The Car2TERA project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824962.

Car2TERA

Terahertz sensors and networks for next generation smart automotive electronic systems

Project presentation, B5G 3TTCW workshop

2021-03-11

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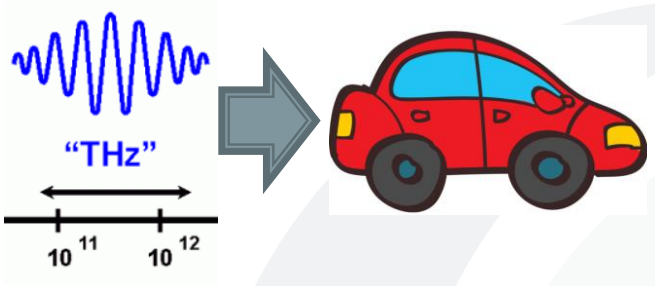
Impact of Car2TERA : Bringing THz technology into the car



- **Maintain Europe's technology/market dominance:**
  - **79% world market share on car radars**
  - **90% world market share on SiGe radar chip sets**
  - **Leading in pushing SiGe into THz gap (f_{MAX}=700 GHz)**
  - **2 of 3 largest telecommunication system providers**
- **Car radar* + in-cabin monitoring**: no. 1 and no. 2 fastest growing car electronics markets**

CAGR CAGR 2018-2023: *18% **49%

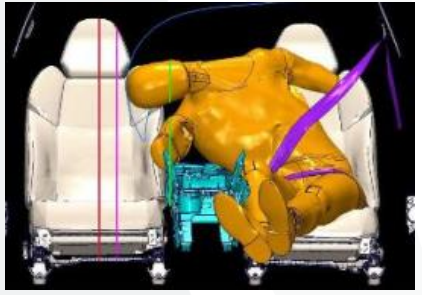
Who are we?

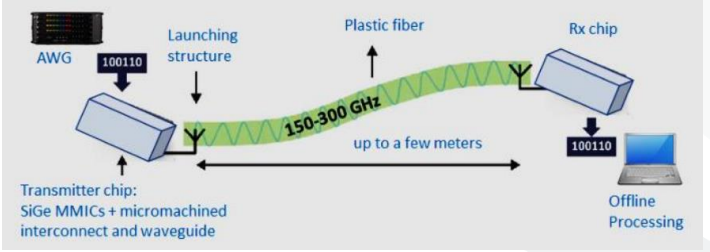
- **3 large enterprises:**
  Veoneer, Ericsson, Infineon
- **3 SME:**
  Technikon*, VIGO/Ent, Anteral
- **2 academic:**
  KTH, Chalmers

*** coordinator**

Car2TERA Demonstrators

- **TRL-4 demonstrators for two high-potential applications:**
  1. **Short-range, high-resolution, low-latency, large-bandwidth, compact radar sensor; for in-cabin passenger monitoring**
  2. **“THz-over-plastic”: low cost, robust high-speed wired short range com-munication link (>100 Gbit/s)**

