

AI/ML IN 5G-ADVANCED AND 6G: PRACTICAL PATHS AND REAL CHALLENGES

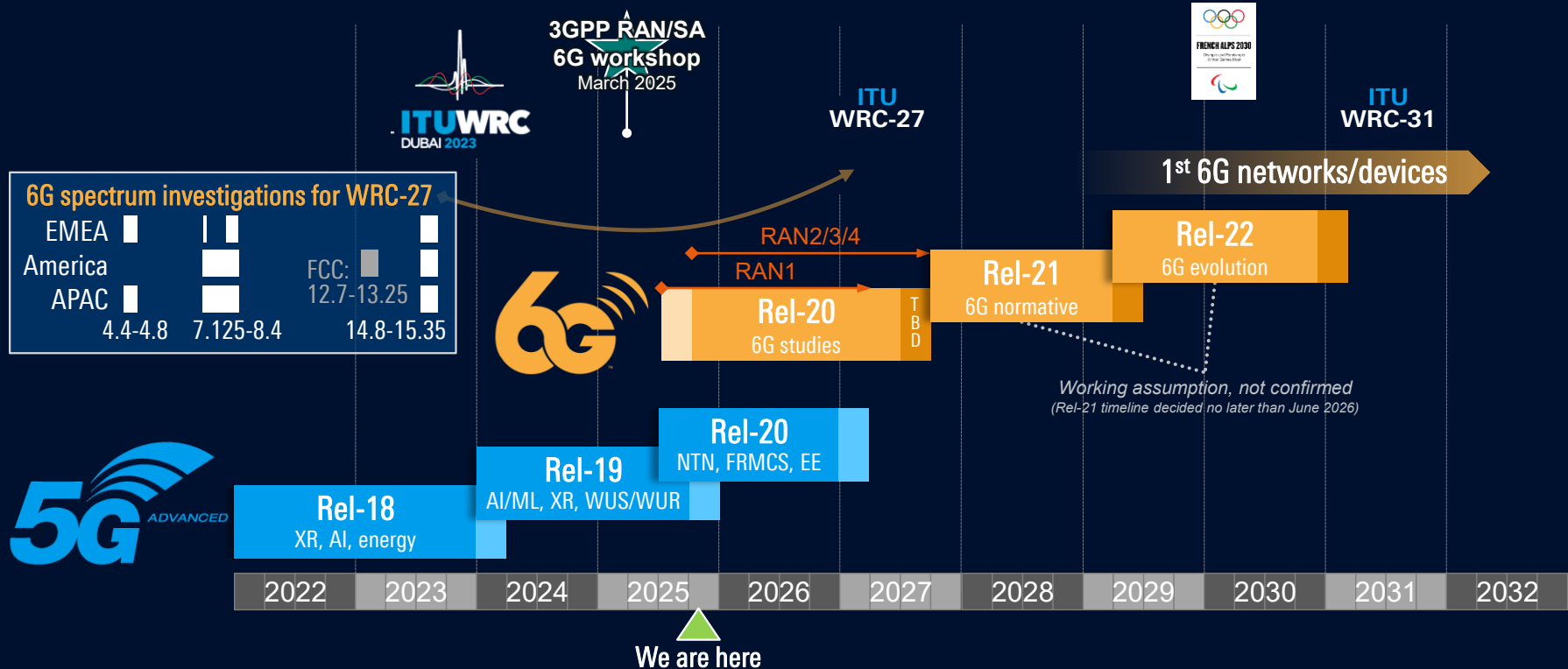
Meik Kottkamp
Technology Manager Wireless

ROHDE & SCHWARZ

Make ideas real



3GPP STANDARDIZATION AND REGULATION ON THE WAY TOWARDS PLANNED 6G LAUNCH IN 2030



6G TECHNOLOGY COMPONENTS

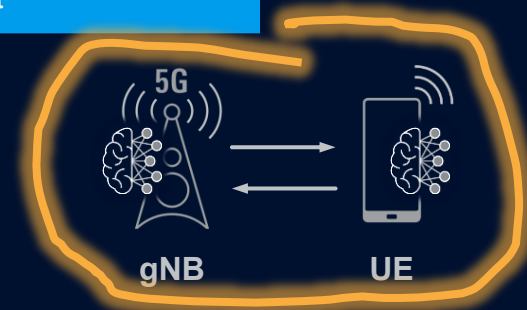
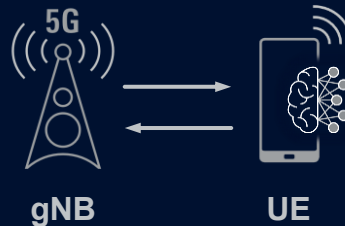
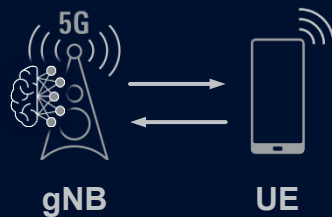
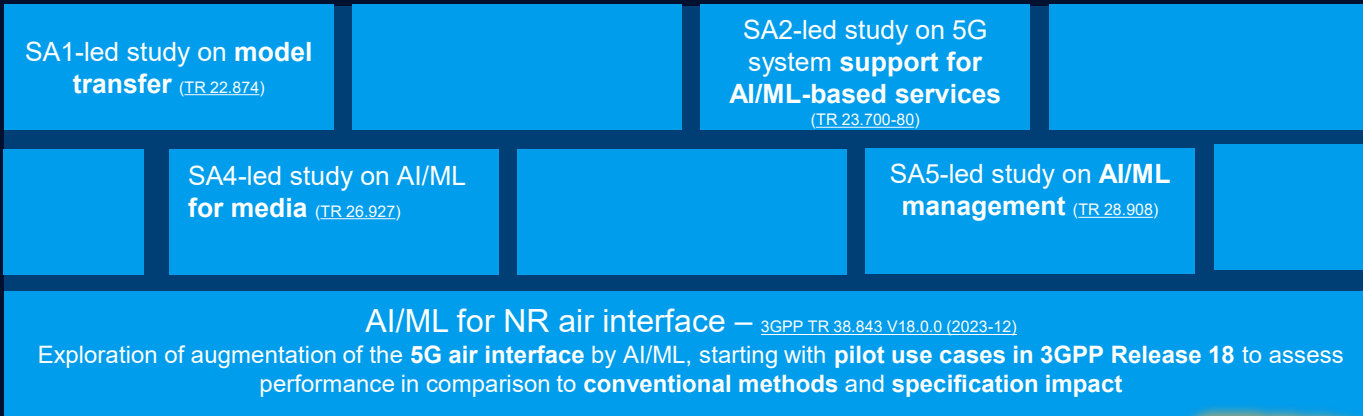


