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12th INTERNATIONAL CONFERENCE ON MICROWAVE MATERIALS AND THEIR APPLICATIONS

From benchmarking to roadmapping – developing good practices and standards for material characterisation for 5G & 6G technologies

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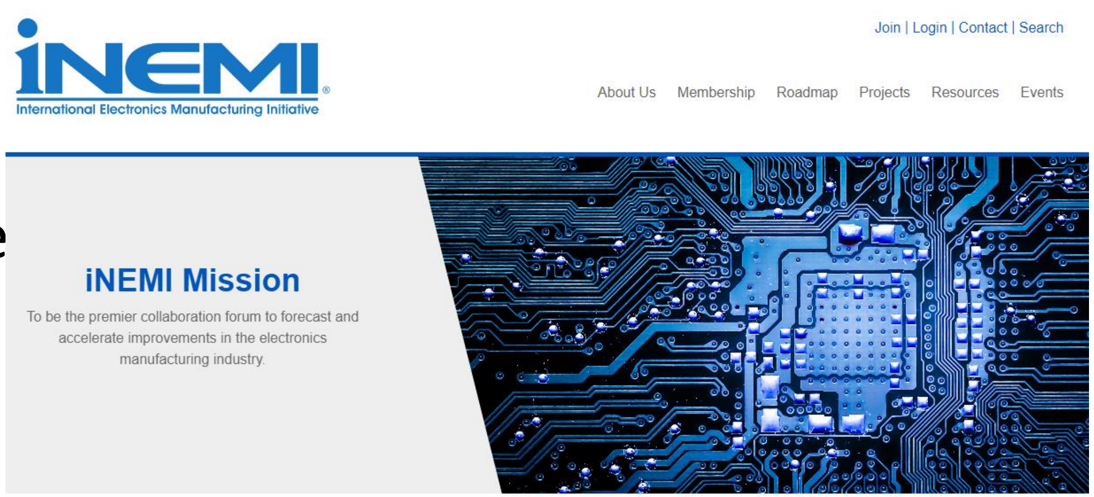
INEMI Overview

- INEMI Overview
- Benchmarking project
- Standard reference material project
- 5G/6G Roadmap

INEMI Overview



- International Electronics Manufacturing Initiative

- *"iNEMI is an industry-led consortium of manufacturers, suppliers, industry associations and consortia, government agencies, research institutes, and universities, and through the combined power of this global membership, we help drive technology development and deployment across the global supply chain. One of the ways we do that is through our project work"*

- 5G/mmWave Materials Assessment and Characterization
- mmWave Permittivity Reference Materials
- 5G/6G mmWave Materials and Electrical Test Technology Roadmap (5G/6G MAESTRO)

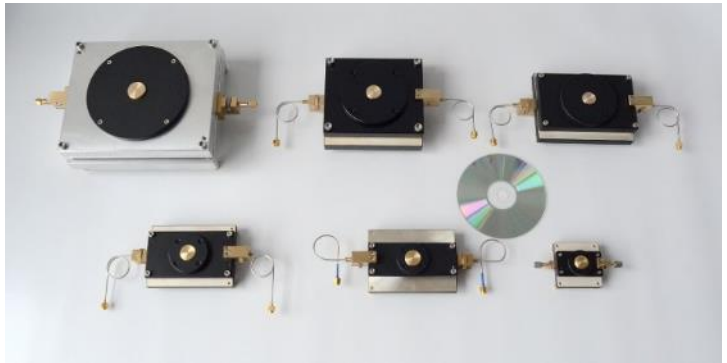
Benchmarking project

- Benchmarking existing characterization methods for dielectric materials
- Resonant methods
- Investigating repeatability and reproducibility
- Known and industrial materials

- Characterization techniques:
  - Split-Post Dielectric Resonator,
  - Split-Cylinder Resonator,
  - Balanced Circular Disk Resonator,
  - Fabry-Perot Open Resonator

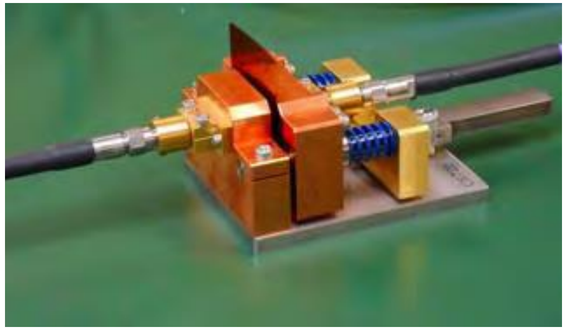
FPOR

SPDRs



BCDR

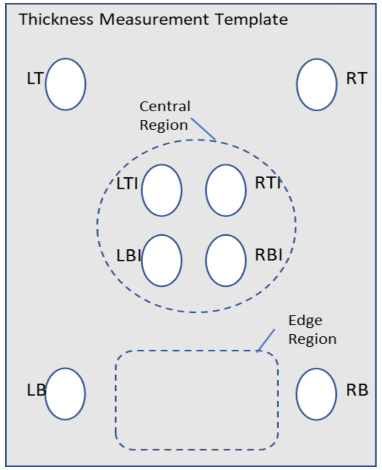
SCR



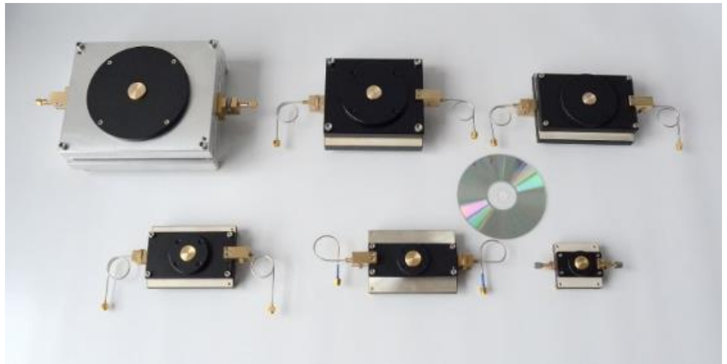
Benchmarking project (2)

- Four resonant methods:
  - SPDR, SCR, BCDR, FPOR
- 3 material types
- 12 samples (6 in each of two sizes)

