



*Presenter:*

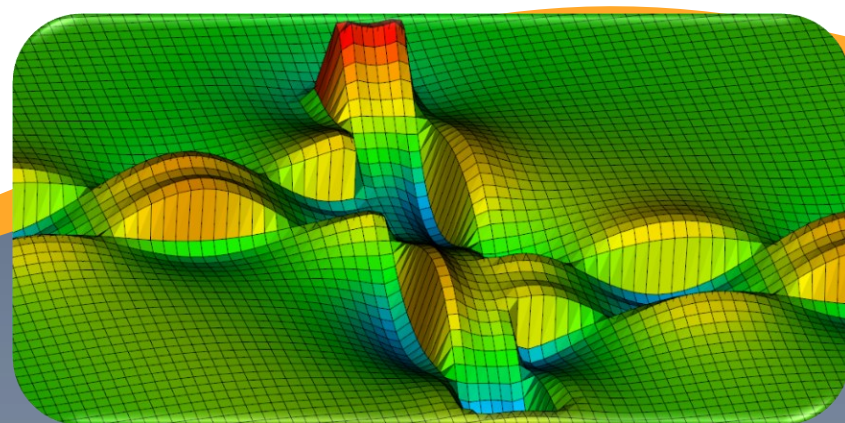
*Malgorzata Celuch*

with contributions from:

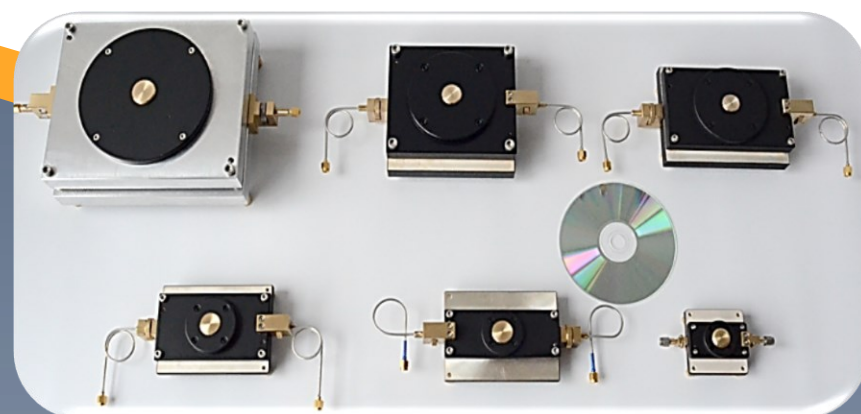
M. Zdrojek, K. Filak  
(Warsaw University of Technology)

M. Olszewska-Placha, J. Rudnicki, L. Nowicki  
(QWED)

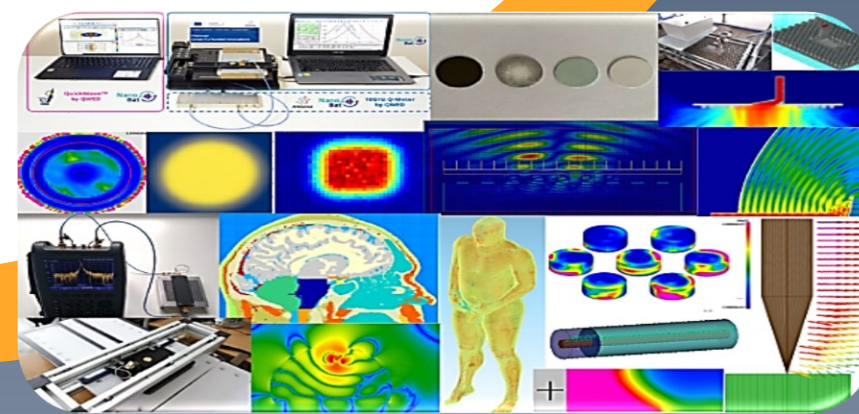
# A new non-destructive microwave technique for quantitative testing of large-scale panels of graphene-based polymer composites for EMI applications



*QuickWave™ Software*



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# Outline



1. Introduction
2. Two Dimensional Scanner based on inverted Single-Post Dielectric Resonator - iSiPDR
3. Sample under Test – Thermoplastic Polymer Composite (ABS/GNP)
4. Results and Discussion
5. Conclusions



# 2D iSiPDR

## Non-destructive and contactless materials characterization

Design: Inverted configuration (iSiPDR) with a sample holder and incorporation into a movement mechanism.

Sample placement: Sample under test (SUT) is placed under the dielectric resonator post at the bottom of the cavity.

