»5G Hardware«

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5G – Herausforderungen:
Die Key Performance Indicators (KPI) der 5G IA

- 1000 times higher mobile data volume per geographical area.
- 10 to 100 times more connected devices.
- 10 times to 100 times higher typical user data rate.
- 10 times lower energy consumption.
- End-to-End latency of < 1ms.
- Ubiquitous 5G access including in low density areas.
- Reduction of the network management OPEX by at least 20% compared to today

Source: https://5g-ppp.eu/kpis/

5G – IHPs European Project Portfolio

2015 2016 2017 2018 2019 2020 2021 2022

H2020 5G-PPP Phase 3b (Field Trials)

H2020 5G-PPP Phase 3a (Test Beds)

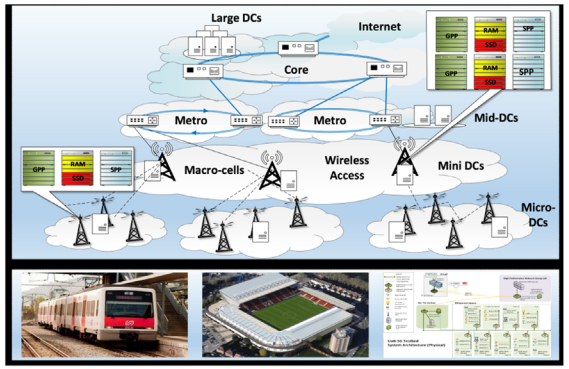
H2020 5G-PPP Phase 2 (Demonstration)

H2020 5G-PPP Phase 1 (Technology)

5G VICTORI

5G Phase 1/2

In Phase-1 and Phase –2 of the 5G research, the main focus is on the development of mmWave Communications for 5G backhaul/fronthaul networks.
For this purpose beamforming mmWave frontends and Line-of-Sight (LoS) MIMO technologies were developed and deployed. Demonstrations are performed in Bristol (GB) and Barcelona (E).



5Genesis

5G Phase 3a/3b

In Phase 3a/3b of the 5G development roadmap, the focus is on large testbeds and experimental evaluation.
IHP contributes to a testbed in the centre of Berlin and in Patras (GR).

5G-XHaul

5G-PICTURE

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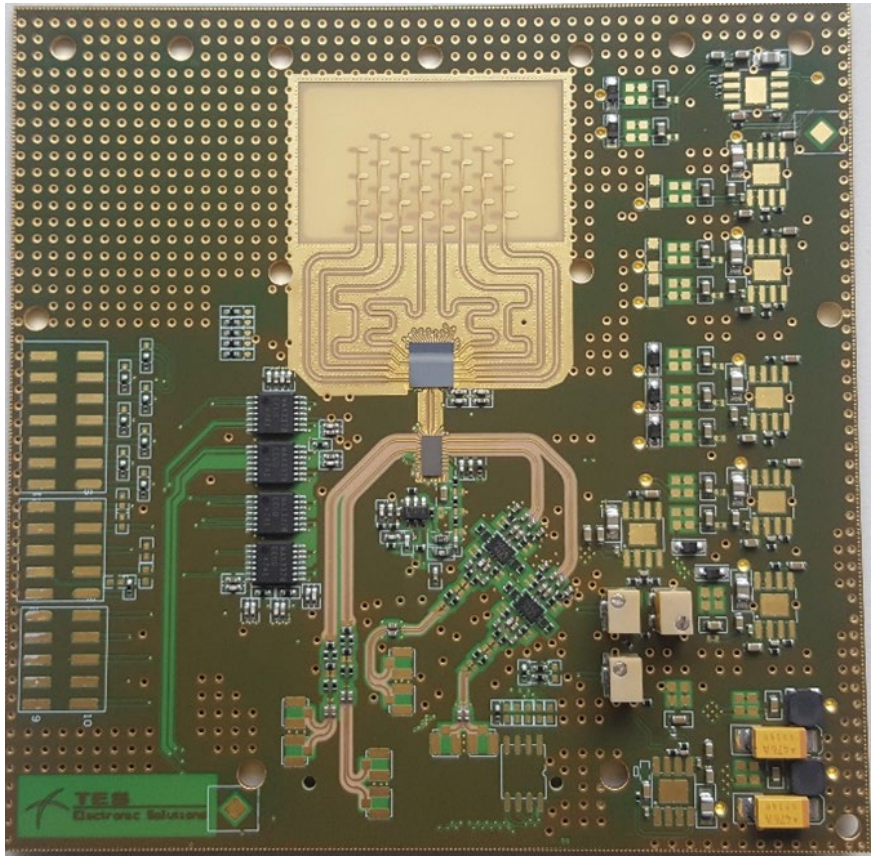
Strategien die KPI zu erreichen (Shannon Kanalkapazität)

