Sub-THz polymer microwave fibers for data links in evolved 5G and 6G base stations

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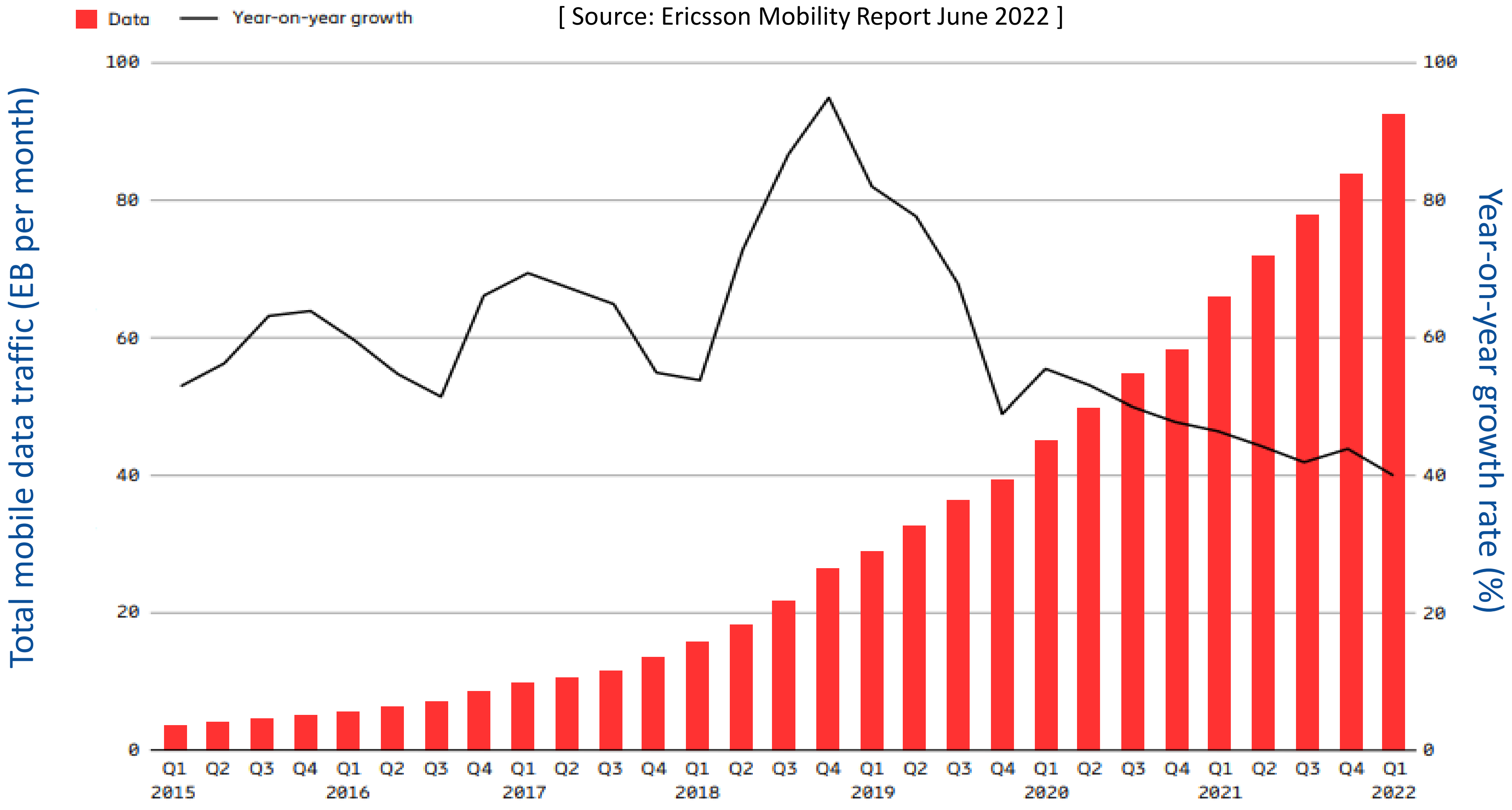
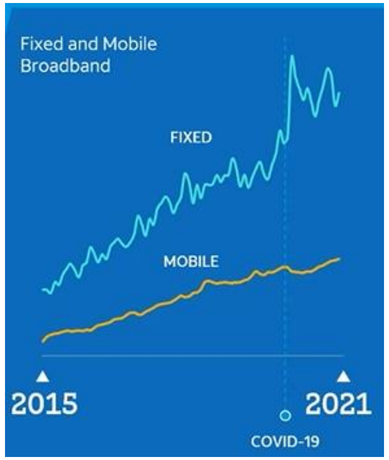
Outline

- Background
  - Use case, advanced antenna system (AAS)
  - Basic requirement of data links
- Polymer microwave fiber (PMF) as short-range, high data-rate link medium
  - In-band group delay and loss variation
  - Proof-of-concept demo system
  - Interface of transceiver MMICs and PMF
    - Car2Tera project
- Some takeaways

Global mobile data traffic measured up to Q1 2022
(EB per month)

[Source: Ericsson Mobility Report June 2022]



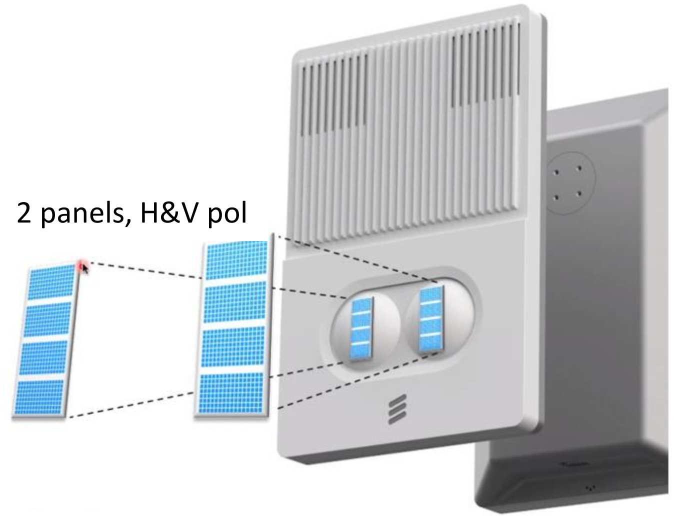


The lower growth rate since Q1 2020 can be partially attributed to COVID-19 when people stay home more than normal and use fixed broadband services.

AAS for 5G evolution and beyond

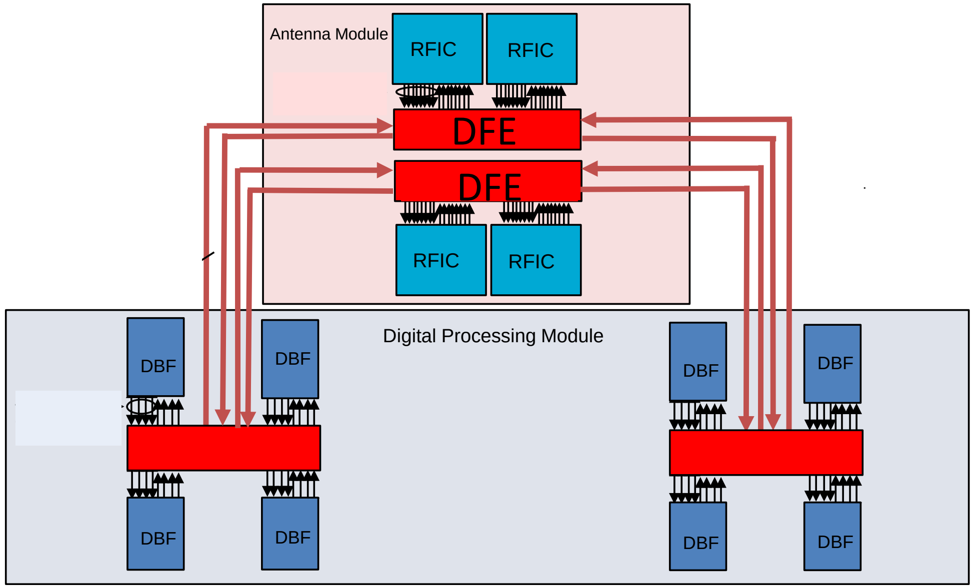
- Higher data-rate per radio: >100 Gbps
- Wider bandwidth: >5 GHz
- mMIMO, D-MIMO /cell-free, ….
- Higher frequency: mmW, sub-THz

