PMF-based data link for 5G evolution and 6G radio systems

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(PMF Workshop, March 7-8, Leuven, Belgium)

Acknowlegement: *the Car2Tera consortium*

- **Anteral** (Spain) for PMF-MMIC transition simulation:

  Victor Torres

- **Chalmers** (Sweden) for MMIC & PCB design, eWLB layout, and test assistance:

  Haojie Chang, Sining An, Yu Yan, Simon He, Frida Strömbeck, and Herbert Zirath

- **Ericsson AB** (Sweden) for system simulation and requirement study, PCB assembly, test fixture design and manufacturing, T&M:

  Per Ingelhag, Björn Gävert, Sandro Vecchiattini, Jörgen Lindwall, Torbjörn Dahl, Richard Lindman, and Yinggang Li

- **HUBER+SUHNER AG** (Switzerland) for providing D-band PMF:

  Hannes Grubinger, Ulf Huegel

- **Infineon Technologies AG** (Austria) for MMIC & eWLB chip manufacturing, and PMF-MMIC transition design:

  Yannis Papananos, Vasileios Liakonis, Krainer Siegfried, and Franz Dielacher

- **The Car2Tera** project has received funding from the EU Horizon 2020 research and innovation programme under grant agreement No 824962.

Advanced antenna system (AAS) for 5G evo and beyond

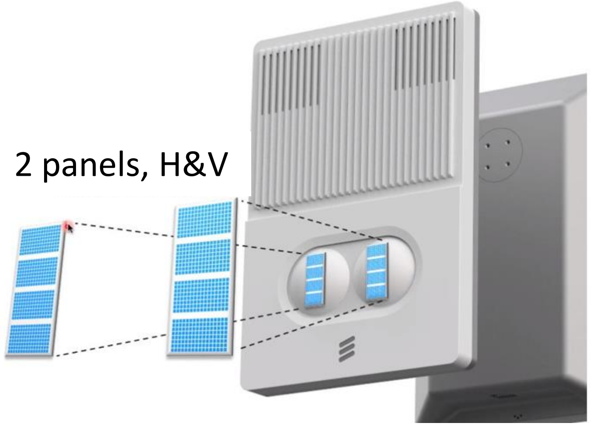
Higher data-rate per radio: >100 Gbps

Wider bandwidth: >5 GHz

mMIMO, D-MIMO: /cell-free, ….

Higher frequency: mmW, sub-THz, …

AAS



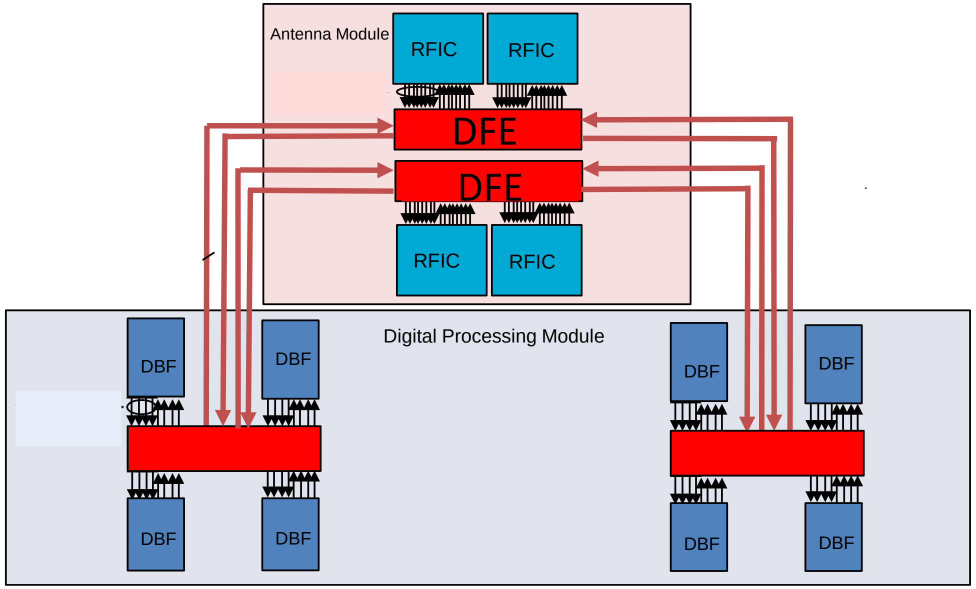
Typical AAS features:

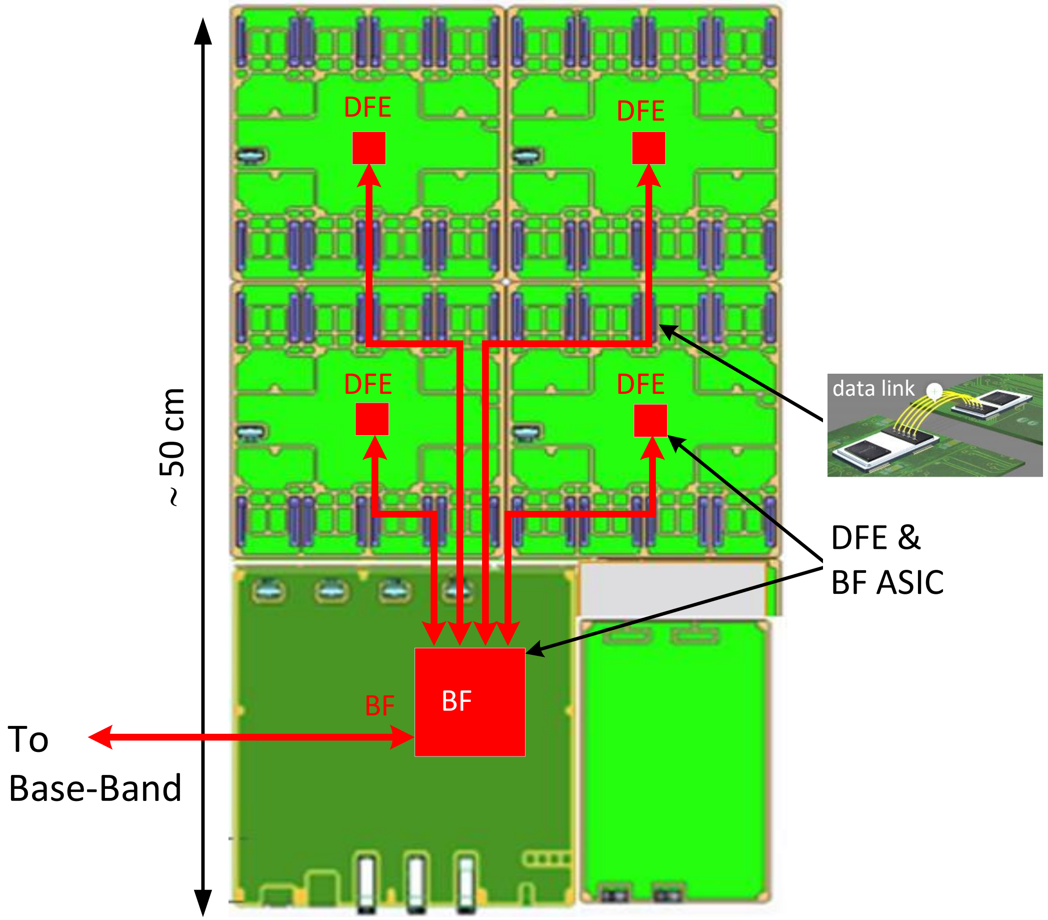
- ~ 10^3 antenna elements
- > 60 analog RFICs
- > 15 digital front-end (DFE) ICs
- Many beamforming (DBF) ICs
- Multiple data interconnect links between a DFE ASIC and a DBF ASIC

