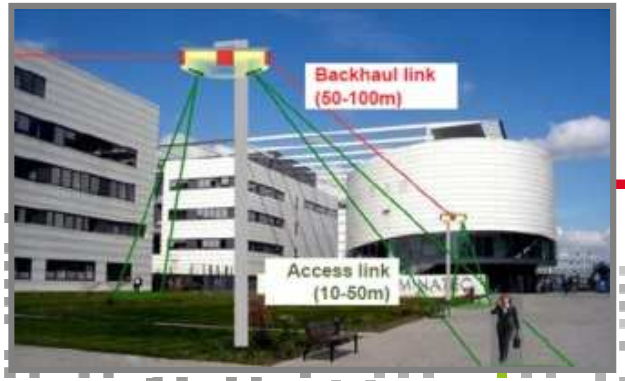

5G RESEARCH AREAS AT CEA-LETI
FROM *5G* RESEARCH TO *5G* PRE-INDUSTRIALIZATION

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CEA-LETI
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SERVING A VARIETY OF 5G WIRELESS APPLICATIONS

Mobile communications

Challenges: increasing data rate , future cellular systems, *4A any rate anytime anywhere affordable*, reduction of communication energy footprint (GreenCom), monitoring interference and service coverage, heterogeneous networks - HetNets, small cells

⇨ **Spectrum efficiency, cooperative communications, HetNets, Femto / Macro RRM, Cognitive radio, *Flexible radio systems*…**

Intelligent Transportation Systems (ITS)

Challenges: traffic management, car centric services (maintenance, routing), Electric Car services, infotainment / entertainment

⇨ **QoS system, mobility management, privacy and security, entertainment communication systems, propagation and adaptable antenna systems …**

Advanced manufacturing

e-agriculture

Challenges: factory of the future, increasing competitiveness, new production and management communication systems, robust communication systems (coexistence, interference management), supply chain management

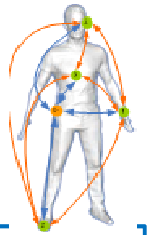
⇨ **Wireless sensor networks, robust communication, M2M, RFID/NFC, indoor localization…**

Health

wellness

Challenges: hospital equipment, management and supply chain support, no-emission wireless communication systems (clean wireless), smart implants, telemedicine, health monitoring, ambient assisted living…

⇨ ***Body Area Network*, *Visible Light Communication*, in vivo integration, contactless autonomous systems, *indoor localisation*, very high data rate communication systems, privacy, security…**

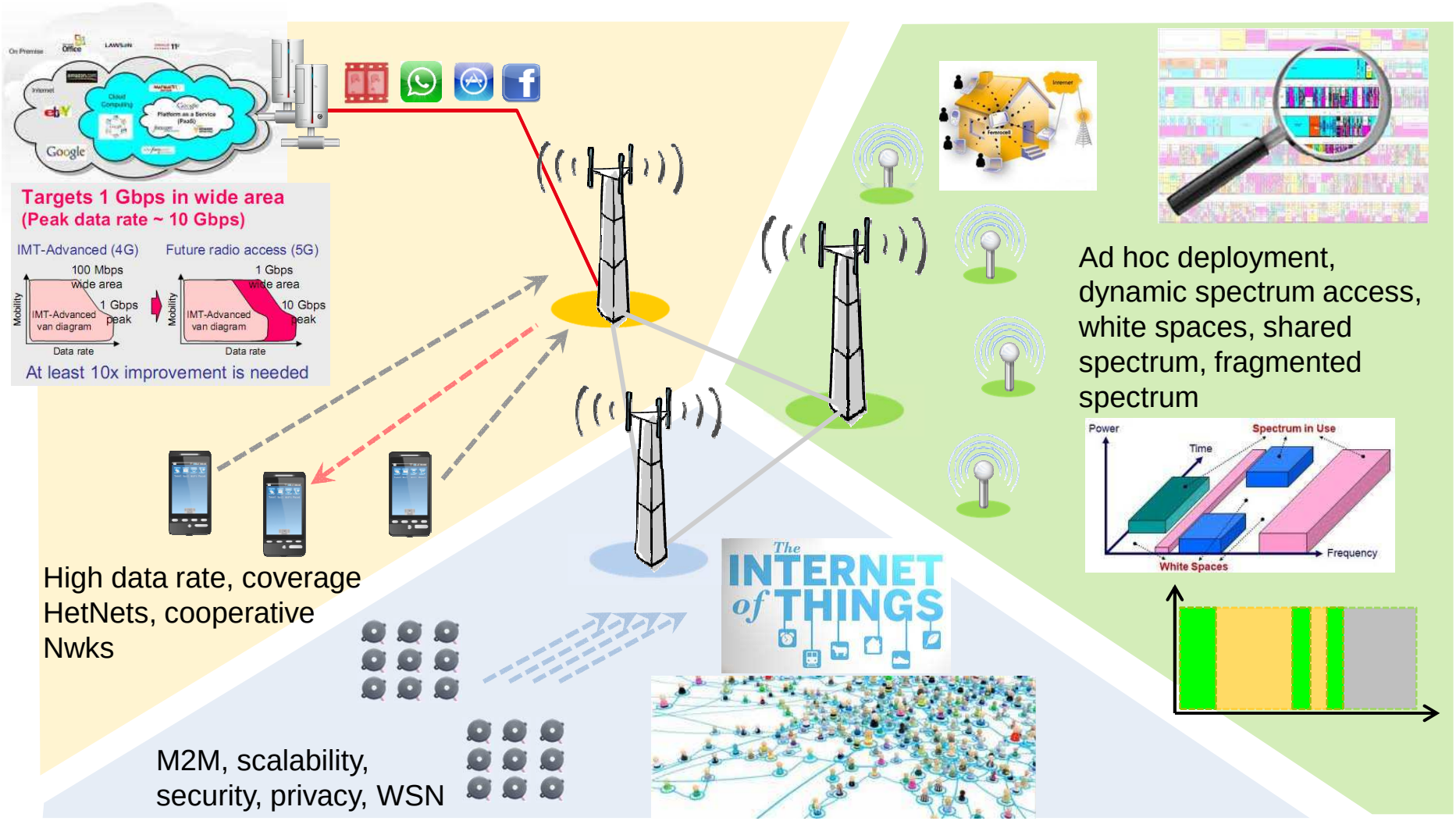


Smart cities, Smart grid

Challenges: infrastructure monitoring, city infotainment services, utility supply chain management, waste collection and management systems, citizen mobiliy assistance, urban smart transportation systems

⇨ **Long range sensor network , *robust communication*, M2M, security and privacy…**

KEY 5G TECHNICAL CHALLENGES



5G TECHNOLOGIES AT CEA-LETI

Antennas optimization

Miniature
Smart
Integration

Chanel propagation modeling

Characterization
Modeling
Emulation

Contactless

Arduous application
VHBR (Very High Bit Rate)
Power harvesting

Cellular IoT

Physical layers
Protocols

Wireless sensors networks (WSN)

Central network
Mesh network
Specific Scenario

Localization

Radio link
Localization algorithms
Multi-modality

COMMUNICATION

RADIO LINK DESIGN, OPTIMIZATION & CHARACTERIZATION

ANTENNAS MINIATURIZATION & INTEGRATION

RFID SOLUTION DESIGN FOR HARD ENVIRONMENT

LOCALIZATION & NAVIGATION

5G below 6GHz

Disruptive air interface
Advanced protocols
Network architecture

5G above 6GHz (mmW)

