mmW Test Solutions for 5G-FR2

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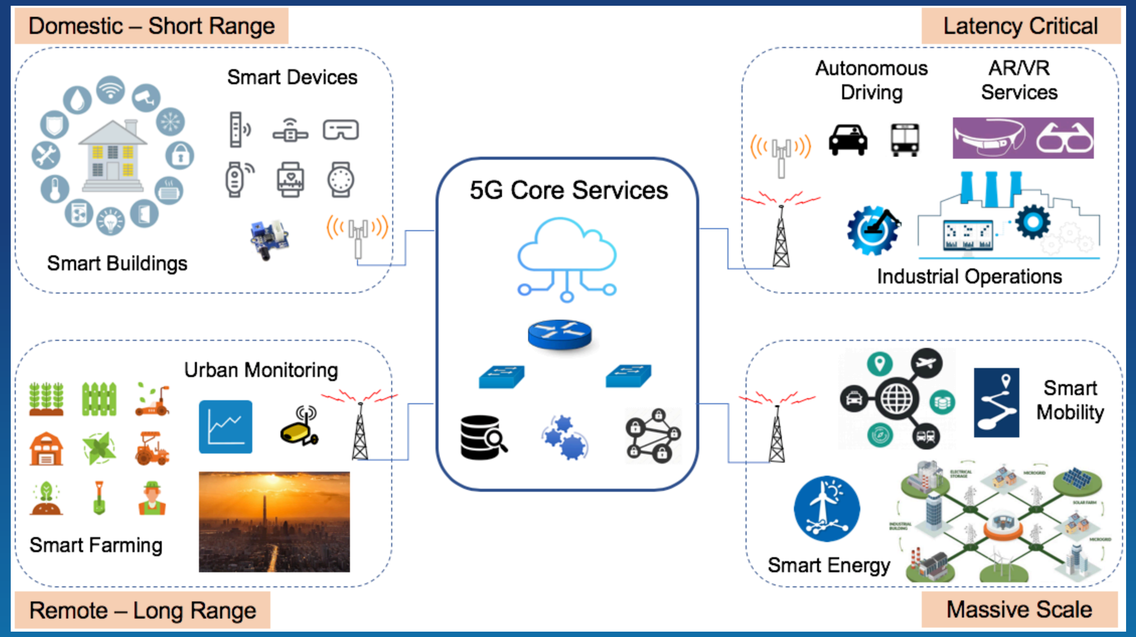
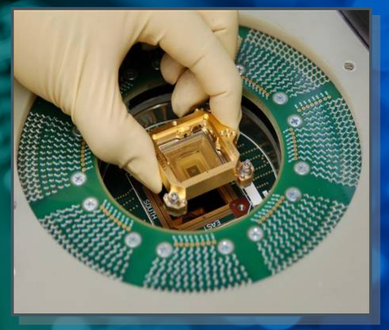
5G Creating New Markets for RF IC Chips

- 5G is increasing the markets for RF chips:
  - Short range – Personal Smart Devices/Buildings
  - Long Range: Smart Farming/Urban Monitoring
  - Latency Critical: Autonomous Driving/AR and VR services/Industrial Monitoring
  - Massive Scale: Smart Energy/Smart Mobility



https://deepai.org/publication/5g-applications-requirements-challenges-and-outlook