Basic data link requirement in a radio system

- Intra-box ASIC-to-ASIC, ~ 30 cm
- >100 Gbps per data interconnect
- Thermally robust
- Many parallel links → *high link density*

An example of basic architecture:





Options for high-speed data links

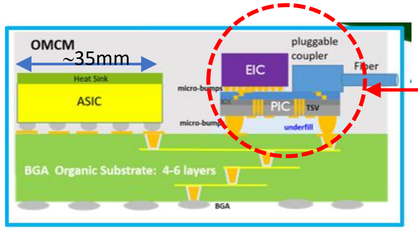
- **PCB** embedded track:
  - \+ Long established, cost efficient (built-in)
  - – Large loss and limited bandwidth ➔ low (distance x rate) product

- **Copper** wire (micro-twinax):
  - \+ Flexible, high wire density, plug-and-play, assembly-friendly
  - – Relatively large loss, limited distance ➔ relative low (distance x rate)

Amphenol, Samtec, TE, Rosenberg, Yamaichi, ...

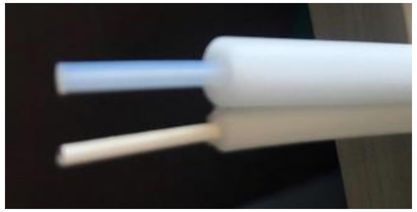
e.g., μ-Linkover 30cm AWG30, 112G PAM measured. 224 Gbps?

- **Optical** fiber
  - \+ “Unlimited” bandwidth, low loss/extremely long range, highest (distance x rate), flexible
  - – Require optical source and E/O converter ➔ cost and power dissipation
  - – Sensitive to temperature, dust, misalignment, ...



E/O device

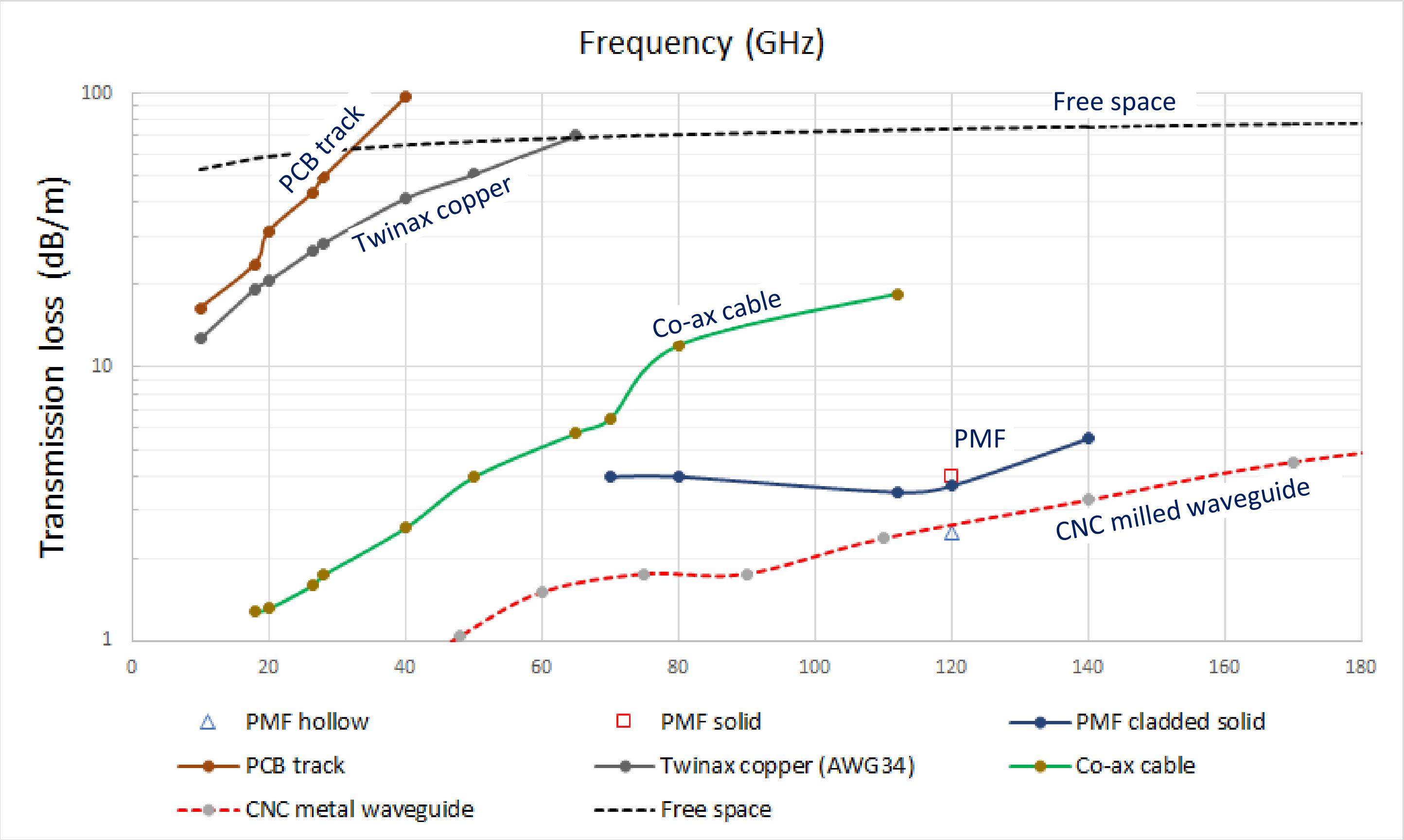
- **PMF**:
  - \+ Low loss, cost efficient, wide bandwidth (no cutoff),
  - ± Semi-flexible (bending loss?)
  - – Relatively bulky, not as mature as the solutions metioned above
  - – Require mmW/sub-THz transceivers



PMF, *a potential game changer for high-speed data interconnect?*

Transmission loss comparison of the commonly used short-to-medium range interconnects

- Free space and CNC-based waveguide for reference.