New physical layers
Evolved protocols

LiFi

Physical layer
Protocol stack
Platforms

Flexible & Cognitive radio

Air interface
MAC layer
Demonstrator

ACTIVITIES

Challenges

- Spectral efficiency for communication systems
- New spectral resources
- Waveforms, modulation and coding
- Radio resource management
- HW/SW architectures

- ***Fields of expertise***
  - Wireless digital communication systems
  - Study, specification and link/system level simulations (PHY/MAC)
    - Information theory and signal processing
    - Wireless communication protocols
  - Algorithm / Architecture analysis and matching
  - Hardware and embedded software architectures for real time digital communication systems
  - Prototype specification and design for advanced proof of concepts
- ***Main applications***
  - Broadband wireless systems
  - Cellular: 5G (below 6GHz and mmW)
  - TVWS and cognitive radio
  - Optical wireless communications
- ***Specific equipments***
  - Computer grid for intensive simulations
  - Lab equipments for prototyping and real time measurement and analysis

ACTIVITIES

Challenges

- Spectral efficiency for communication systems
- New spectral resources
- Waveforms, modulation and coding
- Radio resource management
- HW/SW architectures

- ***Know how***
  - Signal processing: modulation, channel coding, equalization, synchronisation, MIMO techniques, multicarrier systems, …
  - Information theory, cooperative communications, network coding
  - MAC protocols, Radio Resource management and interference mitigation
  - Link Level Simulations (PHY), System level simulations (MAC/RRM)
  - Digital wireless solution specification and design (HW/SW design)
  - Hardware / software partitioning for real-time wireless systems
  - Optimized design with various figure of merit (power consumption, data rate,…)
  - Integration with third party HW/SW/Analog
  - HW demo with design of custom platforms (HW&SW) & field tests

5G BELOW 6GHz

Disruptive air interface

- Waveforms: FBMC, filtered OFDM, single carrier, narrowband
- (M)MIMO, Beam forming
- Full duplex
- Chanel coding: *LDPC & polar code*
- HW and SW flexible platforms

Advanced protocols

- Interference management:
  ICIC, Network controlled Discontinuous transmission
- Flexibility and multi services:
  Scheduling for heterogeneous QoS
  Scheduled/contention based access (RRM)
  Load balancing
- Joint Network channel coding

Network architecture

- Mobile edge cloud computing
  Resources sharing, caching, and clusterization
- Heterogeneous deployments (HETNETS), including access and backhaul

Capacity increase: x100

- *x10 in spectral efficiency: (M)MIMO, Full duplex, out of band radiation*
- *x10 in densification (access points, connected objects)*

Latency reduction: /5

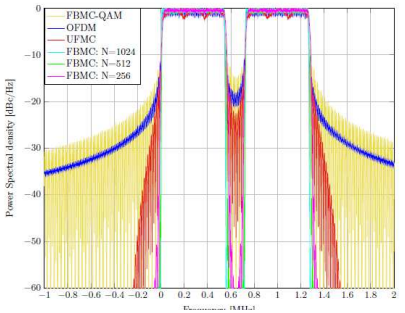
- *Content caching,*
- *Protocols (QoS aware, HARQ)*
- *Flexible TTI*

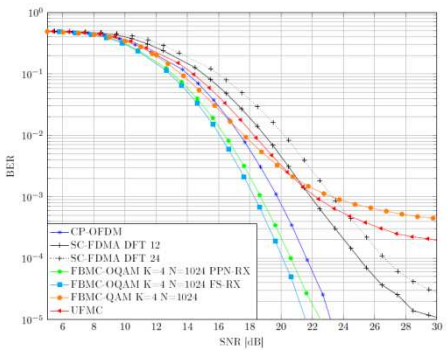
Consumption reduction: /10

- *Network, protocols, components*
- *PAPR (Peak average power ratio) : 7dB*

Reduction of jitter protocol

- *Mission critical applications*
- *Robust PHY layer and quasi deterministic MAC layer*

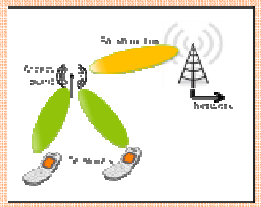




5G ABOVE 6GHz (mmW)

5G Champion

5G MiEdge



New physical layer

- Waveforms: FBMC, BF-OFDM, single carrier
- RF impairments compensation
- Beam forming and tracking: hybrid architecture
- FEC: LDPC
- HW architecture for parallel processing

Evolved protocols

- Mobility : users and access points
- Scheduling for heterogeneous QoS: time / frequency / beam
- Macro-cell off loading and heterogeneous networks
- Interference management: ICIC, Network controlled, Discontinuous transmission, Self-organized network (SON)

Density increase: x100

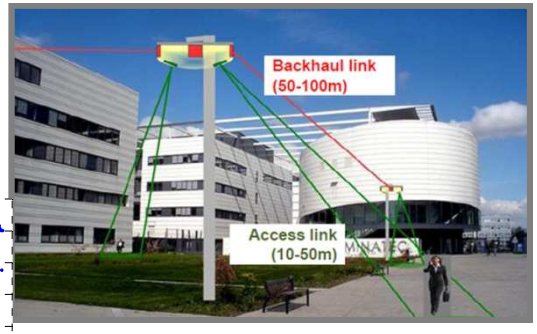
- ultra dense networks (UDN) and Self Organized networks (SON)
- Advanced interference management schemes
- C-RAN vs D-RAN

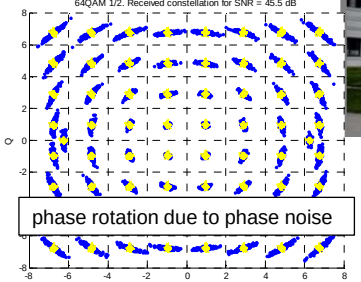
New frequency bands:

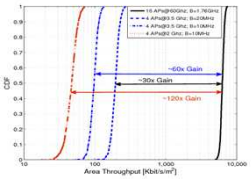
- *x10 in spectrum*
- *100Ghz-300GHz*
- *Adaptation of PHY and RF layers*

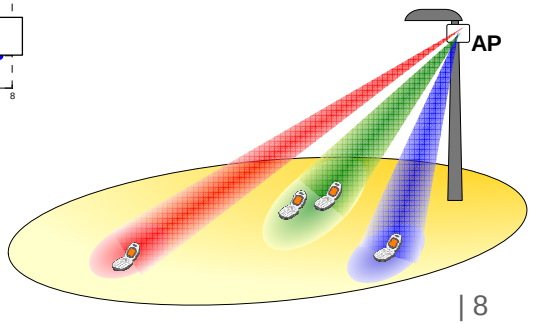
Throughput increase : x100

- *Towards Tbps*
- *Joint optimization of backhaul/fronthaul/RAN*









FLEXIBLE & COGNITIVE RADIO

Air interface

New modulation (FBMC)

Advanced receivers:
- *Oversampled FFT*
- *Channel estimation for fragmented spectrum*

Spectrum quality indicator:
- *Sensing mechanisms*
- *Interference measurement*
- *Primary user detection*

MAC layer

Flexibility and multiservices

Cross layer mechanisms (FBMC)
- *Loose synchronization*
- *Fragmented spectrum*

Shared spectrum access

Offload/aggregation of shared bands

multi-RAT management, DSA, LAA

Demonstrator

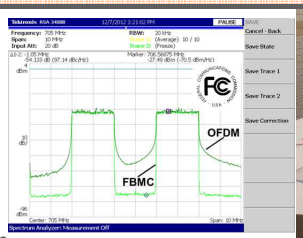
Compatibilty with IEEE DYSPAN P1900.7 (TV White Spaces)