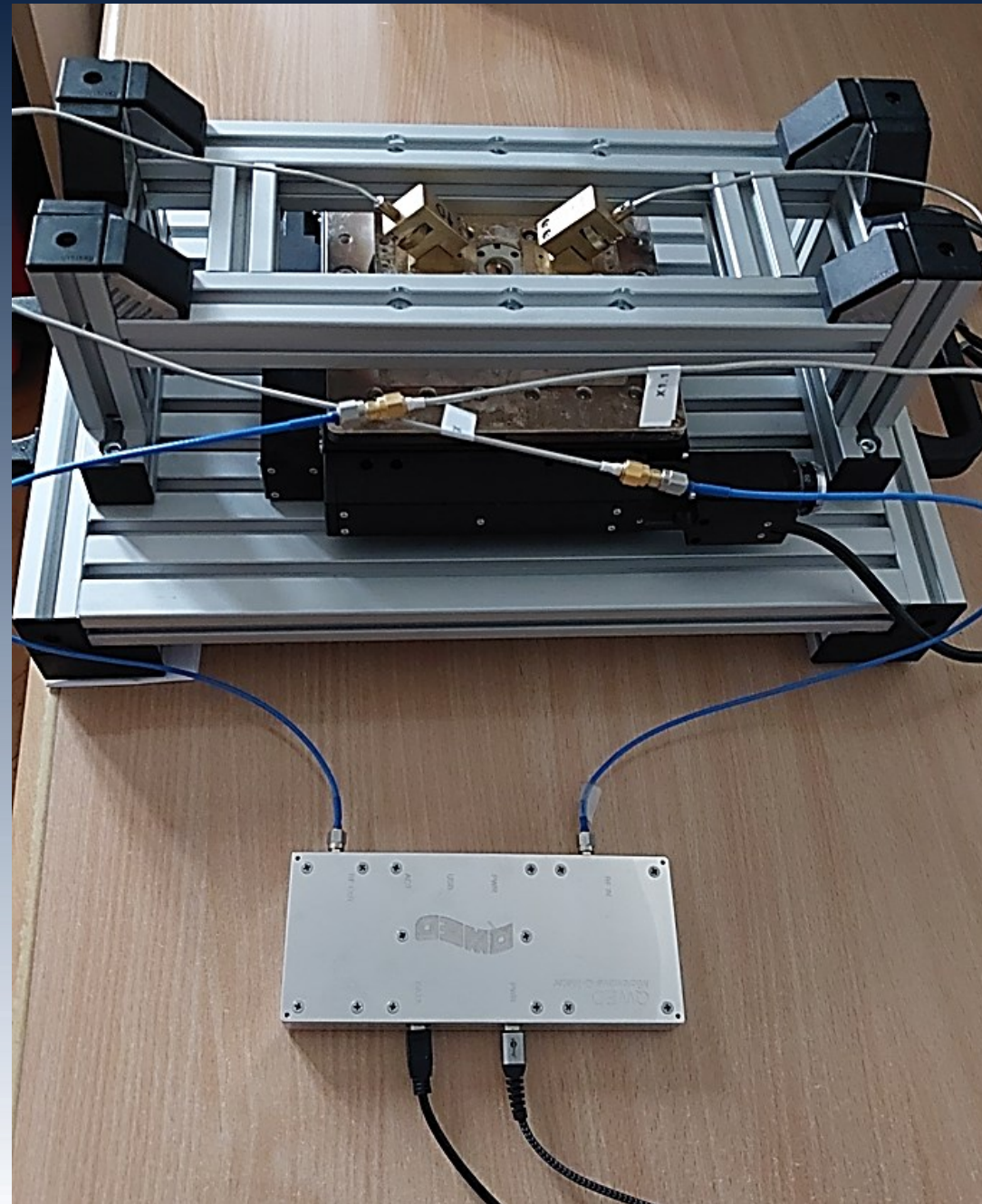
Frequency: **10 GHz.**

Working slot: Allows insertion of SUTs of up to **1 mm thickness.**

Scanner components: Standa 2D motorized translation stage with an incorporated metal reference plate as a sample holder.

Scanning procedure: Metal plate with a sample placed upon is moved over a grid of points with a **spatial resolution** varying in practice in the range of **0.5 – 5 mm**, depending on the SUT lateral size and requested accuracy of the surface imaging.

Scanning area: Spans over a **100 x 100 mm** surface, covering typical sizes of available material wafers.





