6G TECHNOLOGY AND MARKET TREND

Lilei Wang, Technology Manager

ROHDE&SCHWARZ
Make ideas real

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AGENDA

- 5G Evolution and 6G Timeline
- 6G Research Areas
- World Wide 6G Activities & Co-Operations
- R&S Test Solutions

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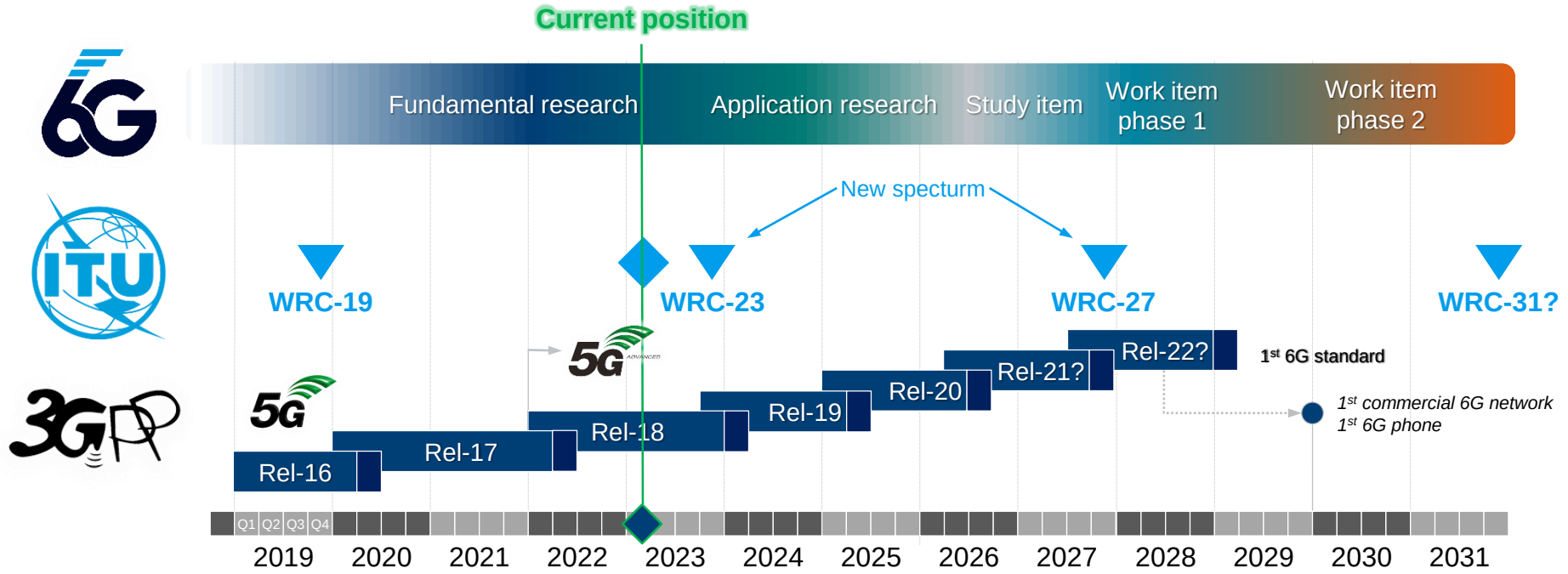
6G EVOLUTION



6G standardization/research may be progressed more quickly than expected

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USE CASES

6G application is highly extended to multiple domains

Immersive XR

Holographic

Intelligent interaction

Sensing

Digital Twin

Full coverage

Source: IMT-2030 whitepaper

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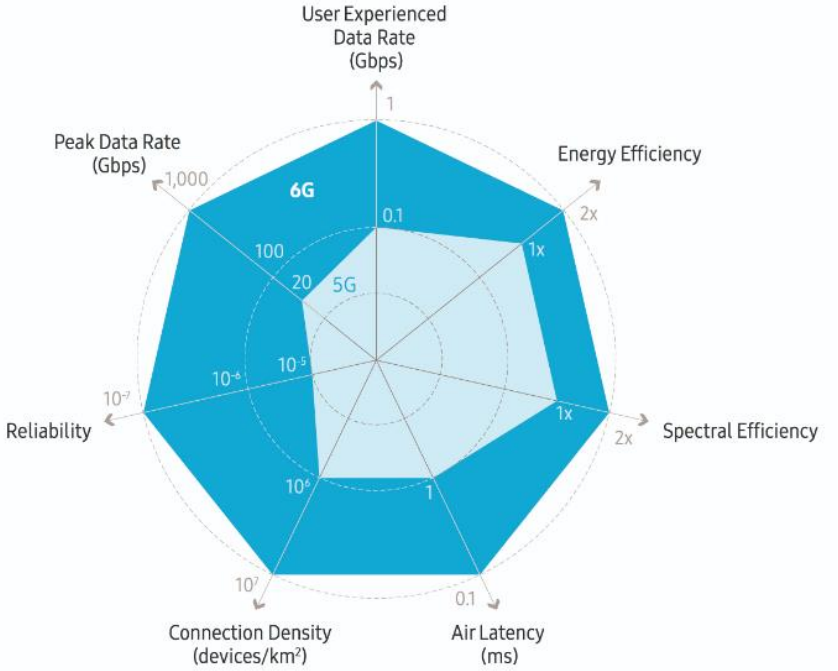
KEY PERFORMANCE REQUIREMENTS



Source: Samsung whitepaper

Key performance indicators (KPI)	5G	6G	Improvement factor
Peak data rate (in Gbps)	10	100 to 1000	10 to 100
User experienced data rate (in Gbps)	0.1	1 to 10	10 to 100
User plane latency (in ms)	1	0.1	10
Connection density (in devices/km²)	10^6	10^7 to 10^8	10 to 100
Reliability	99.999 %	99.99999 %	100
Energy efficiency	1 ×	5 × to 100 ×	5 to 100
Spectral efficiency	1 ×	2 ×	2
Positioning (in cm)	20 to 100 in 2D	1 in 3D	20 to 100
Jitter, i.e. latency variations (in µs)	–	0.1 to 1000	–

Source: R&S whitepaper

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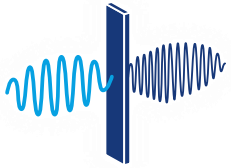
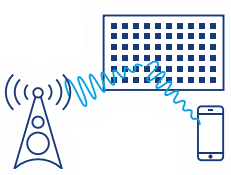
6G RESEARCH AREAS

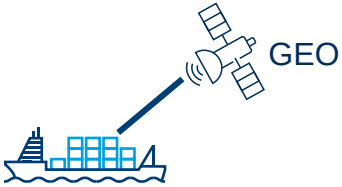


THz communication

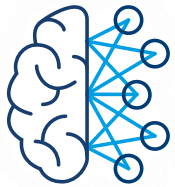
JCAS



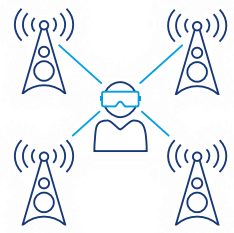
RIS



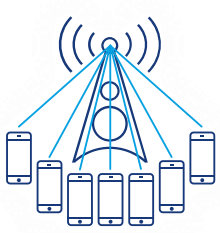
NTN



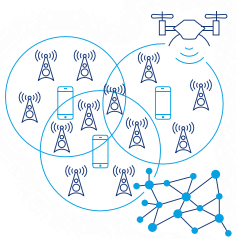
AI



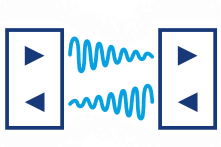
Extreme large-scale MIMO



Coding/modulation



Network topology



Full duplex

VLC

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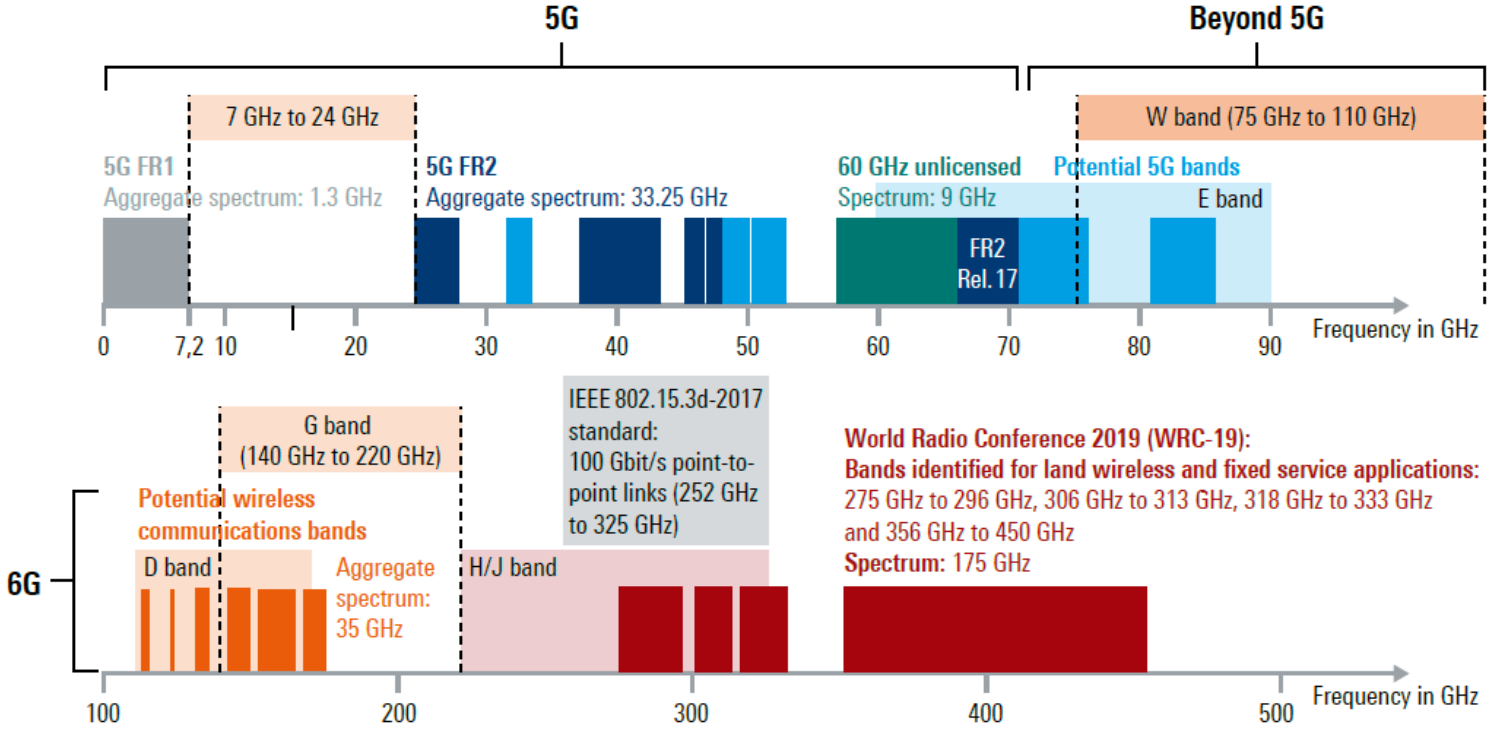
THZ - SPECTRUM