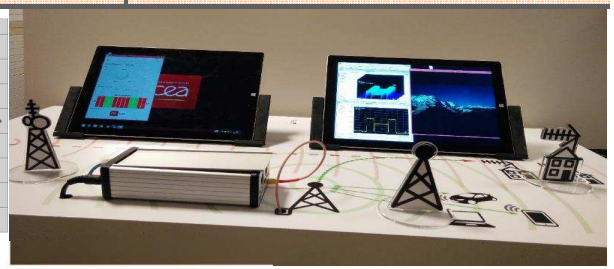
Flexible radio
- *Frequency, band, fragmentation*

Field trials (ARCEP UHF licence)

Identification of new bands

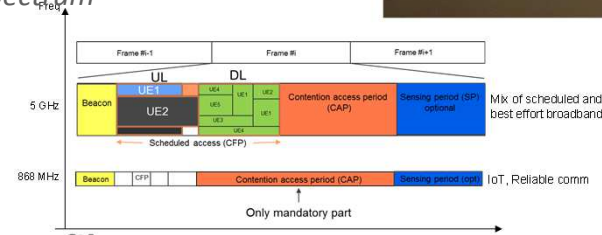
- *Survey of regulatory actions (2.3, 3.5 GHz)*
- *Primary user detection*
- *Definition of a suitable accesss to shared spectrum*





Exploitation of shared bands

- *Aggregation (DL and UL) of these bands*
- *Management of generated interferences*
- *Control and user plane split*

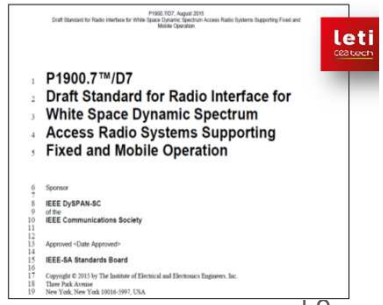


Extension of the standard to new profiles

- *QoS support for unlicensed bands*
- *Contention/scheduled access equilibrium to be integrated in the standard*

Industrial valorisation

- *Technological transfer of FBMC*



LIFI – OPTICAL WIRELESS COMMUNICATION

Physical layer

Waveforms
- *Multicarrier, PAM*
- *Frequency domain equalization*
- *Compensation of optical and analogue impairments*

MIMO

Adaptive processing (Tx/Rx)

Protocol stack

Multi user access

Heterogeneous QoS

Full duplex

Transparent IP link

Platforms

Characterization testbed
- *Spectrum analysis*
- *Propagation channel analysis*
- *Algorithm optimization (HIL)*

HW/SW partitioning

Electronic Architecture
- *Consumption optimization*
- *Reduction of form factor*

Throughput: x5-x20

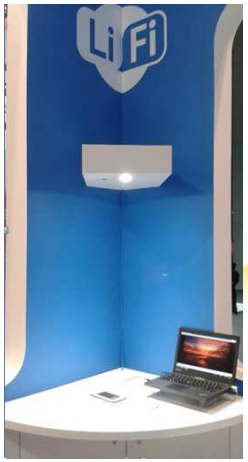
- *Automatic link adaptation*
- *Spectral efficiceny increase (bit loading, MIMO)*
- *Bandwidth increase (RGB LED, micro-LED, Laser sources)*

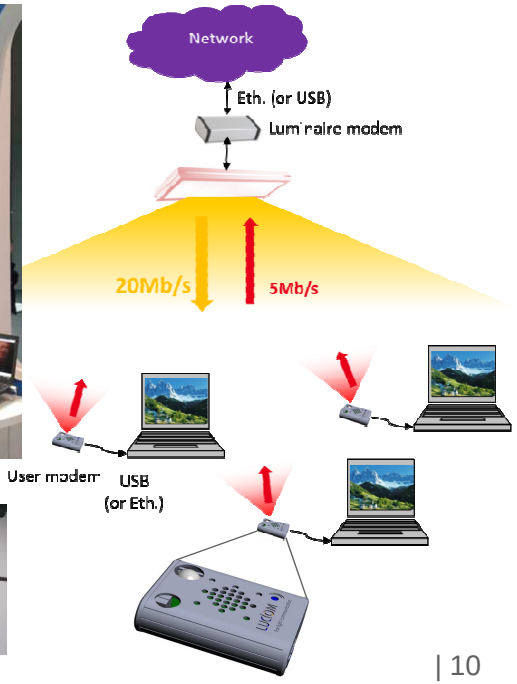
Range: x5

- *Optical front-end: lens, collimation*
- *MIMO processing*

Density increase:

- *Multi-cell access*
- *Interference management*

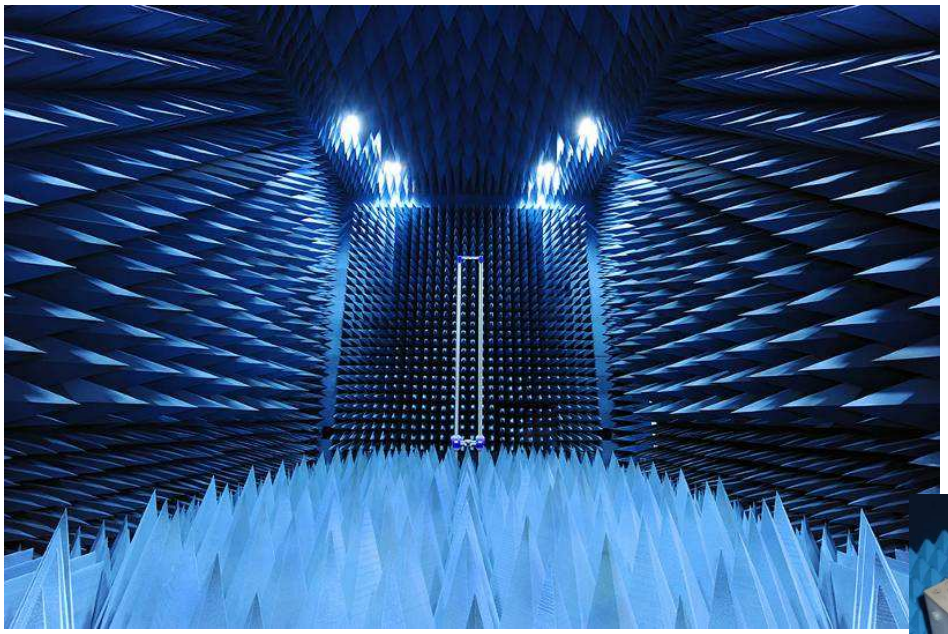




EM field covered from 100 MHz to 90 GHz

VHF-EHF band (100 MHz – 18 GHz)

