5GCHAMPION

“mmW Hotspot Trial, Results and Lesson Learned”

Dr. Giuseppe Destino, University of Oulu - CWC

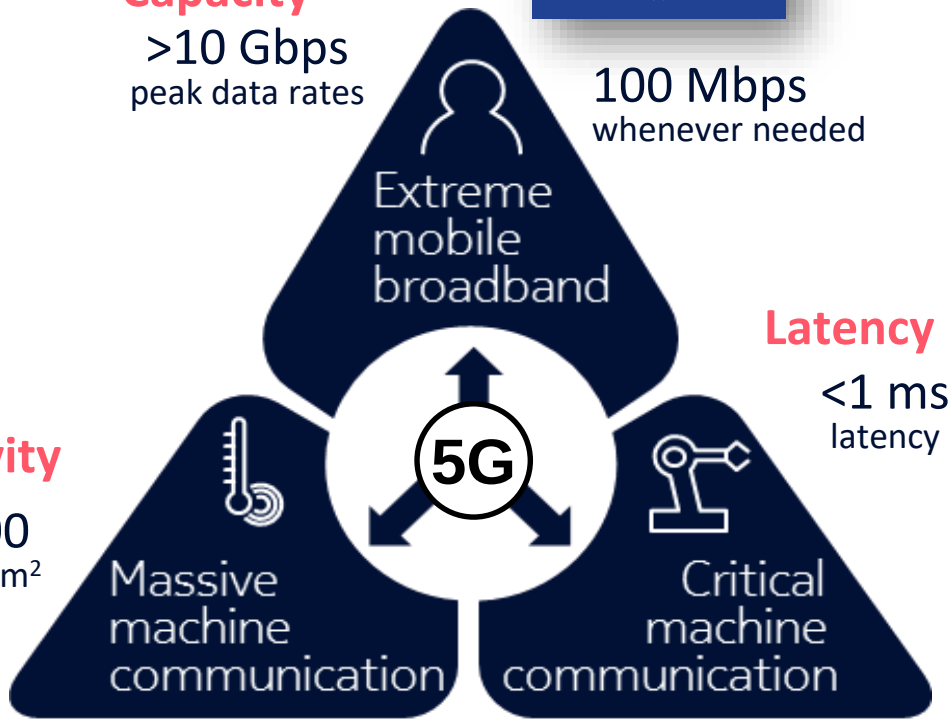
Dr. Gosan Noh, ETRI

EU-KR Symposium on 5G
“From the 5G challenge to 5GCHAMPION Trials at Winter Olympic Games”
SEOUL, KOREA, February 23, 2018

5GCHAMPION in the 5G triangle

Capacity
>10 Gbps
peak data rates

100 Mbps
whenever needed



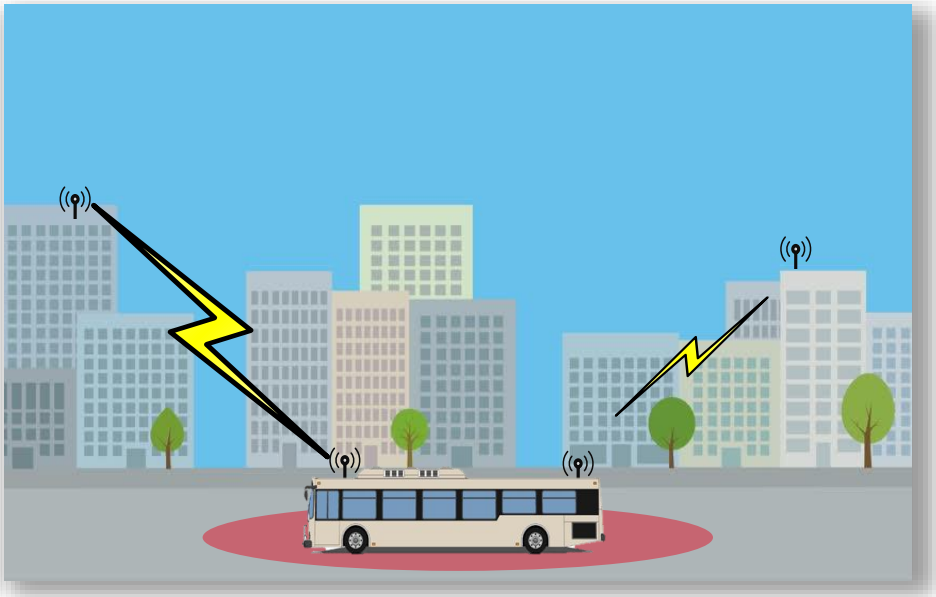
Latency
<1 ms
latency

Connectivity
1,000,000
devices per km^2

10 years
on battery

Reliability

5G mmW – First entrance in the market



Last-mile connectivity

- Extremely high-capacity in home/building/streets (>10Gbps)
- Low-latency
- Smart (adaptive to enviroments)

