Extension of reference materials for standardization in the production of large deployable antennas

Lukasz Nowicki, Malgorzata Celuch, Marzena Olszewska–Placha, Janusz Rudnicki

QWED Sp. z o. o.
Krzywickiego 12
02078 Warsaw, Poland
Email:lnowicki@qwed.eu

Outline

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2. Measurement methods
3. Practical Microwave and Millimetre-Wave resonance methods
4. Results
5. Conclusions

mmWave Permittivity Reference Material Development

Co-Project Leads:
- Nate Orloff (NIST), Michael J Hill (Intel)

INEMI Project Lead:
- Urmi Ray

Project Initiative Team:
- Intel, ITRI, Keysight, NIST, Nokia, QWED

Next-generation 5G/6G solutions require ultra-low loss laminate materials and PCBs/substrates for the efficient design of communications equipment. Development of standard reference materials for precision permittivity characterization metrologies could enable industry to speed development time by reducing the need for iterative design tuning caused by errors in material models.

QWED team actively contributes to the abovementioned industrial projects. In parallel, we continue research and innovation activities in European framework projects concerned with materials modelling and characterisation…

MMAMA

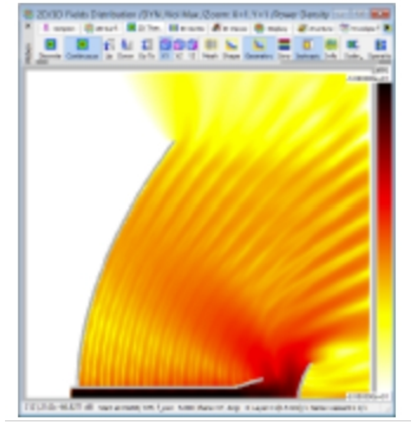
NanoBat

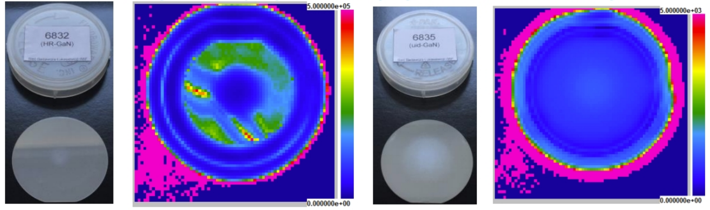
I4Bags

ULTCC6G_Epac

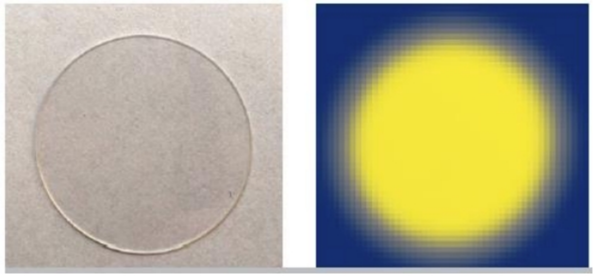
and more…

mmWave Permittivity Reference Material Development

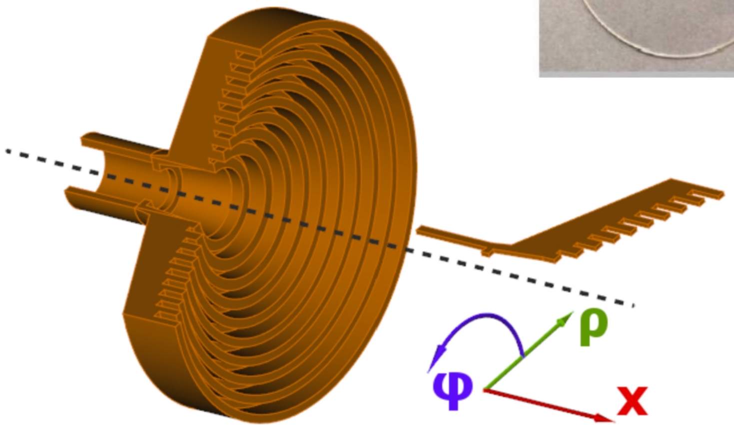




2D surface map of resistivity of semiconductor wafers

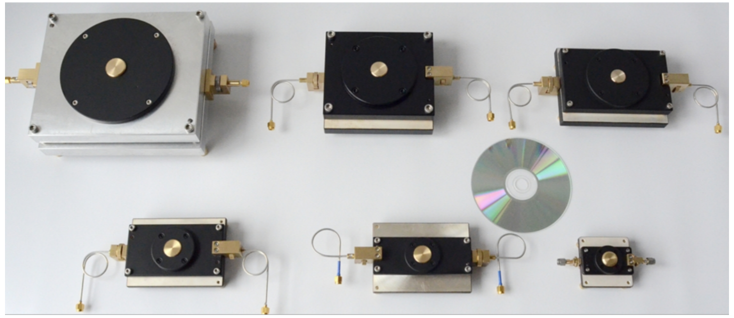


2D surface map of dielectric constant of quartz



This presentation addresses the critical need for characterizing and evaluating materials in antenna research and industry, particularly in the context of mmWave frequencies. Extensive round-robin testing has revealed the challenges posed by increased dielectric losses in microwave materials when applied to mmWave. The study utilizes new measuring setup which results will be include into standardized benchmarking, extracting electromagnetic parameters using consistent principles across laboratories. The focus is on low-loss materials like Cyclo Olefin Polymer and Precision Teflon. Additionally, the paper previews research on standardizing Fused Silica and highlights the role of standardization in space industry, showcasing characterization methods and Digital Twins principles for extracting electromagnetic parameters.

A common benchmark was chosen for all laboratories involved in the iNEMI project.