- 10 samples kits
- 11 labs
- Following common thickness acquisition procedure



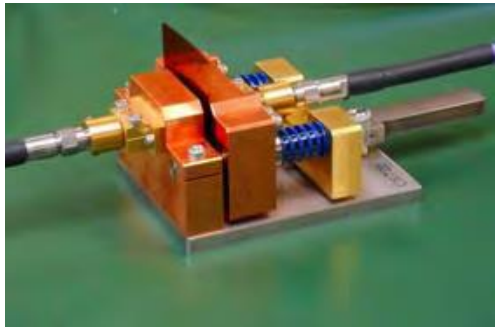
SPDRs



FPOR

BCDR

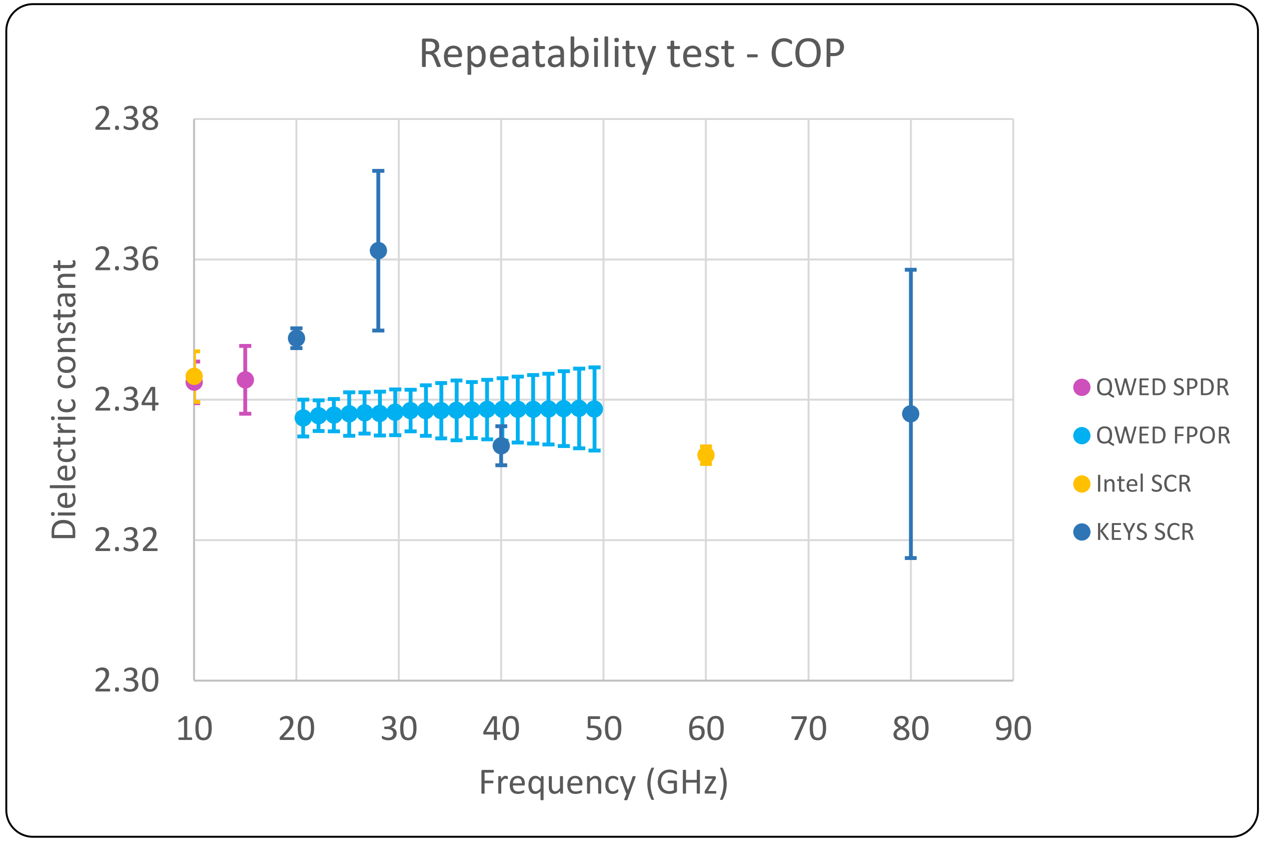
SCR

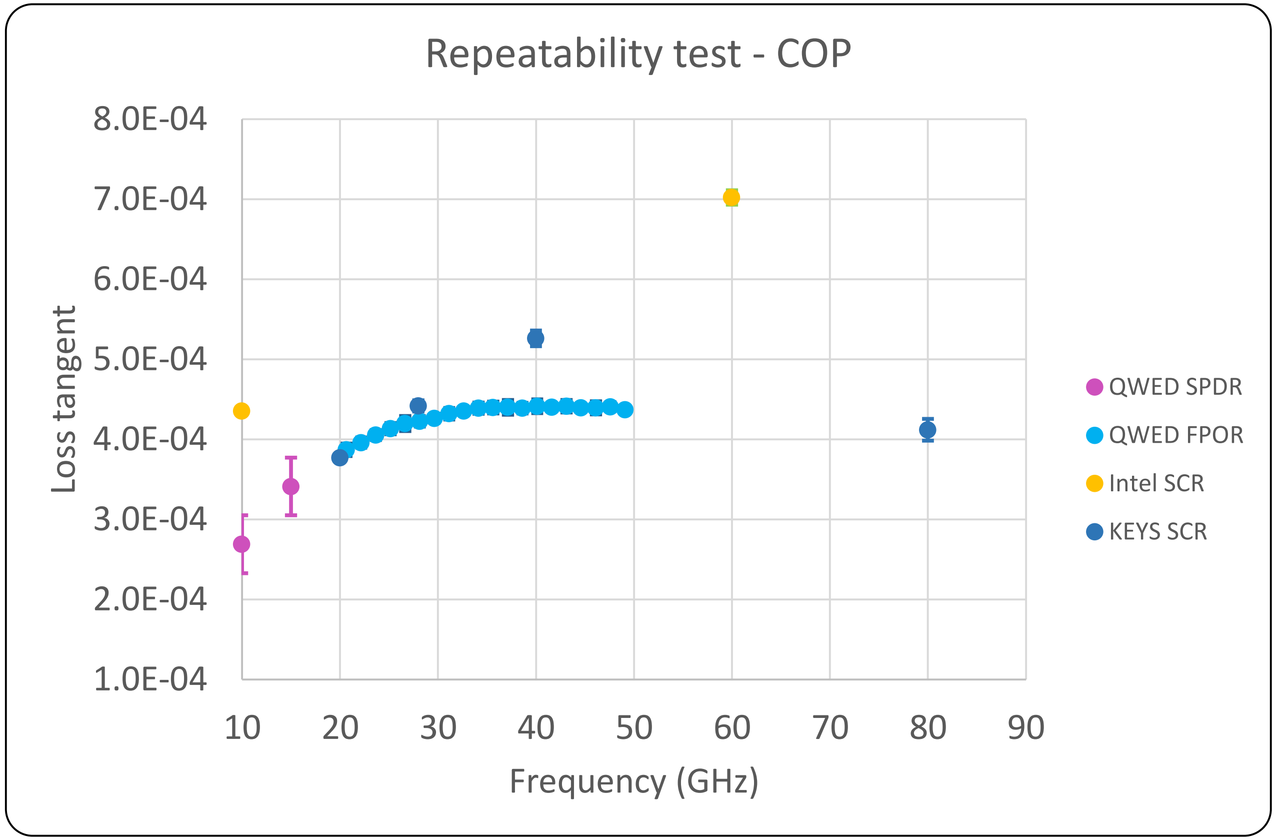


Benchmarking results (1)

Repeatability studies

Each measurement repeated 16 times *Repeatability bounds: ±3σ*





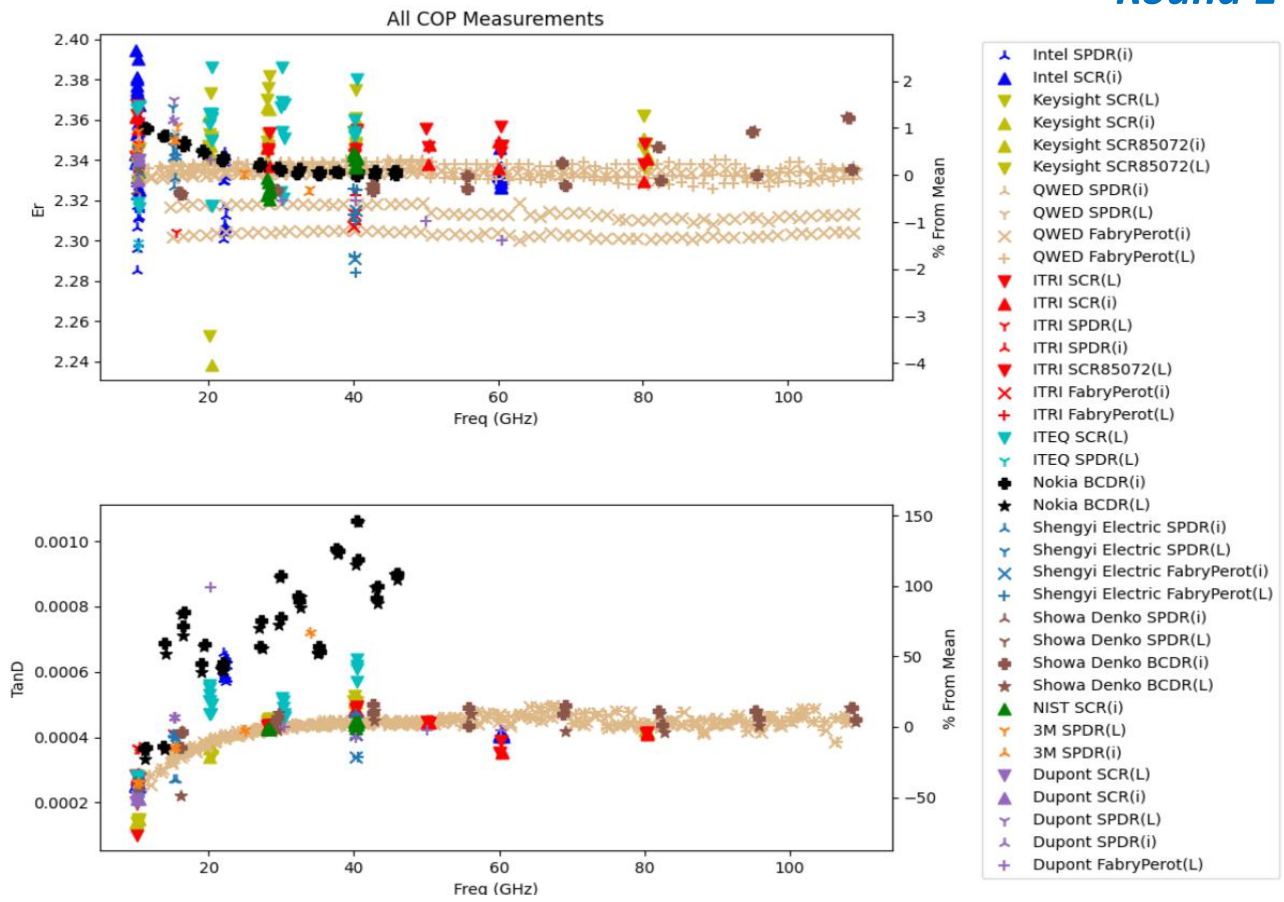
M. Celuch, M.J. Hill, T. Karpisz, M. Olszewska-Placha, S. Phommakesone, U. Ray, B. Salski, "Benchmarking of GHz resonator techniques for the characterisation of 5G/mmWave materials", 51st European Microwave Conference April 2021, pp. 568-571.

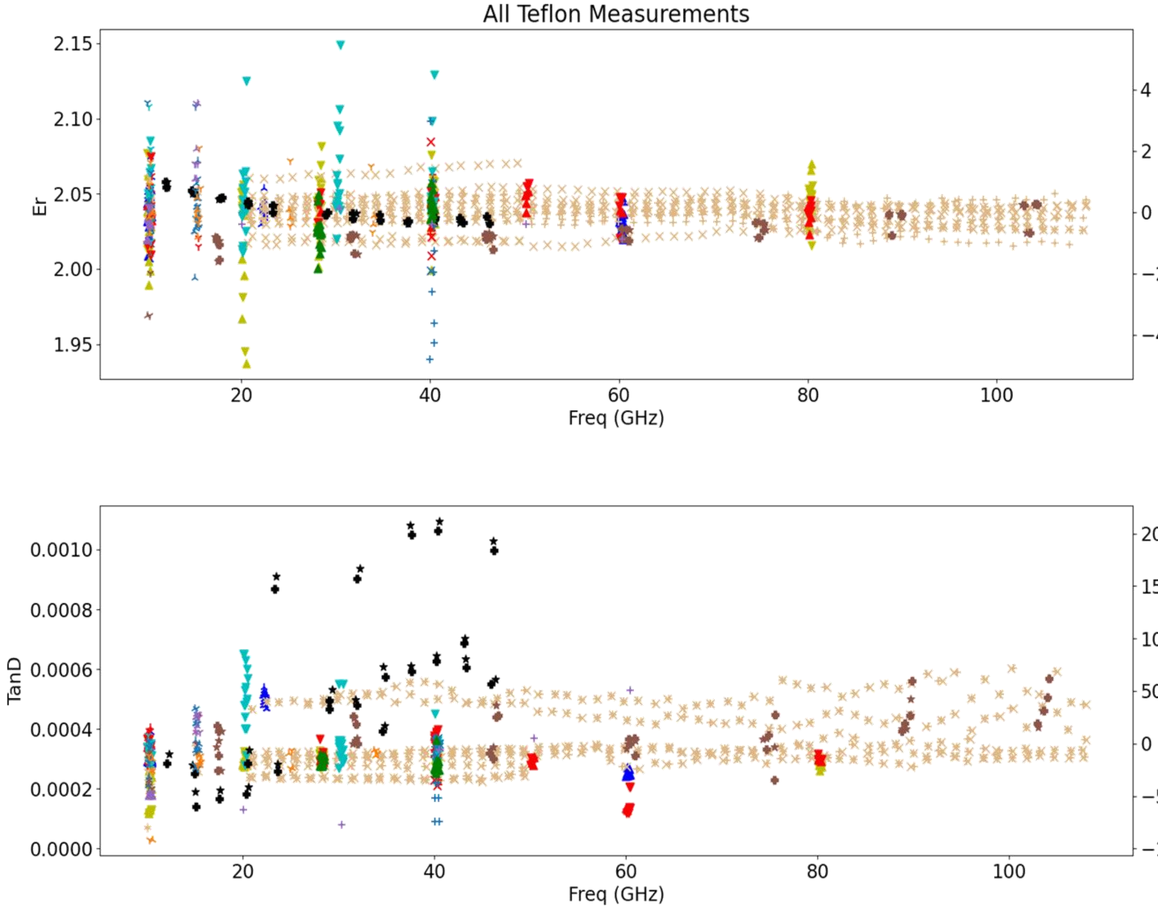
Benchmarking results (2)