Moving hot-spot

- Very high-capacity in bus/car/train
- Mobility
- Low-latency

5G mmW – What does it mean for a ”normal” 5G-user

AR

Video

VR-IoT

Virtual Reality - IoT | Video

5G™ *Extreme mobile broadband*

5G mmW – The great challenge

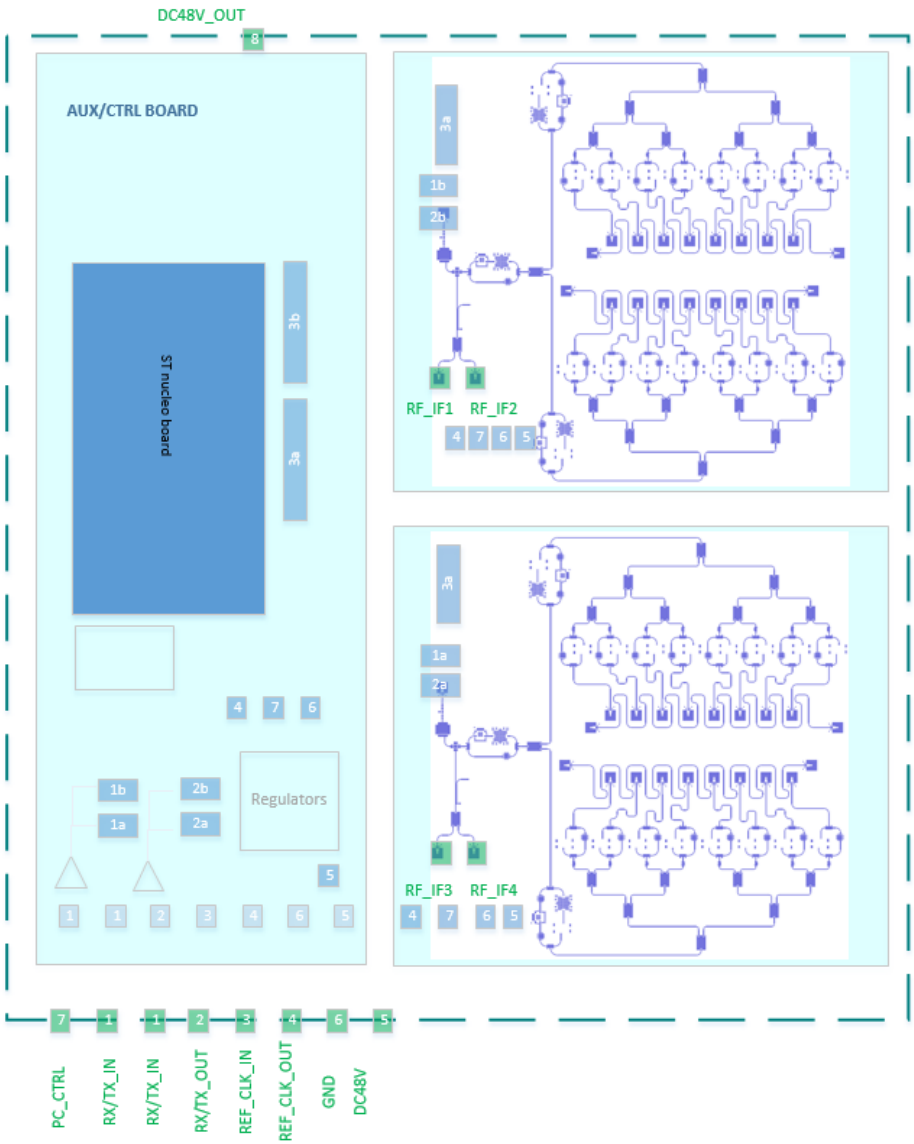
Antenna technology

- Large array gain: long range (~ 1 km)
- Wideband (5 GHz)

RF-FE

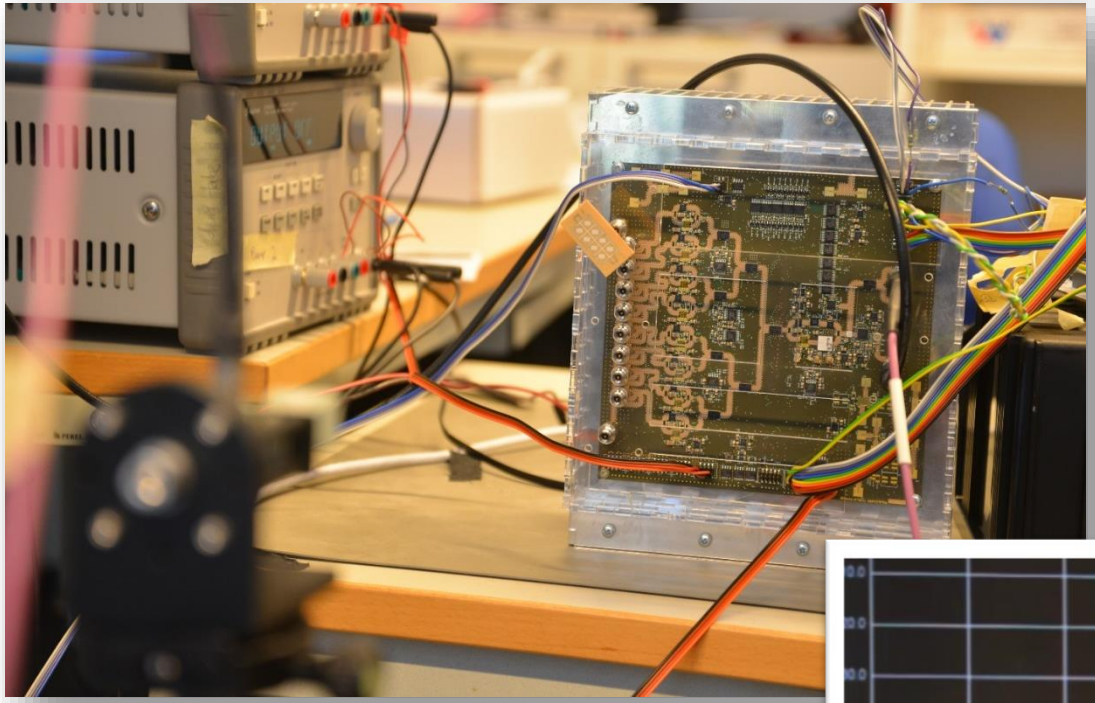
- 27 GHz technology: design, manufacturing and availability of components
- Wideband performance: high data rate
- Optimized architecture: small form-factor, heat dissipation, beamforming
- Smart RF radio: easy installation, usage

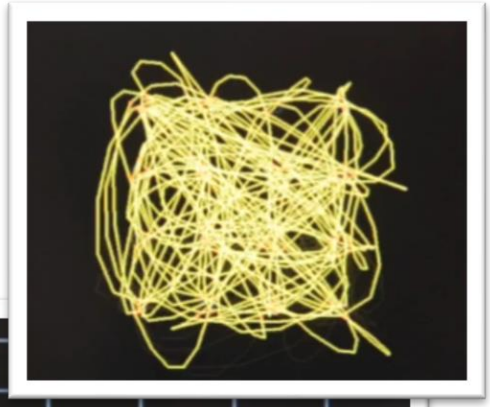
5G mmW – 5GCHAMPION development path (BF design)

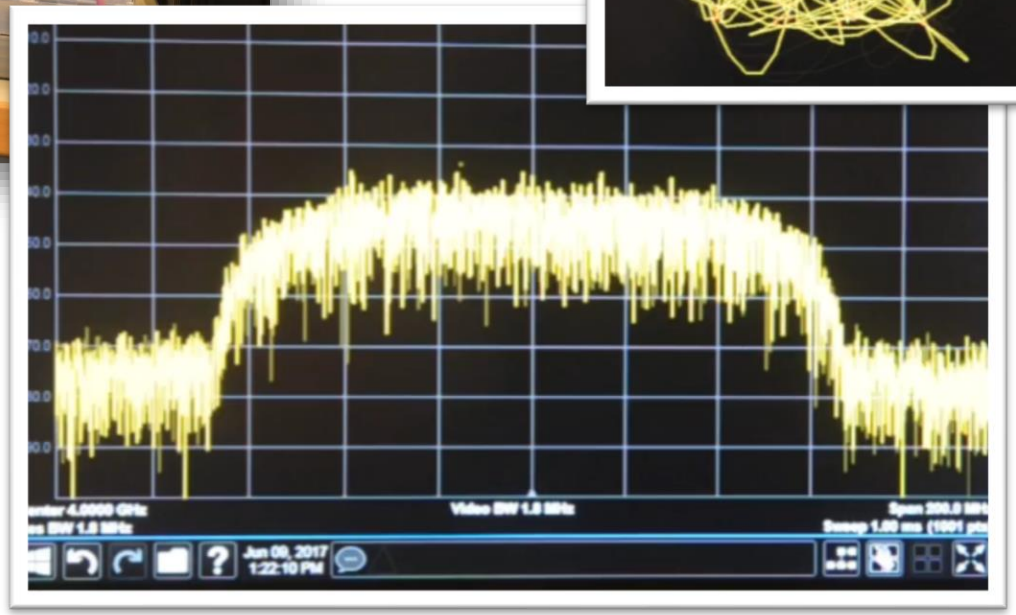


5GCHAMPION PoC
5G mmW Antenna
Wideband 1GHz
Phased-array (16x4 radiators) with/without antenna transmit array
Structure 8x2 RF beamformer – with 2x2 antenna subarray in each, linearly polarized
Maximum gain 22.7 dBi (sim.)
5G mmW RF
26.5-29.3 GHz
Operational band at the Olympics 26.5 to 27.5 GHz
4 RF beamformers (phase-shift based)
Digital phase-shift control
Digital branch enable control
Digital automatic gain control
SMART RF
Adaptive beamsteering
Hierarchical beamforming
Automatic gain control
Automatic beam alignment