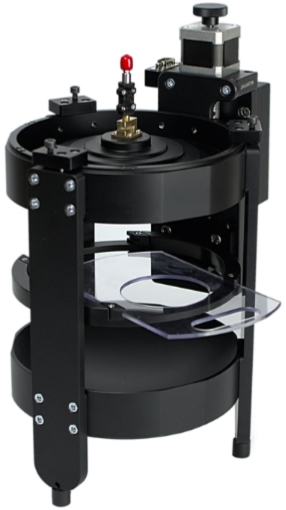
- Split Post Dielectric Resonator (SPDR), which is standardized by the International Electrotechnical Commission (IEC).

The frequencies range from **1.1** to **20** GHz.

- Another resonator is the Split Cylinder Resonator (SCR), which is standardized by the Association Connecting Electronics Industries (IPC).

The frequencies range from **10** to **80** GHz.

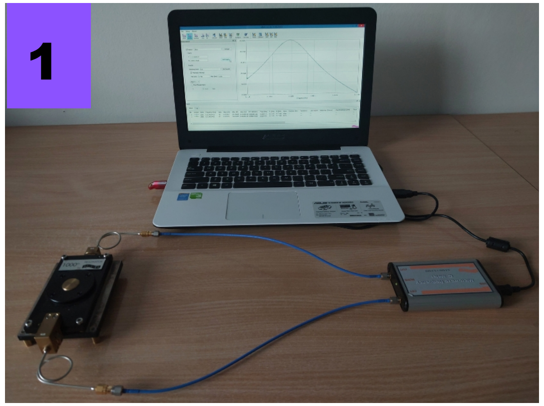
- The last type of resonator used is the automated Fabry-Perot Open Resonator (FPOR), measurements cover frequencies from **20-110 GHz** with a frequency step of **1.5 GHz**.



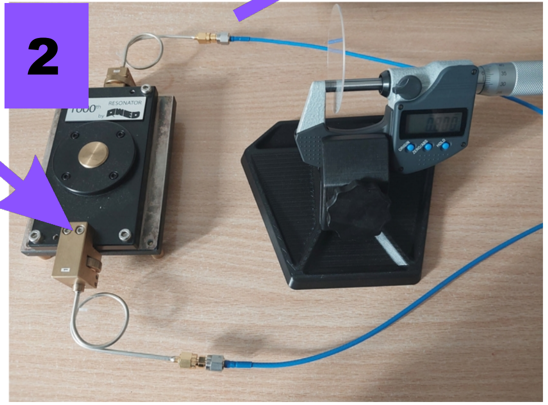
https://www.keysight.com/us/en/product/85072A/10-ghz-split-cylinder-resonator.html

Practical Microwave and Millimetre-Wave resonance methods

0. Connect the SPDR to Q-Meter using SMA cables. Connect Q-Meter to PC using USB cable.



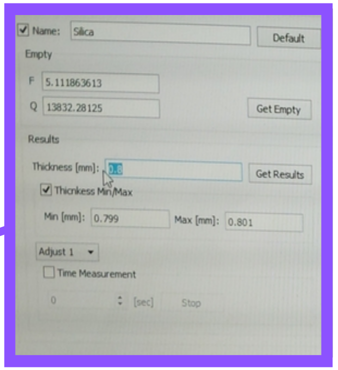
1. **Measure "empty" SPDR - app invoked measurement.**



2. Measure thickness of the sample

3. Insert the sample into SPDR

4. Insert the sample thickness into the PC app


☑ Name: Silica

Empty

F 5.111863613

Q 13832.28125

Results

Thickness [mm]: 0.8

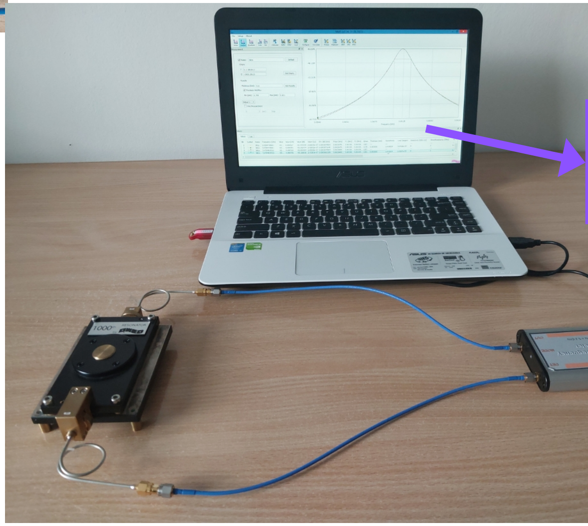
☑ Thicnkess Min/Max

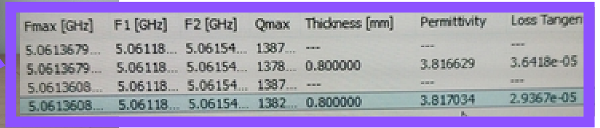
Min [mm]: 0.799 Max [mm]: 0.801

Adjust 1

☐ Time Measurement

0 [sec]





Fmax [GHz]	F1 [GHz]	F2 [GHz]	Qmax	Thickness [mm]	Permittivity	Loss Tangen
5.0613679...	5.06118...	5.06154...	1387...	---	---	---
5.0613679...	5.06118...	5.06154...	1378...	0.800000	3.816629	3.6418e-05
5.0613608...	5.06118...	5.06154...	1387...	---	---	---
5.0613608...	5.06118...	5.06154...	1382...	0.800000	3.817034	2.9367e-05

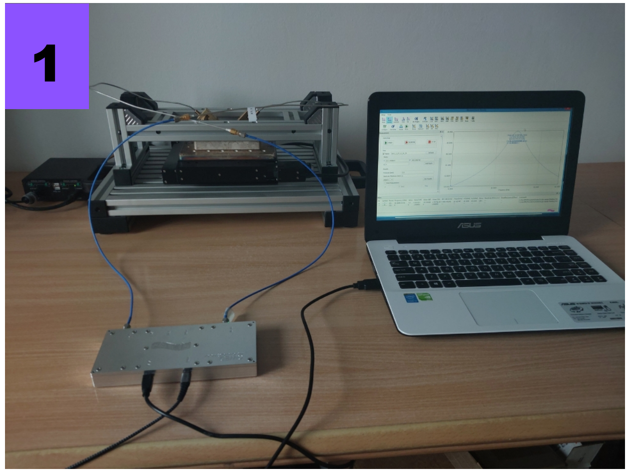
5. Material parameters are extracted automatically