A high-level overview of all these research areas is provided in one of our [#THINKSIX](#) videos

ARTIFICIAL INTELLIGENCE/MACHINE LEARNING IN 3GPP

LAYING THE FOUNDATION WITH 5G-ADVANCED

► 3GPP Release 18: 5G-Advanced



Sources: <https://www.3gpp.org/technologies/finding-ai-in-3gpp>, <https://www.3gpp.org/technologies/ai-ml-nr>, and <https://arxiv.org/ftp/arxiv/papers/2305/2305.05092.pdf>

PILOT USE CASES IN 3GPP RELEASE 18 and 19

AI/ML for NR air interface — 3GPP TR 38.843 V18.0.0 (2023-12)

Exploration of augmentation of the **5G air interface** by AI/ML, starting with **pilot use cases in 3GPP Release 18** to assess performance in comparison to **conventional methods** and **specification impact**

CSI feedback enhancements

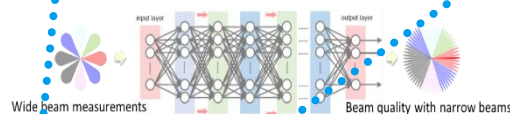
- **Compression and prediction**

Remained a study item in Rel-19



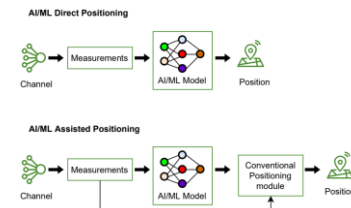
Beam management

- Beam prediction in time, and/or spatial domain for overhead and latency reduction, beam selection accuracy improvement



