Empirical Verification of COMSOL® Simulation of Resonance Frequency of an Archimedean Spiral Coil

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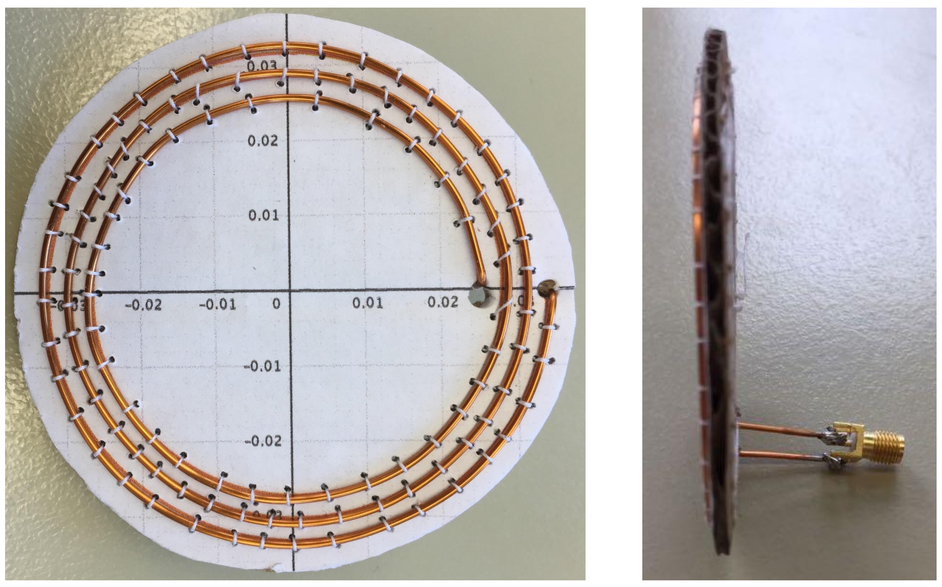
INTRODUCTION: An Archimedean Spiral Coil was build up like shown in Figure 1 and measured with an network analyzer to verify the COMSOL® simulation of the resonance frequency. The measured resonance frequency was round about 100 MHz.



(a) (b)

Figure 1. Side- and front view of the Experimental Spiral Coil

COMPUTATIONAL METHODS: The RF Module of COMSOL® was used in it's 3D Electromagnetic Wave, Frequency Domain formulation with the Eigenfrequency study. The corresponding equations are shown below.

$$\vec{0} = \nabla \times \mu_r^{-1}(\nabla \times \vec{\underline{E}}) - k_0^2 \left(\varepsilon_r - \mathrm{j}\frac{\sigma}{\omega \varepsilon_0} \right) \vec{\underline{E}}$$

$$\lambda = \delta - \mathrm{j}\omega$$

Inner effects like skin effect or inner inductivity are neglected. The geometry was build up in four steps of precision to distinguish between partial influences. As outer geometry, an air-filled cylinder was chosen. Figure 2 shows the model with the highest accuracy.

