R&S 6G TRIALS AND TEST SOLUTIONS

Lilei Wang, Technology Manager

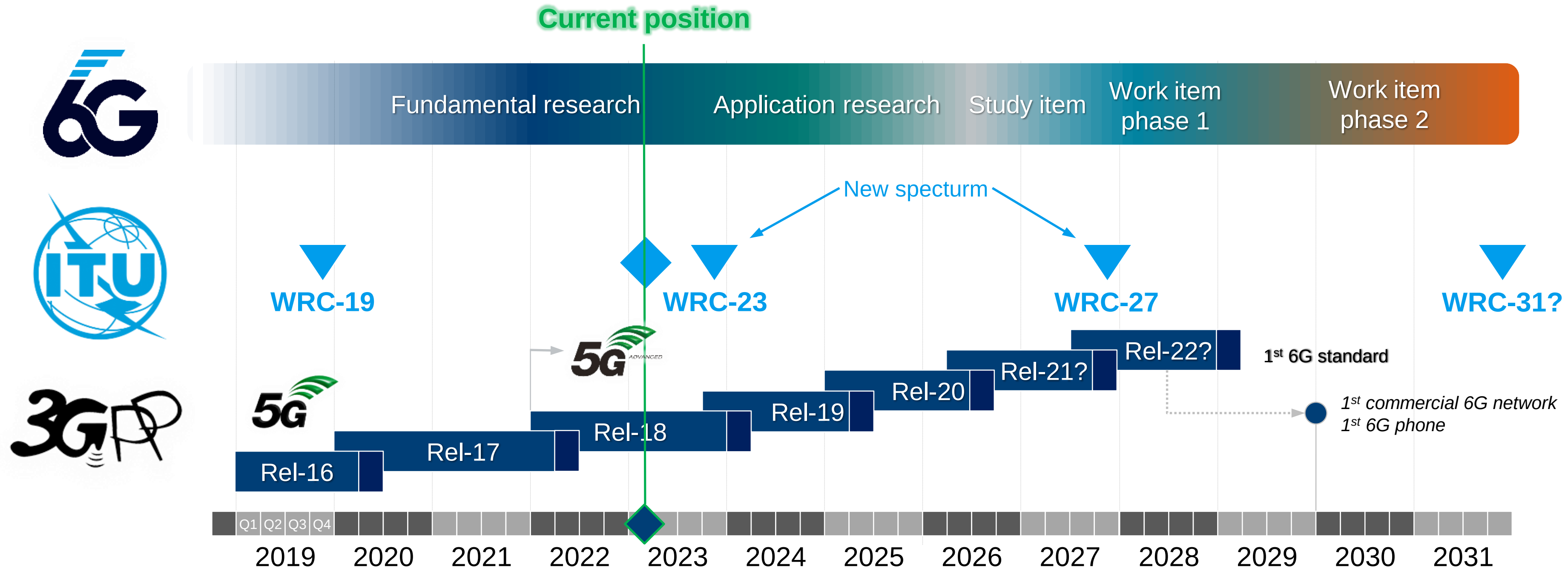
ROHDE&SCHWARZ

Make ideas real

AGENDA

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

6G EVOLUTION



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

USE CASES

6G application is highly extended to multiple domains

Immersive XR

Holographic

Intelligent interaction

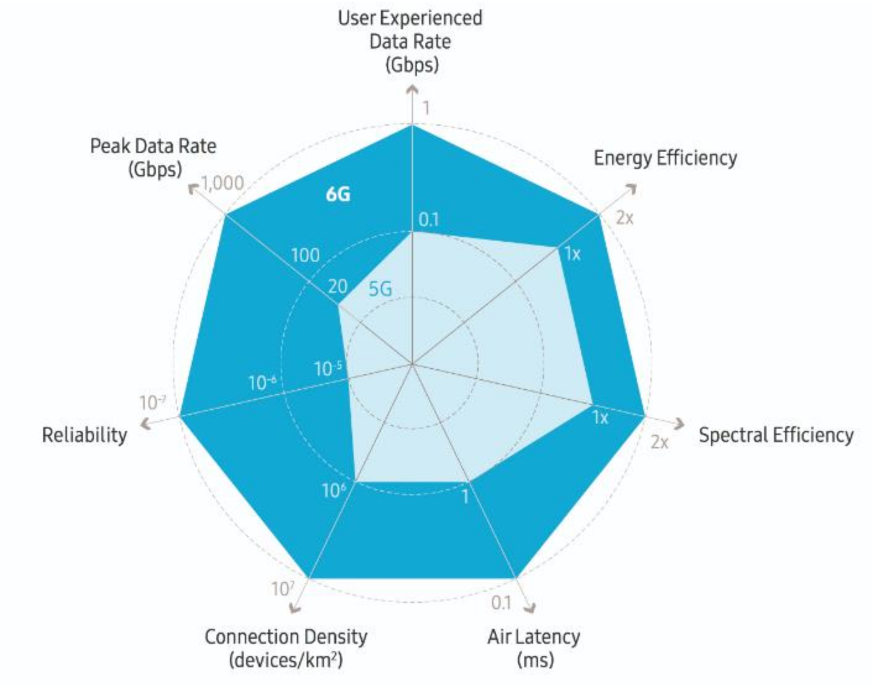
Sensing

Digital Twin

Full coverage

Source: IMT-2030 whitepaper

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/km^2)	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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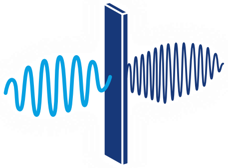
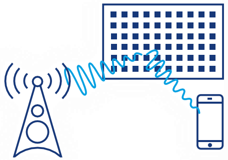
6G RESEARCH AREAS

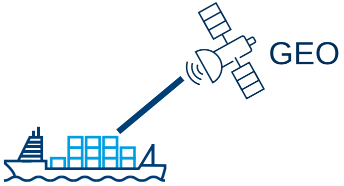


THz communication

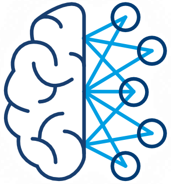
JCAS



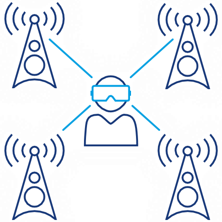
RIS



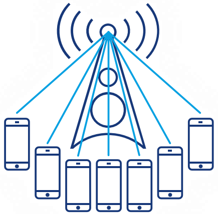
NTN



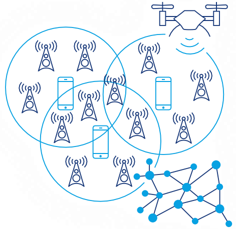
AI



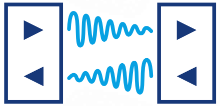
Extreme large-scale MIMO



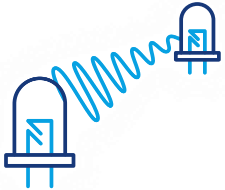
Coding/modulation



Network topology



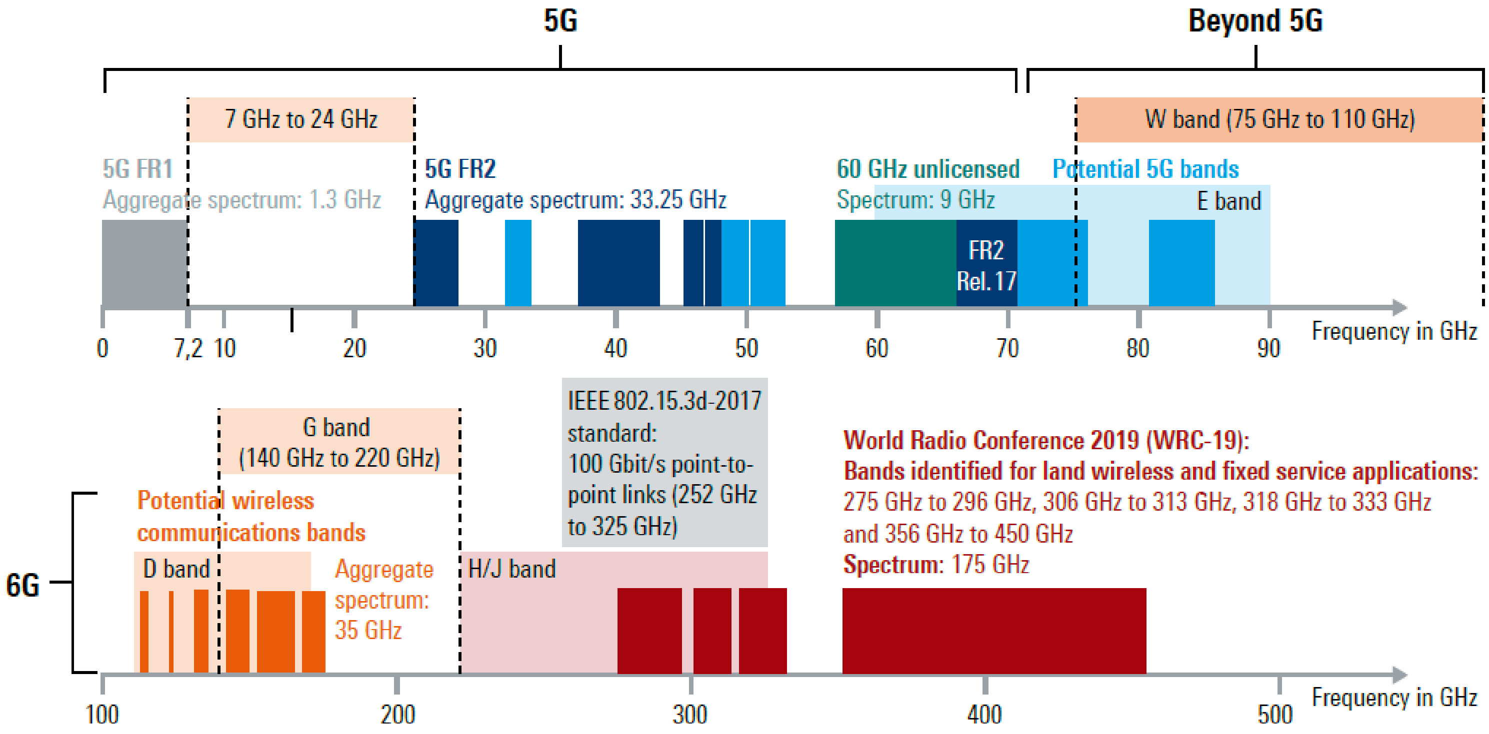
Full duplex



VLC

THZ - SPECTRUM

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



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

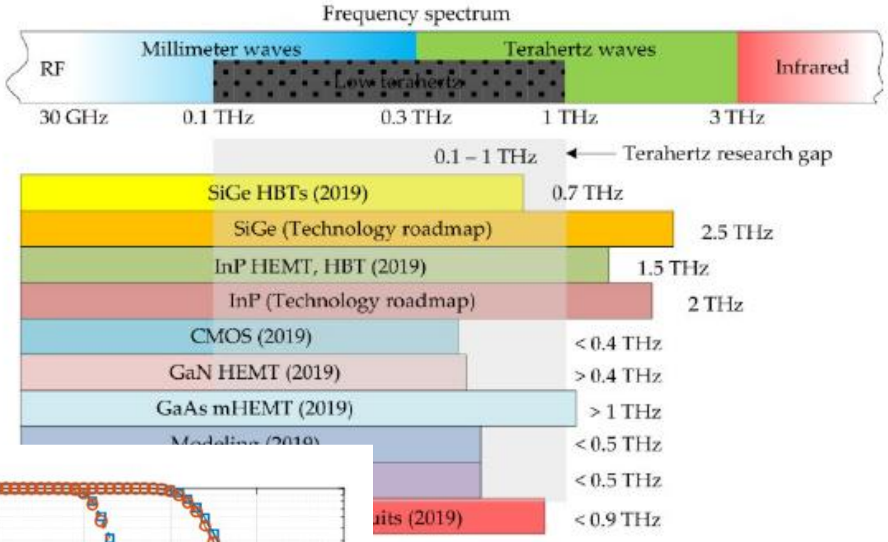
- Ultrafast download of prefixed content (e.g. UHD video, music) at specific locations (vending machines, train stations)
- Chip-to-chip communications