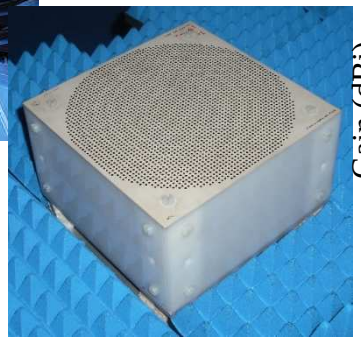
Shielded anechoic chamber

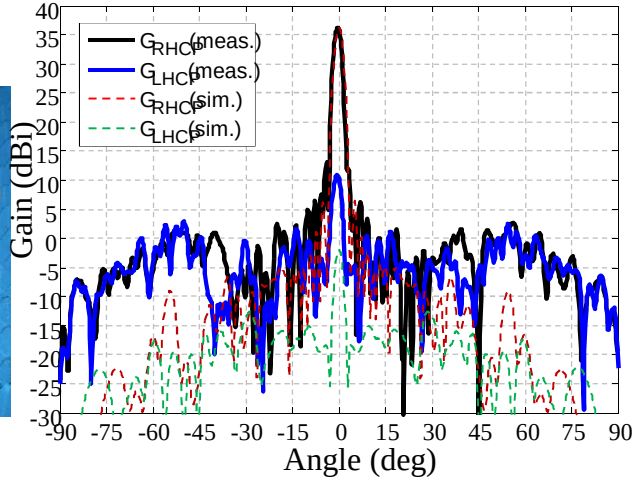


On-vehicle antennas

Antenna arrays (e.g. base station, massive MI

MM-Wave high-gain antennas (e.g. backhaul

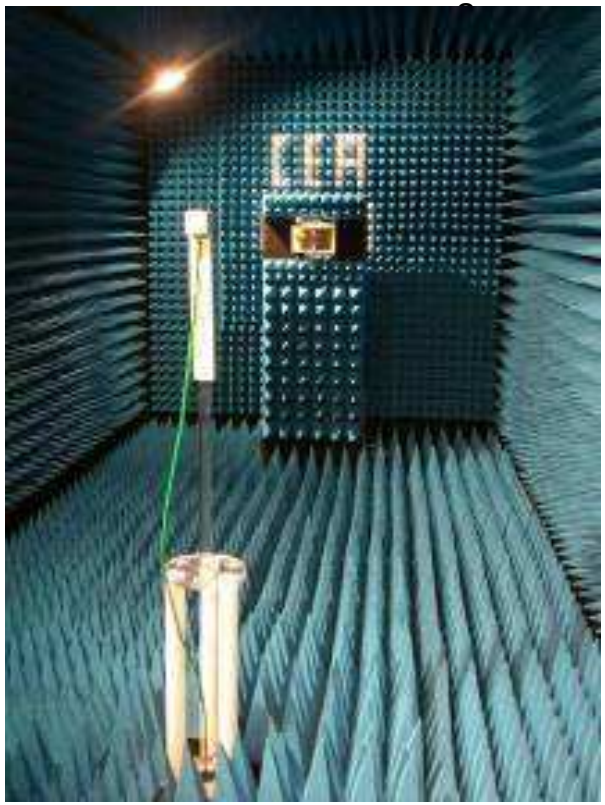




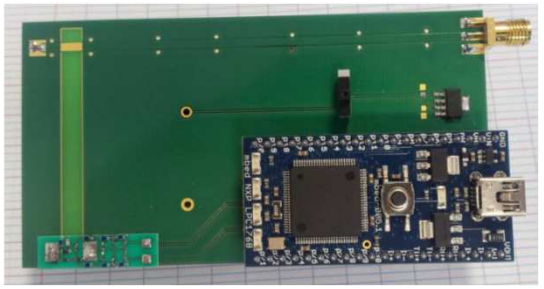
EM field covered from 100 MHz to 90 GHz

UHF-SHF band(900 MHz – 40 GHz)

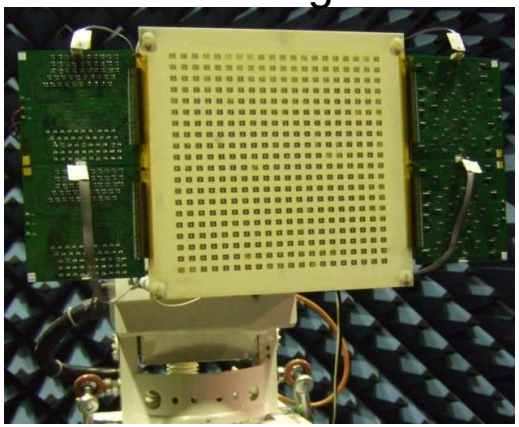
Shielded anechoic chamber

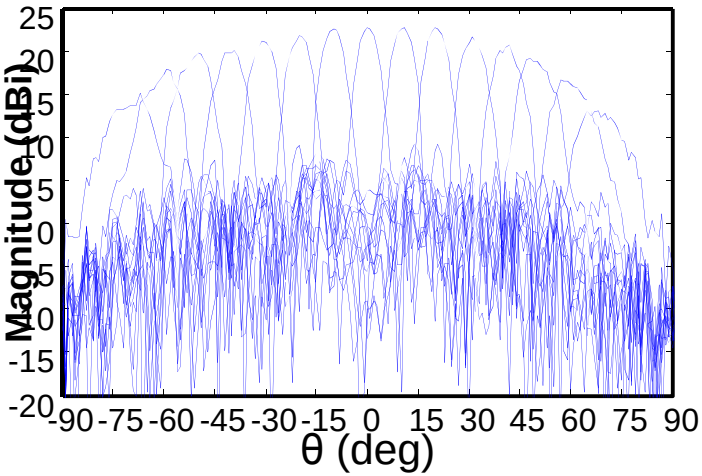


Miniature antennas (e.g. user terminal)