5G mmW – 5GCHAMPION development path (1st test)



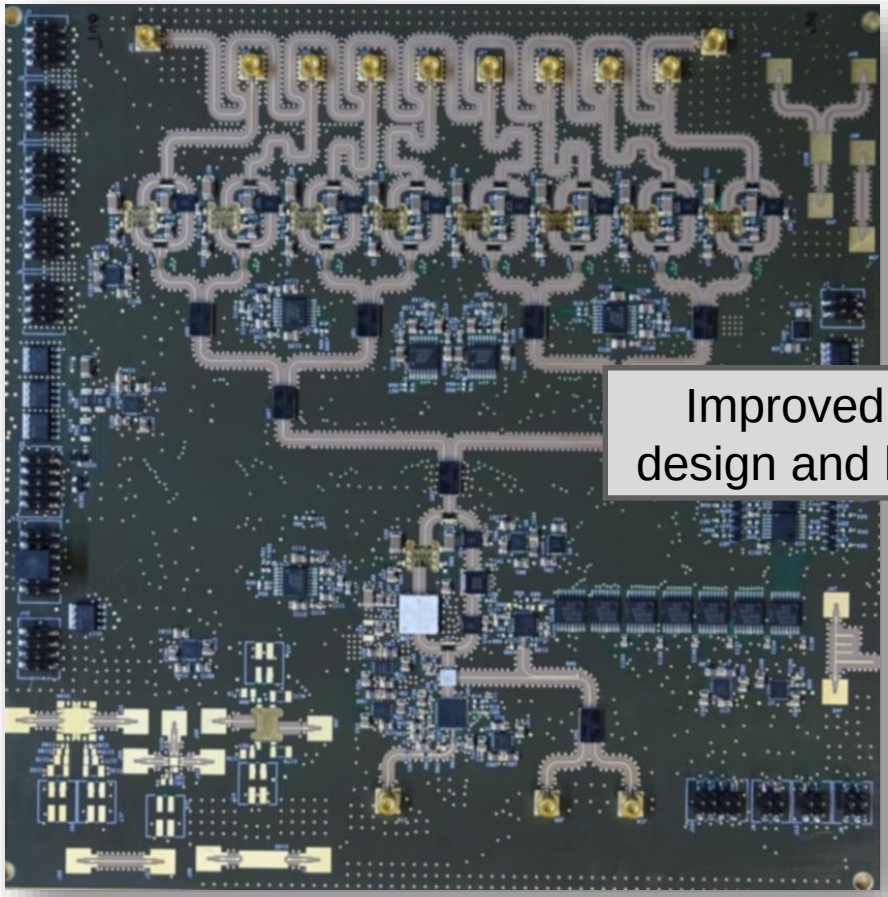




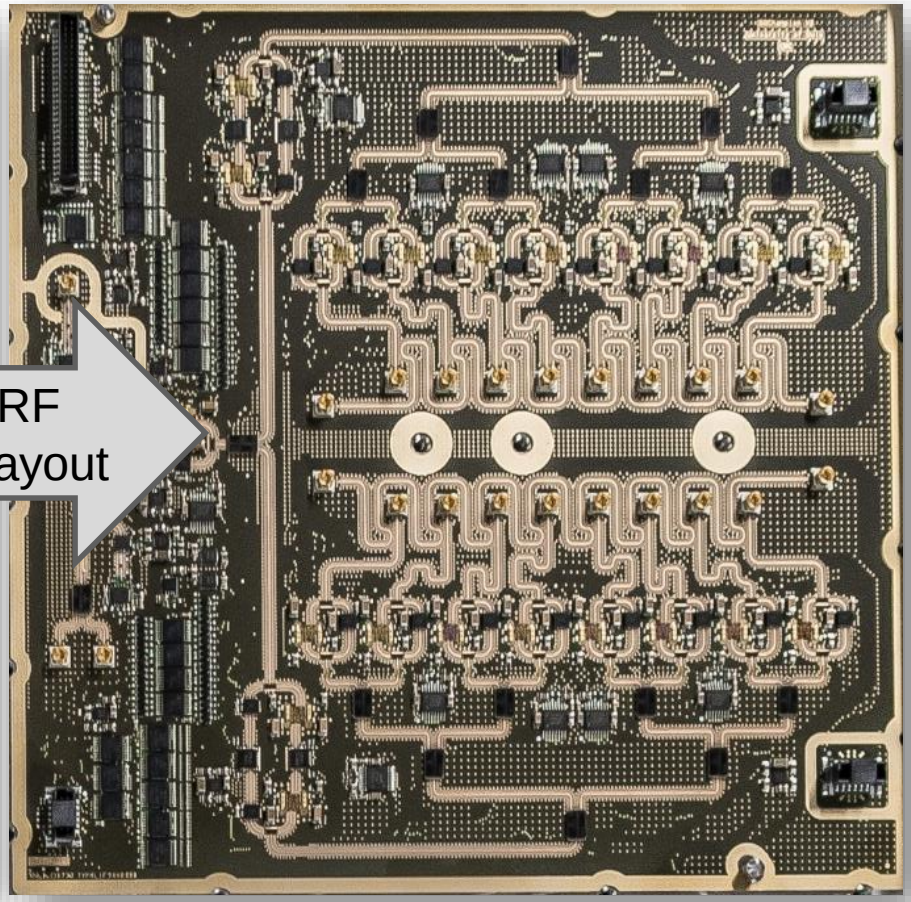
First transmission over the air @27GHz

- Validation of the design
- Discover bottlenecks
- Range and performance

5G mmW – 5GCHAMPION development path (Improved design)