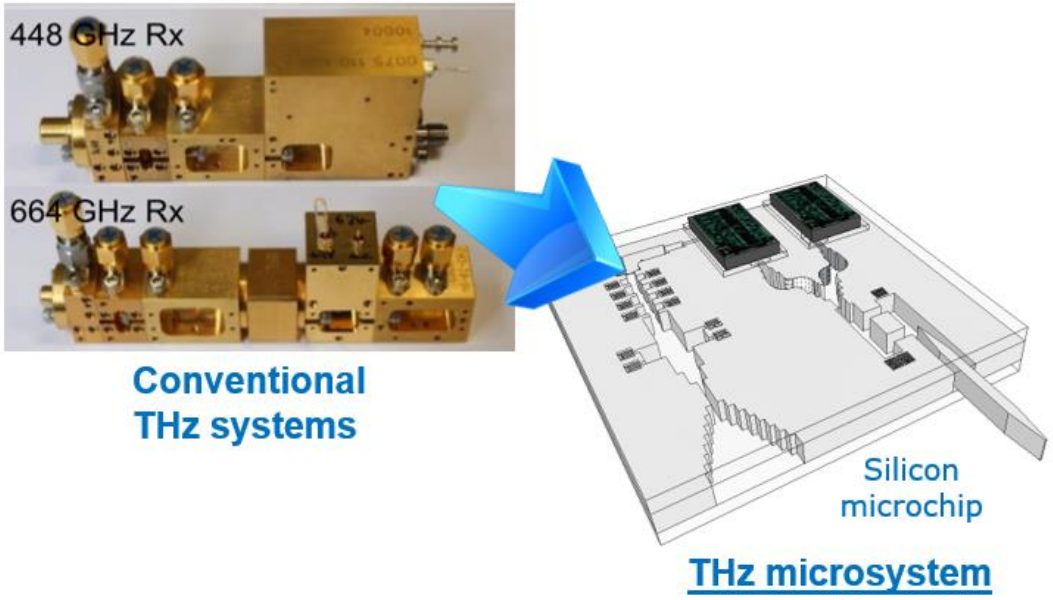




Car2TERA: New and emerging technologies

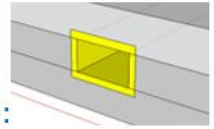
- **Highly integrated, volume-manufacturable THz technology:**
  - **Micromachined THz systems with MEMS reconfigurability**
  - **Latest-generation *industrial* SiGe MMICs with 600 GHz f_{MAX}**
- **2D materials: high-linearity graphene MMICs**
- **Sub-THz radar technology:**
  - **OFDM radar signals**
  - **Unconventional radar concepts (beam-shape switching)**
- **THz-over-plastic data links at sub-THz frequencies**

Micromachined THz system toolbox available to Car2TERA



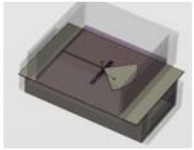
Micromachined THz system toolbox available to Car2TERA

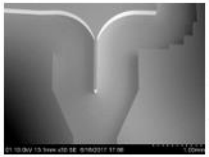
ROYAL INSTITUTE OF TECHNOLOGY

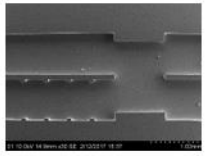


Low loss waveguides:
0.020 dB/mm @ 270 GHz
0.008 dB/mm @ 170 GHz

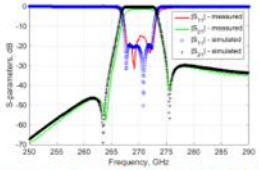
MMICs (SiGe, InP, GaAs) with waveguide interfaces



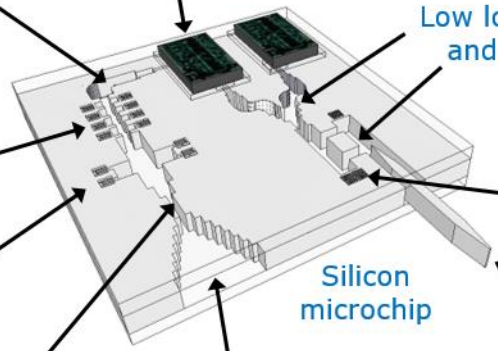




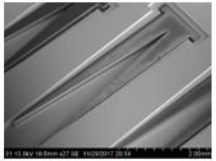
Low loss waveguide power combiners and couplers (0.2dB IL@320GHz)