Positioning accuracy enhancements

- Heavy Non-Line of Sight (NLOS) conditions



Transferred to a work item in Rel-19

New RAN2-led study item in Rel-19:
AI/ML for mobility in NR

SUCCESSFUL VALIDATION OF VENDOR INTER-OPERABILITY FOR ML-BASED CSI FEEDBACK ENHANCEMENT

Wireless AI Performance Verification

ROHDE & SCHWARZ



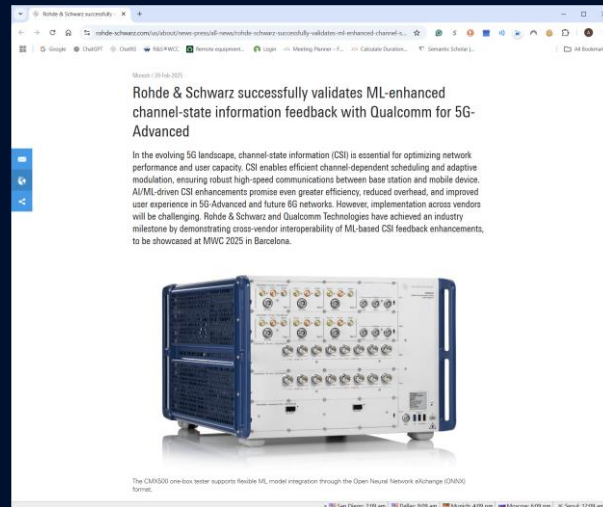
Qualcomm

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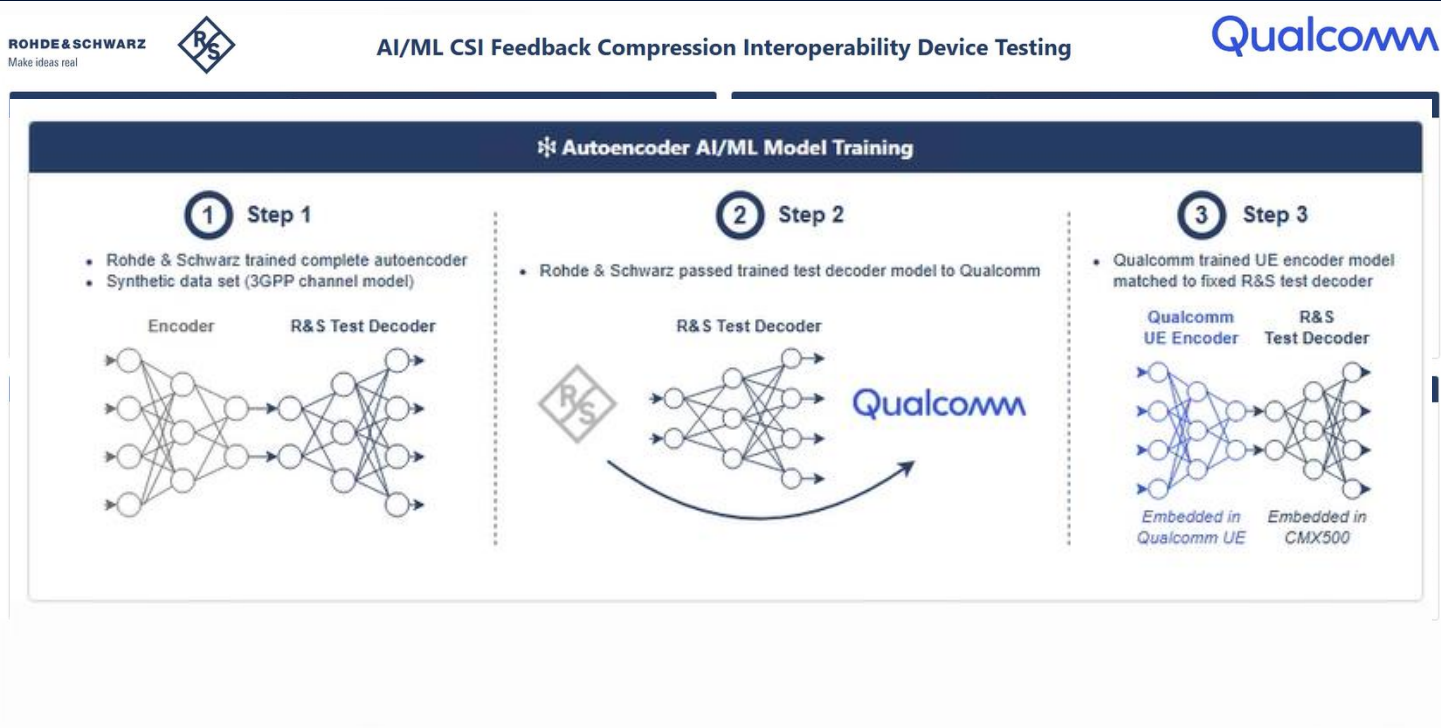
Wireless AI Performance Verification

Yousong Mei

Senior Director Engineering Qualcomm Technologies, Inc.

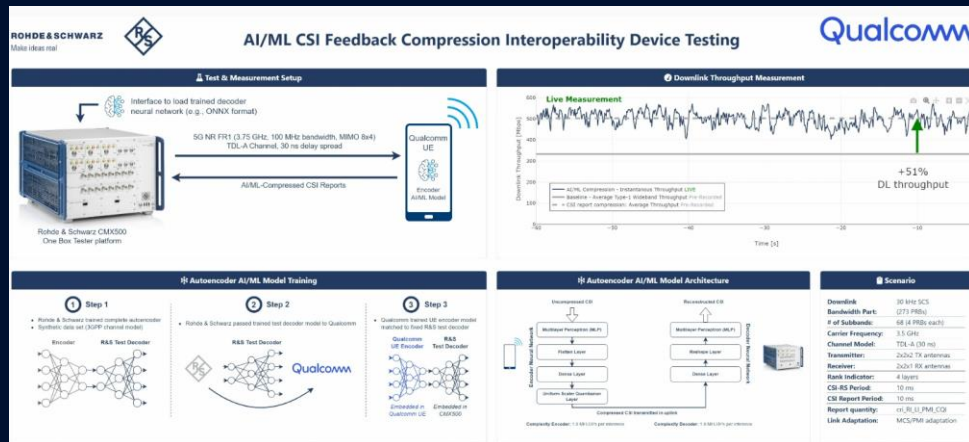


HOW DID WE ACHIEVE INTEROPERABILITY?



ML-CSI FEEDBACK ENHANCEMENT

MWC 2025 DEMO IMPRESSIONS



- R&S@CMX500 5G One Box Signaling Tester allows the import of vendor-designed ML models, e.g., proprietary decoder for ML-CSI feedback enhancement through the support of industry-standard ONNX¹⁾ interface