Practical Microwave and Millimetre-Wave resonance methods - iSiPDR

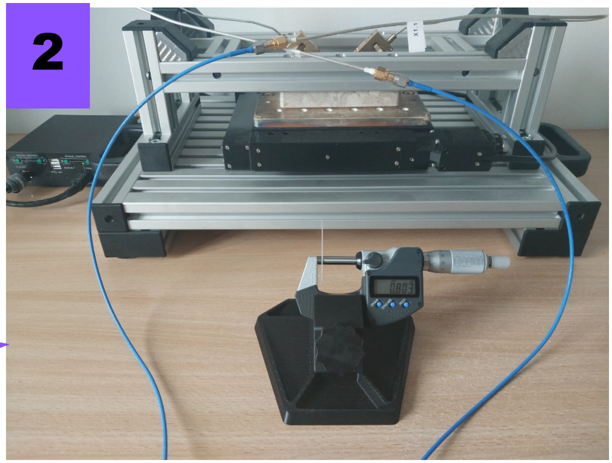
0. Connect the iSiPDR to Q-Meter using SMA cables

Connect Q-Meter and STANDA Motor to PC using USB cable.

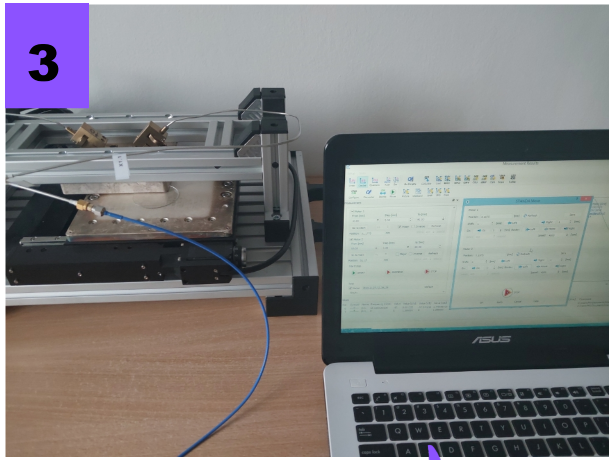
1. Measure "empty" iSiPDR



2. Measure thickness of the sample

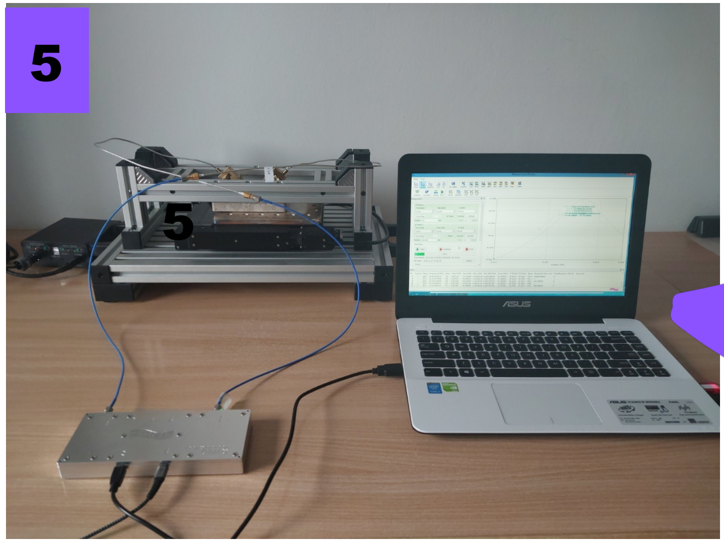


3. Insert the sample into iSiPDR - by using a STANDA Move



4. Insert the sample thickness into the PC app

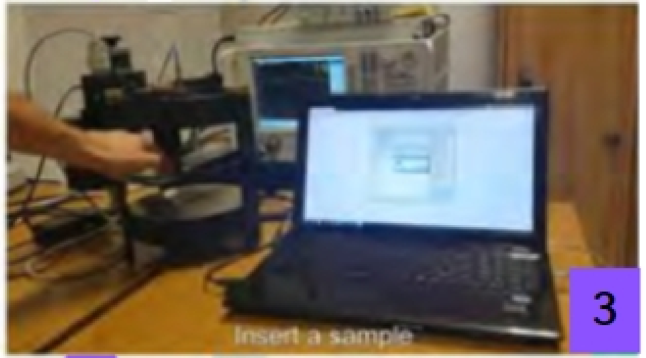
5. Material parameters are extracted automatically with each step