Usually 100GHz – 10THz is the range of THz spectrum and lower band is more prioritized



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THZ - SCENARIOS

Following is desirable scenarios but THz may be extended to more usages, like imaging

Backhaul/fronthaul links

- Ultra-high-speed communications
- Backhaul/fronthaul P2P connections
- Infrastructure in remote locations

Kiosk and intra-device communications

- Ultrafast download of prefixed content (e.g. UHD video, music) at specific locations (vending machines, train stations)
- Chip-to-chip communications

Wireless link in data centers

- Communications inside data centers: remote memory can increase design flexibility and reduce cost by extending CPU memory distance

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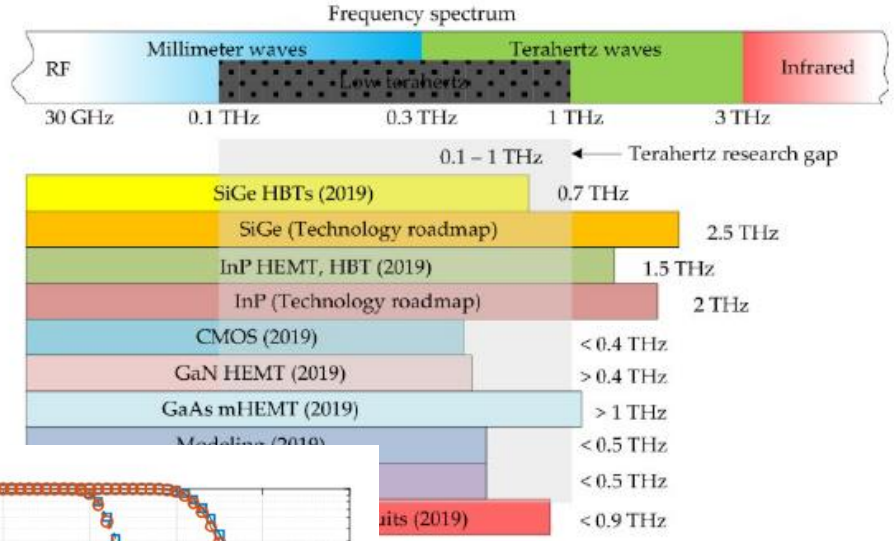
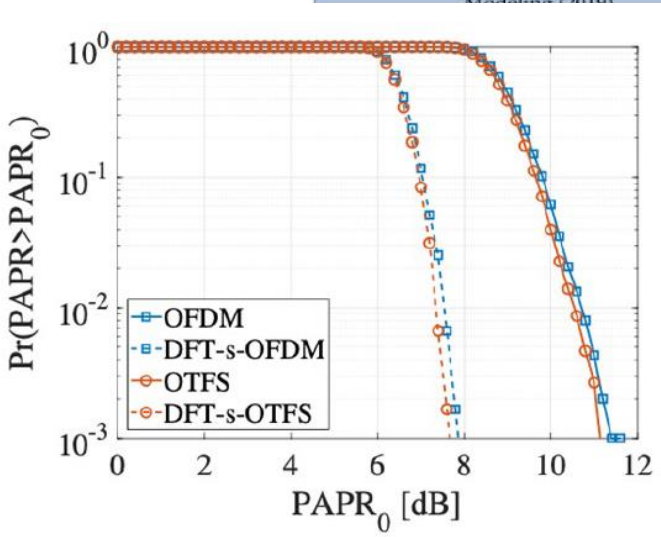
THZ- CHALLENGES

- Semi-conductor material
- Key component of transmitter and receiver
  - Mixer, multiplier, LNA and PA
- Modulation/Demodulation
- Waveform
- AD/DA
- MIMO/beam management
- Channel coding
- Channel modeling





Source: Whitepaper of IMT-2030

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DON’T FORGET “FR3”

- 6.1.6 Potential Spectrum bands for study
  - 6.1.6.1 UHF Band
    - 6.1.6.1.1 1300-1350 MHz
    - 6.1.6.1.2 1780-1850 MHz
  - 6.1.6.2 Lower-cmW spectrum
    - 6.1.6.2.1 3100-3450 MHz
    - 6.1.6.2.2 3980-4180 MHz (TBD)
    - 6.1.6.2.3 4400-4940 MHz
    - 6.1.6.2.4 7125-8500 MHz
  - 6.1.6.3 Upper-cmW spectrum
    - 6.1.6.3.1 10-10.5 GHz
    - 6.1.6.3.2 10.7-12.2
    - 6.1.6.3.3 12.2 – 12.7 GHz
    - 6.1.6.3.4 12.7-13.75 GHz
    - 6.1.6.3.5 13.75-15 GHz
    - 6.1.6.3.6 25.25-27.5 (TBD)
  - 6.1.6.4 EHF Band
    - 6.1.6.4.1 37.0-37.6 GHz
    - 6.1.6.4.2 42-43.5 (TBD)
    - 6.1.6.4.3 92-114.25 GHz (W-band) and 122.25-174.8 GHz (D-band):

Source: NEXT G ALLIANCE Spectrum Working Group

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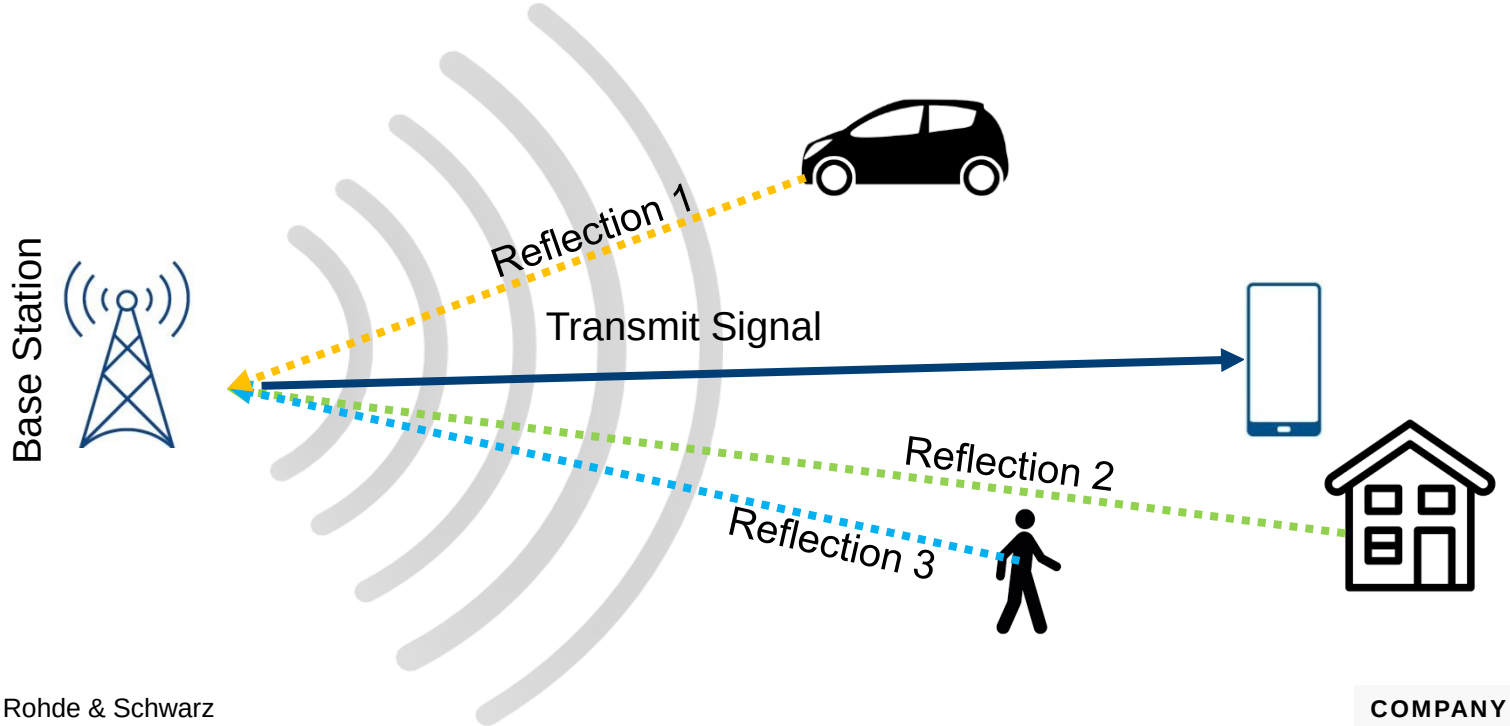
JCAS - CONCEPT

Base station or UE senses the objects (passive or active)



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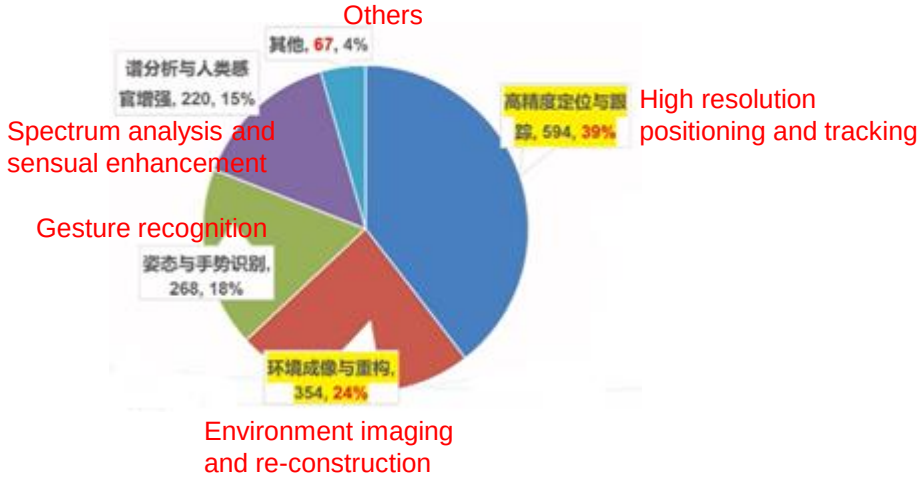
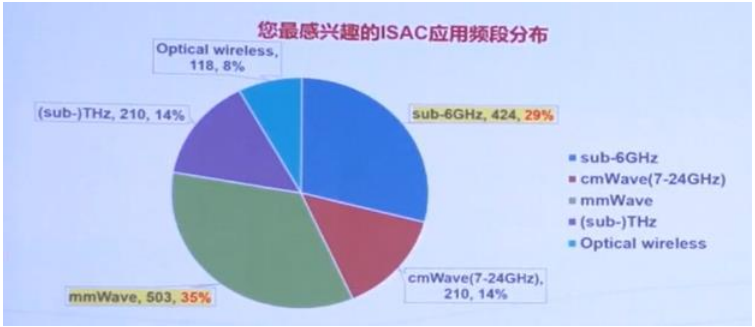
JCAS – USE CASE AND FREQUENCY