Advanced Antenna System (AAS)



Typical AAS features

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

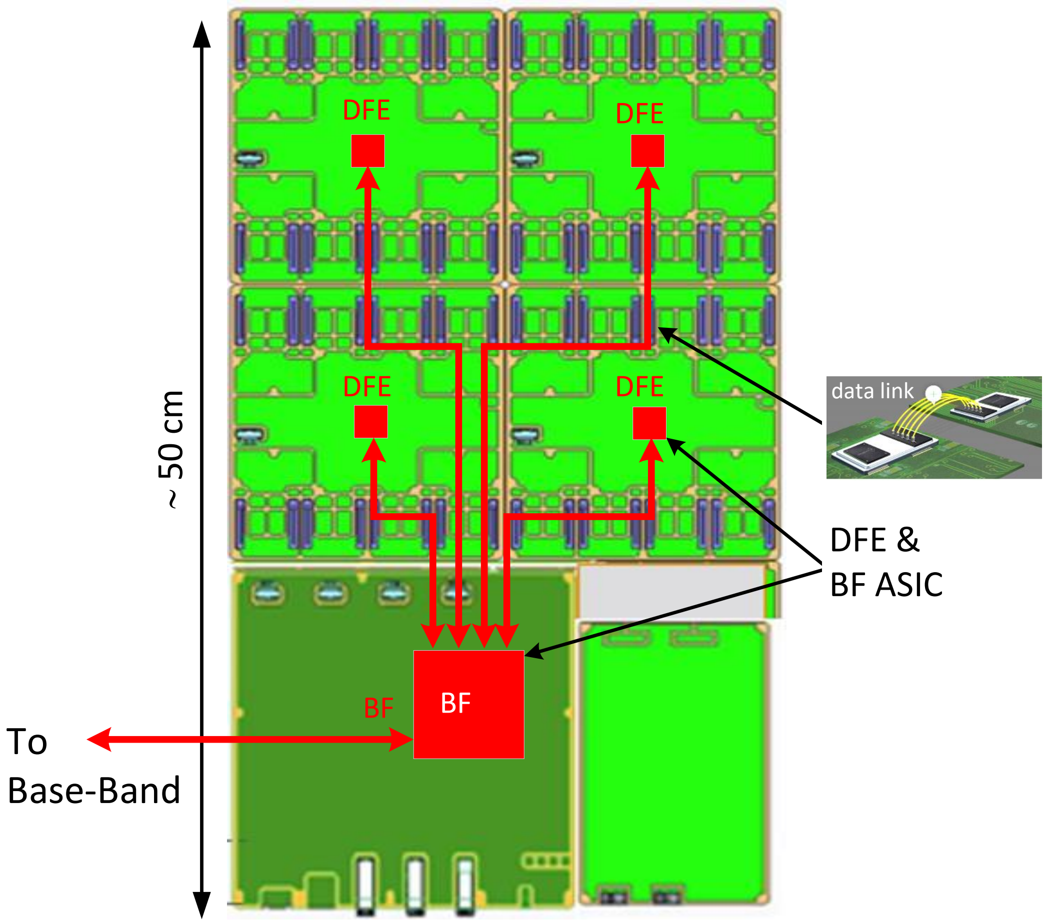


Basic data link requirement

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

→ *Challenging with traditional PCB-based solutions*

One example of basic architecture:



Options for high data-rate links

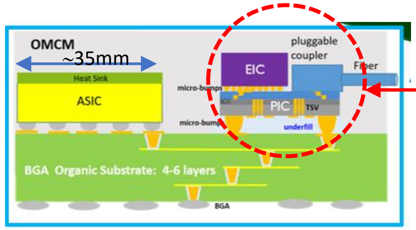
- PCB embedded track:
  - \+ Long established, cost efficient, built-in
  - – Large loss and limited bandwidth ➔ low (distance x rate) product

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

Suppliers: Samtec, TE, Rosenberg, Yamaichi, ...

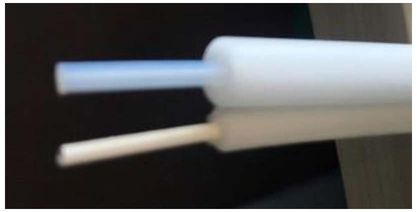
State of the art: 112 Gbps over 6” demonstrated in Sept. 2019

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



E/O device

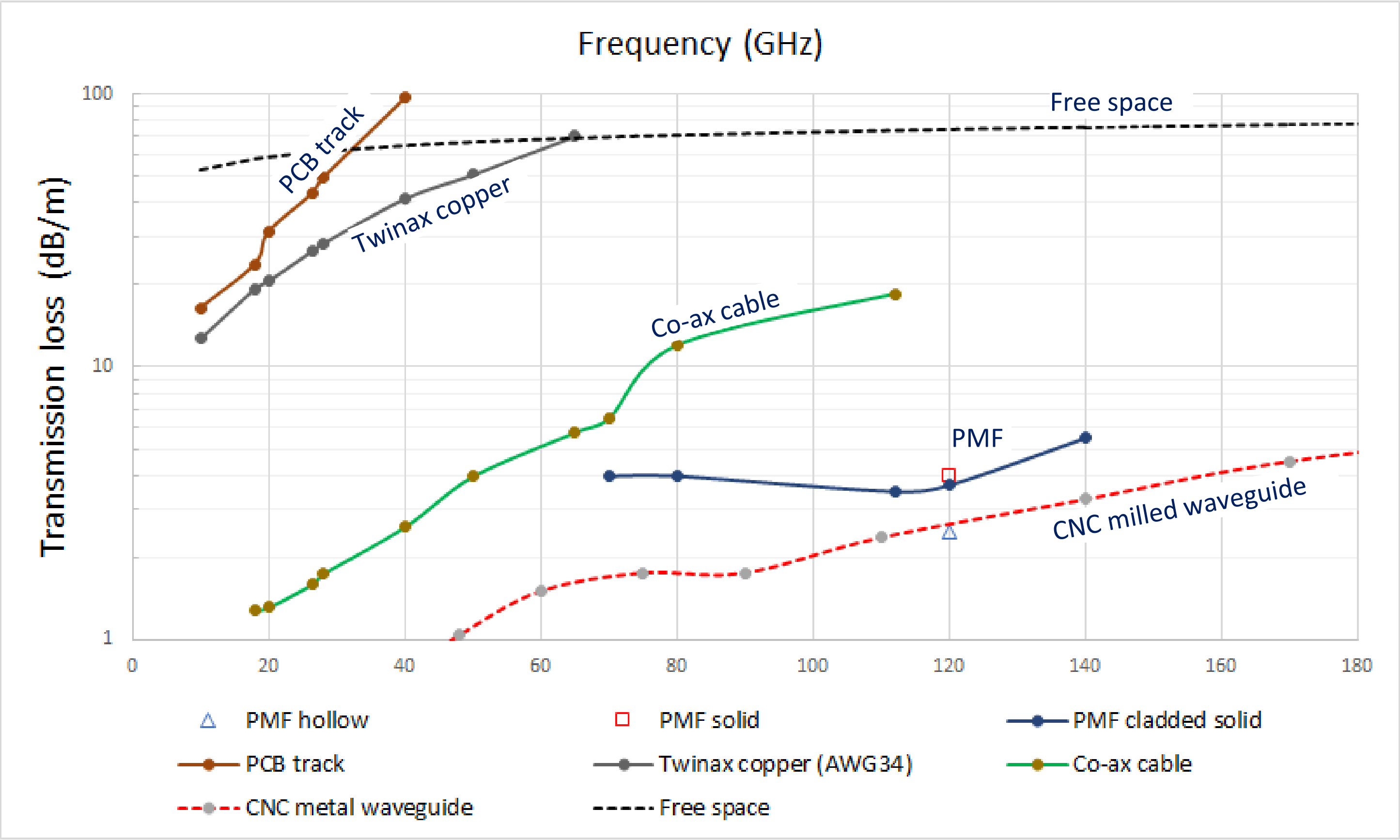
- Polymer/plastic microwave fiber (PMF):
  - \+ Low loss, cost efficient, wide bandwidth (no cutoff),
  - ± Semi-flexible (bending loss?)
  - – Relative bulky today, not as mature as the solutions above
  - – Requires millimeter-wave transceivers