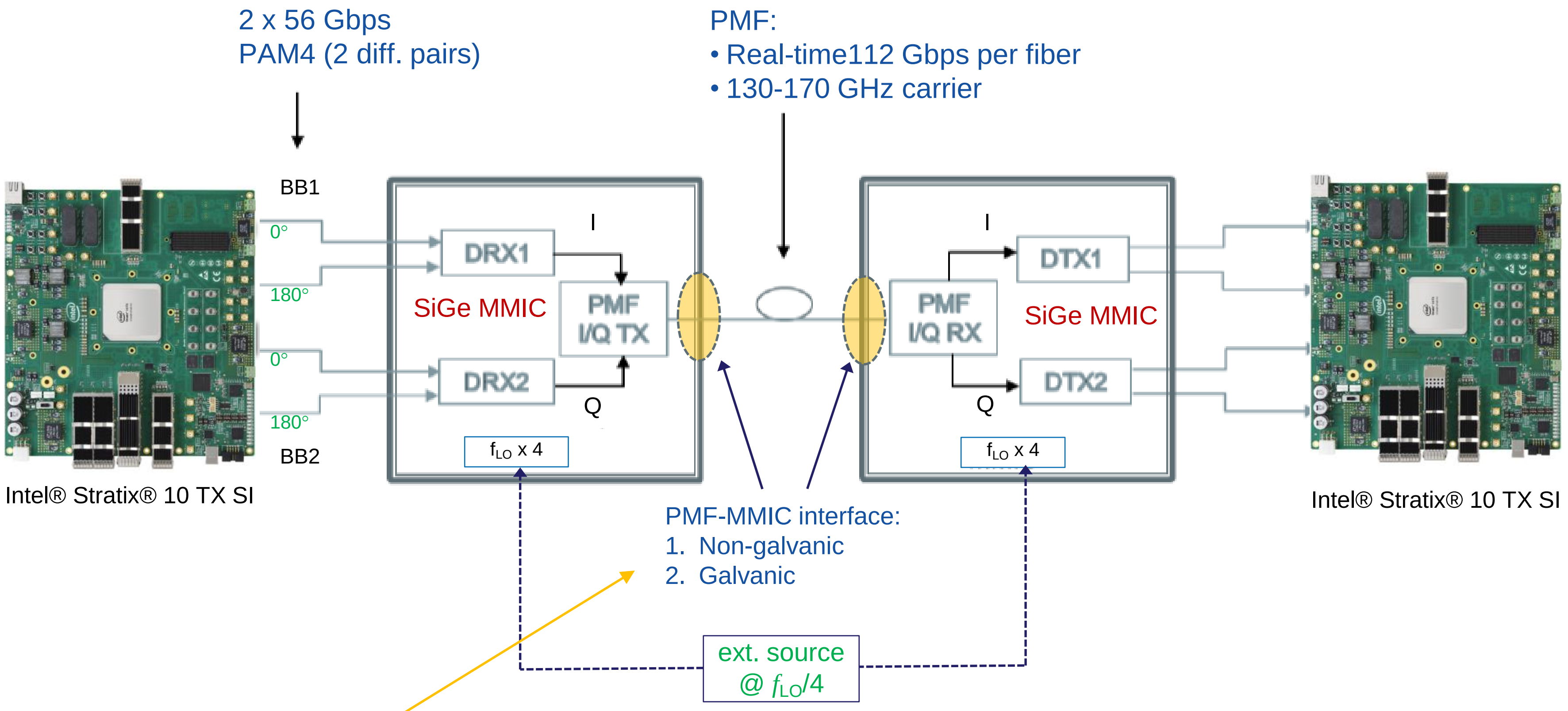


[Source: Ericsson/ER/Yinggang Li, 2021]

Proof-of-concept demo system:

Car2Tera, EU Horizon 2020 programme:

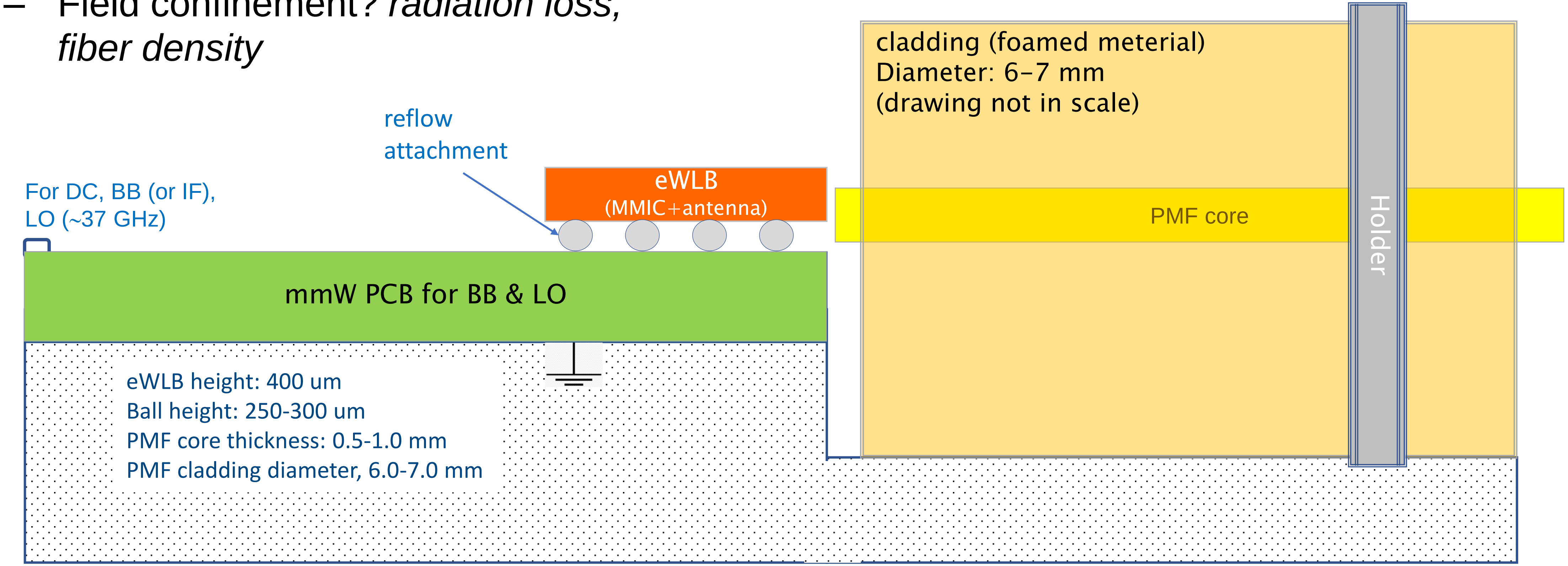
- D/H-band Tx/Rx chipsets in SiGe BiCMOS
- 240 GHz car radar based on silicon micromachining
- 150 GHz short-range data link based on PMF
- www.car2tera.eu