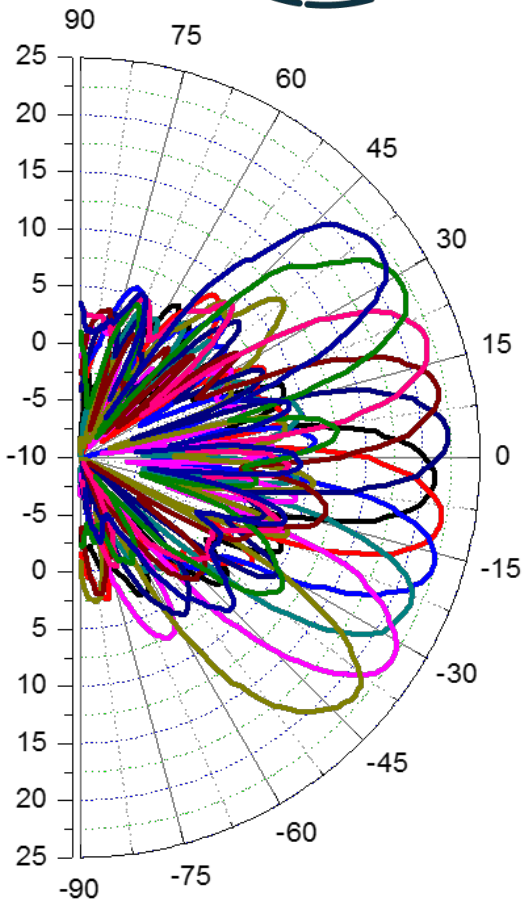
1. *Höhere Bandbreite*
   - *Hohe Trägerfrequenzen*
2. *Besseres Signal zu Rausch-Verhältnis (SNR)*
   - *Kleine Zellen – reduzierte Entfernung*
   - *Besser Hardware*
     - *LNA-Rauschzahl*
     - *PA-Linearität und Ausgangsleistung*
     - *Leistungseffizienz (PA+Transceiver)*
     - *PLL-Phasenrauschen*
     - *…*
3. *Effiziente Ausnutzung der Kanalkapazität*
   - *Waveforms*
   - *Signalverarbeitung*
   - *Protokolle*
4. *Multiplexing*
   - *(Hybrid) Beamforming*
   - *(Line-of-Sight) MIMO*
   - *Orbital Angular Momentum (OAM)*
   - *Polarization*
   - *…*

Strategien die KPI zu erreichen (mmWave Beamforming)

60 GHz beam steering frontend Module with 8-channel vector modulator chip and up/down converter chip (both developed & fabricated by IHP)



Measured beam pattern with 4x8-element Uniform Linear Array (ULA) antenna (developed by TES Electronic Solutions)