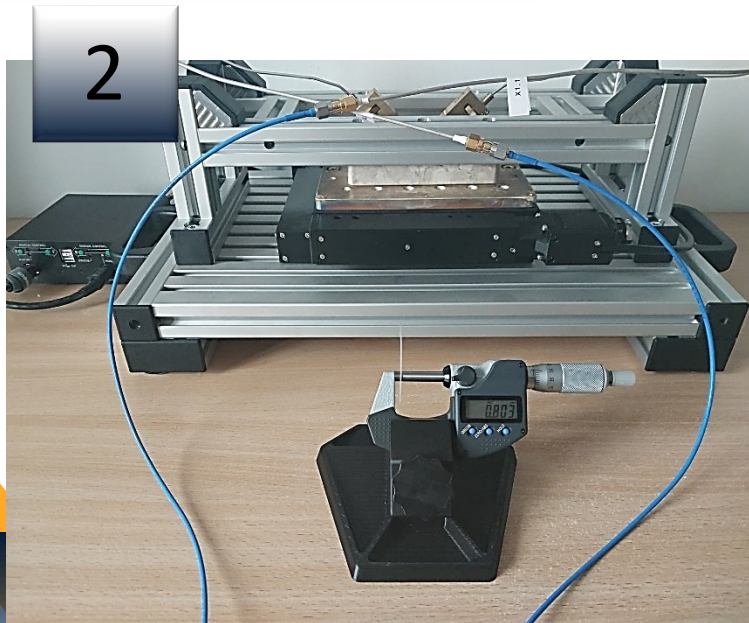
# 2D iSiPDR

## Measurement Procedure

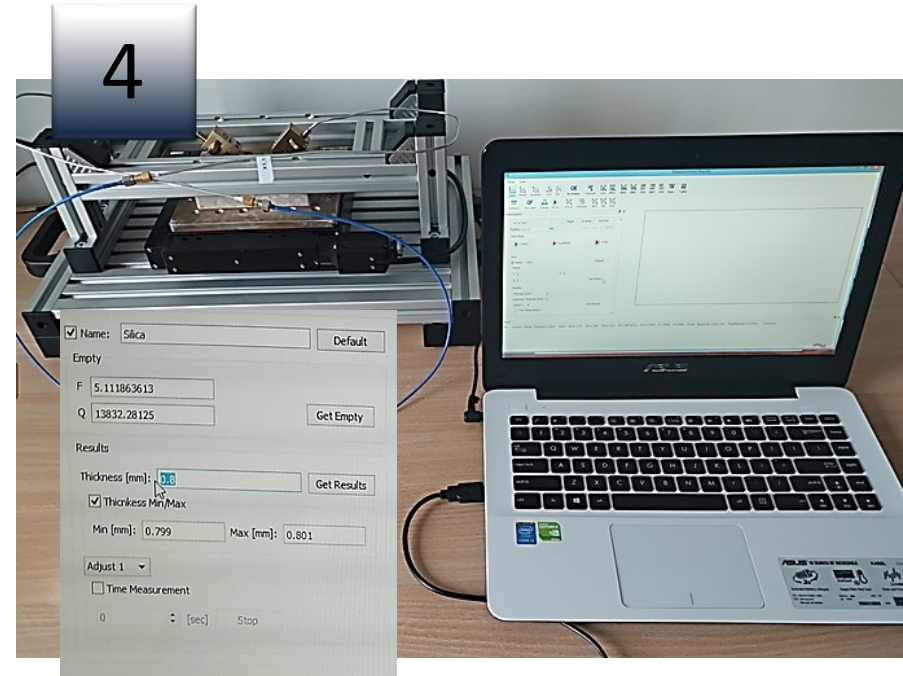
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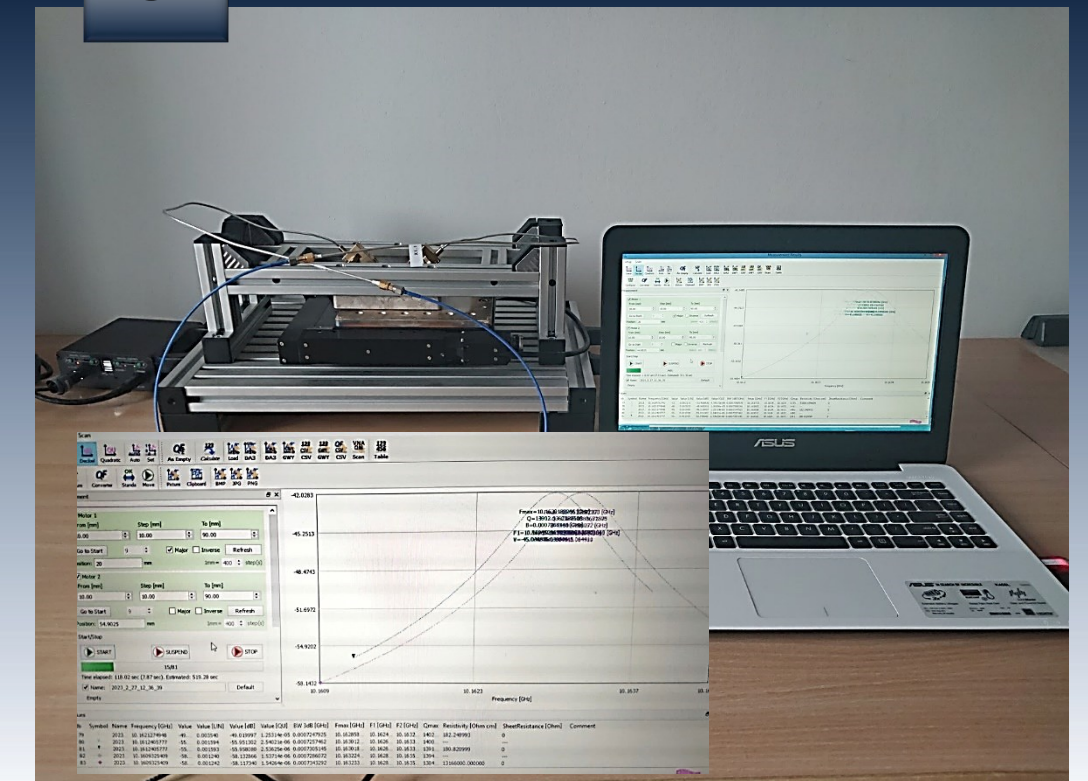
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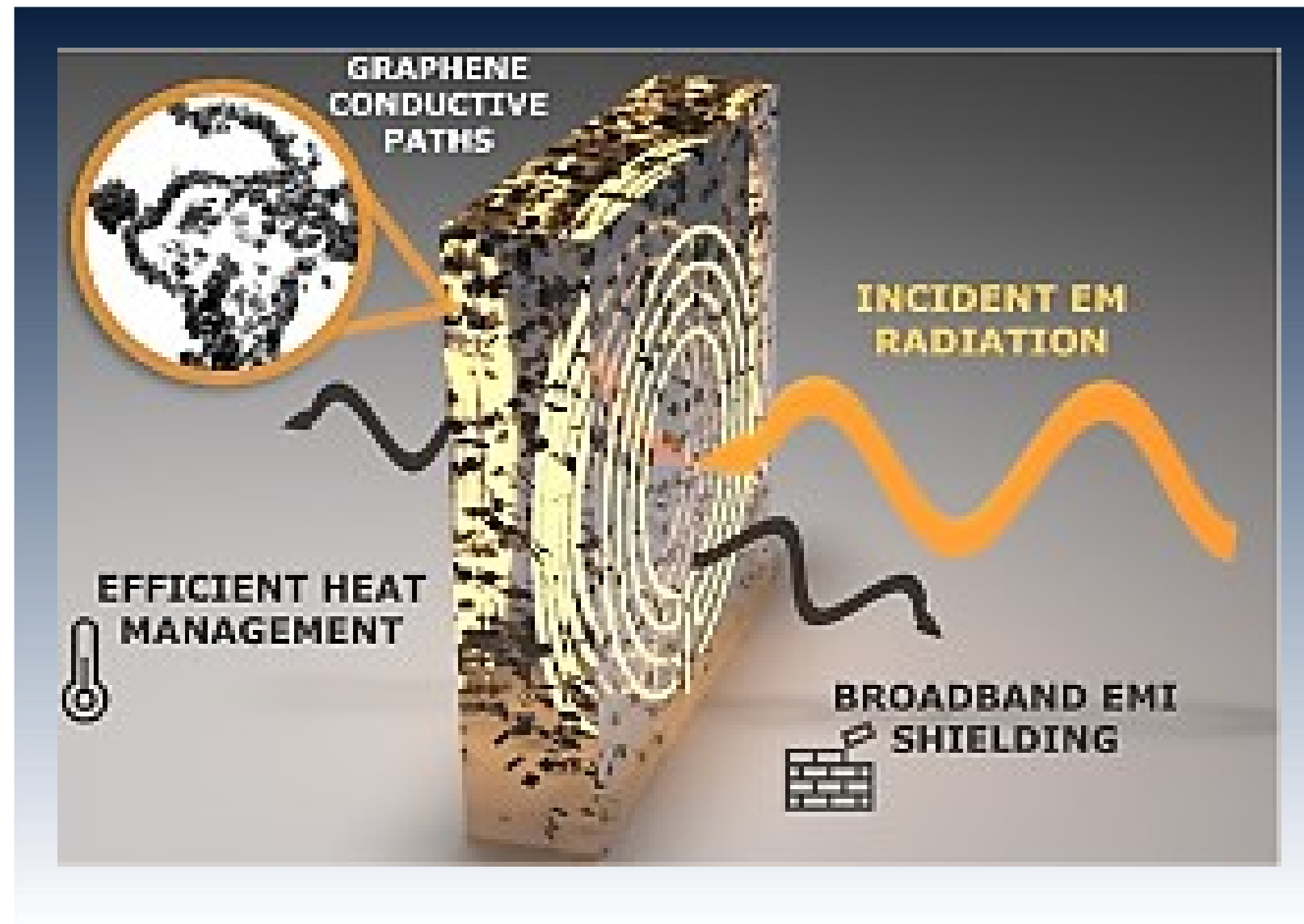
0. Connect the iSiPDR to Q-Meter using SMA cables  
Connect Q-Meter and STANDA Motor to PC using USB cable.
1. Measure "empty" iSiPDR - app invoked measurement.
2. Measure thickness of the sample.
3. Insert the sample into iSiPDR.
4. Insert the sample thickness into the PC app.
5. Material parameters are extracted automatically with each step.