Filters: Q=920@700GHz,
Q=1600@170GHz

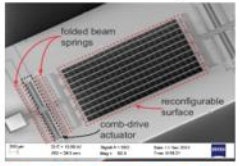


Silicon microchip

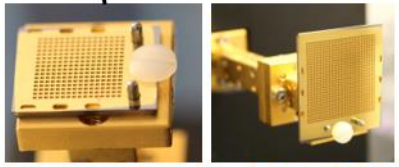


Integrated waveguide absorbers

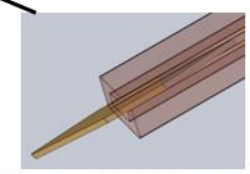
MEMS phase shifters up to 750GHz



MEMS waveguide switches:
220GHz: 50dB ISO, 0.6dB IL
750GHz: 25dB ISO, 2.5dB IL

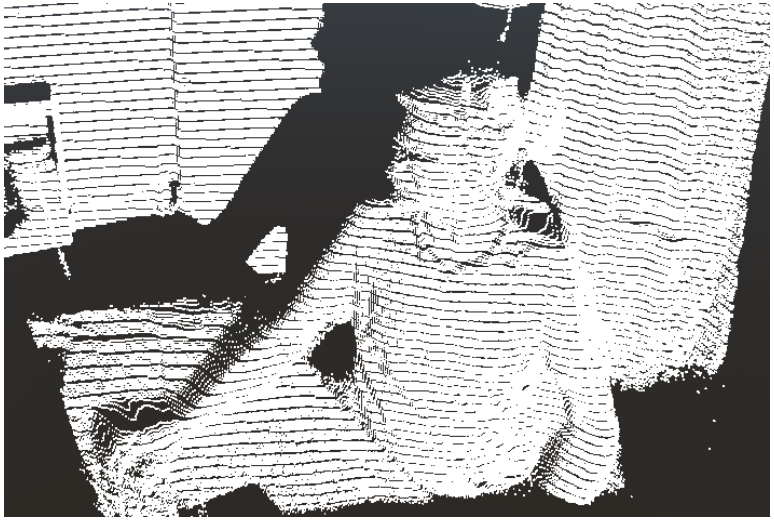


Antenna arrays, 320-400 GHz:
16x16: 34dBi gain, 0.8dB IL
32x32: 38dBi gain, 1.4dB IL



Micromachined medical sensor interfaces

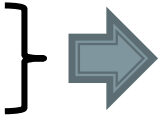
DEMONSTRATOR 1: sub-THz car radar sensor



DEMO1 : sub-THz car radar sensor

- **Primary application: in-cabin passenger monitoring**
- **Requirements:**
  - **High resolution**
  - **Compact size**
  - **Low power; MMIC cost**
- **Proposed solution:**
  - **10 GHz BW, 238-248 GHz band**
  - **Single Tx/Rx channel MMIC**
  - **2 steerable antennas**

Large BW, high-frequency

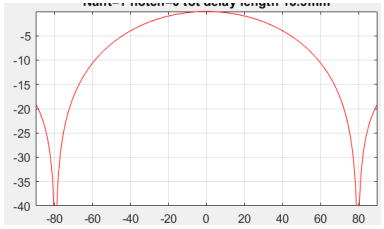


Min. number of TxRx channels, small antenna array

DEMO1 : sub-THz car radar sensor

- **Unconventional radar concept: <u>Beam-shape switching</u>: Trade-off between small physical aperture compensated by complementary information of different beam shapes**

1



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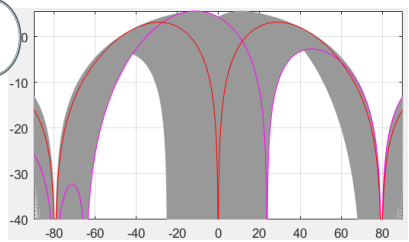
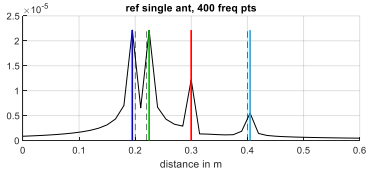
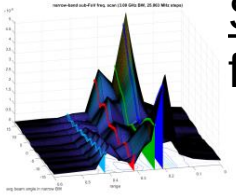