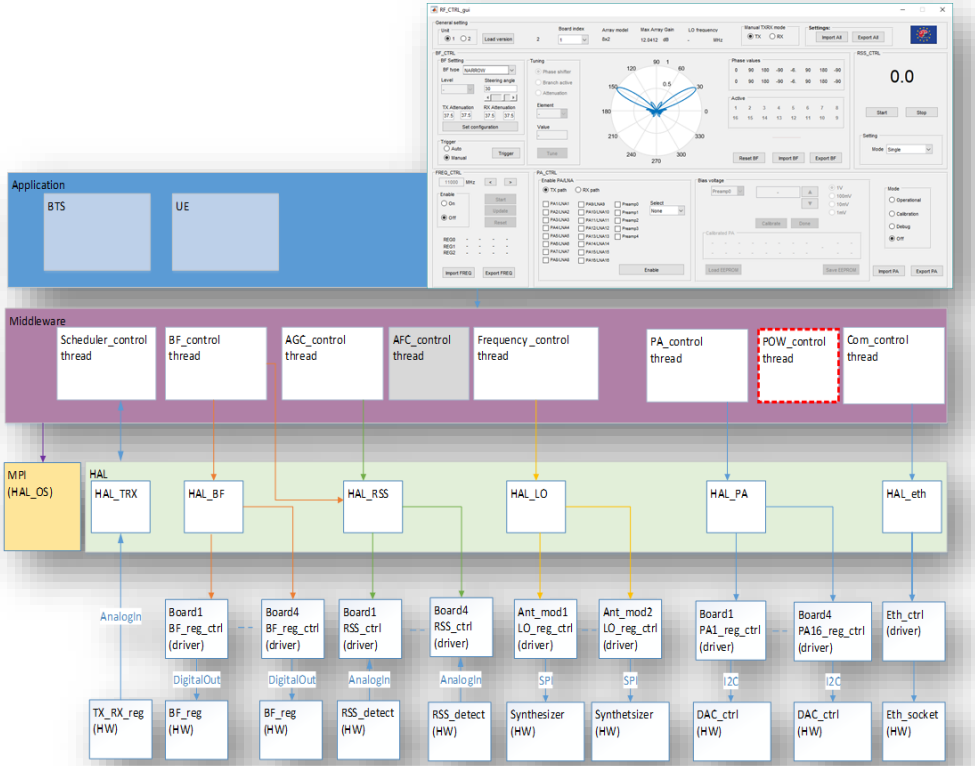
Improved RF design and layout

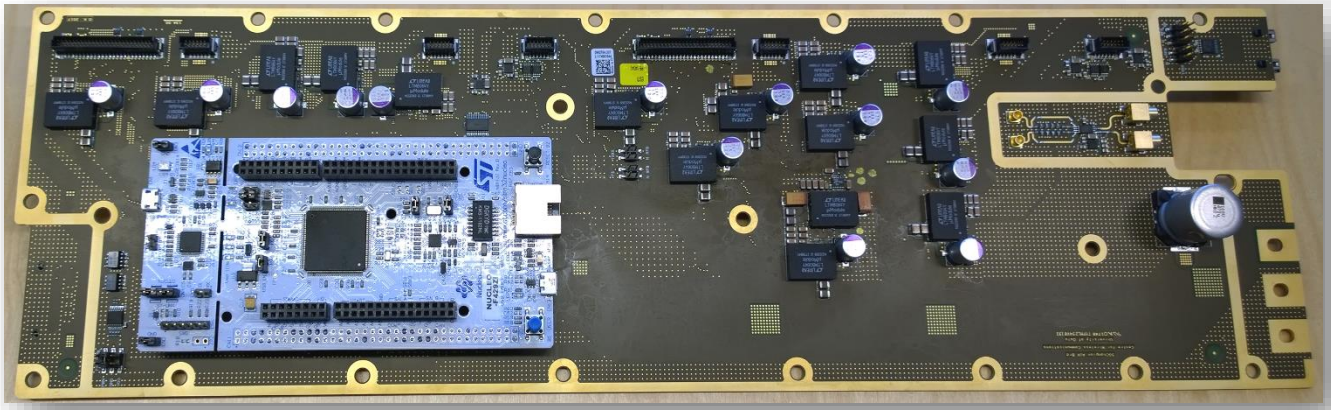


5G mmW – 5GCHAMPION development path (BF-SW)

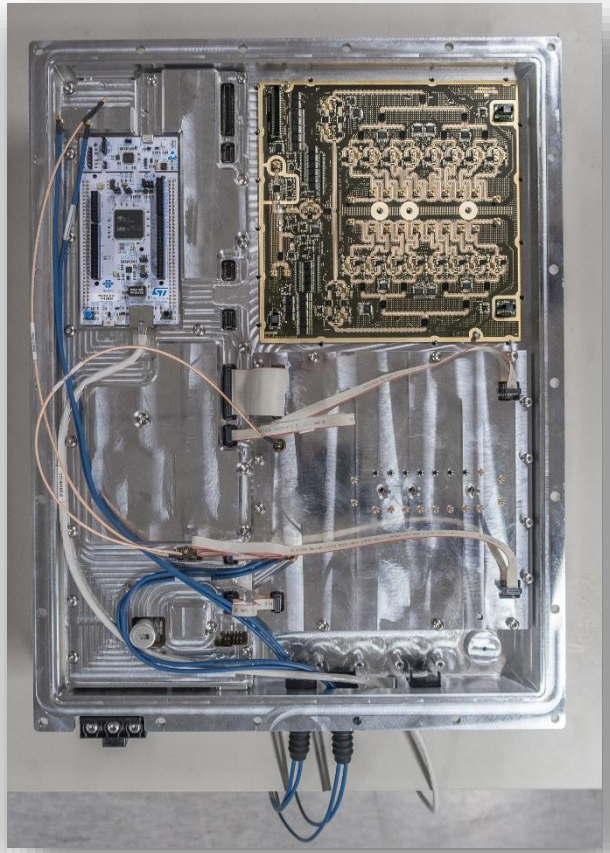
SMART RF-unit

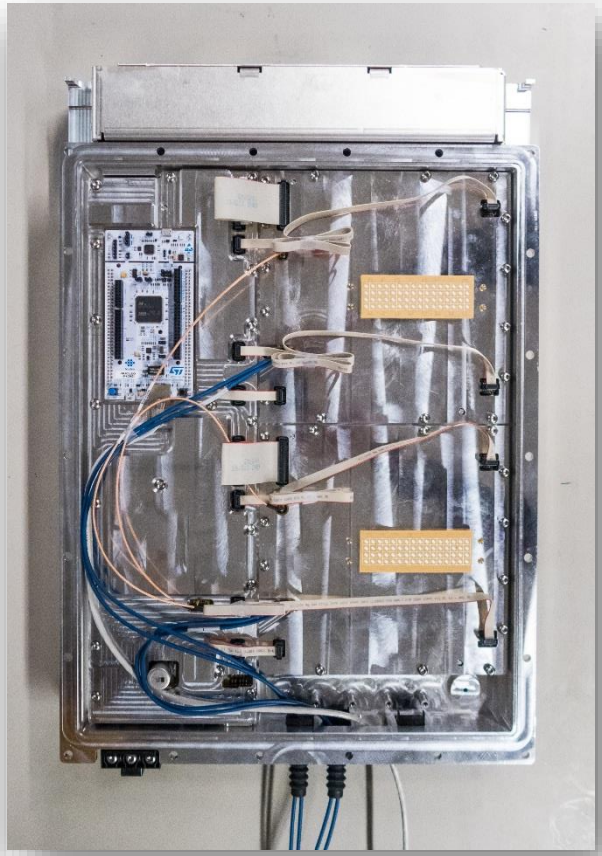
- Control software
- Adaptive beamforming
- Unit synchronization





5G mmW – 5GCHAMPION development path (Integration)

