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# Characterization of the Conductivity of Biocompatible Polymer Based 3D-Printable Compound Filaments at 10 GHz

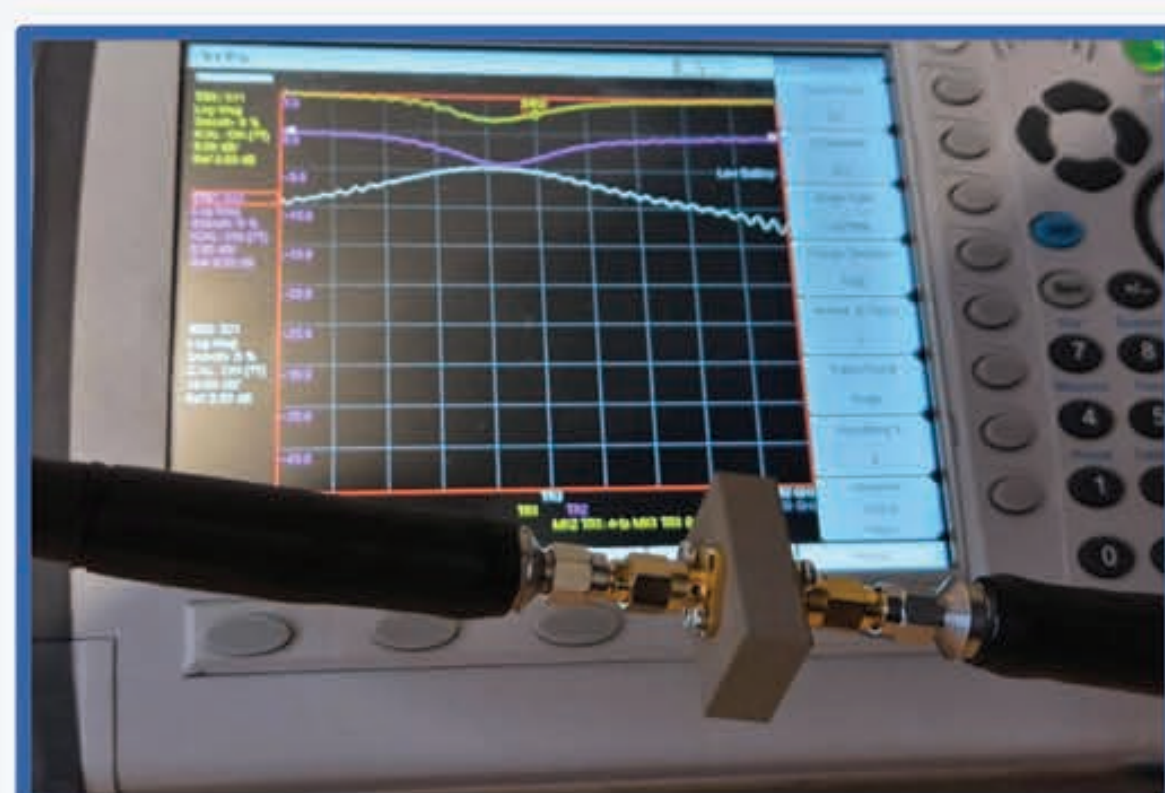
**This study investigates the electrical conductivity at 10 GHz of two commercially available 3D-printable conductive filaments - COLFEED4Print FEco Graphene and Fiber Three Super Conductive Filament (silver based). We are using a rectangular waveguide cavity resonator method with VNA measurements for the quality Q-factor of the resonator and estimate the material conductivity, surface resistance and skin depth from it. The measurements are supported by electromagnetic simulations of the cavity resonator. Results show a significant reduction of the material electrical conductivity - 20.91 S/m for FEco Graphene and 134.85 S/m for Fiber Three Silver.**

## INTRODUCTION

- Conductive 3D-printable filaments composed of biocompatible thermoplastic matrices loaded with conductive fillers for the printing of functional RF devices.
- Material specifications are usually given at DC.
- Resonant method for VNA S-parameter conductivity measurement at 10 GHz of air-filled rectangular cavity resonator samples.
- Electromagnetic simulations of the cavity resonators with Ansys Electronics Desktop in support of the measurements.



