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Telecommunications
Standards Development
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TECH DEEP DIVE

TTDD 2025 CONFERENCE (8th EDITION)

STANDARDISING 6G:

ARCHITECTING INTELLIGENT, SECURE AND SUSTAINABLE NETWORKS & SERVICES

 **Date:** 15-18 July 2025

Media Partner

COMMUNICATIONS TODAY

Session #6 - The OFDM dilemma and Potential new Waveforms for 6G

17 July 2025

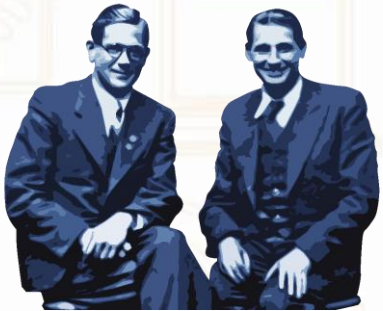
OFDM or no OFDM waveforms for 6G – a T&M perspective

by

Meik Kottkamp, Rohde & Schwarz

Rohde & Schwarz Company Introduction

- Privately owned
(headquarter in
Munich, Germany)
- 90+ years

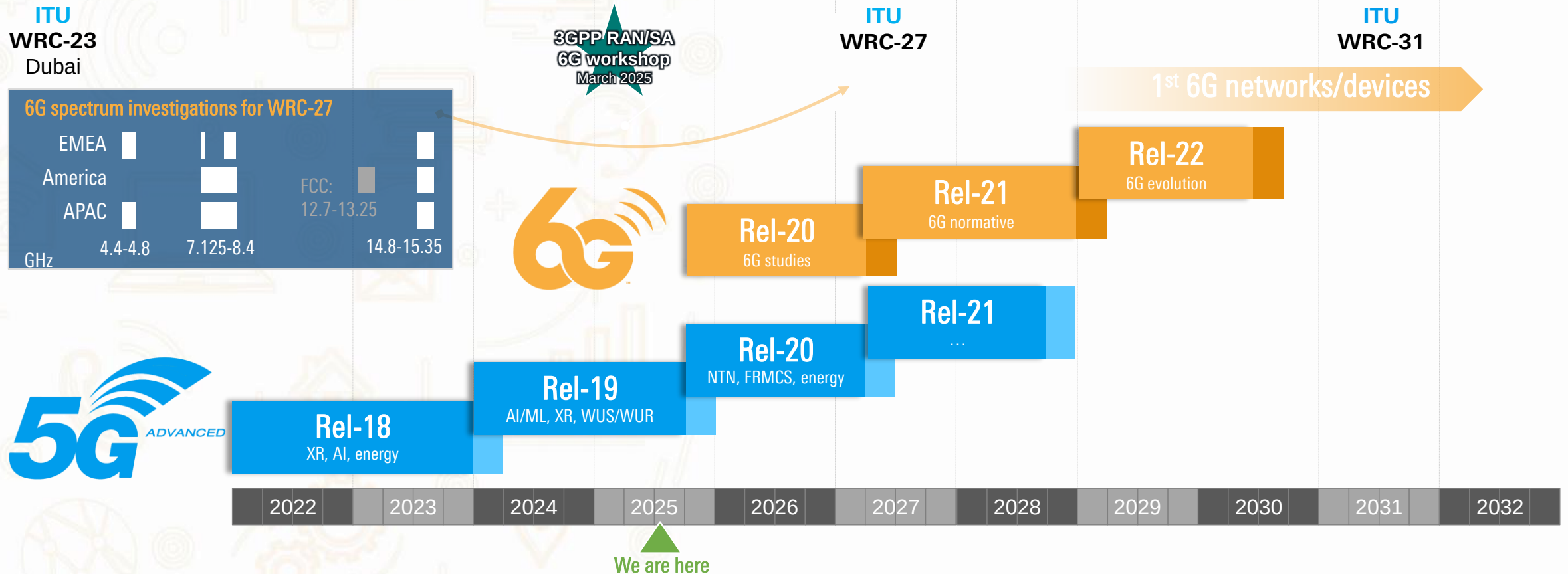


- Locations in around
70 countries
- 14.4k+ employees

TEST & MEASUREMENT	TECHNOLOGY SYSTEMS	NETWORKS & CYBERSECURITY
 Wireless Industry, Components & Research Aerospace & Defense Testing Automotive	 Secure Communications SIGINT / Electronic Warfare Monitoring & Analytics Infrastructure & Networks Strategic Programs	 Endpoint & Mobile Security Secure Networks Certified & High Grade Crypto Solutions