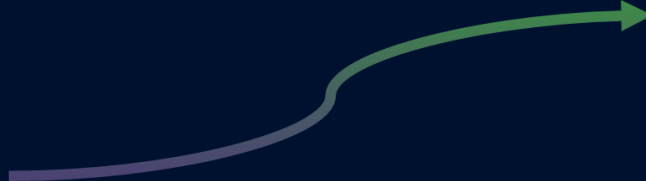
¹⁾ ONNX – Open Neural Network Exchange



3GPP STATUS

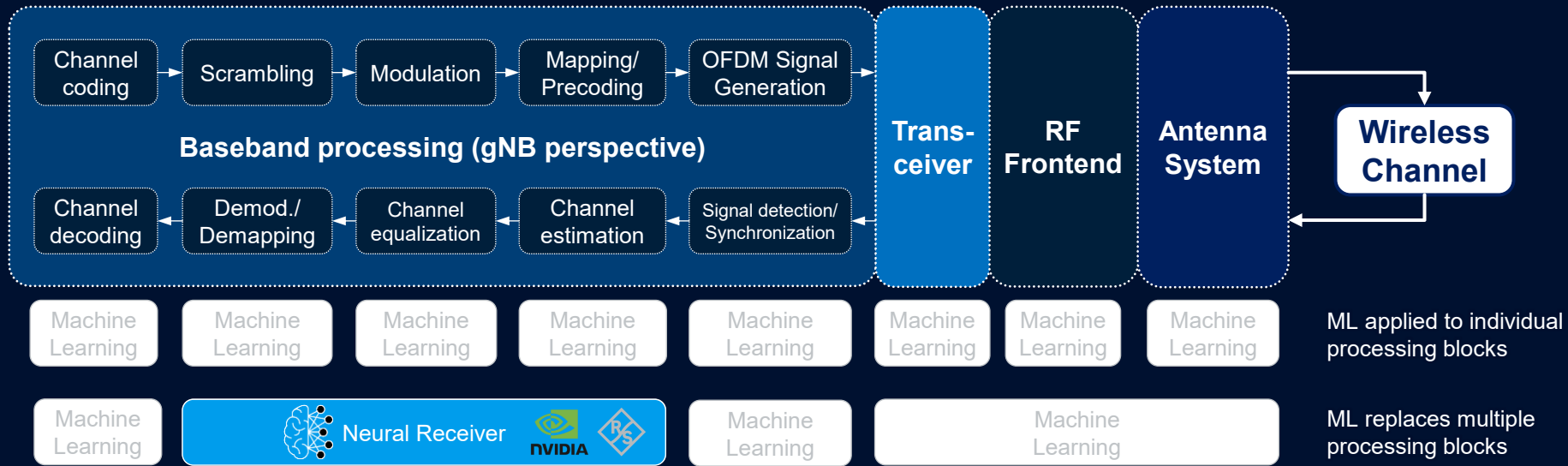
- ▶ ML-CSI feedback becomes work item for 5G-Advanced in 3GPP Release 20
- ▶ RP-251870 – New WI: AI/ML for NR air interface enhancements
 - AI/ML framework for two-sided AI/ML models within the realm of what has been studied
 - CSI-feedback enhancement, encompassing two-sided model
 - Inter-vendor training collaboration for two-sided AI/ML models
 - Data collection; Interoperability and RRM requirement

From an
AI-assisted...



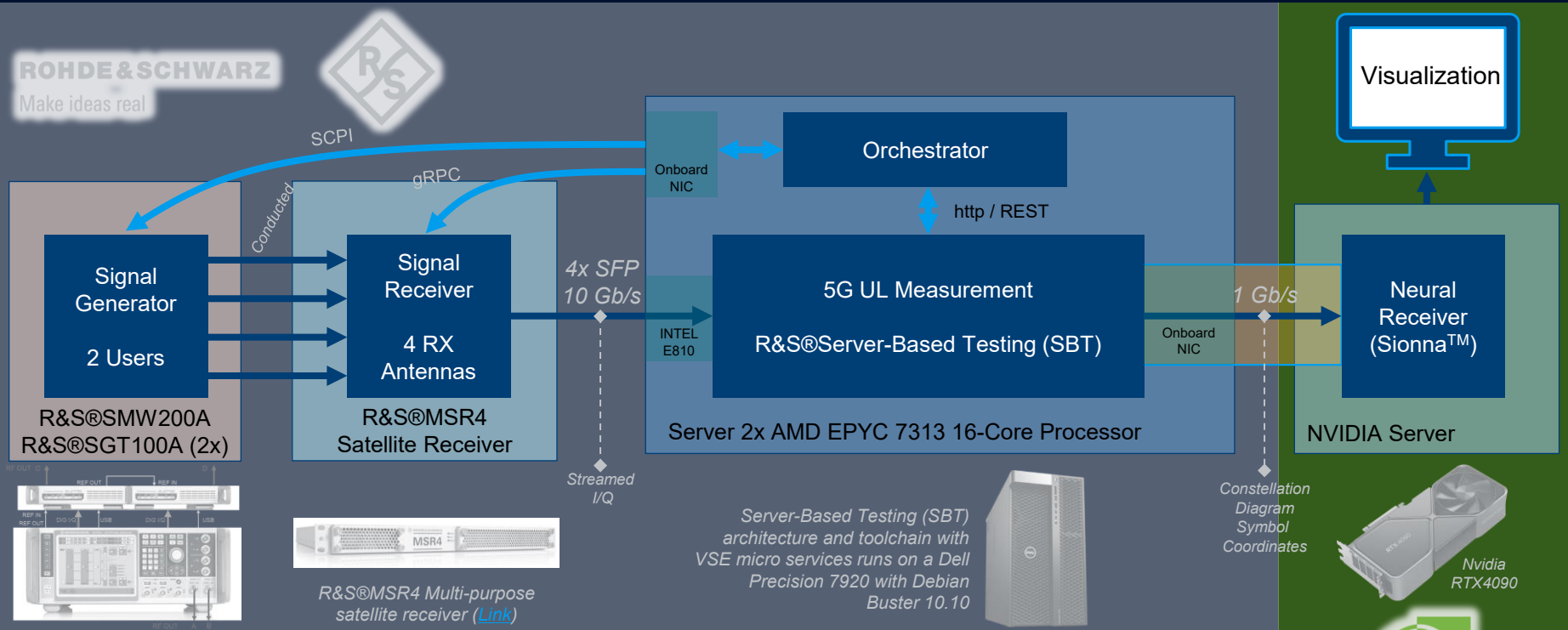
TOWARDS AN AI-NATIVE AIR INTERFACE FOR 6G