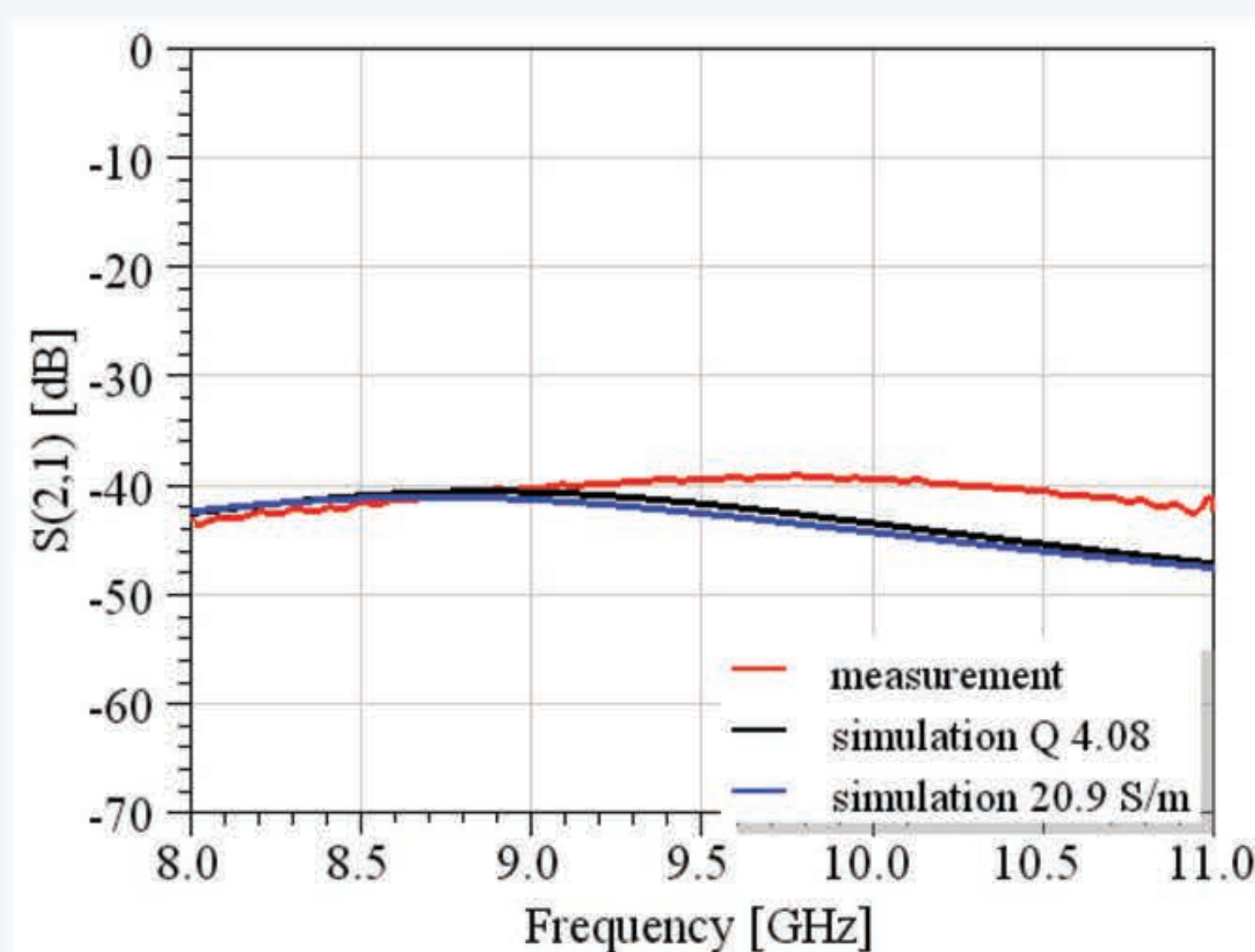
COLFEED4Print FEco Graphene - 15 vol.% conductive graphene particles dispersed in a PLA matrix, DC conductivity of 1100 S/m