<u>Scanning broad beam:</u>
for range resolution

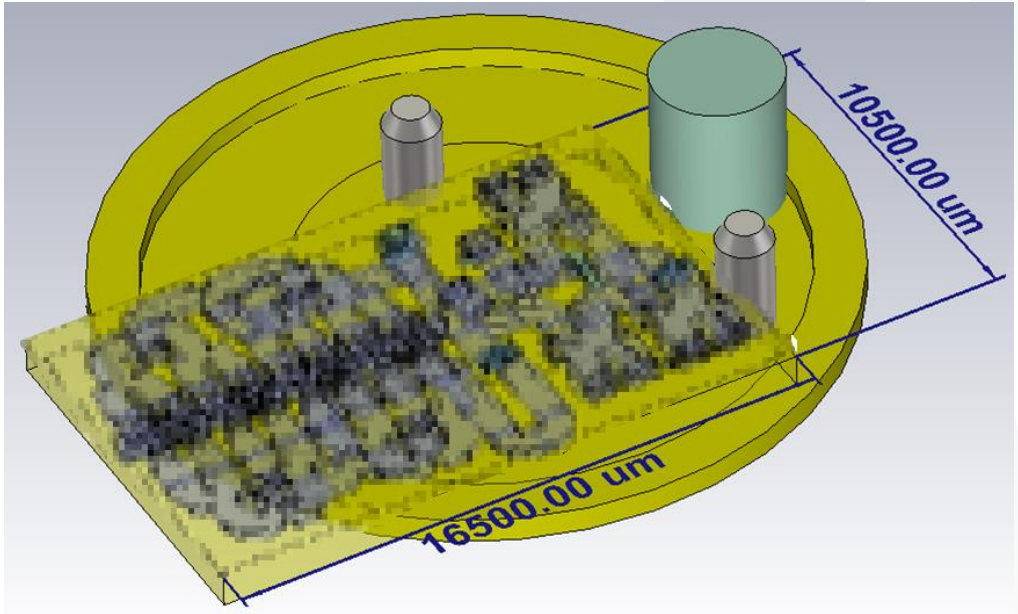




<u>Scanning notched beam:</u>
for angular resolution

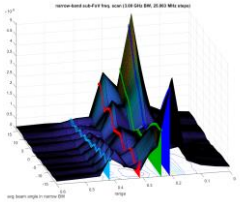
DEMO1 : sub-THz car radar: beam-steering front-end

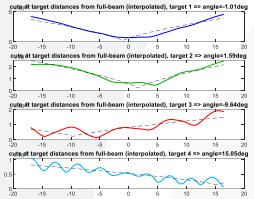
- **Micromachined waveguide system:**
  - **2-level waveguides on silicon micromachined chip**
  - **6 MEMS waveguide switches (IL<0.6 dB; ISO>50dB)**
  - **2x8 antenna array, ampl.tap.**
- **RL: >12 dB; IL: <1.8 dB**
- **Modularity: SiGe MMICs (600 GHz f_{max}) via WM-864 flange**



DEMO1: Car radar sensor: Signal processing strategies

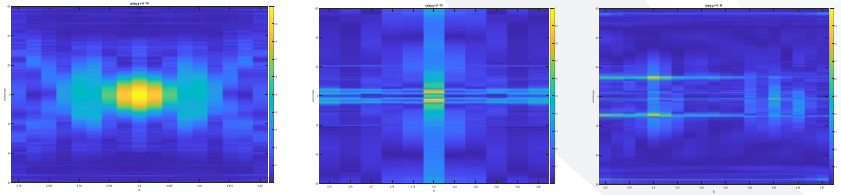
- **Deterministic: iFFT, min/max search:**
  - **Poor performance for distributed targets**