FFI Probe Cards for RF KGD Production

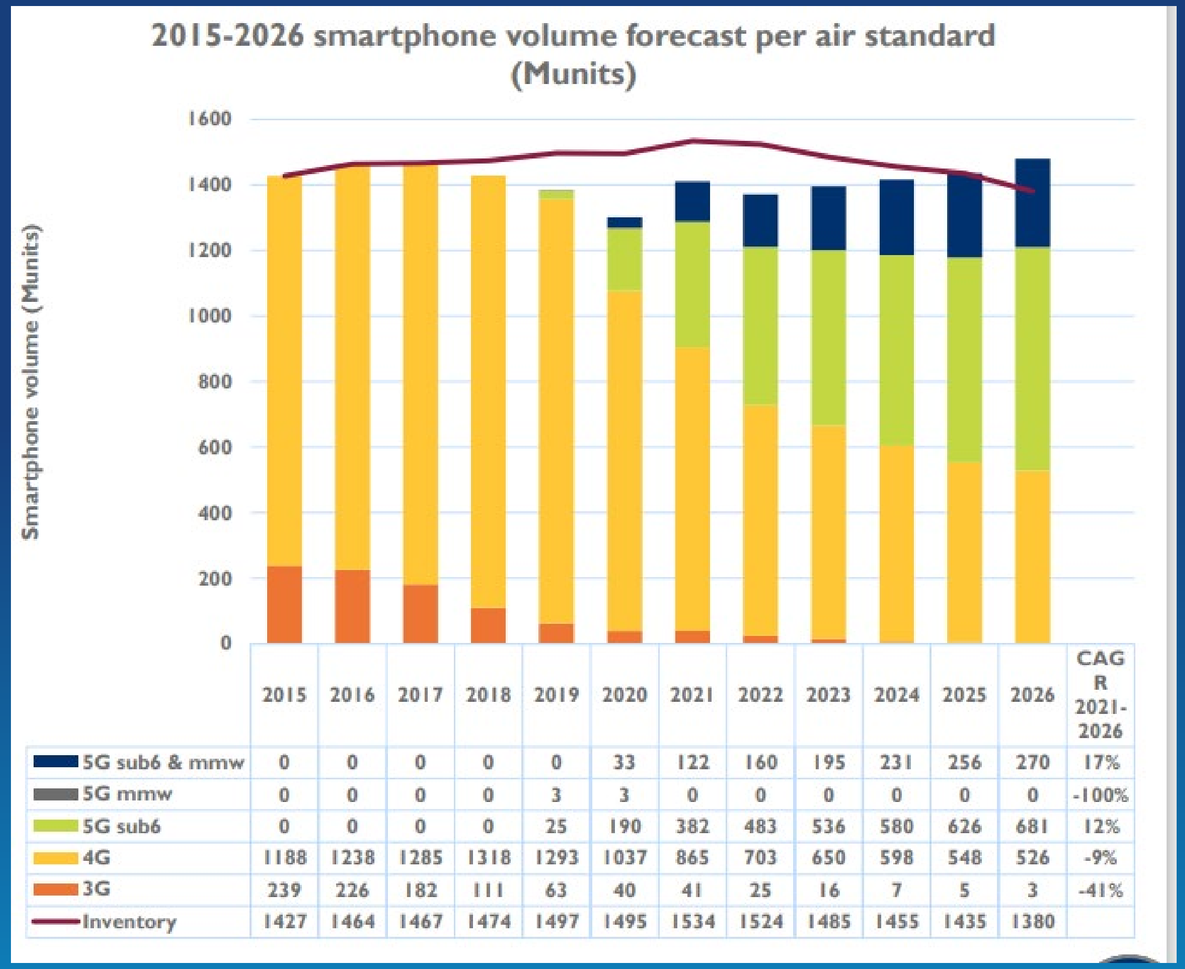


RF Probe Cards from Form Factor provide:

- Frequency range to 81+ GHz with better than -10 dB Return loss to maximize test accuracy out to specified frequency
- Custom layout to match your die to minimize number of touchdowns
- Short, low-loss lines to minimize resonances and overall loss in the measurement
- Low inductance supplies with bypass capacitors close to the DUT
- Low contact resistance
- Minimal pad damage to maintain yield

Growth in 5G

- Based on the Yole report on RF-FE from 2021, there will be more than a doubling in the number of smartphones operating at 5G FR2 (CAGR of 17%) from now to 2026
- Since each phone requires about 3 mmW modules, it is estimated that by 2026, more than 750M 5G mmW modules will need to be tested per year