INEMI *5G/mmWave Materials Assessment and Characterization* project results

Over 2000 measurement points in total

Round 1





Spread of Dk: ±2%

Spread of Dk: ±4%

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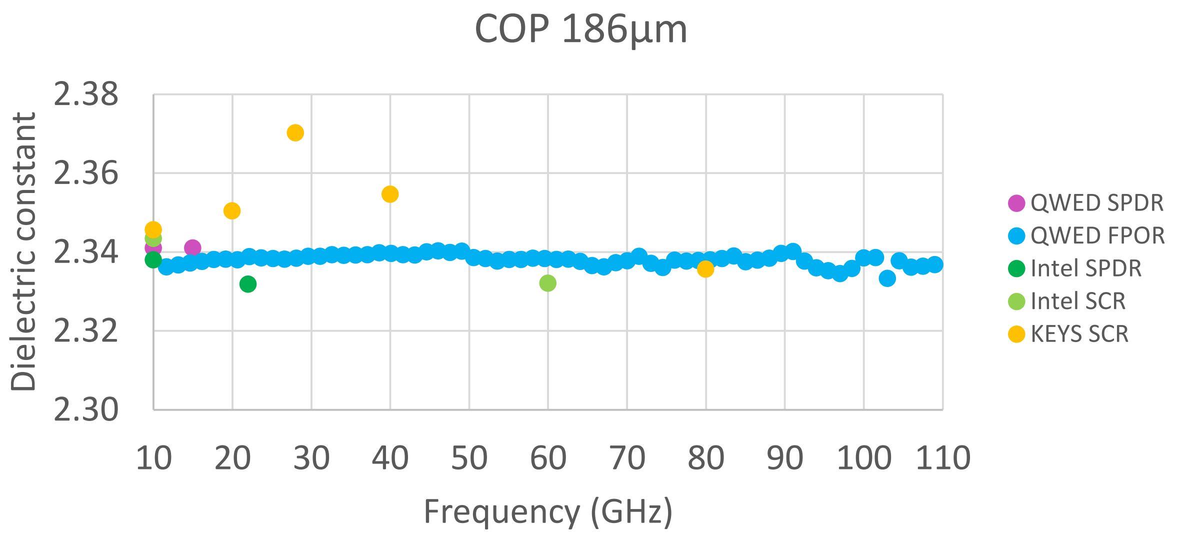
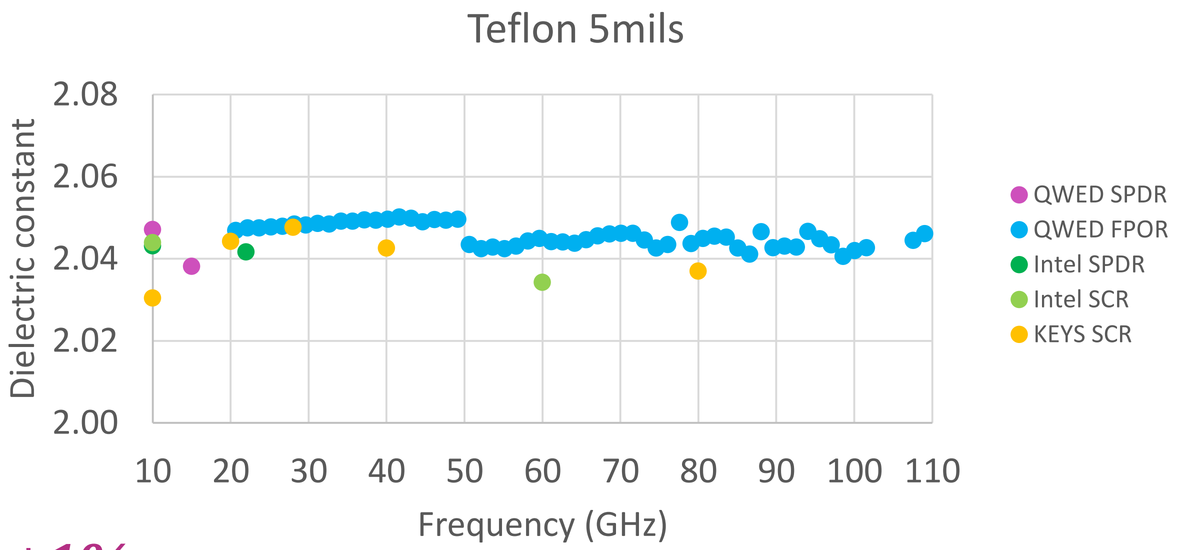
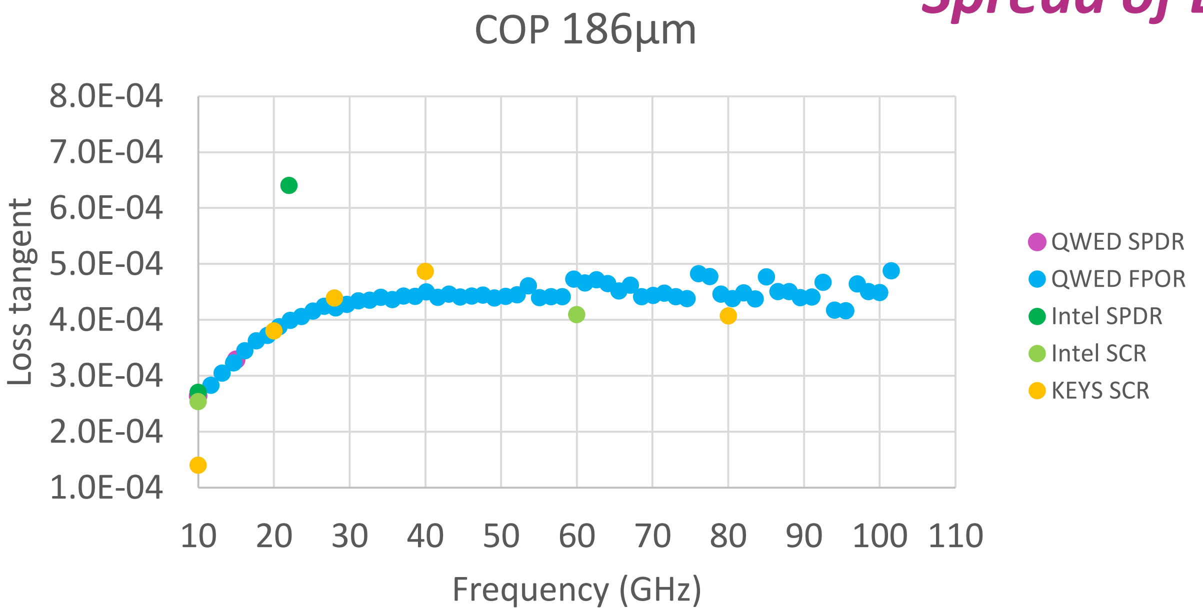
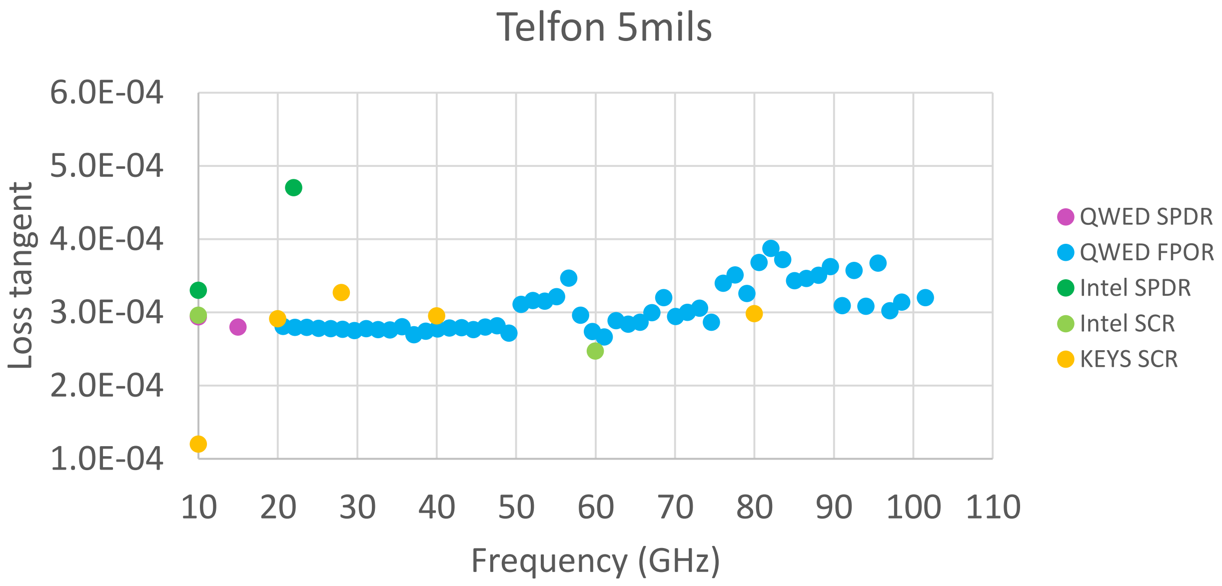
Benchmarking results (4)