3GPP standardization and regulation

On the way towards planned 6G launch in 2030



HEADING FOR THE SLIDE

Sub-Heading

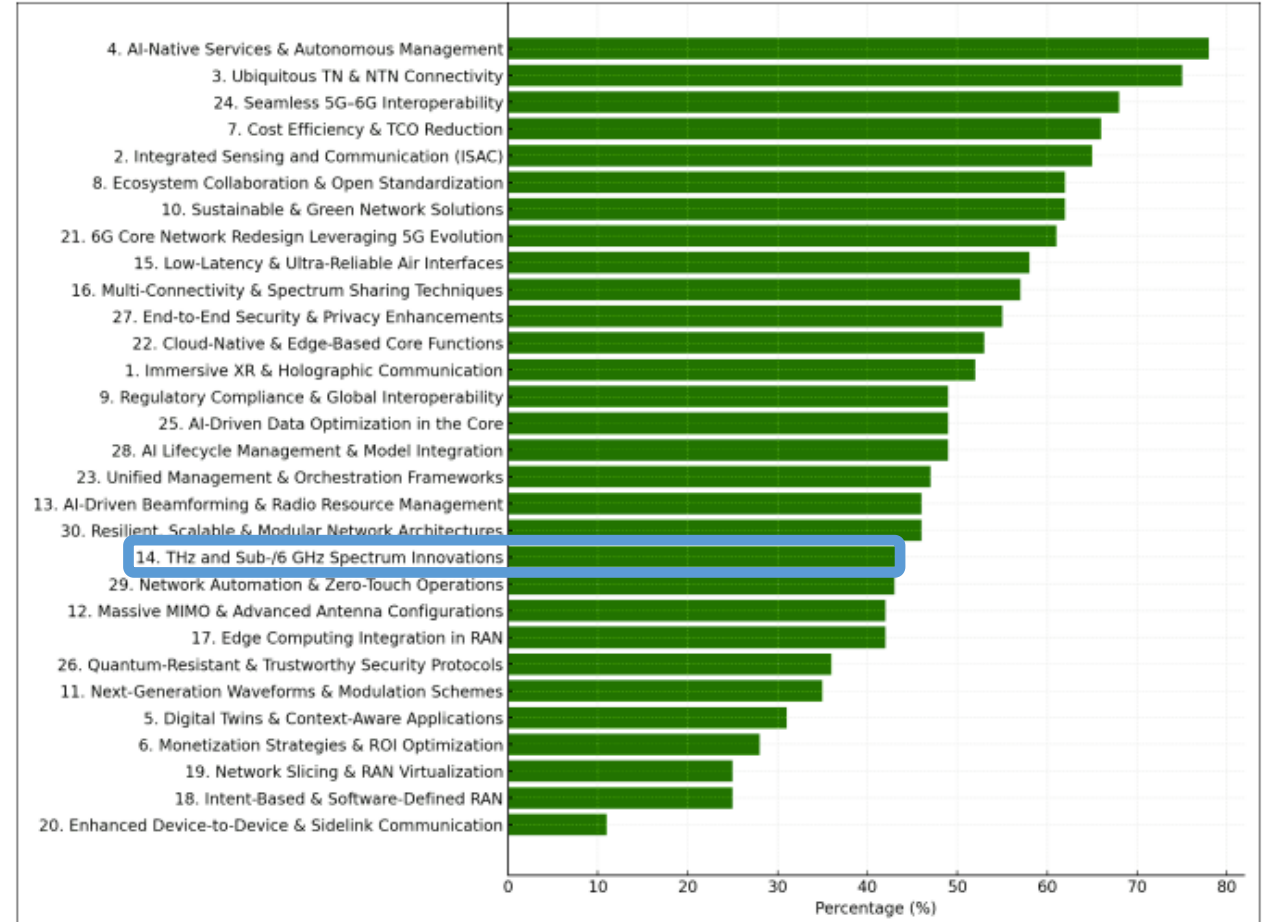
AI Native Services &
Autonomous Management

Ubiquitous TN & NTN Connectivity

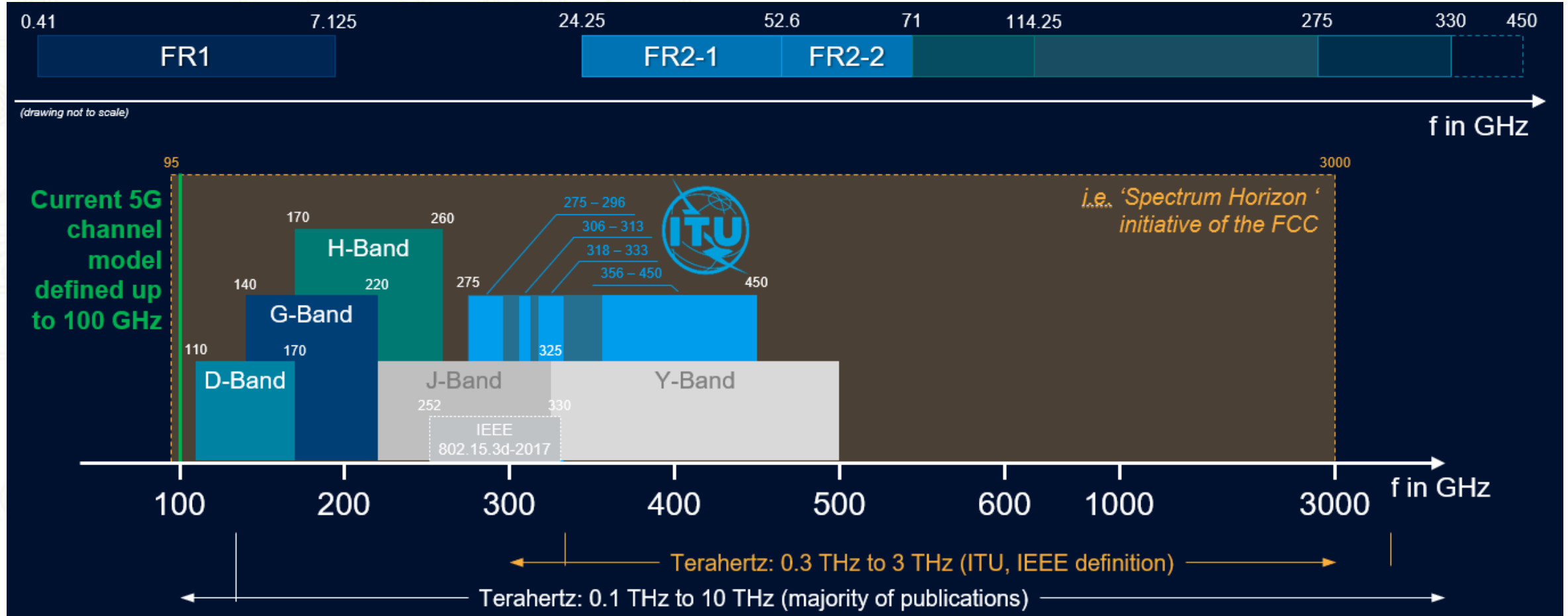
Digital Twins & Context- Aware Applications