WHAT IS R&S DOING ABOUT IT? – NEURAL RECEIVER TESTBED



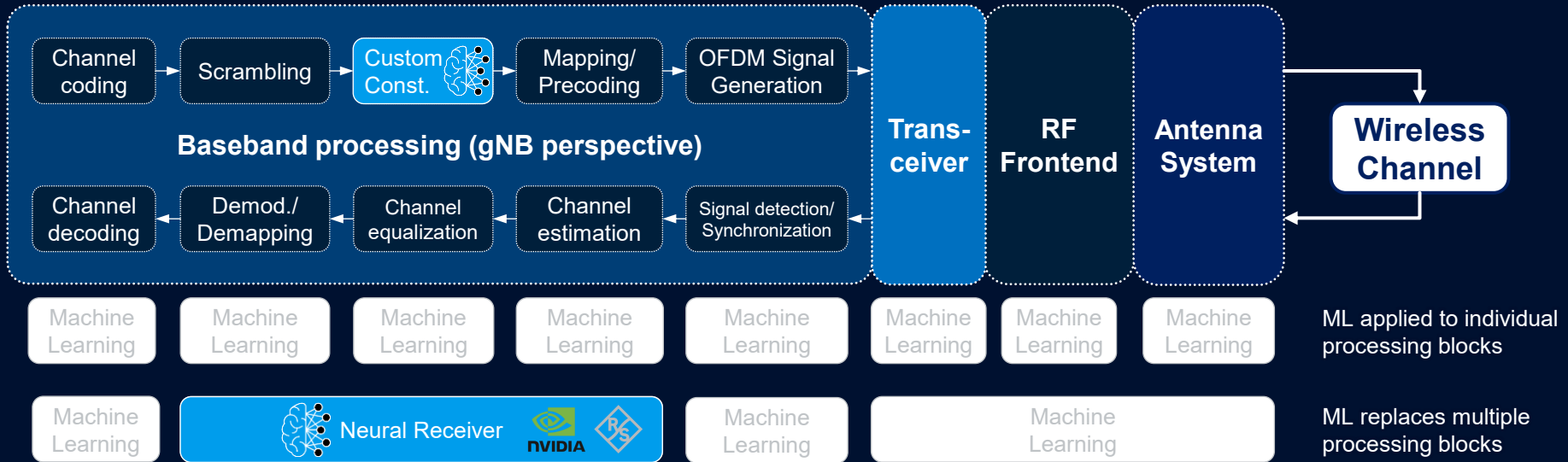
- Rohde & Schwarz's neural receiver model trained with SIONNA for 3GPP's **UMi channel model** for different Doppler shifts and Doppler spreads with random UE' drops
- QAM modulation backed into weights, need to retrain for other modulation schemes
- Model trained for SCS 30 kHz, retraining for other SCS required

NEURAL RECEIVER TESTBED



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



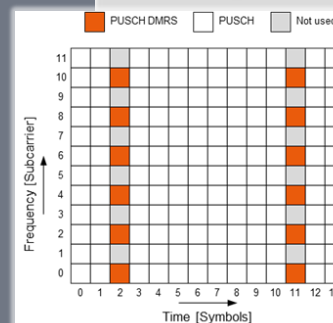
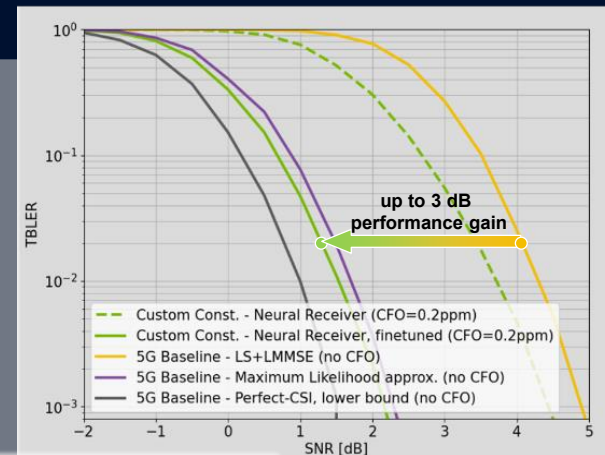
Benefits

- 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,

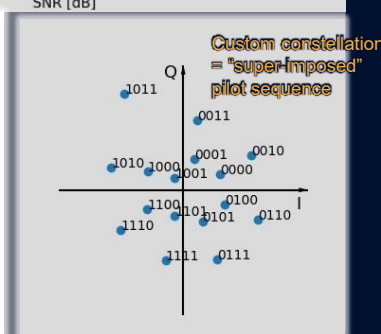


No free lunch!