Spread of Dk: ±1%





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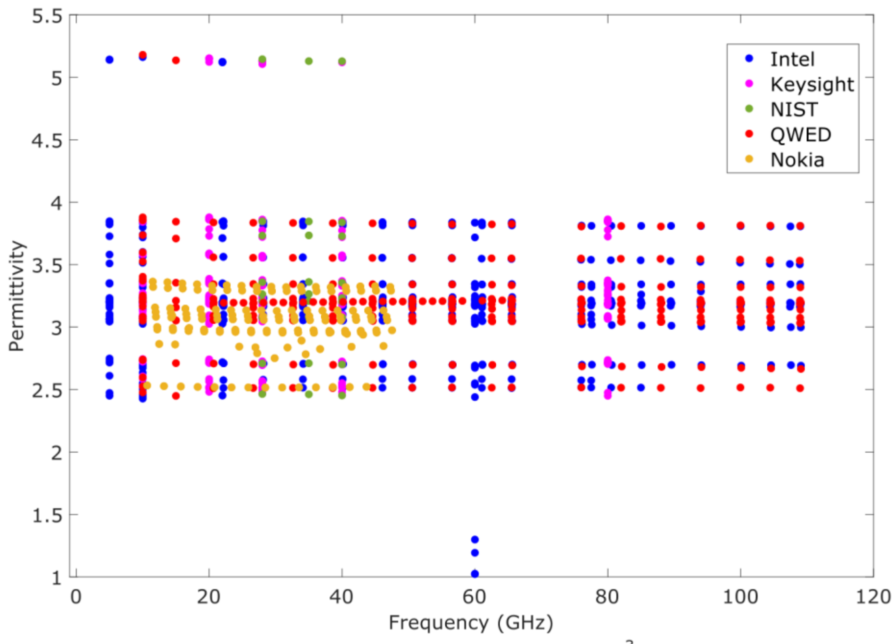
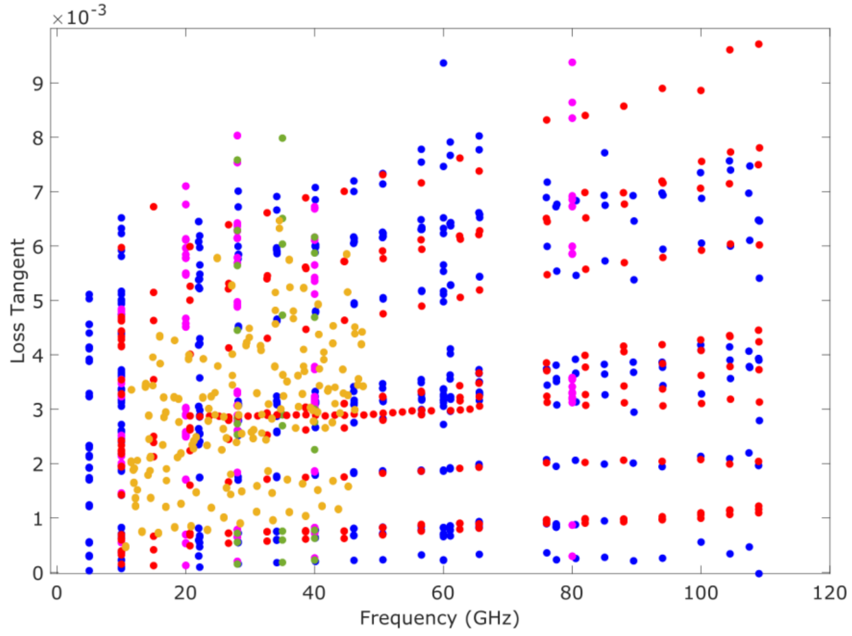
Characterisation of “real” materials

- ❑ Industry samples provided by the members of Project Consortium
- ❑ 2 types of material samples: electronic and automotive
- ❑ Over 50 samples in total
- ❑ 5 labs
- ❑ 4 measurement techniques (SPDR, SCR, FPOR, and BCDR)





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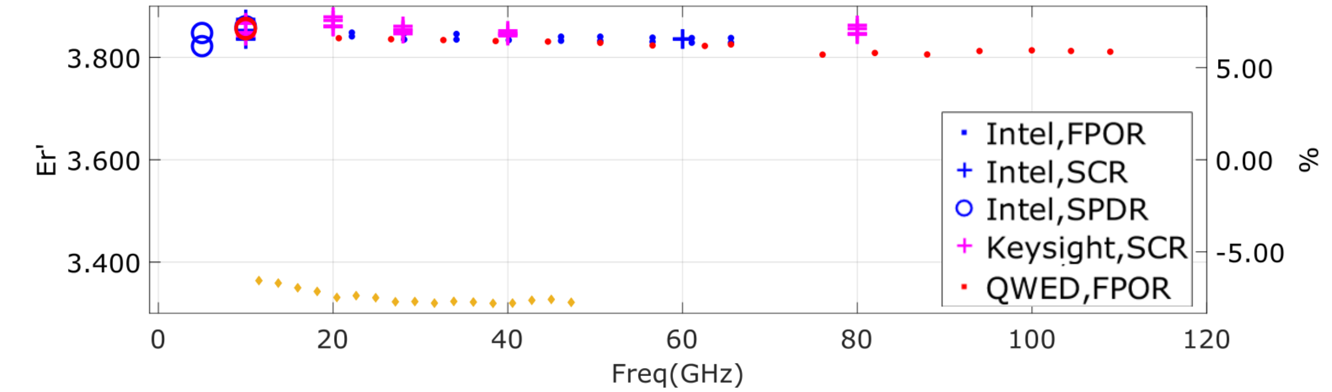
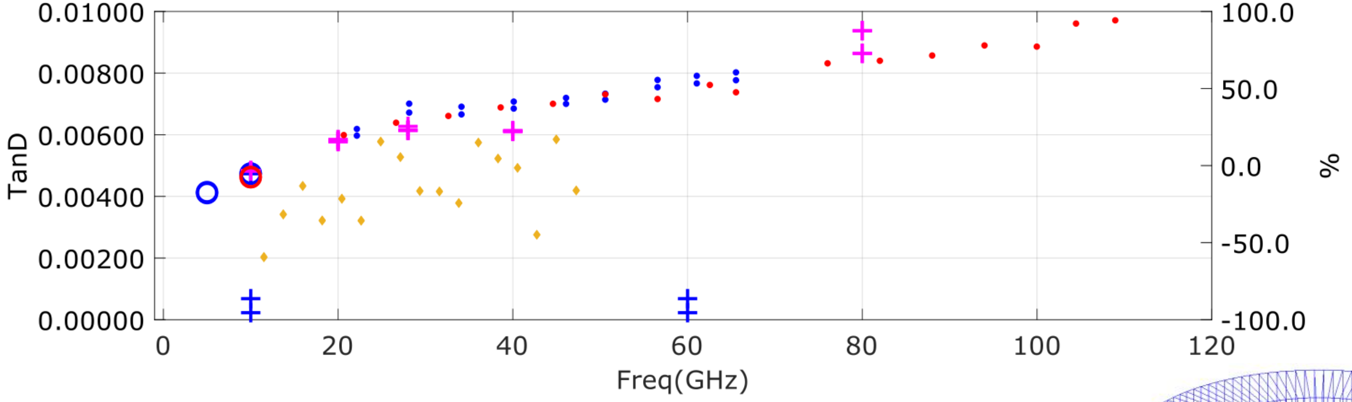
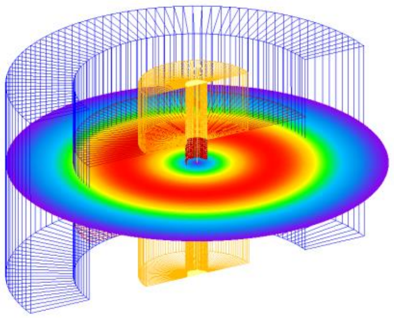
Characterisation of “real” materials (2)

