

Shaping 6G: The RAN4 Perspective

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The Strategic Role of 3GPP RAN4



Physical Boundaries

- RAN4 defines the minimum requirements for Radio Frequency (RF), Radio Resource Management (RRM), and Demodulation (DEMOD).



Practical Reality

- RAN4 translates theoretical mathematical models, 3GPP features and practical implementation constraints into 3GPP requirements, establishing them as design benchmarks.
- RAN4 sets the practical implementation boundaries that determine how those features can actually be realized in real-world deployments.

The 6G Spectrum Frontier

FDD

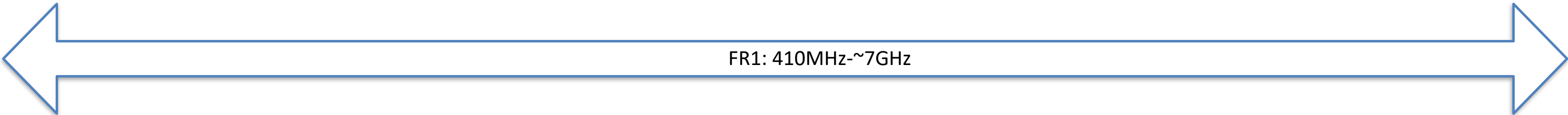
Provides wide-area coverage and deep indoor penetration, anchoring ubiquitous connectivity and massive IoT.

TDD (up to sub-6 GHz):

Continues as the primary coverage—capacity layer, supporting mobile broadband and enterprise use cases with balanced performance.

~7 GHz Band

A premier candidate offering a balance of wide bandwidth and manageable propagation loss. Preserves coverage characteristics of mid-band.



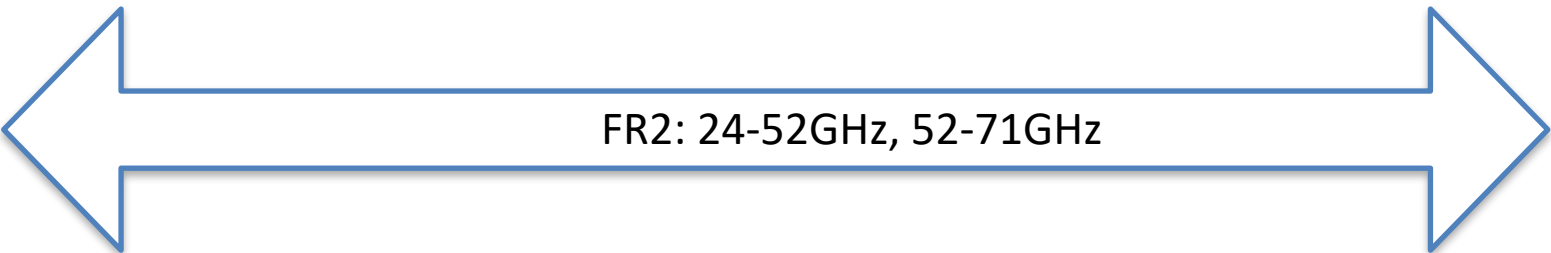
FR1: 410MHz~7GHz

mmWave:

24-56.7 GHz and sub-THz exploration. Addressing extreme capacity needs while managing path loss and beamforming complexity.

Between FR1 and FR2

Focusing on the 10-15 GHz range. Currently exploratory, focusing on feasibility and forward-looking requirement frameworks.



FR2: 24-52GHz, 52-71GHz

The 6G Spectrum Frontier

- All 5G spectrum can be potentially used for 6G. However, new global 6G spectrum is scarce.
- Carrier aggregation remains essential
- Need scalable and concise RAN4 requirement framework
- Supports multiple business and deployment scenarios

The Core Philosophy of UE RF Requirement: Good Neighbors



At its core, RAN4 RF only cares about two things:

- Performance: Can you do your job?
- Coexistence: Are you ruining it for everyone else?



TX requirements rule how a device speaks:

- Output Power (Loudness): Strong enough, but not overwhelming.
- EVM (Clarity): Digital speech must be precise.
- ACLR / Emissions: Stay within your spectral 'table'.



RX requirements define how well a device hears:

- Sensitivity: Ability to detect weak signals.
- Selectivity: Focus amid interference.
- Blocking: Resilience against strong blockers.