...

3GPP RAN/SA
6G workshop
March 2025



(sub)-THz was initially of interest and still plays a role in research ...



... but the commercial 6G spectrum interest is cm-wave (~6 to 15 GHz)



- 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 27.5-27.5 (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: Spectrum Working Group

NEXT G ALLIANCE

6G cmWave performance



This MWC demo used a highly accurate digital model of Dubai, the location for the recent World Radiocommunication Conference (WRC-23), to show how the coverage compares between 3.5GHz, 7GHz, and 14GHz. The basic conclusion is that 7-8GHz is very interesting spectrum that can come quite close to matching the DL coverage of 3.5GHz. This means that re-use of the existing grid becomes a more likely possibility and this needs to be further explored.

Laying the groundwork for new spectrum



Securing spectrum for 6G is a decade-long journey that is already underway. Frequencies between 6 GHz and 15 GHz — known as the upper mid-band — have been identified as prime candidates for 6G use. The International Telecommunication Union (ITU)'s World Radiocommunication Conference 2023 (WRC-23) have initiated studies to identify bands within this range for 5G Advanced and 6G. For instance, one of the most impactful agenda items for WRC-27 involves the identification of several frequency bands, including 4.4-4.8 GHz, 7.125-8.4 GHz and 14.8-15.35 GHz, for potential International Mobile Telecommunications (IMT) use. In addition, many countries throughout the world are planning to deploy IMT services in the upper 6 GHz band (6.425-7.125 GHz).

One example operator view on 6G spectrum



410 - 7125

Supports all bands in FR1 from 410 – 7125 MHz

As 5G NR, 6G continues to support all FR1 bands

Pot. new FR1 spectrum only upper 6 GHz band

Clean exclusive IMT spectrum (without RLAN usage) needed for efficient 6G deployment

u6GHz: 6425 – 7125 MHz for IMT only

200 MHz CBW support (400 opt.)

6425 - 7125

> 24 GHz

“FR2” and (lower) THz

Lower priority for DT, but 6G assumed to work up to 71 GHz as NR does

We do not see lower THz (71-300 GHz) or even higher frequencies as candidate bands for 6G radio deployments

“FR3”

No potential for Europe currently seen

{7-24 GHz}

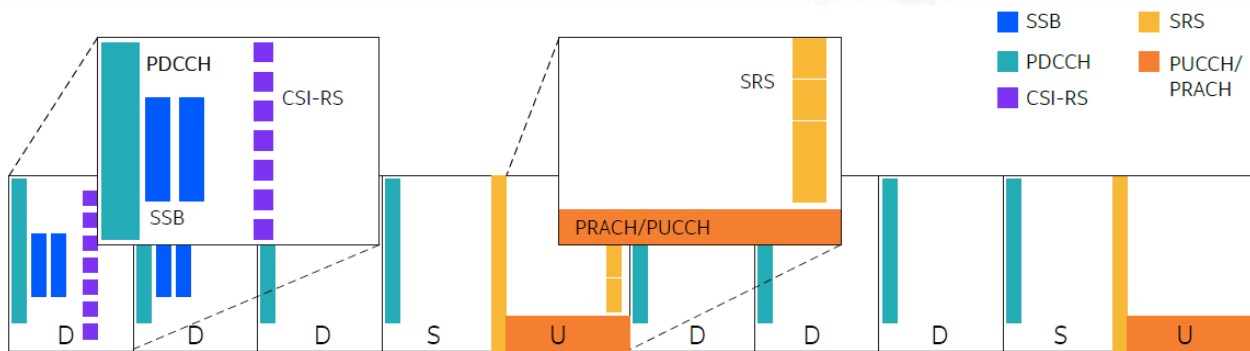


[Source: 6GWS-250011](#)

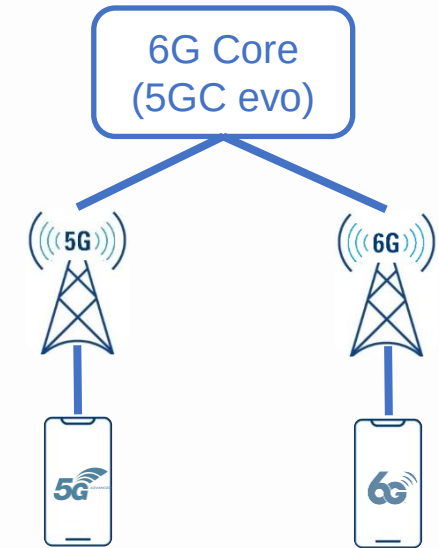
6G waveform at cm-wave spectrum

MRSS motivates similarity with 5G NR

- Clear requirement to allow 6G SA operation in existing FR1 spectrum
- Potential solution: Multi-RAT Spectrum Sharing (MRSS) with focus on 5G/6G
- Based on similar principles than DSS in 5G/4G but leveraging 5G flexibility for always on signals