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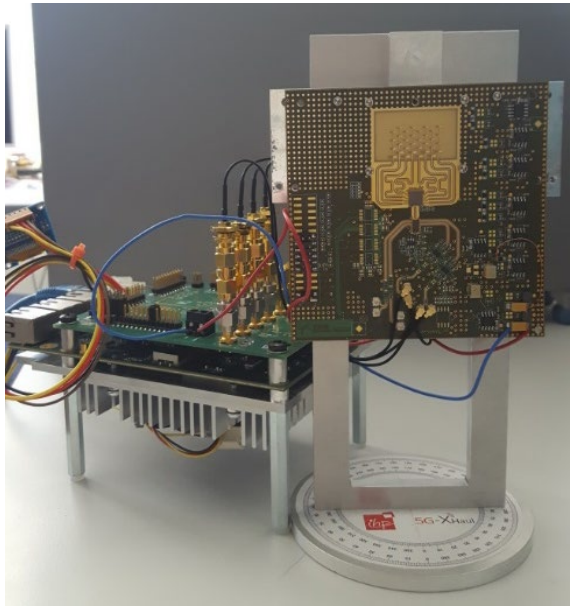
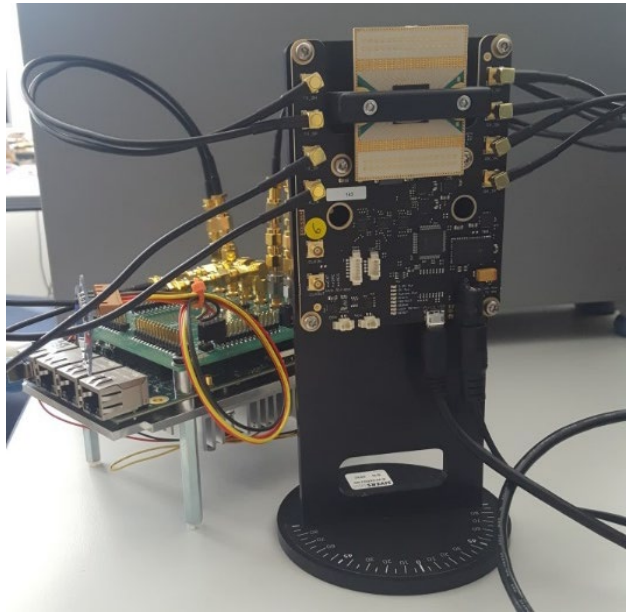
Strategien die KPI zu erreichen (WaveForms & Protocols)

- IHP digiBackBoard platform

  Successfully used in several projects (e.g. proWiLAN, fast-Secure, 5G-Xhaul, 5G-Picture, 5Genesis, Wortecs, …)

- mmWave (60-GHz) beamforming demonstrator with different AFEs

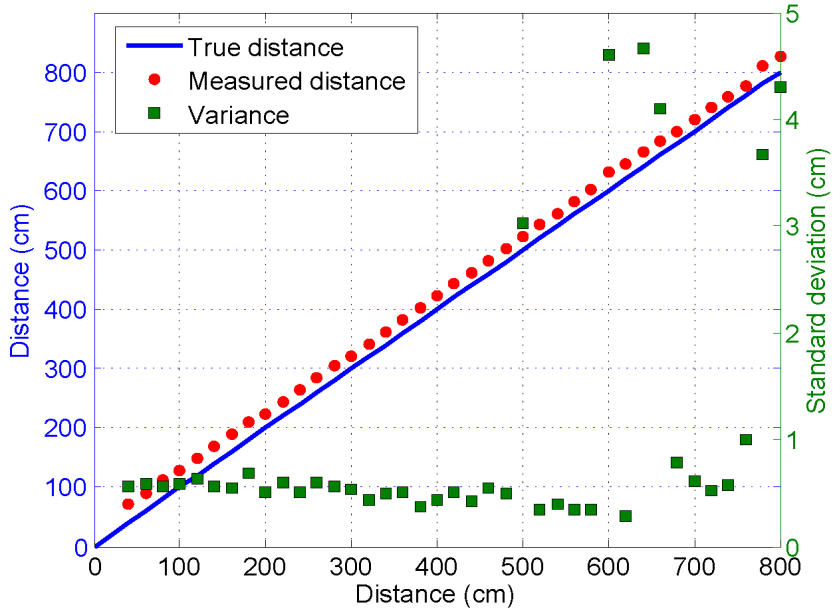




mmWave High Data-Rate Communication & Localization

- Simultaneous Data Transmission and Ranging @ 60 GHz demonstrated
- Data rate: ca 3.6 Gbit/s; Ranging Precision: ca. 1 cm
- Best Demonstrator Award at „11th IEEE Workshop on Positioning, Navigation and Communication (WPNC 2014)“, (M. Ehrig, Mar. 2014)