- Support devices beyond smartphones, including low-cost IoT and high-performance wearables
- Flexible bandwidth and power capability ranges
- Regulatory compliance including SAR and MPE

6G RF Landscape

Topic	Focus Area	Key Agreements & Next Steps
Output Power Requirements	Power Class Framework	Further study is required for power classes higher than PC1.
	PA Capabilities	Continuing studies on power boosting and P _{cm} updates to fully utilize Power Amplifiers. The goal is to determine a solution for 0 dB MPR conditions.
	Multi-Tx (TxD & UL-MIMO)	Power class is reported based on the maximum sum of output power from all antenna connectors. Requirements will initially assume equal power for each UL-MIMO layer and logical port.
	P _{cm} Parameters	Numerical evaluations are needed to justify specifying deltaT _{ib} and deltaT _c in 6G. Decisions on delta-powerclass are postponed until SAR and SRS-switching are concluded.
	Inter-band CA	5G combined UL band constraints are removed for 6G FR1. Devices will instead indicate a per-band power class, with an optional per-band-per-BC (Band Combination) class that can supersede it.

Topic	Focus Area	Key Agreements & Next Steps
Tx Requirements	OOB Boundary	Studying alignment with regulations and evaluating potential gain/MPR reduction in FDD, TDD, and new 6G spectrums.
	SEM Relaxation	Assessing the benefits of Spectrum Emission Mask relaxation for the 1st MHz (considering ITU's 3dB relaxation at ~7GHz) and beyond. This must not cause co-existence issues.
	LO Position	Aiming to select a single derivation method: center of CBW, center of 6G BWP, or center of RB allocation. Studies will evaluate output power gains, granularity, and architectural impacts.
	PA Modeling & Calibration	Companies may use their own PA models but must explicitly state their assumptions (e.g., DPD usage). PA bias and operating point calibration remain up to UE implementation.

Topic	Focus Area	Key Agreements & Next Steps
Rx Requirements	Reference Sensitivity	2Rx is the baseline for current bands, while 4Rx is the baseline for new ~7 GHz bands. The existing REFSENS formula remains the starting point.
	Noise Figure (NF)	Case studies will evaluate potential NF improvements on specific bands (n5, n3, n41, n77, n104), factoring in the complexity of commercial smartphones (e.g., Wi-Fi, foldables).
	REFSENS UL Config	For FDD bands, three options are under study: no change from 5G, a small number of RBs in the middle, or the maximum restricted RBs that keep Tx interference below Rx thermal noise.
	MSD Requirements	Evaluating whether to define minimum Maximum Sensitivity Degradation requirements. The goal is to streamline via Look-Up Tables (LUTs) and band groups to prevent delays in 6G CA rollout.
	ACS & Blocking	Interfering signal parameters will remain distinct below 2.7 GHz and above 3.3 GHz. NB-blocking is specified for FDD <2.7 GHz, with further study needed for channels >100MHz.

Radio Resource Management (RRM)

- RRM defines how a UE measures, evaluates, and reports the surrounding radio environment and primarily addresses the following issues
 - Which cell should I connect to?
 - Is there a better cell nearby?
 - When should I switch to another cell?

RRM Function	Intuitive Meaning
Cell Detection	Can the UE find available cells?
RSRP Measurement	How strong is the signal?
RSRQ Measurement	How clean is the signal?
SINR Measurement	How understandable is the signal?
Measurement Accuracy	How trustworthy are the measurements?
Reporting Performance	Can the network rely on the UE's observations?