Simplifying spectrum migration from 5G to 6G

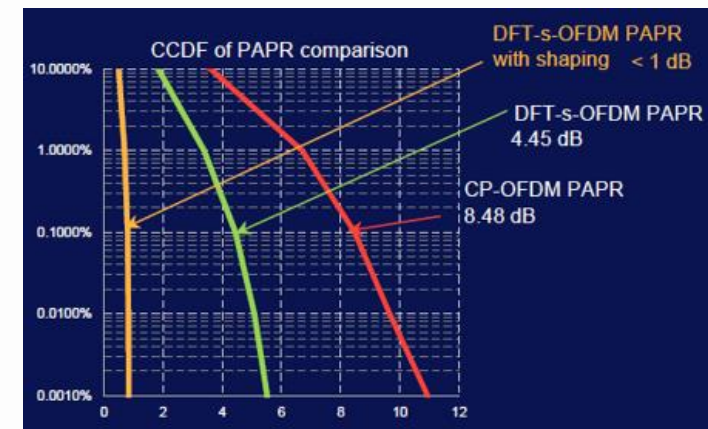
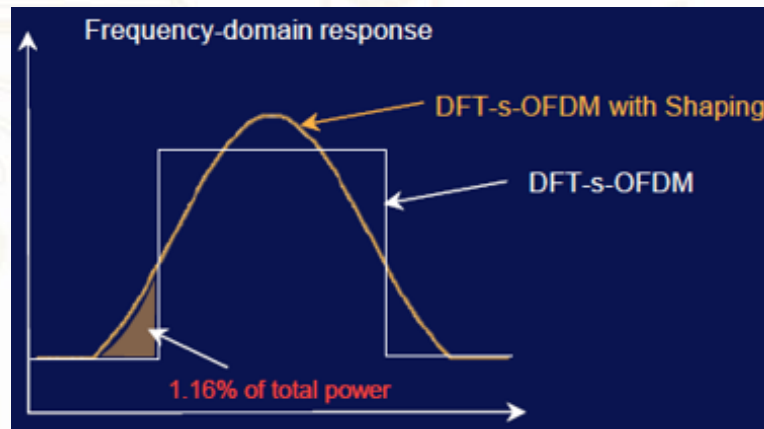


Chair's summary of the 3GPP WS on 6G radio interface ([6GWS-250243](#)):

“Non-backwards compatible (from a UE perspective) to exploit full potential, with certain characteristics (e.g. waveform, modulation and channel coding) based on 5G NR with possible enhancements.”

6G waveform proposals

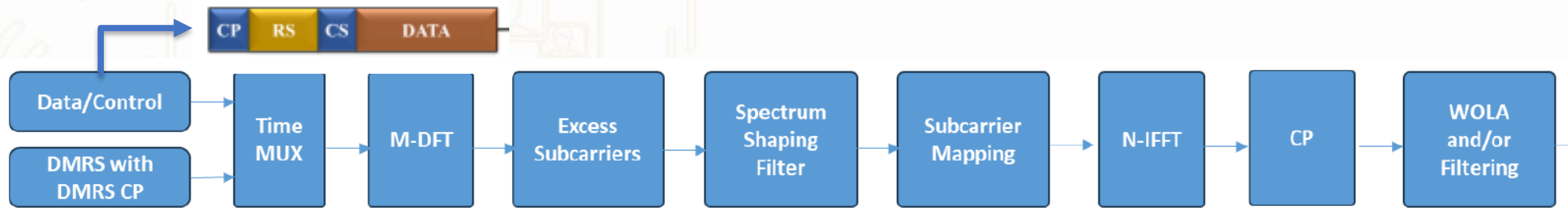
Frequency-domain spectrum shaping (FDSS) in UL



[Source: 6GWS-250036](#)

6G waveform proposals

Orthogonal Time Frequency Division Multiplexing (OTFDM)



Time Division Multiplexing in one Symbol

- Time multiplexing of Data and Control & DMRS with DMRS CP
- Instantaneous Channel Estimation with low DMRS overhead
- Information transfer in one shot with the Least Possible Latency

DFT Excess BW Spectrum Shaping Filter

- Nyquist Criterion for Zero ISI
- Excess BW signal shaping Controls the ISI caused by the pulse, reduces the tails of the ISI channel power to a below-noise floor, Reduces Effective ISI channel length, Enables DMRS-based estimation of the effective ISI channel
- Excess BW reduces PAPR further

Standard OFDM Operations

- Subcarrier mapping enables the multiplexing of multiple users/signals
- CP to offer frequency domain receiver processing
- Same spectral properties as OFDM - WOLA/filter for spectral confinement

OTFDM achieves the targets: low PAPR, Hyper low-latency
Enables multi-user multiplexing in time/frequency
Applicable in DL and DL