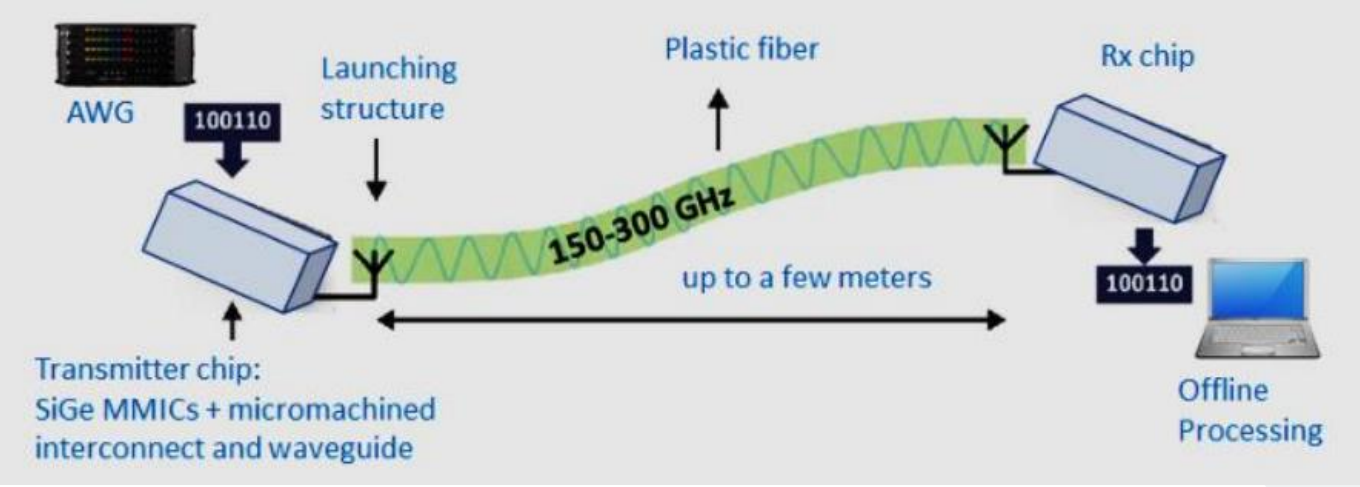


- **AI / machine-learning:**
  - **CNN/MLP networks**

- **Computational imaging:**
  - **Most promising for distributed targets**

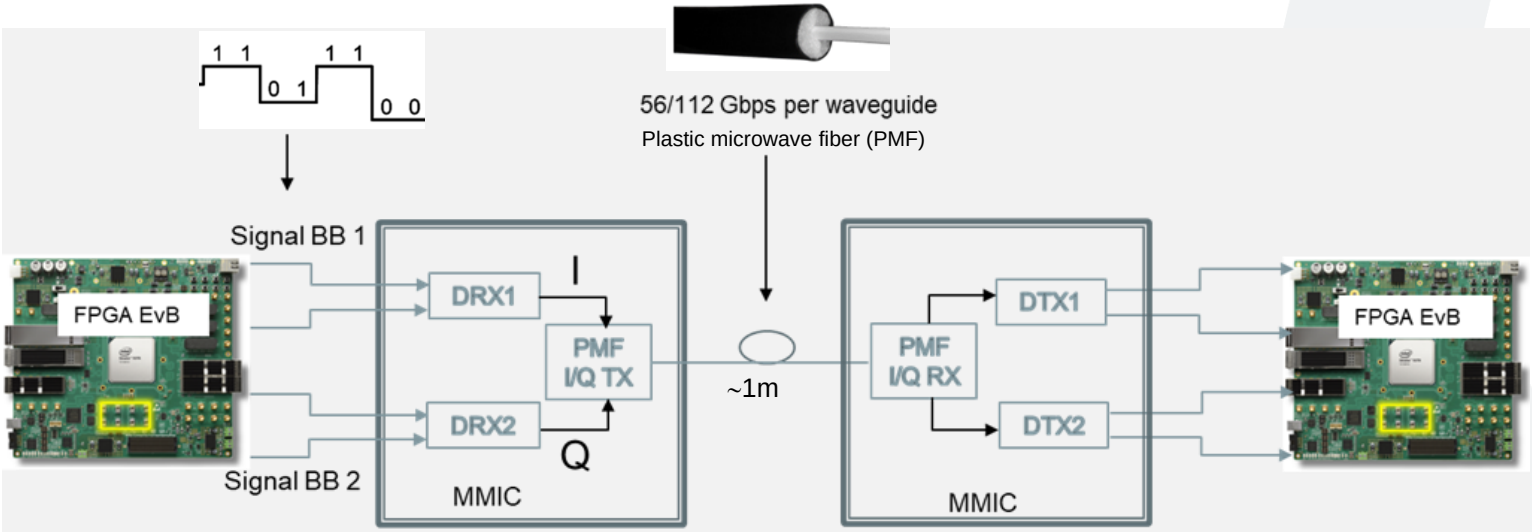


DEMONSTRATOR 2: THz over plastic