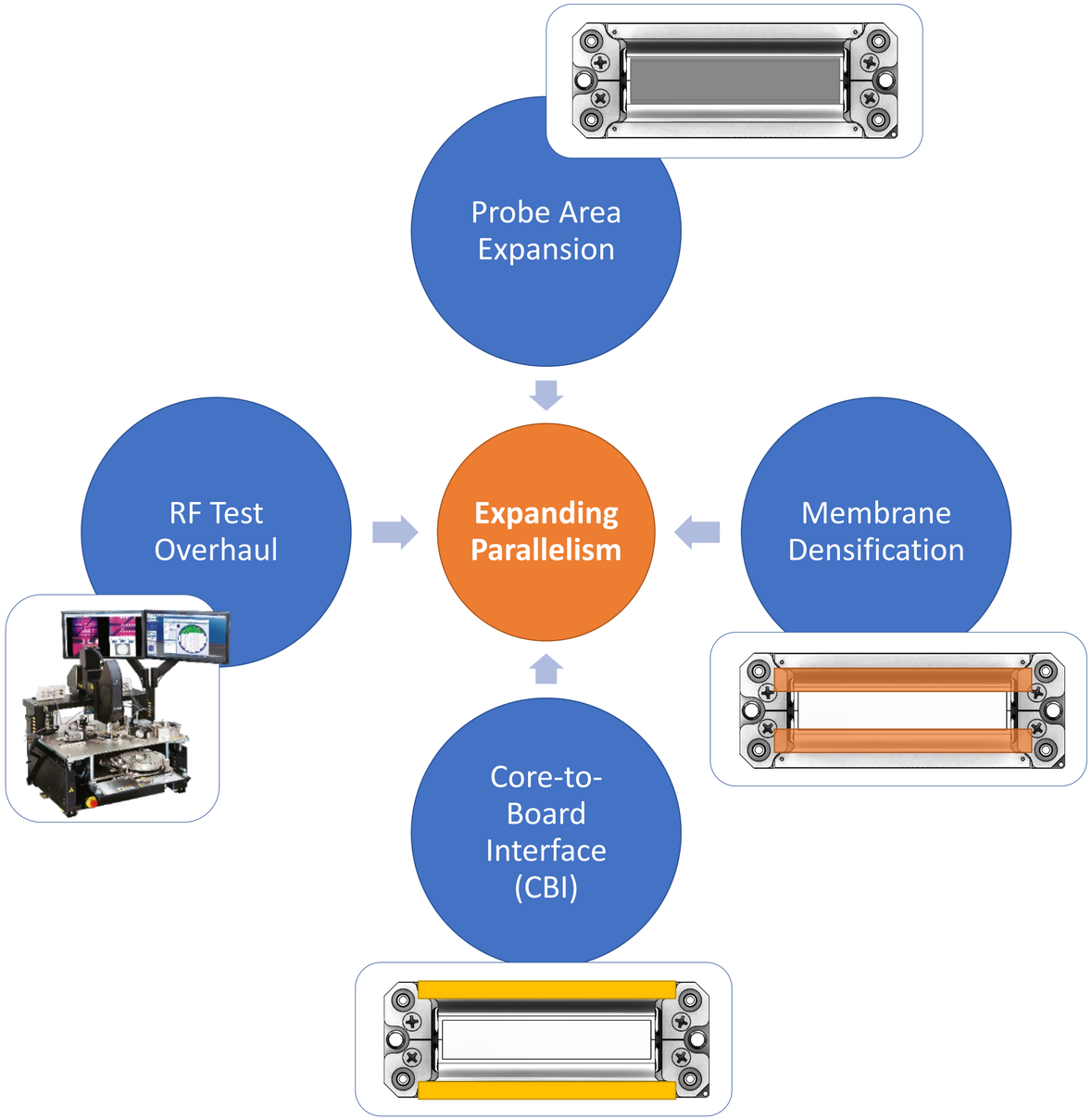
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	CAGR 2021-2026
5G sub6 & mmw	0	0	0	0	0	33	122	160	195	231	256	270	17%
5G mmw	0	0	0	0	3	3	0	0	0	0	0	0	-100%
5G sub6	0	0	0	0	25	190	382	483	536	580	626	681	12%
4G	1188	1238	1285	1318	1293	1037	865	703	650	598	548	526	-9%
3G	239	226	182	111	63	40	41	25	16	7	5	3	-41%
Inventory	1427	1464	1467	1474	1497	1495	1534	1524	1485	1455	1435	1380	