Demonstrator Setup



Measurement Results

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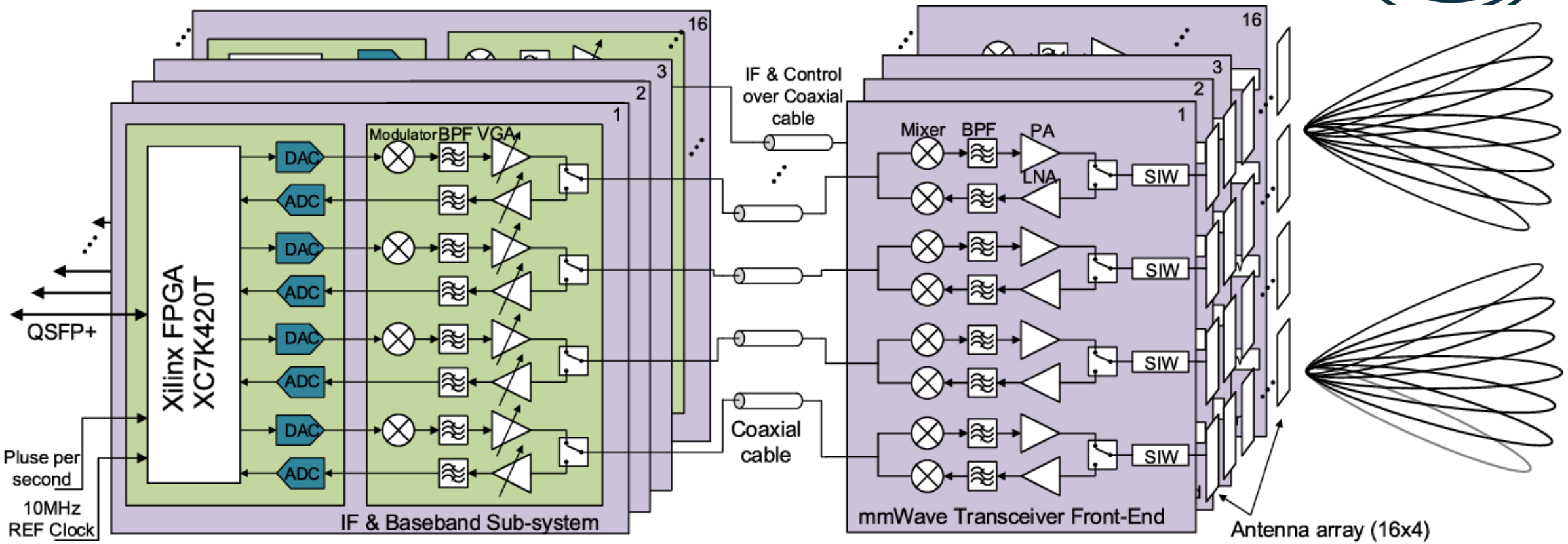
5G Hardware: Status

- Timeline 5G roll-out
  - 1st step: Frequency bands < 6 GHz (e.g., 3.5 GHz)
    - Hardware solutions close to existing 2 GHz components
    - New: Massive MIMO (antenna arrays) on BTS side
  - 2nd step: mm-wave bands
    (28 GHz range for first prototypes)
    - Full technical solutions still under research/development
- Different scenarios
  - Handset / base station (BTS) / backbone

Starting Point: The 4G Base Station

- Output power determined by radio link budget
  - typ. 100 W peak
- Antenna via cable
- Target: Energy efficiency & linearity
  - most critical component: Power amplifier (PA)
- Digital linearization
  (Digital Predistortion, DPD)

The MIMO Challenge (I)



Source: Yang, Binqi et al. "Digital Beamforming-Based Massive MIMO Transceiver for 5G Millimeter-Wave Communications." IEEE Transactions on Microwave Theory and Techniques 66 (2018): 3403-3418.

The MIMO Challenge (II)

- Complexity of system and packaging
  - Antenna dimensions governed by $\lambda/2$ pitch between element patches (3 GHz -> 5 cm)
  - Integration of antenna with radio front-end attractive/indispensable
- Measurements: only air interface on antenna side

The MIMO Challenge (III)

- Efficiency & linearity
  - Beamforming:
    max. radiated power = sum of all transmitters
  - Massive MIMO = increasing number of patches
    - Output power required per channel reduces
      – holds for RF power consumption as well
    - DC power for DAC/ADC and digital linearization (DPD) grows
      - even more critical for large bandwidths, due to high-speed digital signal processors
  - In contrast to present BTS - limits the number of parallel digital channels

The MIMO Challenge (IV)

- Solutions under investigation
  - Hybrid MIMO system
    - Form analog subgroups (beam steering by phase shifters etc.)
    - Less power-hungry signal digital circuitry
  - Simplify linearization (analog approaches)

The mm-Wave Challenge

- Antenna size shrinks (pitch patches @ 30 GHz: 5 mm)
  - reduced form factor of transceiver needed
- Semiconductor circuit performance changes
  - Degradation in output power and efficiency
  - Higher cost, less maturity (in general)
- Which semiconductor technology for BTS radio front-ends?
  - Criteria: Output power and efficiency, integration capabilities, cost
    - RF-CMOS, SiGe, GaAs, GaN
    - Hetero-integration?