Rest of my presentation will focus on PMF-MMIC transition

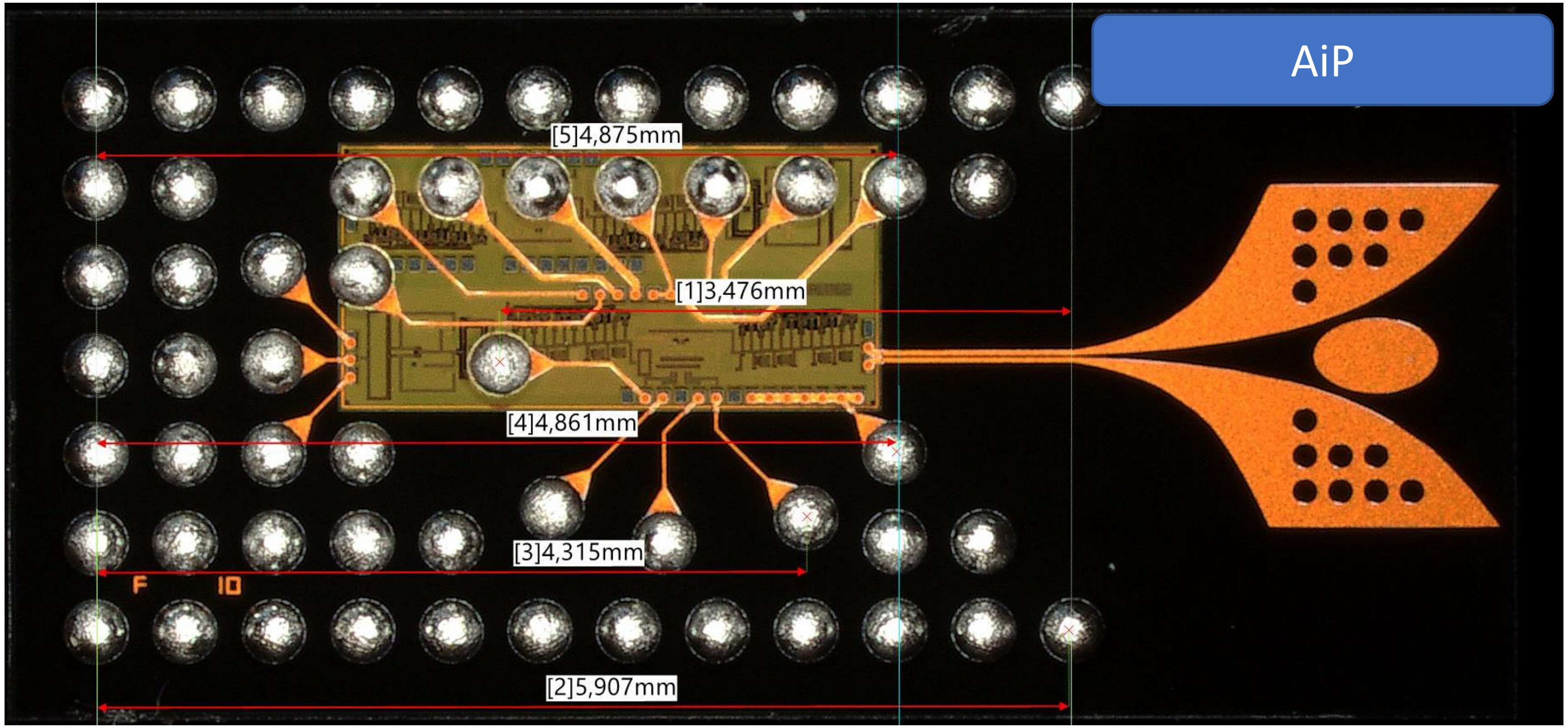
PMF-MMIC transition: *non-galvanic coupling*

- + AiP, air interface
- + No need for D-band substrate
- – Field confinement? *radiation loss, fiber density*



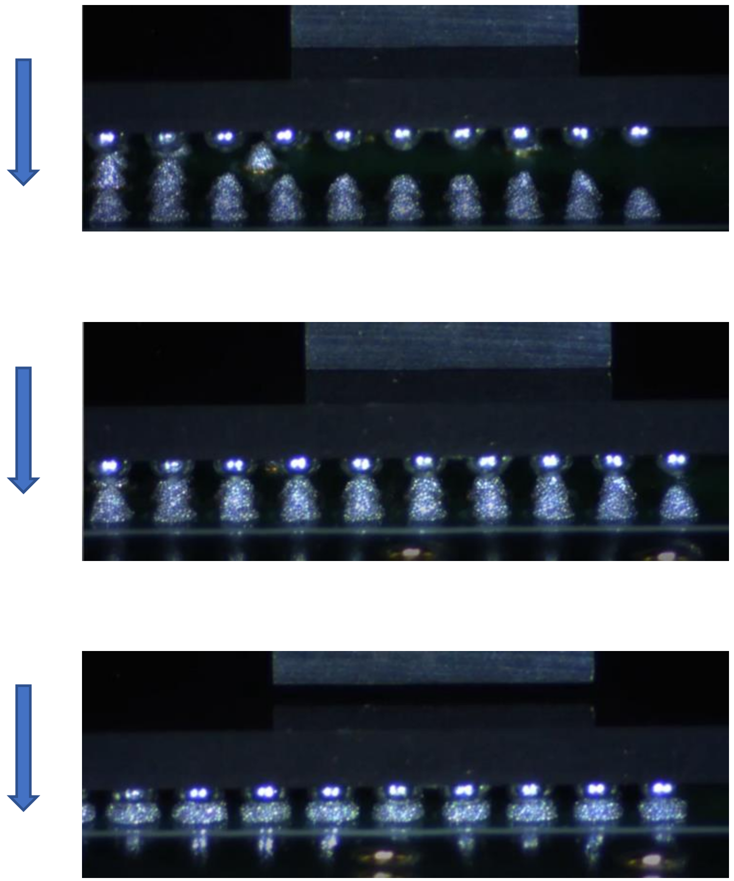
Non-galvanic coupling: *eWLB and AiP*

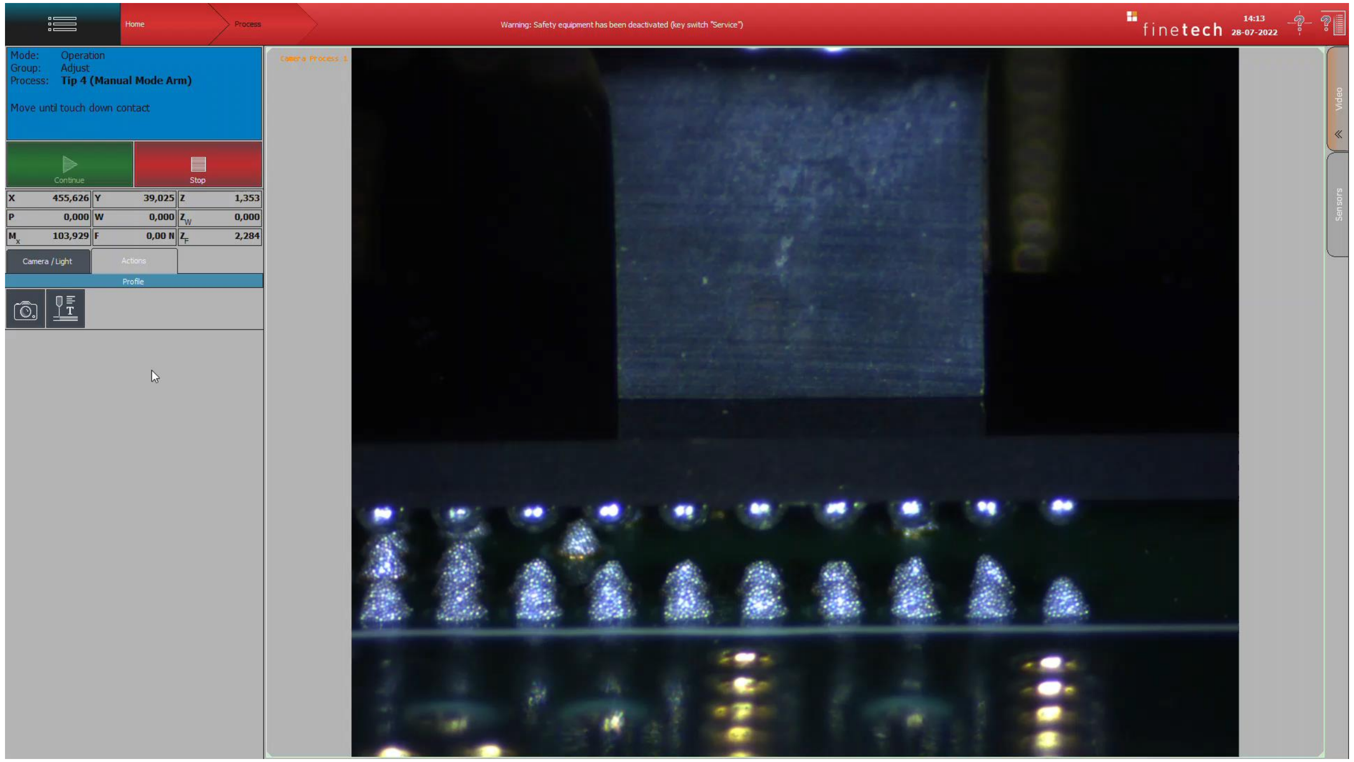
- 150 GHz MMIC in eWLB package
- Vivaldi antenna in the RDL providing lateral coupling to PMF