Without Good RRM

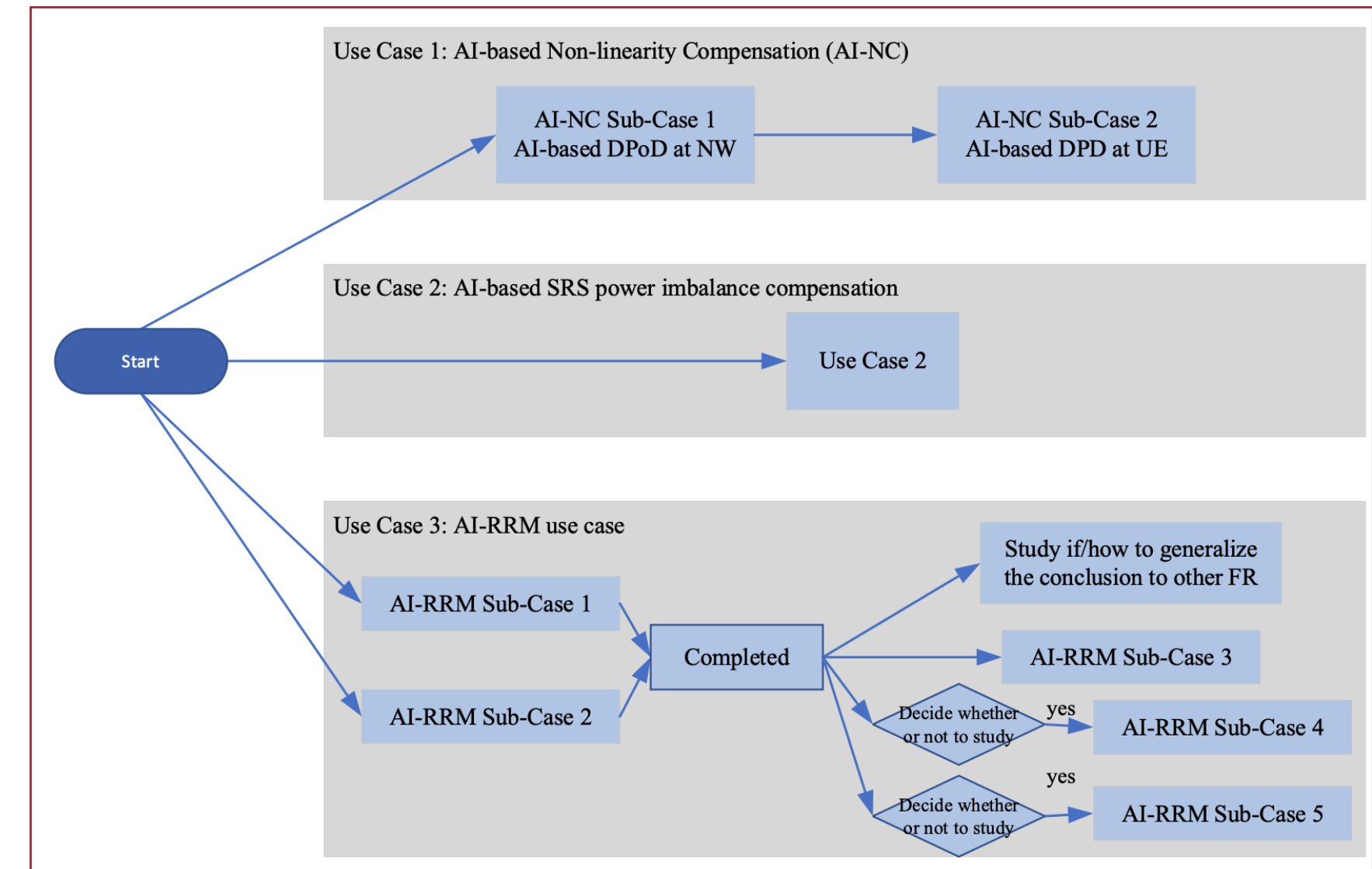
- ✗ Late handover → Call drop
- ✗ Early handover → Unnecessary signaling
- ✗ Wrong measurement → Poor cell selection
- ✗ Unstable measurements → Ping-pong handovers

6G RRM Landscape

- 6G measurement gap(MG)-less and interruption
 - Aim to significantly reduce MG overhead.
 - Potential hardware impacts include **increasing #searcher and RF chains**, etc.
 - In 5G, **MG overhead in FR1 and FR2 is 15% and 25%**, respectively.
- 6G unified measurements for RRM
 - **Differentiate the measurement delay requirement and the related measurement opportunities sharing** based on measurement purpose (e.g. HO, SCell activation) and the services (e.g. delay sensitive)
- 6G UE group for RRM (e.g. serving cell and intra-/inter-frequency cells measurements)
 - **Enable sharing RRM/CSM functions across different UEs**, including the mechanism/criteria to group UEs
 - Example: Phone and Watch share the RRM measurement
 - Case 1: Watch acts as a wake-up radio of the Phone to take all RRM measurement and the Phone is in long and deep sleep in IDLE state
 - Case 2: Phone and Watch share the measurement 50/50 to reduce the measurement overhead and increase the sleep duration