Ref: Cellular RF Front-End Technologies for Mobile Handsets 2021. market and Technology Report 2021, Yole Development

Expanding Test Parallelism

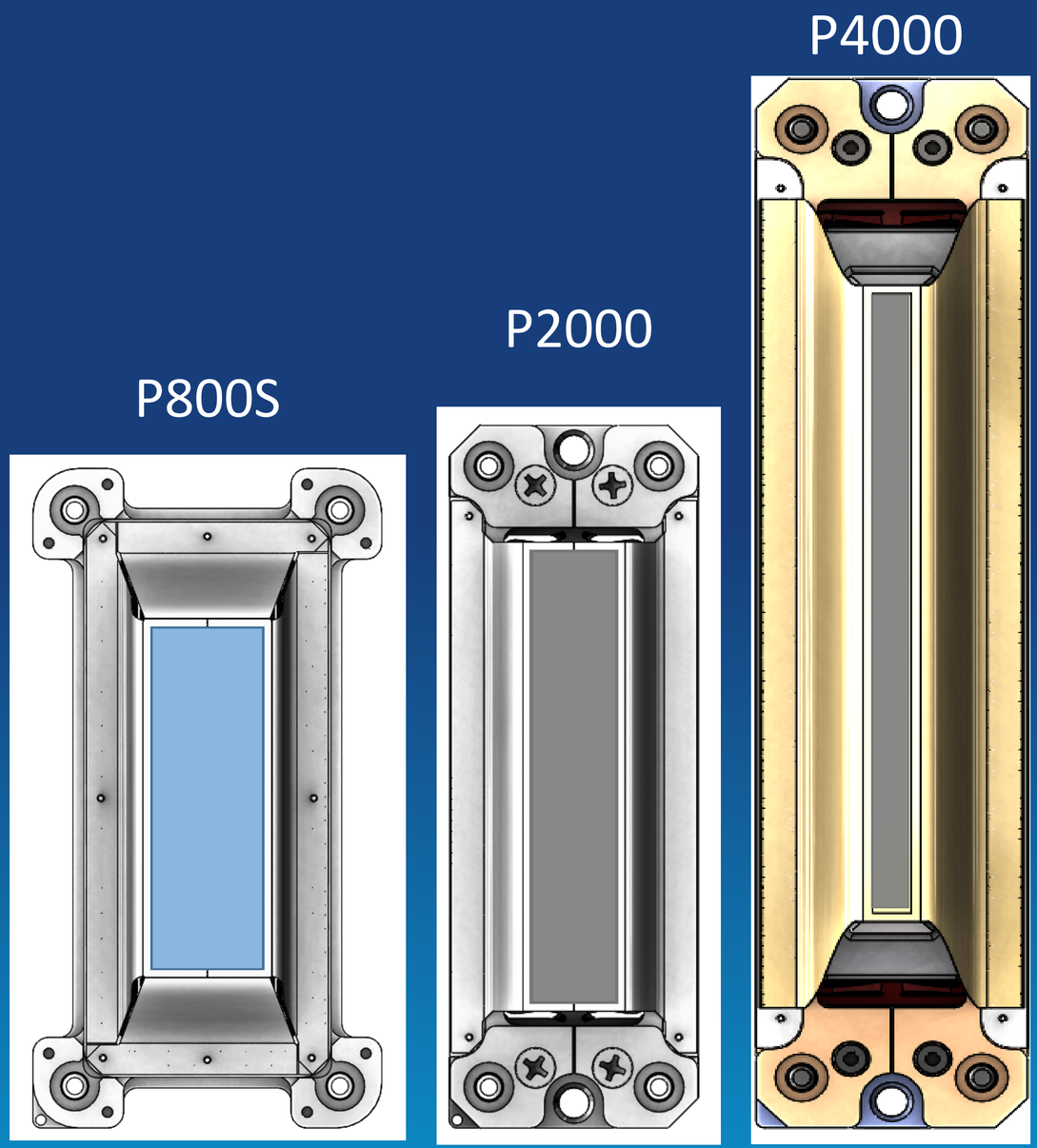
FormFactor's RF product evolution centralizes on **increasing the active probing area** and **densifying the membrane** while maintaining **best-in-class RF measurements to address the increased mmW test parallelism**