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

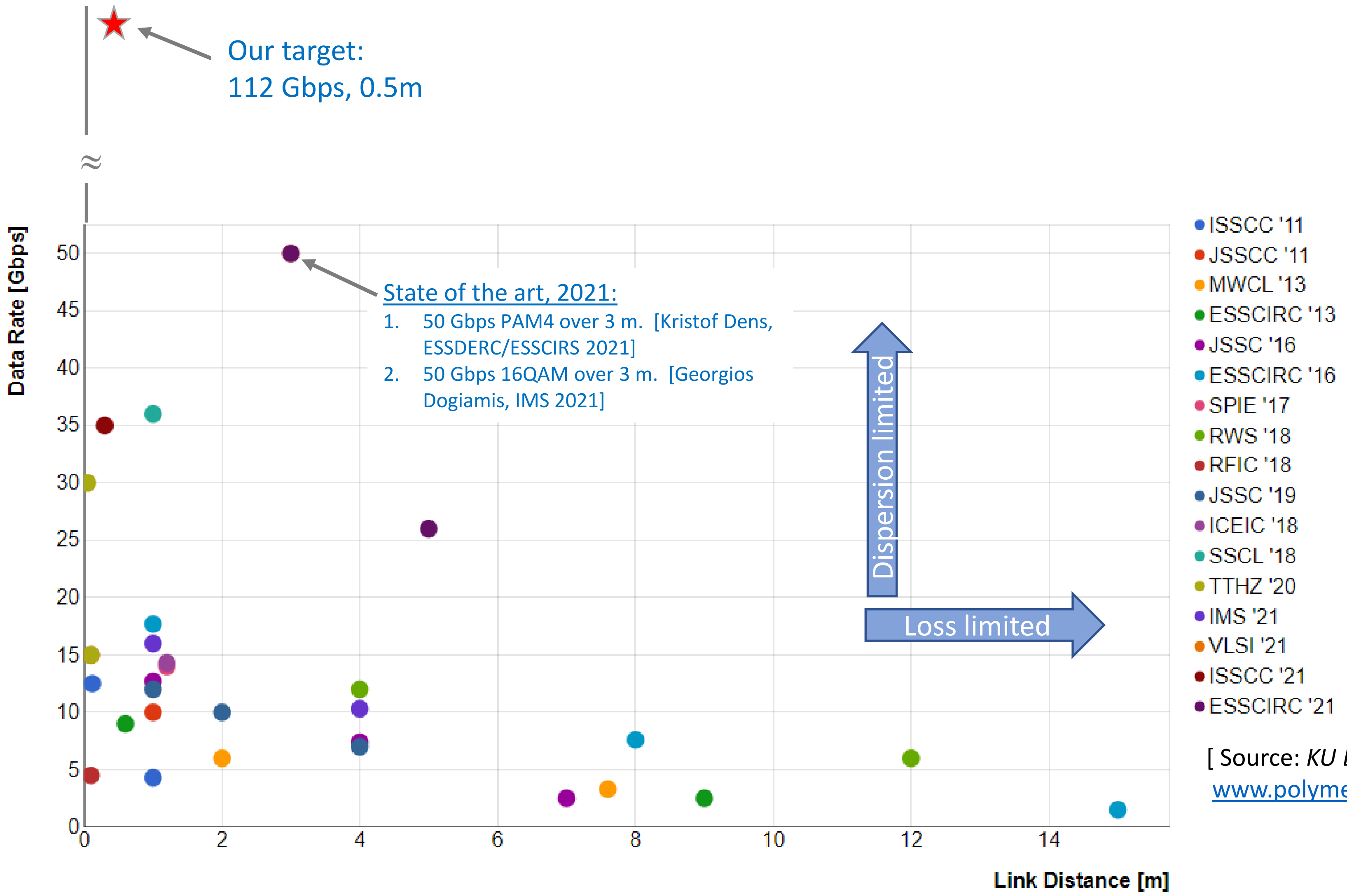
Transmission loss comparison of the commonly used short-to-medium range interconnects

- Free space and CNC milled metal waveguide included for reference (dashed lines)