OTFDM publication pre-print

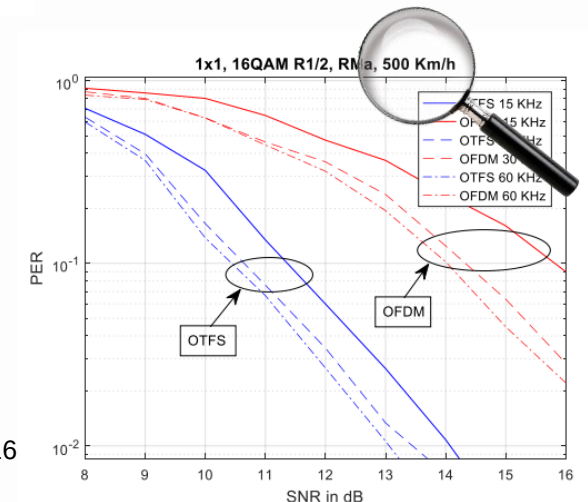
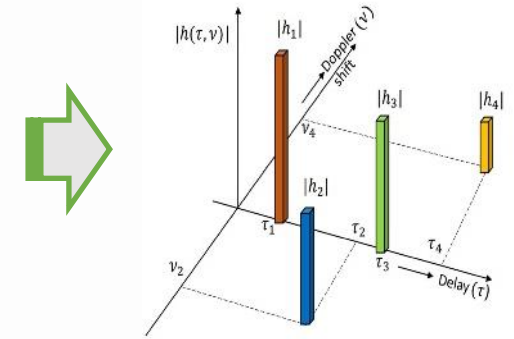
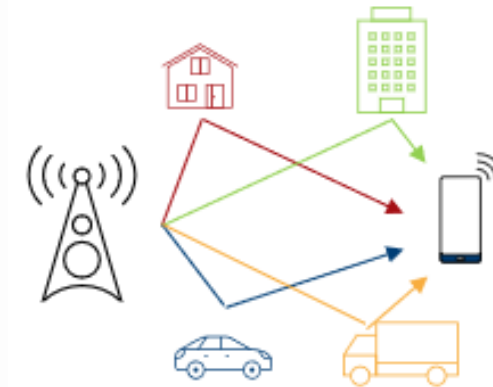
<https://arxiv.org/abs/2409.01114>

[Source: 6GWS-250026](#)

6G waveform proposals

Zak-OTFS (Orthogonal Time Frequency Space) modulation

- For TDM and FDM the signal is localized in time or in frequency $\rightarrow$ time selective or frequency selective fading
- Idea: Go to the Delay-Doppler (DD) domain
- Doppler Delay Modulation (DDM)
 - Information is carried over DD domain pulse
 - Delay period τ_p ; Doppler period $\nu_p = 1/\tau_p$
 - Zac transform $\mathcal{Z}_t$, used to transform the DD signal to a TD signal $x(t)$

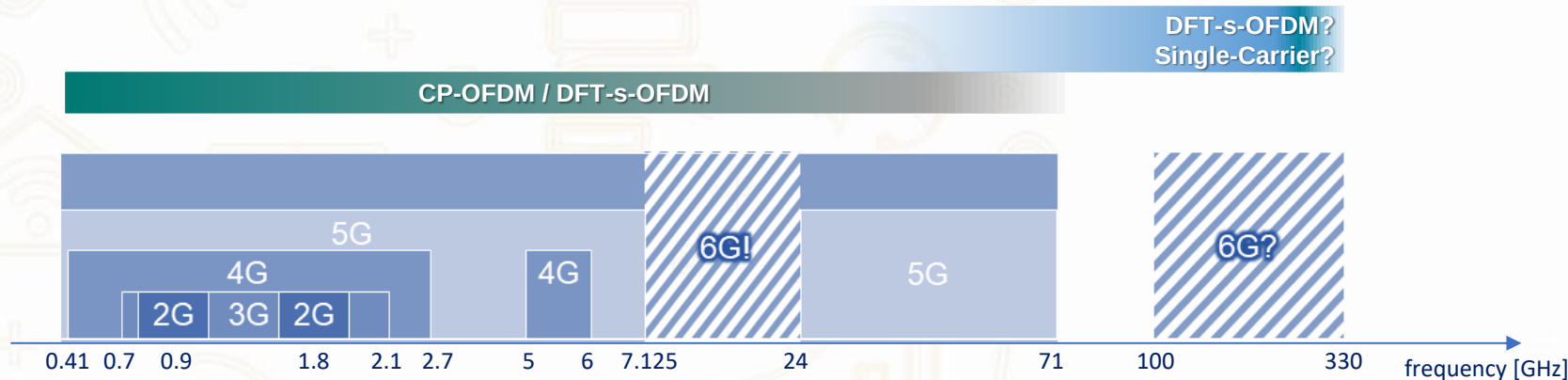


Source: [6GWS-250233](#)

Ref: [R1-1609825](#), 3GPP TSG RAN WG1 Meeting #86bis, 2016

Working assumptions for future 6G waveform

Established industry players claim: Baseline for a future 6G standard is CP-OFDM, with DFT-s-OFDM as an option for uplink and downlink



- Acknowledgement of specific waveforms for specific use cases, e.g.:
 - “Zero-energy” devices, wake-up radio?
 - NTN and high-mobility scenarios (i.e. OTFS)?
 - Integrated Communication and Sensing (OTFS, AFDM, OCDM)?
- AI-native air interface for 6G: learning of waveform

Waveform and numerology

- High spectrum efficiency must be supported
- Maintain NR numerology for efficient spectrum compatibility in existing bands to enable smooth evolution
- No need for slots as in NR. The basic transmission structure could be one OFDM symbol

Spectrum range	Downlink waveform	Numerology
Low band	OFDM	15 kHz
Mid-band		30 kHz
6G mid-band (7-15 GHz)		Proposal: 30, 60 or 120 kHz
mmW		120 kHz
60 GHz	Single-carrier (DFTS-OFDM)	120 or 480 kHz
sub-THz		Proposal: ≥960 kHz

