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# Task Group Proposal

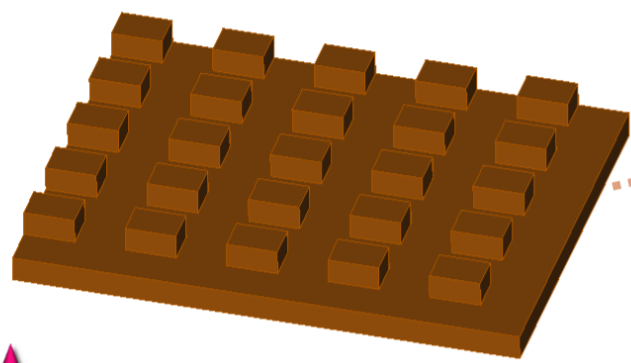
## Modelling and Characterisation of Rough Conductive Surfaces

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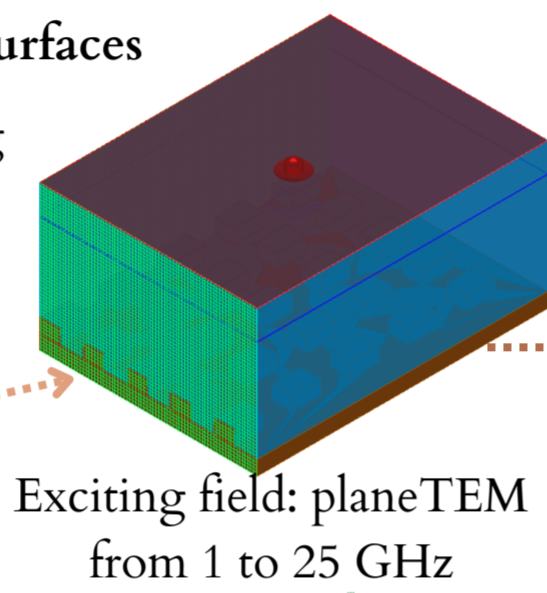
This work presents initial results from the EUREKA-Eurostars 5G\_Foil project, which aims to develop industrial screening methods for copper foils used in high-frequency applications. A measurement technique based on the Ruby Dielectric Resonator (RuDR) is validated for the rapid determination of effective microwave conductivity, with results correlated to surface topology parameters. A strong exponential correlation is observed between conductivity and the Developed Interfacial Area Ratio (Sdr), achieving a coefficient of determination of 0.97. Measurements were conducted at 13 GHz and 21 GHz using a VNA to extract Q-factors and determine conductivity through full-wave modeling.

### Modelling of Rough Conductive Surfaces

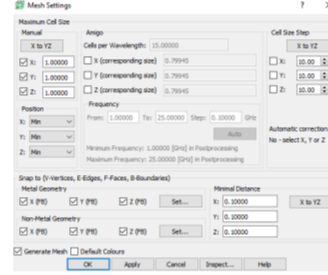
Example of surface roughness modelling in QW-Modeller



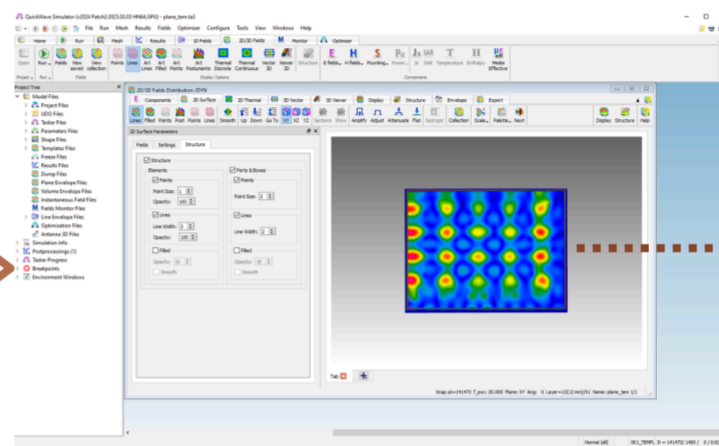
QW-Modeller for QuickWave is a workbench for the open source FreeCAD general purpose parametric 3D CAD modeller.