AI from RAN4 Pespective

- Use Case 1: AI-based non-linearity compensation (AI-NC)
 - AI-NC Sub-Case 1: AI-based DPoD (Digital Post-Distortion) at NW
 - AI-NC Sub-Case 2: AI-based DPD (Digital Pre-Distortion) at UE
 - Objective: **Relax UE EVM requirements for better trade-off between power boosting and EVM** to improve UL coverage
- Use Case 2: AI-based SRS power imbalance compensation
 - SRS power imbalance is due to switch insertion loss and antenna efficiency difference across different Tx.
 - Both of them are UE implementation details and can be hardly obtained by NW
 - Objective: **Compensate SRS imbalance without disclosing UE implementation details.**
- Use Case 3 AI-L3 RRM measurement prediction use cases
 - Phase I:
 - AI-RRM Sub-Case 1: FR2-1 L3 **spatial domain beam-level prediction** for Tx (intra-cell)
 - Objective: **reduce RRM delay**
 - AI-RRM Sub-Case 2: FR1 L3 **frequency domain cell-level prediction** (inter-cell, non-collocated)
 - Objective: **reduce measurement gap overhead**
 - Phase II:
 - AI-RRM Sub-Case 3: Spatial domain Rx prediction for intra-cell
 - AI-RRM Sub-Case 4: AI/ML-based prioritization for MOs
 - AI-RRM Sub-Case 5: Non-collocated frequency domain prediction in beam level