The Efficiency Challenge (I)

- Broadband modulation schemes: peak P(out) >> average P(out) (PAPR typically 10 dB)
- Conventional PAs: low power-added efficiency (PAE)
- Alternatives
  - Doherty PA

The Efficiency Challenge (II)

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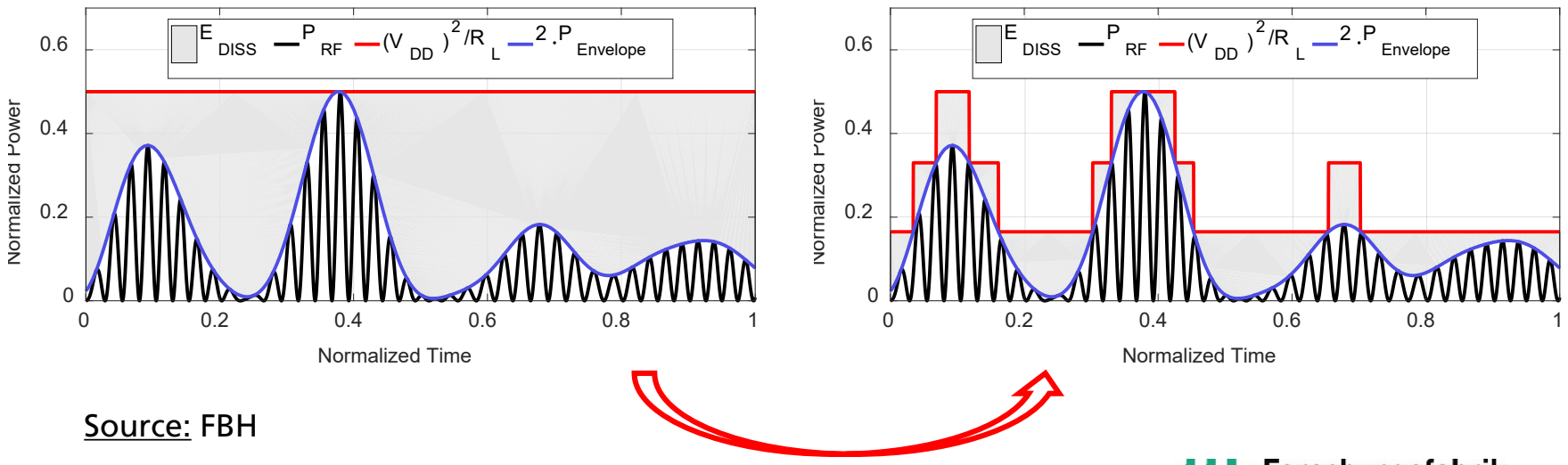
  - Envelope Tracking



Source: FBH

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- High bandwidth -> high-speed DSPs -> high energy consumption

FMD Expertise and Services for 5G

- Comprehensive competence on semiconductor and circuit level
  - SiGe and GaN components, < 6 GHz and up to >100 GHz
  - Circuit concepts (energy-efficient transceivers, mm-waves)
  - Integration on wafer and module level

- …on system level
  - FPGA platform for rapid prototyping & demonstration (+ A/D & D/A converter)
  - Base-band processors for various applications (MATLAB, VHDL, IC)
  - Protocol processors in hardware and software (low latency, high throughput)

Future Activities (Outlook beyond 5G)

- Research on 6G is already ongoing
- Focus on higher frequency bands with unprecedented bandwidth
- Examples
  - D-Band (140 GHz) transceivers and waveforms
    - Extremely broadband transceiver from 110 – 170 GHz (6G-Kom project)
  - 240 GHz transceivers and scalable baseband processor + localization
    - Application for Augmented Reality in indoor scenario (WORTECS project)
  - High capacity, high cell density backhaul using mm-wave spectrum beyond 100 GHz
    - HORIZON2020 project ULTRAWAVE

Kontakt

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