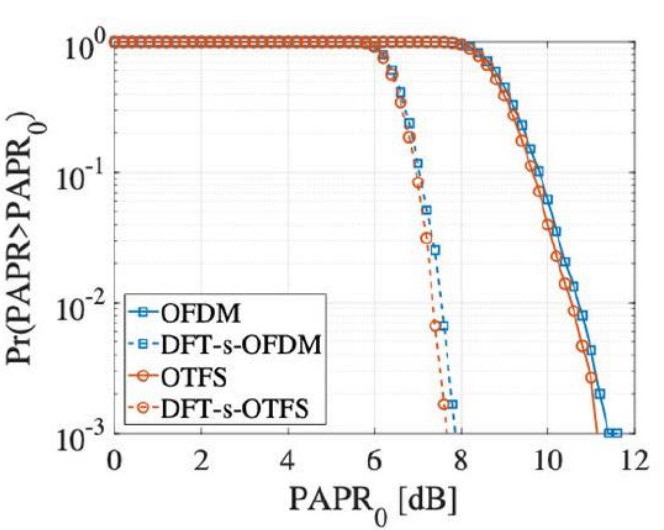
Wireless link in data centers

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

THZ- CHALLENGES

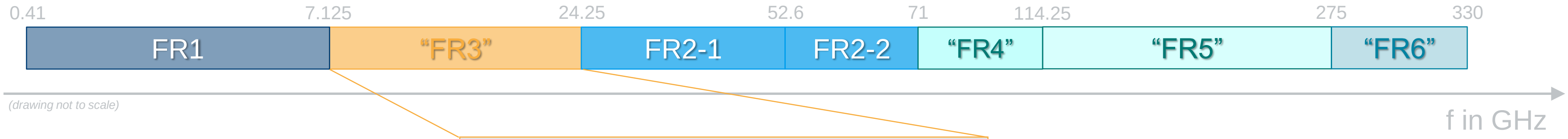
- Semi-conductor material
- Key component of transmitter and receiver
  - Mixer, multiplier, LNA and PA
- Modulation/Demodulation
- Waveform
- AD/DA
- MIMO/beam management
- Channel coding
- Channel modeling





Source: Whitepaper of IMT-2030

DON'T FORGET "FR3"

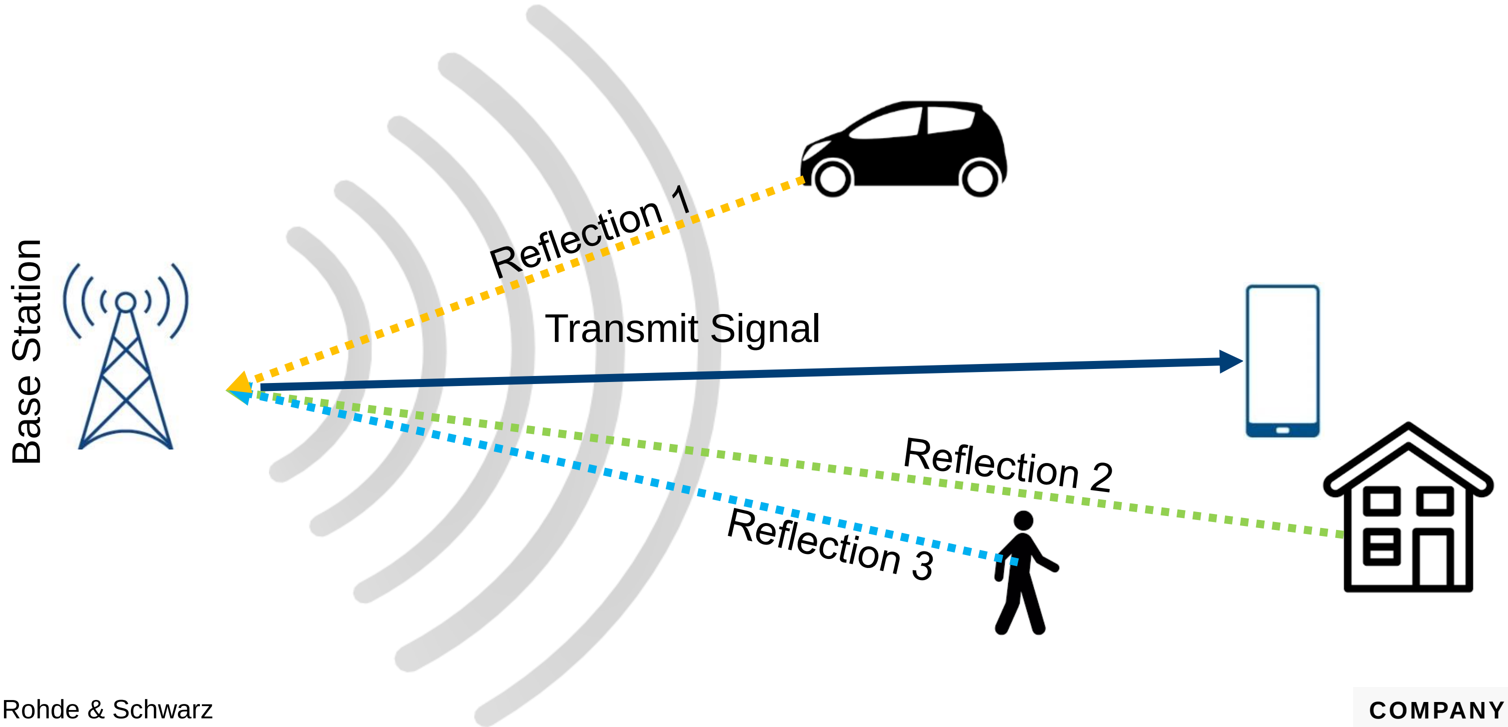


- 6.1.6 Potential Spectrum bands for study
  - 6.1.6.1 UHF Band
    - 6.1.6.1.1 1300-1350 MHz
    - 6.1.6.1.2 1780-1850 MHz
  - 6.1.6.2 Lower-cmW spectrum
    - 6.1.6.2.1 3100-3450 MHz
    - 6.1.6.2.2 3980-4180 MHz (TBD)
    - 6.1.6.2.3 4400-4940 MHz
    - 6.1.6.2.4 7125-8500 MHz
  - 6.1.6.3 Upper-cmW 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):

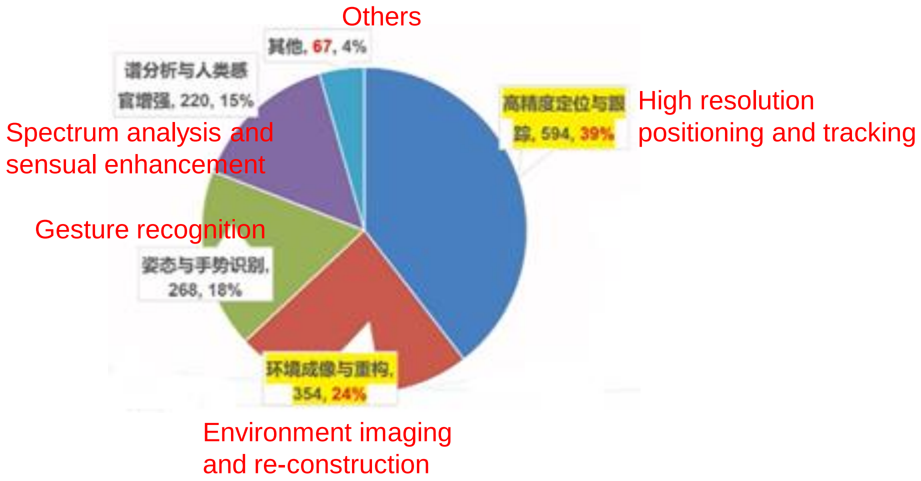
Source: NEXT G ALLIANCE
Spectrum Working Group

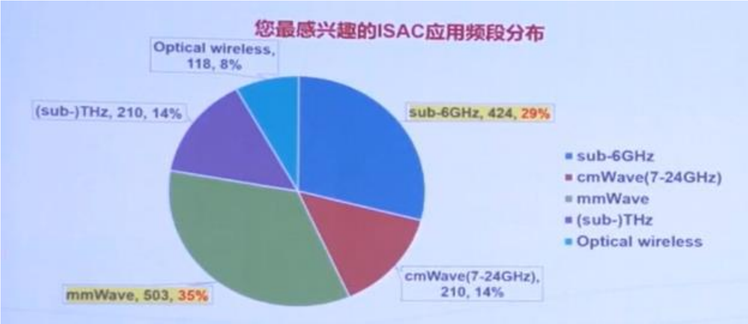
JCAS - CONCEPT

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



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

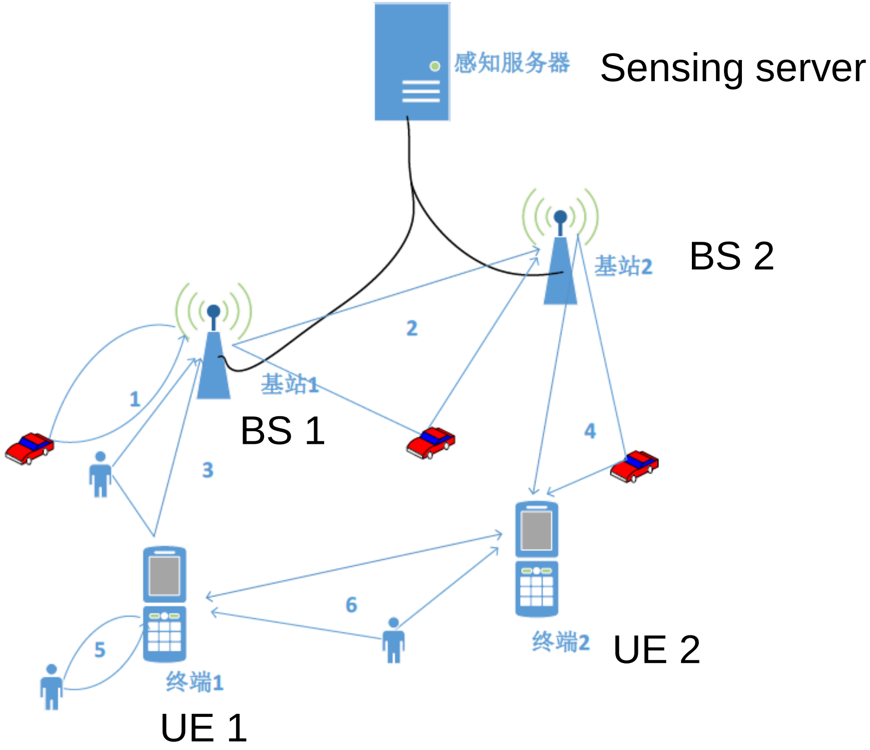
JCAS - CHALLENGES

- Air interface design
  - Waveform
  - Beamforming
  - Interference cancellation
  - Positioning
  - Sensing algorithm