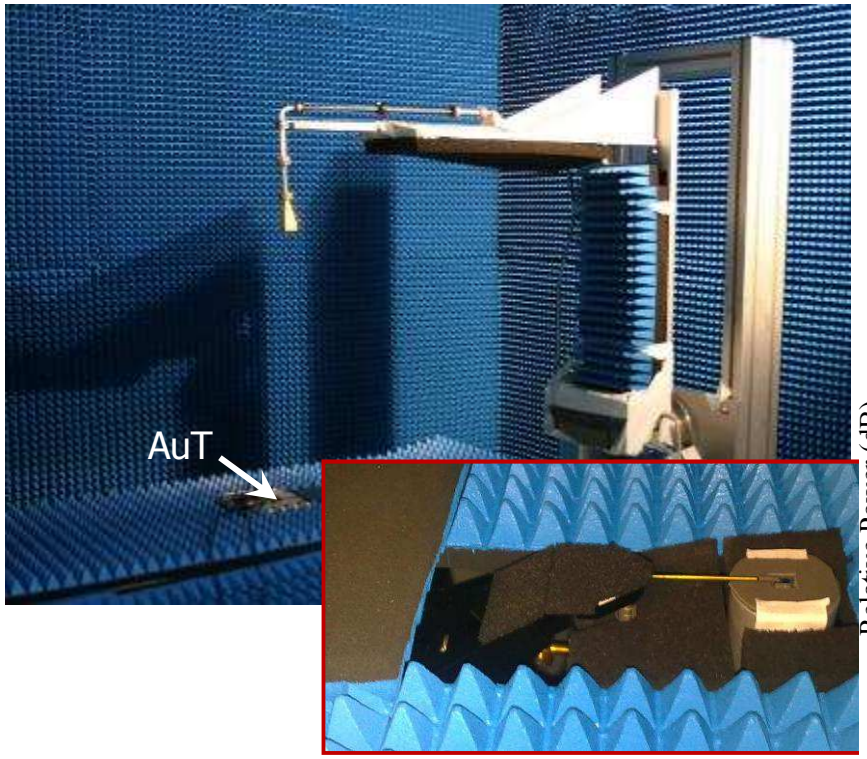
Beam-steering antenna arrays



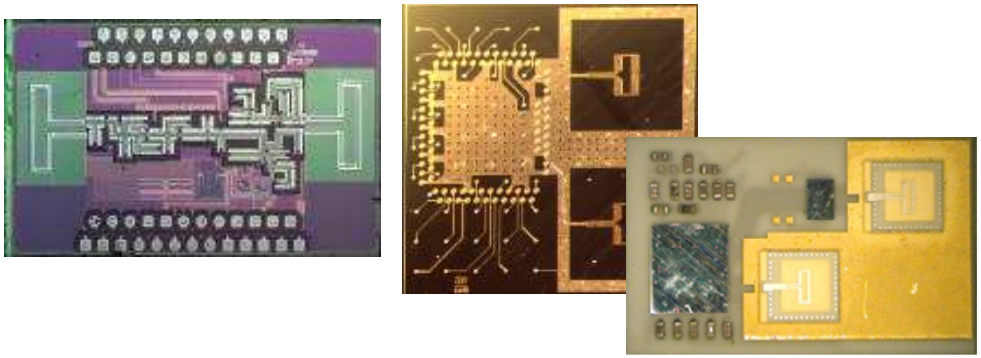


EM field covered from 100 MHz to 90 GHz

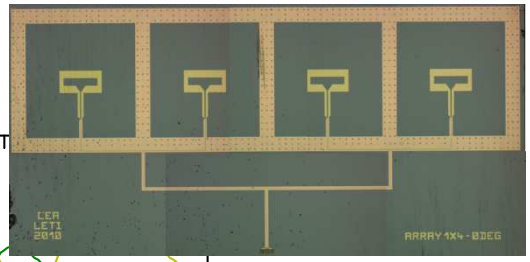
MM-Waves (30-90 GHz)
Anechoic chamber with
on-chip probing capability
2.3x2.3x3.4 m^3.

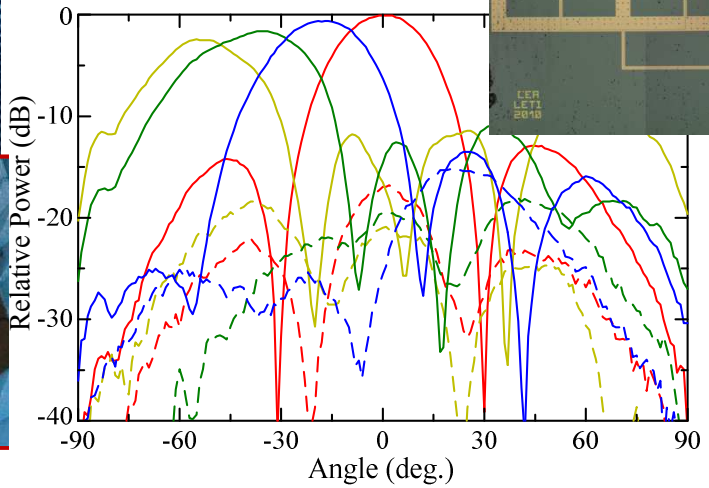


On-chip/in-package antennas



In-package antenna arrays



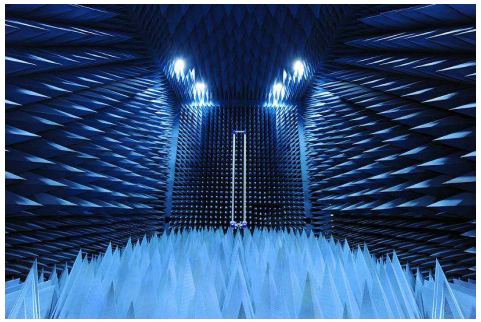


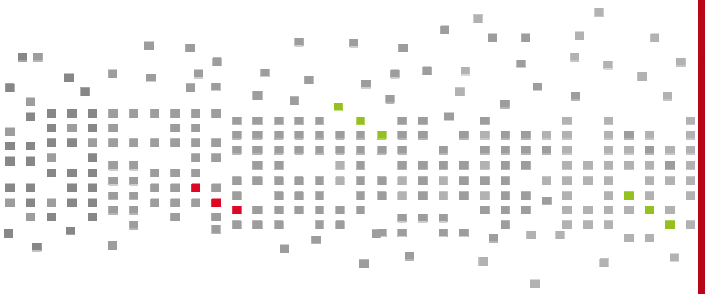
OTA EMULATED CHANNEL REPLAY (BELOW 6 GHZ)

Full chain tested **under** ***realistic and controlled channel*** **models**

Evaluation of the impact of antennas, housing (smartphone, tablets, laptops, set-top-box,…), environment

+

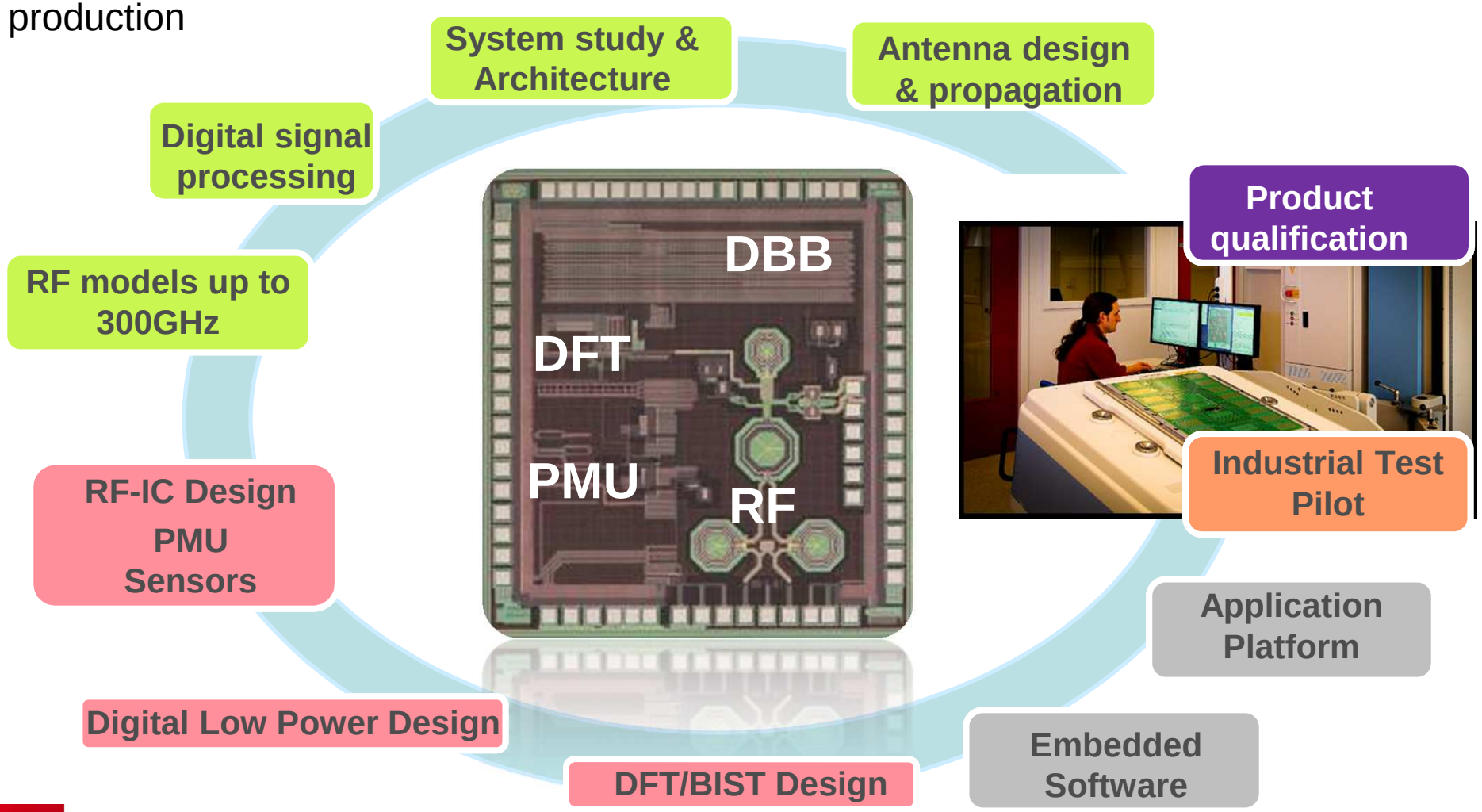




Leti, technology research institute
Commissariat à l'énergie atomique et aux énergies alternatives
Minatec Campus | 17 rue des Martyrs | 38054 Grenoble Cedex | France
www.leti.fr