Migrating to 6G: Prioritize 6G Standalone for a range of benefits

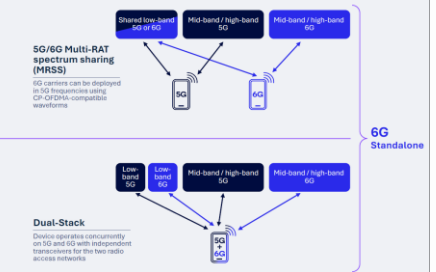
Multi-RAT Spectrum Sharing (MRSS) and Dual-Stack are complementary tools for enhanced 6G experiences over wide areas

Provide wide area 6G coverage with MRSS

Enhance the robustness of 6G with MRSS for accessing a reliable low-band coverage anchor
 Deploy 6G efficiently using CP-OFDM-compatible 6G waveforms for MRSS in existing 5G bands
 Combine existing carriers with new 6G carriers in higher frequencies for higher capacity

Improve user experiences with Dual-Stack

Simplify 6G introduction by eliminating 5G-6G RAN coordination with Dual-Stack
 Move 5G-6G interworking complexity to the device to reduce the RAN transformation effort
 Provide unprecedented user experiences by combining 5G and 6G network capacities



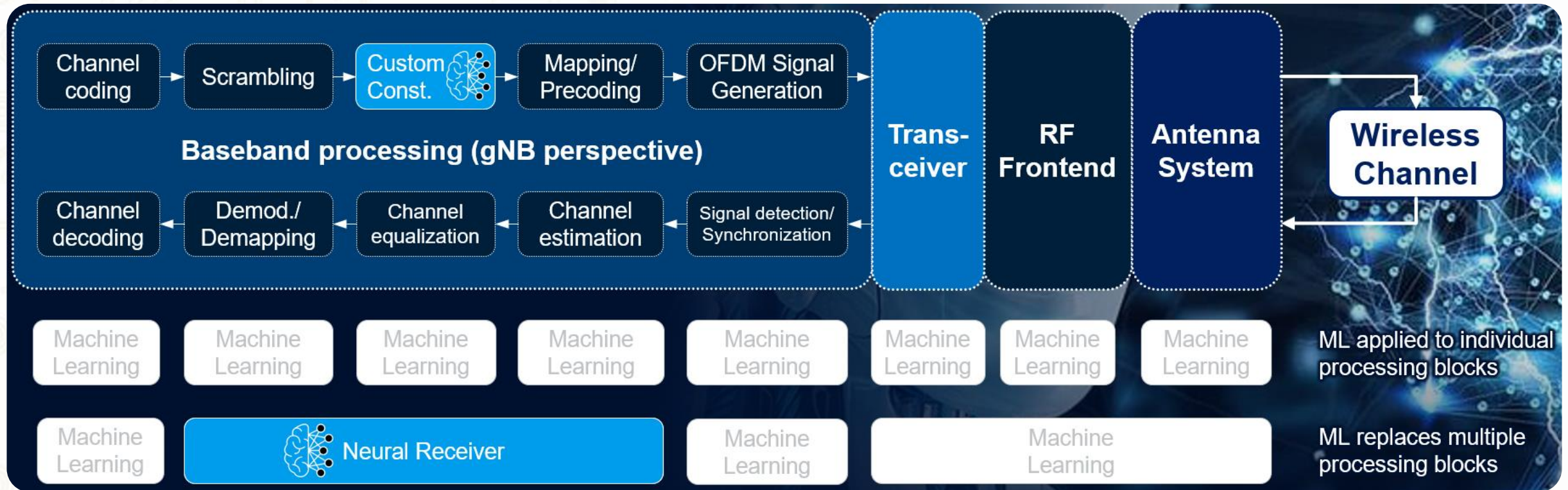
Waveform Learning for Next-Generation Wireless Communication Systems