- Positioning and tracking is No.1 use case that people is interested in
- Transportation and UAV detection may be first scenario to be deployed

- mmWave frequency is more popular
- Sub-10GHz is also good frequency range for JCAS for coverage purpose

Source: JCAS forum held in Chengdu, China in 2022

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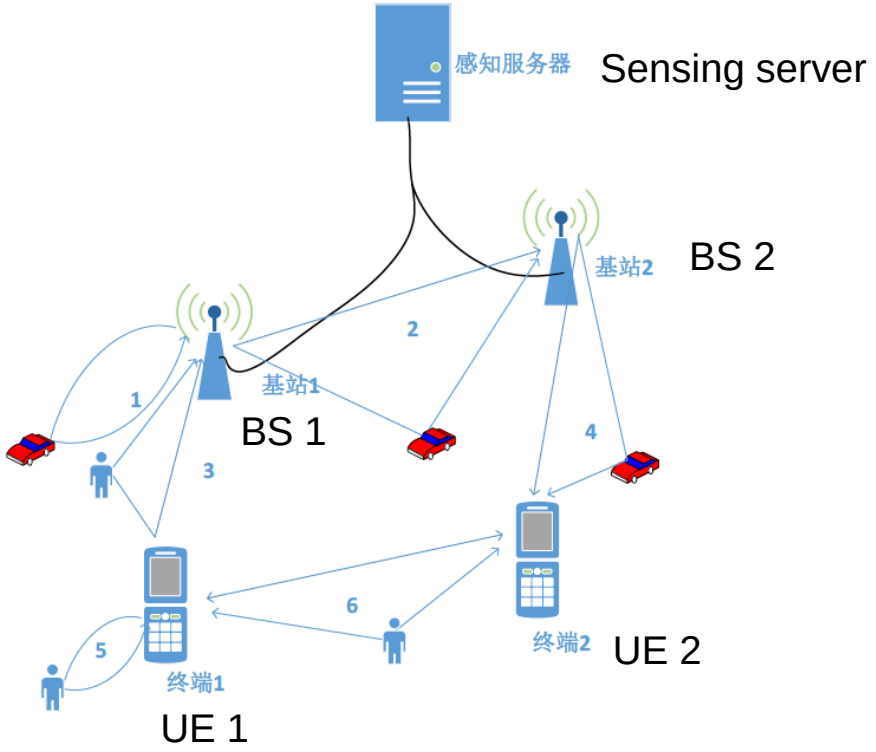
JCAS - CHALLENGES

- Air interface design
  - Waveform
  - Beamforming
  - Interference cancellation
  - Positioning
  - Sensing algorithm
- Architecture and networking design
- Hardware design
  - Full duplex issue
  - Isolation circuit
- Channel modeling



Source: IMT-2030 whitepaper

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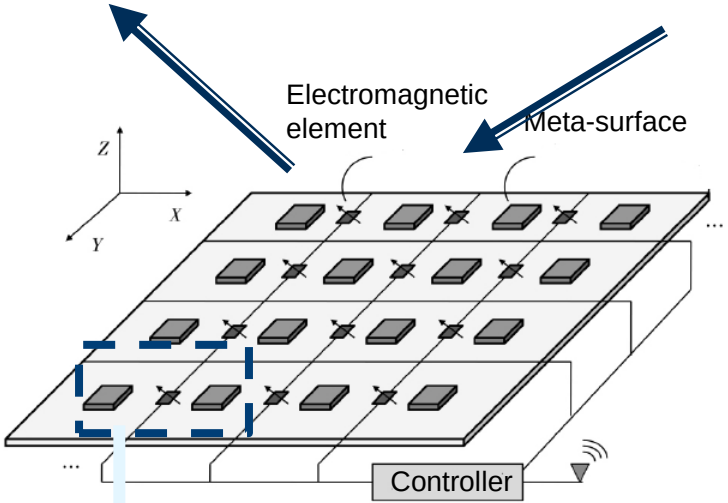
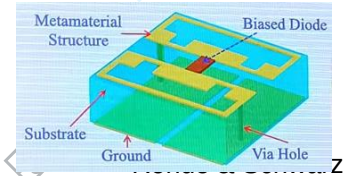
RIS - STRUCTURE AND SCENARIOS



Structure of RIS

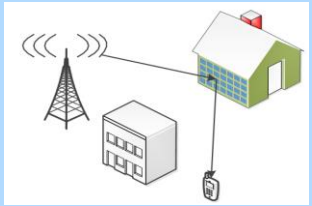


Source: CCSA

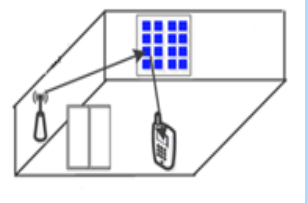
Scenarios

Popular scenarios

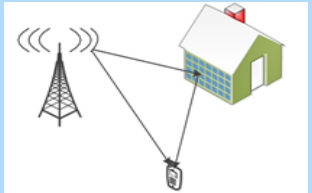
a) Blinding (outdoor)



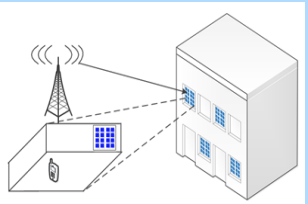
b) Blinding (Indoor)



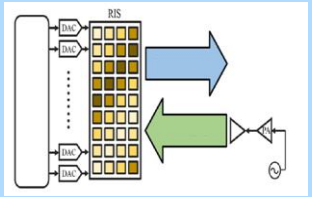
c) Rank increase



d) Transparent transmission



e) Radio enhancement



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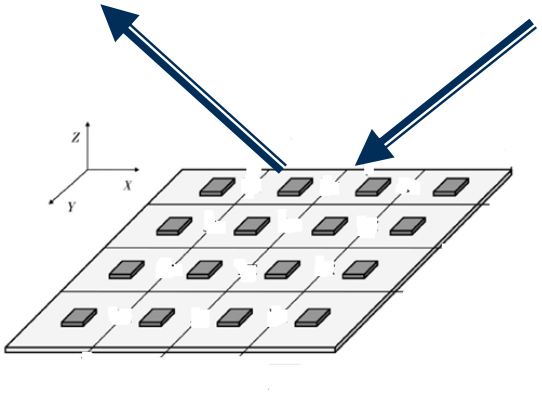
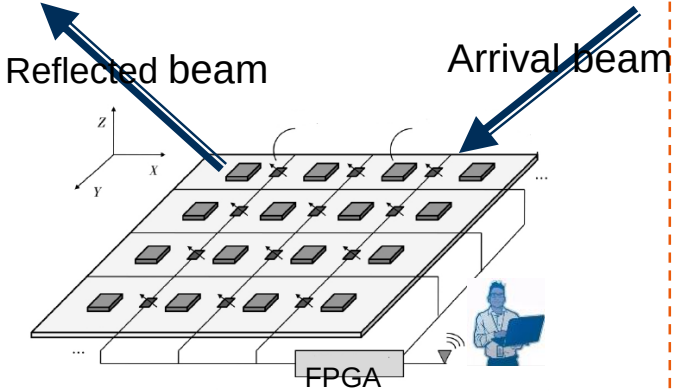
RIS TYPES

Available in the market



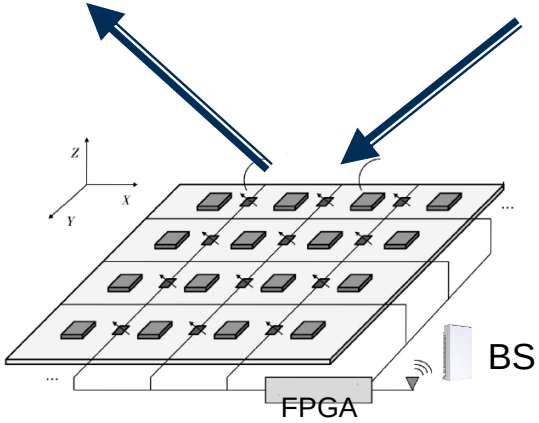
Passive RIS

	Description
Power	No
Control interface	No
Support SW	No



Passive/Hybrid RIS (manually controlled)

	Description
Power	<10 Watts
Control interface	RS485/Ethernet
Support SW	FPGA related, User interface



Passive/Hybrid RIS (controlled by BS)

	Description
Power	< 20 Watts
Control interface	Fiber or Uu like
Support SW	Radio/BB SW, interface of RIS

Note: may need standard work

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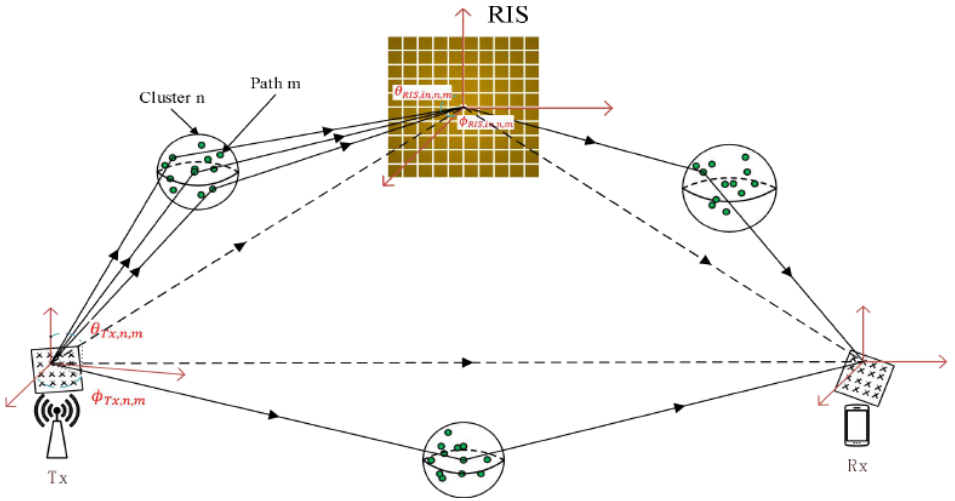
RIS - CHALLENGES

- Hardware/material
- Protocol design (dynamically control RIS)
- RF performance
- Architecture and networking
- Channel modeling
- Engineering issue (like deployment, power supply)



Channel modeling (from whitepaper published by RISTA)