INSTITUT CARNOT CEA LETI

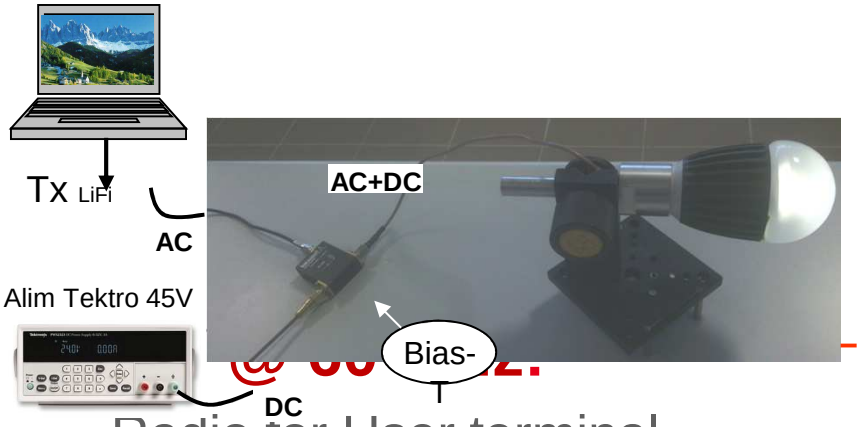
- 5 labs: **200+ people** dedicated to telecommunications & RF SoC CMOS integration
- Address manufacturability issues to accelerate the transfer from research to production



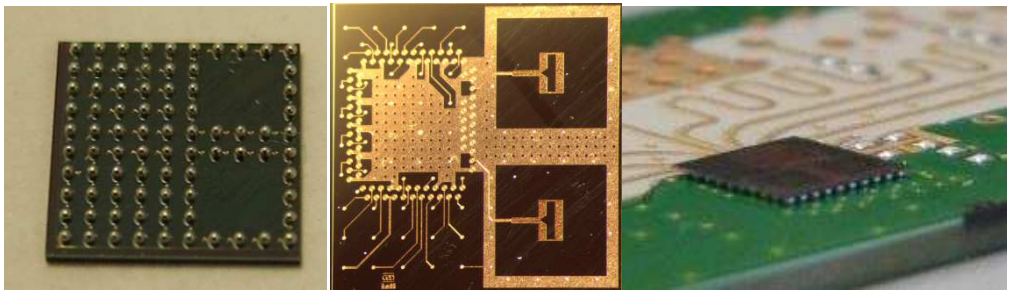
FBMC: New 5G modulation for efficient spectrum usage

VLC: Visible Light Communications

- Use off-the-shelf LED

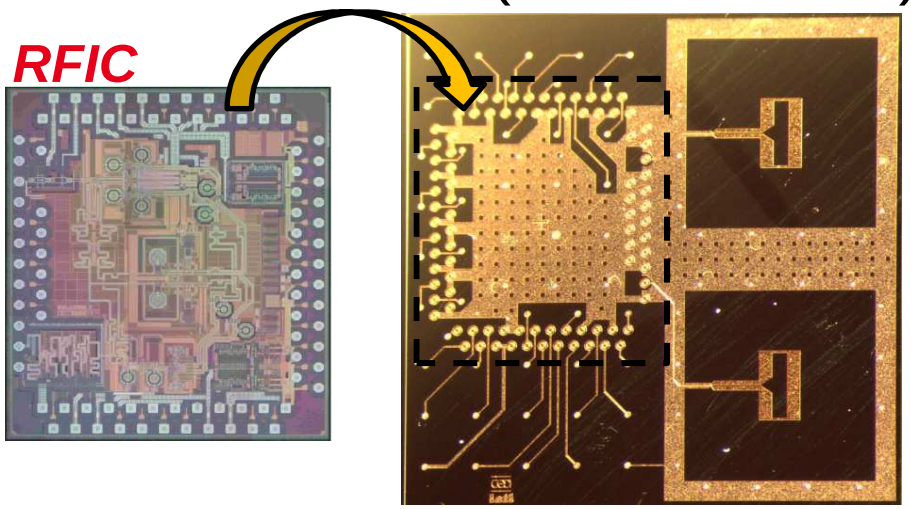


- Radio for User terminal and Backhaul



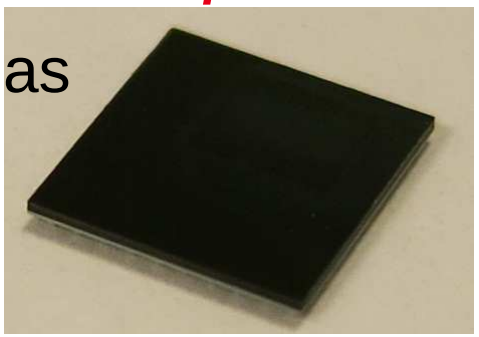
60-GHz Transceiver module on HR silicon (CEA-LETI)

- Compact size: 6.5×6.5×0.6 mm3,
- HR silicon integration with integrated antennas
- CMOS transceiver (CMOS 65 nm)

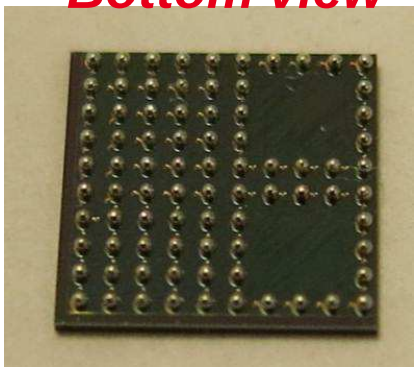


Size : 6.5x6.5x0.6 mm3

Top view



Bottom view



Ref.:Y. Lamy, et al., IEEE Int. 3D Systems Integration Conference (3DIC), Oct. 2-4, 2013.

