Fraunhofer Institut für Integrierte Schaltungen IIS

Non-profit organization, founded 1985, > 1136 employees, annual budget approx. 167.9 Mio €
16 locations in 12 cities: **Erlangen**, Nurnberg, Fuerth, Dresden, Ilmenau, …

public

Fraunhofer IIS – Communication Systems Division

Standardization Efforts, Partnerships & Associations

- **IIS Participation in Standardization**
    - 3GPP, since 2015 (V2X, Satellite, MIMO, Positioning, RedCap, …)
    - DVB (DVB-T2, DVB-SH, DVB-S2X)
    - ETSI (European Satellite Digital Radio ESDR, MIOTY)
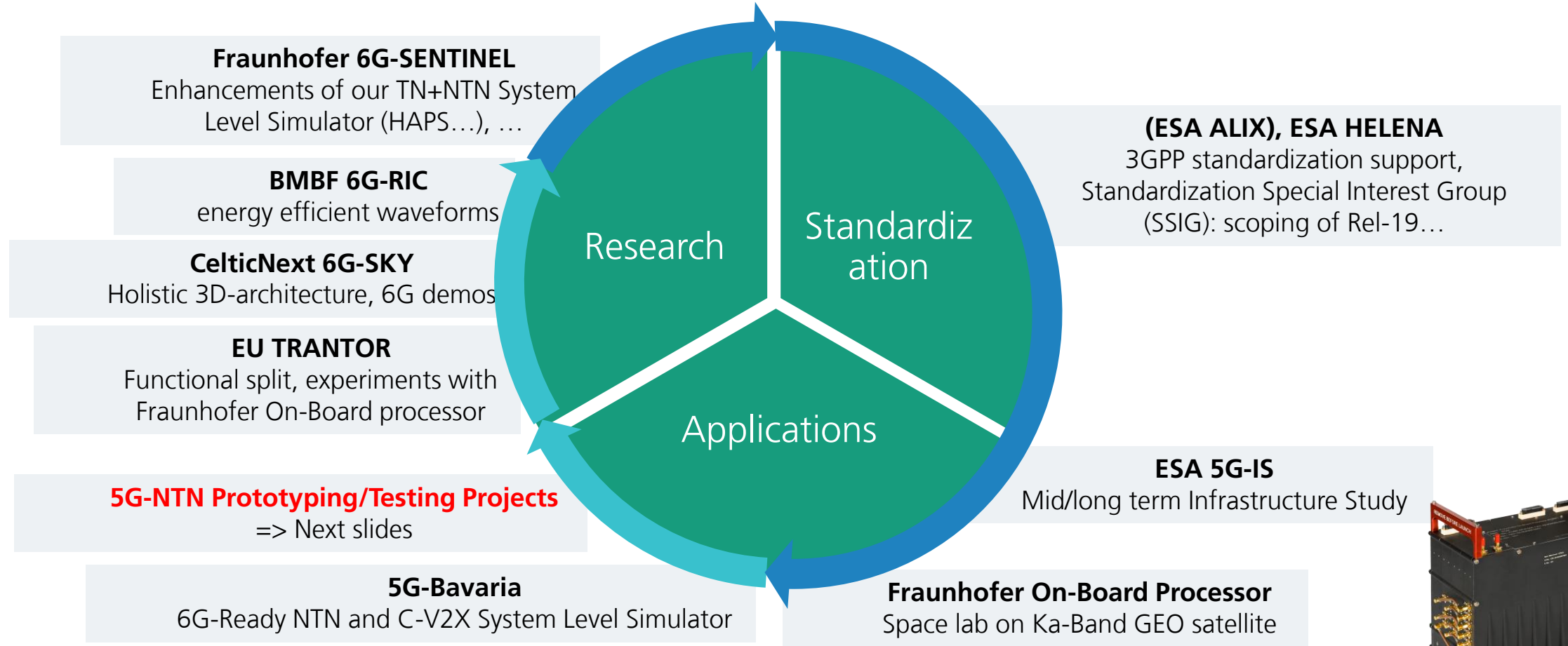   - Not standardized: Worldspace, XM Radio