- 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

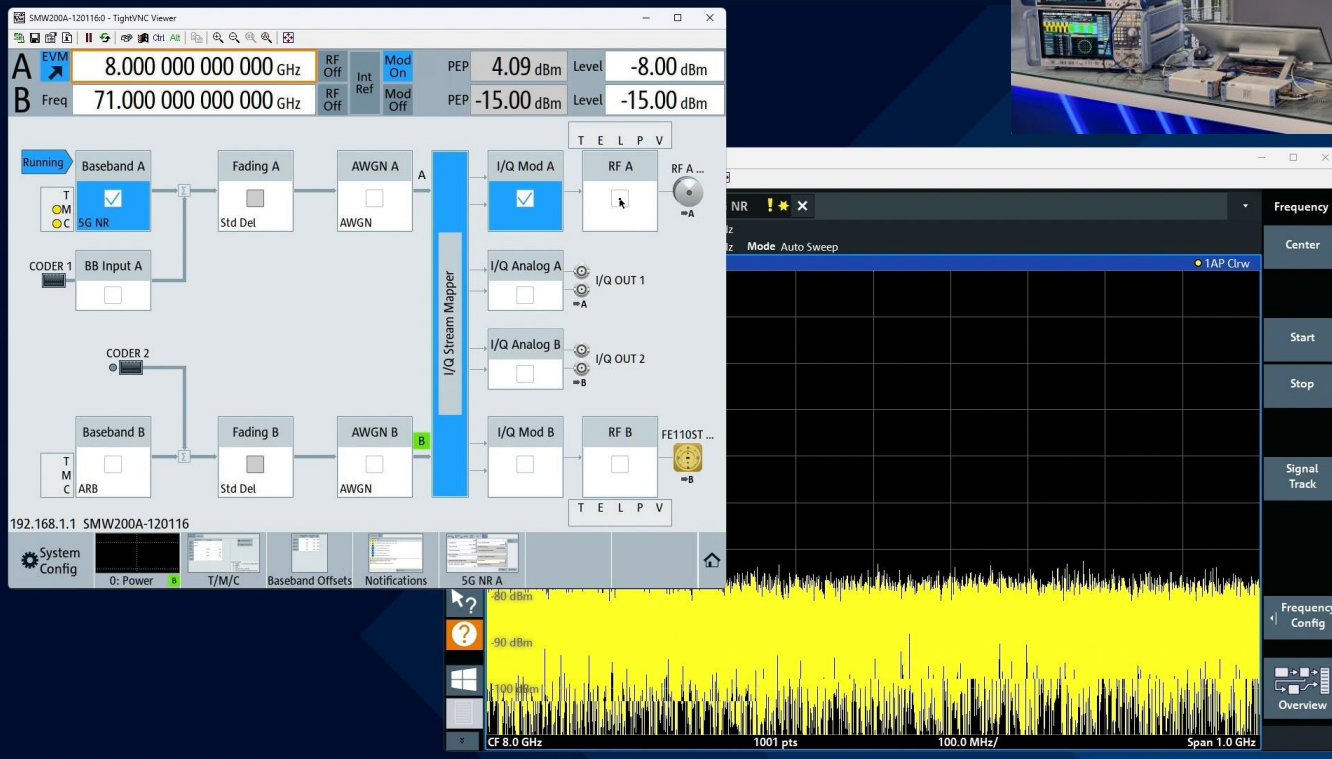


12 x 14 = 168 RE
12 RE for pilots, 12 RE unused
24/168 = ~14%



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

CUSTOM CONSTELLATION IN PRACTICE



TOWARDS AN AI-NATIVE AIR INTERFACE FOR 6G

SUPPORT OF CUSTOM CONSTELLATION WITH OPTION K184

- Rohde & Schwarz implemented a 'custom constellation' feature into its 5G NR software options for signal generator and spectrum analyzer; next step: end-to-end learned neural receiver with custom constellation

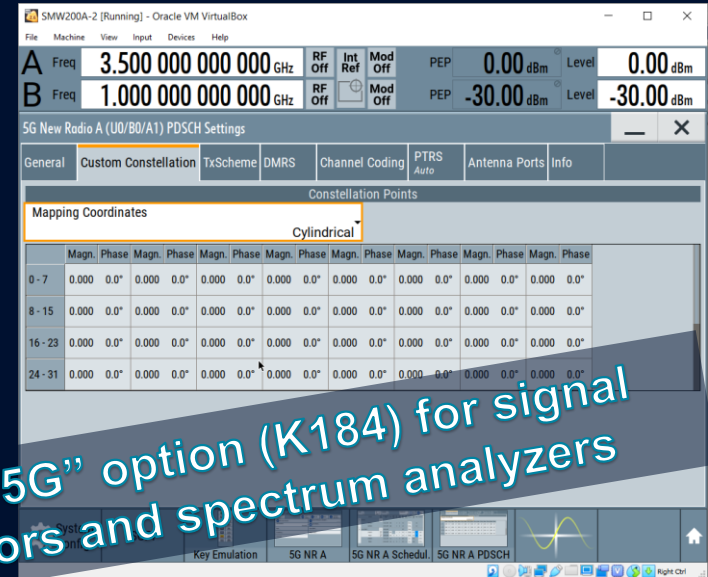
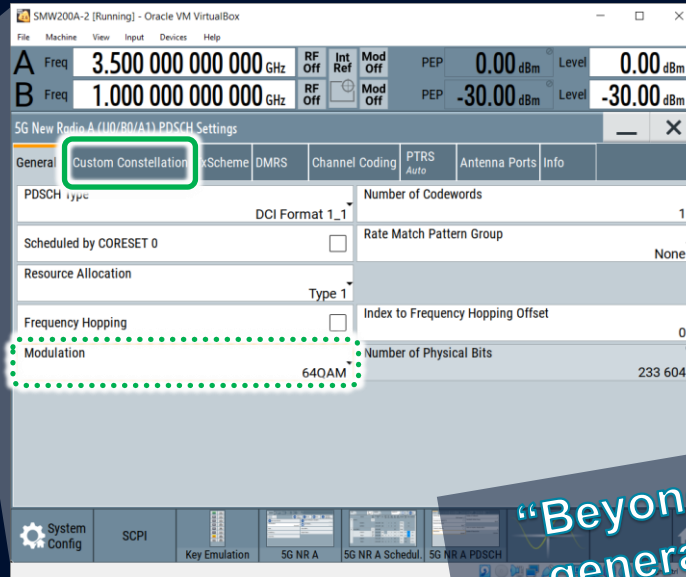