Fayçal Ait Aoudia, *Member, IEEE*, and Jakob Hoydis, *Senior Member, IEEE*

<https://arxiv.org/pdf/2109.00998v2.pdf>

Toward an AI-native air interface for 6G

Neural receiver with custom constellation



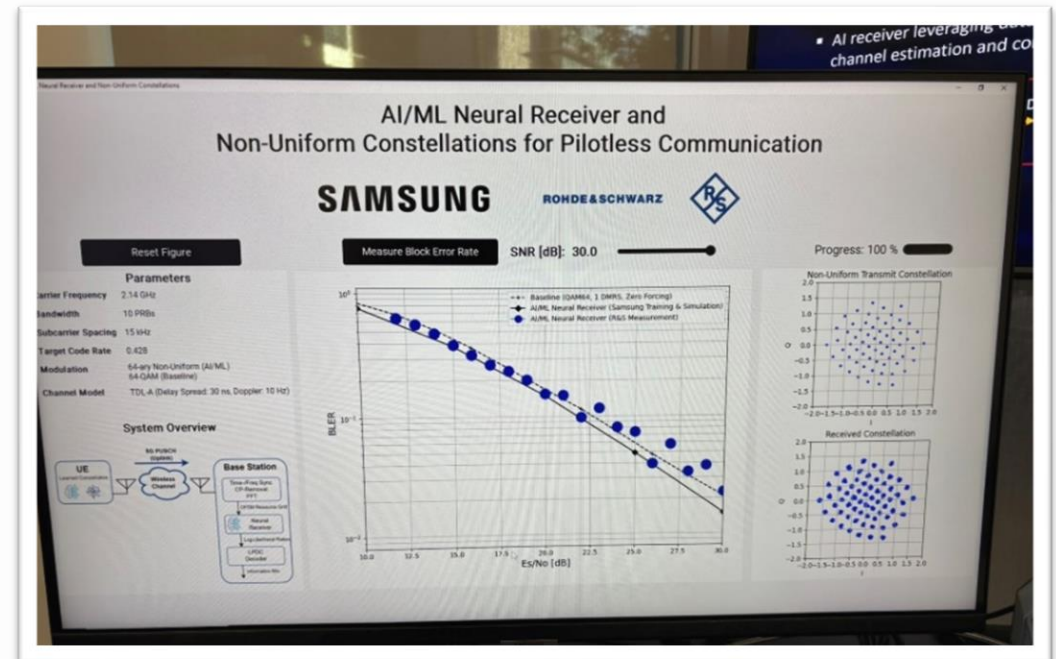
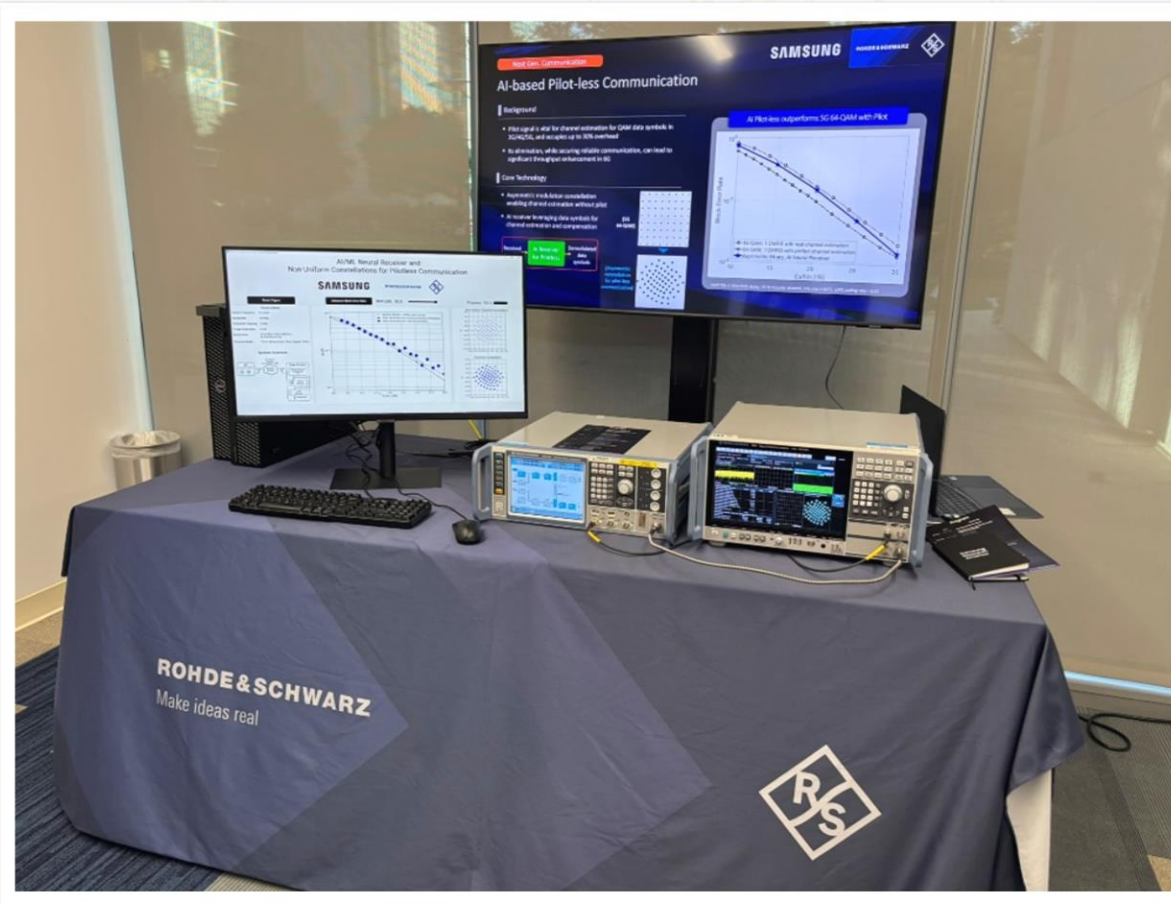


Example learning custom constellation

Samsung Electronics Demonstrates AI-RAN Technologies, Paving the Way for Convergence of Telecommunications and AI