Non-galvanic coupling: *eWLB assembly*

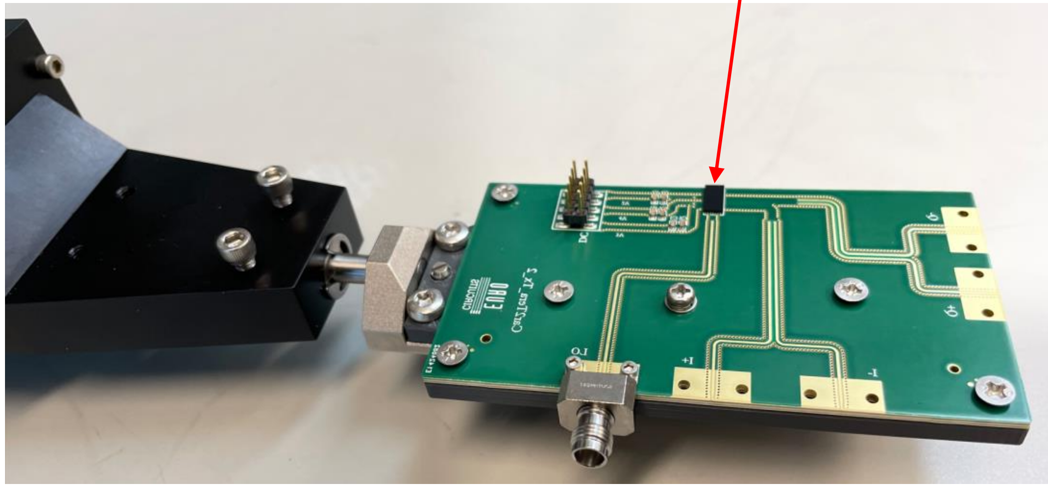
- Flip-chip with fine pitch assebmled in standard soldering process at Ericsson





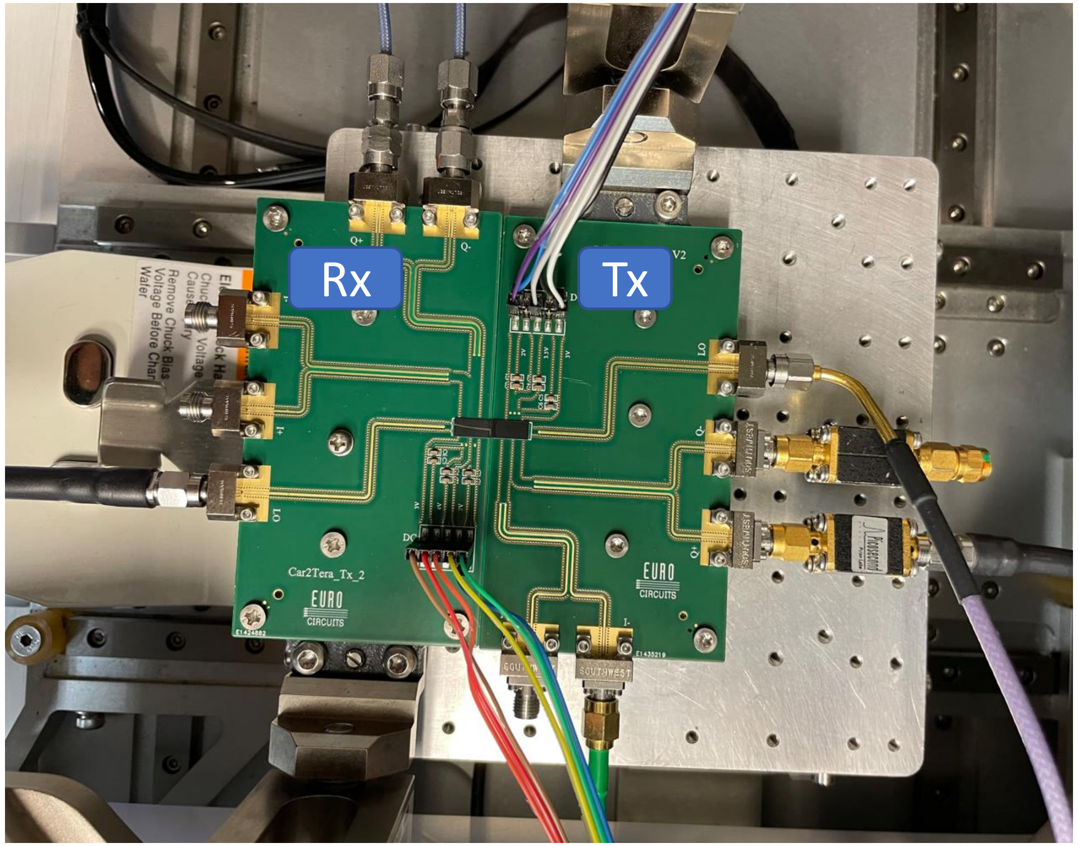
Non-galvanic coupling: *T&M*

eWLB chip

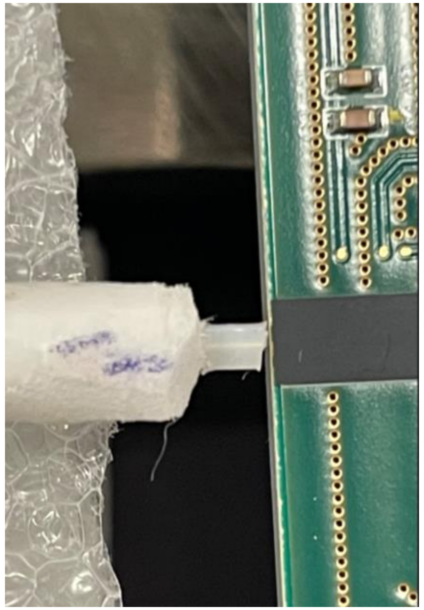


3D printed PCB fixture, designed to be mountable on a comercial probe-station munipulator for fine alignement and the air-gap control on μm scale