- **IIS Memberships around 5G**
    - 5GAA, NGMN, 5G-ACIA, VDMA
    - 6GIA, 5G-Media Initiative
    - OpenAirInterface

public

NTN Projects @ Fraunhofer IIS
Standardization, Applications, Research

Fraunhofer 6G-SENTINEL
Enhancements of our TN+NTN System Level Simulator (HAPS…), …

BMBF 6G-RIC
energy efficient waveforms

CelticNext 6G-SKY
Holistic 3D-architecture, 6G demos

EU TRANTOR
Functional split, experiments with Fraunhofer On-Board processor

5G-NTN Prototyping/Testing Projects
=> Next slides

5G-Bavaria
6G-Ready NTN and C-V2X System Level Simulator

(ESA ALIX), ESA HELENA
3GPP standardization support, Standardization Special Interest Group (SSIG): scoping of Rel-19…

ESA 5G-IS
Mid/long term Infrastructure Study

Fraunhofer On-Board Processor
Space lab on Ka-Band GEO satellite

© Fraunhofer IIS/Paul Pulkert

public

Fraunhofer
IIS

02

NTN Prototyping and Testing

ESA funded activities 5G-GOA, 5G-LEO

Motivation and Background

Support the creation of early prototypes for validating key 5G NTN design aspects and providing feedback to the 3GPP standardization process;

Having an NTN compliant protocol stack implementation is essential;

Adapt and extend the OpenAirInterface™ open-source implementation of the 3GPP protocol stack to support both geostationary and non-geostationary – 5G NR connectivity in compliance with 3GPP Rel-17 and considering Rel-18.
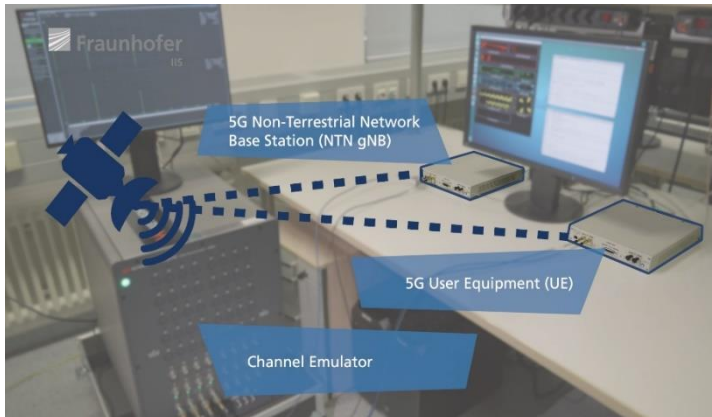
5G New Radio for NTN (5G-NTN)