Electronic materials

Highest measured permittivity material

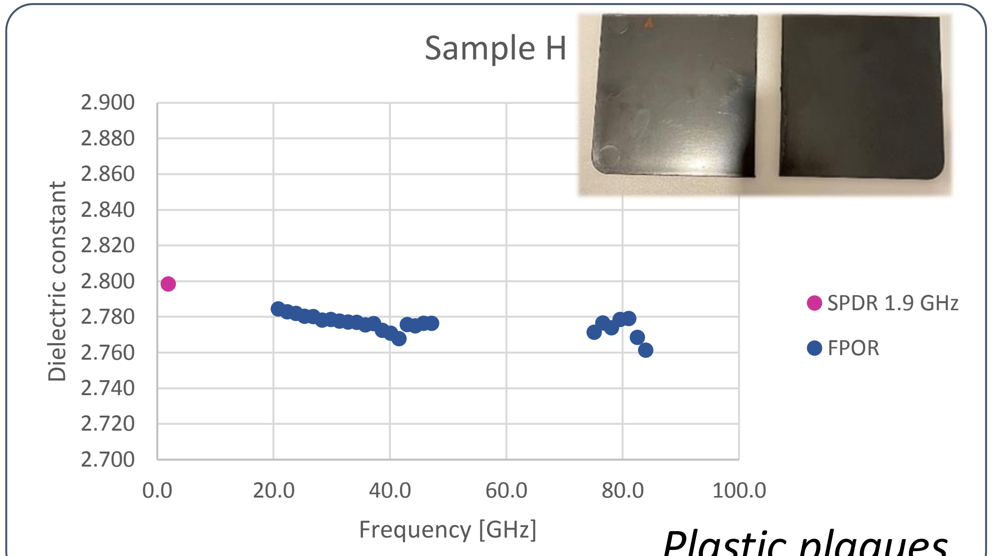




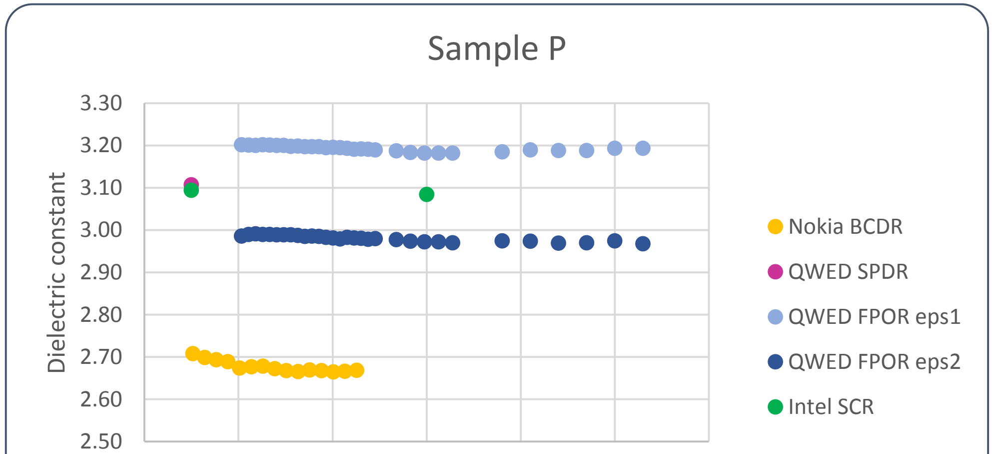


Electric field in SPDR

Automotive materials



Plastic plaques



Foils with thin films deposited

Observations and conclusions

- Two sample size sufficient to cover all considered test methods
- Accurate thickness evaluation is of high importance
- Thickness variation and sample flatness determine uncertainty of Dk extraction
- Results variation across the labs of ±2%

- *Standard reference materials are of high interest*

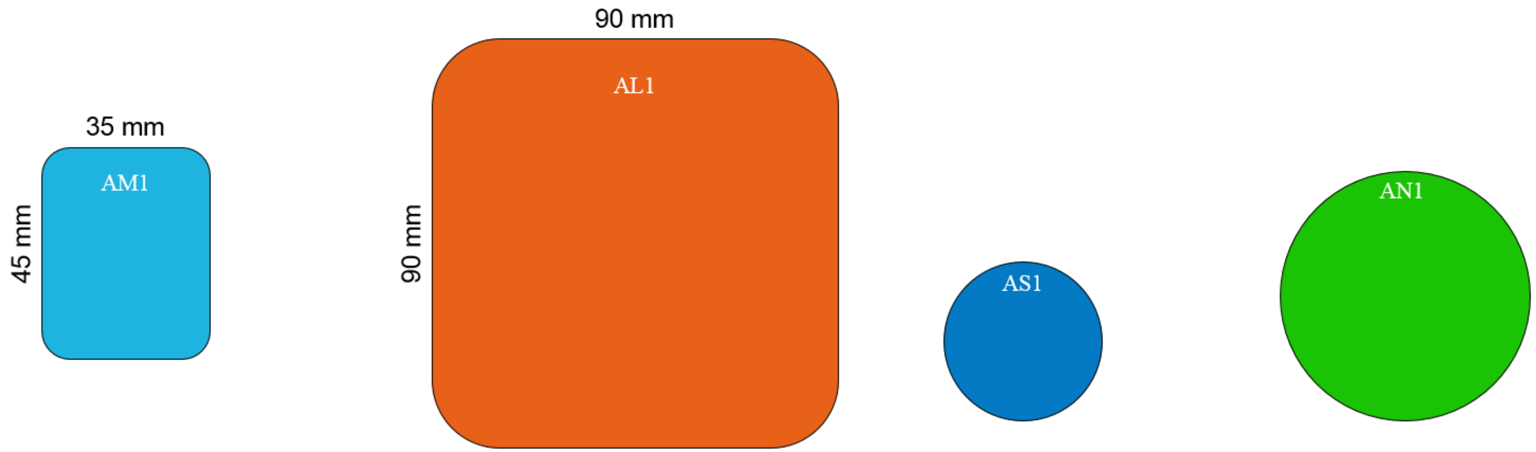
Standard reference material

- A strong need for standard reference material
- *Traceable standard – dielectric parameters certified by NIST*
- Calibration of 5G & 6G material characterization fixtures

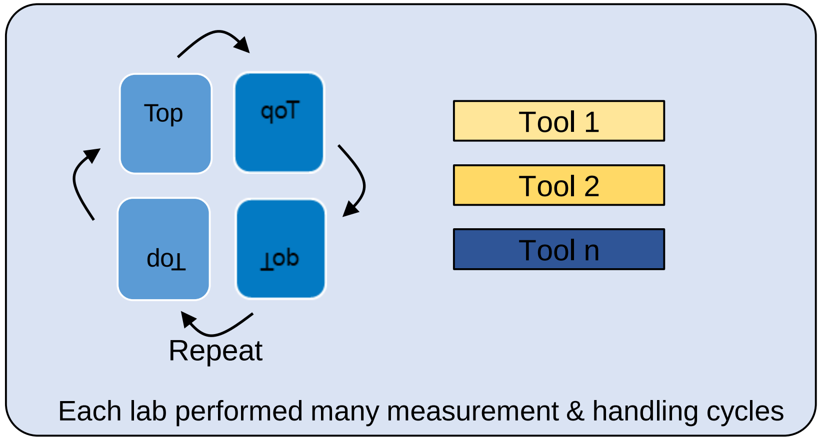
- Round Robin testing to support SRM development
- Targeting 0.2% uncertainty in SRM in round robin results
- 9 labs in round robin testing

Round Robin 1

- SRM candidate material – fused silica
- 137um – thick sample
- Four characterization methods: *SCR, SPDR, FPOR, BCDR*
- Three sample sizes:
  - 90 x 90 mm
  - 35 x 45 mm
  - Dia 30 mm & dia 49 mm



- 9 labs involved
- Testing in-plane (FPOR) and out-of-plane (BCDR) anisotropy



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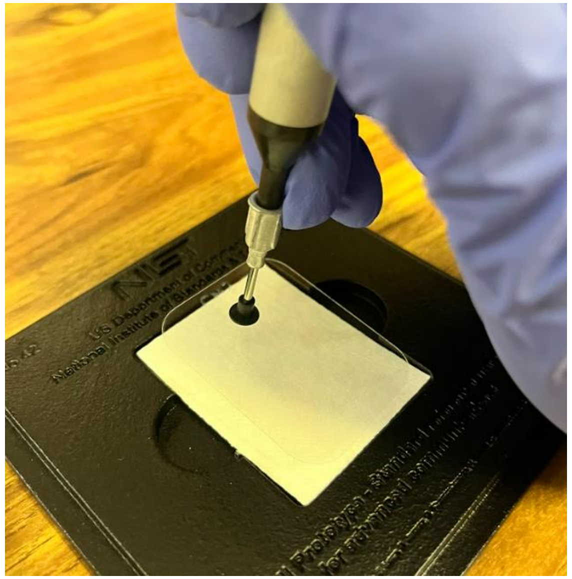
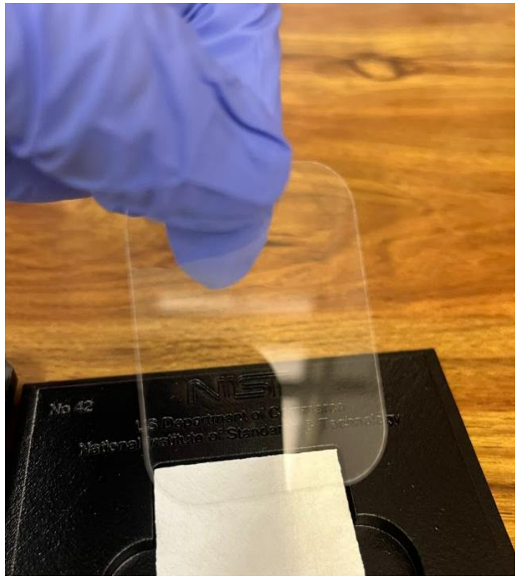
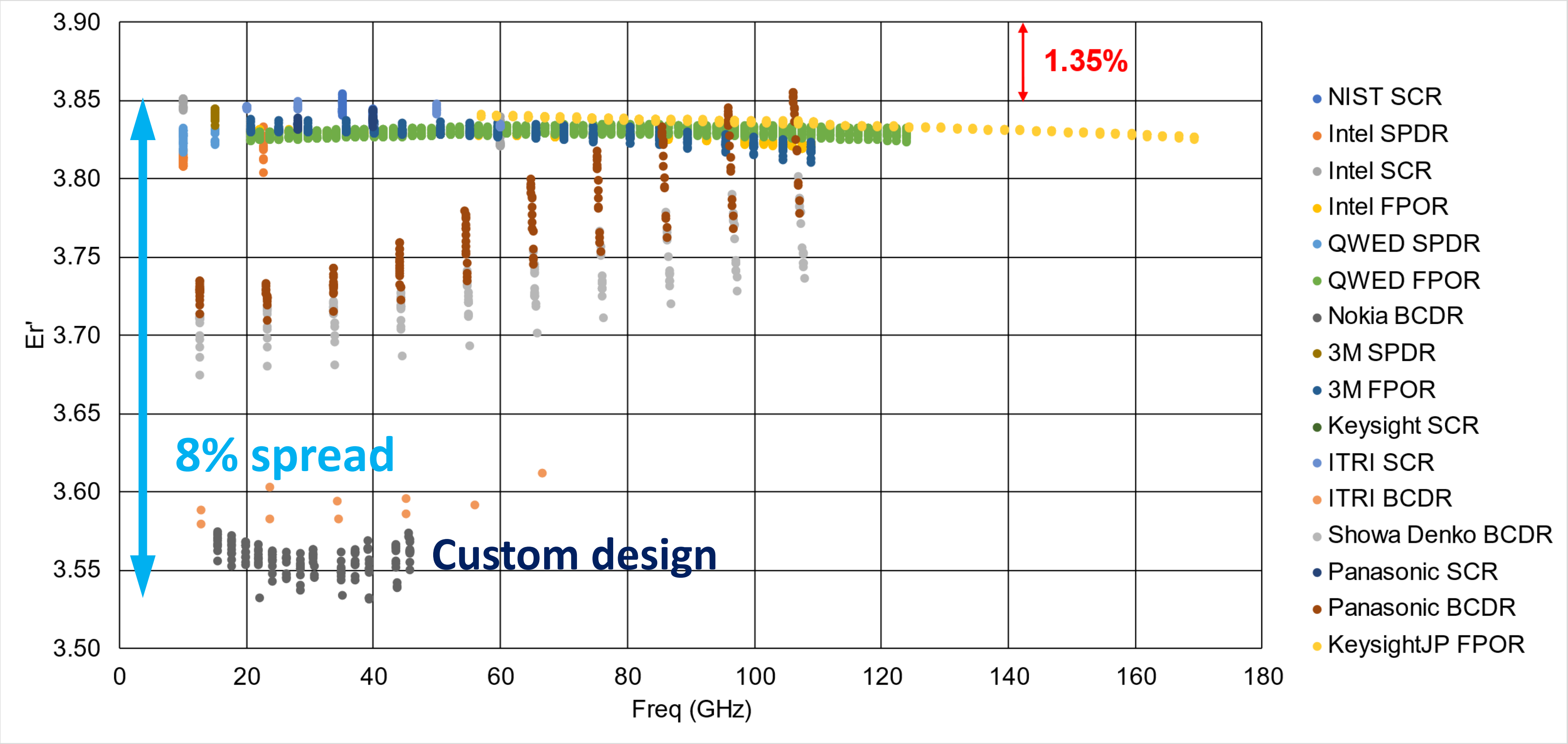
SRM candidate