- Architecture and networking design

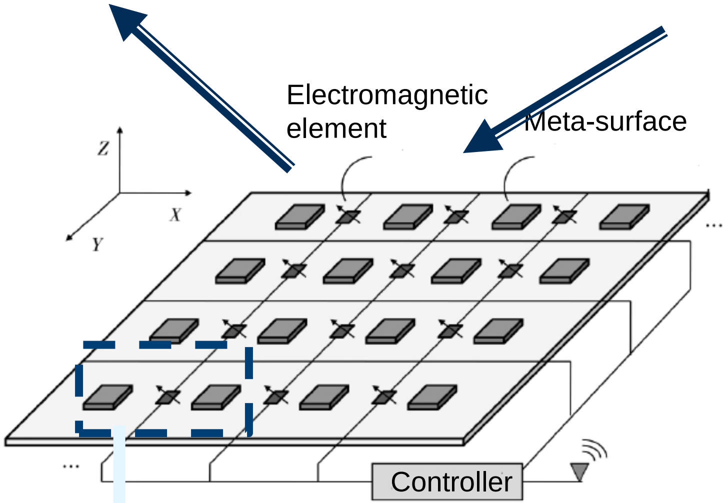
- Hardware design
  - Full duplex issue
  - Isolation circuit

- Channel modeling

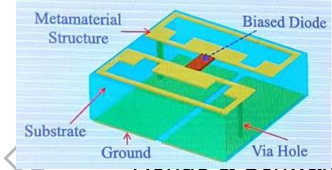


Source: IMT-2030 whitepaper

RIS - STRUCTURE AND SCENARIOS



Structure of RIS

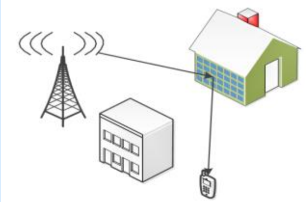


Source: CCSA

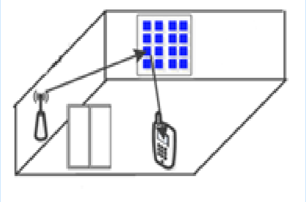
Scenarios

Popular scenarios

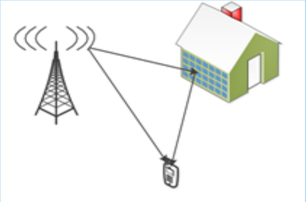
a) Blinding (outdoor)



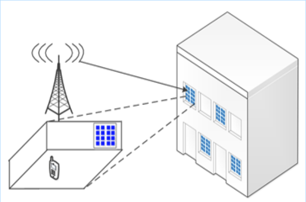
b) Blinding (Indoor)



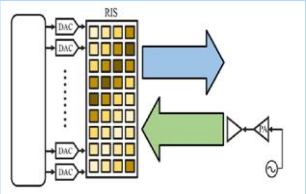
c) Rank increase



d) Transparent transmission

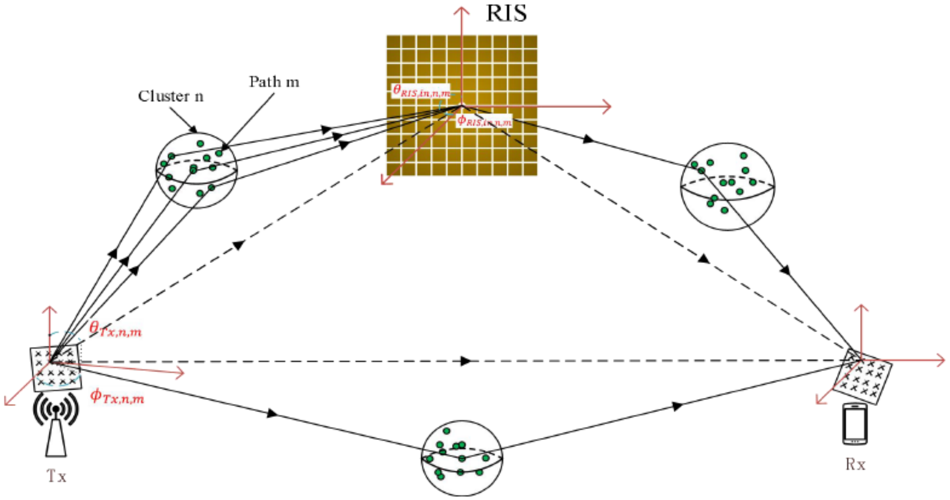


e) Radio enhancement



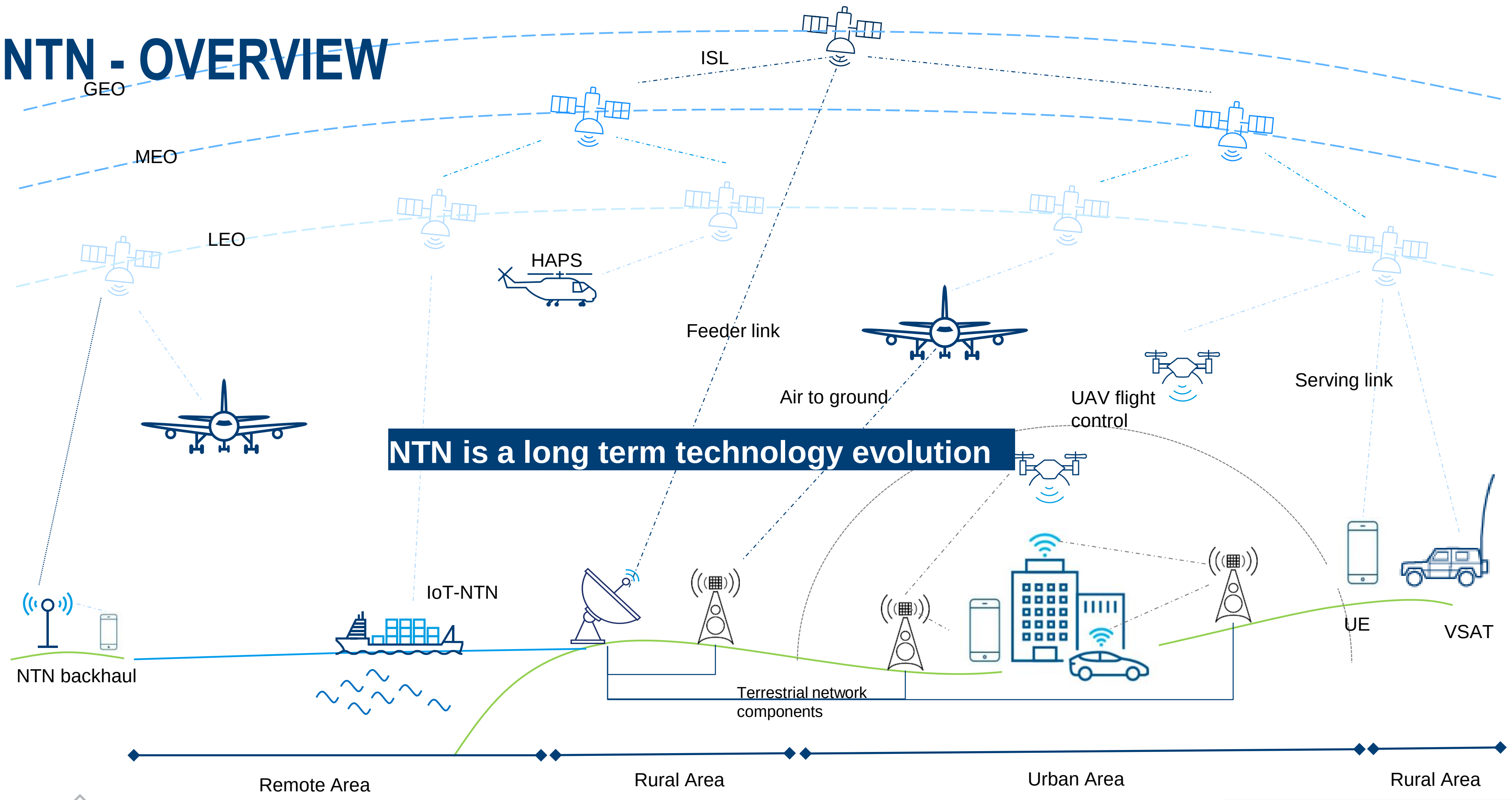
RIS - CHALLENGES

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

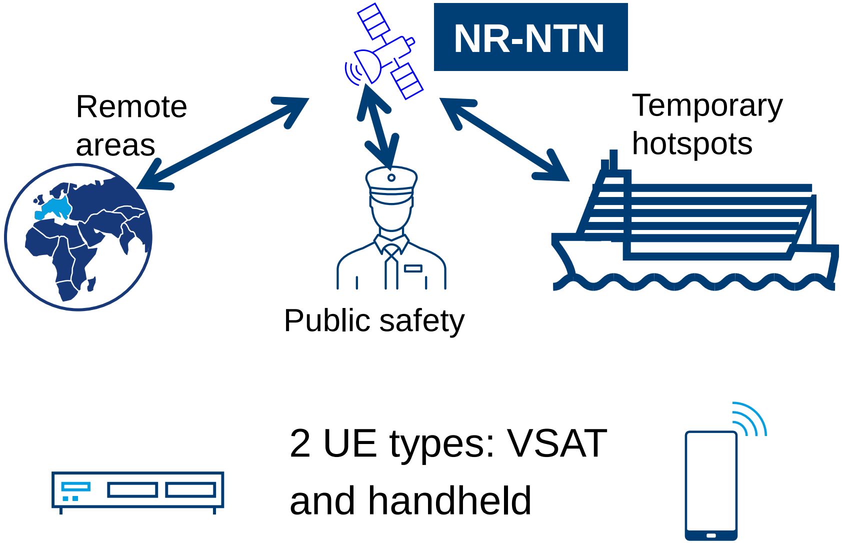


Channel modeling (from whitepaper published by RISTA)