Practical Microwave and Millimetre-Wave resonance methods - FPOR

1. Connect the FPOR to VNA and PC with control app.

2. Measure "empty FPOR" (resonant frequency and Q-factor at M..N modes)

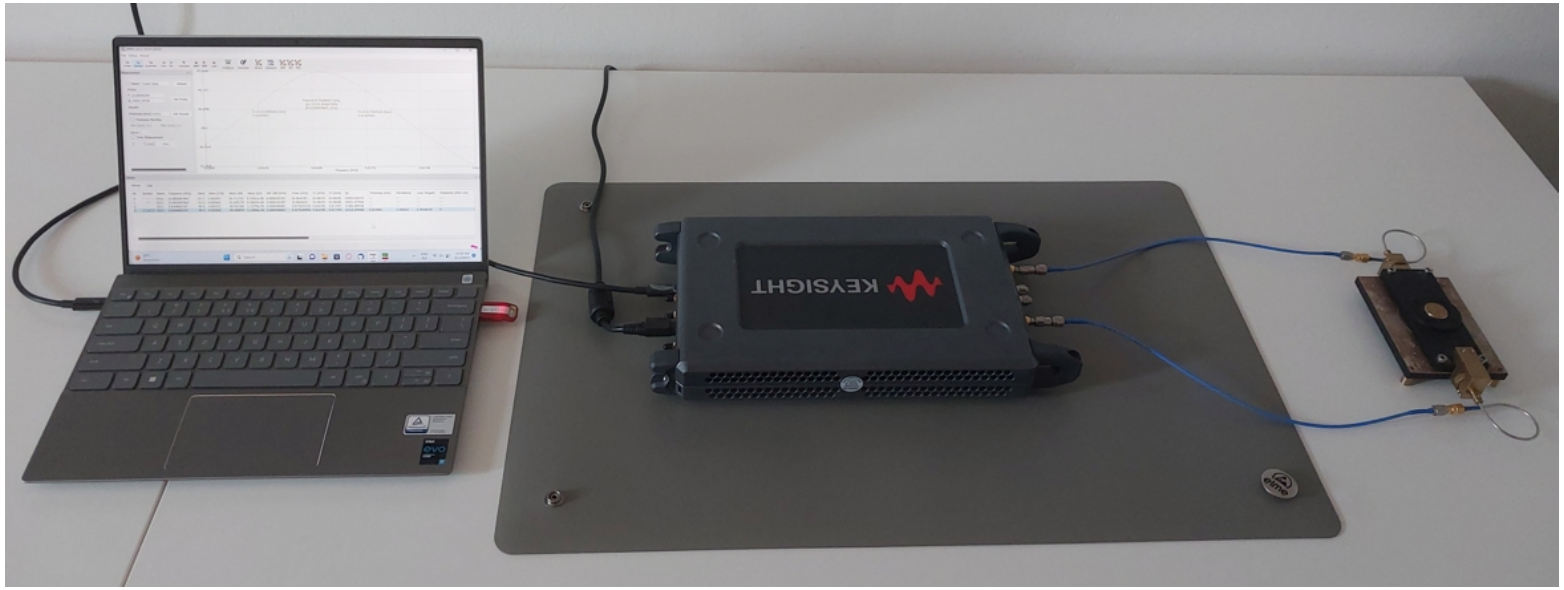


3. Insert the sample into FPOR.

4. Automatic procedure finds M..N modes of sample-loaded FPOR.

5. Material parameters at consecutive frequencies (modes) are extracted automatically.

Practical Microwave and Millimetre-Wave resonance methods

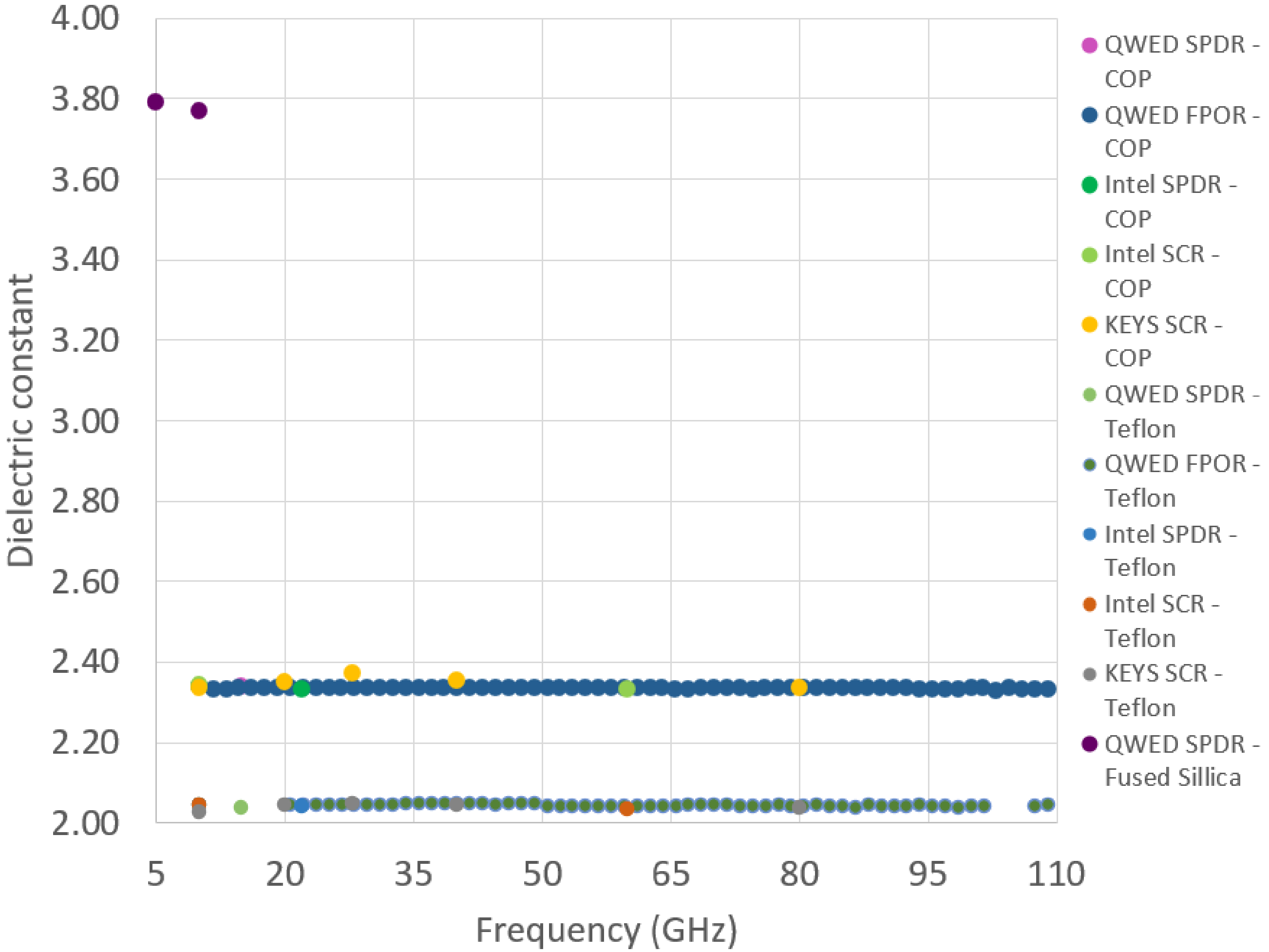


A new measurement station has been set up that uses a VNA, SPDR and a Laptop equipped with an application to operate the VNA and extract material parameters from the sample.