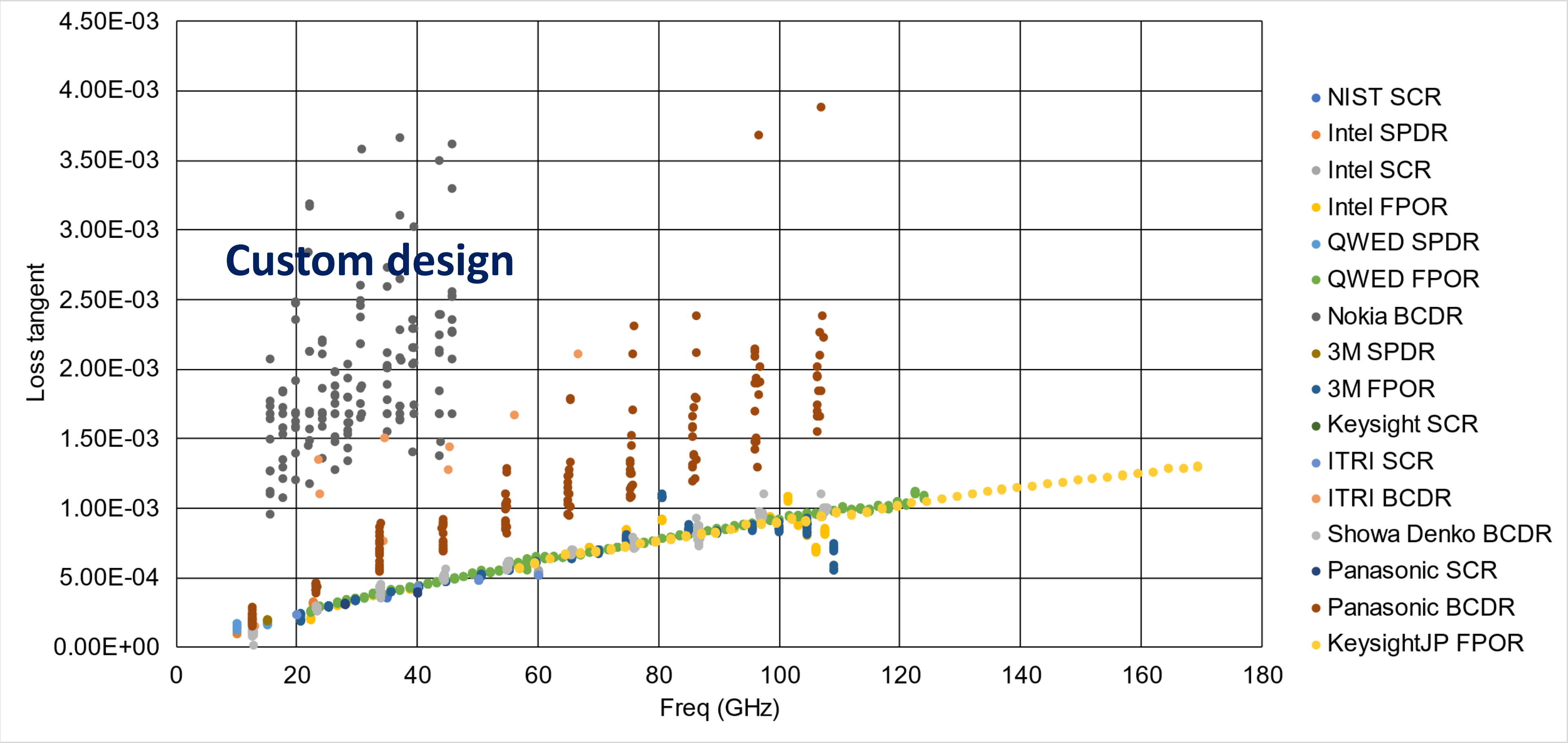
Round Robin 1 results (1)

Total of 2991 measurement points



Round Robin 1 results (2)

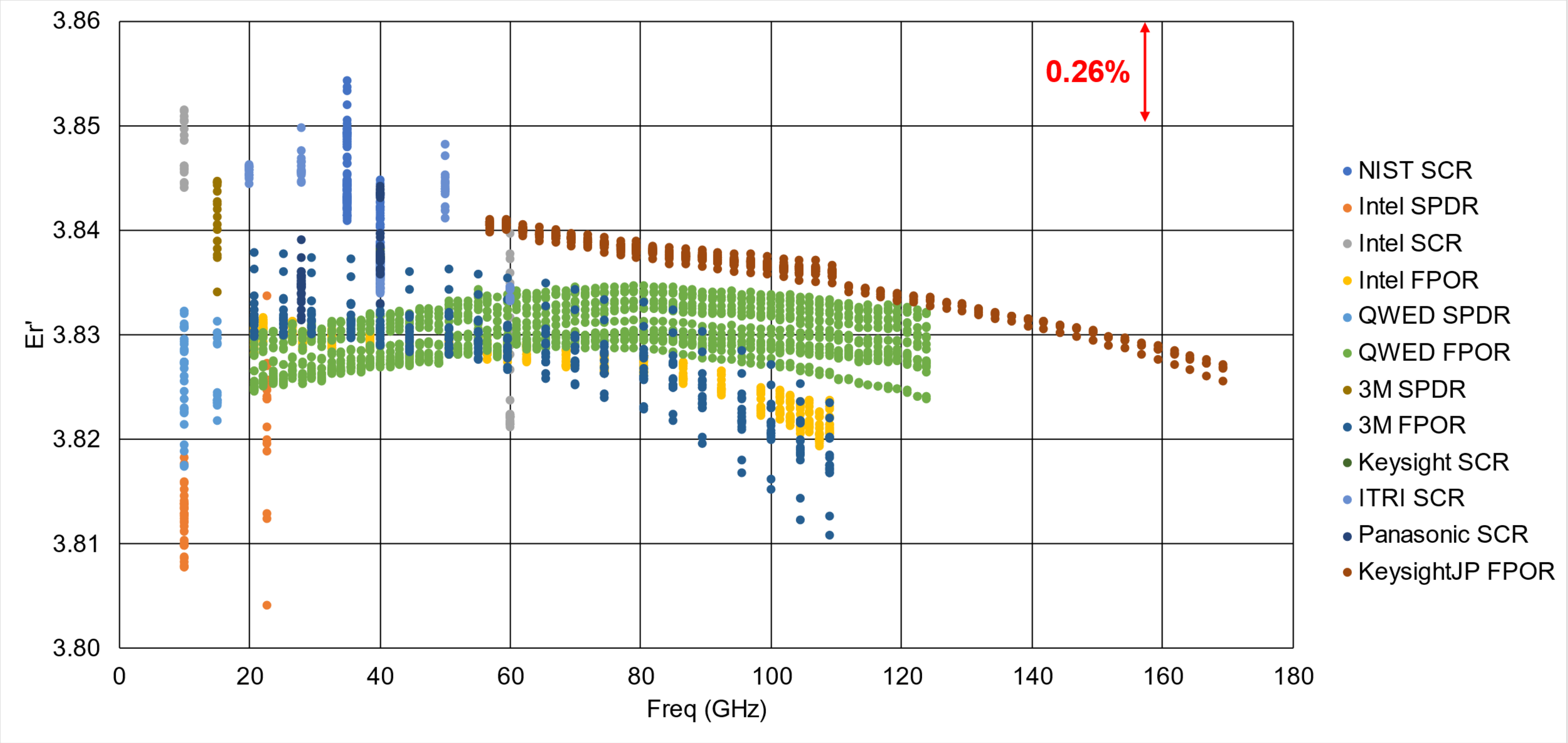
Total of 2991 measurement points



Round Robin 1 results (3)