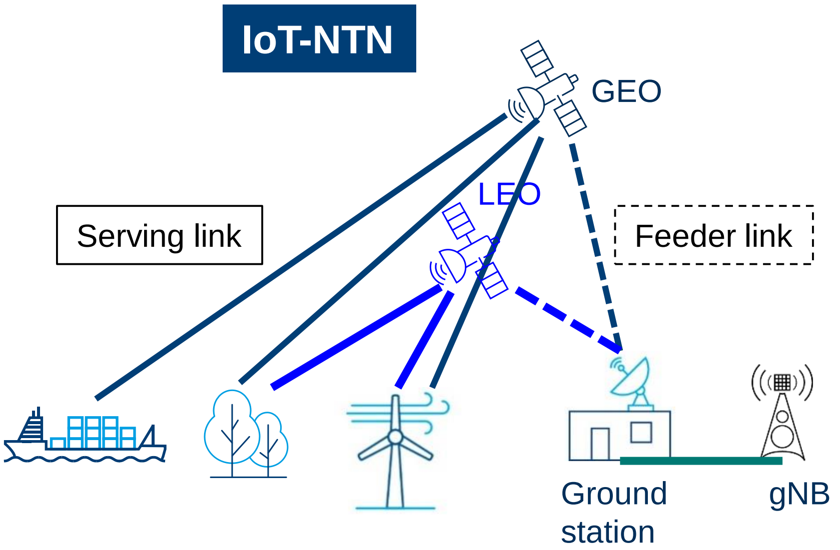
NTN - OVERVIEW



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 ☺

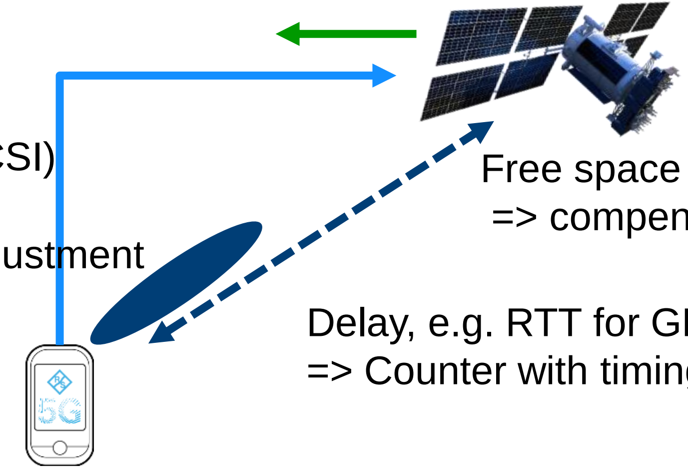


IoT over satellite: Major use case = ubiquituous connectivity.
Low complexity UE, best effort QoS

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)

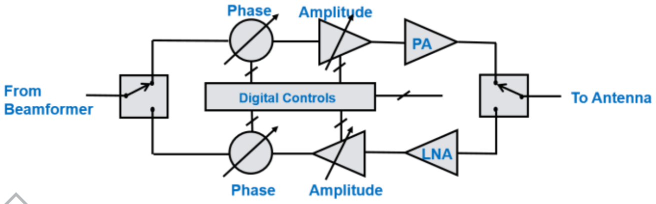


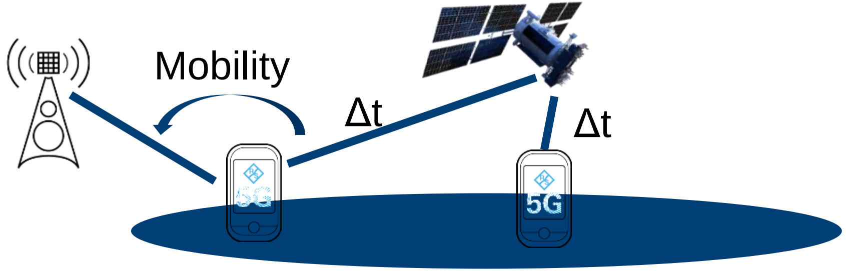
Free space path loss and link budget
=> compensation: beamforming + TX power

UL&DL beam adjustment

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

AI – APPLICATION AREA

Spectrum intelligence and adaptive resource management

- Spectrum sharing & access
- Optimal resource allocation
- Coverage & capacity optimization
- Traffic & mobility prediction
- Data transfer mobile crowd sensing
- Energy efficiency optimization

Network Intelligence and adaptive system optimization

- Cooperative Edge Caching
- Self-interference cancellation
- Location Verification
- Context-aware cross-layer optimization
- Digital Frontend

Transmission Intelligence and adaptive baseband processing

- Adaptive Modulation & Coding based on ML
- Channel decoding
- Non-linear MIMO detector
- Channel equalization & signal detection
- Channel prediction

AI - STANDARDIZATION STATUS IN 3GPP

SI: study item, WI: work item

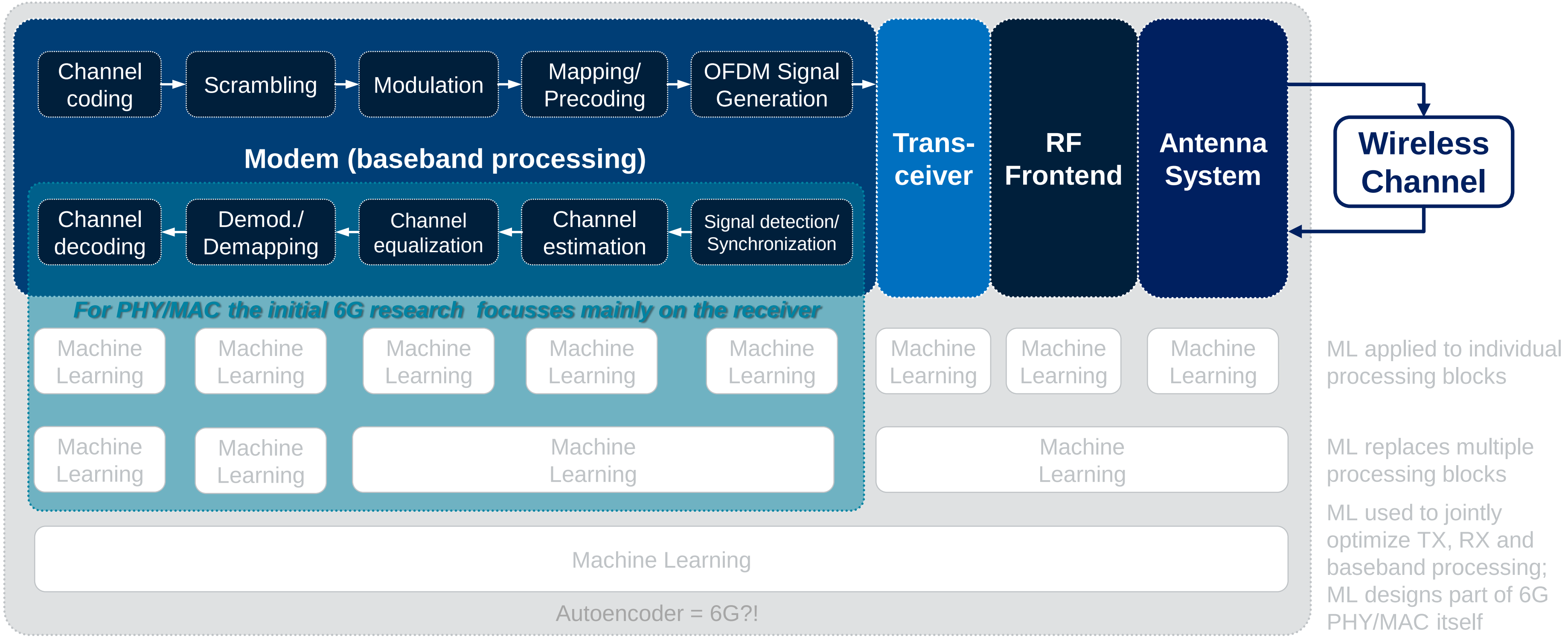
	Rel-15	Rel-16	Rel-17	Rel-18
RAN1				AI/ML for NR Air (SI)
RAN2				
RAN3			Data collection for NR & EN-DC (SI)	AI/ML for NG-RAN (WI)
SA1				AI/ML Model Transfer (WI)
SA2	NWDAF introduced	eNA (WI)	eNA Ph.2 (WI)	eNA Ph.3 (WI) 5G System support for AI/ML-based service (WI)
SA3				
SA4				AI/ML for media (SI)
SA5			eMDAS (WI)	AI/ML management (WI)
SA6				ADAES (SI)

CN: Core Network, NWDAF: Network Data Analytic Function, eNA: enabler for Network Automation, EN-DC: E-UTRAN New Radio - Dual Connectivity
eMDAS: enhancement of Management Data Analytics, ADAES: Application Data Analytics Enablement Service

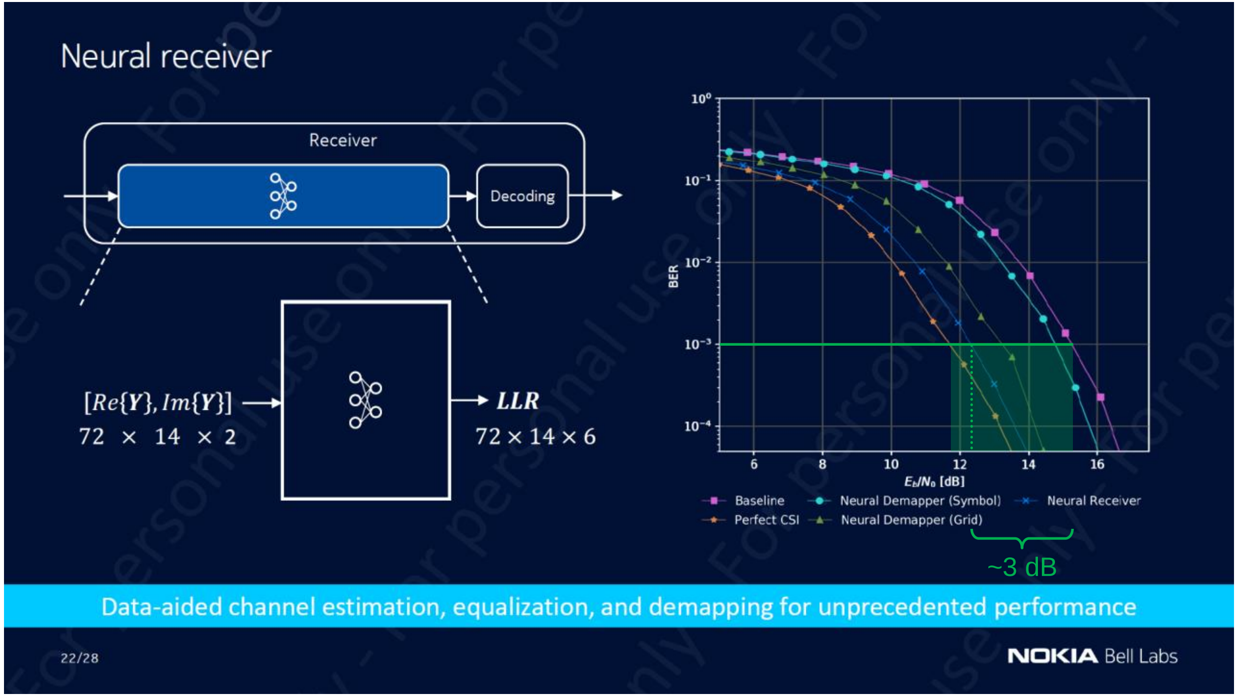
RAN | System/ OAM | Service/ Application