Tx and Rx eWLB chips connected back-to-back



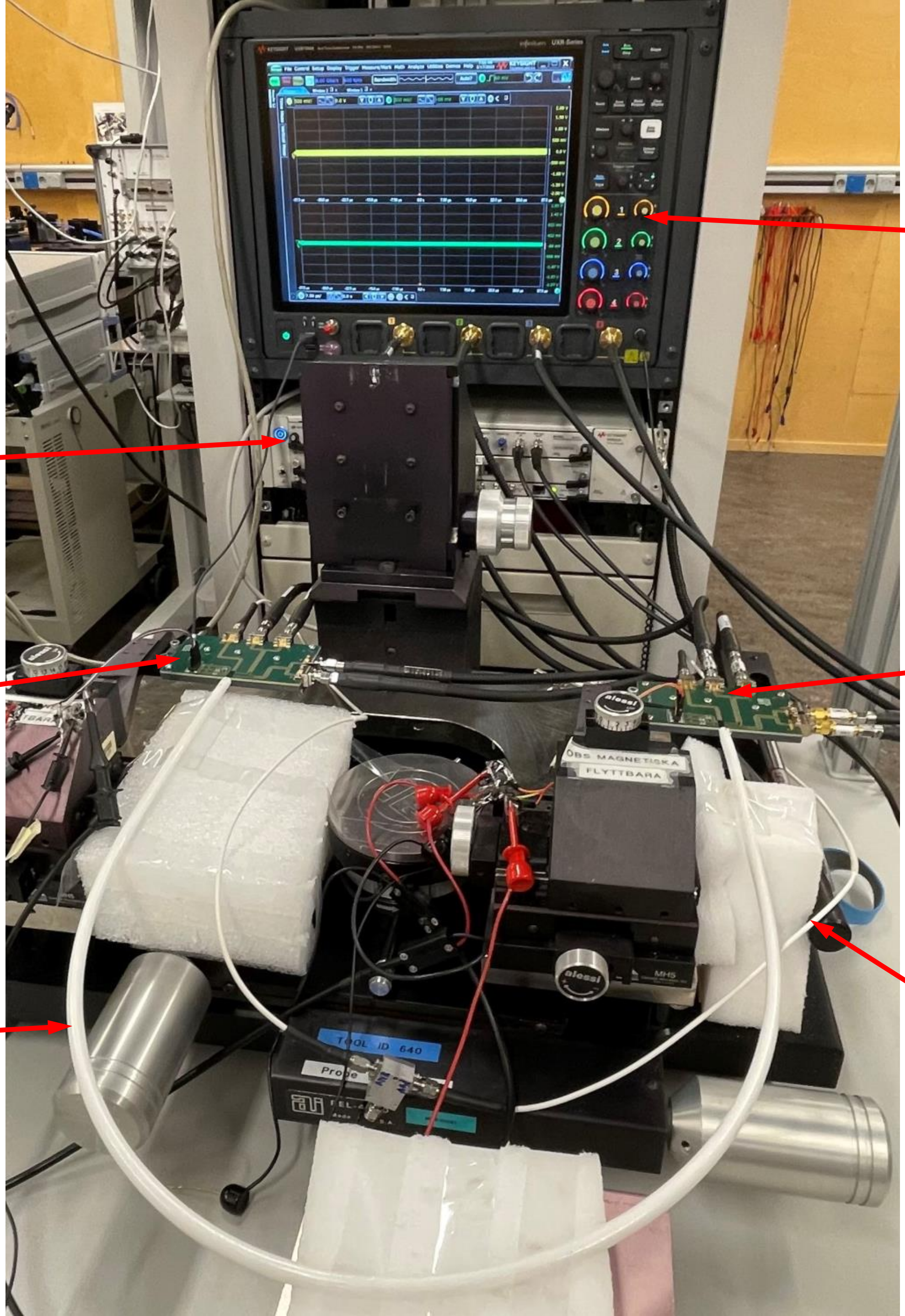
Test setup



AWG

Tx

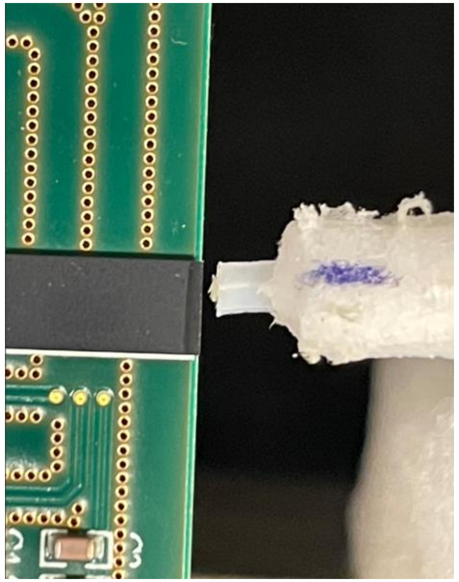
93cm PMF



wideband
oscilloscope

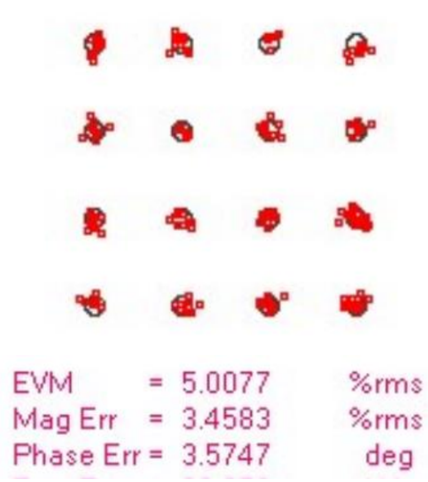
Rx

LO @ *fc/4*

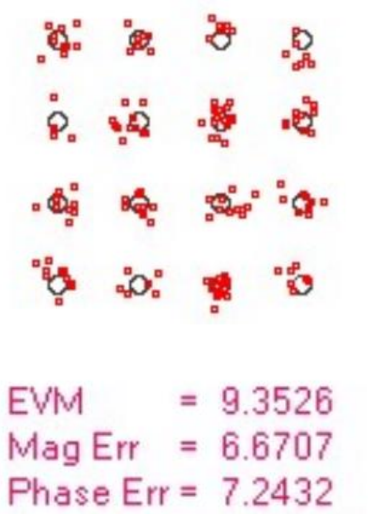


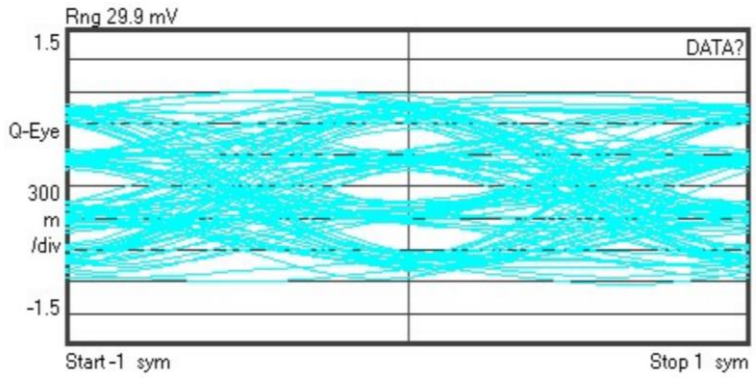
Non-galvanic coupling: *T&M*

1 Gbaud, 16QAM, 5GHz IF



5 Gbaud, 16QAM, 5GHz IF





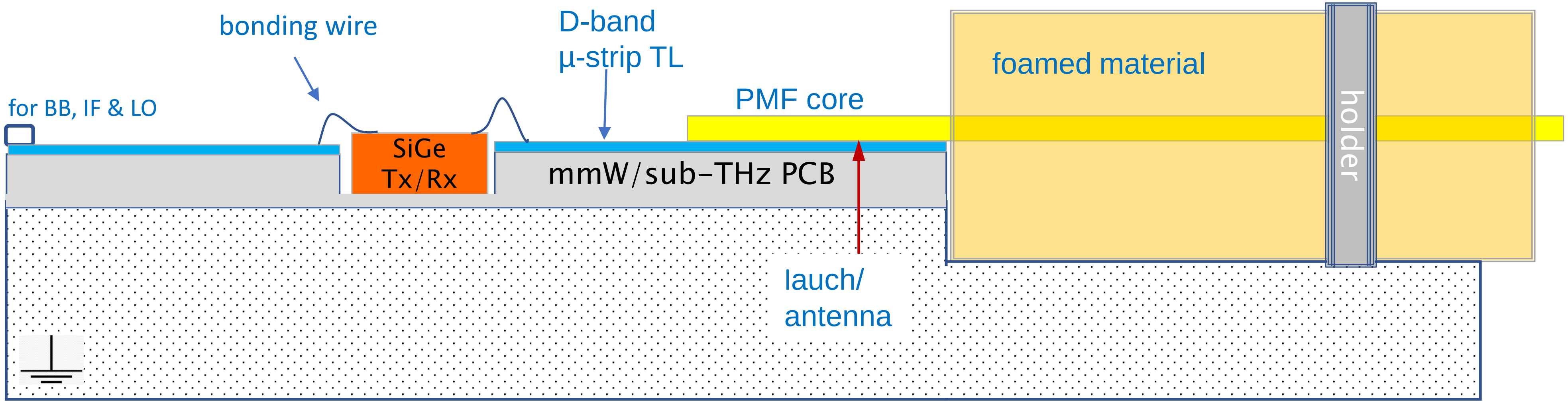
➔ 20 Gbps, but:

- Initial test only, not optimized
- LO power not high enough
- No equalizer applied
- Poor PMF core cutting
- Not the best MMICs (CHALM62)

- **Next step: real-time T&M, BER**