R&S®SMW200A
Vector Signal Generator



R&S®FSW
Signal and spectrum analyzer

+ Vector Signal Explorer
(VSE) software

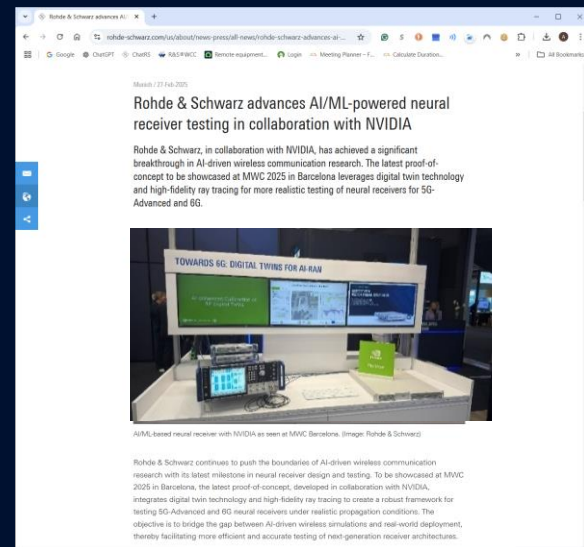
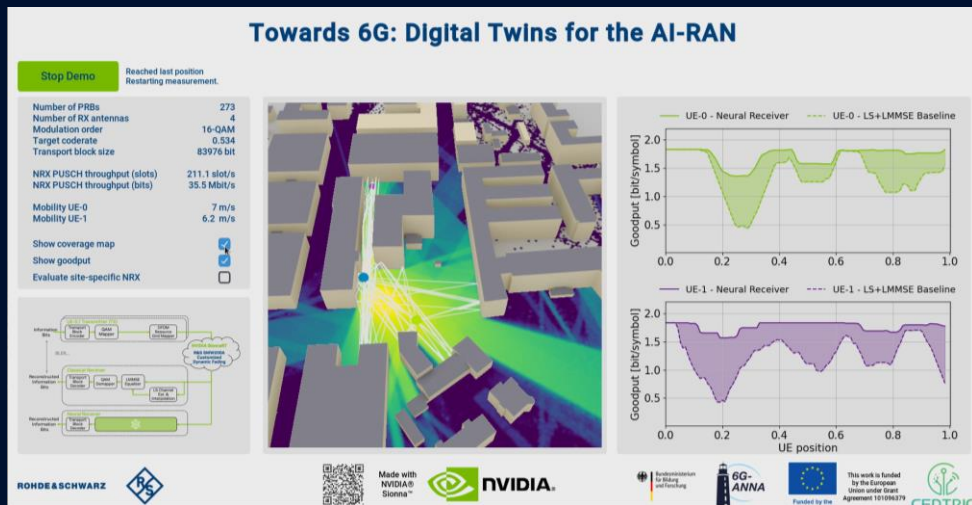


“Beyond 5G” option (K184) for signal
generators and spectrum analyzers

THE NEXT STEP – TRENDS IN RESEARCH

DIGITAL TWINS FOR AI-RAN

Demoed @ **MWC** GSMA BARCELONA 3 - 6 MARCH 2025



site-specific adaptation of a **neural receiver** model by ray tracing simulation to accurately characterize the wireless channel in the targeted deployment area

BRING RAYTRACING TO THE LAB

R&S®SMW200A
Vector Signal Generator with
Customized Dynamic Fading



Transition ray tracing
simulation into fading
profile using customized
dynamic fading option



RF Channel Modeler
generates custom
wireless channel models
for laboratory testing of
real 5G/6G hardware



SUMMARY NEURAL RECEIVER TESTBED ON THE PATH TO SITE-SPECIFIC ML-BASED SIGNAL PROCESSING

Mobile World Congress 2023

Industry-first Neural RX Testbed



Towards 6G: Rohde & Schwarz showcases AI/ML-based neural receiver with NVIDIA at MWC Barcelona

With research on the technology components for the future 6G wireless communication standard in full swing, the possibilities of an AI-native air interface for 6G are also being explored. Rohde & Schwarz, working with NVIDIA, is taking a step forward from simulations to implementing artificial intelligence and machine learning (AI/ML) in future 6G technology. At MWC Barcelona, the companies will present the industry's first hardware-in-the-loop demonstration of a neural receiver, showing the achievable performance gains when using trained ML models compared to traditional signal processing.

Brooklyn 6G Summit 2023

End-to-End Learning Testbed

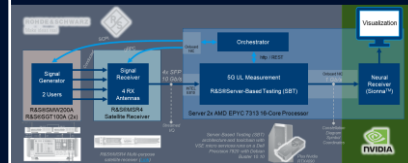


Enabling an AI-native air interface for 6G: Rohde & Schwarz showcases AI/ML-based neural receiver with optimized modulation at Brooklyn 6G Summit, in collaboration with NVIDIA

With research on the technological components of the future 6G wireless communication standard in full swing, the possibilities of an AI-native air interface for 6G are also being explored. In collaboration with NVIDIA, Rohde & Schwarz takes another step forward and presents an enhancement to its recent hardware-in-the-loop demonstration of a neural receiver, showing the achievable performance gains when using trained ML models compared to traditional signal processing — while for the first time also optimizing the transmitter side.