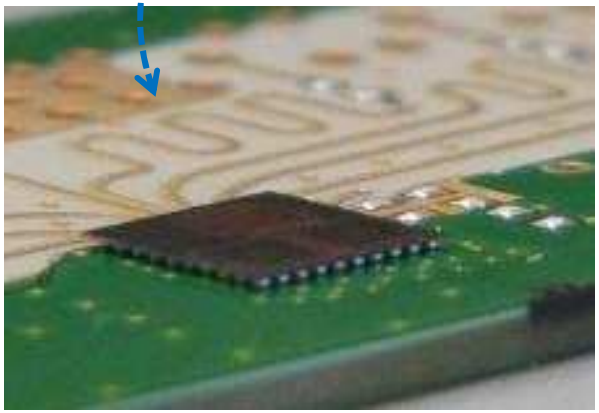
MMW HW @ 60 GHZ RADIO FOR USER TERMINAL

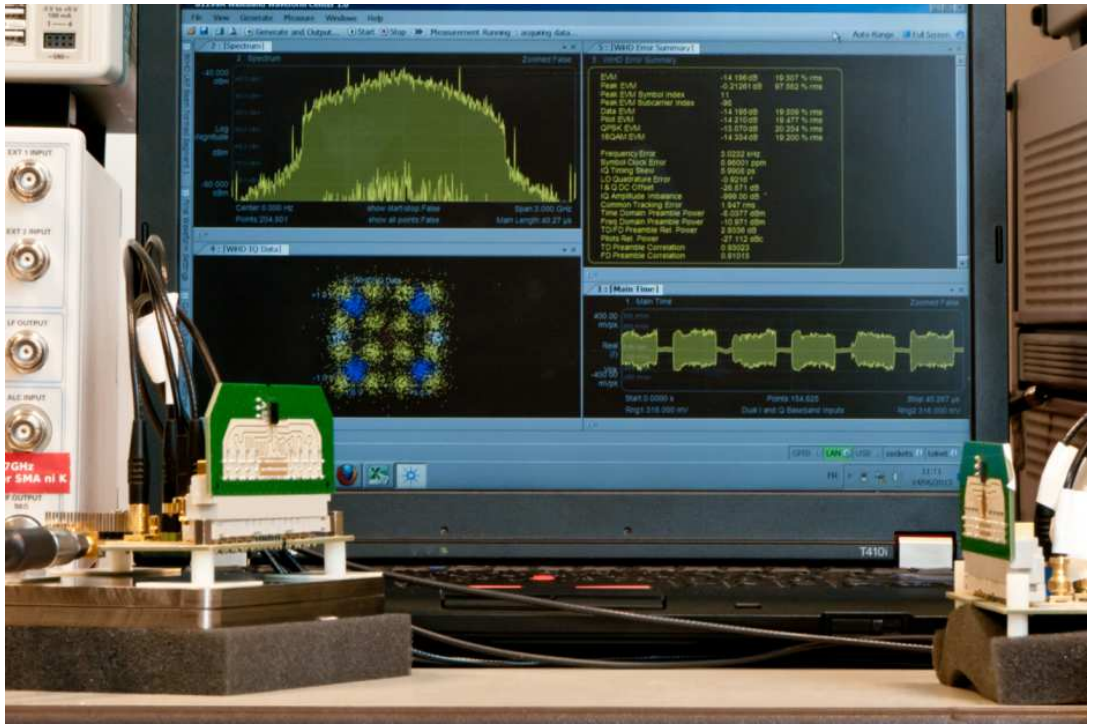
60-GHz Transceiver module on HR silicon (CEA-LETI)

- Wireless HD std: 7 Gbps (OFDM 16QAM)
- Operates over the 4 IEEE channels between 57 and 66 GHz.

Experimental test bed

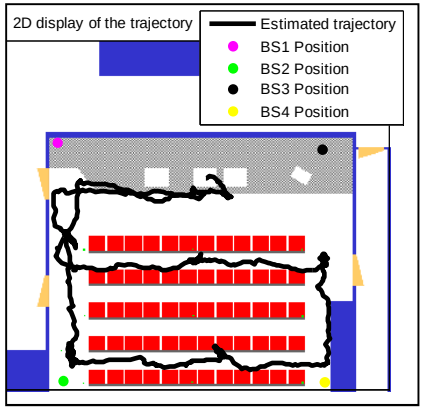
Test board



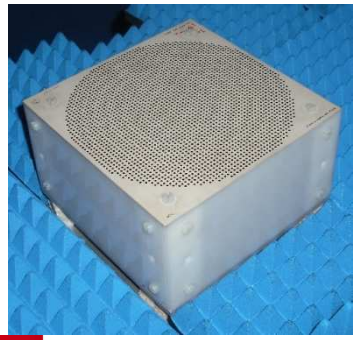


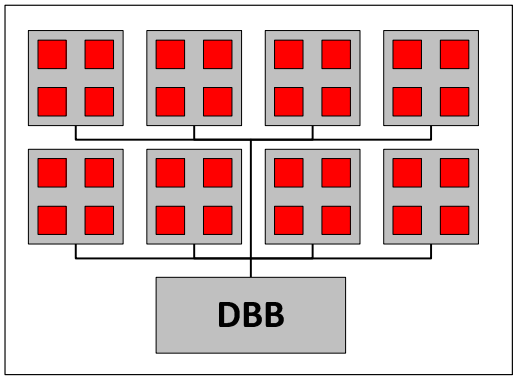
Localization & Tracking (Indoor and Outdoor):

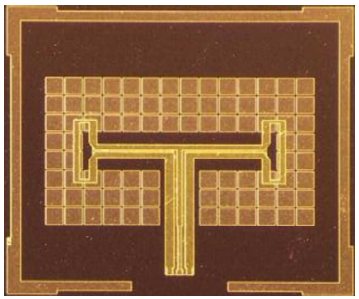
- Complete SoC (Tx/Rx radio IC + Embedded SW)



Antennas Design







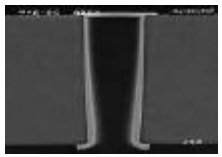
PACKAGING, INTEGRATION, MEMS : A NEED FOR MMW PRE-INDUSTRIALIZATION

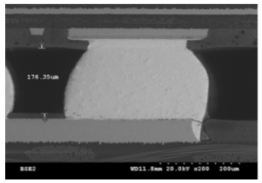
8000 m2 clean rooms with state-of-the-art pre-industrial 200-mm micro-fabrication facilities

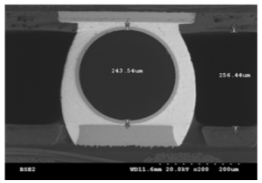
3D packaging & integration

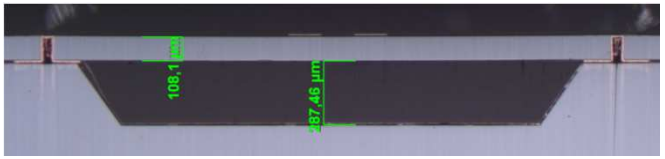
- Silicon interposer technology
- Passive components and antenna integration