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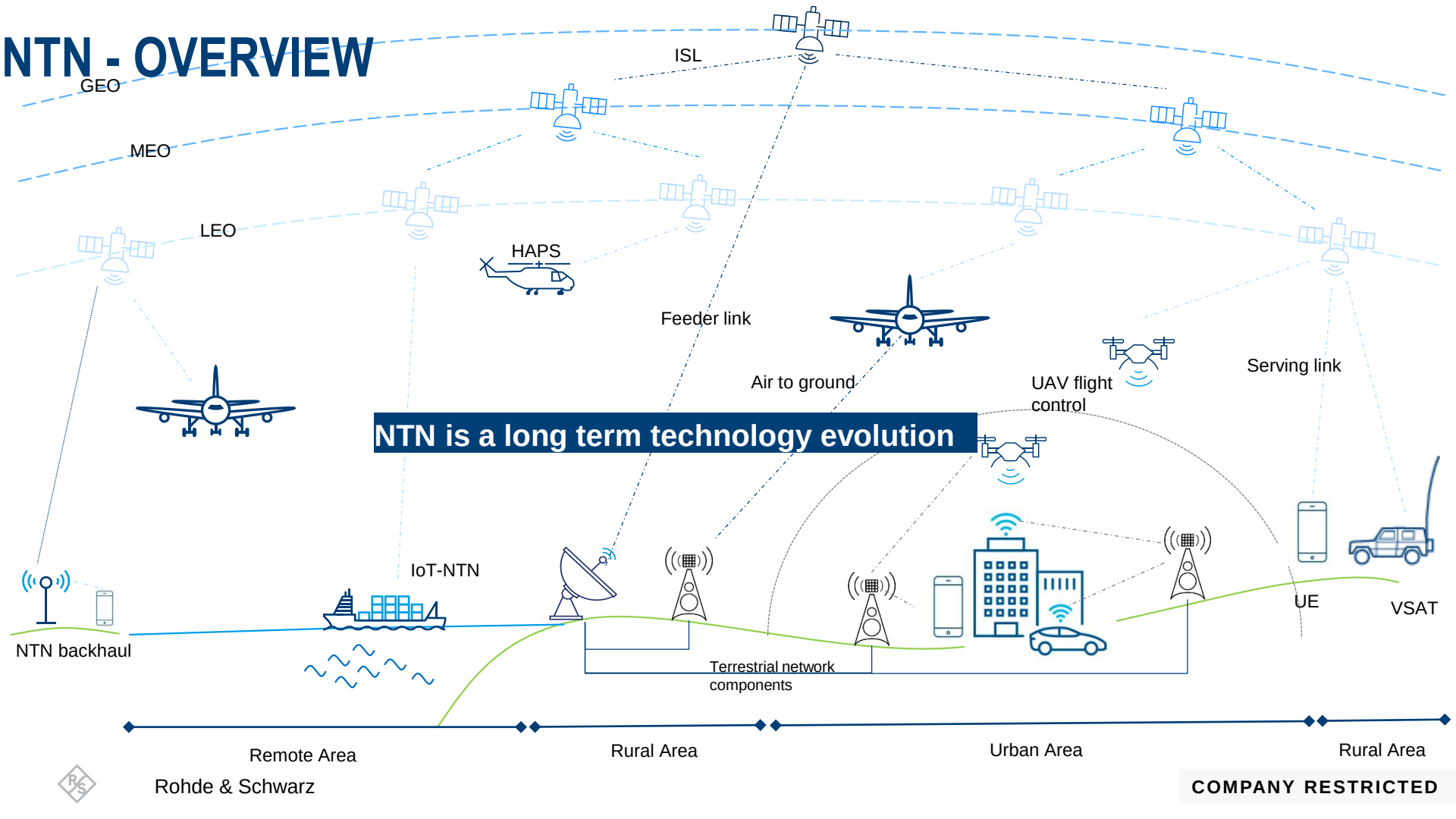
NTN - OVERVIEW



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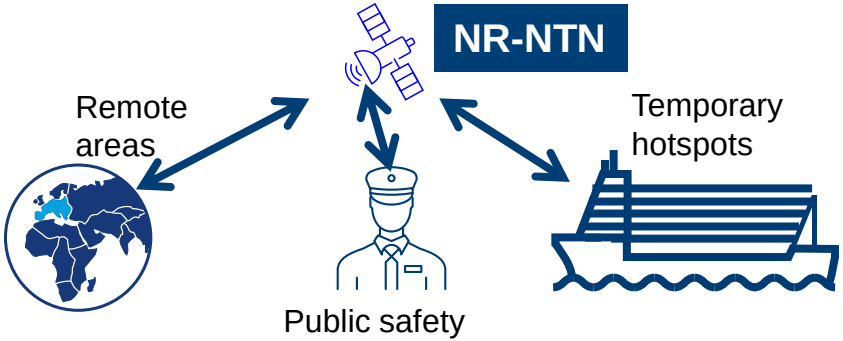
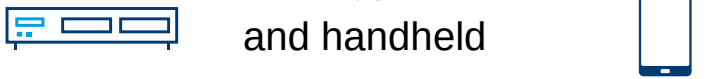
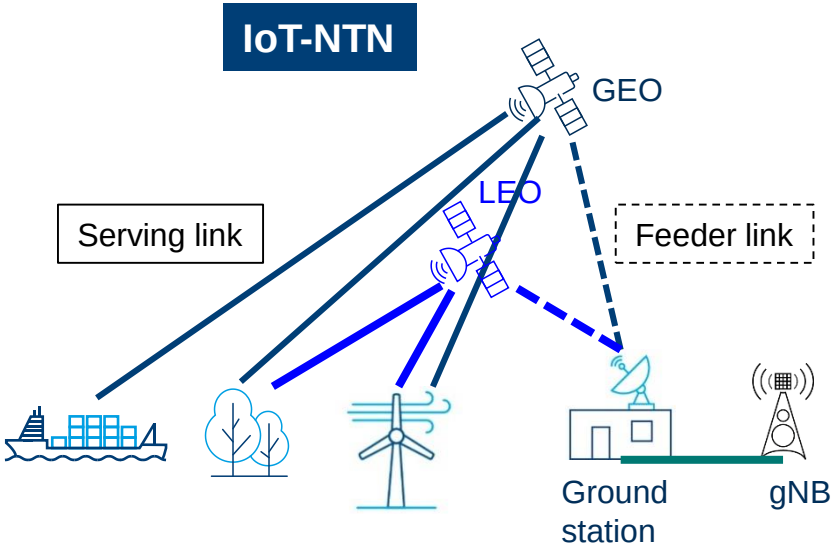
NTN - TWO FACETS





5G NR over satellite: Major use case = extending coverage.
Note: Throughput and latency will always be higher and faster in terrestrial 5G ☺



IoT over satellite: Major use case = ubiquituous connectivity.
Low complexity UE, best effort QoS

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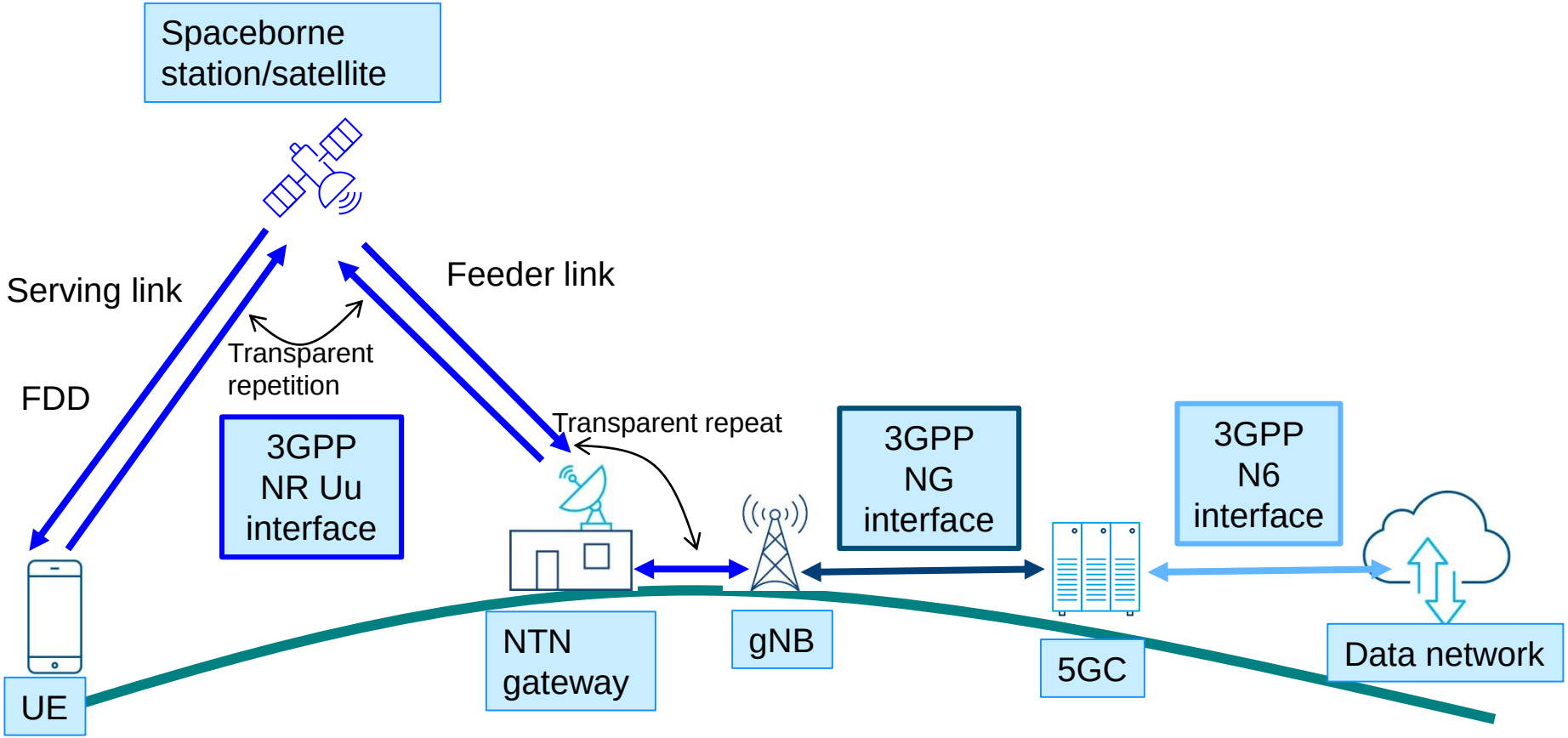
NTN - TRANSPARENT MODE ARCHITECTURE



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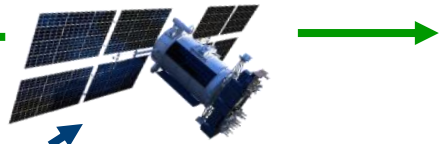
NTN - CHALLENGES

Doppler shift due to UE and/or gNB mobility => use location/orbit info to compensate Doppler

Long delay:
no perfect
channel info (CSI)

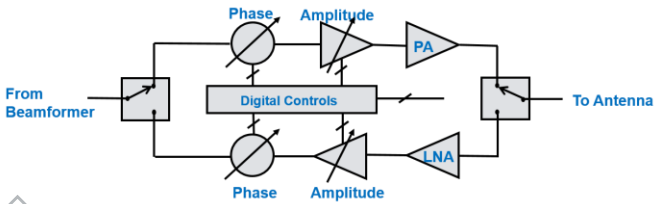
UL&DL beam adjustment

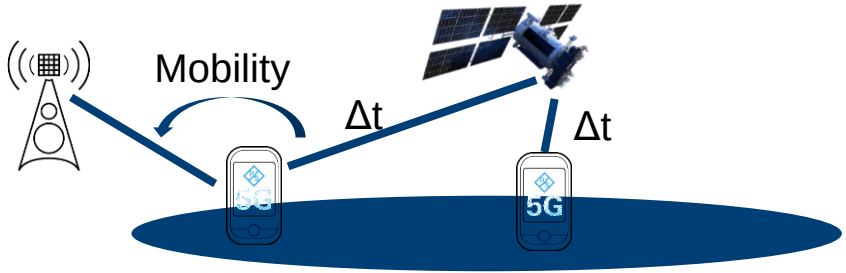


Free space path loss and link budget
=> compensation: beamforming + TX power

Delay, e.g. RTT for GEO satellites ~544ms (note: NR max RTT = 2ms)
=> Counter with timing advance strategies