Pyramid P2000 x4 AiP Probe Core

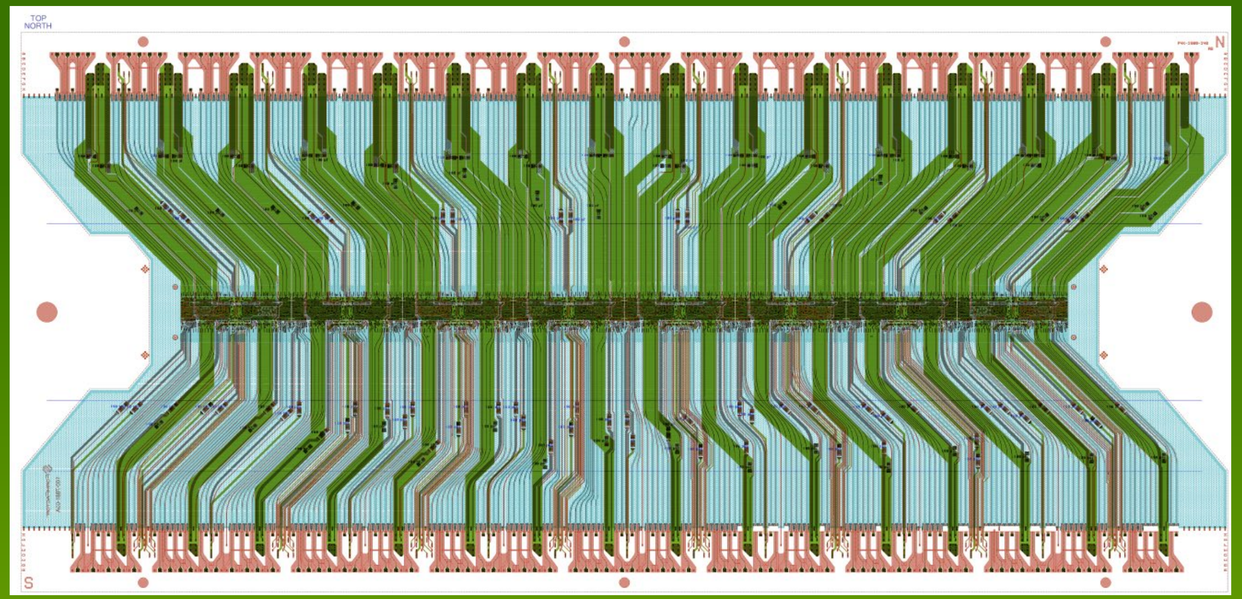


Pyramid Probe Area Expansion

- New P2000 core design in Beta release to increase test capability
  - P2000 supports a **4x AiP layout**
  - P2000 includes improved core-to-board interface density, increasing the number of I/O from 804 in P800S to 2112 on P2000
  - Will be in full release late 2021
- Pyramid membrane performance on all cores:
  - Excellent RF measurements
  - Stable CRES with consistent probe marks
  - Replaceable cores from tester
  - No off-stepping



