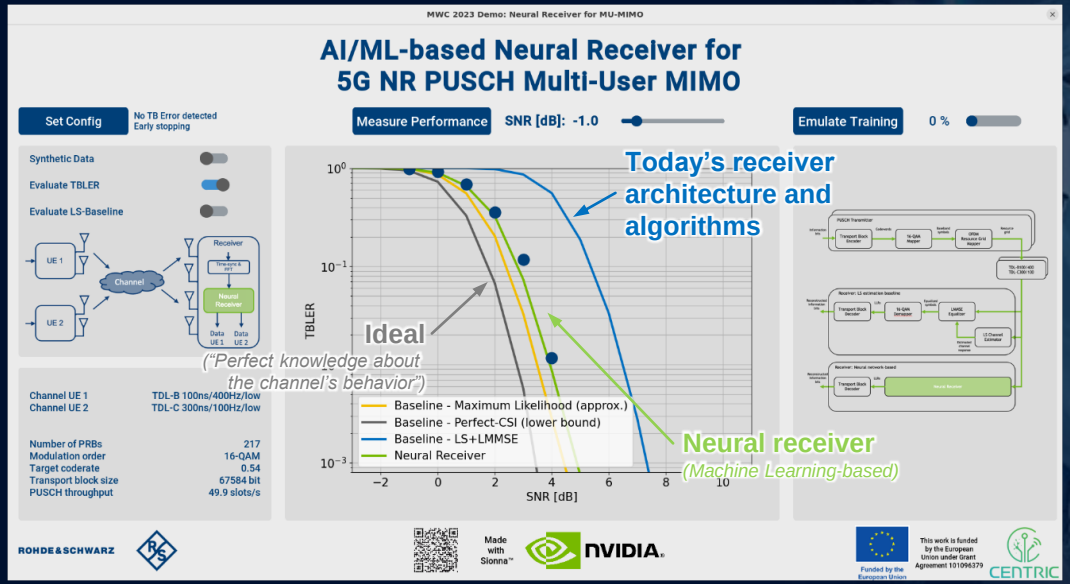
CAN MACHINE LEARNING SUPPORT, EVENTUALLY REPLACE, TODAY'S SIGNAL PROCESSING ALGORITHMS?

- Initial research and experiments state, "It can!" – How can we initially prove this?