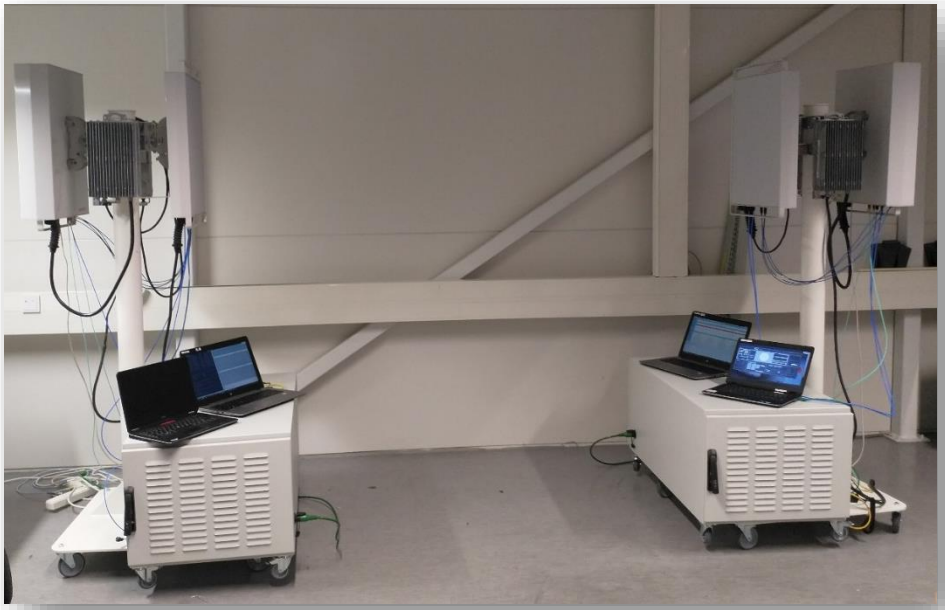


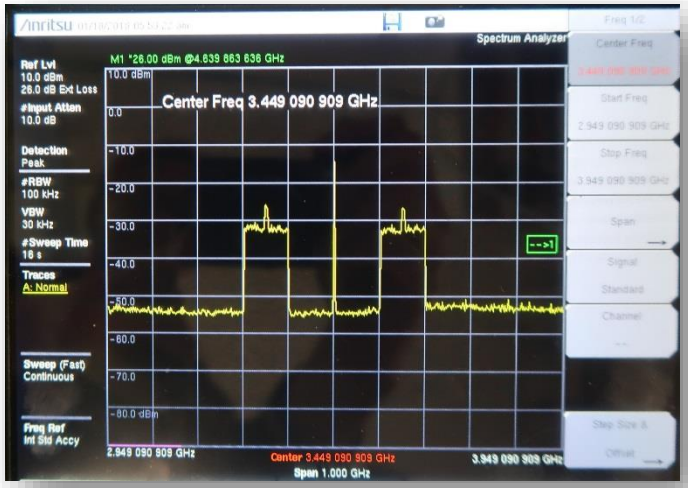


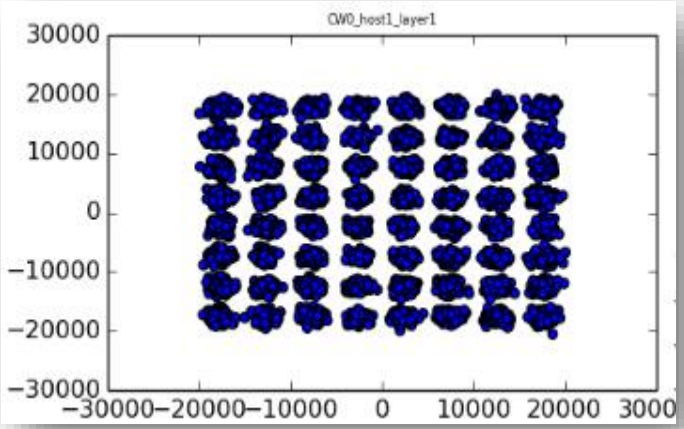
5G mmW – 5GCHAMPION development path (Testing)

First system test

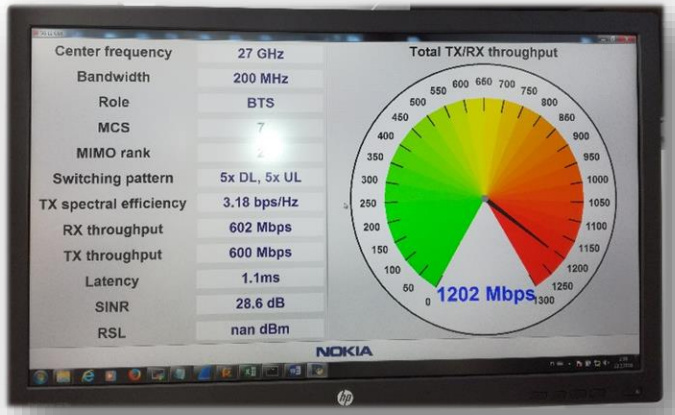
- Validation of the design
- Validation of the interface
- Performance







5G mmW – 5GCHAMPION PoC (today)



- Intercontiental 360 video streaming
- 1.2 Gbps, 1ms (air) latency
- VR and IoT

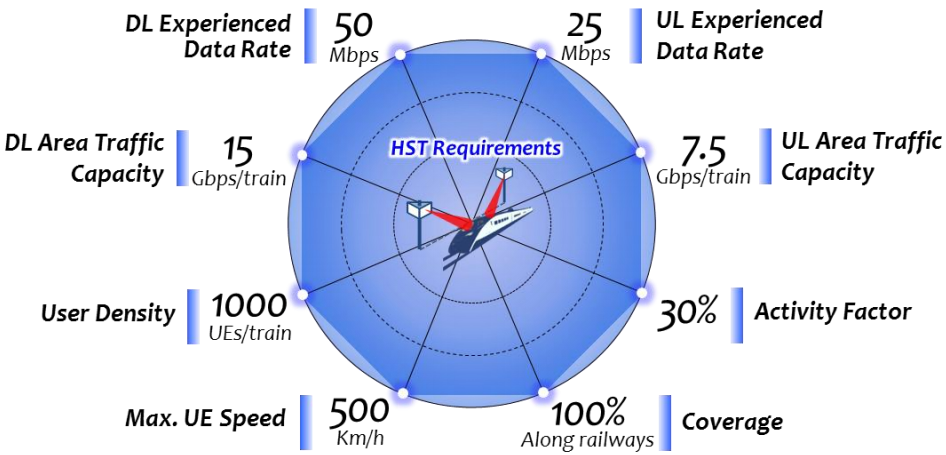
mmWave-based Mobile Hotspot

Motivation

- Evaluating feasibility and potential effectiveness of the mmWave-based mobile backhaul transceiver
  - ✓ High speed train (HST) scenario with speed up to 500 km/h
  - ✓ Around 25 GHz carrier frequency band

Performance requirements

< From 3GPP SA1* >



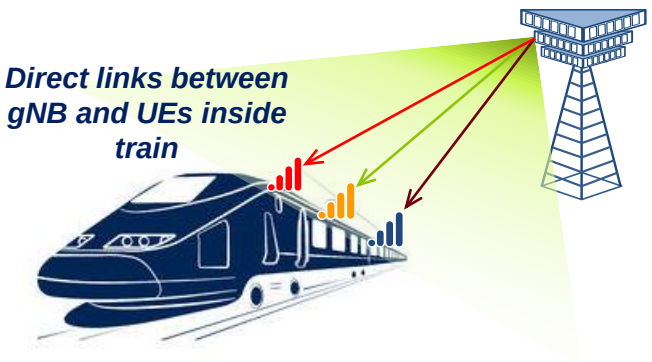
< From 5G CHAMPION KPIs >

- Provide a **mmWave high capacity backhaul link with 2.5 Gbit/s** maximum data-rate
- Provide in the high mobility scenario a **user-experience of 100 Mbit/s**

*3GPP TS 22.261, "Service requirements for the 5G system (Stage 1)," V1.1.0, Jan. 2017.