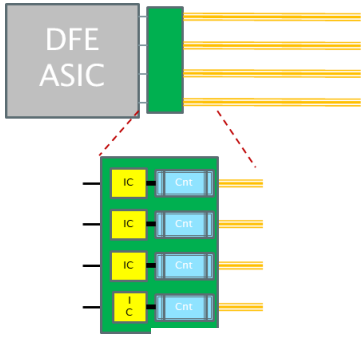


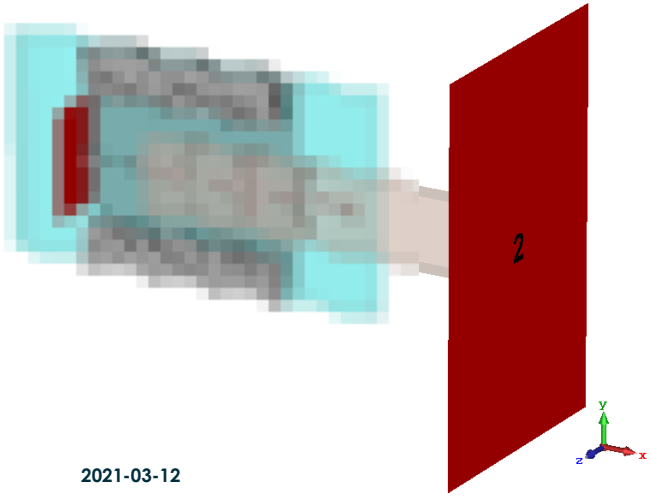
Proposed Demo-2 setup

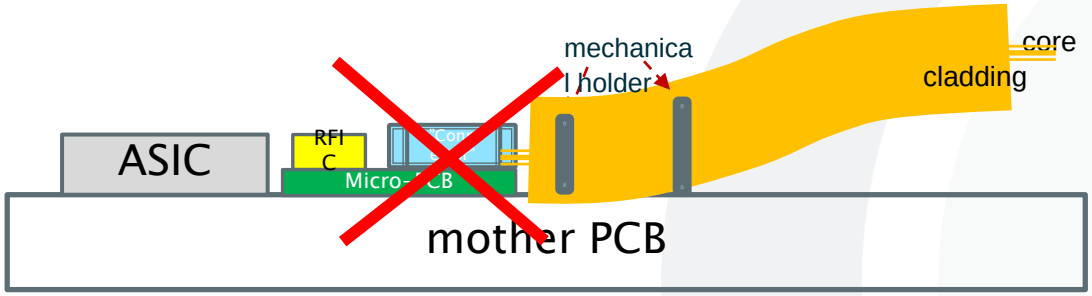
- 56/112 Gbps over 0.5m (exploring >10 m as well)
- RF carrier in PMF: 200 - 250 GHz
- Waveform: PAM4 *(with NRZ and 16QAM option)*