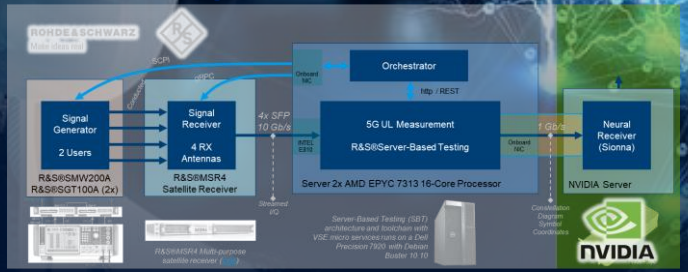


MACHINE LEARNING BASED SIGNAL PROCESSING HAS THE POTENTIAL TO IMPROVE TODAY'S PERFORMANCE

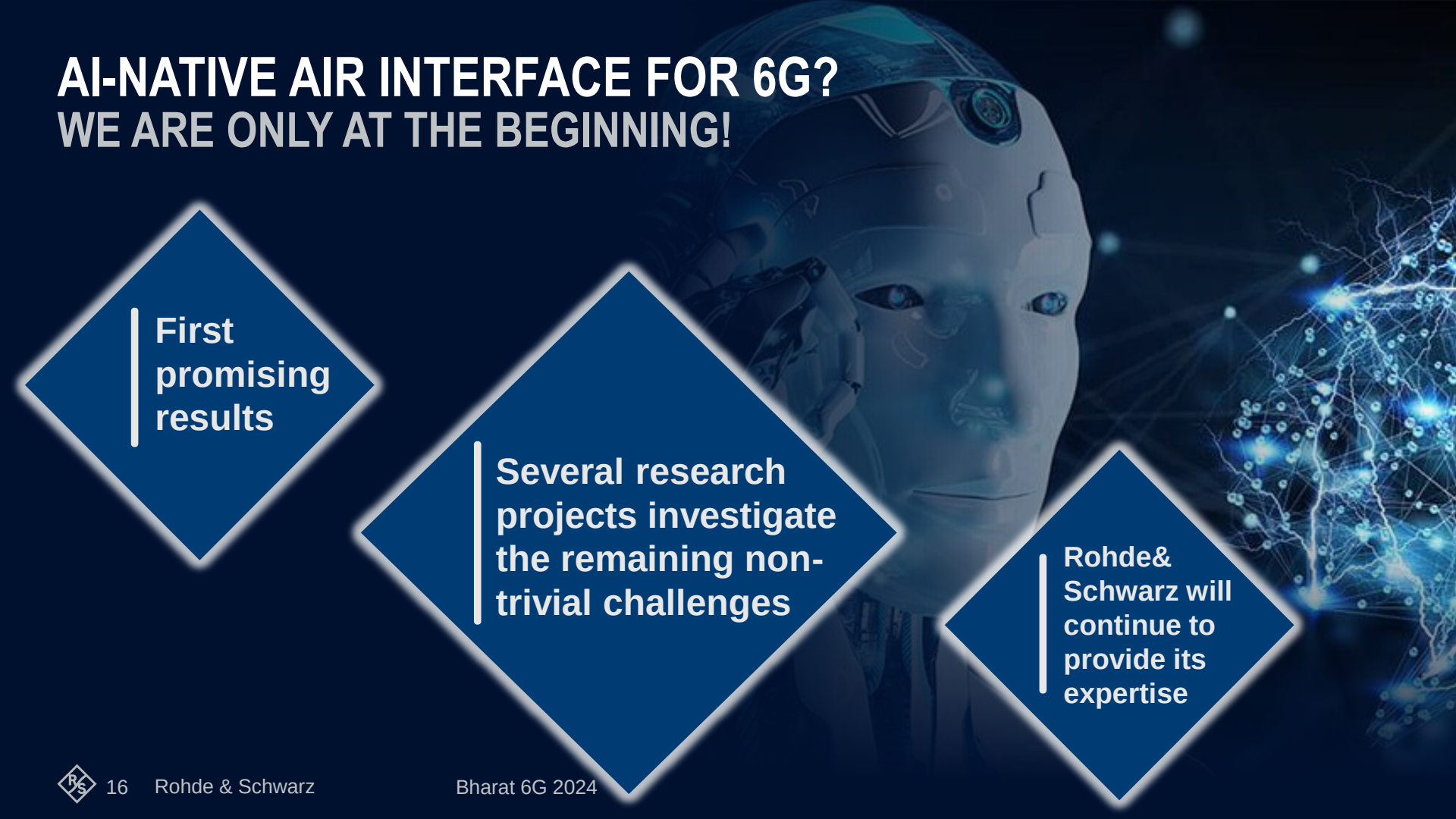


Demoed @ MWC GSMA

Hardware setup



AI-NATIVE AIR INTERFACE FOR 6G?
WE ARE ONLY AT THE BEGINNING!