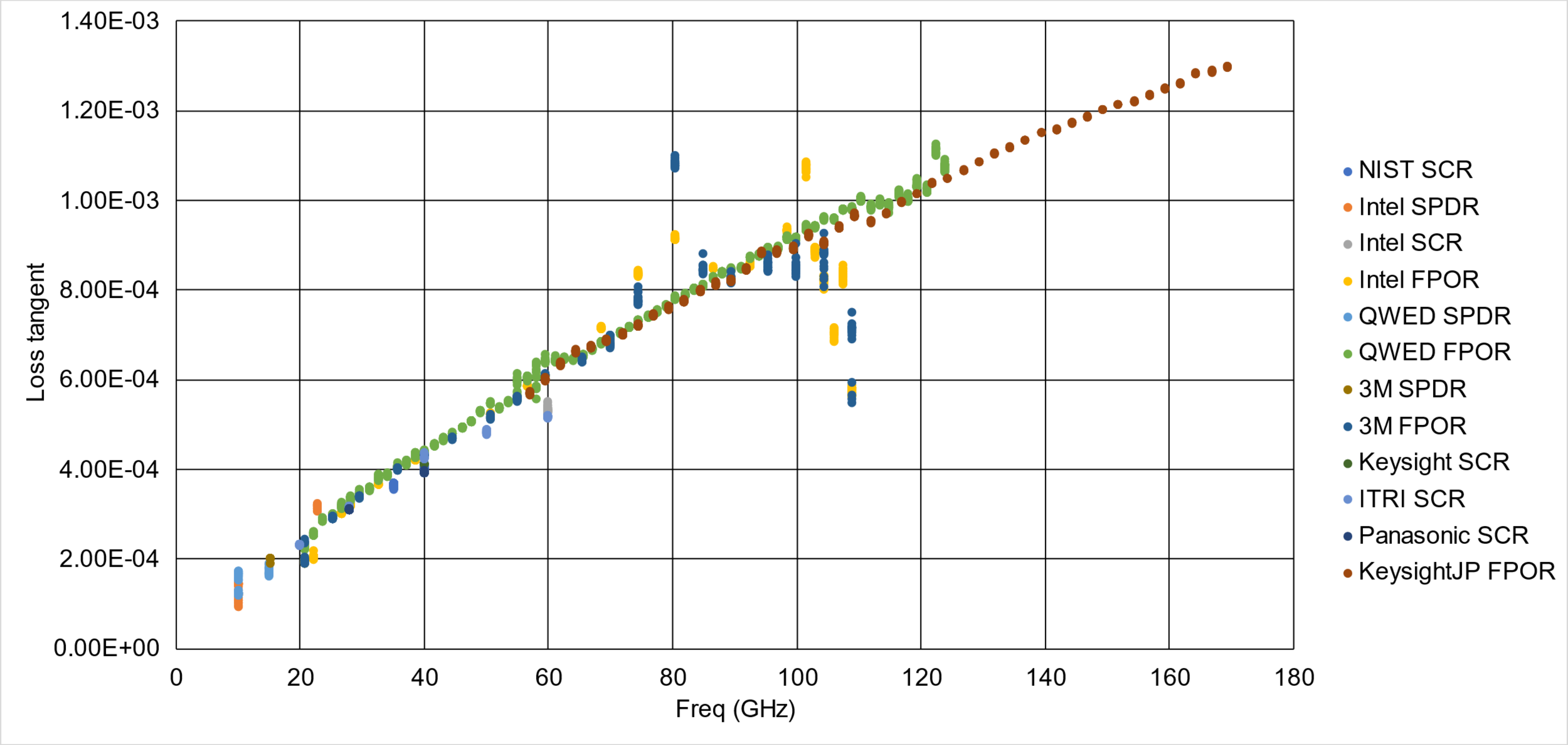
In-plane measurements

Agreement within 1.6%



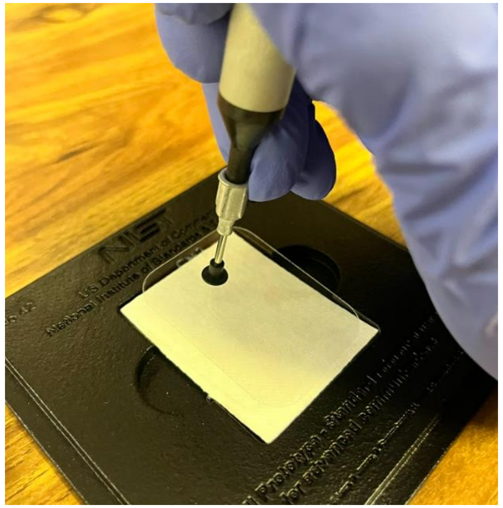
Round Robin 1 results (4)

In-plane measurements

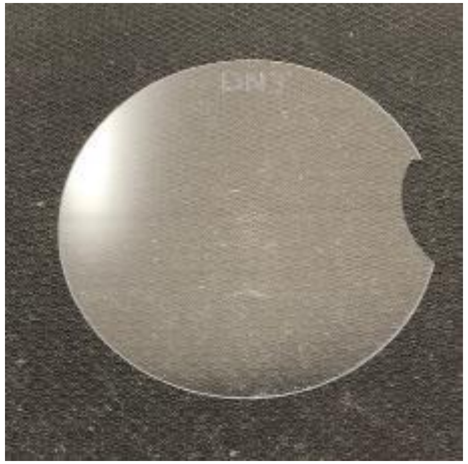


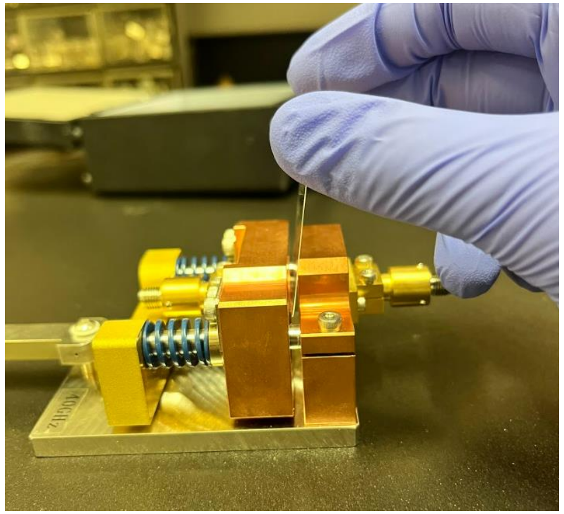
Challenges

- 137 um SRM candidates tested
- Handling issues - samples breakage:
  - Samples clamping
  - Thickness measurements
  - In between measurements
- Thickness uncertainty → potential source of Dk spread

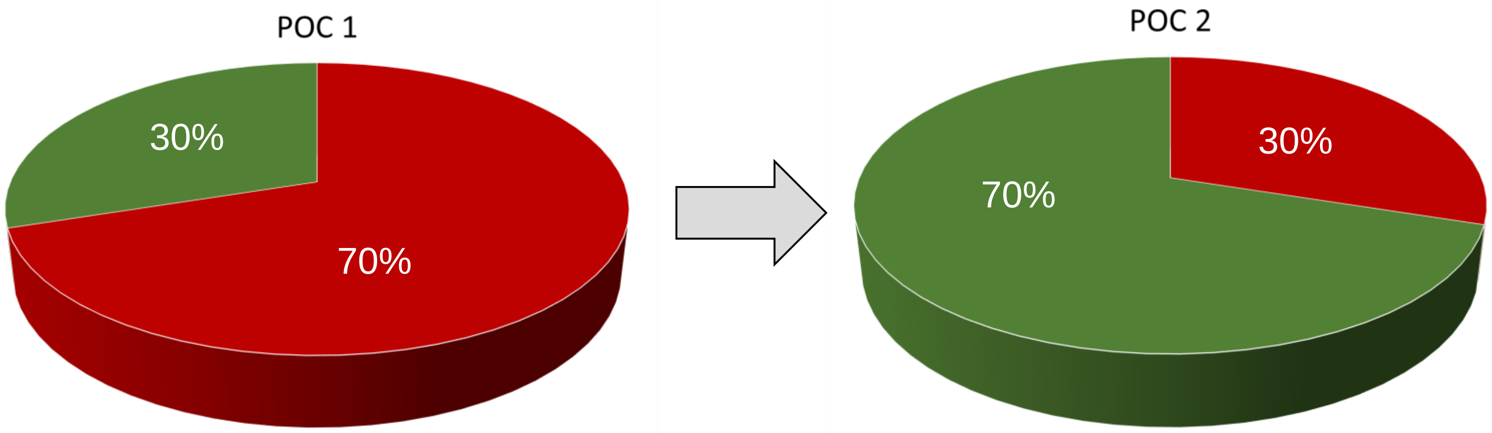


- Round Robin 2:
  - Improving handling – 150um thick sample
  - Expected 'strength' to increase ~th^3
  - Thickness measurements insight
  - Healed edges to reduce crack initiation sites