Carrier frequency offset





Large cell sizes: Round-trip(RTT) time delay spread

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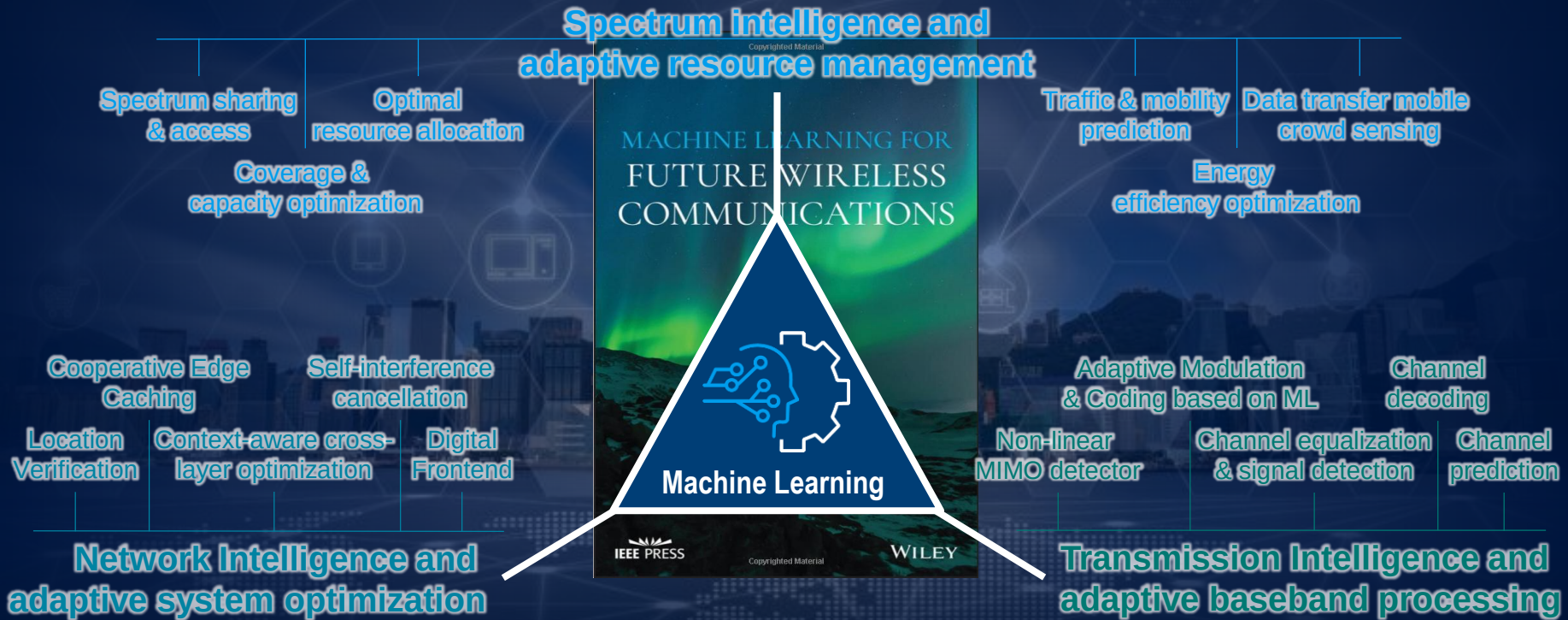
AI – APPLICATION AREA



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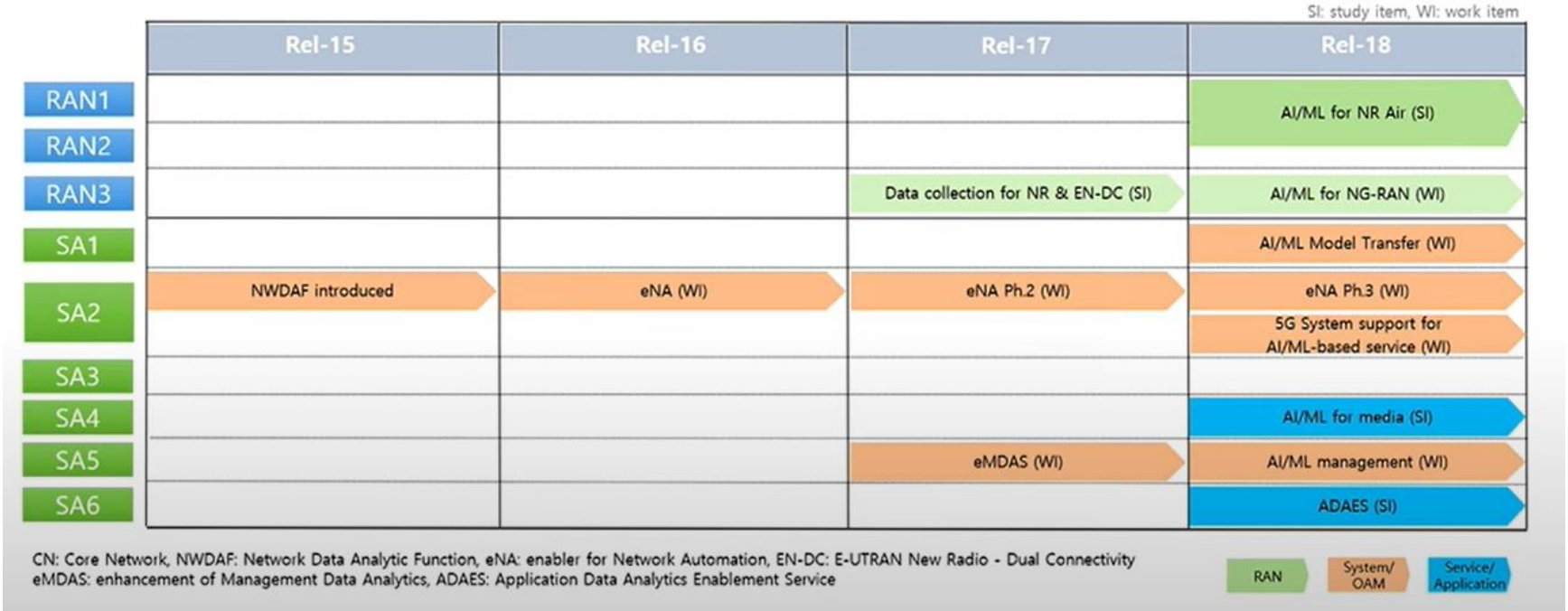
AI - STANDARDIZATION STATUS IN 3GPP



Source: Samsung 6G forum

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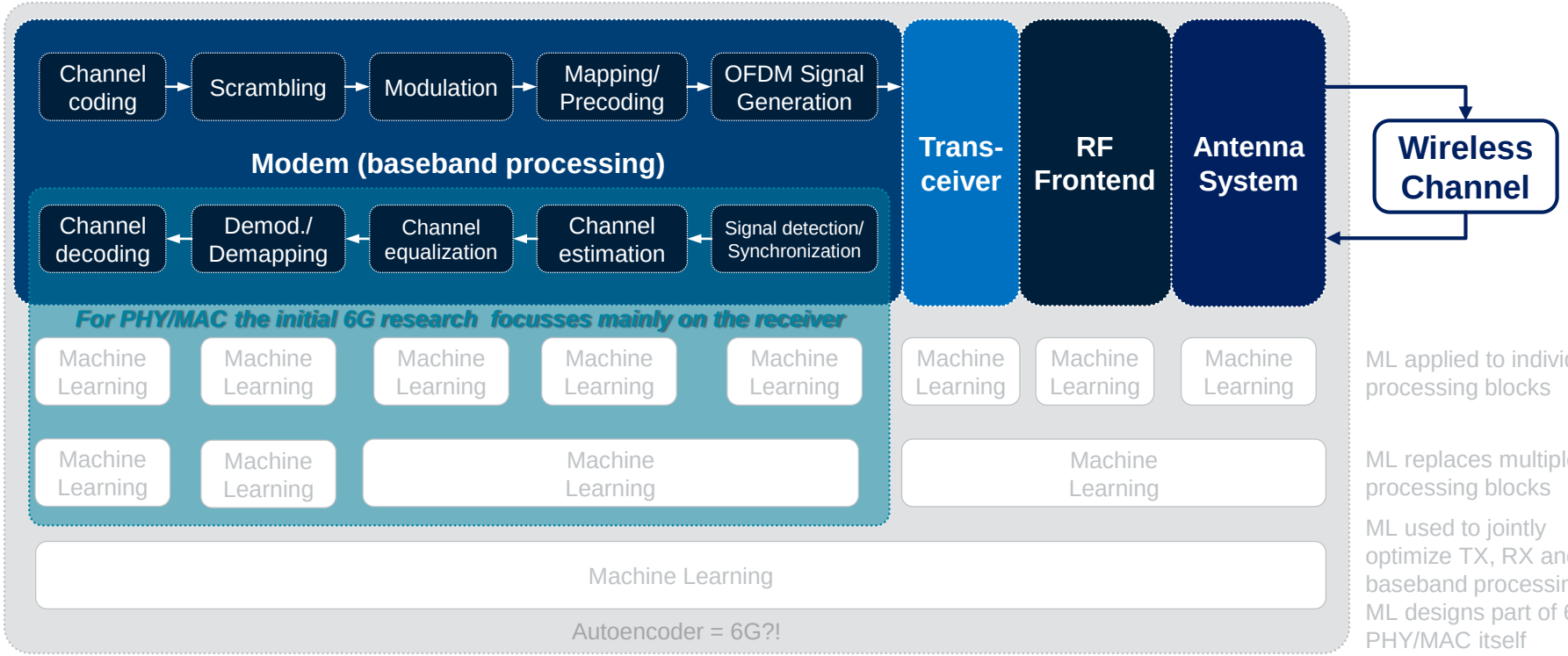
AI – APPLICATION FOR RADIO/BASEBAND



ML applied to individual processing blocks

ML replaces multiple processing blocks

ML used to jointly optimize TX, RX and baseband processing; ML designs part of 6G PHY/MAC itself