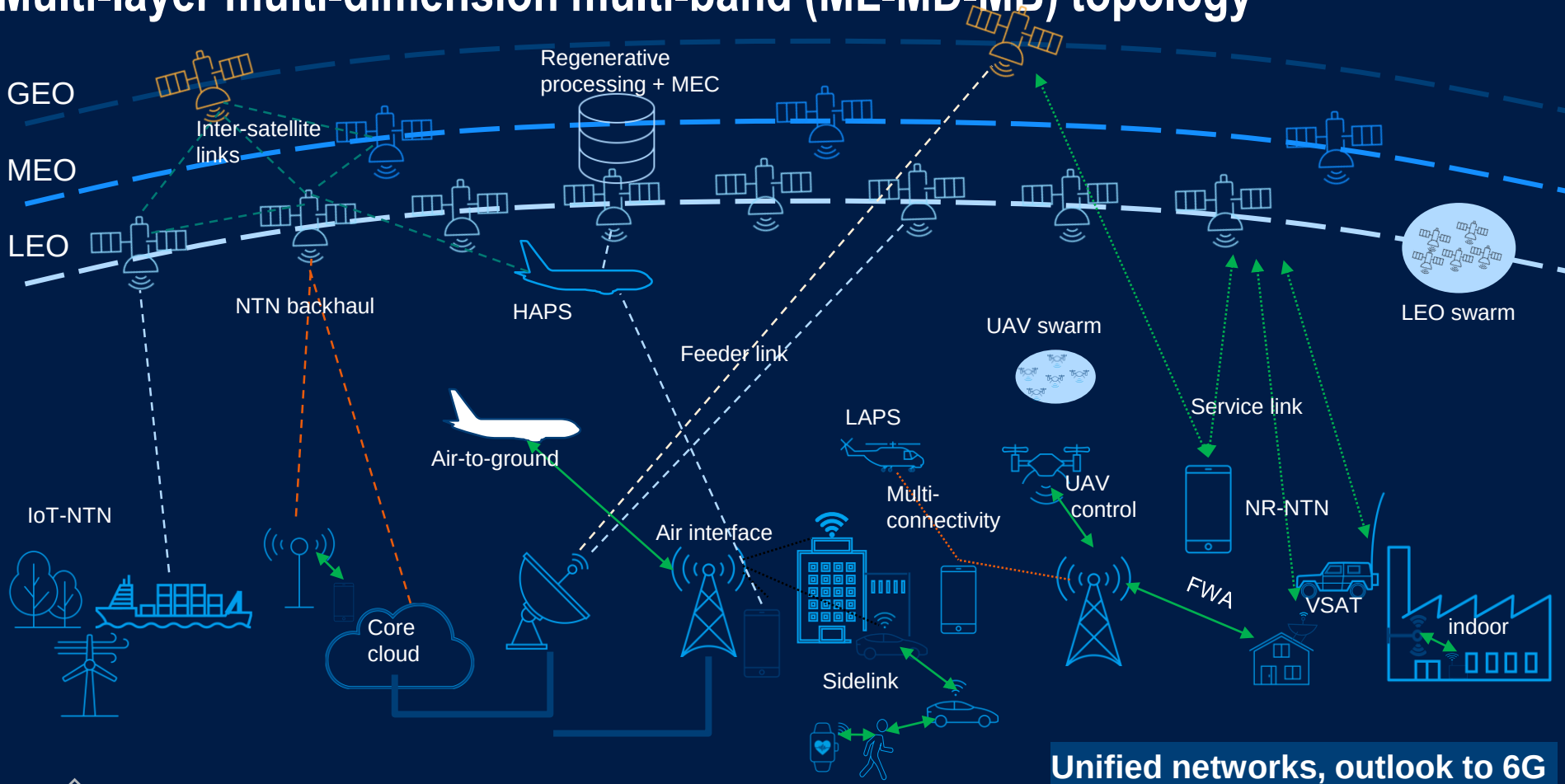


First promising results

Several research projects investigate the remaining non-trivial challenges

Rohde& Schwarz will continue to provide its expertise

Multi-layer multi-dimension multi-band (ML-MD-MB) topology



Unified networks, outlook to 6G

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ADJUST THE CHANNEL – ALONG WITH THE SIGNAL

$$r(t) = h(t)s(t) + n(t)$$

- The classical approach to maximize reception quality:
  - Adapt s(t) transmission scheme to target channel h(t), e.g., CP-OFDM for the multipath channel, carrier frequency, and bandwidth, pre-coding/equalization, modulation and coding schemes, etc.
- IRS offers an adaptation of channel h(t) to maximize reception quality.

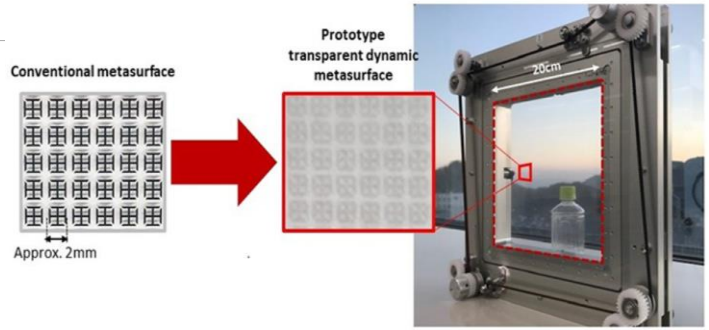
Press Release

https://www.nttdocomo.co.jp/english/info/media_center/pr/2020/0117_00.html

January 17, 2020

DOCOMO Conducts World's First Successful Trial of Transparent Dynamic Metasurface