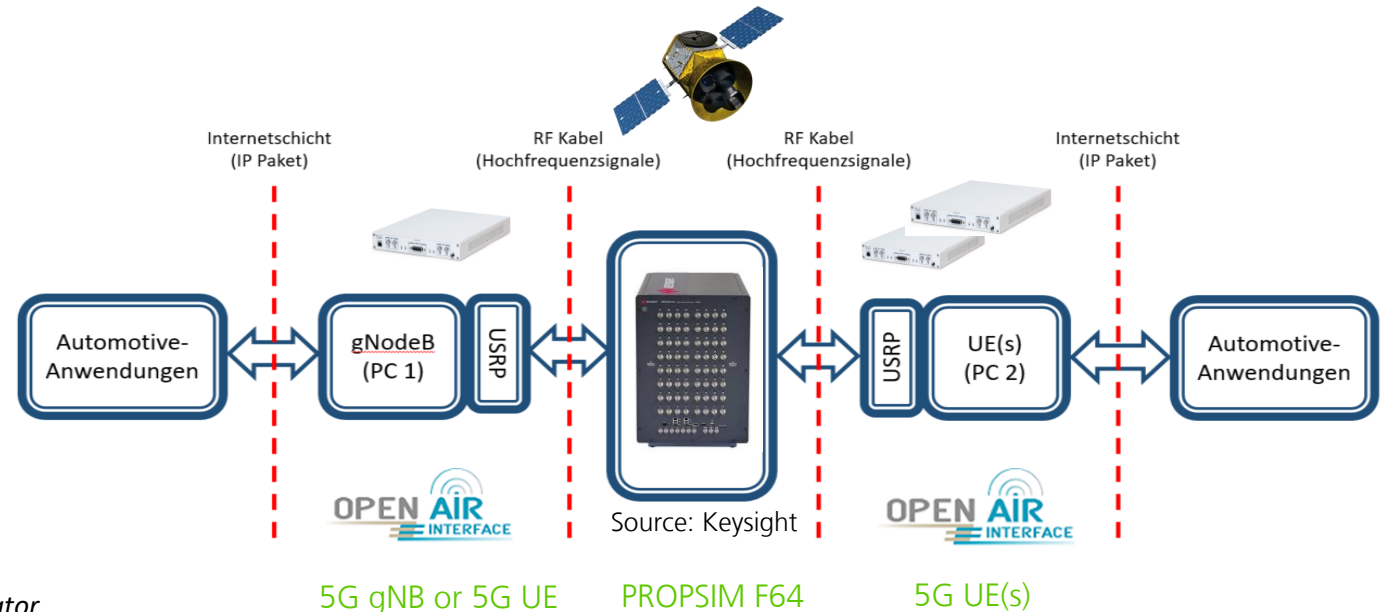## Early Test & Demonstration parallel to 3GPP Standardization

General Setup: Software Defined Radio for fast Prototyping

- OpenAirInterface (OAI): Open-source software project for **RAN (gNB, eNB), 5G-Core, UE, O-RAN RICs**

- Propagation channels:

  1. Channel emulator supporting satellite

  2. Over-the-Air via antenna

  3. Over-the-Air via real satellite

5G-NTN E2E lab setup with OAI

5G NR testbed with hardware platforms for gNB and UE and Keysight F64 channel emulator

5G gNB or 5G UE   PROPSIM F64   5G UE(s)

ESA 5G-GOA
5G-NTN for GEO satellites

Physical

Terrestrial functions (PTRS, 5 MHz with 15 kHz SCS, BWP)

NTN specific (Timing for UL scheduling, disable HARQ)