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

Demonstrated PMF data links



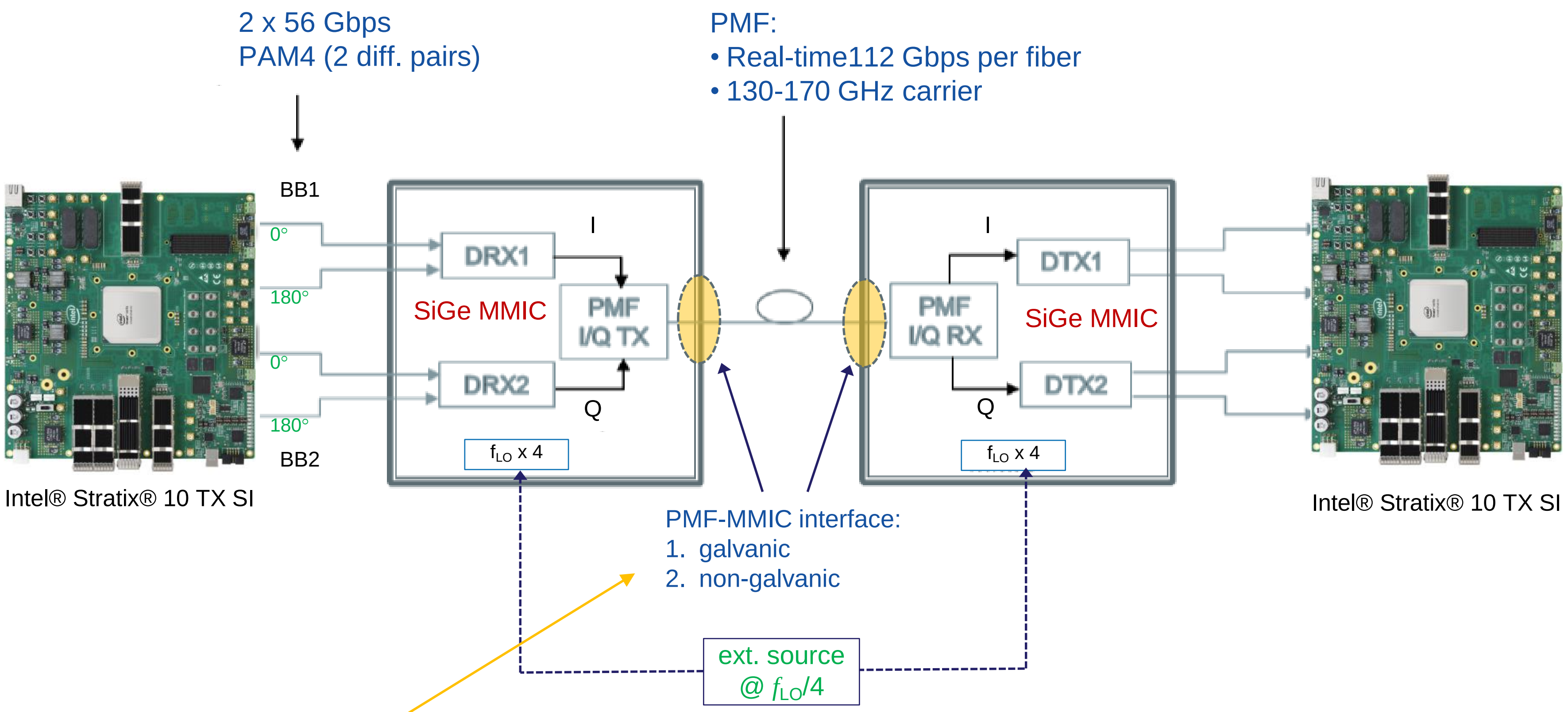
[Source: *KU Leuven, ESAT-MICAS,* www.polymermicrowavefiber.com]

Proof-of-concept demo system:

Car2Tera, Horizon 2020 programme:

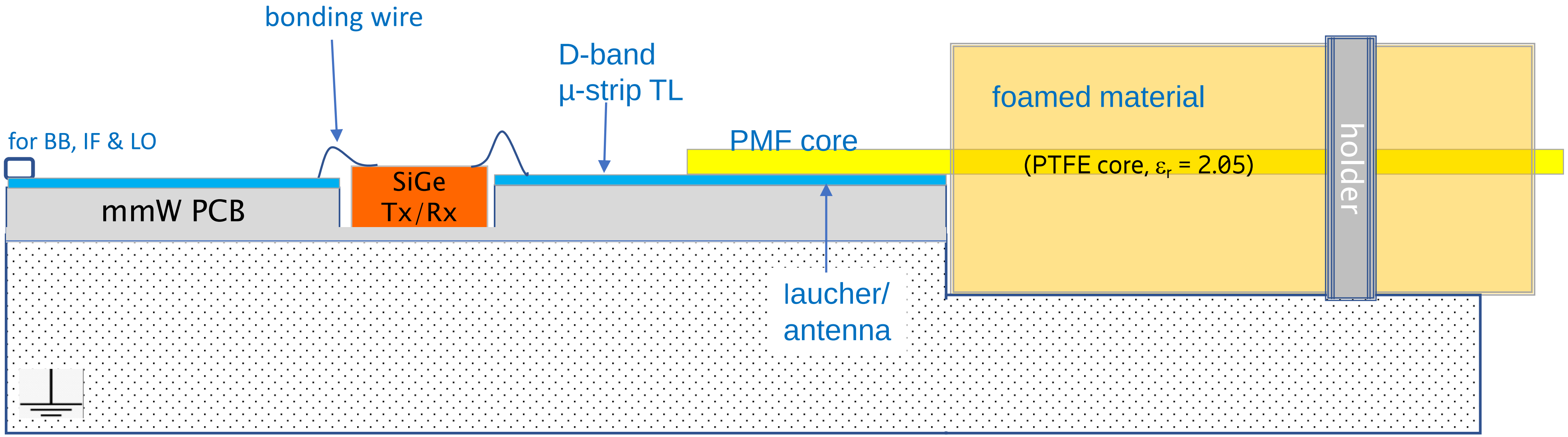
- D/H-band Tx/Rx chipsets in SiGe BiCMOS
- 240 GHz car radar based on silicon micromachining
- 150 GHz short-range data link based on PMF
- To be demonstrated by end of 2022

www.car2tera.eu



Rest of my presentation will focus on PMF-MMIC transition

PMF-MMIC transition: *galvanic coupling*

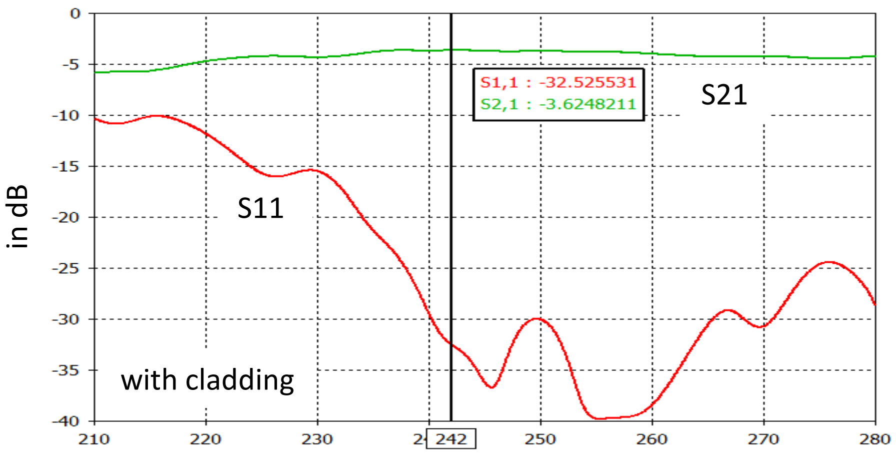


Sub-THz PCB substrate comparison

Rogers RT5880:

- ε_r = 2.2, Df = 0.0009 @ 10 GHz
- Not suitable for wire bonding
- Low loss, 3.7 dB per transition at 250 GHz

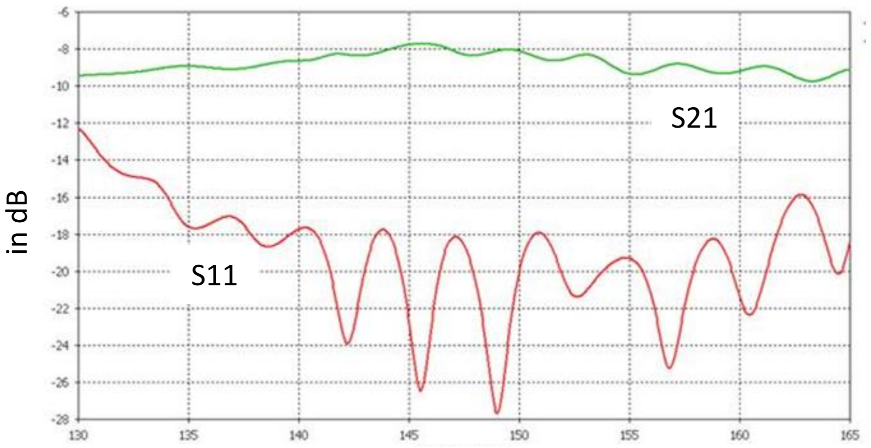
Simulated for one transition



isola Astra MT77:

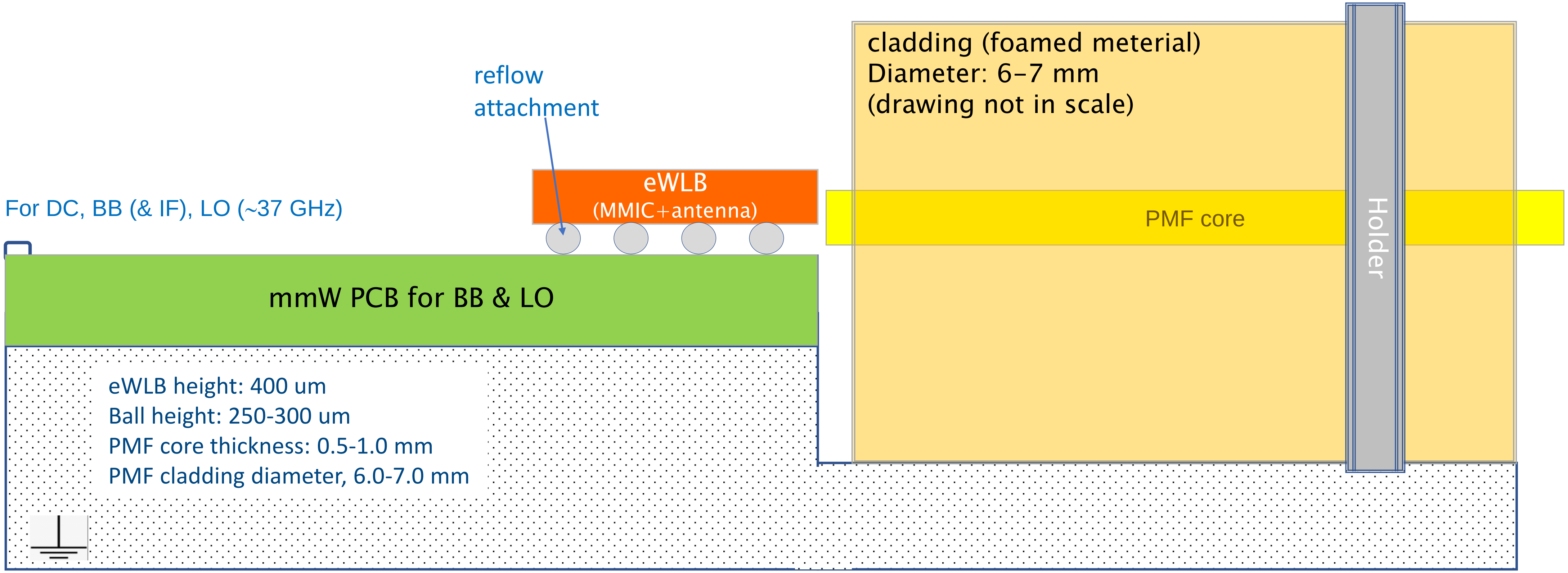
- ε_r = 3.0, Df = 0.0017 @ 10 GHz, and 0.008 @140 GHz
- Good bonding ability
- Larger loss, 4dB per transition at 150 GHz

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



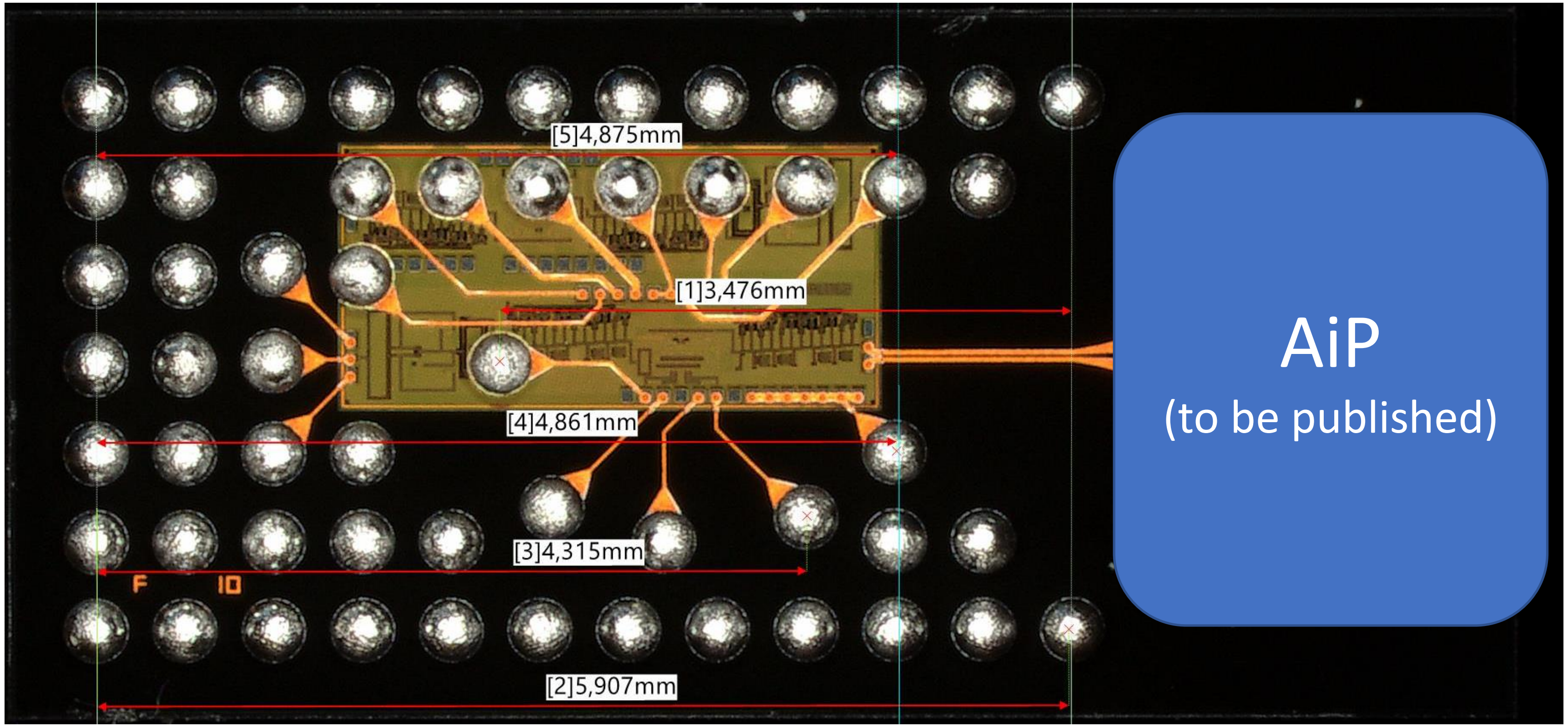
- Astra MT77 is chosen for robust bonding, sacrifying ~ 1dB
- Experimental verification expected in end of 2022