The VNA measures complex scattering parameters, which describe how electromagnetic signals interact with a SPDRs.

The VNA incorporated into this measurement station is the **Keysight P5008 Streamline**. It's provides a frequency range spanning from **100 kHz** to an **53 GHz**. Such a range fills the need for the SPDR used in this case. To ensure accurate measurements, it is imperative that the fused silica samples are flat and uniform. Any irregularities in the sample can introduce errors in the permittivity **ε** and loss tangent **tanδ** extraction.

Results

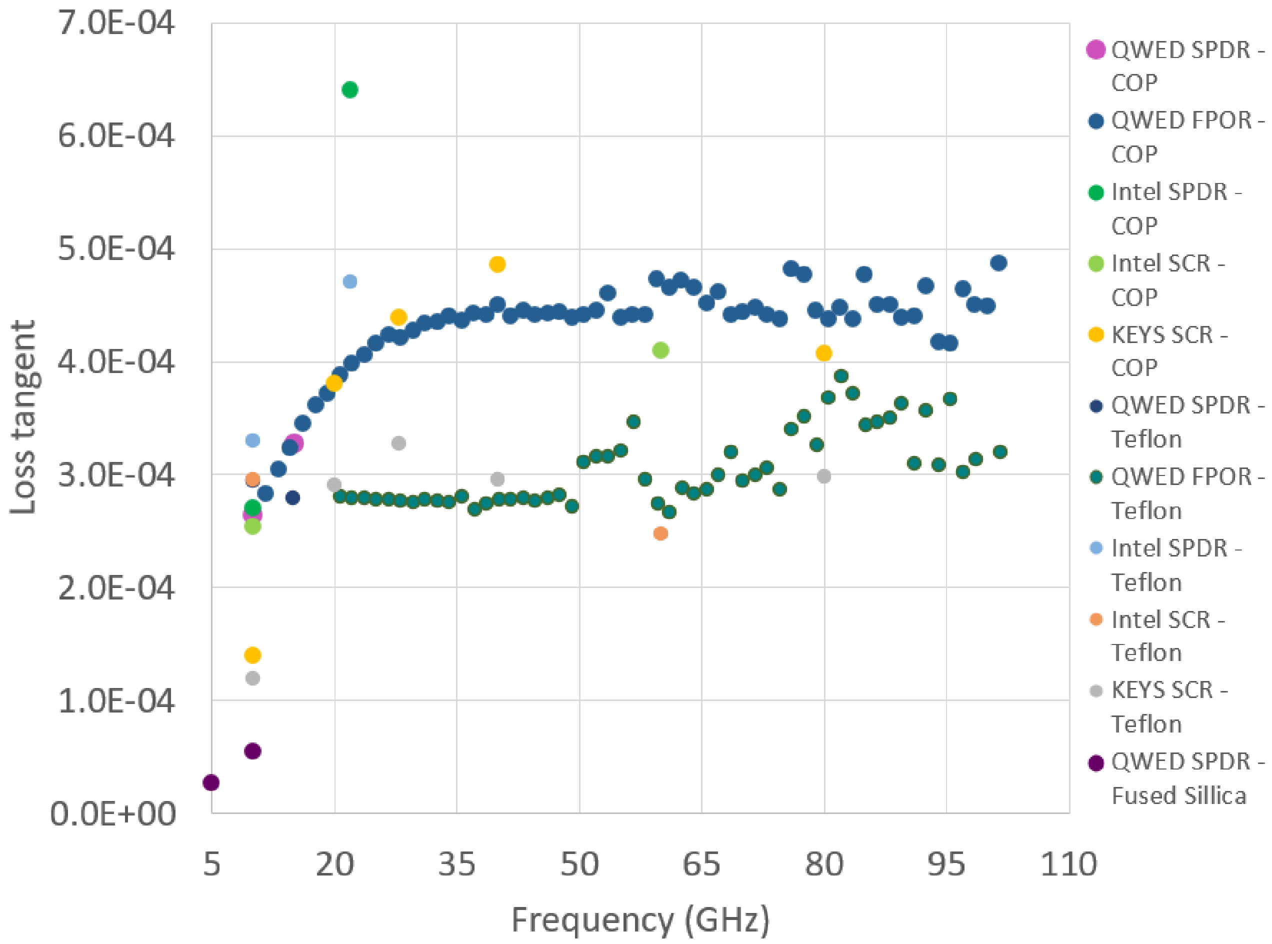


Summary of results of dielectric constant measurements obtained by SPDR, SCR and FPOR methods for Cyclo Olefin Polymer (COP), Teflon and Fused Sillica.

Our study focused on samples characterized by a low dielectric constant, thickness from 0.2 mm to 0.8 mm, and minimal dispersion coefficients. Fused Sillica closes the upper limit of low dielectric constants. We chose these criteria to align with the requirements of 5G technology. Notably, to ensure consistency in our findings, samples were transferred between collaborating laboratories involved in the measurements, prompting the establishment of rigorous protocols for sample transportation and storage.