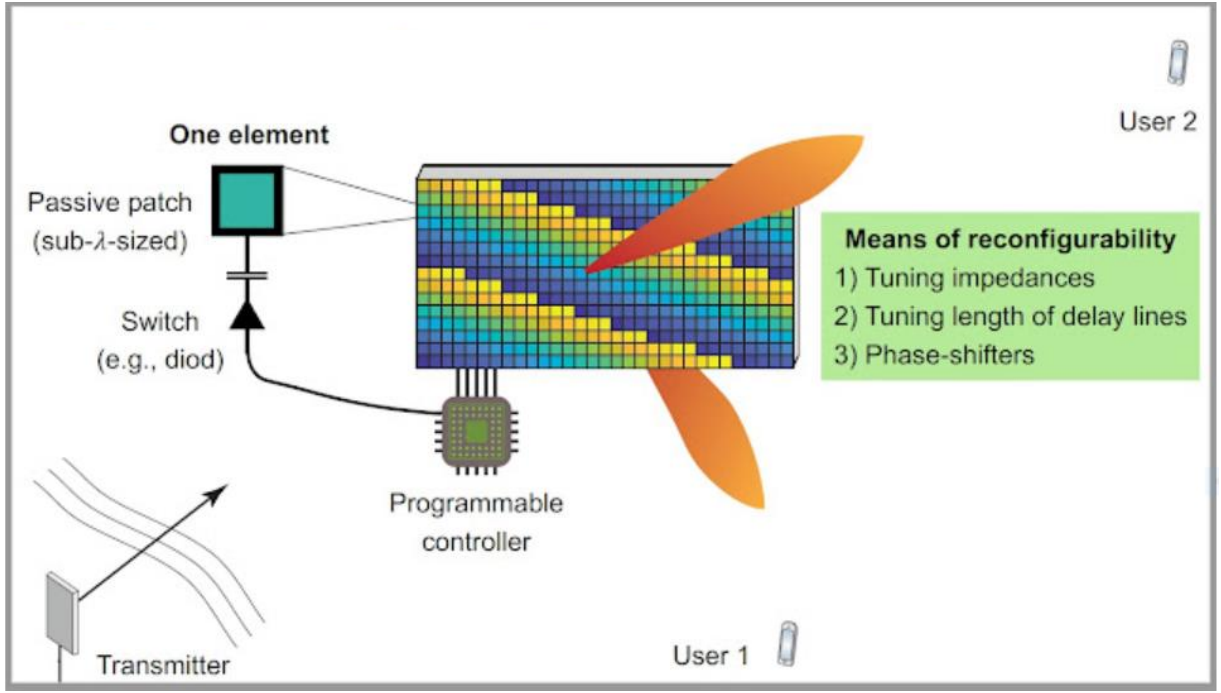
— Dynamic wave manipulation and high transparency expected to optimize 5G network construction —