on December 31, 2024

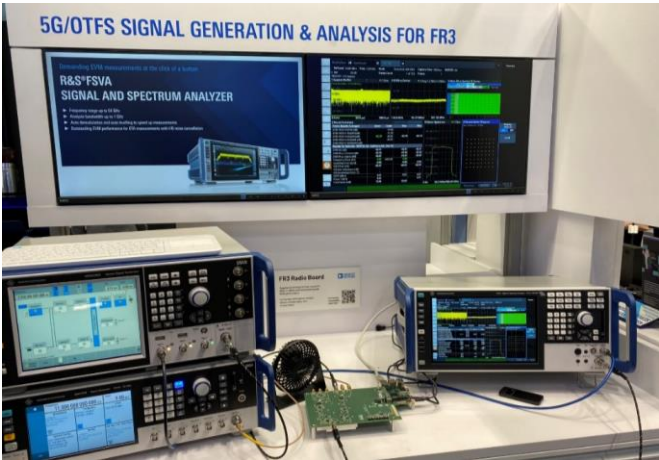
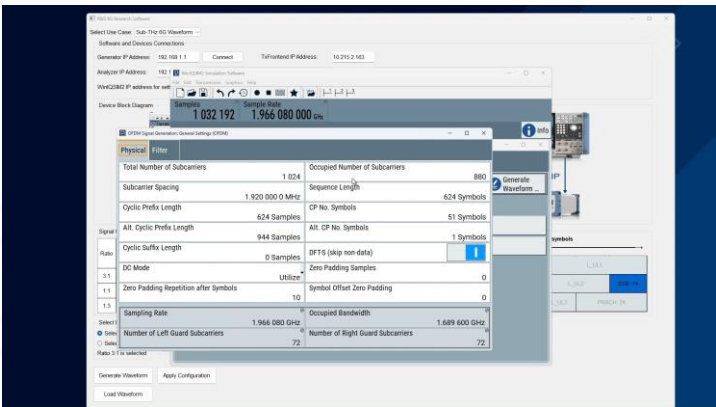
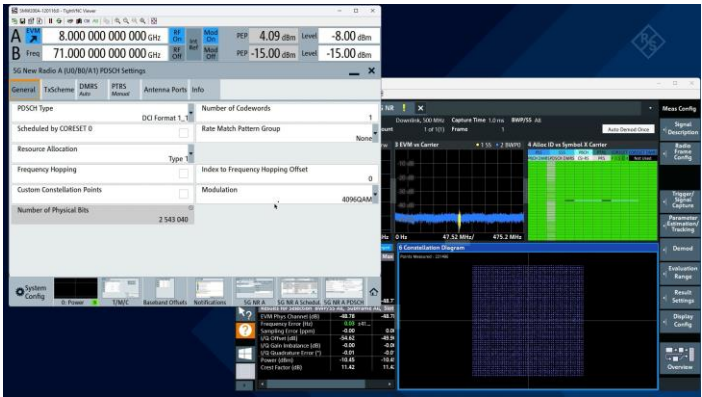
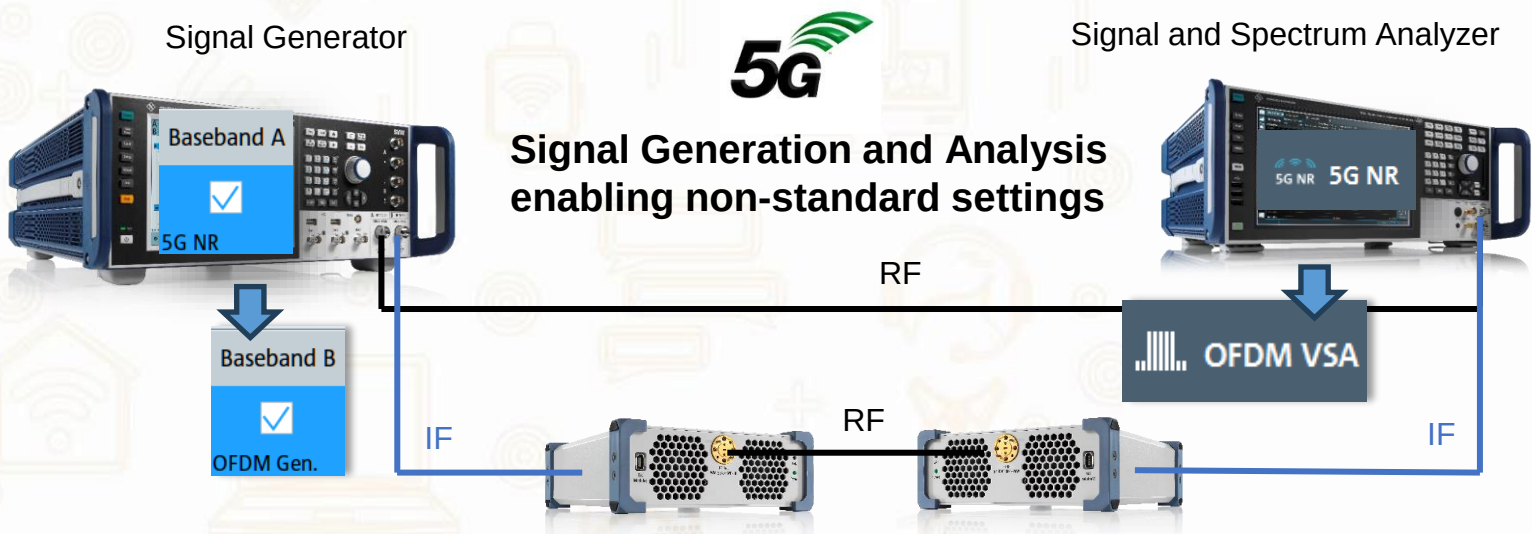
Audio Share



<https://news.samsung.com/global/samsung-electronics-demonstrates-ai-ran-technologies-paving-the-way-for-convergence-of-telecommunications-and-ai>



Illustrations how to test



MWC 2024

“No one can whistle
a symphony. It takes
a whole orchestra to
play it.”

Halford E. Luccock (1885-1960)

Thank You
Meik Kottkamp
Technology Manager Wireless

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