MAC

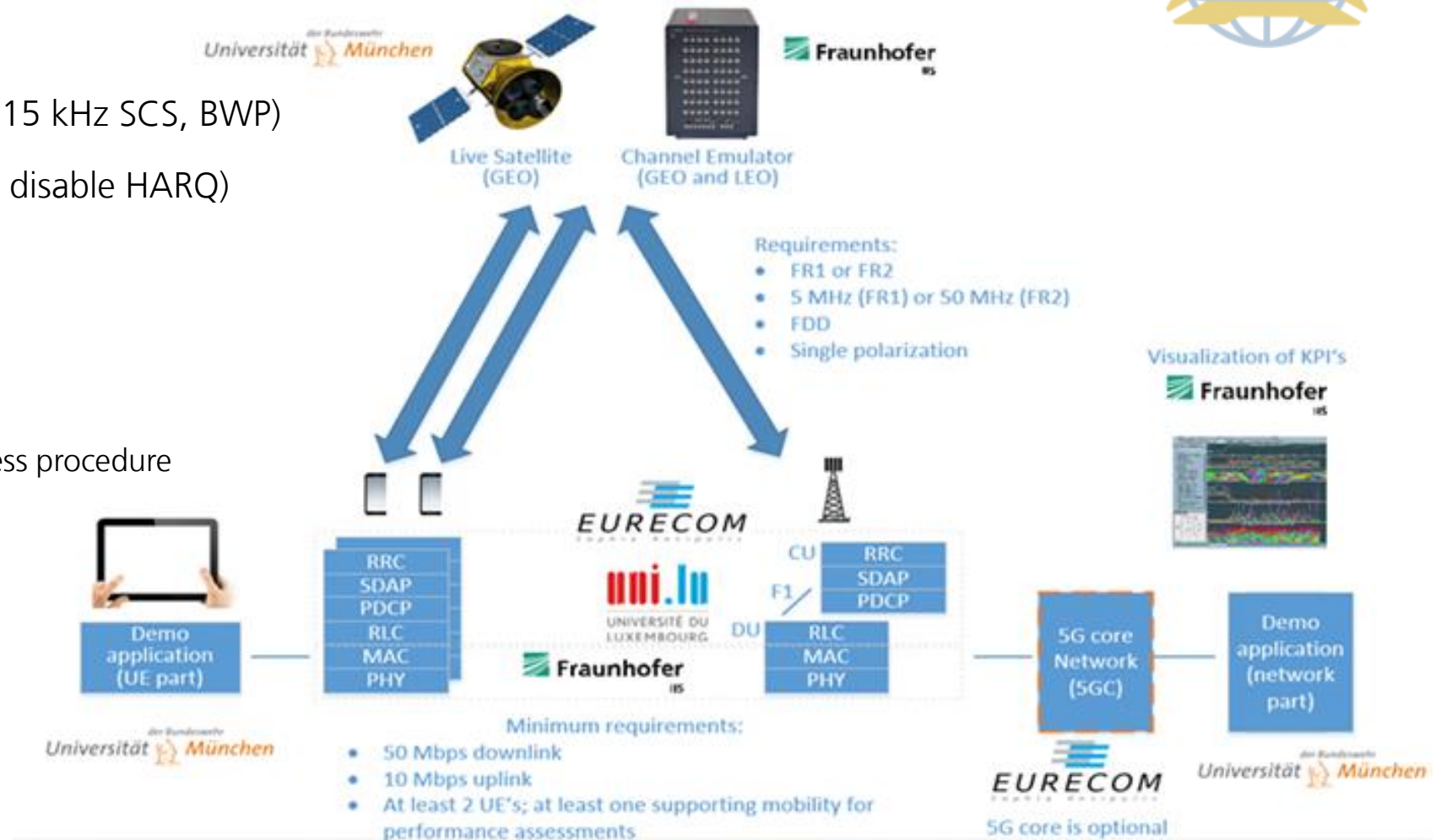Support for Multi-UE

Implementation of real FDD Scheduling

Adapting Timing Advance and Random-Access procedure

RLC, PDCP, RRC

HARQ/ARQ interaction

Update different timers and buffers

Implementation of a new KPI GUI

ESA 5G-LEO
5G-NTN for LEO satellites

PHY, MAC

Continuous frequency offset compensation

SNR measurement, Channel State Information (CSI) Reporting

Uplink Power Control

Adaptive Modulation and Coding

RLC, PDCP, RRC

Update of different timers

Other

Handover (intra CU between DUs)