# Sample under Test

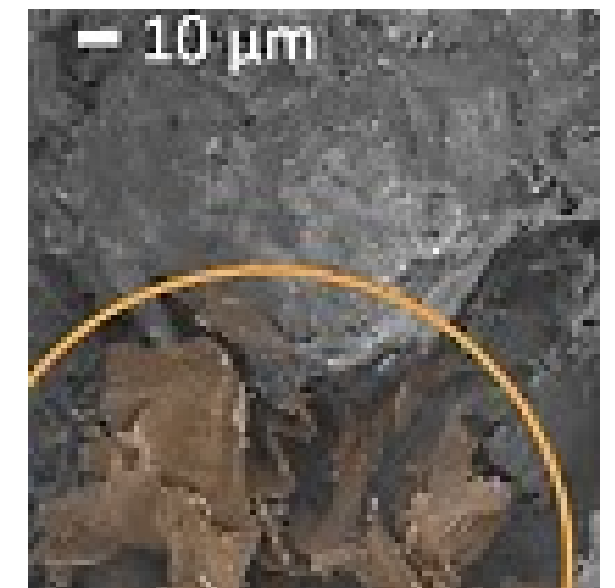
## Thermoplastic Polymer Composite

Acrylonitrile–butadiene–styrene (ABS) with graphene nanoplatelet (GNP)



„Graphene-Based Thermoplastic Composites as Extremely Broadband and Frequency-Dependent EMI Absorbers for Multifunctional Applications”

Resinex Poland supplied ABS in a powder form that had a melt flow rate of 43 g/10 min (220 °C/10 kg) and a density of 1.04 g/cm<sup>3</sup> according to the provided technical datasheet. Sigma-Aldrich provided GNPs in the form of a powder with an average lateral dimension of 25 μm and a surface area of 120-150 m<sup>2</sup>/g. To fabricate ABS/GNP composites, the graphene powder was first mixed with ABS using different concentration ratios of 0.5, 1, 2, 5 and 10 wt%. Hot press method was then used to fabricate nanocomposite samples. The prepared dried mixture was placed in a hydraulic press, where the mold temperature was set at 290 °C, and a pressure of 20 MPa was applied. As a result, composite samples were obtained.



Klaudia Żerańska-Chudek, Karolina Filak, Konrad Wilczyński, Agnieszka Siemion, Norbert Pałka, Konrad Godziszewski, Yevhen Yashchyshyn, Mariusz Zdrojek