Mobile World Congress 2024

Neural RX + Impairment Compensation



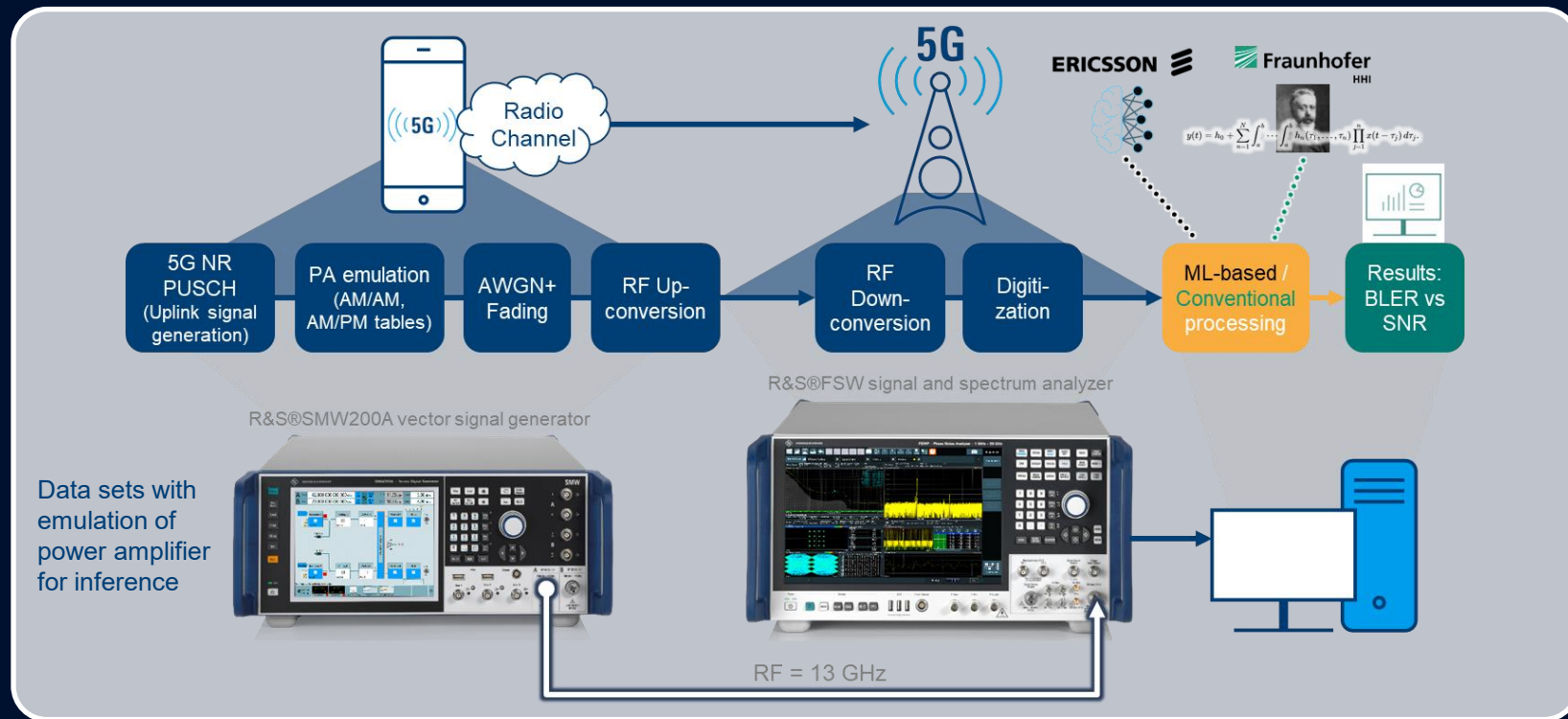
Mobile World Congress + IMS 2025

Digital Twin for AI-RAN



THE NEXT STEP – TRENDS IN RESEARCH

COMBINE NEURAL RECEIVER AND DIGITAL POST-DISTORTION



MOBILE TEST SUMMIT 2025
Virtual conference connecting the World

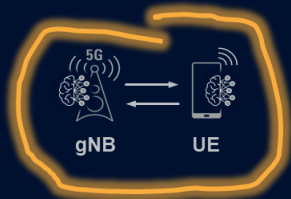


AI/ML IN 5G-ADVANCED AND 6G – PRACTICAL PATHS AND REAL CHALLENGES – KEY TAKEAWAY'S



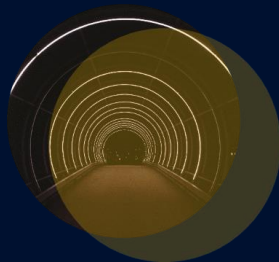
5G-Advanced establishes the foundation for AI/ML integration

- Initial framework defined in 3GPP Rel-18/19 and expected to continue with Rel-20.
- Model transfer, monitoring, and lifecycle management are still under study by 3GPP*).
- Research on neural receivers and digital twinning to validate feasibility before 6G standardization.



Two-sided AI/ML models use cases stretch interoperability requirements

- Split model execution across devices and networks. Multi-vendor integration complexity requires new validation approaches.
- Rohde & Schwarz showcased vendor interoperability in a recent demonstration with Qualcomm Technologies



Test and measurement enable AI/ML-driven wireless systems

- T&M acts as a neutral platform for cross-vendor interoperability, benchmarking, and validation.
- Critical for accelerating real-world deployment of AI/ML in wireless.

TEST ♦ MEASURE ♦ INNOVATE

 **MOBILE TEST
SUMMIT 2025**
Virtual conference connecting the World

**THANK YOU
VERY MUCH**

ROHDE & SCHWARZ

Make ideas real