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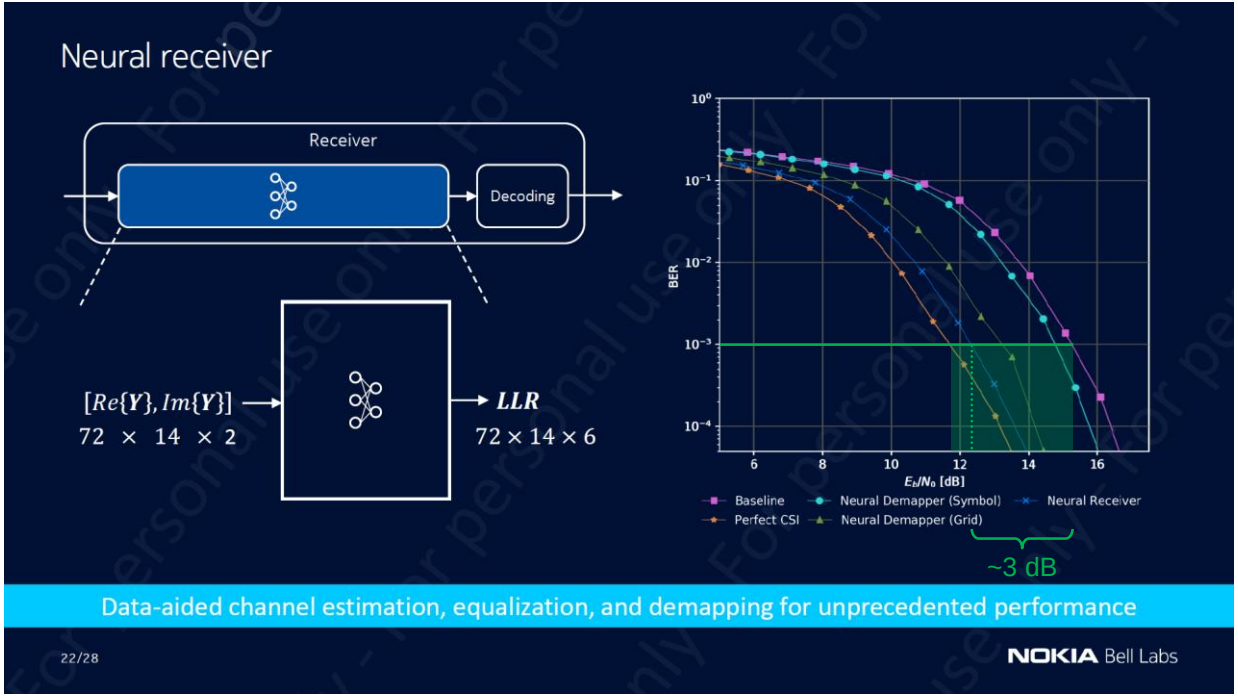
AI – HELPING CHANNEL ESTIMATION



Source: https://aiforgood.itu.int/events/the-road-towards-an-ai-native-air-interface-for-6g/ [Nov 2020]

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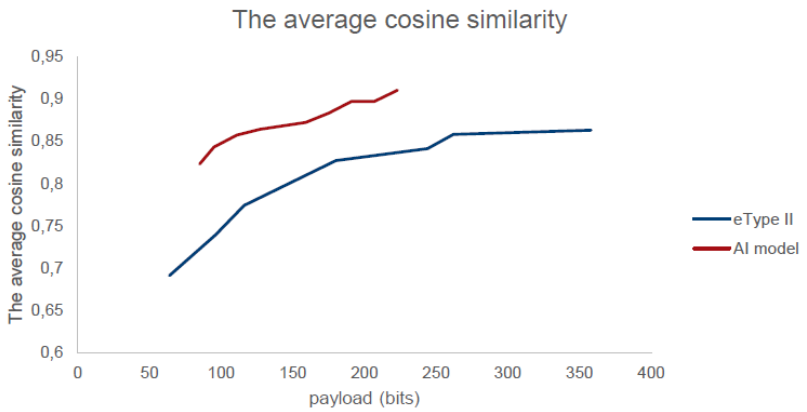
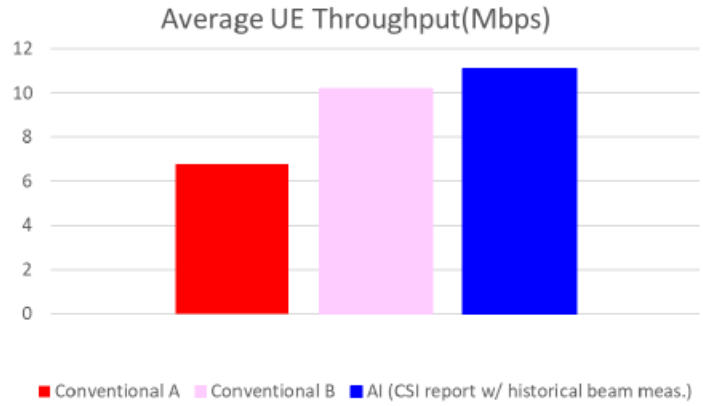
AI – HELPING CSI COMPRESSION, BEAM MANAGEMENT AND POSITIONING





LOS	Positioning Accuracy @90%
Baseline LOS	6.447m
AI/ML LOS	0.353m

Source: above results are from RAN1 contributions of VIVO, NTT DCM and Huawei, respectively

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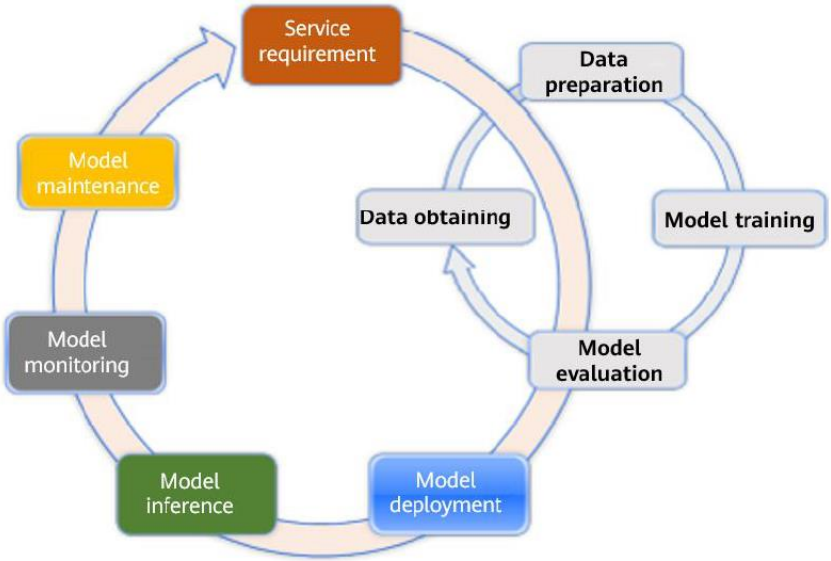
AI - CHALLENGES

- AI model lifecycle management
  - Signalling procedure, RAN functions
- Computing resources
  - May impact existing hardware design
  - Issue of power consumption, complexity for devices
- Dataset construction
- AI model generalization
- Network architecture
- Trustiness/security



Source: 6GANA whitepapers

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- World Wide 6G Activities & Co-Operations
- R&S Test Solutions

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COOPERATION BETWEEN R&S AND 6G BODIES

R&S closely cooperates with different standardization bodies in the world

Academia & research institutes

RWTH AACHEN UNIVERSITY

Fraunhofer HHI

Deutsches Forschungszentrum für Künstliche Intelligenz GmbH

TECHNISCHE UNIVERSITÄT DRESDEN

Technische Universität München

6G FLAGSHIP

5G Lab GERMANY

TECHNISCHE UNIVERSITÄT DRESDEN

Fraunhofer IAF

ihp innovations for high performance microelectronics

Bundesministerium für Bildung und Forschung

6GKOM

6G @ UT

CHALMERS UNIVERSITY OF TECHNOLOGY

Industry alliances &Standardization body

ETSI

ITU

NGMN

3GPP

IEEE Advancing Technology for Humanity

中国通信标准化协会 China Communications Standards Association

Thinknet 6G

IMT-2030 Promotion Group 6G

未来移动通信论坛 FUTURE MOBILE COMMUNICATION FORUM

Metaverse STANDARDS FORUM

NEXT G ALLIANCE

6GANA

RISTA RIS TECH ALLIANCE

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EUROPE

R&S is actively involved in different 6G projects funded by BMBF in Germany

Bundesministerium
für Bildung
und Forschung

[This Link provides more information]

6G-ANNA

Ganzheitliche Ansätze für Mobilfunknetze der 6. Generation

6G-TakeOff

Holistische 3D-Kommunikationsnetze für 6G

6G-LICRIS

Rekonfigurierbare Oberflächen erweitern 6G-Netzabdeckung

6G-TERAKOM

Schlüsselkomponenten der Terahertz-Kommunik
Generation

6G-ADLANTIK

Laser-Architekturen zur Nutzbarmachung des Terahertz-Frequenzbereichs für die 6G-Kommunikation

KOMSENS-6G

Perzeptive Kommunikationsnetzwerke mit integrierter Funk-Sensorik für die 6. Generation des Mobilfunks

Perzeptive und sensorische Kommunik
im automatisierten Fahren oder in der

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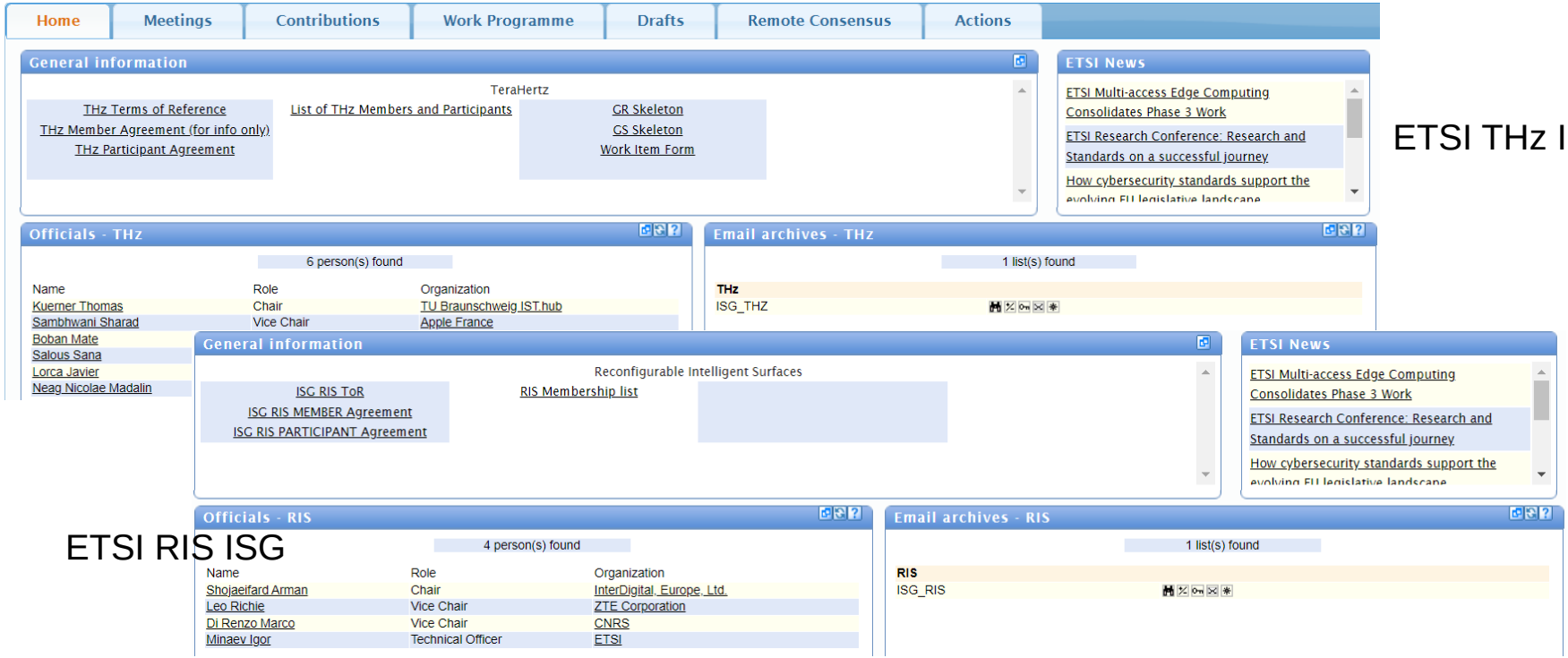
R&S is actively involved in ETSI 6G standardization