The dielectric constant measurements for CPO, Teflon and Fused Sillica samples, with each data point corresponding to independent measurements conducted in various laboratories as indicated in the legend. The results range from 1% to 2.34%

Results

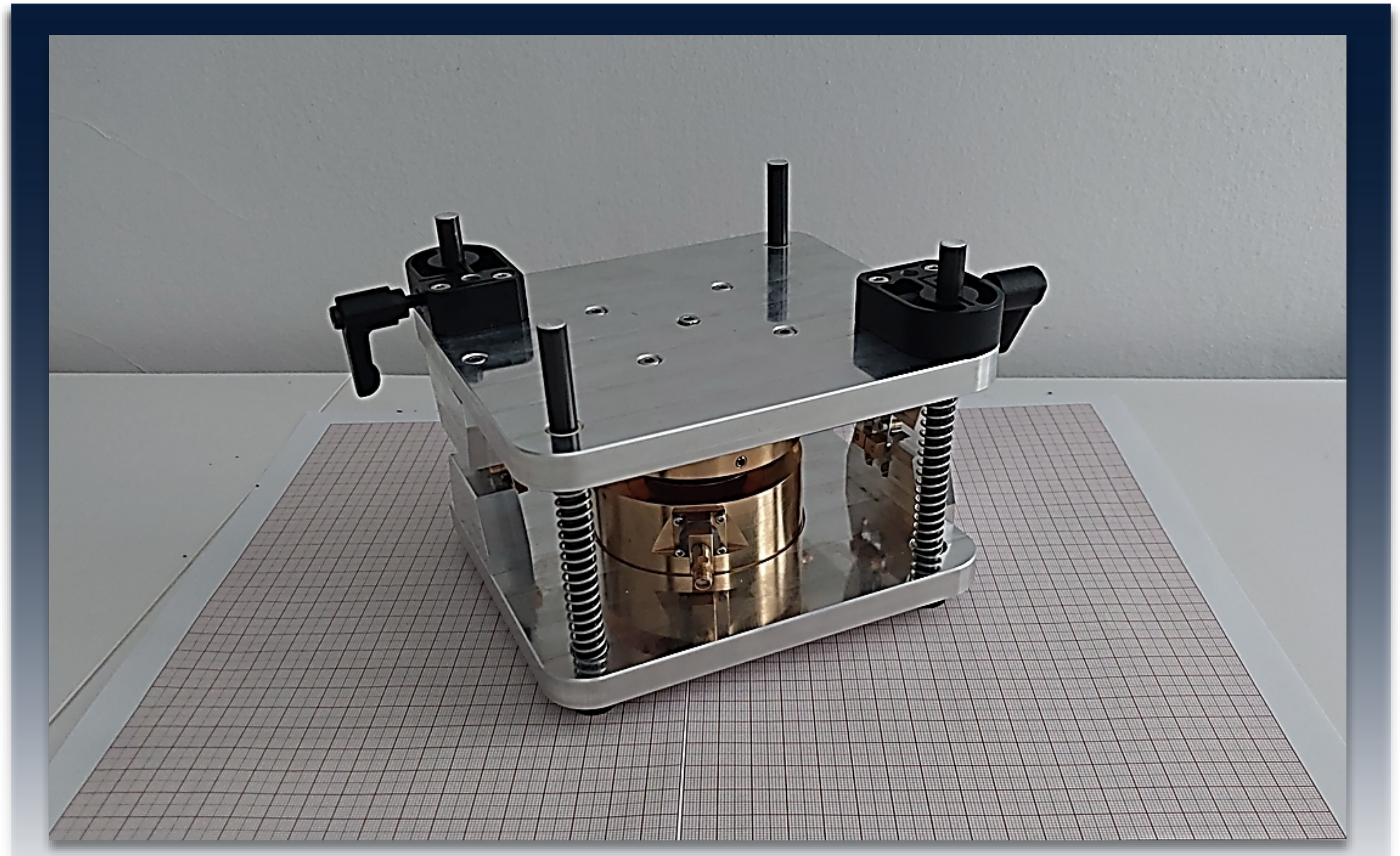


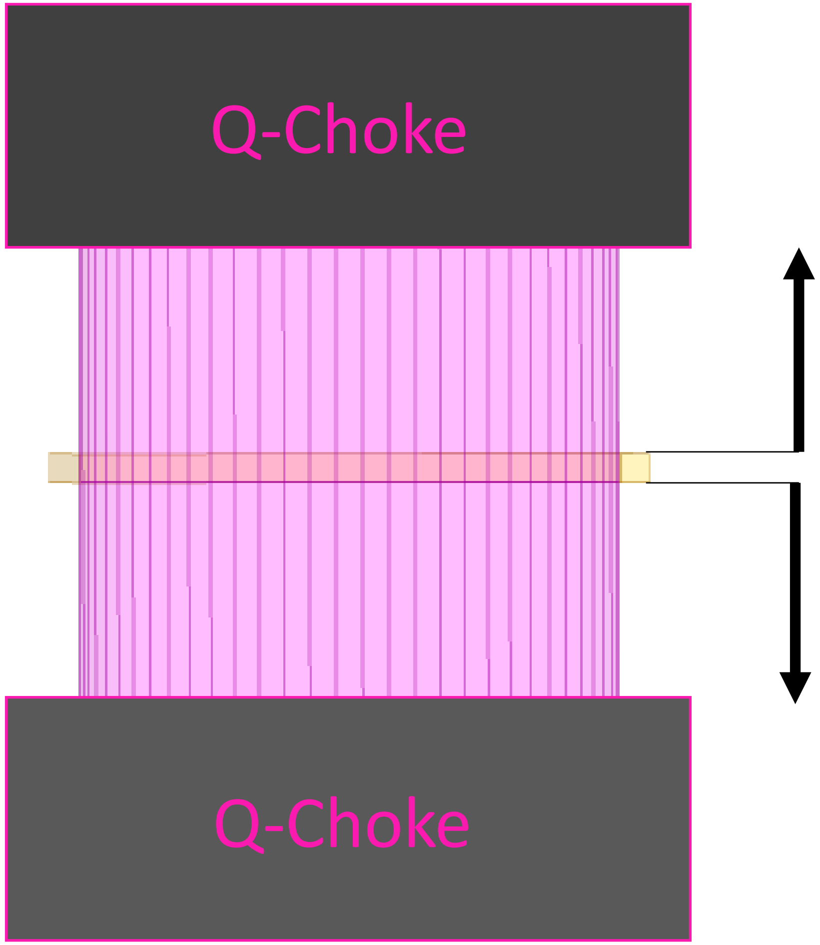
Summary of results of loss tangent measurements obtained by SPDR, SCR and FPOR for COP, Teflon and Fused Sillica.