Source: Samsung 6G forum

AI – APPLICATION FOR RADIO/BASEBAND

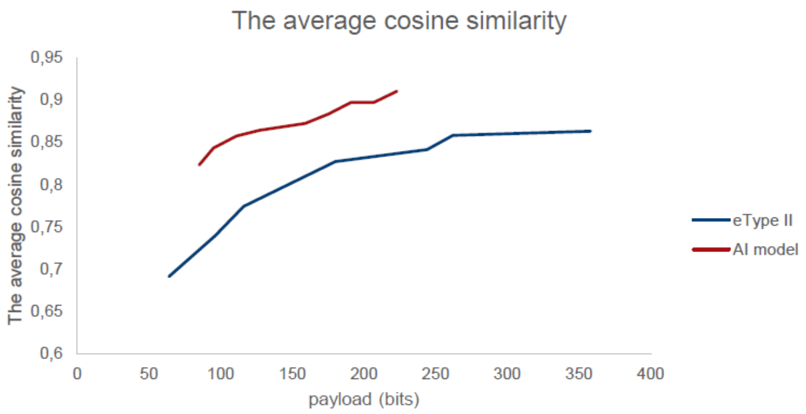


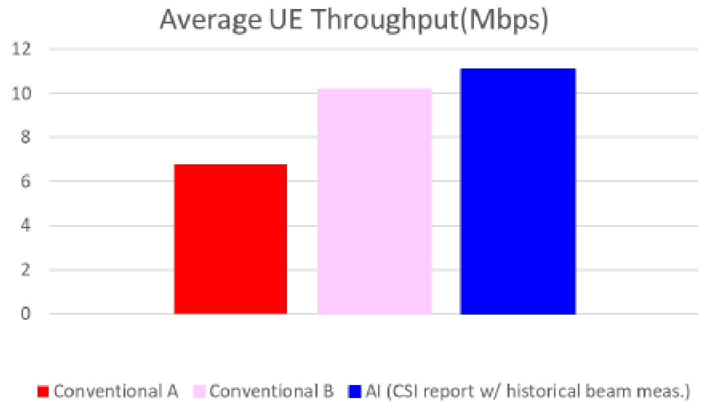
AI – HELPING CHANNEL ESTIMATION



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

AI – HELPING CSI COMPRESSION, BEAM MANAGEMENT AND POSITIONING



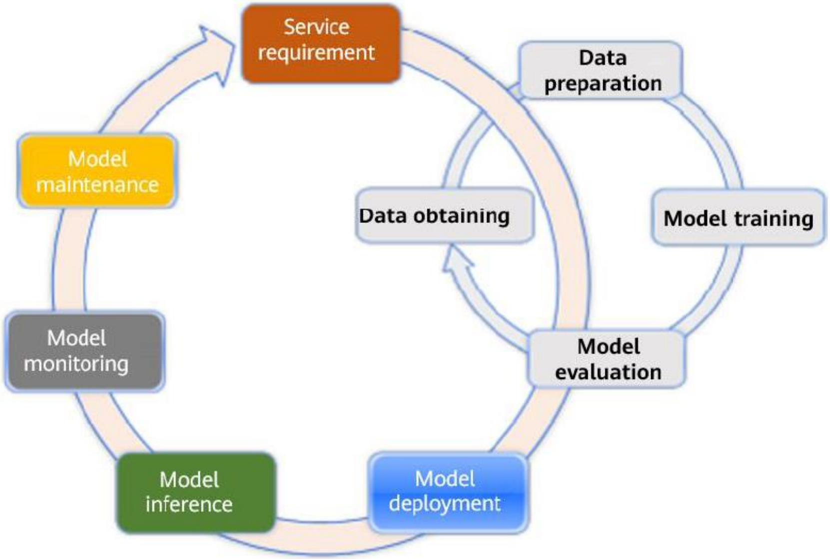


LOS	Positioning Accuracy @90%
Baseline LOS	6.447m
AI/ML LOS	0.353m

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

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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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

TUM 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

EUROPE

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

Bundesministerium
für Bildung
und Forschung

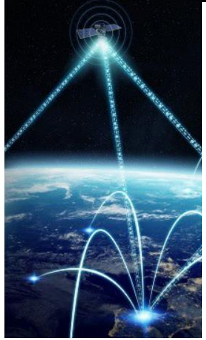
[This Link provides more information]

6G-ANNA

Ganzheitliche Ansätze für Mobilfunknetze der 6. Generation

6G-TakeOff

Holistische 3D-Kommunikationsnetze für 6G

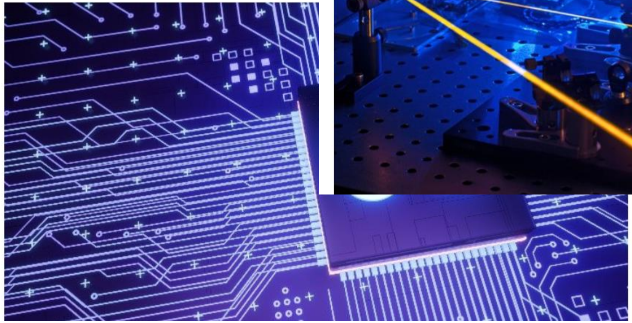


6G-LICRIS

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

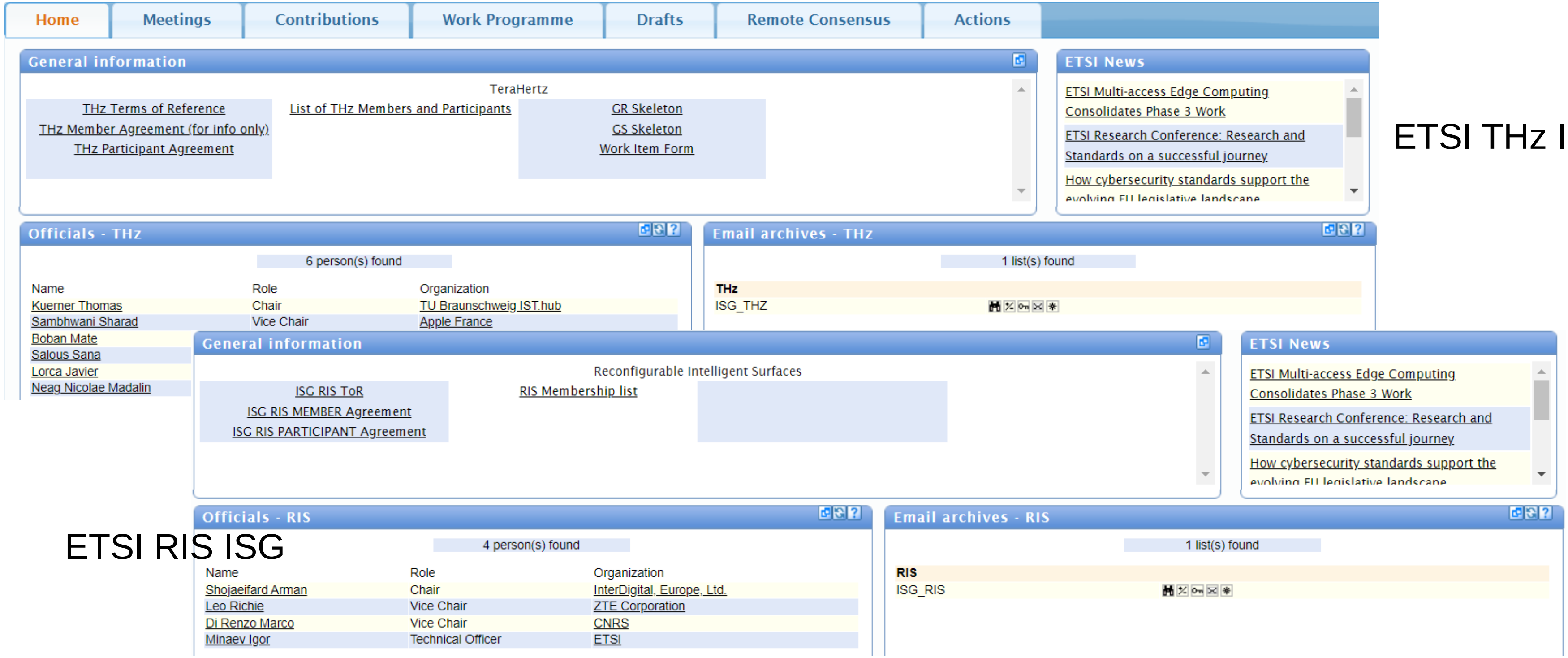
KOMSENS-6G

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

Perzeptive und sensorische Kommunik
im automatisierten Fahren oder in der

EUROPE

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.

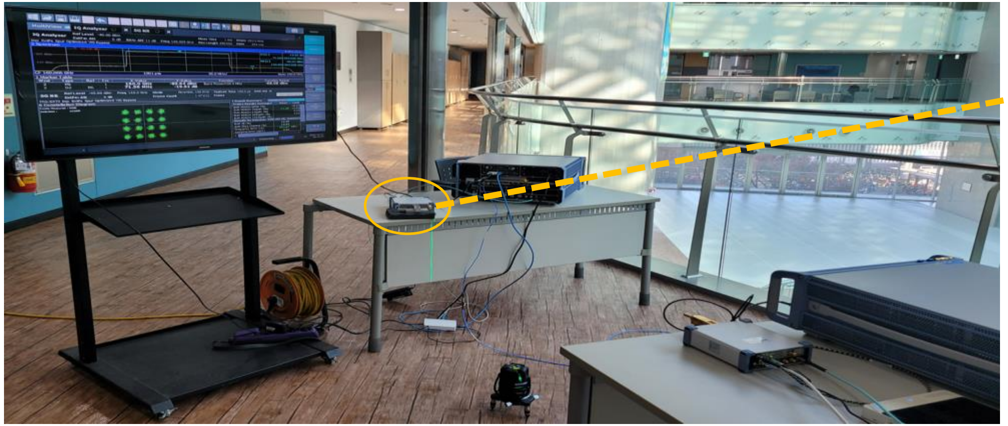
US

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)

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



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

Cooperation

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 &

AGENDA

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

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)

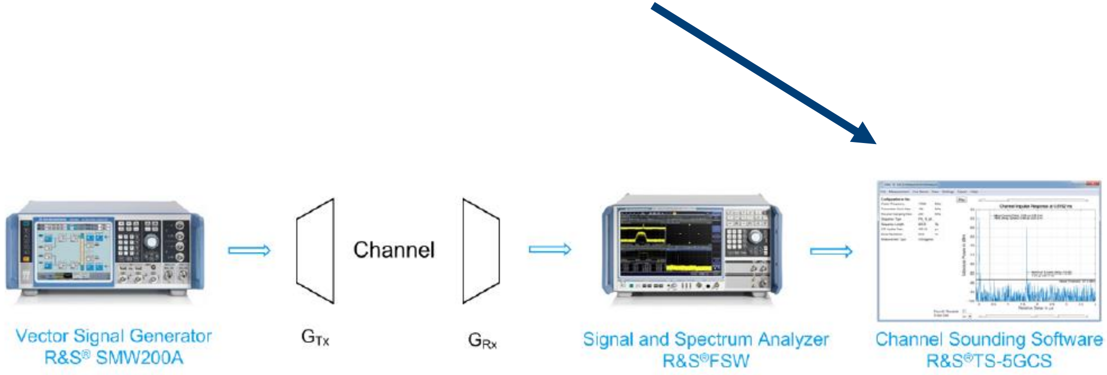
Network analyzer

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

THZ CHAMBER/CHANNEL SOUNDING

D-band based OTA test chamber

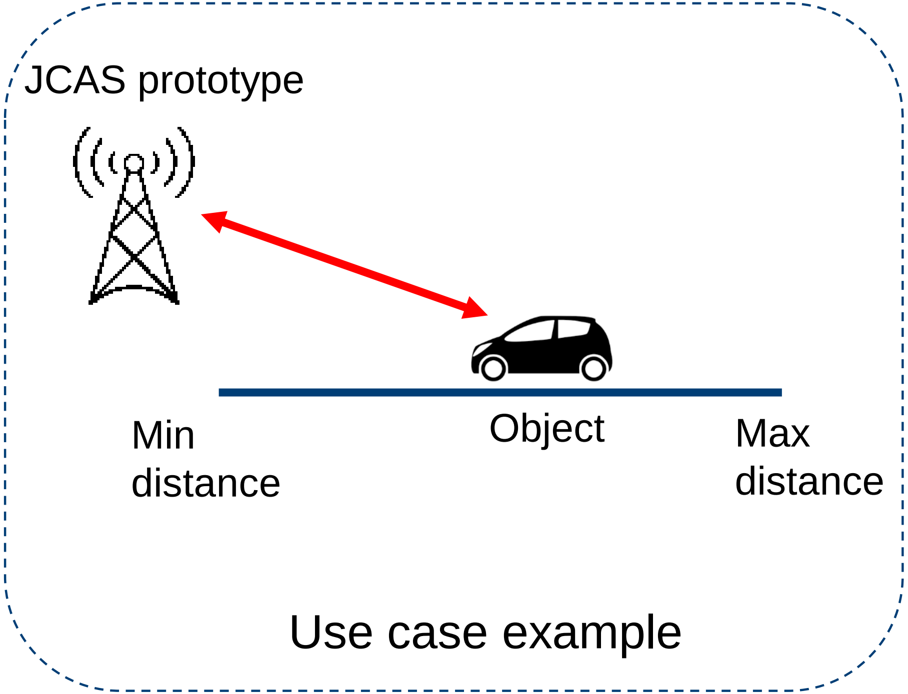
R&S TS-5GCS is a software tool to do channel sounding



JCAS

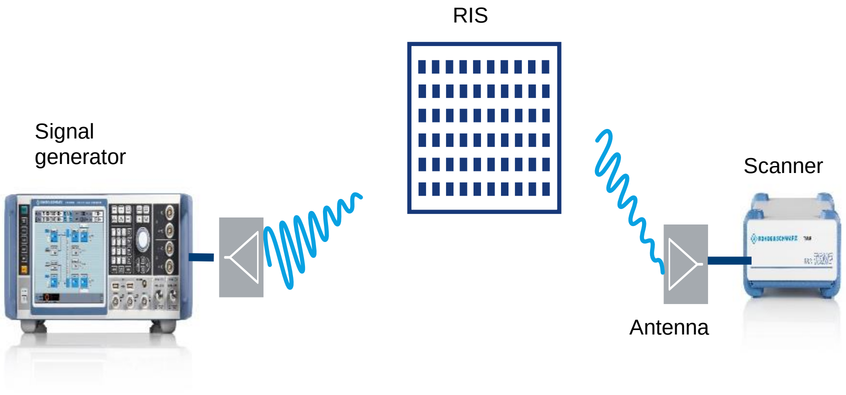
Object simulator is available and improvement for JCAS test is ongoing

AREG800A



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

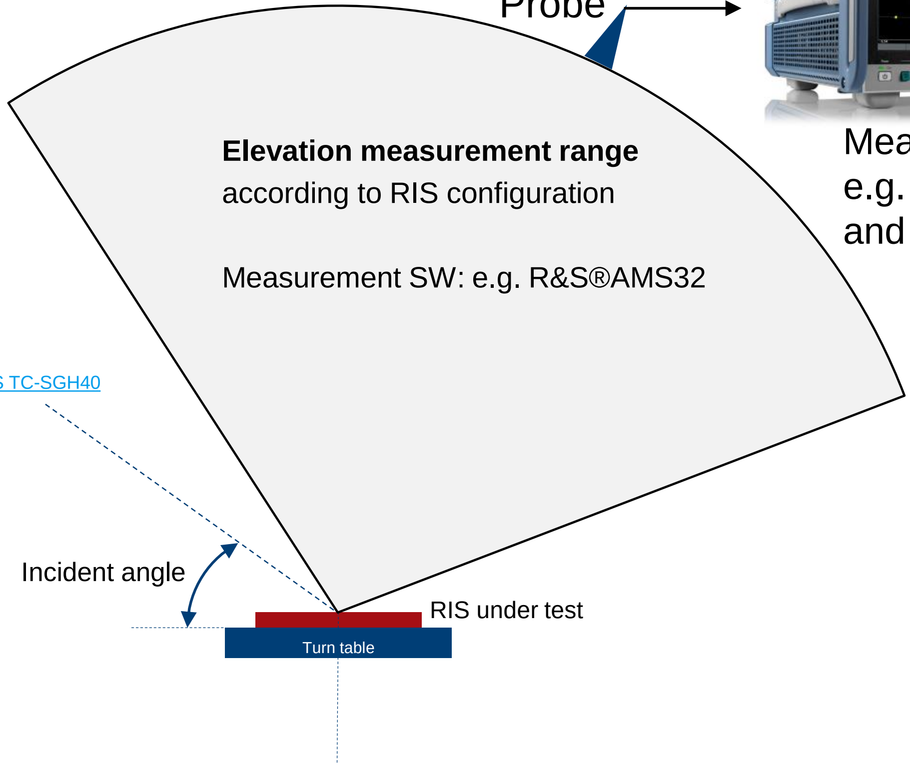
RIS

3D measurement
chamber prototype

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

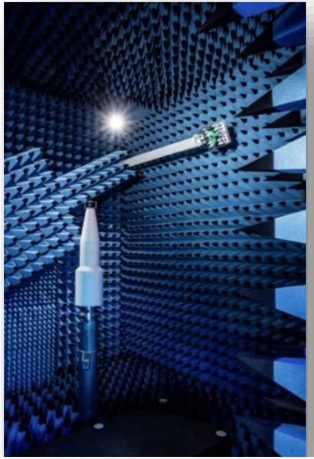
Feed path

SGH
e.g. R&S TC-SGH40



e.g. R&S TC-TA85CP
Probe

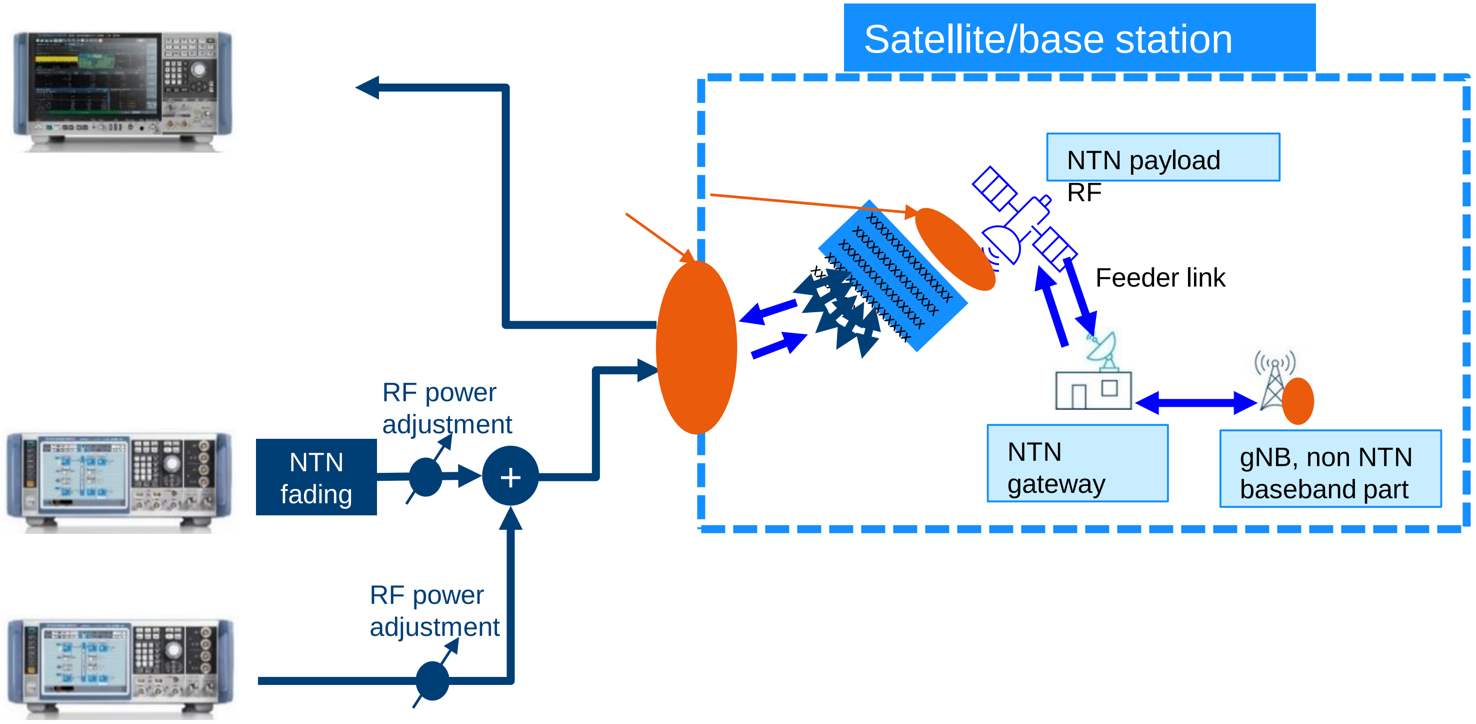
Measurements
e.g. R&S®FSW signal
and spectrum analyzer



WPTC like chamber

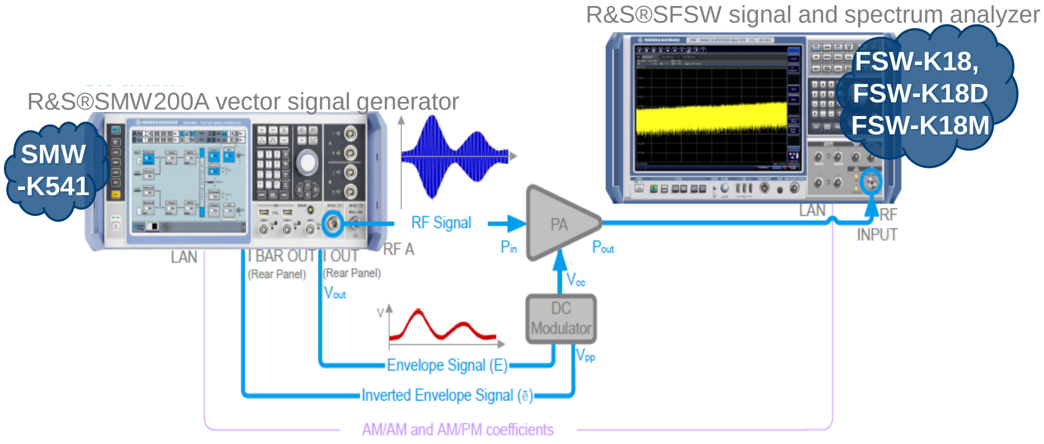
NTN

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



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)

6G CLASSROOM

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

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

This video introduces the background theory and termi-nology 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 po-tential for next-generation wireless services.