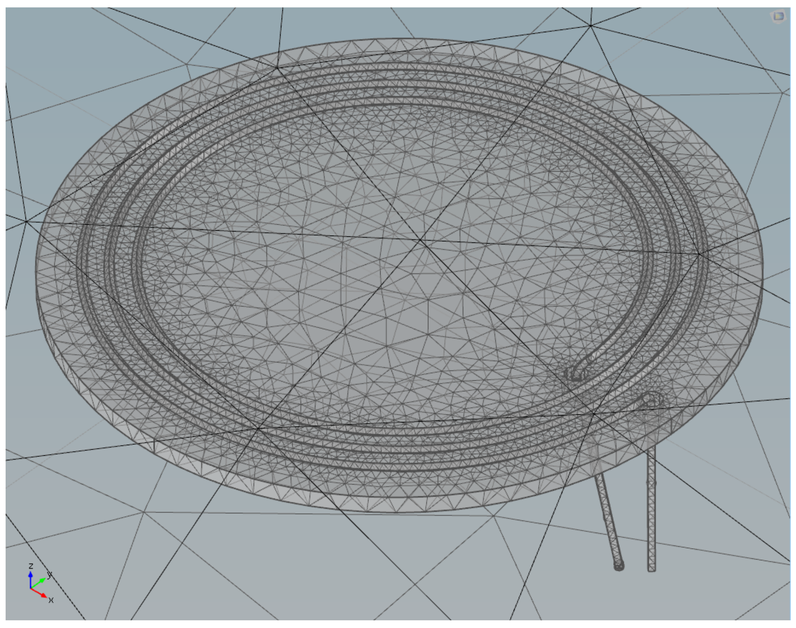


Figure 2. Geometry Model of Archimedean Spiral Coil and Tedrahedral Mesh

RESULTS: The higher the model accuracy, the better the simulated resonance frequency matches the measurement result.

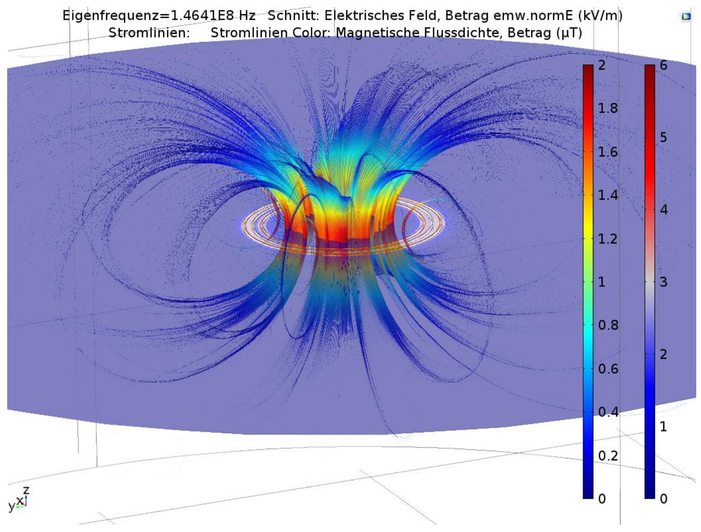


Figure 3. Distribution of Electrical Field and Magnetic Field Lines

1.Archimedean Spiral:
156 MHz

2.Archimedean Spiral with connection wires:
146 MHz

3.Archimedean Spiral with bended connection wires:

$\theta/°$	f_R/MHz
12	144.81
15	144.07
18	143.12

Table 1. Variation of Bending Angle of Connection-Wire

4. Archimedean Spiral with 18° bended connection wires and cardboard:

ε_r	R/mm	d/mm	f_R/MHz
2	0.4	2.8	137.7
2	0.4	3	139.1
2	0.4	3.2	140.22
2	0.5	2.8	134.38
2	0.5	3	136.13
2	0.5	3.2	137.41
2	0.6	2.8	130.87
2	0.6	3	132.87
2	0.6	3.2	134.31
3	0.4	2.8	131.77
3	0.4	3	133.1
3	0.4	3.2	134.16
3	0.5	2.8	129.22
3	0.5	3	130.83
3	0.5	3.2	132.09
3	0.6	2.8	126.35
3	0.6	3	128.16
3	0.6	3.2	129.48
4	0.4	2.8	127.55
4	0.4	3	128.84
4	0.4	3.2	129.78
4	0.5	2.8	125.52
4	0.5	3	127.05
4	0.5	3.2	128.21
4	0.6	2.8	123.04
4	0.6	3	124.72
4	0.6	3.2	125.93

Table 2. Variation of Permittivity, Wire-Radius and Average Wire-Distance

CONCLUSIONS: Due to the neglect of internal effects, it can be said that the simulation result represents a good approximation of the measurement result.The addition of skin effect and internal inductance would further reduce the resonance frequency.

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