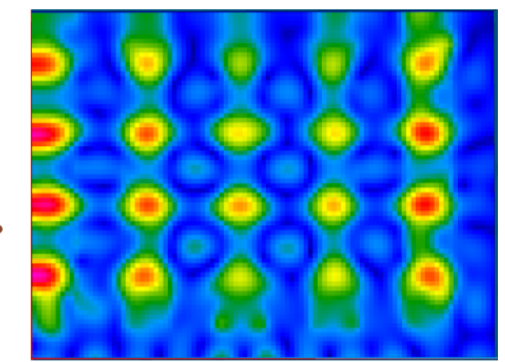
Configuring the mesh:



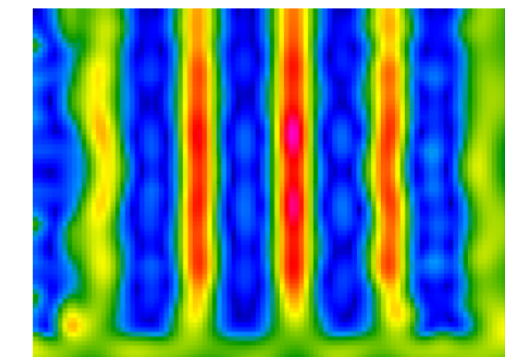
### Continuum modelling - QuickWave



QuickWave 3D, is a universal user-friendly three-dimensional electromagnetic simulation package based on the conformal FDTD method