Round Robin 1 & 2 results



138um No healing etch

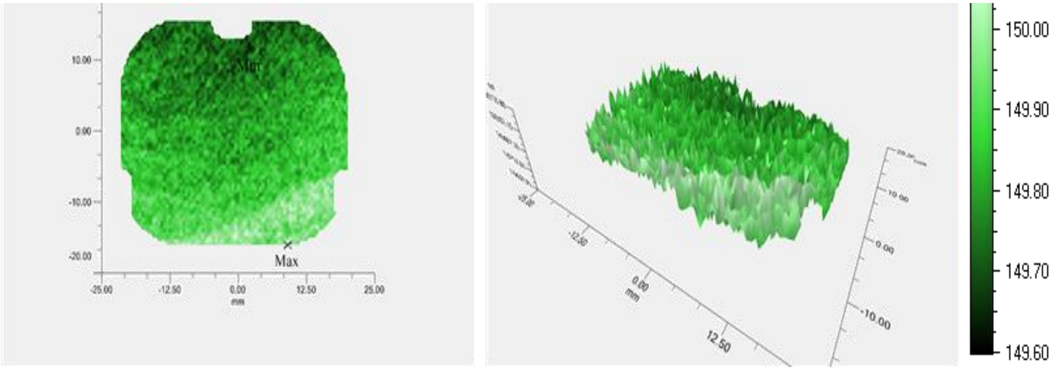
150um With healing etch

RR2: 9 labs, >2500 data points

Labs with breakage

Labs without breakage

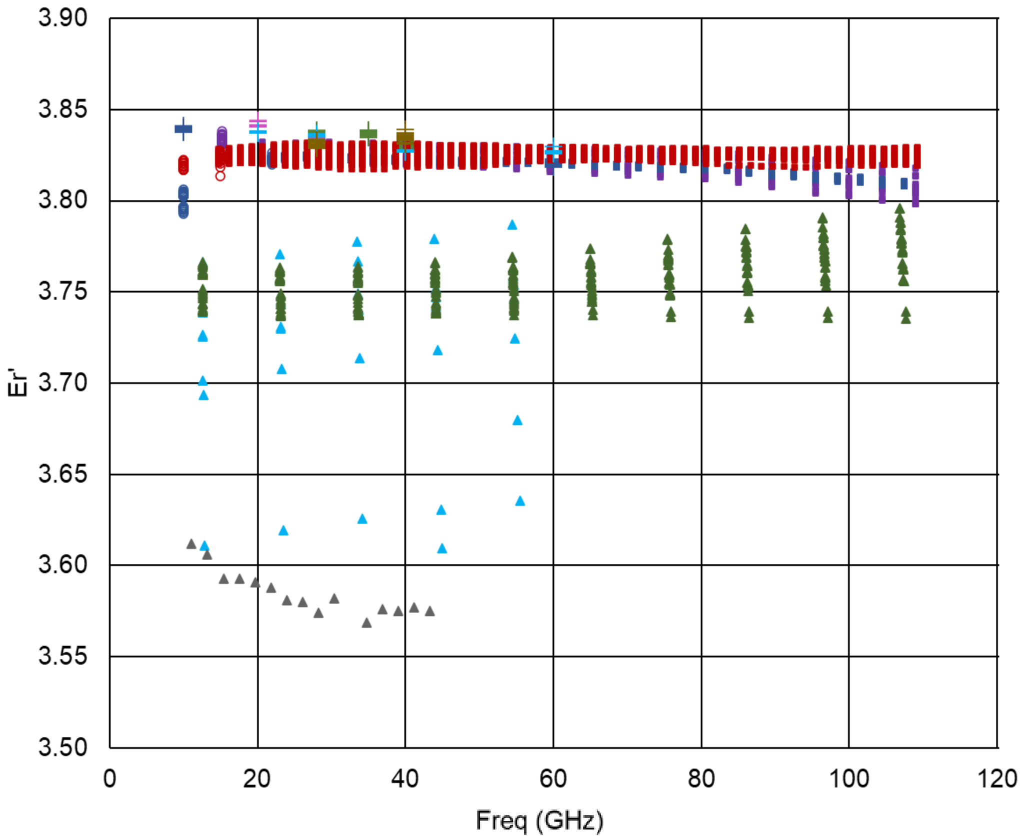
2D mapping of thickness - interferometer

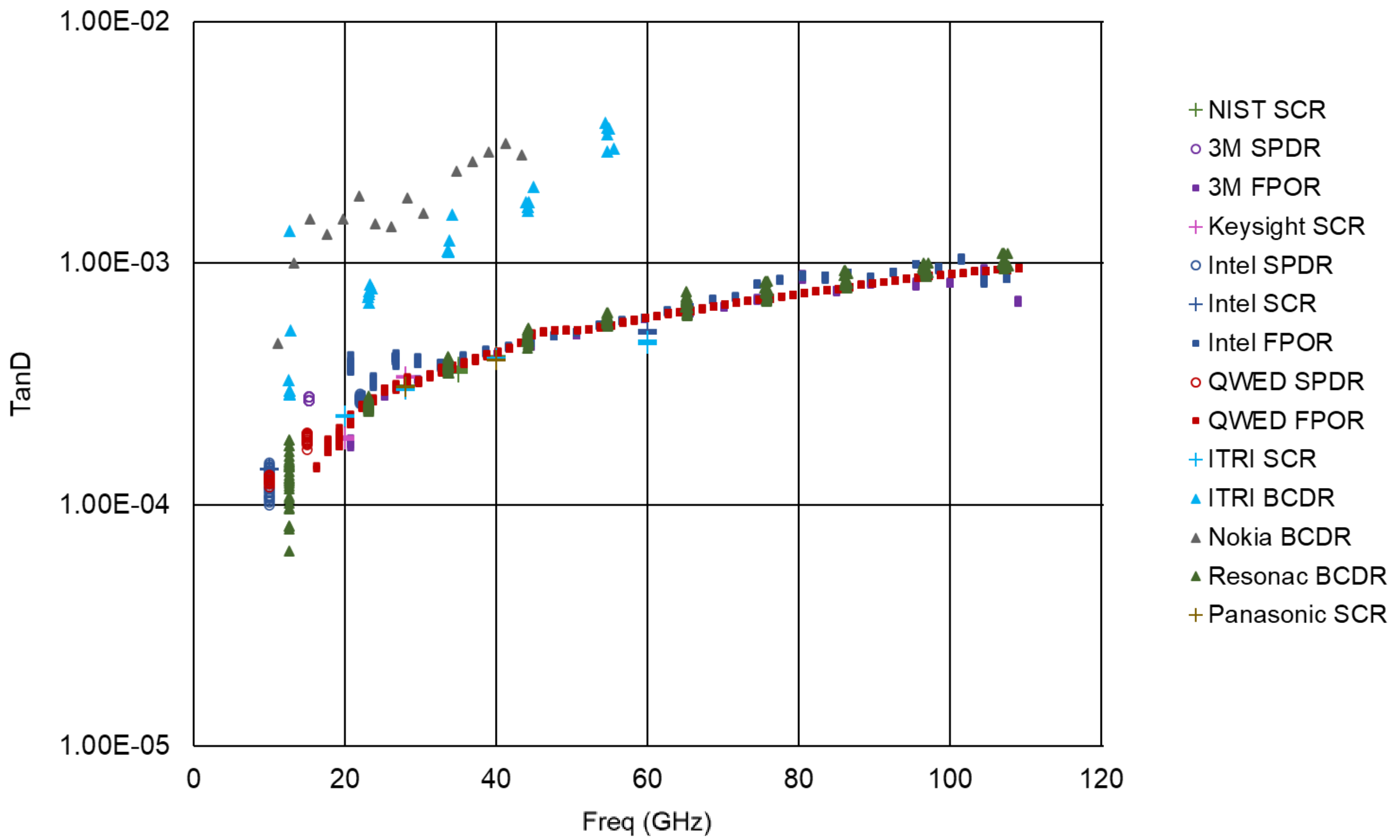


- Significant improvement in handling robustness
- Represents hundreds of measurement cycles
  - Remove – rotate – insert
  - Lots of mechanical handling

Fused silica samples are robust enough for SRM

Round Robin 2 results





- Results similar to RR1 with less breakage
- Generally good repeatability within-lab

- **Unknown Accuracy – this is why we need a standard**

iNEMI 5G/6G MAESTRO: Partners

Roadmap contributors are leaders in this field
from industry, universities and research institutes

NIST RF
Technology
Center

MAESTRO Roadmap

Table 5G-3 Materials Characterization Needs, Gaps, and Today's Technology Status with Respect to Current and Future Needs

	ROADMAP TIMEFRAME			
TECHNOLOGY ISSUE	**TODAY (2023)**	**3 YEARS (2026)**	**5 YEARS (2028)**	**10 YEARS (2033)**
	Frequency Range= 28-110 GHz	**Frequency Range= 110-170 GHz (D-Band)**	**Frequency Range= 220-350 GHz (G Band)**	**Frequency Range= >500 GHz**
CHARACTERIZATION FREQUENCY RANGE				
NEED	Tools needed at 5G frequencies (28-39 GHz)	Tools needed at D-band (110-170 GHz)	Tools needed G-band (220-350 GHz)	Tools needed for >500 GHz
CURRENT TECHNOLOGY STATUS	**Solutions deployed or known**	**Solutions need optimization**	**Solutions not known**	
GAP	(NO GAP?)	Few tool options	Robustness and availability	
CHALLENGE	Limited tool availability for high frequencies	Supporting equipment is expensive (i.e., 100 GHz VNA)	Expensive supporting equipment	
CHALLENGE	High frequencies place burden on mechanical precision of equipment	Methods still in academic space		
CHALLENGE	High equipment cost			

Publications & Reports

Roadmaps

Low Loss Dielectric Materials Characterization Roadmap (April 2023)

www.inemi.org/article_content.asp?adminkey=cc22bf8eb1bfb8248c594509fe54dd9b&article=275

Thank you for your attention!