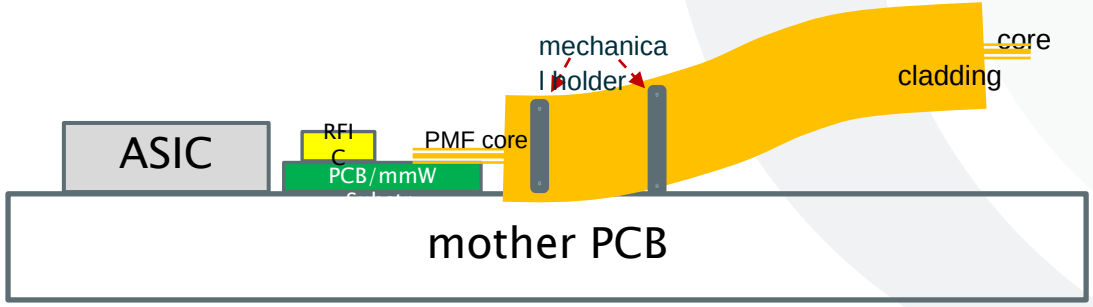


Integration perspective: Avoiding carrier/interposer

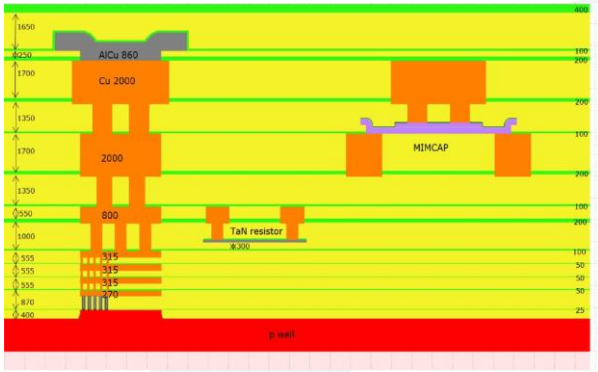






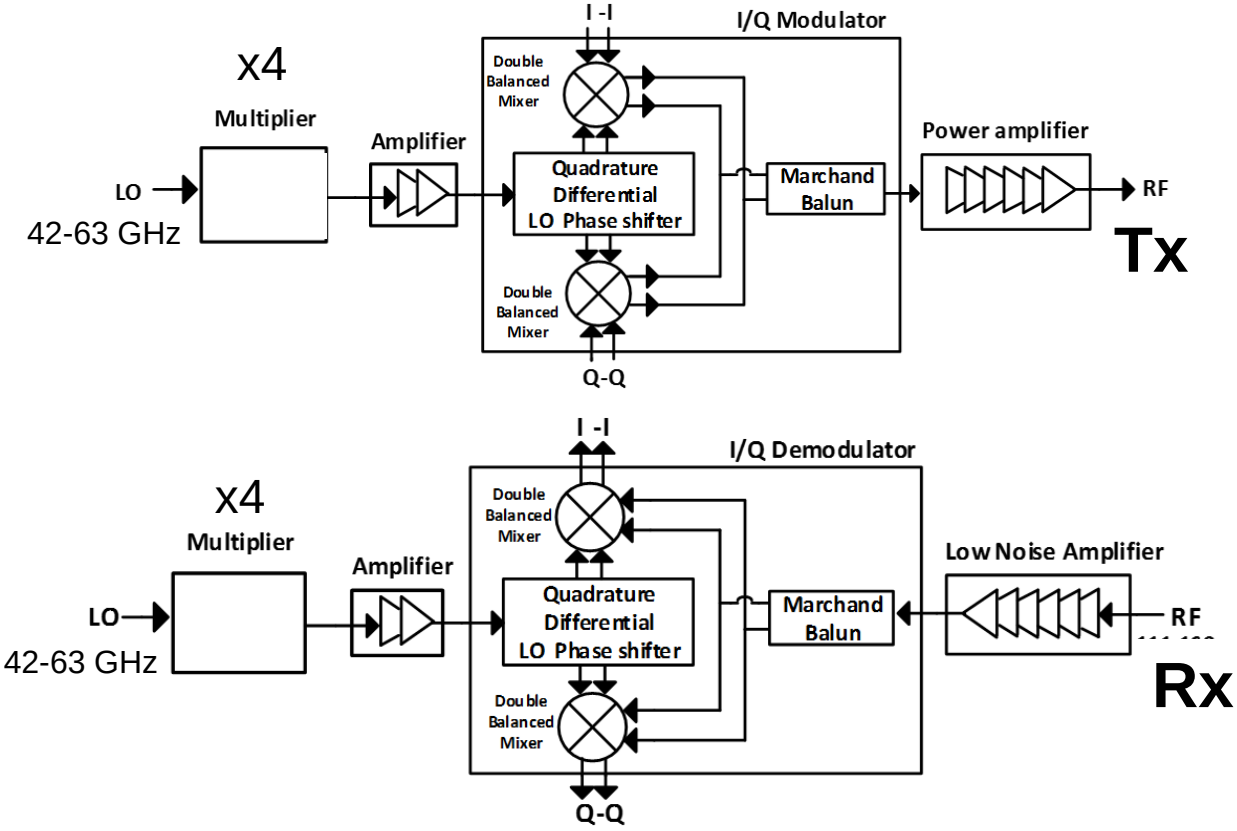


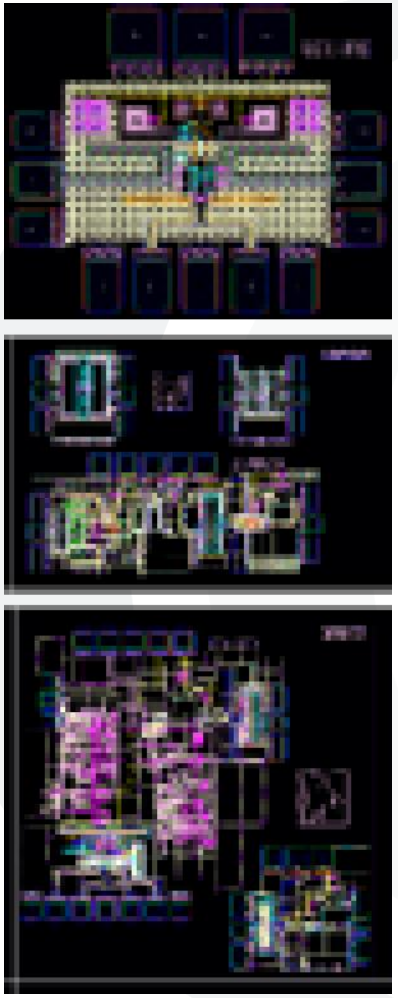
Industrial-grade SiGe multi-function MMICs used for both demonstrators



- **Infineon's B12HFC process:**
  90-nm SiGe BiCMOS 300/600-GHz f_T/f_{max}, 7 Cu-BEOL
- **generic circuits including amplifiers, I-Q/PAM modulators and demodulators, voltage controlled oscillators, RF-DACs, and frequency multipliers**
- **=> Multifunctional, highly integrated MMICs**

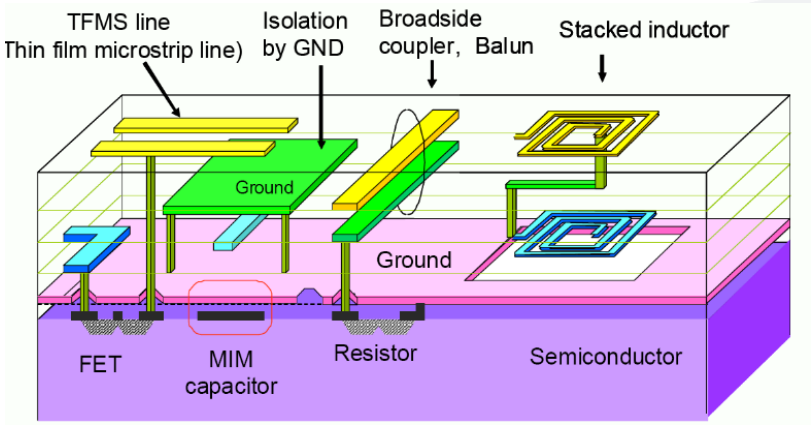
MMIC architecture, 170-250 (280) GHz