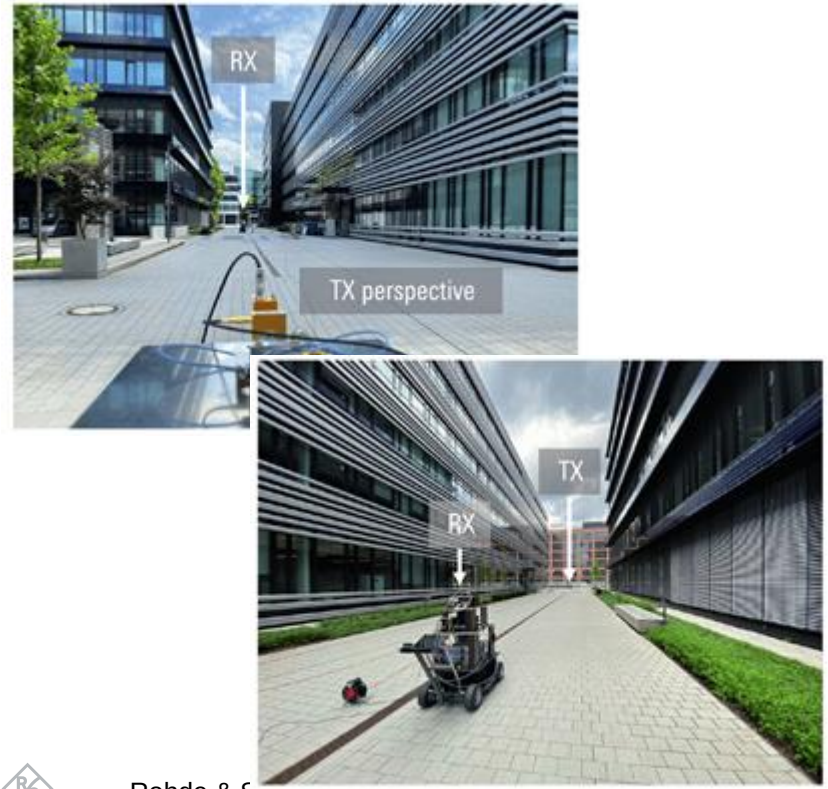


ETSI THz ISG

ETSI RIS ISG

EUROPE

R&S is consistently contributing to ITU standardization



Munich / 11-Jan-2023

Rohde & Schwarz drives 6G with sub-THz channel propagation measurements

The development of sub-THz communications as envisioned for 6G will only be possible with a solid understanding of the properties of electromagnetic wave propagation. The new frequency range between 100 GHz and 330 GHz gains worldwide interest and thus has been the focus of recent Rohde & Schwarz measurement campaigns. The company's findings have contributed to the report of the ITU-R Working Party 5D (W5PD), which will provide information to the International Telecommunication Union (ITU) World Radio Conference 2023, where frequency bands beyond 100 GHz are expected to be discussed and considered for allocation.

US

Rohde & Schwarz and FormFactor support the University of Texas at Austin in research on improved RF switches for 5G and 6G

The R&S ZNA connected to R&S ZC170 frequency extenders allows S-parameter measurements in the D-band. (Image: Rohde & Schwarz)

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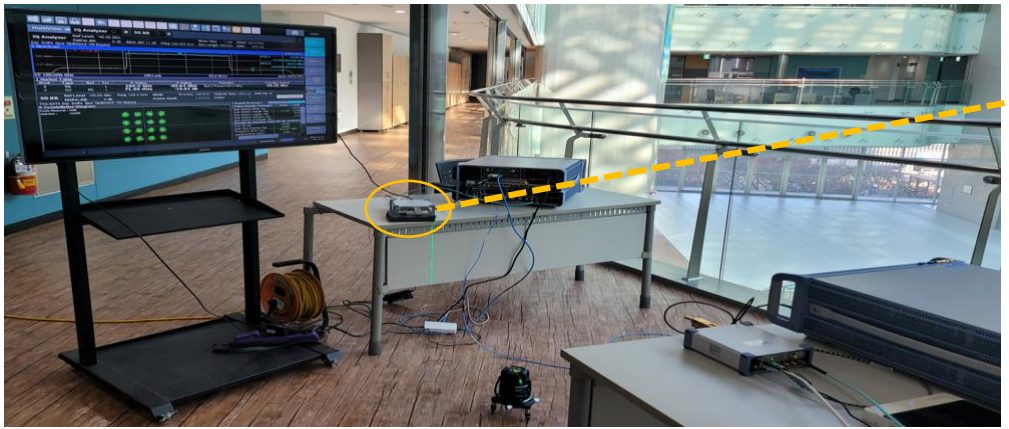
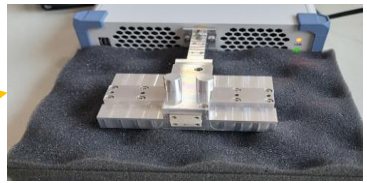
KOREA

R&S closely cooperates with partners (e.g., KAIST, ETRI, KRISS) to test D-band/G-band THz based on up/down frequency converters & signal generator/analyzer





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JAPAN

R&S closely cooperates with partners (e.g., DCM) to test mmWave/THz

Tokyo and Munich / 27-Nov-2018

DOCOMO and Rohde & Schwarz cooperate in pioneering beyond 5G with frequency bands up to 150 GHz

NTT DOCOMO INC. and Rohde & Schwarz have joined forces to set up the world's first ultra-wideband channel sounder for mobile communications exceeding 100 GHz. They conducted radio wave propagation experiments at frequencies up to 150 GHz. The frequency bands from 100 GHz to 300 GHz are expected to enable further high-speed and large-capacity communication for the next generation beyond 5G.

DOCOMO and Rohde & Schwarz cooperate in pioneering beyond 5G with frequency bands up to 150 GHz | Rohde & Schwarz (rohde-schwarz.com)

CHINA

R&S cooperates with partners on 6G topics like JCAS, RIS and THz

Rohde & Schwarz and China Mobile Research Institute collaborate on 6G JCAS research and early validation

The China Mobile Research Institute and Rohde & Schwarz have joined forces to research and validate joint communication and sensing (JCAS). They plan to use the latest R&S AREG800A automotive radar echo generator from Rohde & Schwarz as an object simulator in a JCAS testing solution, thereby accelerating the research and development of JCAS and readying it for industrialization.

RIS tests with partners

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TAIWAN

R&S cooperates with partners to verify 6G technologies

MediaTek Powers World's First Satellite 5G NTN Smartphone Communication

MediaTek's collaboration with Rohde & Schwarz demonstrates the potential of 5G NTN technology to bring fast and reliable 5G connectivity everywhere via satellite

Aug 16, 2022 - 9:00 PM

HSINCHU, Taiwan – August 16, 2022 – MediaTek reached a new 5G milestone by powering a smartphone with a 5G Non-Terrestrial Network (NTN) connection in a lab environment for the first time. Through a transfer of data to ITRI's Next Generation NodeB network (gNB) test over a Low Earth Orbit (LEO) satellite channel emulated in collaboration with Rohde &

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AGENDA

- 5G Evolution and 6G Timeline
- 6G Research Areas
- World Wide 6G Activities & Co-Operations
- R&S Test Solutions

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THZ CONVERTER

R&S has released a series of THz converters (right) to match different instrument (left)

Signal generator/Analyzer

Up to 170GHz now but higher frequency converter is under plan

RPG FS-Zxx Harmonic mixers (up to 325GHz)

Network analyzer

R&S®ZCxxx millimeterwave converters (Up to 1THz)

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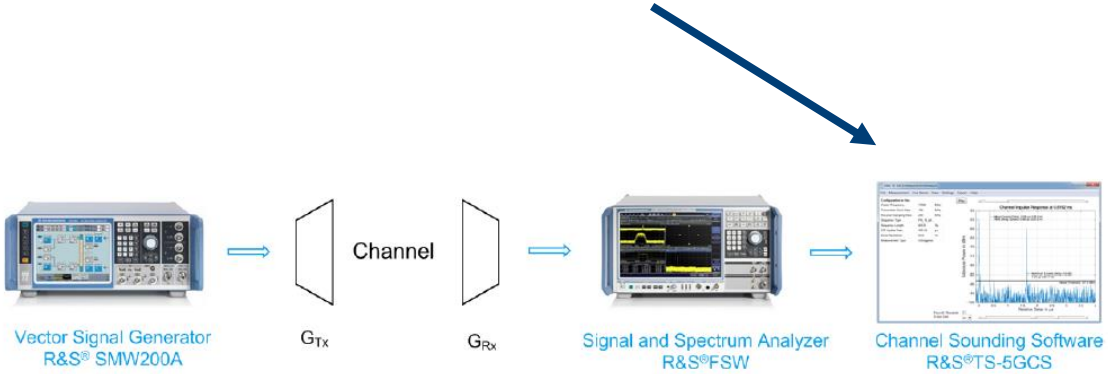
THZ CHAMBER/CHANNEL SOUNDING