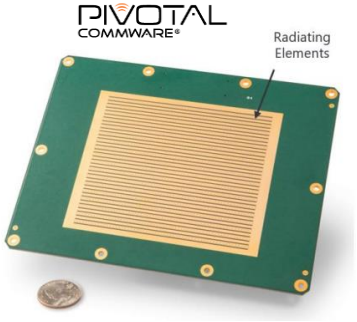


Prototype of transparent dynamic metasurface

INTELLIGENT REFLECTING SURFACES

OPERATION IN A NUTSHELL

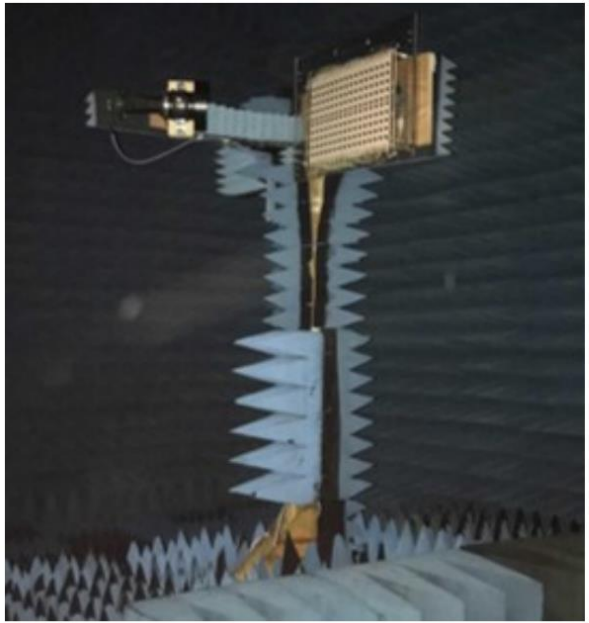


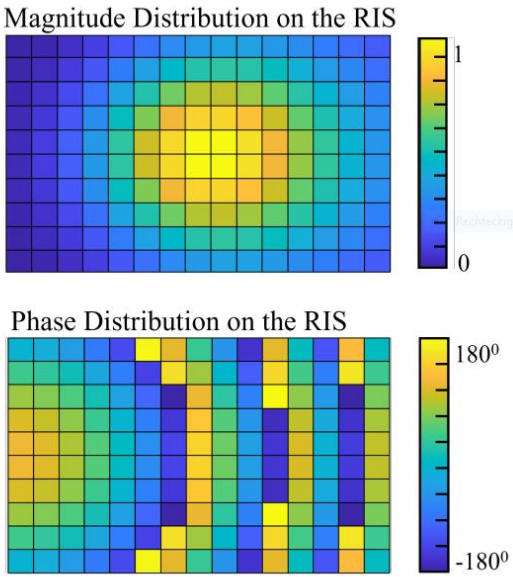


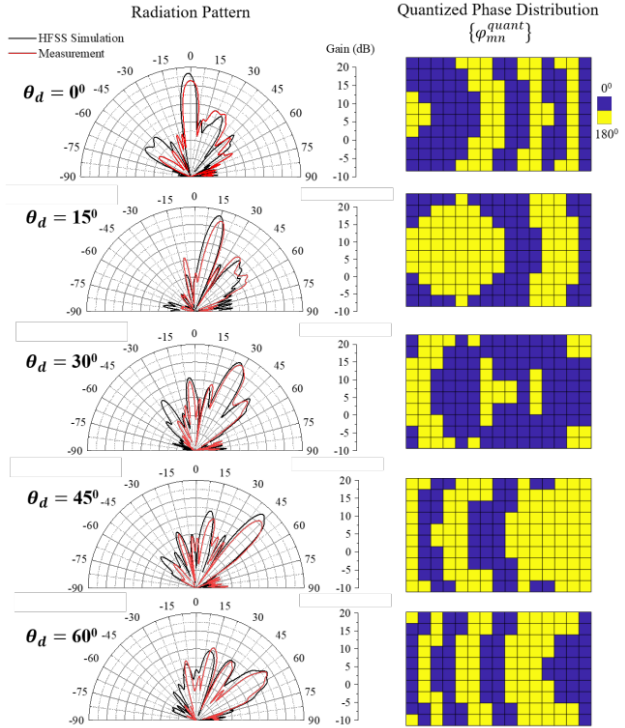
Sources: https://www.free6gtraining.com/2020/12/communications-using-intelligent.html and https://www.youtube.com/watch?v=9cBn5pil9Ms