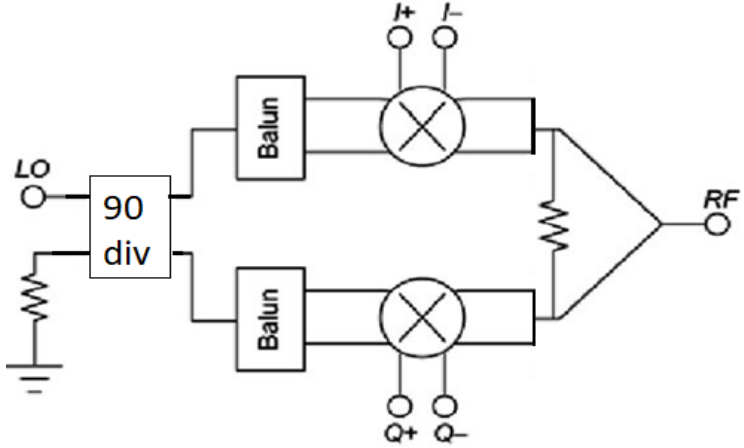




GFET MMIC development

- GFET FoM (sim): Switching time
  R_gC_g = 0.5 ps => 320 GHz
- Expected conversion loss:
  Min (CL) = 13 dB
- Expected IIP3:
  Max(IIP3) = 26 dB
- Fabrication under way





Conclusions

- Large number of emerging THz technologies
  - Micromachined THz system integration; MEMS-waveguide switches
  - Industrial-grade 600-GHz SiGe
  - Graphene-FET
  - THz-over-plastic
  - Beam-shape switched radar sensors
- 2 demonstrators:
  - in-cabin car radar sensor
  - THz-over plastic communication link

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Grant Agreement No. 824962

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