PMF-MMIC transition: *non-galvanic coupling*



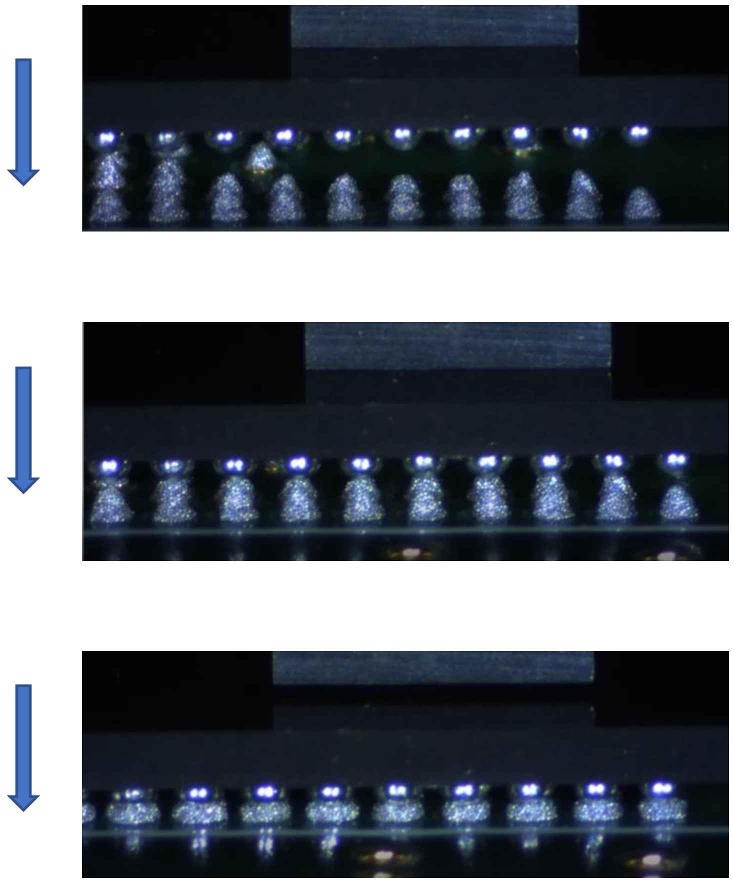
Non-galvanic coupling: *eWLB and AiP*

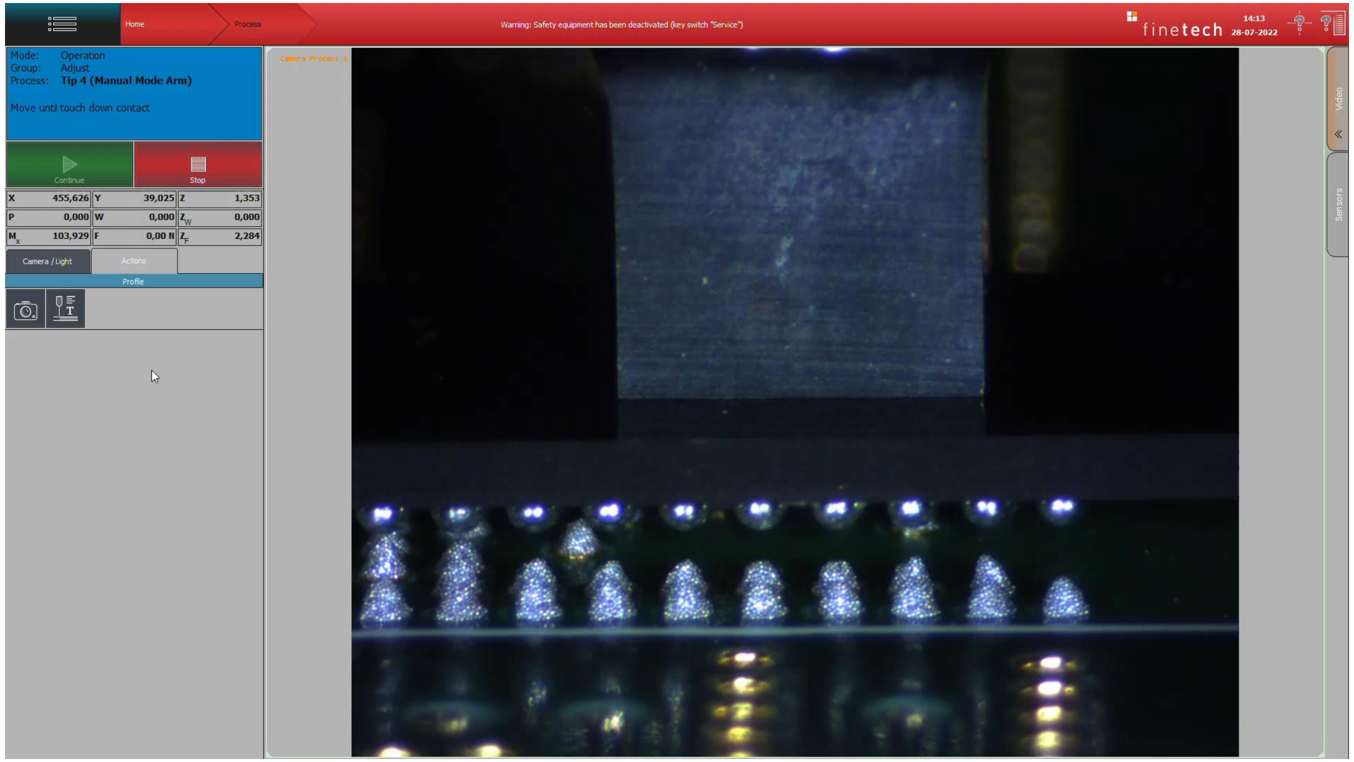
- D-band (150 GHz) MMIC packaged in eWLB technology
- AiP providing coupling to PMF



Non-galvanic coupling: *eWLB assembly*

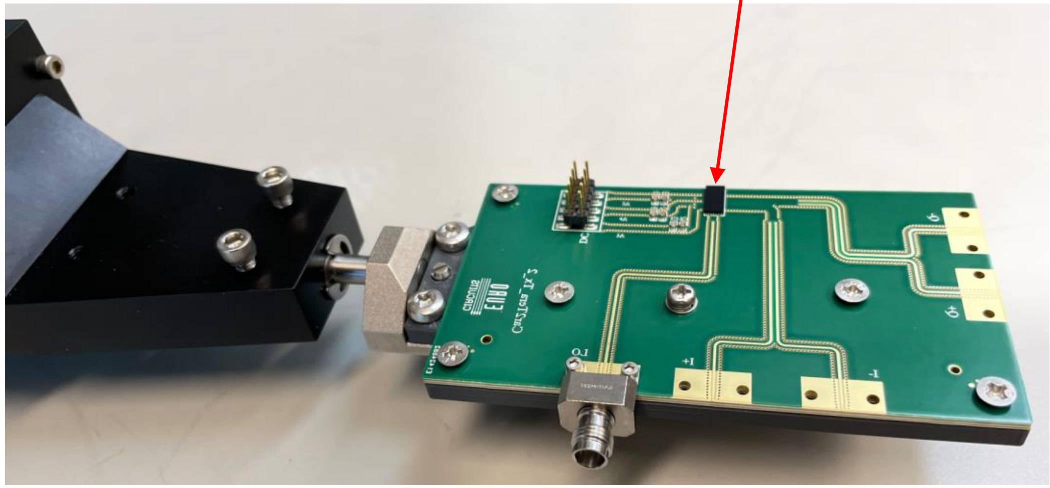
- Flip-chip with fine pitch assebmled in standard soldering process at Ericsson