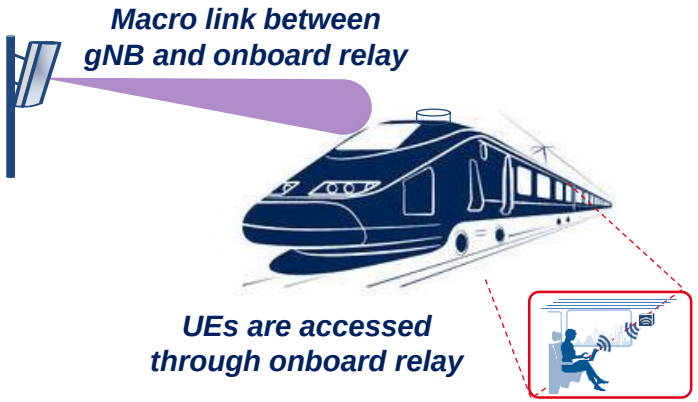
Layout Options for High Speed Train

Direct access



- High carriage penetration loss
- Group handover → Signaling storm
- Higher UE power consumption and requirements

Onboard relay-based access

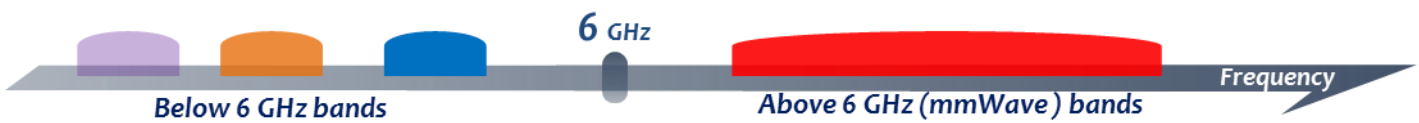


- No carriage penetration loss
- No group handover
- Less UE power consumption and requirements (same as indoor UE)

Spectrum Options for High Speed Train

Carrier frequency candidates

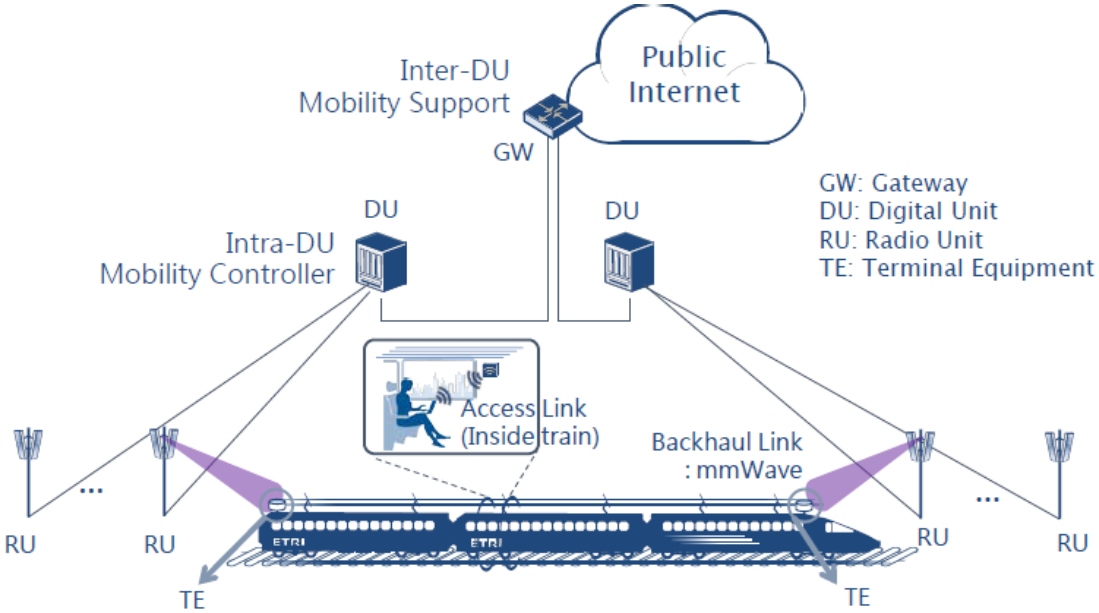
Below 6 GHz	*mmWave*
• Scarce available spectrum • NLOS-dominant • Lower path-loss	• Abundant available spectrum • LOS-dominant • Higher path-loss • Large array gain at the same aperture size



System Description - mmWave-based Mobile Hotspot

High speed train scenario

- Supporting very high traffic volume with very high mobility on high speed train (HST)



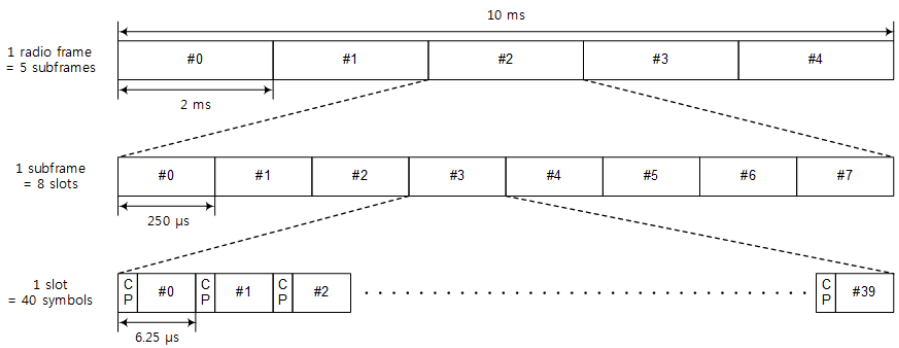
Architecture

- Hierarchical relay network
  - Backhaul link between RU and TE
  - Access link inside a train
- Backhaul link
  - Around 25 GHz (mmWave band)
- Access link inside train
  - WiFi
  - Femtocell
- Speed
  - Up to 500 km/h