D-band based OTA test chamber

R&S TS-5GCS is a software tool to do channel sounding



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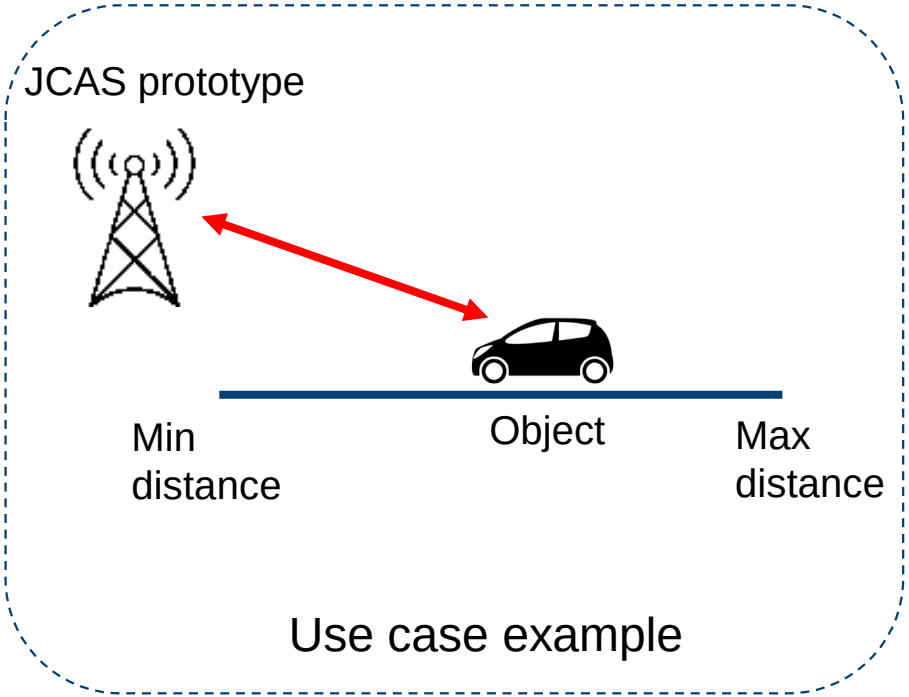
JCAS

Object simulator is available and improvement for JCAS test is ongoing

AREG800A



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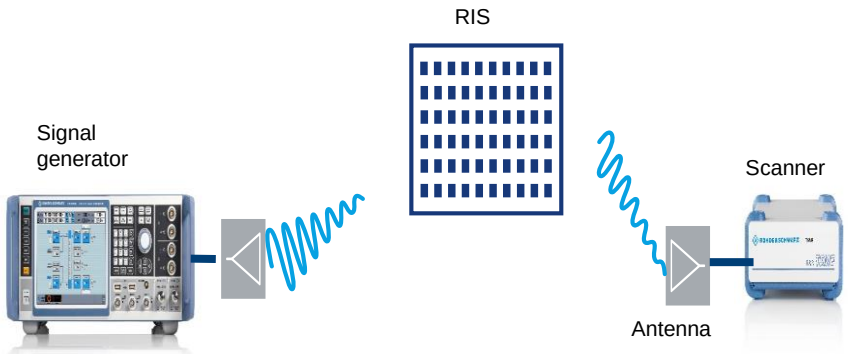
RIS

Part of existing instruments are available to test basic RIS performance while other test solutions like chamber are under optimization



Available to test RSRP like performance

ATS1800M like chamber

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RIS

3D measurement chamber prototype

Feed signal generation
e.g. R&S®SMW200A
vector signal generator

Feed path

SGH
e.g. R&S TC-SGH40

e.g. R&S TC-TA85CP
Probe

Measurements
e.g. R&S®FSW signal
and spectrum analyzer

Elevation measurement range
according to RIS configuration

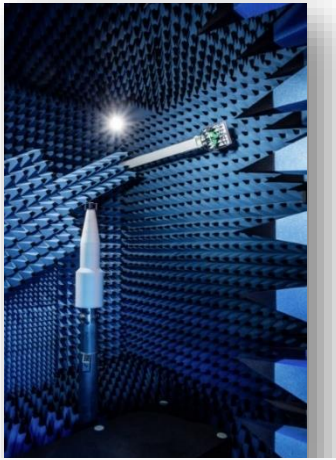
Measurement SW: e.g. R&S®AMS32

Incident angle

RIS under test

Turn table

WPTC like chamber



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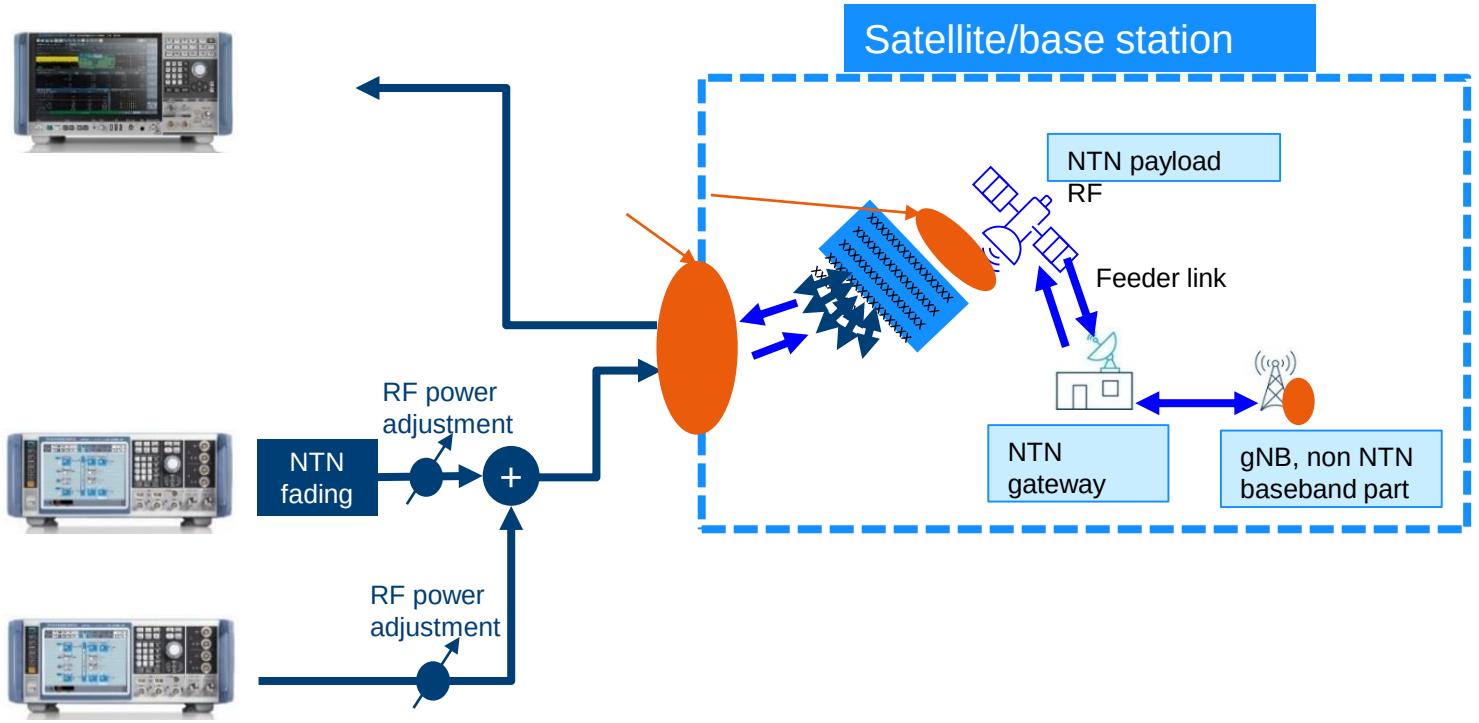
NTN

Feasible to use existing signal generator/analyzer to test RF performance of satellite or UE



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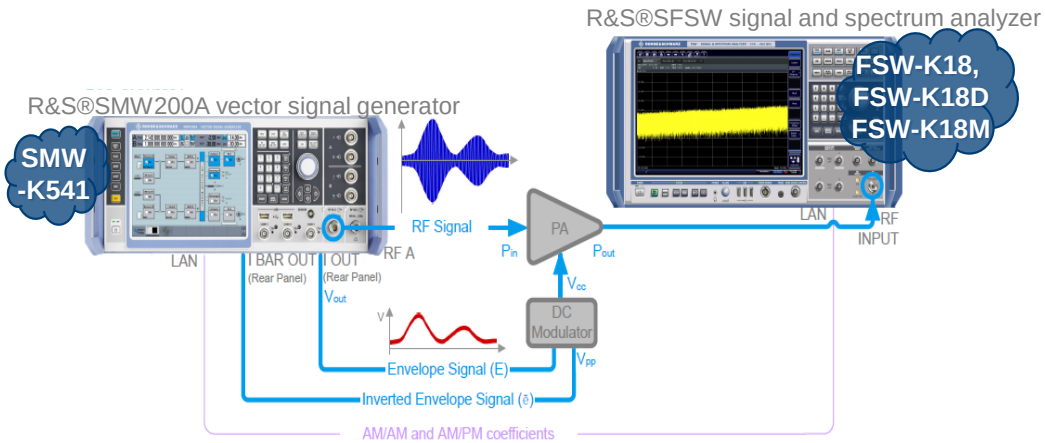
AI

Development of T&M solutions on supporting AI/ML research is ongoing



DPD optimization

Neural receiver to improve UL MU-MIMO performance (demo at Barcelona MWC 2023)

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6G CLASSROOM

R&S shows viewpoints on 6G topics in public media

#Think Six - Is it time for wireless communication to get smart(er) with AI/ML? Part 1.

This video introduces the background theory and terminology of AI and ML.

#ThinkSix - Spectrum for 6G

This video runs through the frequencies from 7.125 GHz to 24.25 GHz, highlighting the bands with the maximum potential for next-generation wireless services.

#Think Six - Which new spectrum for 6G? A practical review

Based on a need for available spectrum and experiment licenses, this video explains the reasons for candidate frequencies for fundamental 6G research in the D band (110-

#Think Six - Channel measurements in the D-band

High frequencies completely new to mobile radio mean that researching channel characteristics to determine the effects on transmitted signals of propogation delays re-

https://www.rohde-schwarz.com/us/solutions/test-and-measurement/wireless-communication/cellular-standards/6g/6g-overview_253278.html

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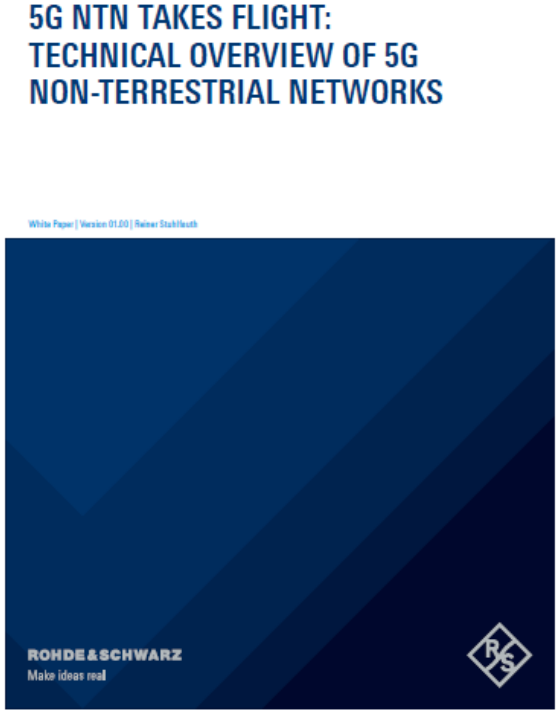
6G WHITEPAPERS



R&S published NTN and THz whitepapers

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SEE YOU SOON

R&S is planning to show 6G demos

Welcome to visit our booth!

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Thank you
very much
ROHDE&SCHWARZ
Make ideas real
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