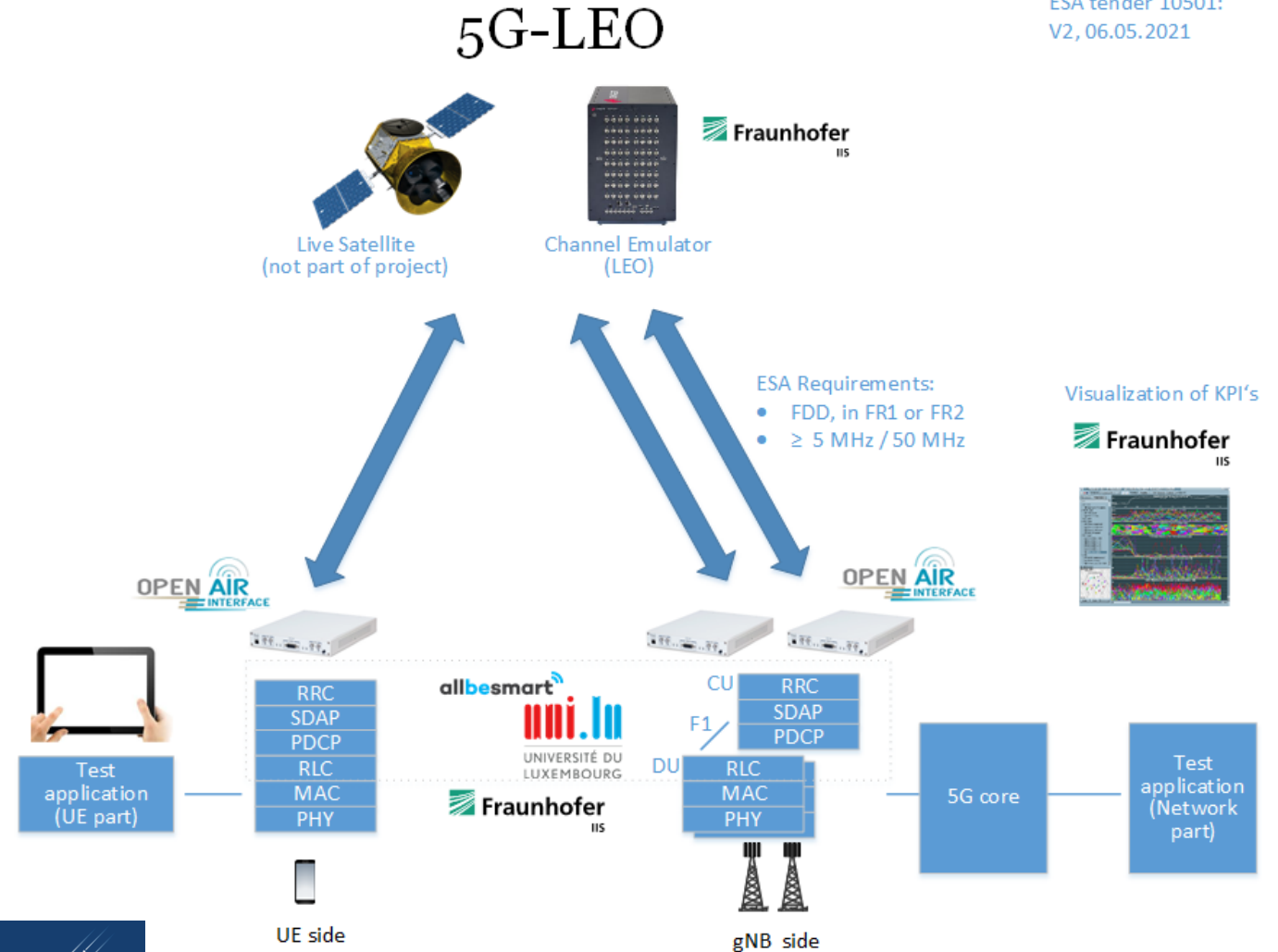Extensions to the OAI gNB and UE KPI GUI

Signaling from gNB to UE: SIB19

ESA 5G-METEORS NTN Timing project: Signaling of satellite ephemeris and common timing

5G-LEO

ESA tender 10501:
V2, 06.05.2021

Live Satellite
(not part of project)

Channel Emulator
(LEO)

ESA Requirements:
- FDD, in FR1 or FR2
- ≥ 5 MHz / 50 MHz

Visualization of KPI's

public

ESA 5G-GOA, 5G-LEO
PHY/MAC Features already merged to public OAI development branch

- **Support for Phase Tracking Reference Symbols in PDSCH and PUSCH**

- **Support for 5 MHz BW with 15 kHz SCS**

- **Extended support for multiple bandwidth parts (BWP)**

- **Support for Multi-UE**

- **Implementation of real FDD Scheduling**

- **Basic implementation of QoS scheduling**

- **Implementation of a new KPI GUI**

public

ESA 5G-GOA, 5G-LEO, (5G-METEORS)
PHY/MAC Features not yet merged to public OAI development branch

- **Extend OAI rf-simulator to support simulation of large delay:** => A similar feature was merged to OAI => needs to be checked and probably extended to achieve what was developed in 5G-GOA

- **Consider timing relation for UL scheduling at gNB:**
  => to be cleaned and be pushed, but it also depends on the previous feature to be merged first.