Baseband Design

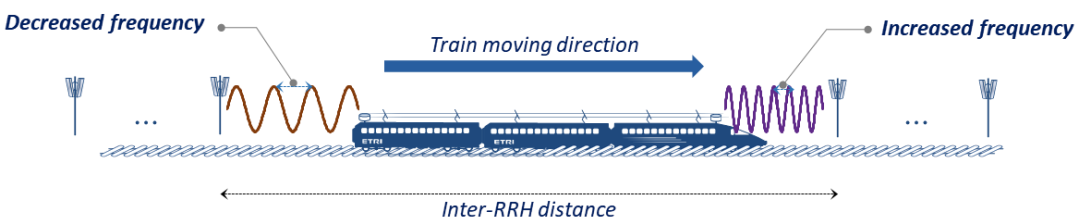
Frame structure

- OFDMA for downlink/uplink
- Subcarrier spacing = 180 kHz
- TDD
- TTI = 250 us



Doppler mitigation

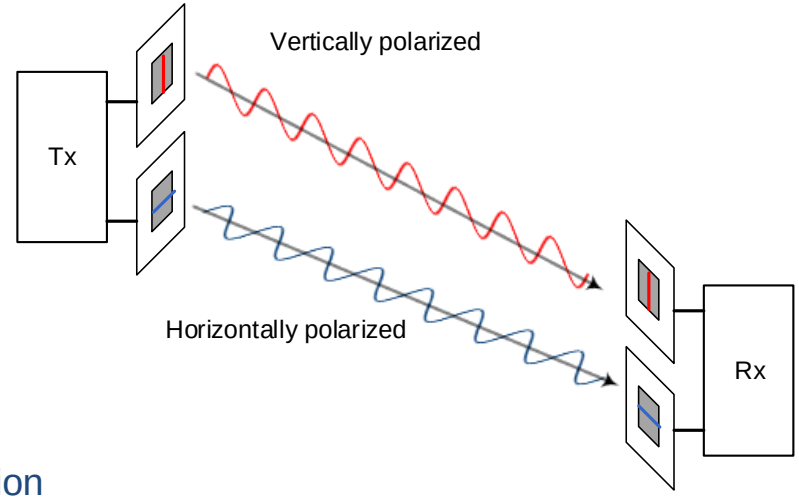
- Train speed up to 500 km/h
- Large Doppler shift → AFC
- Uplink frequency offset estimation range
  - ✓ [-26.67, 26.67] kHz



Baseband Design

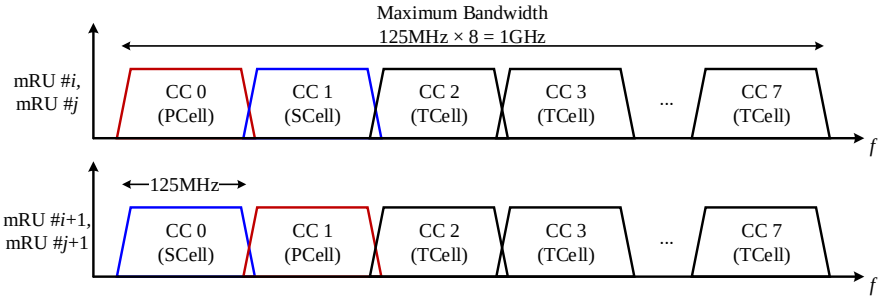
Multi-antenna schemes

- Strong LoS component
  - ✓ Dual-polarized 2x2 MIMO
- Very high mobility
  - ✓ Open-loop spatial multiplexing
  - ✓ Receiver processing for compensating channel depolarization



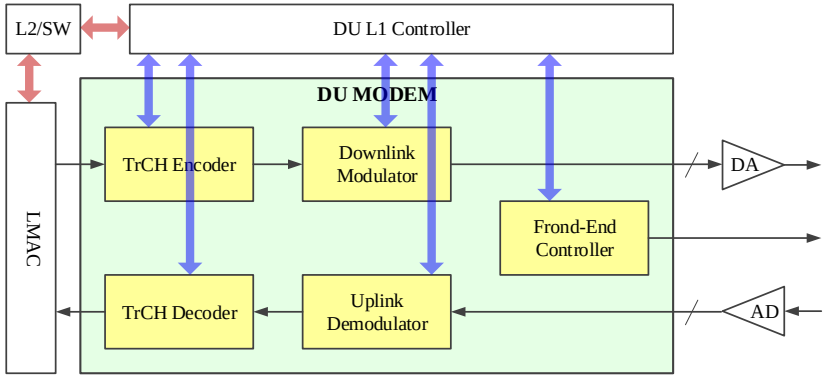
Carrier aggregation

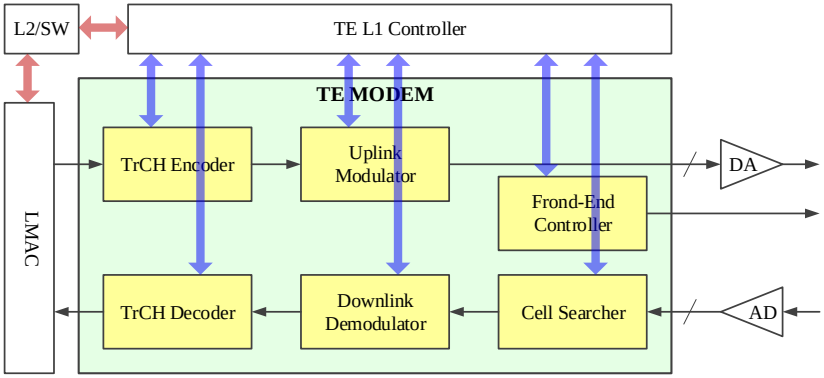
- Max. 8 component carriers (CCs)
  - ✓ 125 MHz BW per CC
  - ✓ Total 1 GHz BW
- CC allocation for mobility performance improvement



Baseband modem design

- Front-end controller
  - ✓ Controls and monitors the operations of the RF front-end
- Cell searcher
  - ✓ Acquires time and frequency synchronization, frame timing, and cell identity

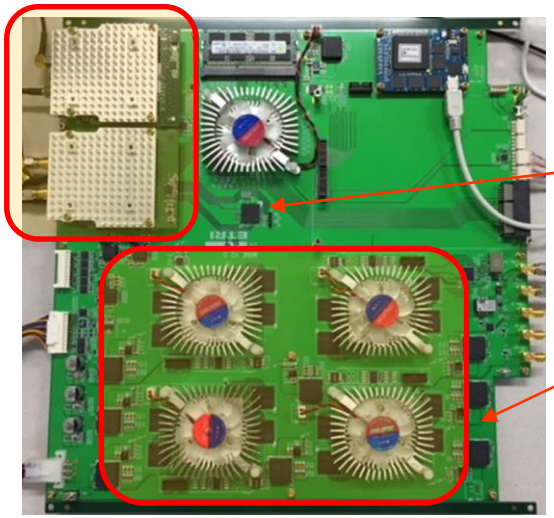




Baseband Design

Baseband modem implementation

- Baseband Implementation
  - ✓ Xilinx FPGA (Kintex7 UltraScale)
- AD/DA converter
  - ✓ DIF frequency = 1843.2 MHz (1 GHz bandwidth)
- L1 control
  - ✓ MCU (Model: STM32F746NGH6)



RF front-end design

RF and antenna designs

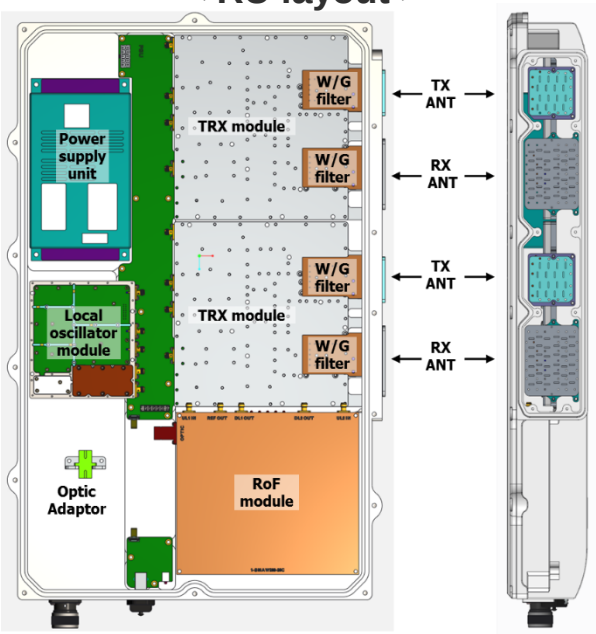
- Carrier aggregation of 8 CCs
- Slotted array waveguide antenna
  - ✓ Beamforming gain = 19 dBi (Tx)/22 dBi (Rx)