For CPO, the loss tangent remains constant above 30 GHz as a function of frequency. Below this threshold, we observed an intriguing relationship, corroborated by other independent resonance methods. In the case of Teflon, there is some variability in the FPOR results obtained above 50 GHz, attributable to the switching of frequency extenders on the VNA used for measurements.

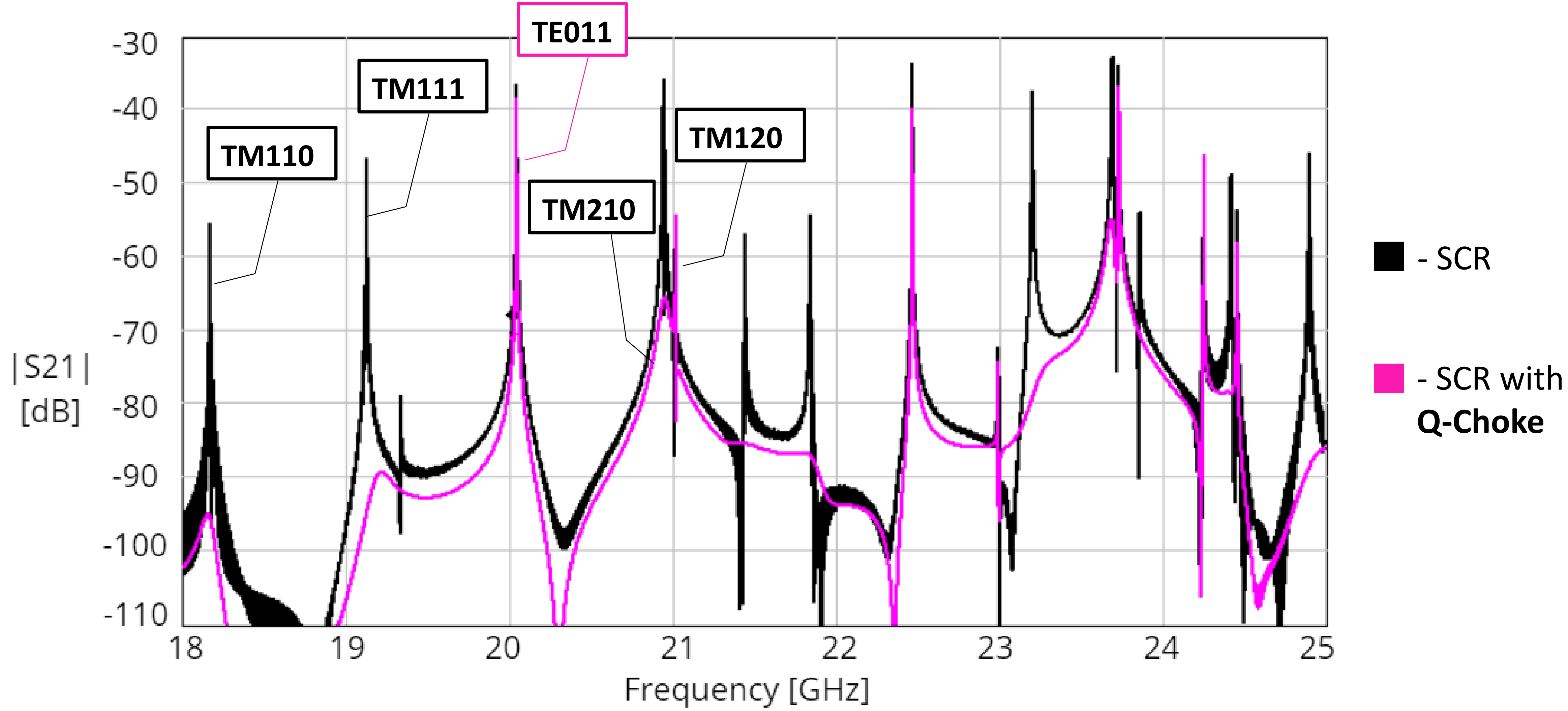
Frequency [GHz]:	ε	tanδ
5	3.792749	2.7371e-5
10	3.768553	5.4918e-5