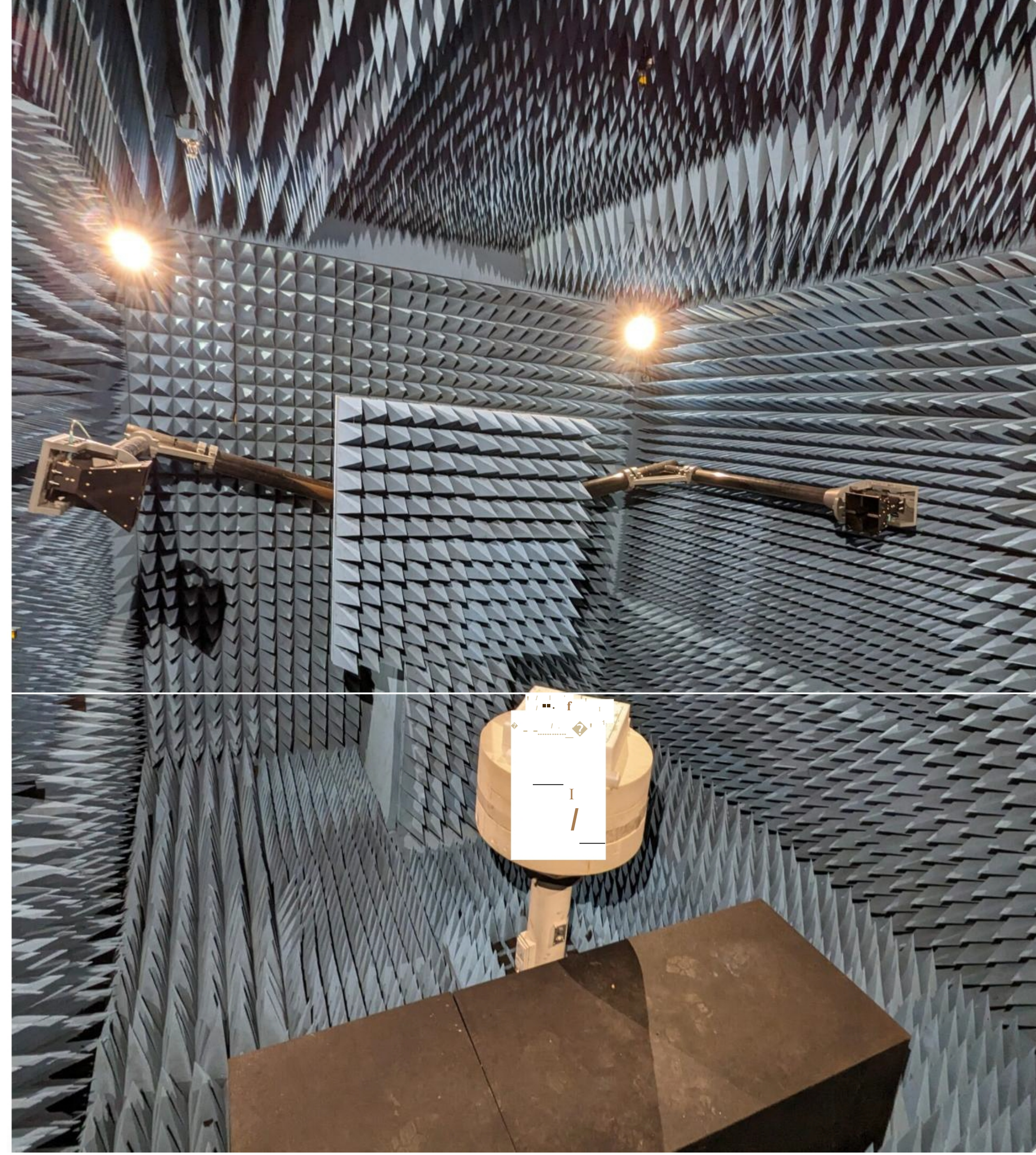


The OTA Standard

The New Testing Cornerstone

Over-the-Air (OTA) test frameworks are now fundamental. Conducted measurements cannot capture the true performance of integrated, beamforming based systems.

- Validating coverage and beam management.
- Ensuring interoperability across vendors and covering new services and device types, including AI and NTN
- Accounting for device orientation and spatial dynamics.



Test and Compliance Requirements

Table 1

Directions/Topics	Description
Topic #1: Improved testability of Conducted Requirements	Discussion of some potential improvement of testability for conductive requirements (including MSD)
Topic #2: New test methodologies for new 6GR frequencies	Discussion of testability framework and feasibility of new frequencies for 6GR
Topic #3: OTA test methods for Multi-Tx and CA	Testability of band combination radiated performance
Topic #4: Testability for different Device types	Testability study to accommodate different UE types
Topic #5: AI testability	Testability for different Use cases for AI
Topic #6: Harmonized testing for TN and NTN	Testability discussion to harmonize the methodology to cover TN and NTN
Topic #7: Improved test methods and metric for SISO OTA	Improvement of single layer OTA measurements
Topic #8: Improved test methods and metric for DL MIMO OTA	Improvement of MIMO OTA measurements
Topic #9: Efficiency improvement (Test and requirements)	Discussion of framework and guidance on how to improve the test efficiency and how to specify OTA requirements efficiently

Demodulation requirements

Requirement Type	Historical Focus (3/4/5G)	6G Evolution (RAN4 Focus)
Channel Modeling	Idealized/Static Models	Realistic, High-Fidelity Channels
Performance Metric	Target BLER/Throughput/ CSI feedback	Robustness in "Messy" Real-World Deployments
Receiver Testing	Pristine Laboratory Environment	Commercial-Grade Chaotic Scenarios

REFERENCE on RAN4 6G STUDY

6G Topics	Latest WF and Agreement	Running Summary
System parameters	R4-2607334 (part I) R4-2607320 (part II)	R4-2605766
General RF and UE RF	R4-2607365 (part I) R4-2607357 (part II)	R4-2606942
BS RF and coexistence	R4-2607723	R4-2606353
Spectrum	R4-2607341 (part I) R4-2607342 (part II)	R4-2606410
RRM	R4-2607349 (part I) R4-2607347 (part II)	R4-2605290
Demodulation	R4-2607571 (part I) R4-2607518 (part II)	R4-2605375
AI	R4-2607361 (part I) R4-2607362 (part II)	R4-2606602
Spectrum sharing	R4-2607337	R4-2606055
Sensing	R4-2607738 R4-2607742	R4-2606889
Testability and OTA	R4-2607572	R4-2605989
RAN4 operation efficiency	R4-2607302	R4-2606212

THANK YOU