- **Disabling HARQ at gNB and UE:** This feature needs to be made configurable via RRC, currently it uses a command line flag

- **Adapting Uplink timing advance and RA procedure:**
  => needs to be cleaned and be pushed, but it also depends on the extended timing relation for UL scheduling feature above.

- **Continuous frequency offset compensation**: This feature was just finished in the 5G-LEO project. => to be cleaned and be pushed.

- **SNR measurement and Channel State Information (CSI) Reporting**:
  This feature was just finished in the 5G-LEO project. => to be cleaned and be pushed.

- **Uplink Power Control (Open loop & Closed loop):** This feature was just finished in the 5G-LEO project. => to be cleaned and be pushed.

- **Adaptive Modulation and Coding (AMC):** UL & DL AMC using the block error rates if HARQ is enabled is already available in the public OAI develop branch. The 5G-LEO project just finished developing AMC based on the SNR measurement reports => to be cleaned and be pushed.

- **Extensions to the OAI gNB and UE KPI GUI:** This feature was just finished in the 5G-LEO project => to be cleaned and be pushed.

- **ESA 5G-METEORS: SIB19 for lab and live satellite setups** => to be cleaned and pushed

Trials and Testing with OAI
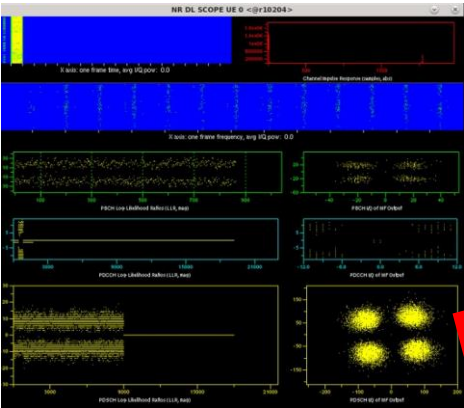## World's first Over-the-Air Satellite trials of bi-directional 5G-New Radio (PHY+MAC)
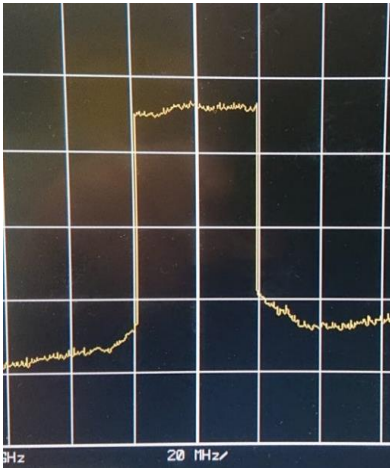
2023: Ka-Band Trials with Inmarsat GEO satellite, 2x 40 MHz, UL+DL [RP-231304]

02/21: Setup at UniBW, Munich, FDD 2x 10 MHz, X-Band, high SNR, UL+DL

11/21: Mobile Setup in US, FDD 2x 10 MHz, Ku-Band, very low SNR, UL+DL (Kymeta, Intelsat)

© Kymeta

© Inmarsat

PDSCH @ UE

PUSCH @ gNB

© UniBw, Munich

NTN in the Market
5GAA, GSOA

Automotive interest in NTN

- Seamless connectivity, even in areas w/o terrestrial coverage!
- Narrowband, wideband and broadband data rate services

5GAA Work Items NTN4V2X , NTN-RaS

- White paper: automotive demands for NTN towards new European Satellite Constellation IRIS^2
- Automotive demands by 5GAA to 3GPP
  - Rel-19 workshop [RWS-230164]
  - Automotive terminal characteristics @FR1/FR2 [RP-232733]
- Technical report to be published soon

GSOA: Deployment Considerations

- Liaison Statement to 3GPP [RP-232732]
- Covering GEO, Non-GEO, large frequency range
- IoT-NTN and NR-NTN

5GAA Position on the Secure Space-Based Connectivity Programme and Focus on the European Communication Satellite Constellation

5G Automotive Association Position Paper

3GPP NTN Based Satellite Network Deployment Plans

Matrix of industry initiatives/areas of interest led by satellite network operators for the different deployment scenarios:

	Narrowband connectivity to IoT devices (NTN-IoT in FR1)		Narrowband/Broadband connectivity to handheld devices (NTN-NR in FR1)	Broadband connectivity to non-handheld devices (VSAT) (NTN-NR in above 10 GHz Band)	
Space Segment	Re-use of existing GSO	NGSO	NGSO	GSO	NGSO
Operators	EchoStar Viasat-Inmarsat TerreStar Solutions	Sateliot EchoStar OmniSpace Viasat-Inmarsat	EchoStar OmniSpace Viasat-Inmarsat SES	Intelsat Eutelsat-Oneweb Viasat-Inmarsat SES	Intelsat Eutelsat-Oneweb Viasat-Inmarsat SES
Timeline Indication	2023-2025	2024-2029	2026-2029		

5G-NTN Prototyping with OAI – Enabler for Industry and Academia
Summary, Outlook
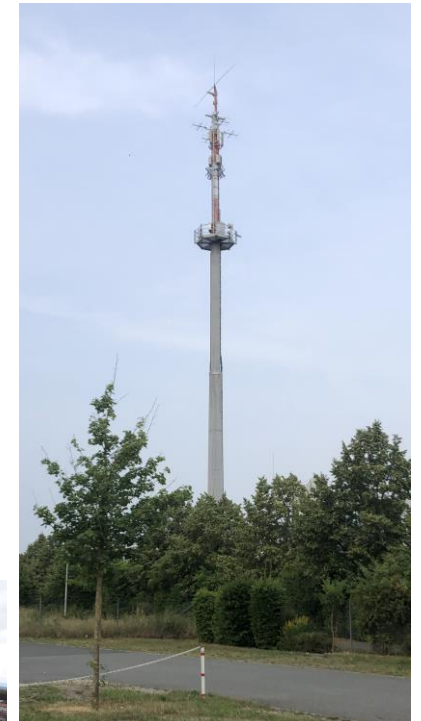
5G-NTN E2E Prototyping supported by ESA!

- Excellent open-source basis for further enhancements towards 3GPP Rel-18++/6G
- Supports lab-experimentation, Over-the-air transmission, over real satellite

Roadmap

- 5G-GOA developments finished and already available in OAI repository
- 5G-LEO, 5G-METEORS in finalization stage, available until end of May
- Fraunhofer IIS: Plans for NTN with FR2 numerology with FPGA acceleration, CHO
  => please contact us for details!

Raising Market Interest in 5G-NTN

- 5GAA expressed strong interest to 3GPP
- GSOA deployment considerations
- (Closed source) solutions now appearing for IoT-NTN and NR-NTN

Over-the-air NTN experimentation facilities for L-, S- and C-Band
@ Fraunhofer IIS

Fraunhofer
IIS

Contact

Thomas Heyn
Head of Mobile Communications Group
Communication Systems Division
Phone +49 9131 776 6311
Mobile +49 160 5840 473
Thomas.heyn@iis.fraunhofer.de

Fraunhofer IIS
Am Wolfsmantel 33
91058 Erlangen
www.iis.fraunhofer.de

5G-NTN
Links for further reading

- https://5gaa.org/5gaa-position-on-the-secure-space-based-connectivity-programme-and-focus-on-the-european-communication-satellite-constellation/

- https://connectivity.esa.int/projects/5ggoa
- https://connectivity.esa.int/projects/5gleo
- https://connectivity.esa.int/projects/5g-meteors
- https://connectivity.esa.int/projects/helena-highly-skilled-satellite-community-members-drive-3gpp-nonterrestrial-network-standardization
- https://connectivity.esa.int/projects/5gis

- https://www.iis.fraunhofer.de/en/ff/kom/mobile-kom/6g-sentinel.html
- https://www.6g-sky.net/
- https://6g-ric.de/
- https://www.trantor-he.eu/
- https://www.iis.fraunhofer.de/de/ff/kom/mobile-kom/5g-bavaria/5g-testzentrum.html
- https://www.iis.fraunhofer.de/en/ff/kom/satkom/obp/fobp.html

Fraunhofer
IIS