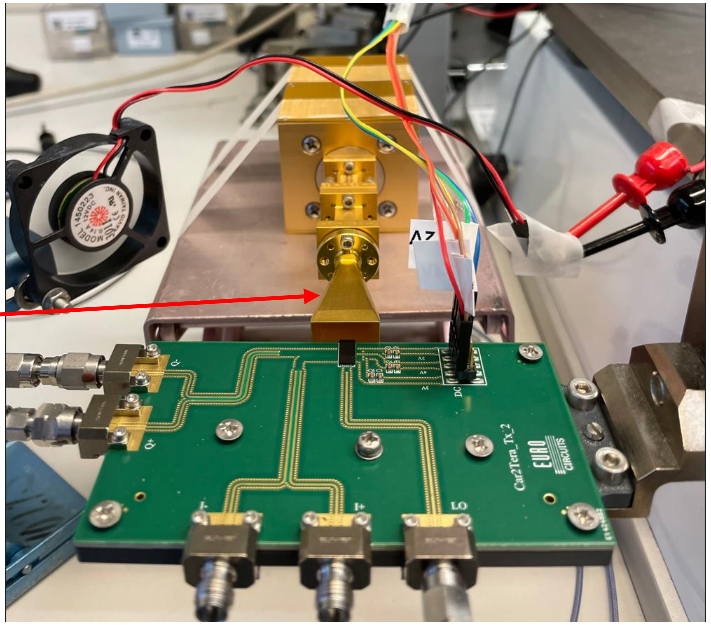
Non-galvanic coupling: *T&M*

eWLB chip

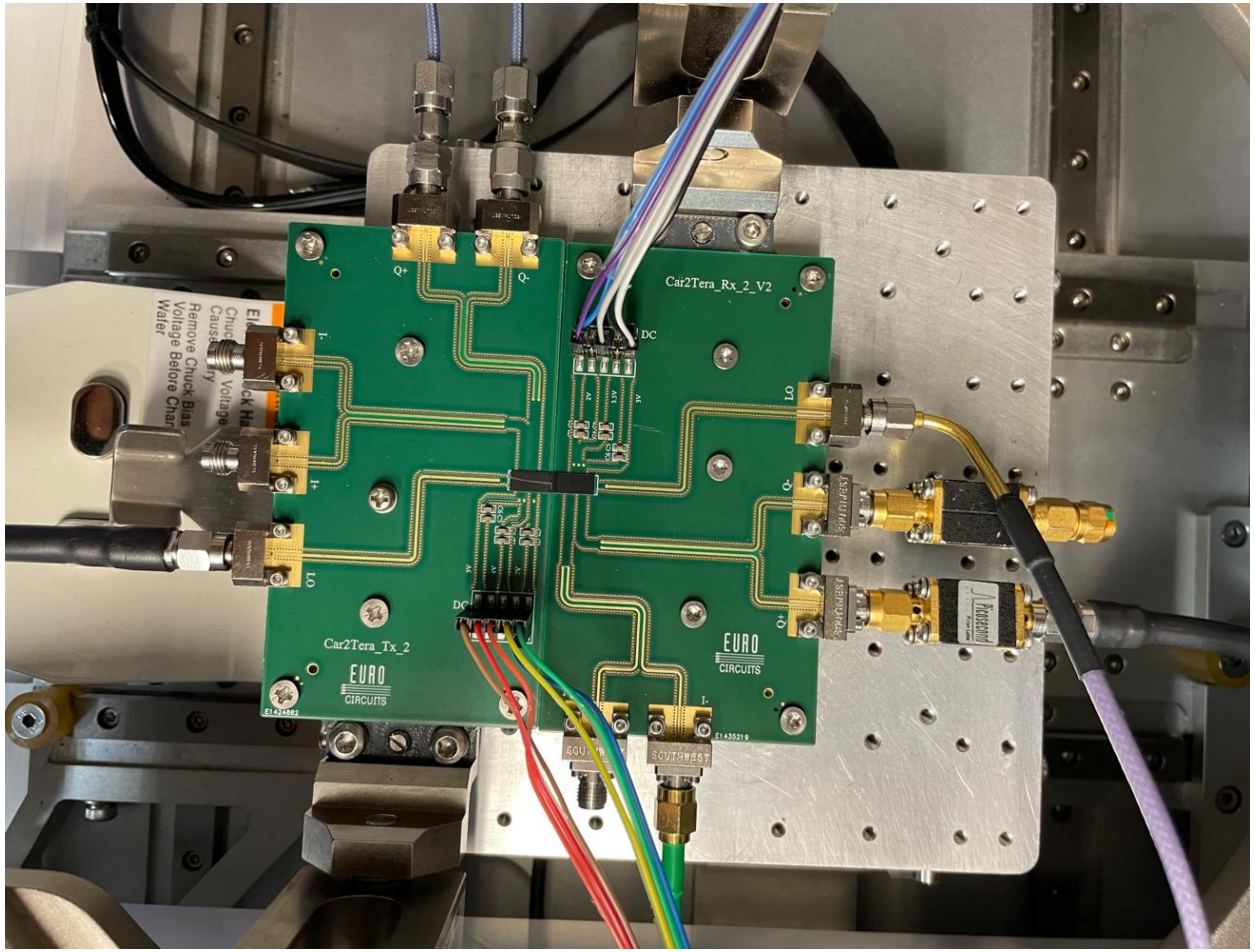


3D printed PCB holder, designed to be mountable to a comercial probe-station munipulator for fine alignement with PMF on µm scale

A D-band horn used to probe the Tx output power



Non-galvanic coupling: *T&M*



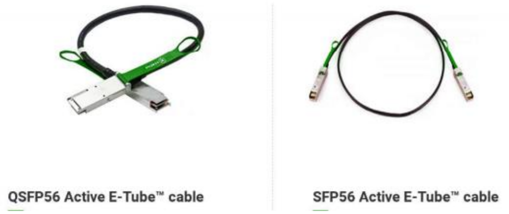
- First link test with the Tx AiP and the Rx AiP placed close to each other
- All DC currents are correct, and an IF signal is observed at the receiver, showing that the ball grid array survived in the soldering process
- At the moment, we are experincing a low Tx output power and large conversion loss issue, debugging on going

Key issues for successful commercial application

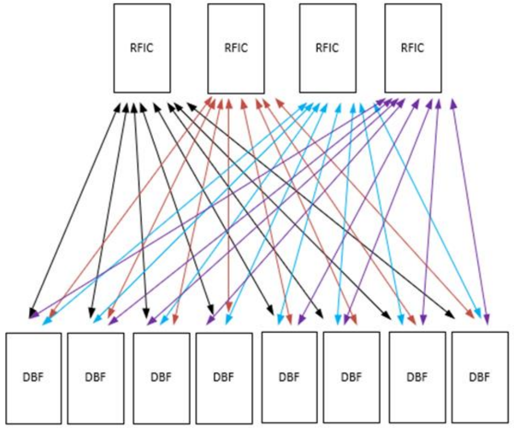
- ASICs are typically 4 cm x 4 cm with multiple data IOs per side (4-8 diff pairs)
- High fiber density is key: *fine pitch, high isolation*
- Low-loss (<3dB) and compact IC-PMF interface is key
- Easy to use, plug-and-play, ….