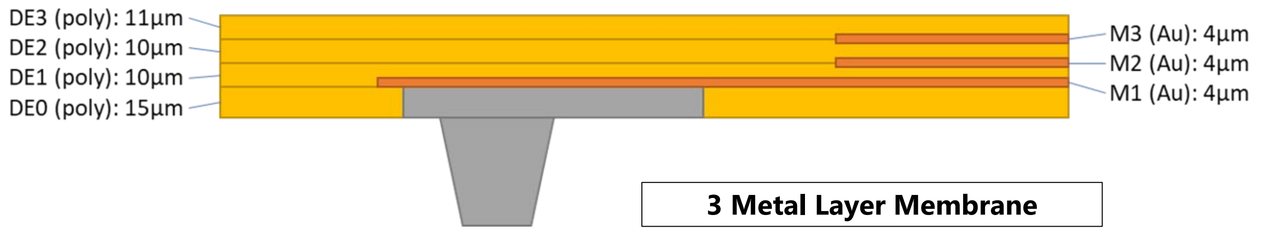
New Membrane Layer Count Capability



FFI has been working to improve our membrane fabrication capabilities

This includes improving:

- Overall membrane yield improvements
- Increasing the number of layers in the membrane from 2 routing layers (2ML) to 3 routing layers (3ML)
- 3ML enables dense die breakout and routing



2ML Performance with 1 mm Connector

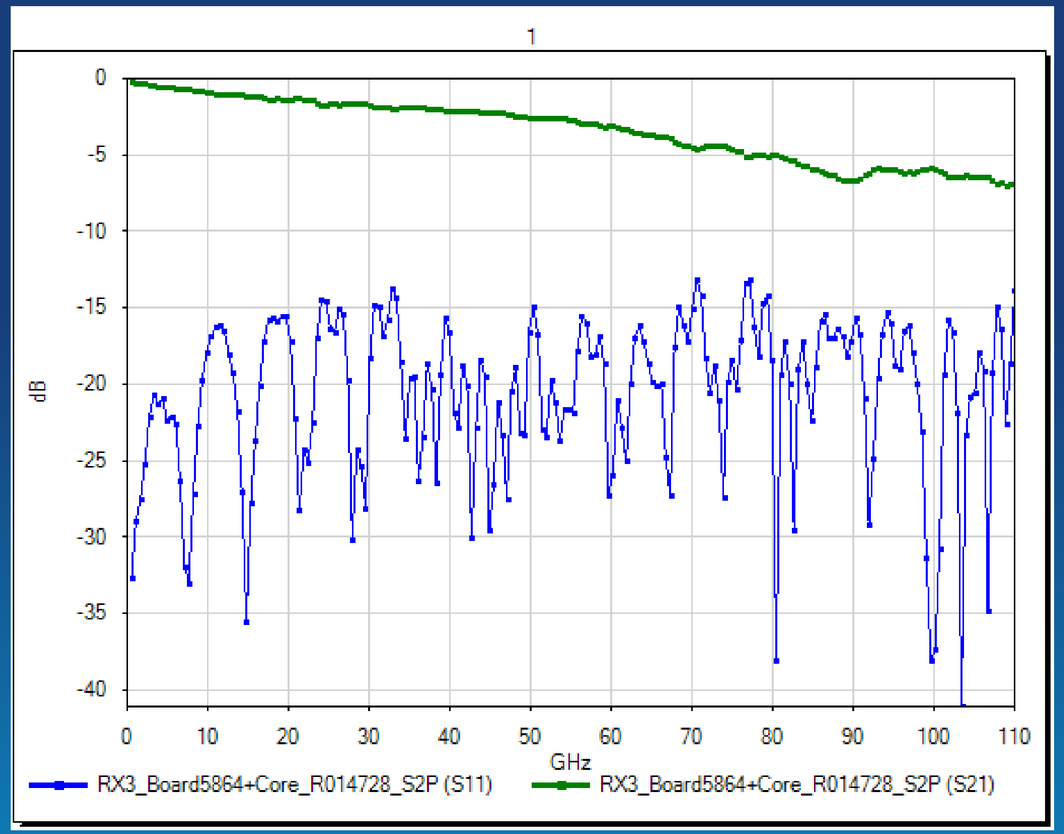
RFC-MW size core
- Maximum probing area of 5.334 x 5.334 mm