Split Cylinder Resonator with Q-Choke

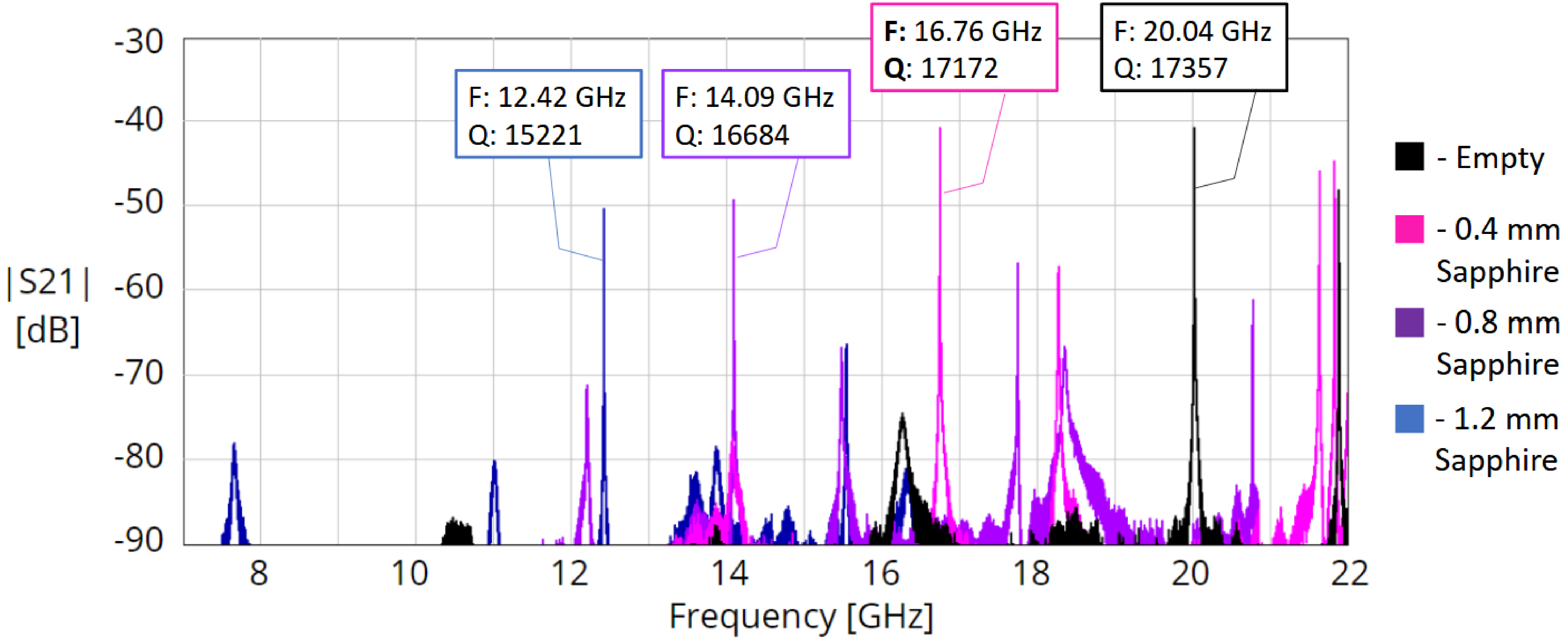




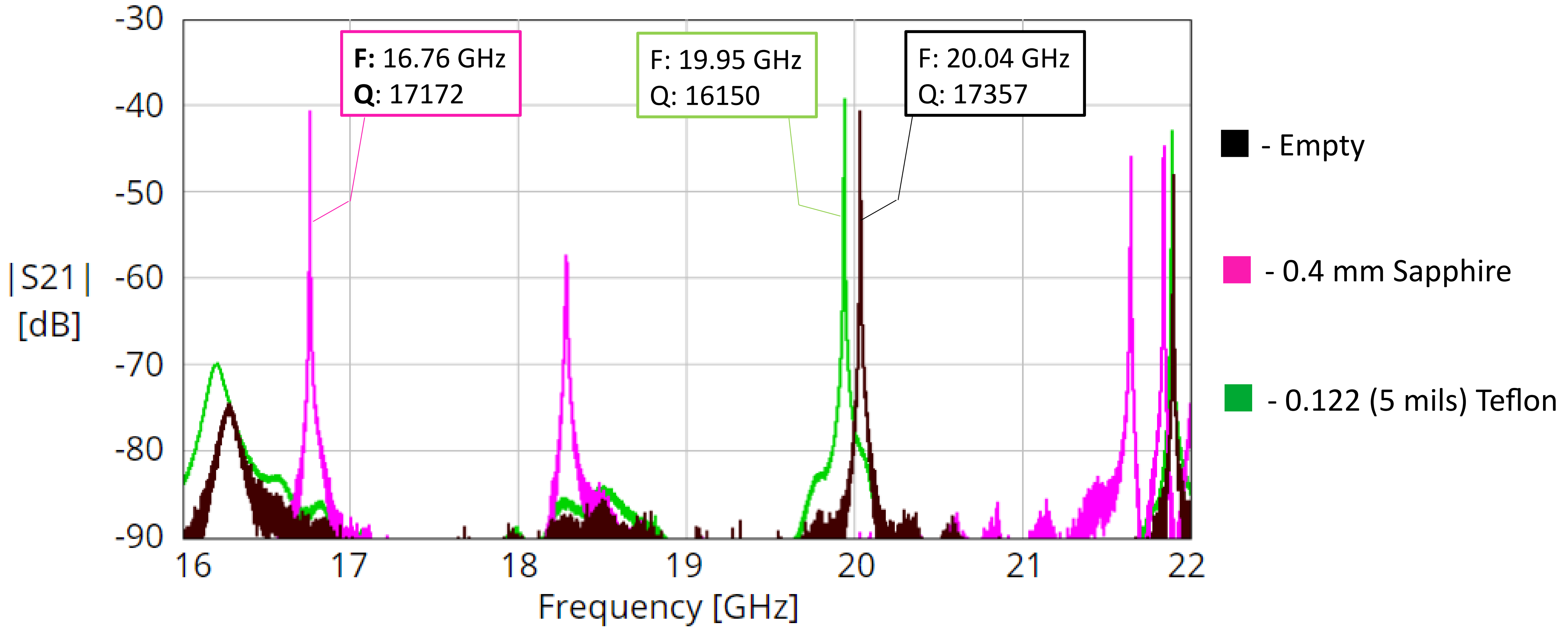
Split Cylinder Resonator with Q-Choke



Practical Microwave and Millimetre-Wave resonance methods



Practical Microwave and Millimetre-Wave resonance methods



Conclusions

1. We shown a comprehensive benchmark for dielectric materials tailored for high-frequency applications in deployable antennas.
2. Three different resonator types were used, and strict sample transportation and storage procedures were followed to ensure the reliability of the results.
3. Dielectric constant and loss tangent measurements for COP, Precision Teflon, and Fused Silica offer valuable insights across a wide frequency range.
4. It is very important to prepare accurate characterization and stringent procedures in multi-laboratory investigations for high-frequency dielectric materials.
5. Further research in this area can lead to the development of more advanced and efficient materials for emerging high-frequency technologies.
6. The inclusion of **Fused Silica** in the standardization process expands its application areas to fields such as aerospace, optics, and photonics.
7. Future work will include results of Fused Silica in a broader frequency range from all iNEMI partners, and the next benchmark material will be rexolite. New measurement methods will be adapt into benchmark.

Acknowledgement

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