Intel Stratix 10 SI evaluation board tested and ready to use

PMF-MMIC transition: *galvanic coupling*



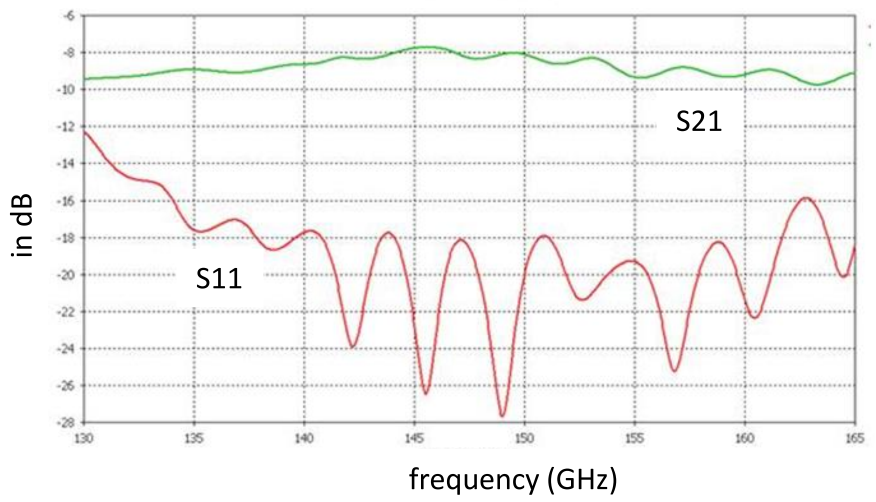
- Wire bonding at D-band
- mmW/sub-THz substrate
- $\varepsilon_{subst} > \varepsilon_{PMF}$

Substrate comparison

isola Astra MT77:

- ε_r = 3.0, Df = 0.0017 @ 10 GHz, and 0.008 @140 GHz
- Good bonding ability
- 4dB IL per transition at 150 GHz

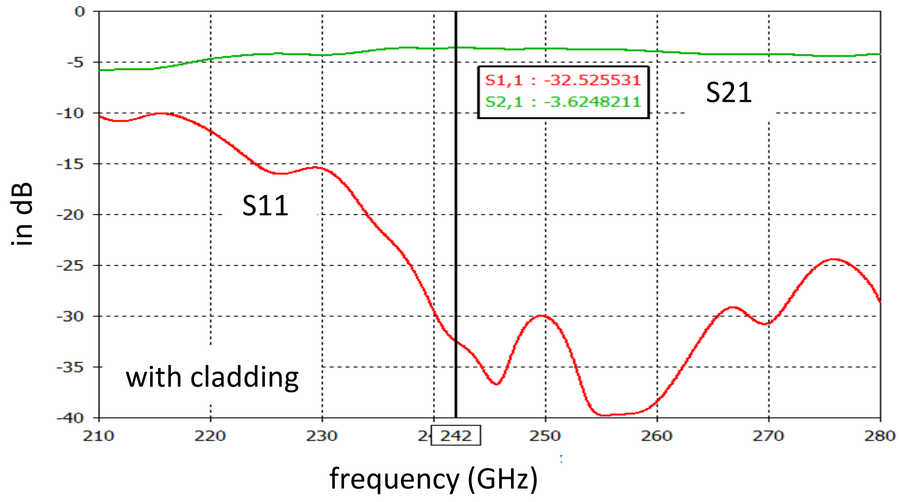
Simulated for two transitions (connected back-to-back)



Rogers RT5880:

- ε_r = 2.2, Df = 0.0009 @ 10 GHz
- Not suitable for wire bonding
- 3.7 dB per transition at 250 GHz (<3 dB at 150 GHz)