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

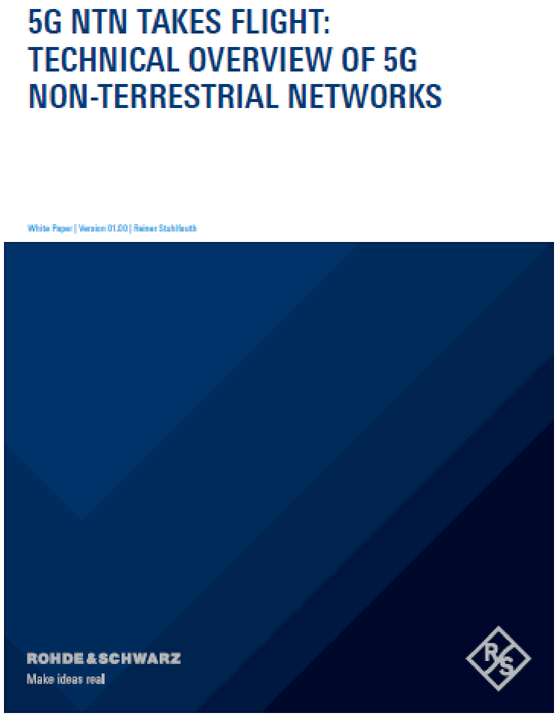
Based on a need for available spectrum and experiment li-censes, this video explains the reasons for candidate fre-quencies for fundamental 6G research in the D band (110-

#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 sig-nals of propogation delays re-

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

6G WHITEPAPERS



R&S published NTN and THz whitepapers

SEE YOU SOON

R&S is planning to show 6G demos

Welcome to visit our booth!

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- R&S Test Solutions
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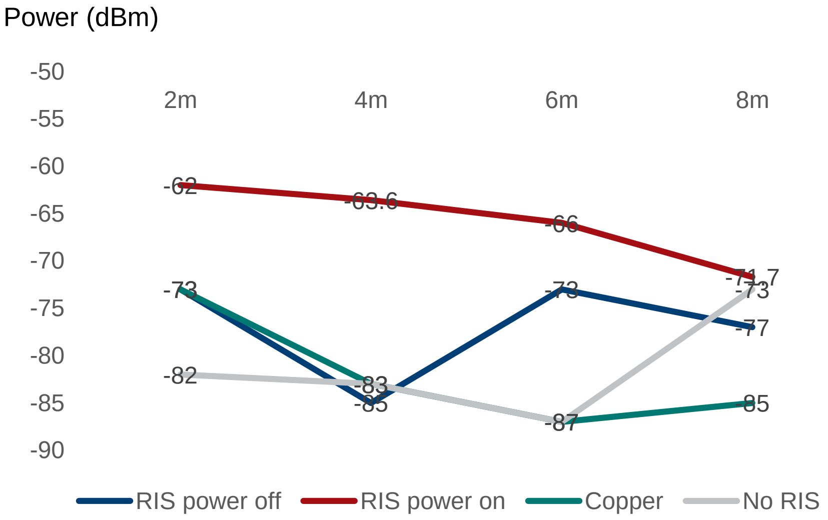
INDOOR SCENARIO

Open Area (focused)

L type corridor

TEST RESULTS IN FR1

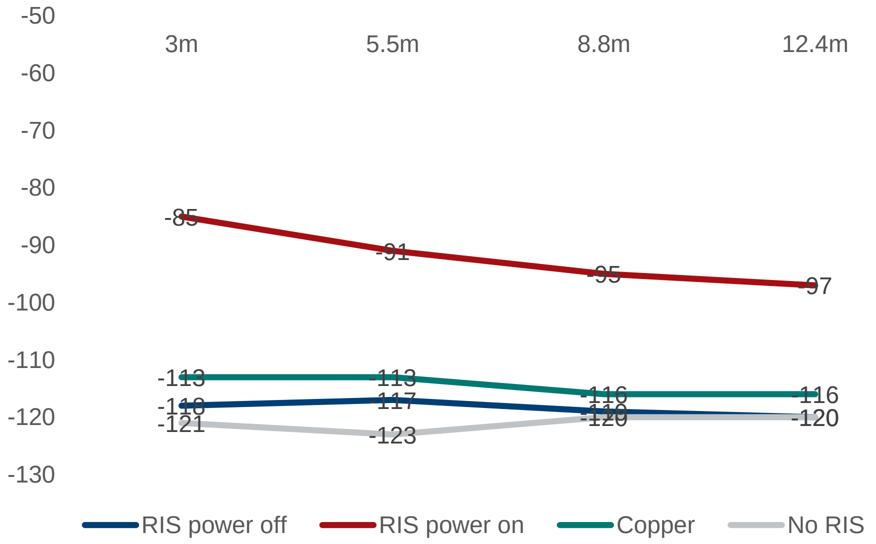
3.5G Hz, Indoor Open Area, SG-RIS distance = 1m



- RIS gain achieves 20dB in case of short distance of reflecting
- The gain is largely reduced in case of longer distance of reflecting
- RIS with power off can also obtain certain gain compared with no RIS case

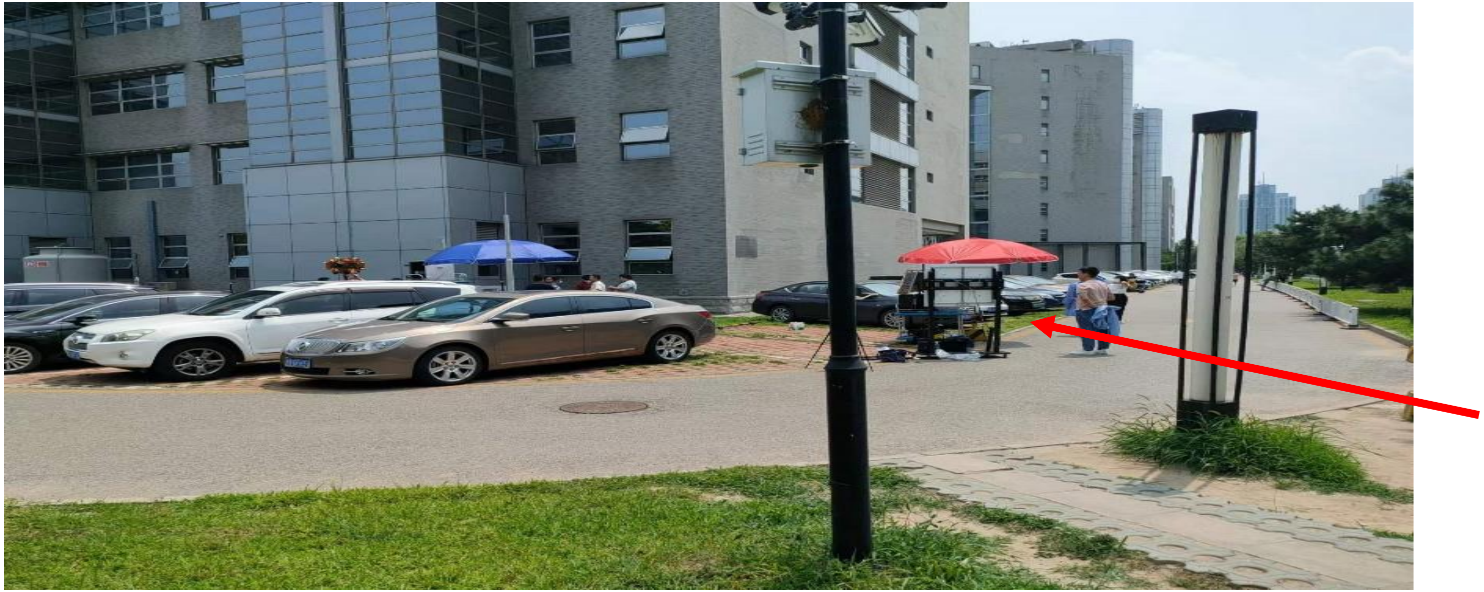
TEST RESULTS IN FR2

25G Hz, Indoor open area, SG-RIS distance = 4.64m



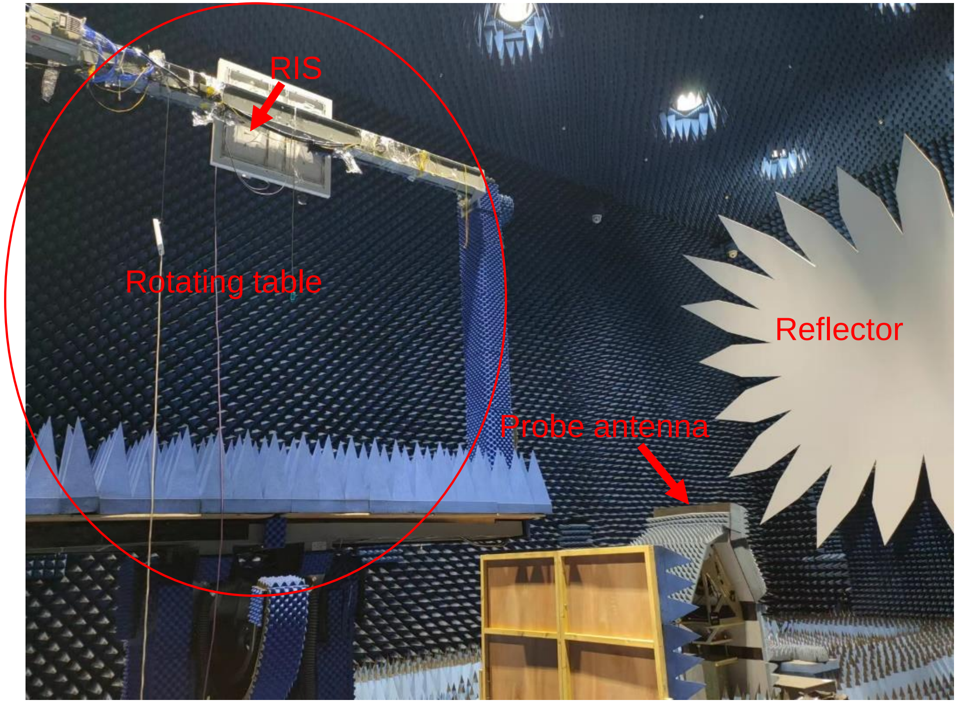
- ➢ More than 25dB gain can be achieved but the gain reduces a little bit with the increase of SG-RIS distance
- ➢ The gain is more stable compared with FR1

OUTDOOR SCENARIO



- For FR1, 4-5dB gain of RIS is obtained
- For FR2, 10dB gain of RIS is obtained and the gain is a little larger with increase of RIS-receiver distance
- Both of them shows quite smaller gain compared with indoor scenario.

CHAMBER SETUP IN FR1



Chamber

- ➢ CATR
- ➢ Chamber size: LxWxH = 20m x 10m x 10m

RIS

- ➢ Size = 860mm*860mm (4 panels)
- ➢ Cell size is 20x20
- ➢ 3.5GHz frequency
- ➢ 200MHz bandwidth (3.4GHz-3.6GHz)
- ➢ Hybrid (with FPGA controller)
- ➢ 2 bit control accuracy

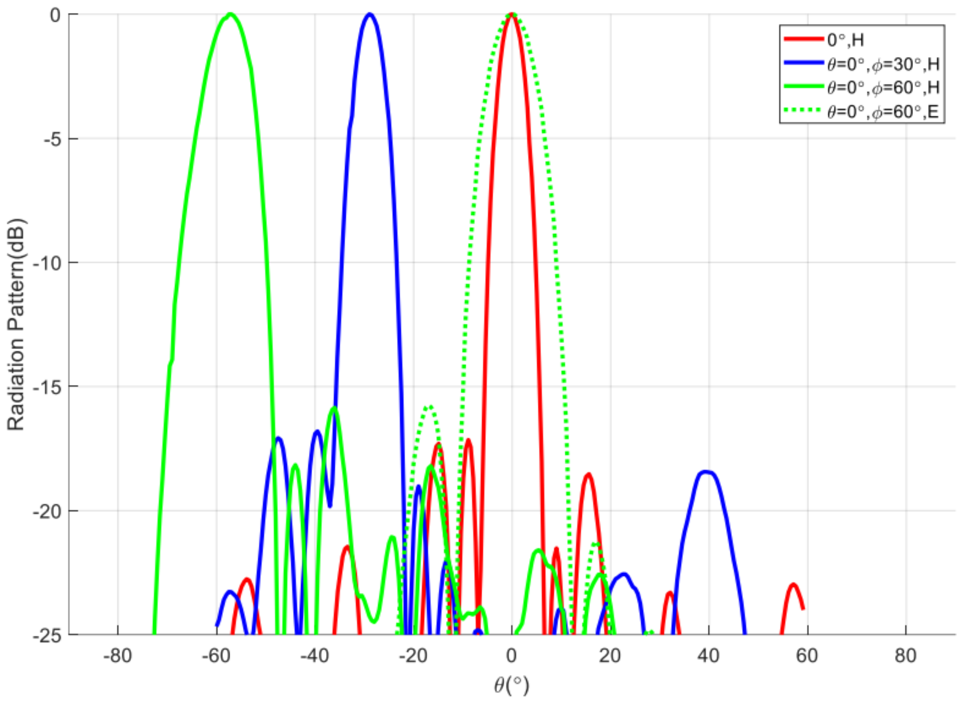
Instrument

- ➢ SMW200A
- ➢ FSW43

Signal setting

- ➢ SSB only
- ➢ 30KHz SCS
- ➢ 3.5GHz
- ➢ 6dBm level of output power

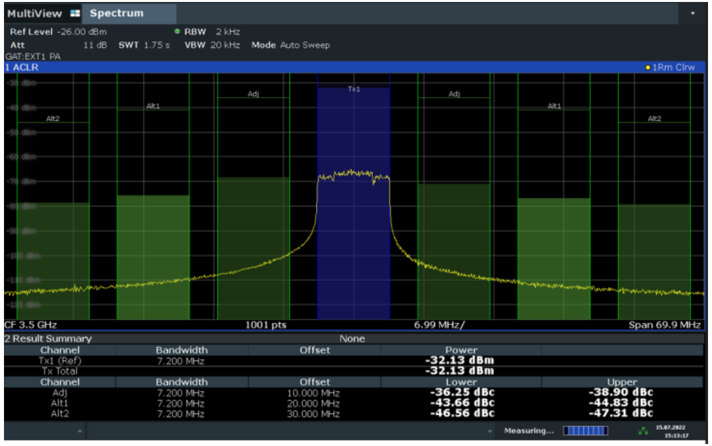
RESULTS ON ANTENNA PATTERN

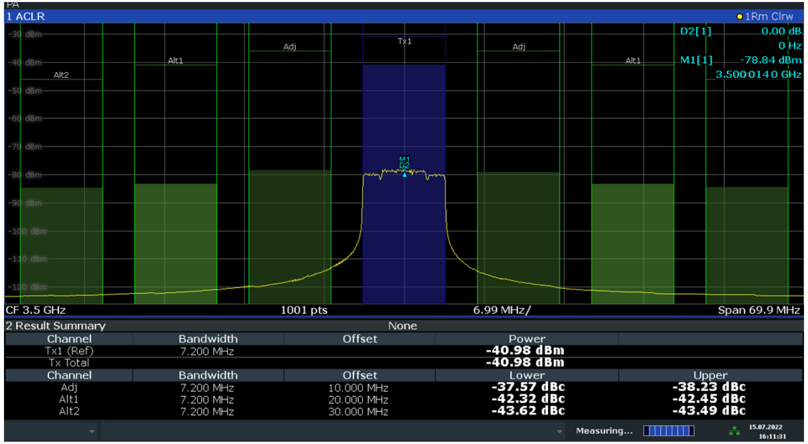


- Larger the reflected beam angle is, larger beam width is
- 0º - 0º case seems a little better than 0º - 30º and 0º - 60º cases from side lobe point of view
- The beam is not narrow as we expected

ACLR TEST IN FR1

Impinging beam = 0º, reflected beam = 0º



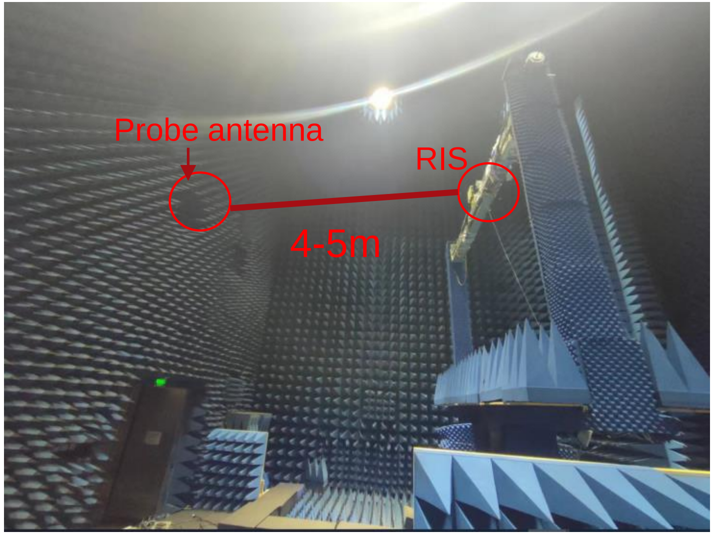


Impinging beam = 0º, reflected beam = 30º

Impinging beam = 0º, reflected beam = 60º

- 37 dBc is not good enough comparing with -45dB requested by base station

CHAMBER SETUP IN FR2



Antenna of feed signal and RIS are combined

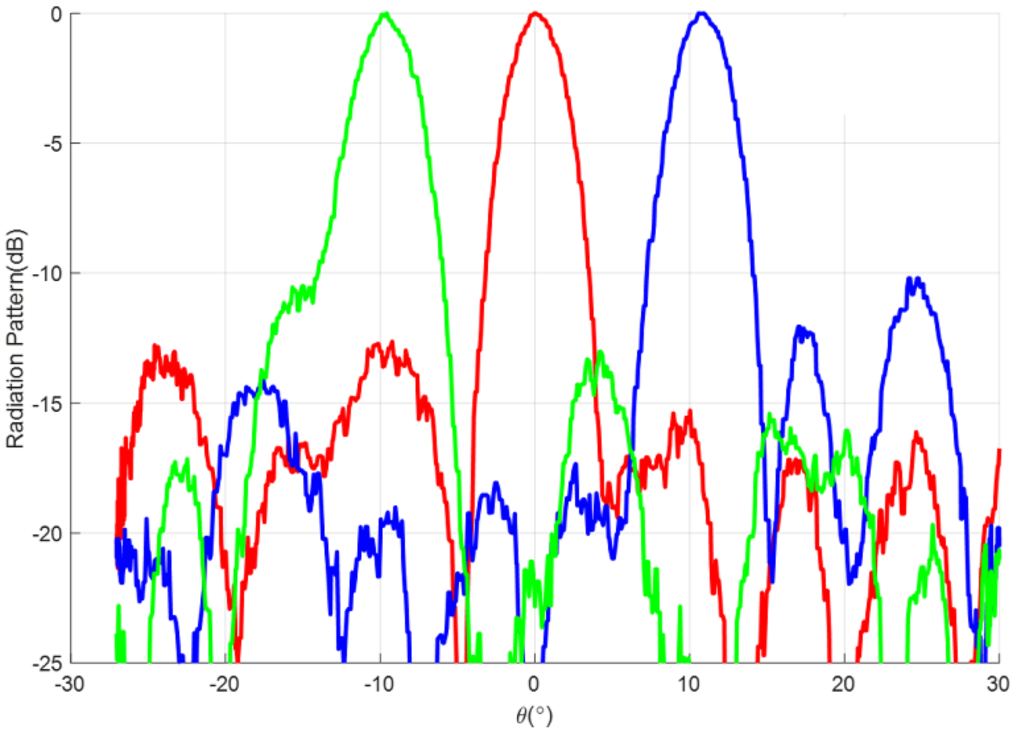
Chamber
- Direct far field
- Chamber size: LxWxH = 20m x 10m x 10m

RIS
- Size = 180mm*180mm (4 panels)
- Cell size is 32 x 32
- 25GHz frequency
- 23.8GHz-25.8GHz bandwidth
- Hybrid (with FPGA controller)
- 1 bit control accuracy

Instrument
- SMW200A
- FSW43
- VNA
- PA(0.5w)
- LNA

Signal setting
- SSB only
- 120KHz SCS
- 25GHz
- 6dBm level of output power

RESULTS ON ANTENNA PATTERN



The side lobe is still a problem

ACLR TEST IN FR2

Initial ACLR is about -19dBc/ -16.xdBc based on different RIS but both of them are worse than requirement of base station.
 - Only SSB is transmitted

Table 9.7.3.3-1: *BS type 2-O* ACLR limit

BS channel bandwidth of lowest/highest carrier transmitted $BW_{Channel}$ (MHz)	BS adjacent channel centre frequency offset below the *lowest* or above the *highest carrier* centre frequency transmitted	Assumed adjacent channel carrier	Filter on the adjacent channel frequency and corresponding filter bandwidth	ACLR limit (dB)
50, 100, 200, 400, 800, 1600, 2000	$BW_{Channel}$	NR of same BW (Note 2)	Square (BW_{Config})	28 (Note 3) 26 (Note 4) 24 (Note 5)

NOTE 1: $BW_{Channel}$ and BW_{Config} are the *BS channel bandwidth* and *transmission bandwidth configuration* of the *lowest/highest carrier* transmitted on the assigned channel frequency.
NOTE 2: With SCS that provides largest *transmission bandwidth configuration* (BW_{Config}).
NOTE 3: Applicable to bands defined within the frequency spectrum range of 24.25 – 33.4 GHz
NOTE 4: Applicable to bands defined within the frequency spectrum range of 37 – 52.6 GHz
NOTE 5: Applicable to bands defined within the frequency spectrum range of 52.6 – 71 GHz.

ACLR requirement of BS type 2-O based on 3GPP 38104

Thank you very much

ROHDE&SCHWARZ

Make ideas real