INTELLIGENT REFLECTING SURFACES

DESIGN AND EVALUATION





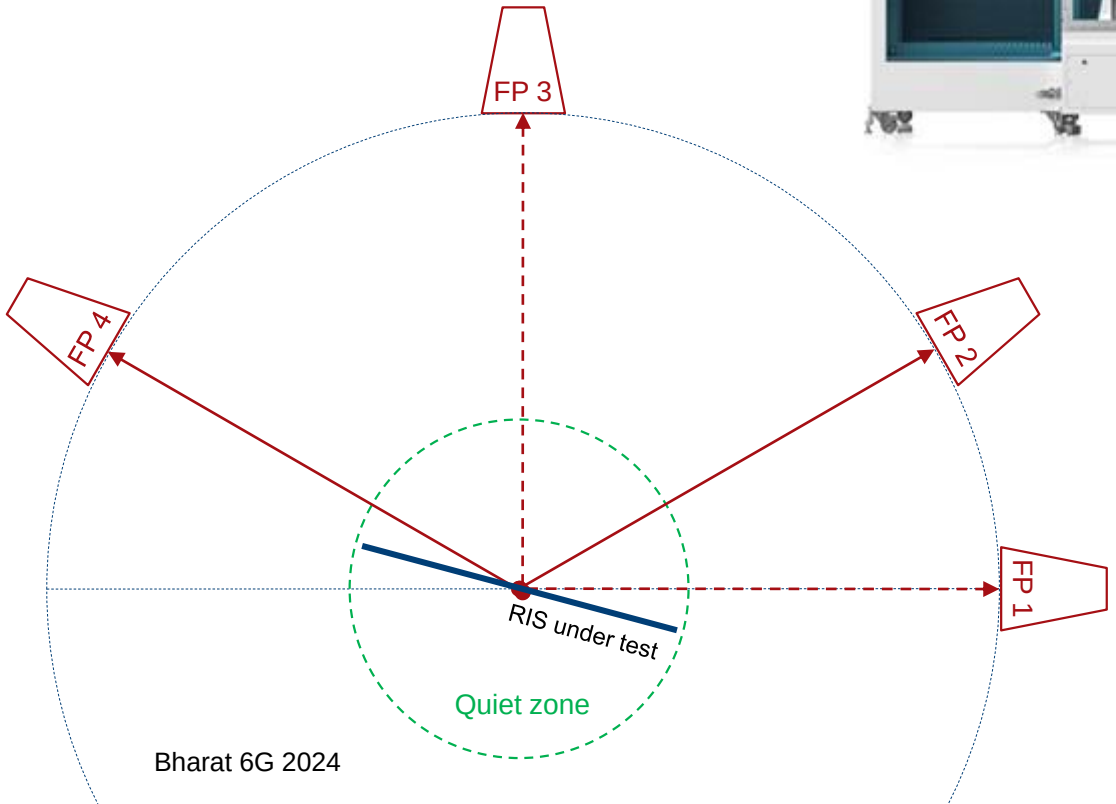


Source: Design and Evaluation of Reconfigurable Intelligent Surfaces in Real-World Environment by Georgios C. Trichopoulos, Panagiotis Theofanopoulos, Bharath Kashyap, Aditya Shekhawat, Anuj Modi, Tawfik Osman, Sanjay Kumar, Anand Sengar, Arkajyoti Chang, and Ahmed Alkhateeb

MULTI-ANGLE IRS ASSESSMENT SETUP

FP* = Feed or Probe

FP	Angle
FP1	0°
FP2	30°
FP3	90 °
FP4	150°



*Any FP can be used either as feed for impinging wave or probe for reflecting wave.

Turning of RIS allows any impinging wave angle

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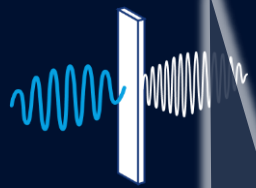

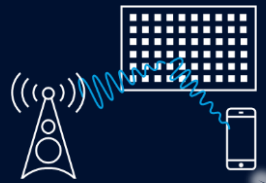

A high-level overview of all these research

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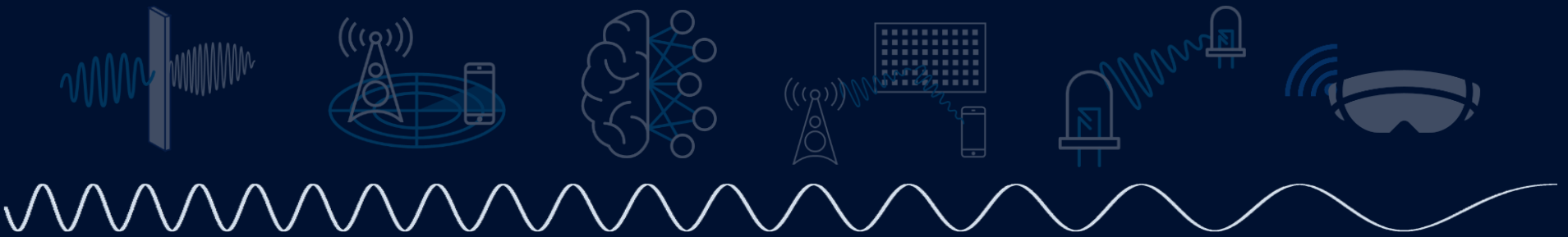