# Results and discussion

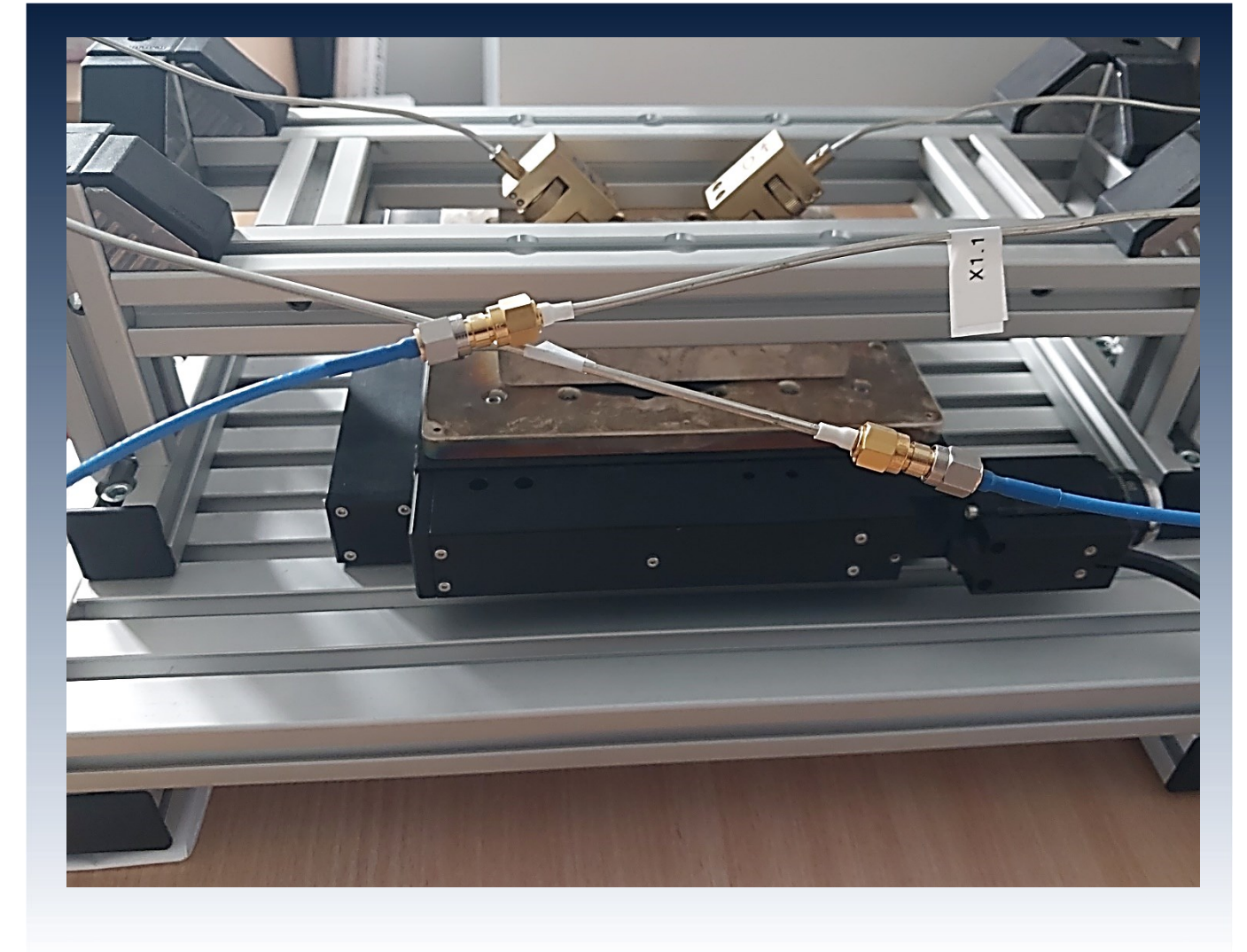
## Setting up the measuring system

ABS/GNP



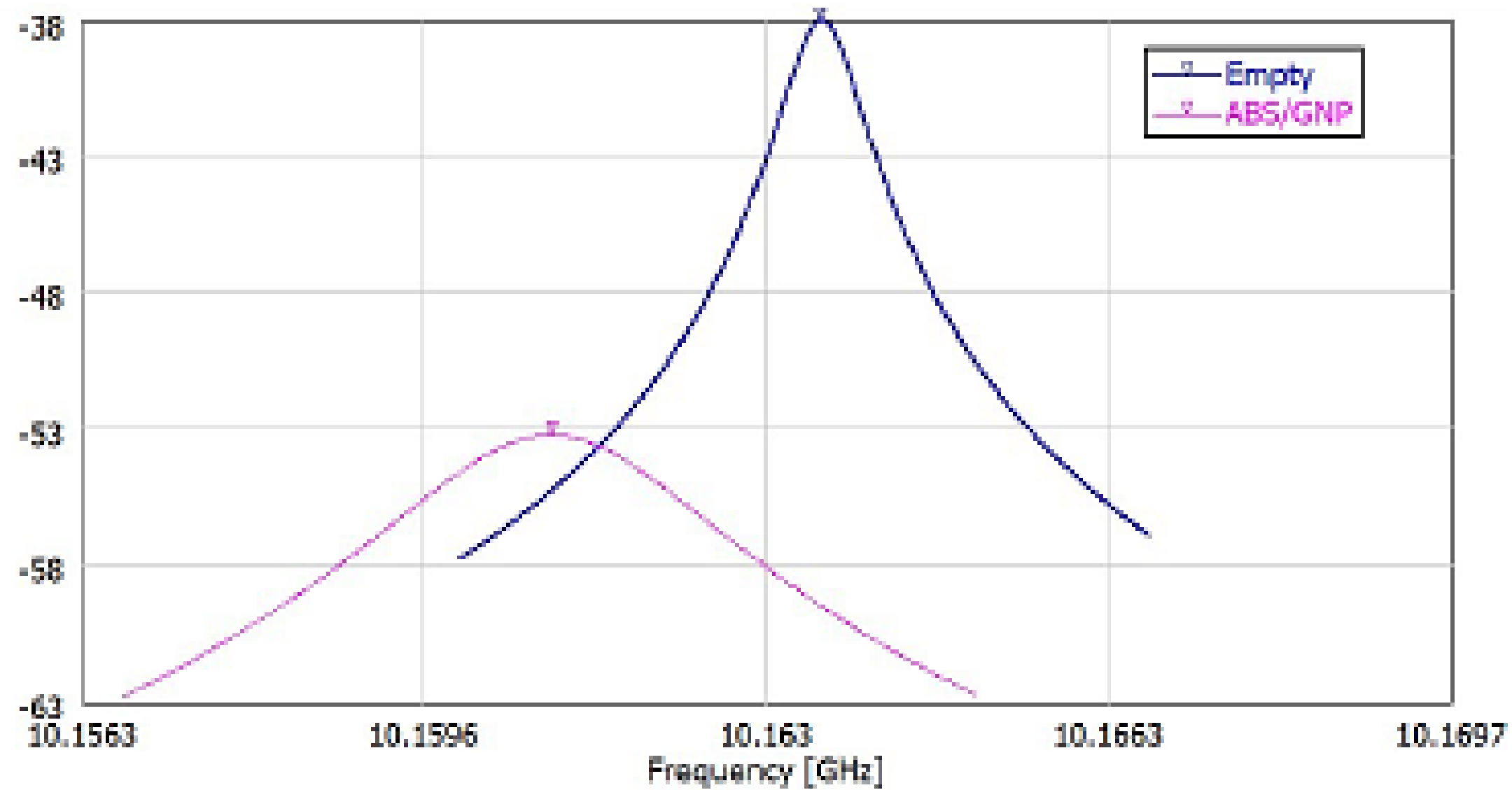
Average thickness: 429.9 [ $\mu\text{m}$ ]  
Maximum: 480 [ $\mu\text{m}$ ]  
Minimum: 362 [ $\mu\text{m}$ ]

Insert the sample  
into iSiPDR



Measurement setup for 2D imaging of graphene-based  
polimer composites

# Results and discussion

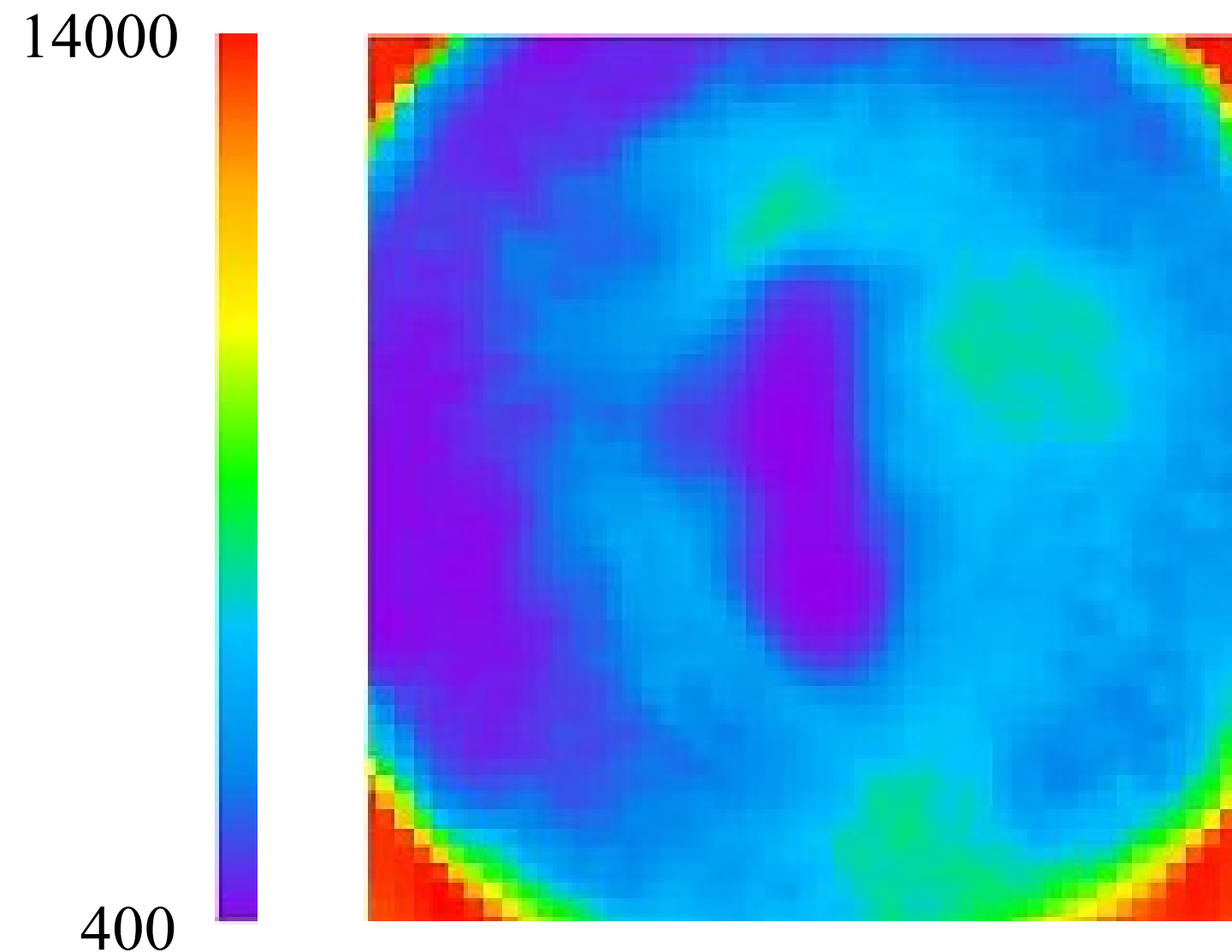


Transmission (abs (S21)) through the 10 GHz iSiPDR mounted in the scanner and placed at two selected positions: over an empty region (blue) and at a selected point over the ABS/GNP sample (pink).



# Results and discussion

Q-Factor of iSiPDR scanned over the ABS/GNP sample.



The Q-Factor and resistivity maps are based on the scattering matrix transmission parameters  $|S_{21}|$  obtained at each position of the iSiPDR head in the scanner. After each step, the resonance curve is analyzed and its maximum indicating the resonant frequency (of the iSiPDR loaded with the material currently within its head), and 3dB bandwidth indicating the losses (of the iSiPDR head loaded with the materials). For reference, a single measurement is first taken of the empty iSiPDR. Its frequency was **10.1635 GHz** and its Q-factor **13948.868**. Inserting a sample shifts the resonant frequency and decreases the Q-factor.

For fast and accurate extraction of resonant frequencies and Q-factors at many scanning steps, the measured transmission curves are considered only in a limited frequency range close to the resonance, so that the extraction not burden the speed of data acquisition from the scanner and their post- processing.

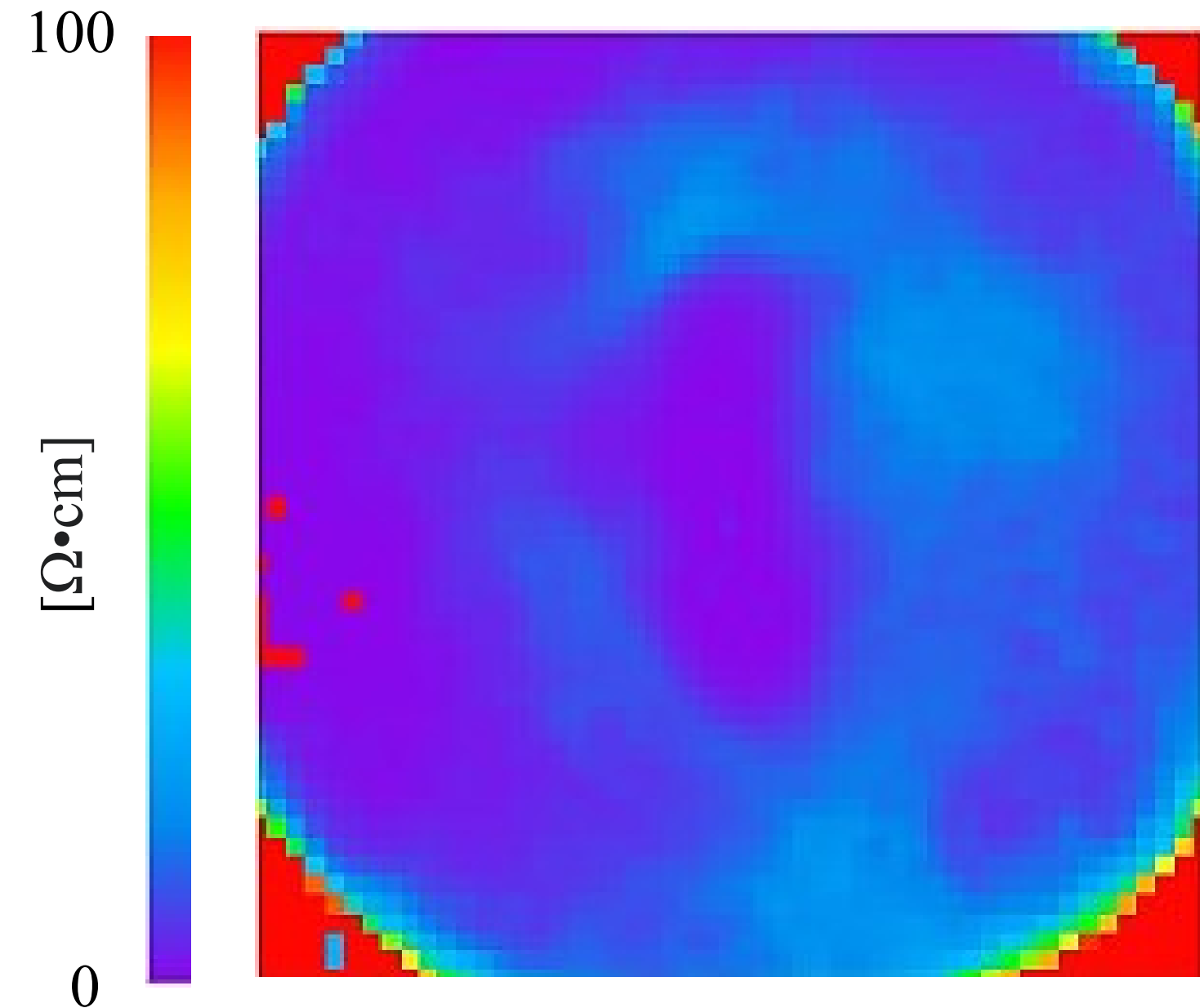


# Results and discussion

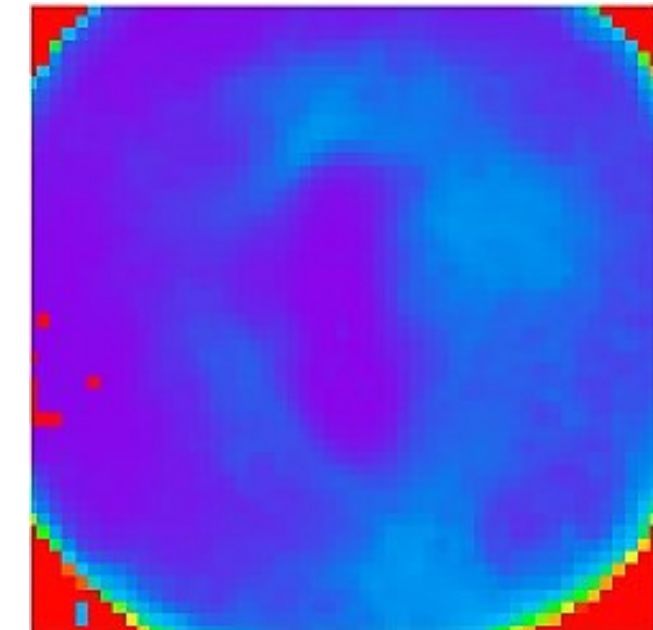
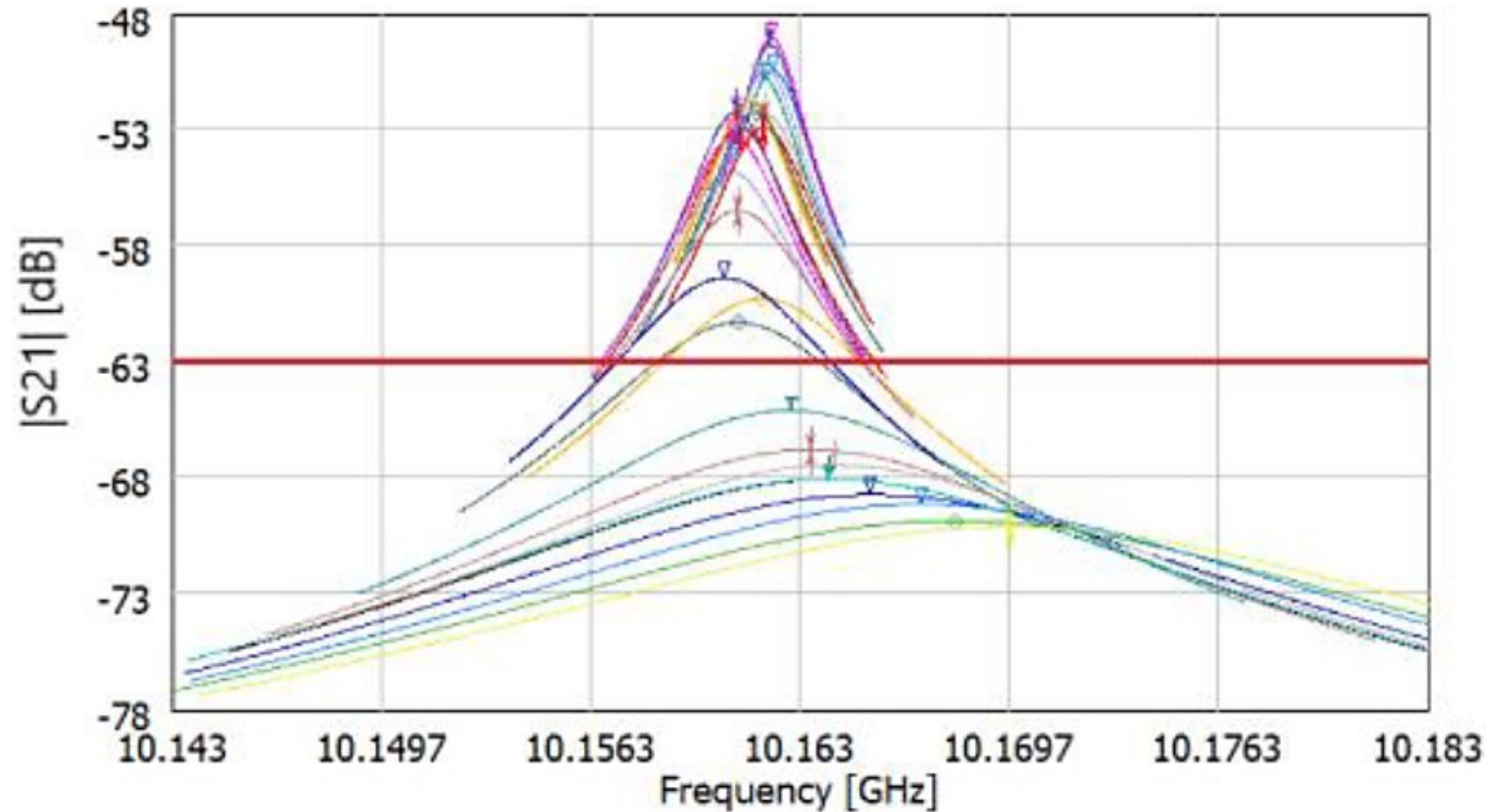
2D maps of resistivity of ABS/GNP sample for iSiPDR scanning.

Shielding properties of graphene-based polymer composites (GBPC) are enhanced by uniform dispersion of graphene flakes within the polymer matrix. Little attention has been given thus far to the rigorous studies of spatial inhomogeneities of the electrical and dielectric properties of GBPCs, due to nonuniform filler distribution in practical fabrication.

Experimental results for large (**10cm x 10cm**) GBPC panels, demonstrating a tremendous effect of the fabrication process parameters on inhomogeneities of the surface resistance, which degrade the shielding efficiency.



# Results and discussion



After analyzing all the results, it can be seen that the resonant frequency varies up to **10 MHz** up and down, for consecutive steps. At the very center of the sample we obtain the curves below the red straight line. These resonance curves are much wider thus indicating lower Q-factors calculated for them. Thus, the algorithm used returned very low resistivity values

Transmission in a 10 GHz scanner depending on the position of the head along the middle of ABS/GNP sample.

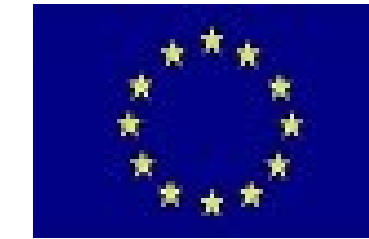
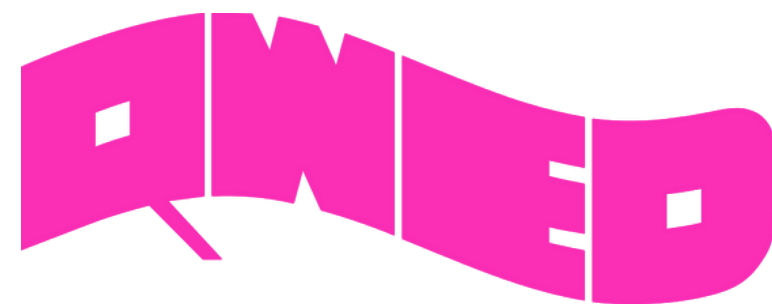


# Conclusions

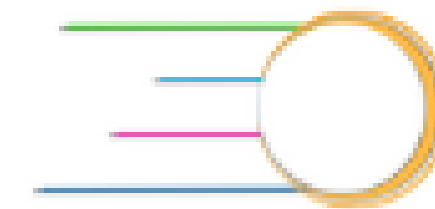
- 10 GHz Inverted Single-Post Dielectric-Resonator (iSiPDR) mounted into a 2D scanner to construct 2D Q-factor maps of the iSiPDR loaded with different fragments of the scanned ABS/GNP material.
- The Q-factor maps are modeled using an **ultra-fast BoR FDTD** electromagnetic simulation and advanced QProny post-processing to convert them to the material's resistivity maps.
- The initial samples of ABS/GNP showed significant surface inhomogeneities, indicating the need for improvements in the material fabrication process.
- Thicker areas of the sample appear to be more lossy, making it seem like they are made of lower resistivity material than they actually are.
- This does not limit the practical sense of the measurement since the overall losses of the sample are relevant for EMI applications.

# Acknowledgement

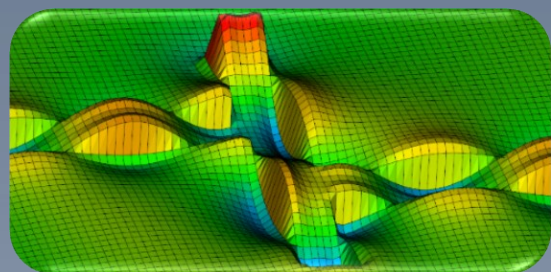
The work received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement **NanoBat** No. 861962 and is currently co-funded by the Polish National Centre for Research and Development under contracts M-ERA.NET2/2020/1/2021 (**ULTCC6G\_Epac**) and M-ERA.NET3/2021/83/**I4BAGS**/2022.



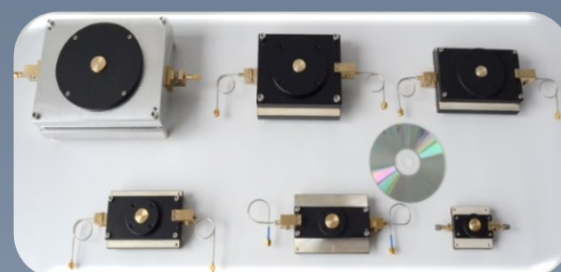
**ULTCC6G\_EPac**



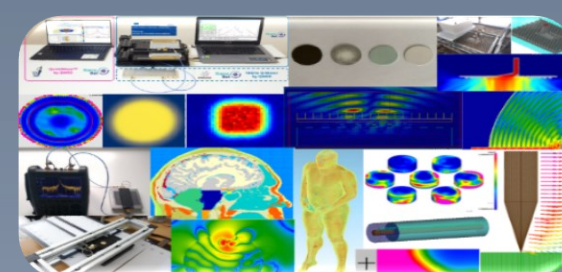
**I4BAGS**



QuickWave™ Software



Materials Measurement



R&D Projects