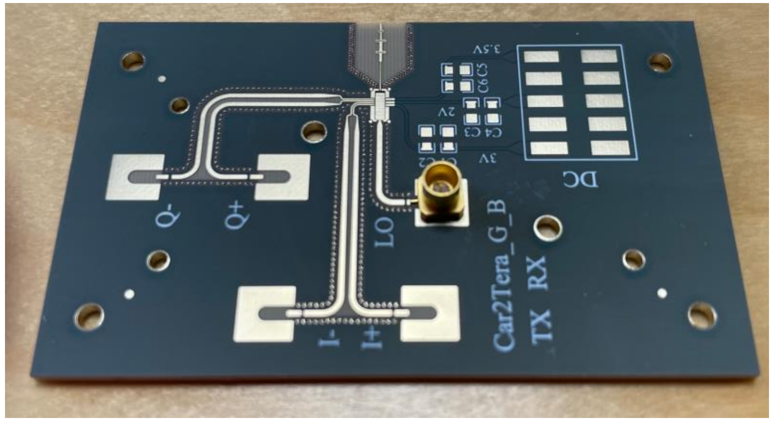
Simulated for one transition

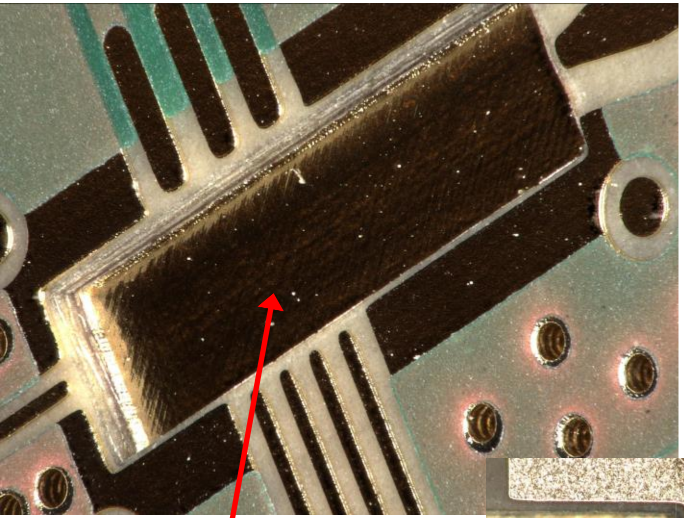


- Astra MT77 is chosen for robust bonding, sacrifying ~ 1 dB
- The larger IL is mainly due to the higher ε_r (not the higher Df)

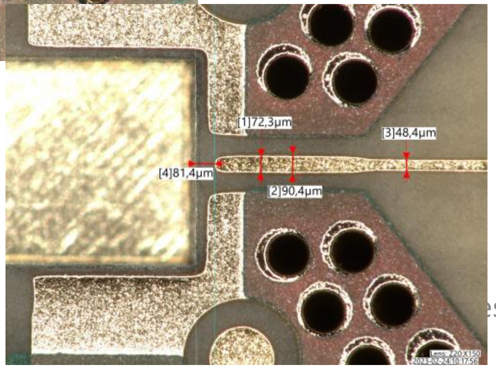
Galvanic coupling: *status*

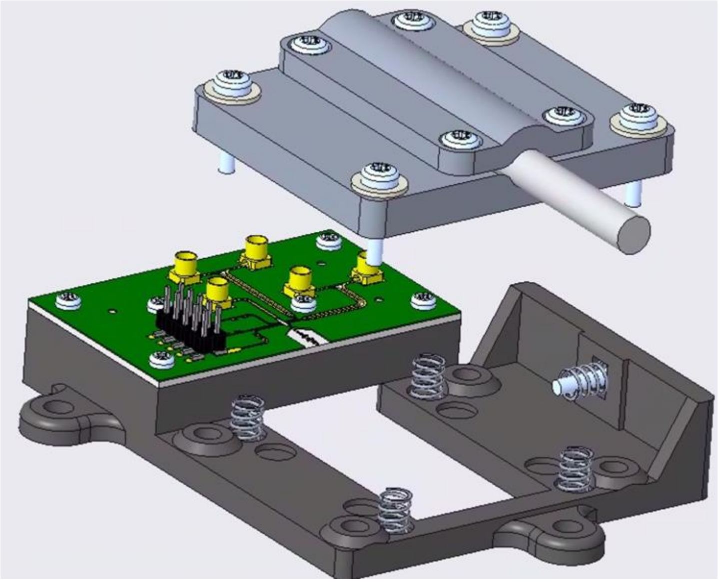
- PCB manufactured, MMIC cavity looks good
- Wire bonding and PCB assembly this week at Ericsson Borås
- Mechanical fixture ready-printed
- T&M to be started in 1 - 2 weeks

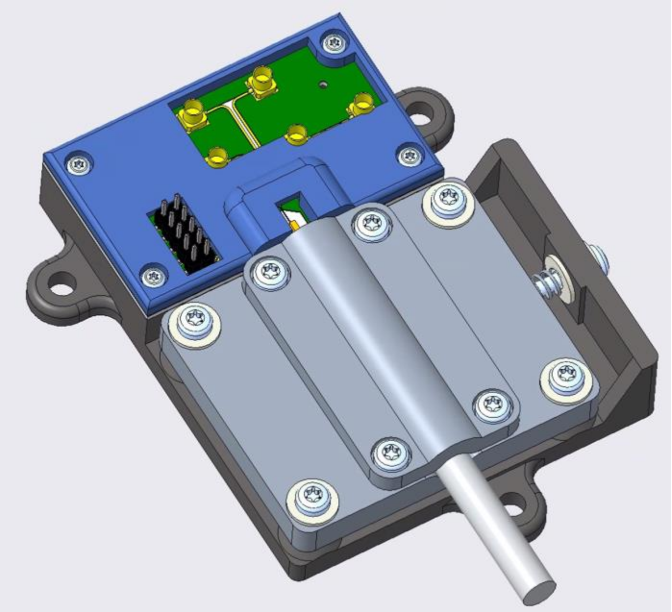




PCB-embeded chip cavity



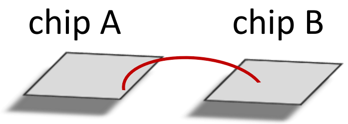




Mechanical fixture with position adjustment possibility

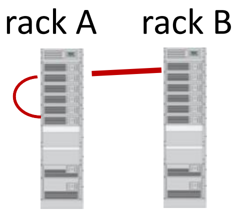
Additional use cases

Intra-box / on-board



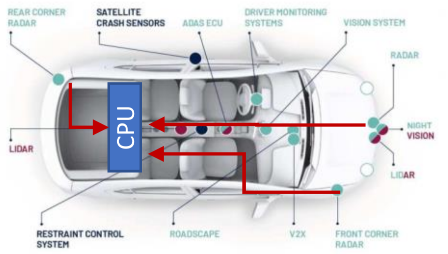
< 0.5 m

Data center



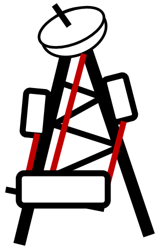
~ 2 - 10 m

Automotive sensor fusion



< 3 m

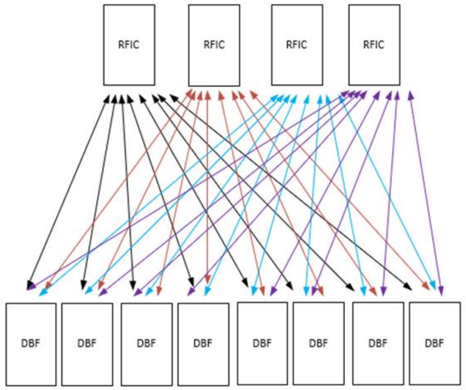
Inter-box in base-station



< 10 m

Some take-aways, *from commercialization perspective*

- PMF: a promising alternative to copper wires and optical fibers as short-to-medium range physical medium
- High fiber density is key (# of diff pairs/cm): *fine pitch with high isolation, mini-SFP, plug-and play*
- Duplexing solution: using two fibers is not an attractive solution (H/V, FDD, etc.)
- Energy efficient IC-PMF transition, >4 dB at 150 GHz is too “luxury”.
  - *Power generated at sub-THz is very specious*
- In short-term future (3-5 years), Cu wires (twin-ax) are more competitive as a short-range (<50 cm) solution for data interconnect.
  - *PMF more competitive for >200 Gbps and/or > 1m*



plug and play