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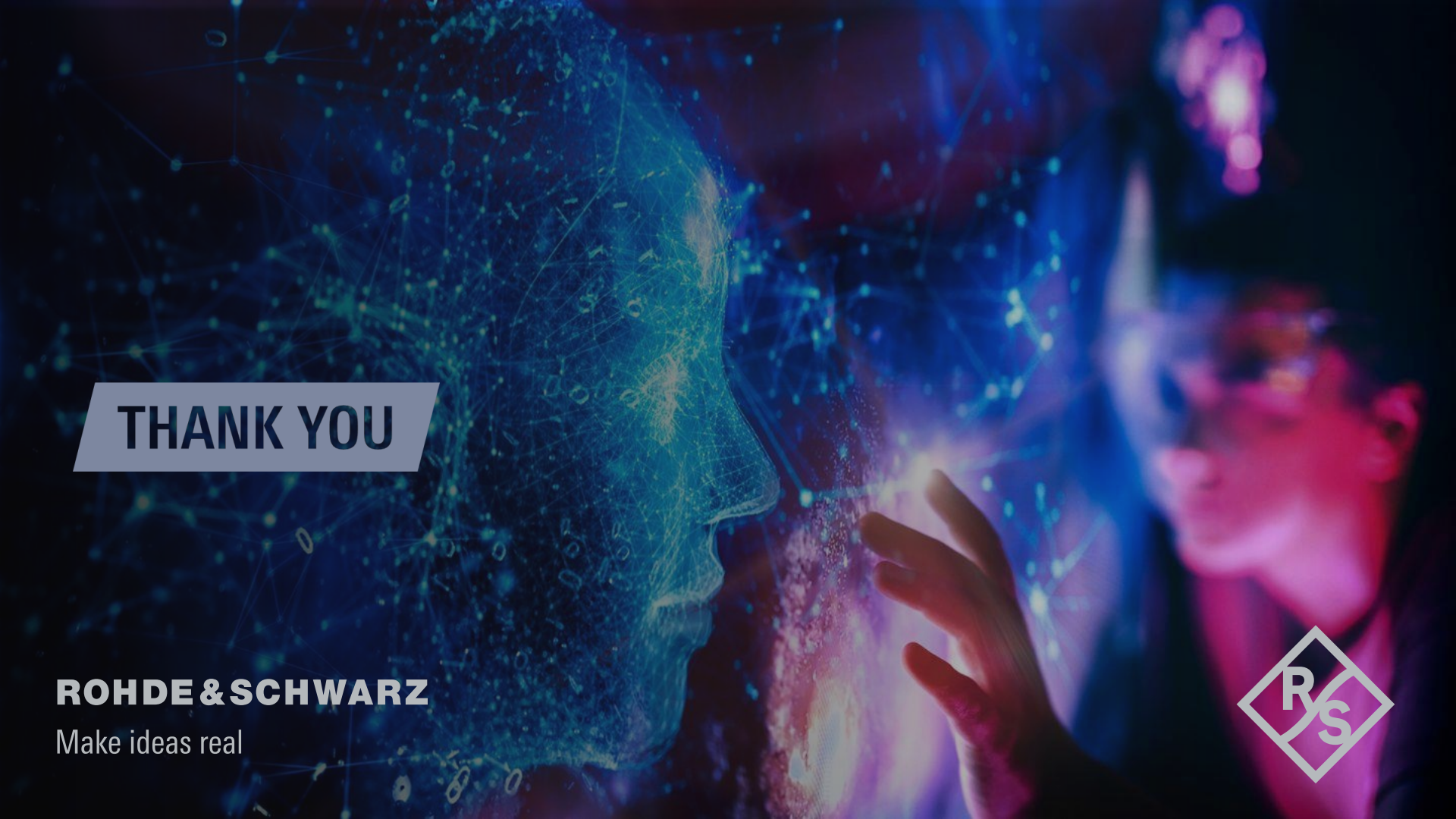
ROHDE & SCHWARZ SUPPORTS 6G RESEARCH GLOBALLY


THANK YOU
ROHDE&SCHWARZ
Make ideas real