< RF design parameters >

	Parameter	Range
Common	Operating frequency	25.1056-25.5376 GHz
	Bandwidth	430MHz
	DIF frequency	705.6-1137.6 MHz
	TDD switching time	< 5usec
Tx	TX DIF input	-20dBm
	Output power	> +17dBm
	Gain	> 37dB
Rx	Noise figure	< 8dB
	Input level	-20dBm ~ -61dBm
	Gain	> 51dB
	DIF output	-10dBm

< RU exterior >

< RU layout >

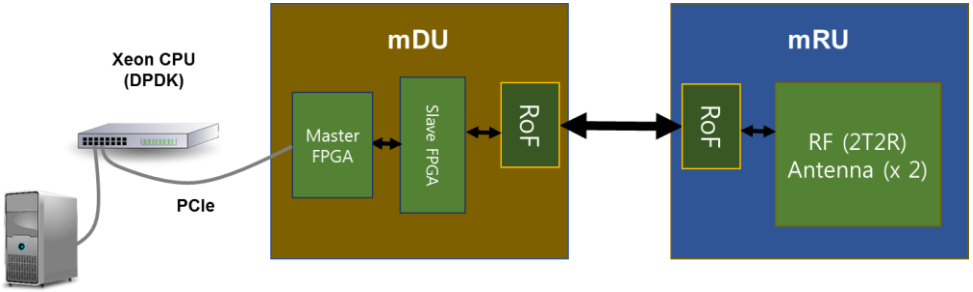


Testing procedures and results

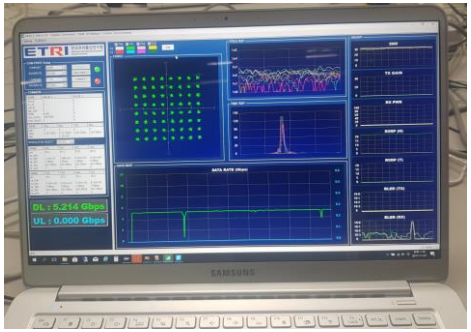
Indoor test

- PHY modem test
  - ✓ 1 GHz BW
  - ✓ 2x2 polarized MIMO → Max. 5.2 Gbps

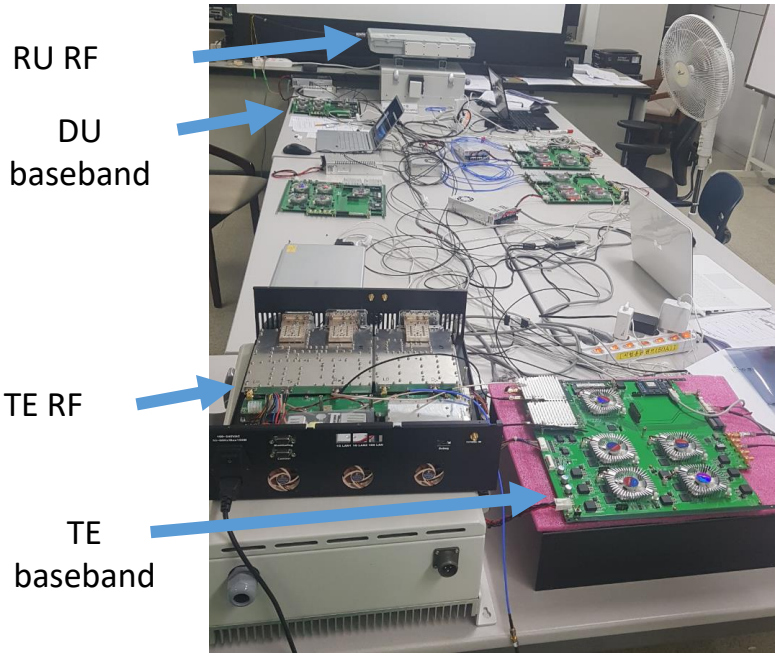
< Testbed configuration >



< Test monitoring >

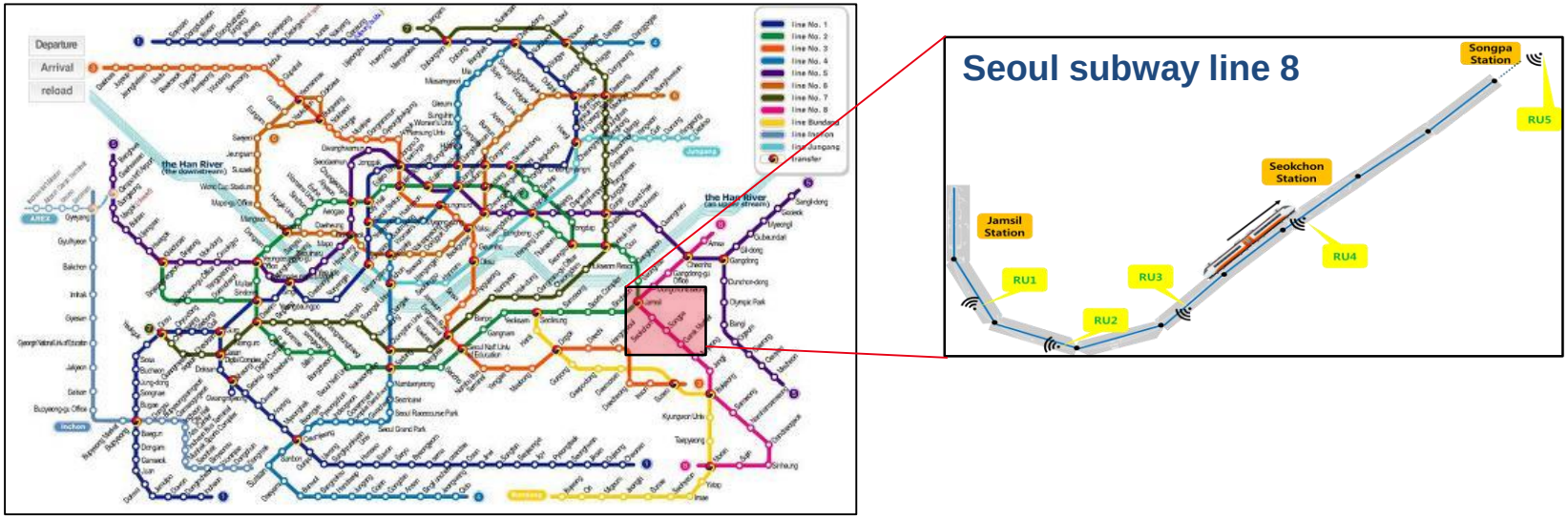


< Indoor test setup >



Testing procedures and results

Subway field test



- ✓ Speed = Up to 80 km/h
- ✓ Data rate = 1.25 Gbps

Thank you