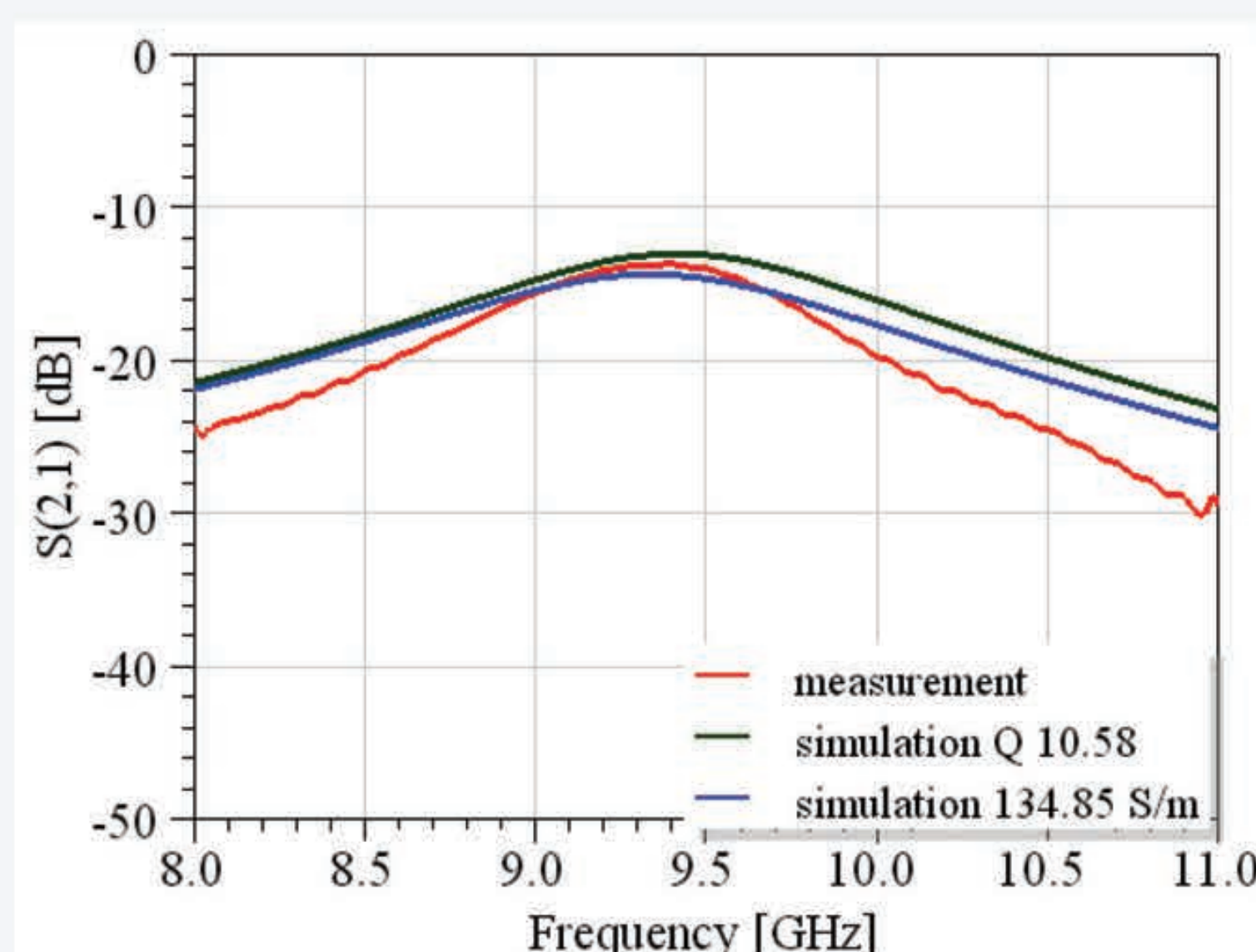
Fiber Three Super Conductive polymer filament with silver content, DC surface resistance of  $10^4 \Omega$

## S-PARAMETER MEASUREMENT AND SIMULATION

- VNA 2-port measurement of the resonators transmission coefficient  $S_{21}$ .
- Determination of the unloaded Q-factor and material conductivity.
- Simulated S-parameters with tuned material conductivity matching the measured Q-factor and with material conductivity matching the calculations.



Transmission coefficient  $S_{21}$  for FEco Graphene



Transmission coefficient  $S_{21}$  for Fiber Three Silver

## RESULTS

	$f_c$ [GHz]	$f_r$ [GHz]	$f_b$ [GHz]	Q
Fiber Three Silver	9.39	9.778	8.89	10.57
Feco Graphene	9.78	10.857	8.46	4.08

Measured unloaded Q-factor.

	$R_s$ [ $\Omega$ ]	$\sigma$ [S/m]	$\delta$ [mm]
Fiber Three Silver	16.58	134.85	0.45
Feco Graphene	42.97	20.91	1.1

Surface resistance, conductivity and skin depth calculated from the measurements.

	$R_s$ [ $\Omega$ ]	$\sigma$ [S/m]	$\delta$ [mm]
Fiber Three Silver	14.81	169	0.4
Feco Graphene	39.42	24.85	1

Surface resistance, conductivity and skin depth calculated from simulations with materials conductivity calculated from the measurement.

## Conclusion

The electrical conductive properties of two types of 3Dprintable compound filaments have been investigated at 10 GHz - COLFEED4Print FEco Graphene and Fiber Three Super Conductive Filament (silver based). We have estimated the materials electrical conductivity of respectively 20.91 S/m and 134.85 S/m, surface resistances of 42.97 $\Omega$  and 16.58 $\Omega$  and skin depth of 1.1mm and 0.45 mm. The results show significant reduction in the electrical conductivity of the materials at high frequencies and that they should be utilized in thick layers when used.