Test board used 1 mm RF connector (110 GHz)

Return loss (S11) spec
- **Better than -10 dB at 81 GHz**

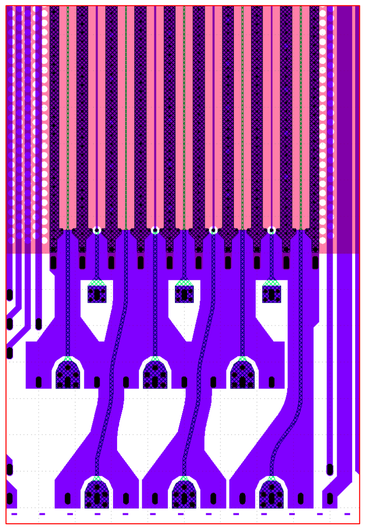
Insertion loss (S21), typical
- Better than -6 dB at 81 GHz

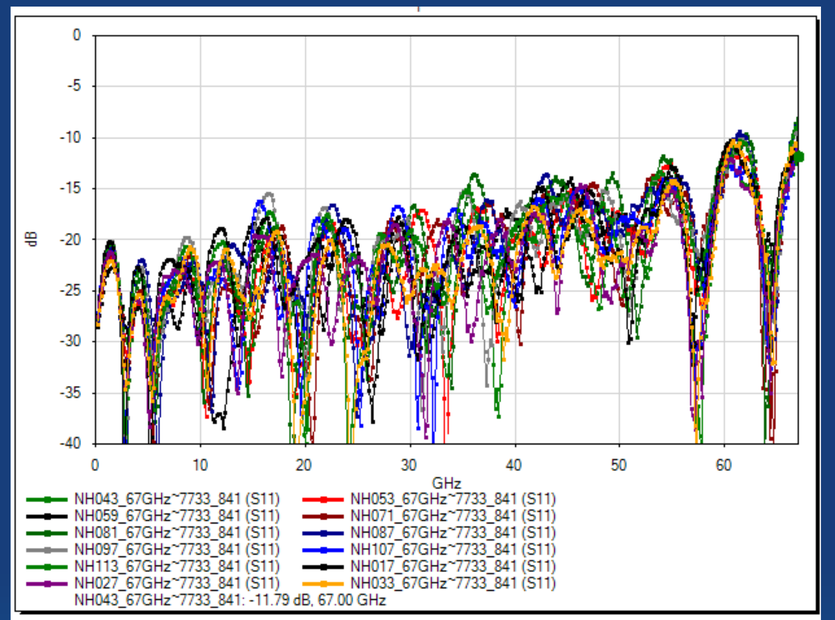
Actual performance dependent upon specific design of DUT