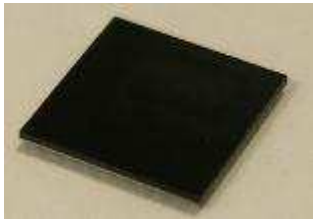
Higher miniaturization

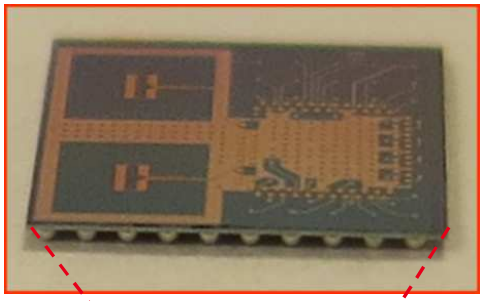


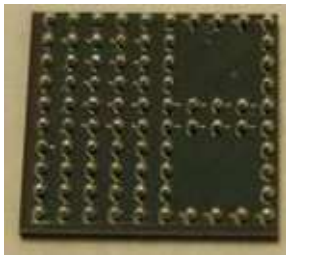


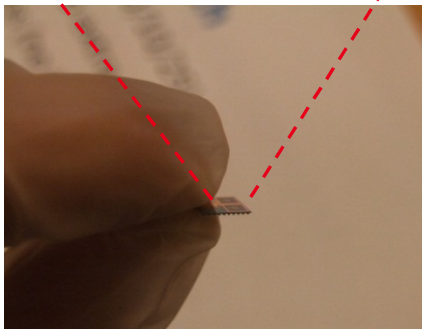


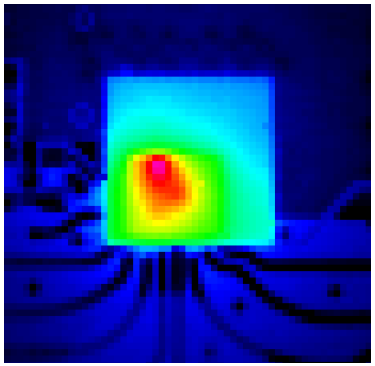


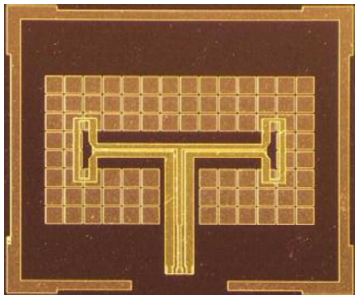










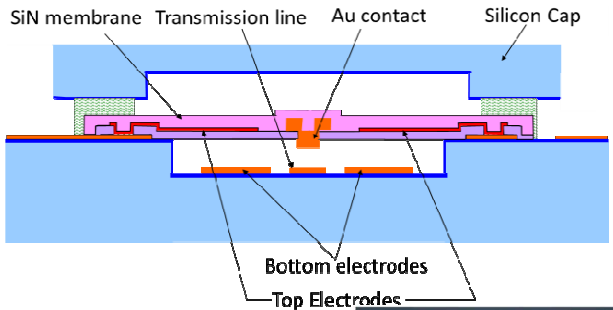


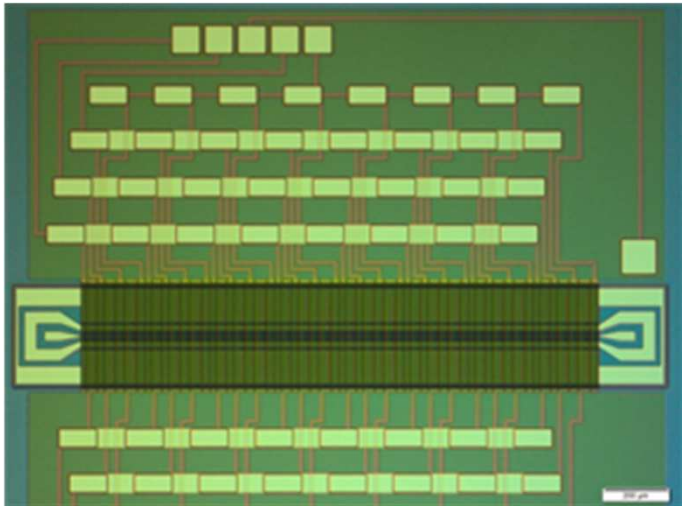
MMW RECONFIGURABLE ANTENNAS EXEMPLE

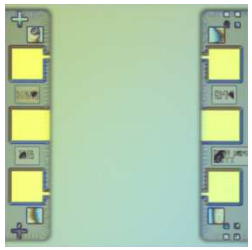
RF MEMS switches and capacitors

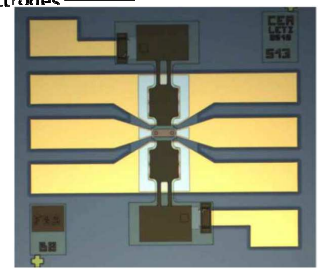
(*Ex. for mmW reconfigurable antennas*)

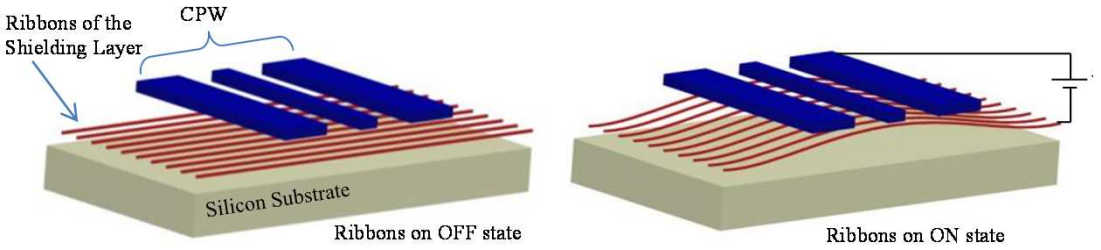
- Low-loss switches
- Low-loss phase-shifters





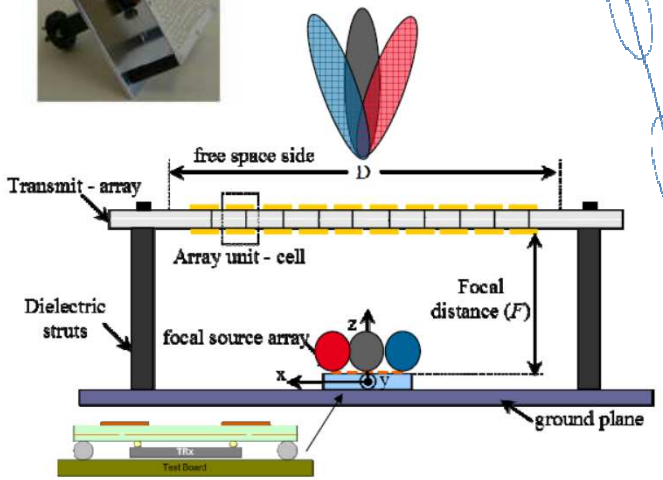




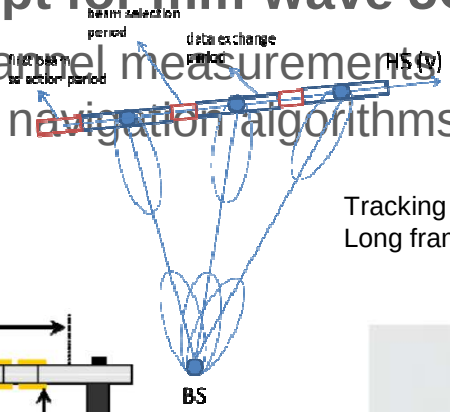


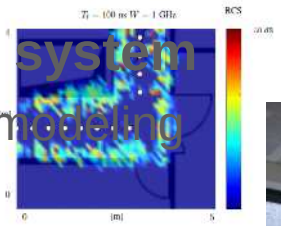
5G SMART ANTENNA SYSTEMS – INNOVATIONS

- **Low-complexity system architectures for beam steering**
  - Beam steering transmit array, hybrid beamforming, dynamic tracking algorithm, multi-user beam control
  - High-gain wideband compact antenna
- **Proof-of-concept for mm-wave 5G/radar system**
  - mm-wave channel measurements and 3D modeling
  - mapping and navigation algorithms



Beam tracking transmit array system
Switchable radiating source on silicon interposer





Tracking algorithm for moving hotspot
Long frames and high order modulations

>31dBi
ø100mm

V-band backhauling antenna
Requirements on PA output power
(photo courtesy of Radiall)

Benchmark of mm-wave personal radar architectures
Requirements on system design