Fields  
E  
Electric

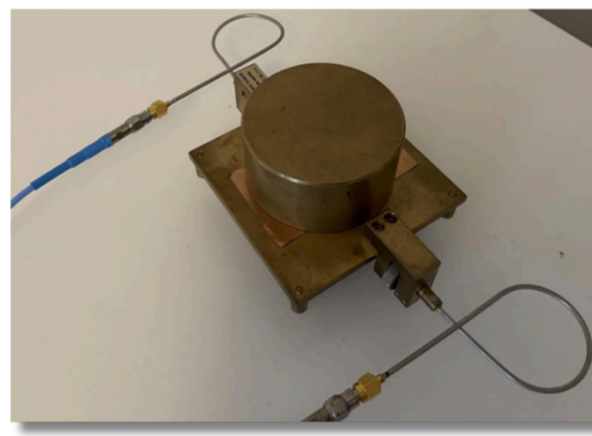


H  
Magnetic

### Characterisation of Rough Conductive Surfaces

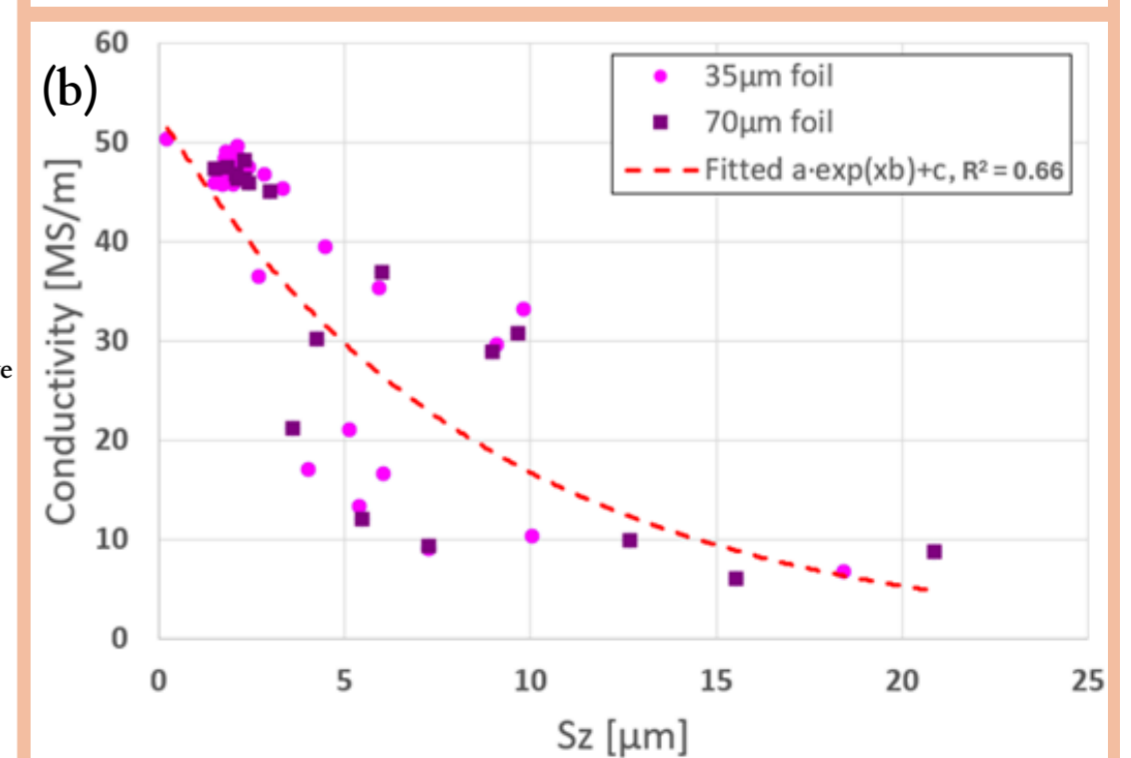
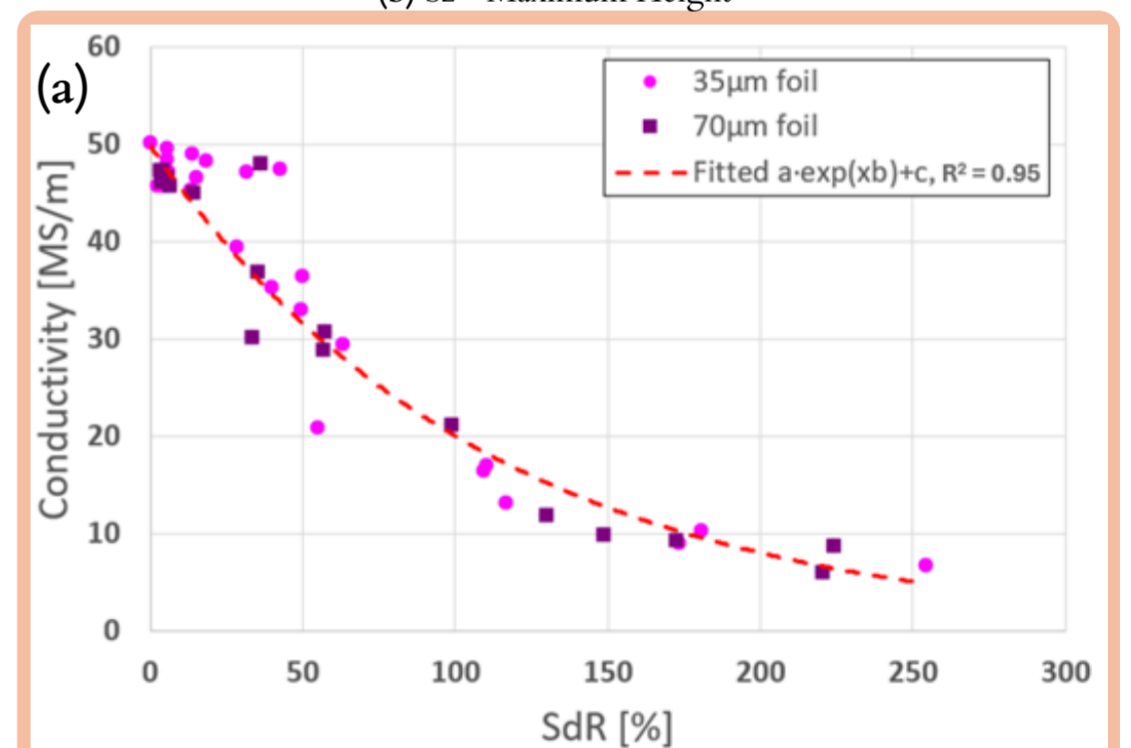
Ruby Dielectric Resonator RuDR operates with TE<sub>011</sub> mode at 13 GHz and TE<sub>021</sub> mode at 21GHz is used to measure conductivity of the given samples. The resonator is connected to VNA through coaxial wiring which is operated via application on a laptop. The measurements take place in the closed and air-conditioned laboratory room. For measurements, you need two identical samples that were previously cut to dimensions of 60 by 60 millimeters. Another important thing that you need to pay attention to when selecting the sample is whether it has any creases and you need to be careful not to make any creases when inserting it into the resonator. To obtain a reliable measurement, the VNA parameters should be appropriately adjusted, such as: number of points, frequency range, IFBW and signal averaging.