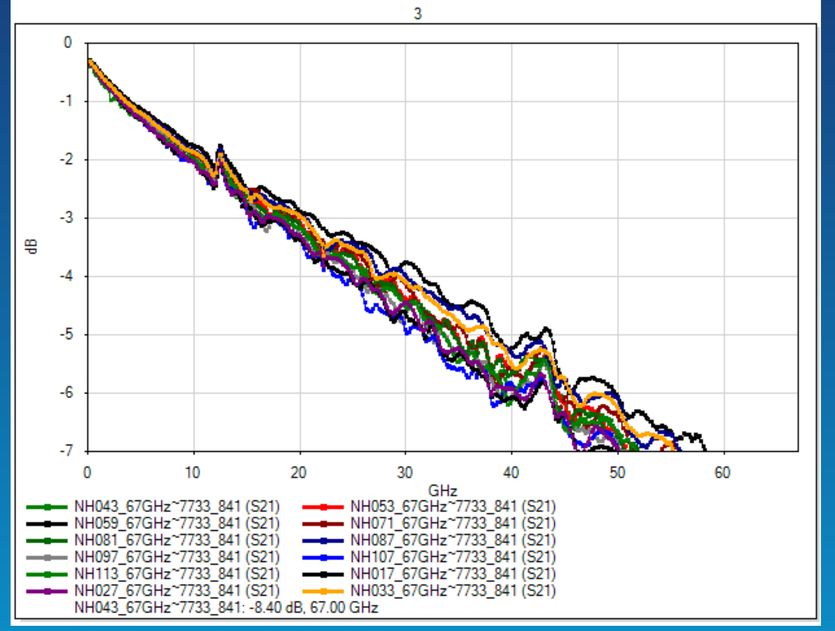


3ML on P2000 Performance

- P2000 sized core using 3ML transmission lines
  - The traces are longer than in other core designs, increasing loss
  - Maintains the better than -10 dB RL out to 55 GHz with good margin
  - This is the layout of the P2000, using microstrip for the core-to-board interface for isolating lines from PCB and for increasing density , but going to CPW on the wing for best performance

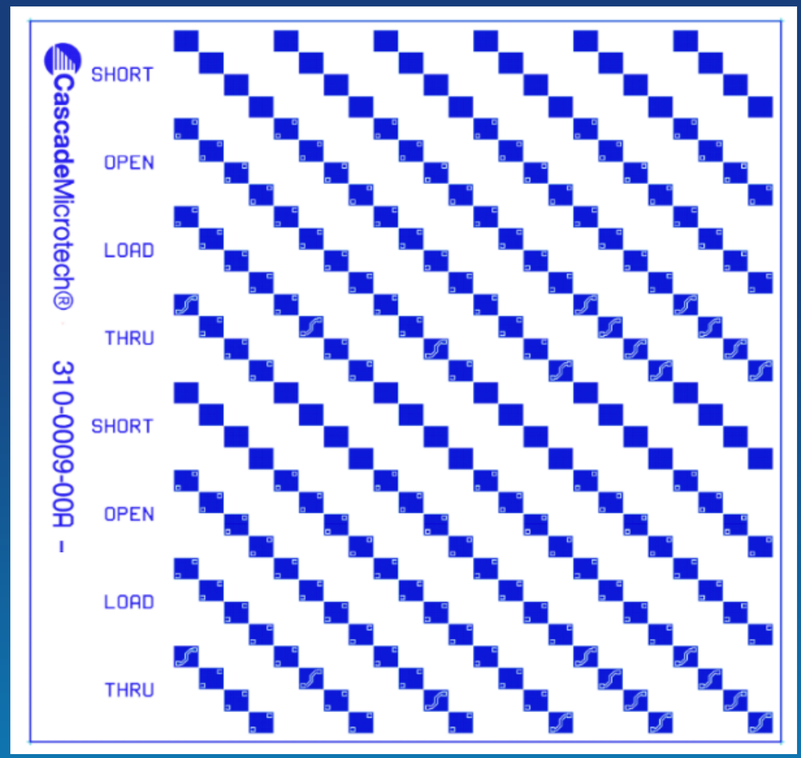






Cascade Custom Calibration Substrate

- Designed to exactly match the die layout
- Supports multi-DUT calibration
  - Ability to control the RF impedance of all lines simultaneously for more accurate calibration
  - Uncontrolled RF lines can resonate through excited currents and fields
- Standard 50Ω loads as well as non-standard loads are available
- Accuracy guaranteed to 1%
- Designed and built by FormFactor. Ships in same box as the probehead



Summary of Benefits

- Ship KGD: Performance Test to Product Specifications
  - Controlled Impedance Signal Traces
  - High-Power Transmission
  - High-Bandwidth 81+ GHz RF signals
  - Excellent Signal Isolation
  - Accurate Package Emulation
- New Core size to increase the parallelism capability for 5G
- Full Calibration Solutions
- Probe all Pads and Solder Balls
  - Less damage and particle-generation
- Lower your Cost-of-Ownership
  - Multi-Site testing
  - Lower Maintenance Overheads

THANK YOU