SFP28 module with 135 GHz CMOS radios targets replacement of optical modules in data centers

plug and play



[Source: Point 2, point2tech.com]



Many parallel data links in AAS, dependng on AAS archtecture

Some take-aways

- Polymer microwave fibers (PMF) is a promising alternative to copper wires and optical fibers as short-to-medium range physical links for high data-rate transmission:
  - *No laser source, insensitive to temperature variation, dust and misalignment, wideband operation, relatively cheap*
- A 112 Gbps data link based on PMF over 50 cm will be demonstrate in Car2Tera project by end of 2022
- Two issues need to be addressed in order to commercialize the PMF technology in telecom and other industrial applications:
  - *Power efficient and compact interface between the PMF and the transceiver ICs*
  - *High fiber density is key: fine pitch, mini-SFP, good isolation, plug-and play, ……*

Acknowlegement

- **Ericsson AB** (Sweden) for PMF requirement study, PCB assembly, PCB holder design and manufacturing, T&M:

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

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

  Yannis Papananos, Vasileios Liakonis, Krainer Siegfried, Franz Dielacher

- **Chalmers/MEL** (Sweden) for development of the D-band Tx and Rx MMICs:

  Herbert Zirath, Haojie Chang, Yu Yan, Simon He, Frida Strömbeck

- **Anteral (Spain)** for PMF-MMIC transition design

  Victor Torres

- **HUBER+SUHNER AG** (Switzerland) for providing D-band polymer microwave fibers:

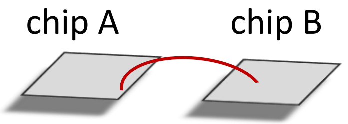
  Hannes Grubinger, Ulf Huegel

- The **Car2Tera** project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824962

Back up slide hereafter

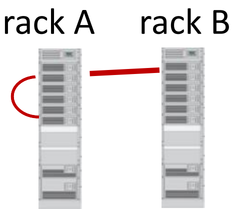
Additional use cases

Intra-box / on-board



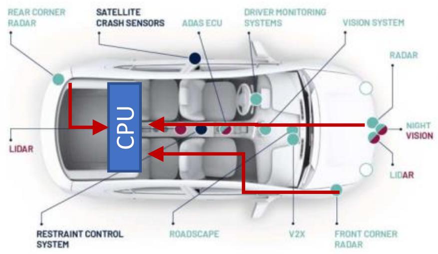
~ 10s of cm

Data center



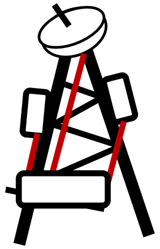
< a few meters

Automotive sensor fusion



< 3 m

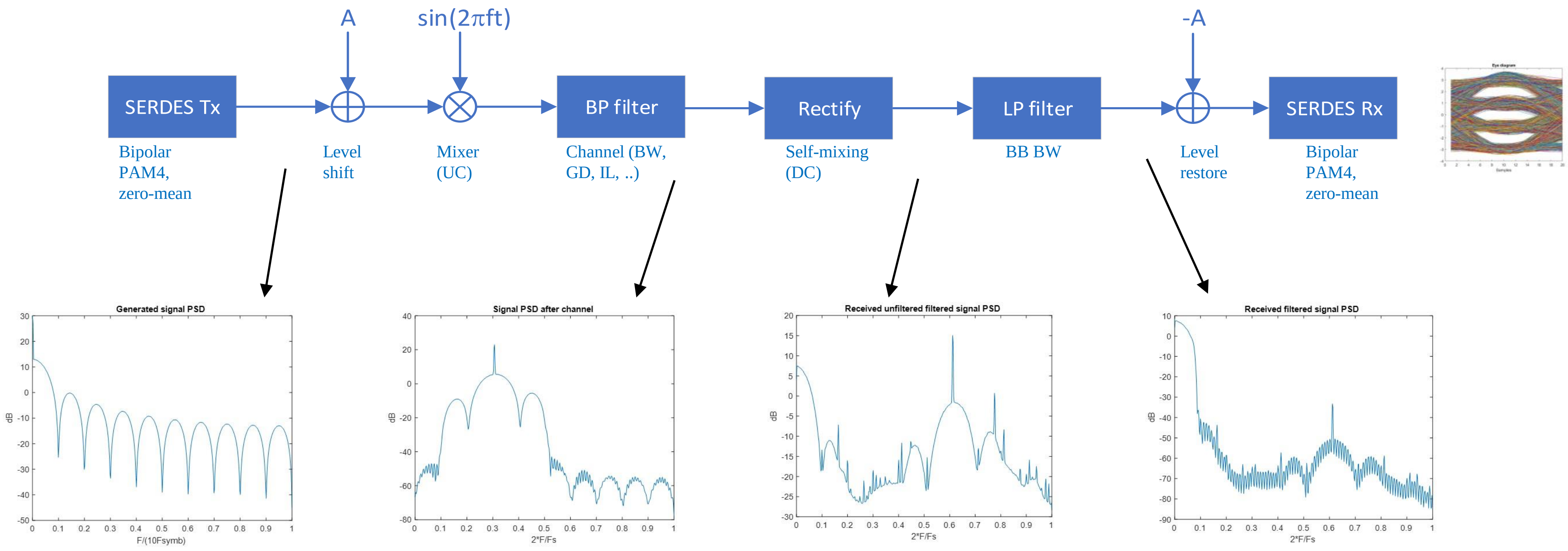
Inter-box in base-station



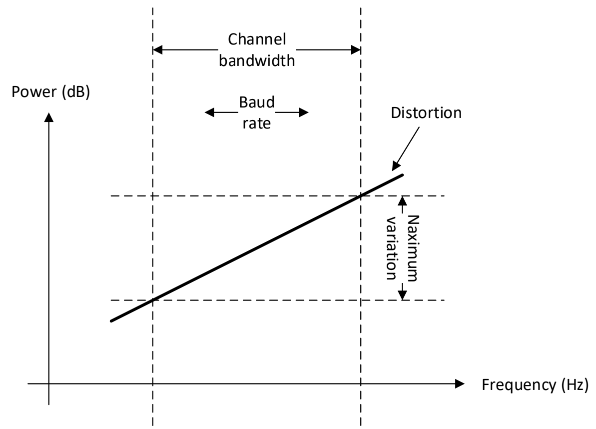
< 10 m

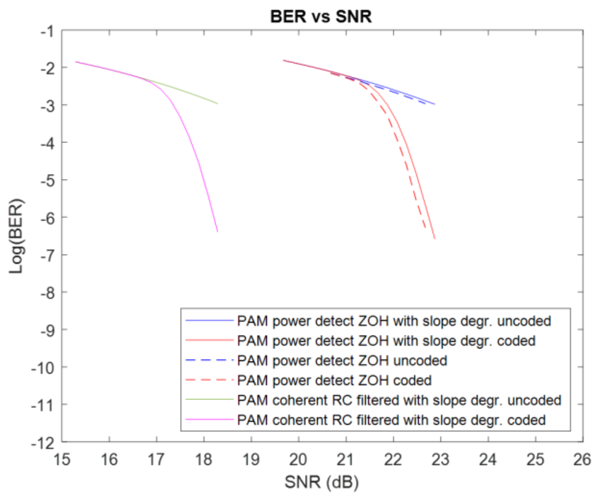
Chennal flatness requirement

- Impact of in-band variation in group delay and insertion loss is studied numerically for the use case



Chennal flatness requirement





Symbol rate F_{symb} (Gbaud)	Channel bandwidth $2*F_{symb}$ (GHz)	Maximum peak-to-peak group delay variation		Maximum peak-to-peak amplitude variation	
		Over entire channel (ns)	In terms of ps/GHz	Over entire channel (dB)	In terms of dB/GHz
10	20	1.20	60.0	10	0.50
20	40	0.60	15.0	10	0.25
30	60	0.40	5.0	10	0.17
40	80	0.30	3.7	10	0.13
50	100	0.24	2.4	10	0.10

- The max. allowed variation
  - max. allowed variation is for whole Tx-Rx chain, not just for PMF
  - max. allowed variation depends on the used criteria (1 dB system degradation)
  - max. allowed variation depends on the use case (modulation, BP_WB, LP_BW, etc.)
- For the current use case, dispersion is not a serious issue