#### RuDR

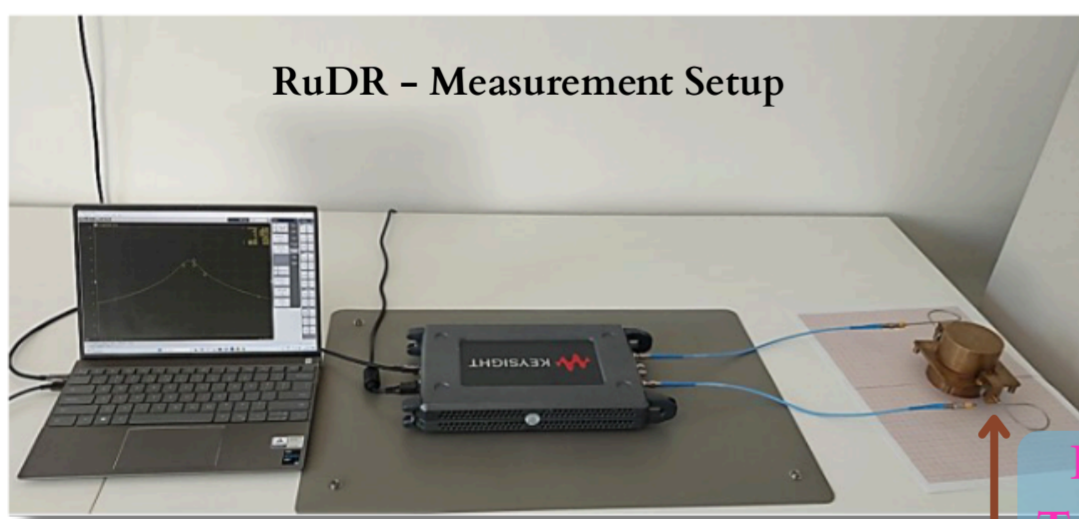


### Characterisation results

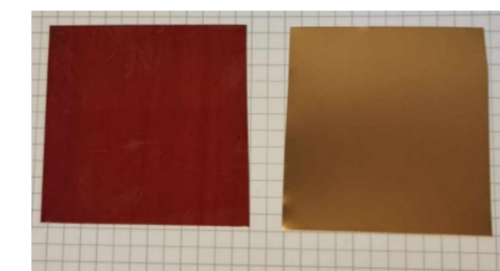
Correlation between effective conductivity  $\sigma$ , measured at 13 & 21 GHz in the RuDR test-fixture and surface roughness parameters:  
 (a) Sdr - Developed Interfacial Area Ratio,  
 (b) Sz - Maximum Height



M. Celuch, T. Devahif, T. Nalecz, J. Rudnicki, "A Systematic Study of Correlation between Surface Roughness and Microwave Effective Conductivity of Copper Foils for Ultra-Low-Loss Applications", 25th International Microwave and Radar Conference MIKON, 1-3 July 2024, Wroclaw, Poland



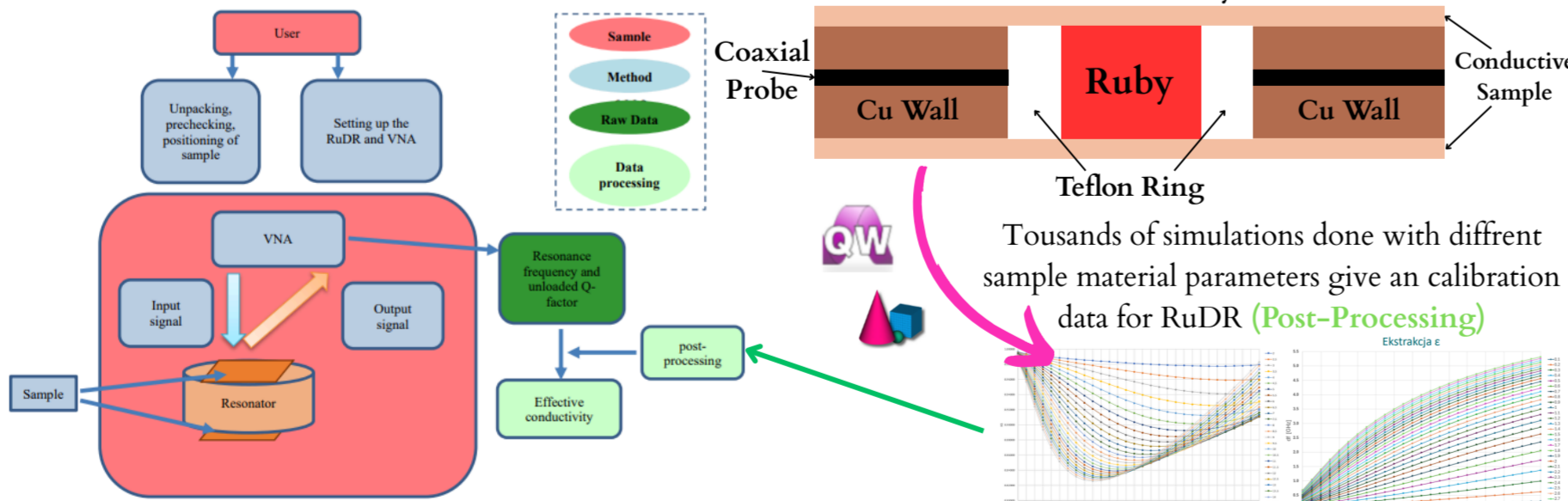
RuDR - Measurement Setup



Samples under measurement  
Measurements

Digital Twinning

#### MODA&CHADA Workflow



Example of Calibration data

### Acknowledgement

This work is performed within the EUREKA-Eurostars project 5G\_Foil and co-funded by the Polish National Centre for Research and Development under contract InnovativeSMEs/4/100/5G\_Foil/2023 and by the Ministry of Economy, Luxembourg, under contract 2023-A127-X187.



5G Foil project website:

