Bachelor Thesis

Design of Resonators for Wireless Energy Transfer (Reducing the Resonance Frequency)

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About the Student

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Project Introduction: Electric cars are the present and the future, but more part of the future than the present. The problem is that they still have high production costs, because of the batteries, and also the range on the batteries does not satisfy most of our needs. The idea is to be able to wirelessly charge electric cars, mainly busses and taxis which have a high stationary time. By wirelessly charging these electric cars, the number of batteries would then be reduced and this will also lead to lower costs.

For this purpose resonant inductive coupling is used. Resonant inductive coupling is the near field wireless transmission of energy between two coils that resonate at the same frequency. These coils would be positioned as shown in Figure 1. The resonators are basically Archimedean spirals as shown in Figure 2 (designed using CST Microwave Studio).

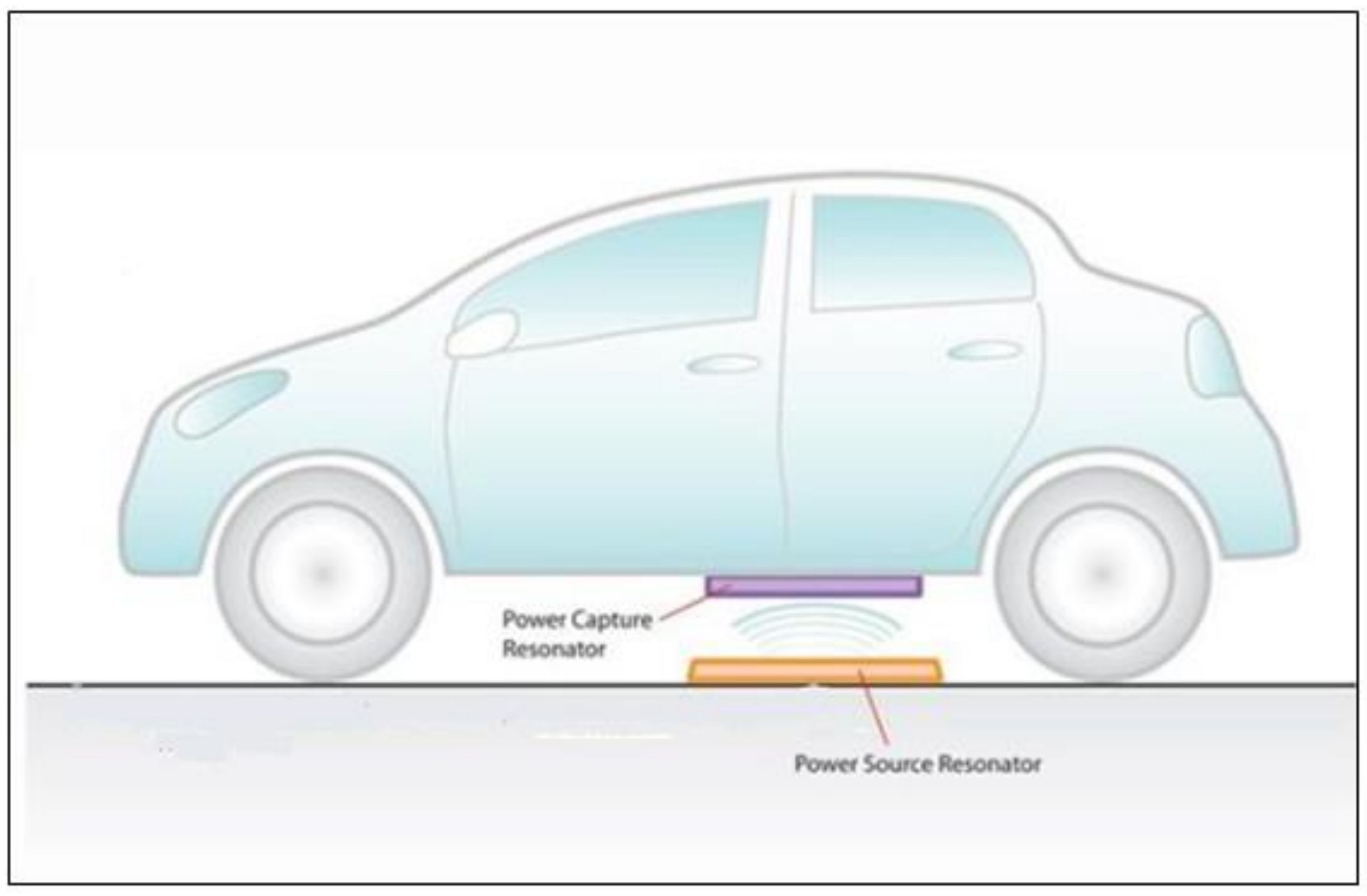

Figure 1 Electric Car with the Power capture and source resonators

Archimedean Spiral Formulas:

$$X = (progress * \alpha + radius) * \cos(\alpha)$$

$$Y = (progress * \alpha + radius) * \sin(\alpha)$$

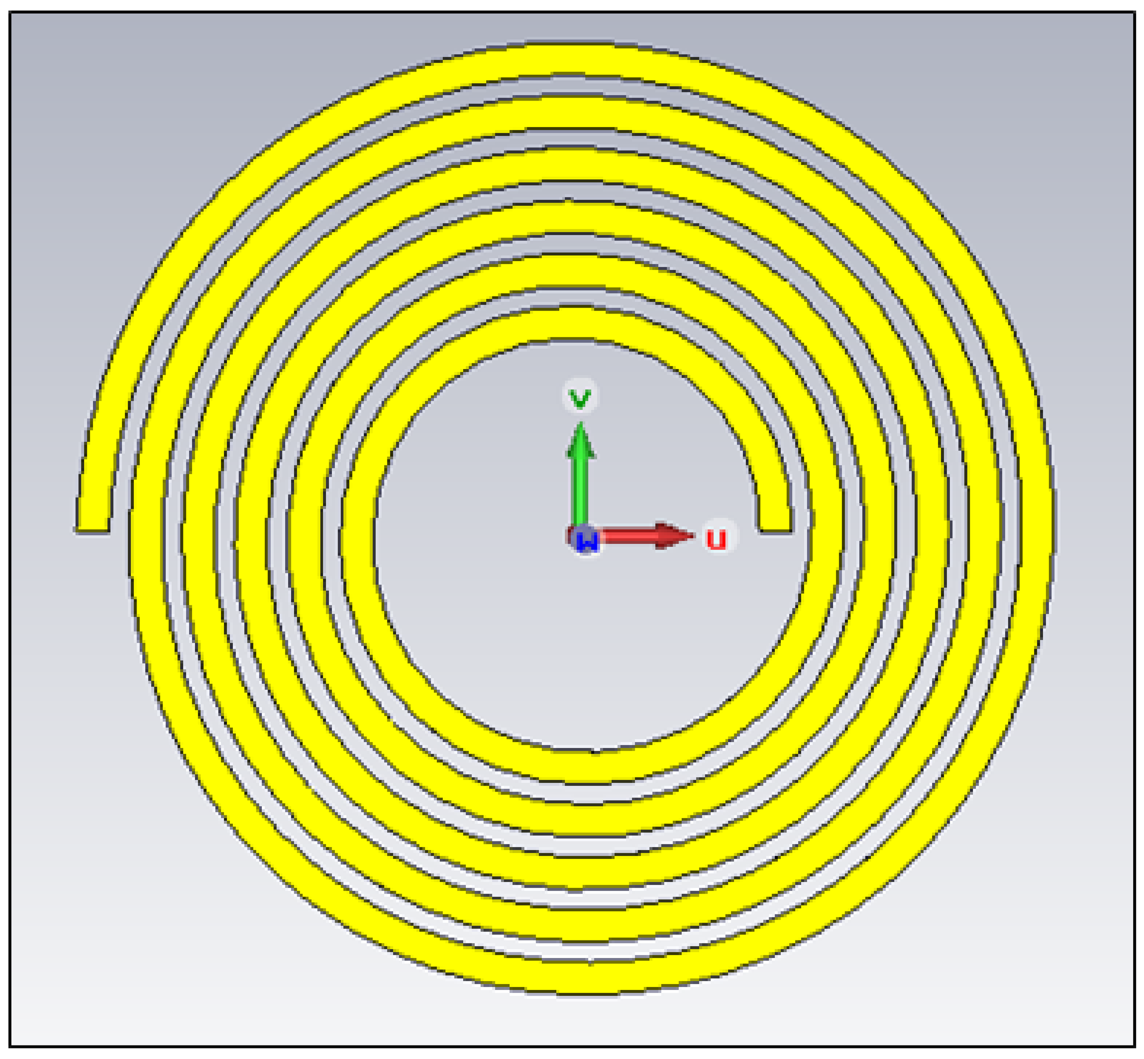

Figure 2 Archimedean Spiral

After simulating the Archimedean spirals the results showed a very high resonance frequency (approx. 21.5 MHz). These high resonance frequency would lead to a low transmission efficiency. The goal of the project was to reduce this frequency.

Solution: Knowing that the resonance frequency is $f = \frac{1}{2\pi * \sqrt{LC}}$ there are only two ways to reduce it, either by increasing the capacitance or by increasing the inductance. Increasing the inductance will lead to high Ohmic losses, so the best solution was to increase the capacitance. The capacitance will be increased by inserting the so called stubs in the spiral. These stubs are just cuboid shaped copper elements. The inserted stubs in the spiral can be seen in Figure 3.

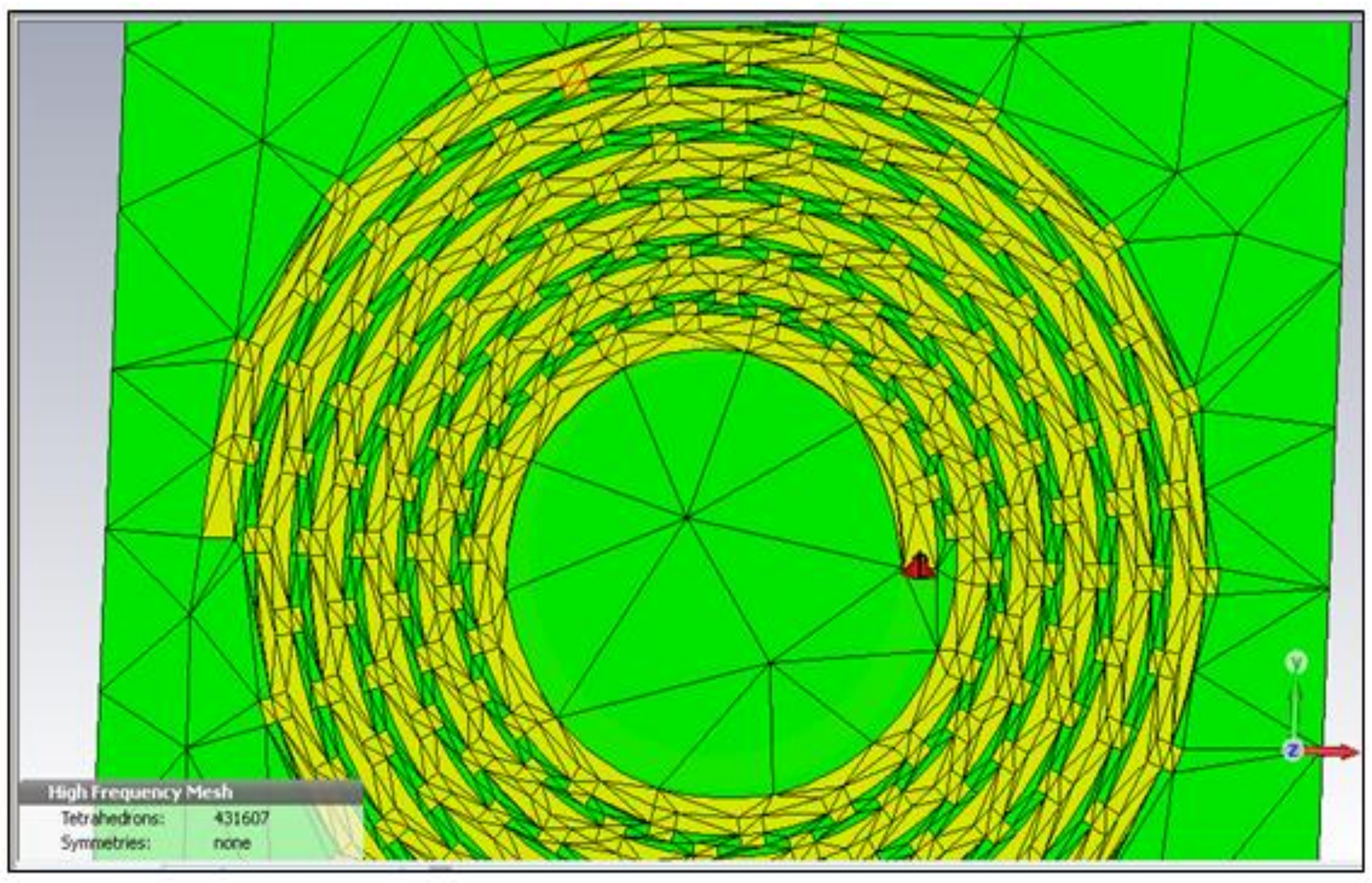

Figure 3 Spiral with inserted stubs, without Boolean add (Mesh View)

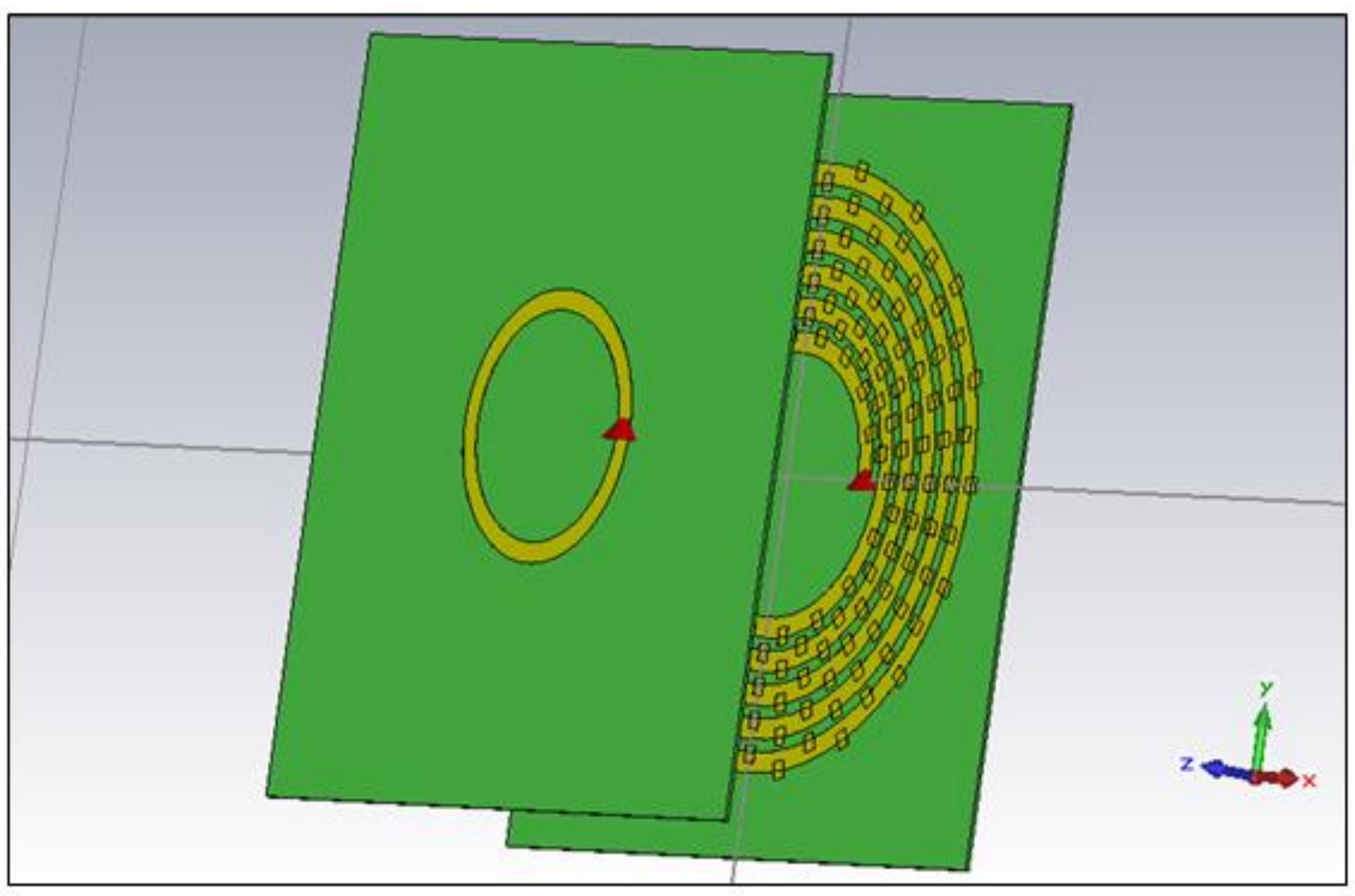

Figure 4 Final Design

As one can see in Figure 1, we need two coils which resonate at the same frequency in order to have a resonant inductive energy transfer.
To complete the design we have to add the coupling loop at the back side of the board (with the discrete port) and then translate the model in Figure 3 (Mesh View) to get the complete design in Figure 4. In Figure 3 the stubs are inserted into the spiral but there was no Boolean add operation performed, because the meshing is better performed without the Boolean add operation (with Boolean add 415000 Mesh cells, without 431000).
The design then was simulated using the Frequency Domain Solver of CST and the results were satisfactory. We saw from the results that the resonant frequency was reduced to 16.75 MHz as displayed in Figure 5.

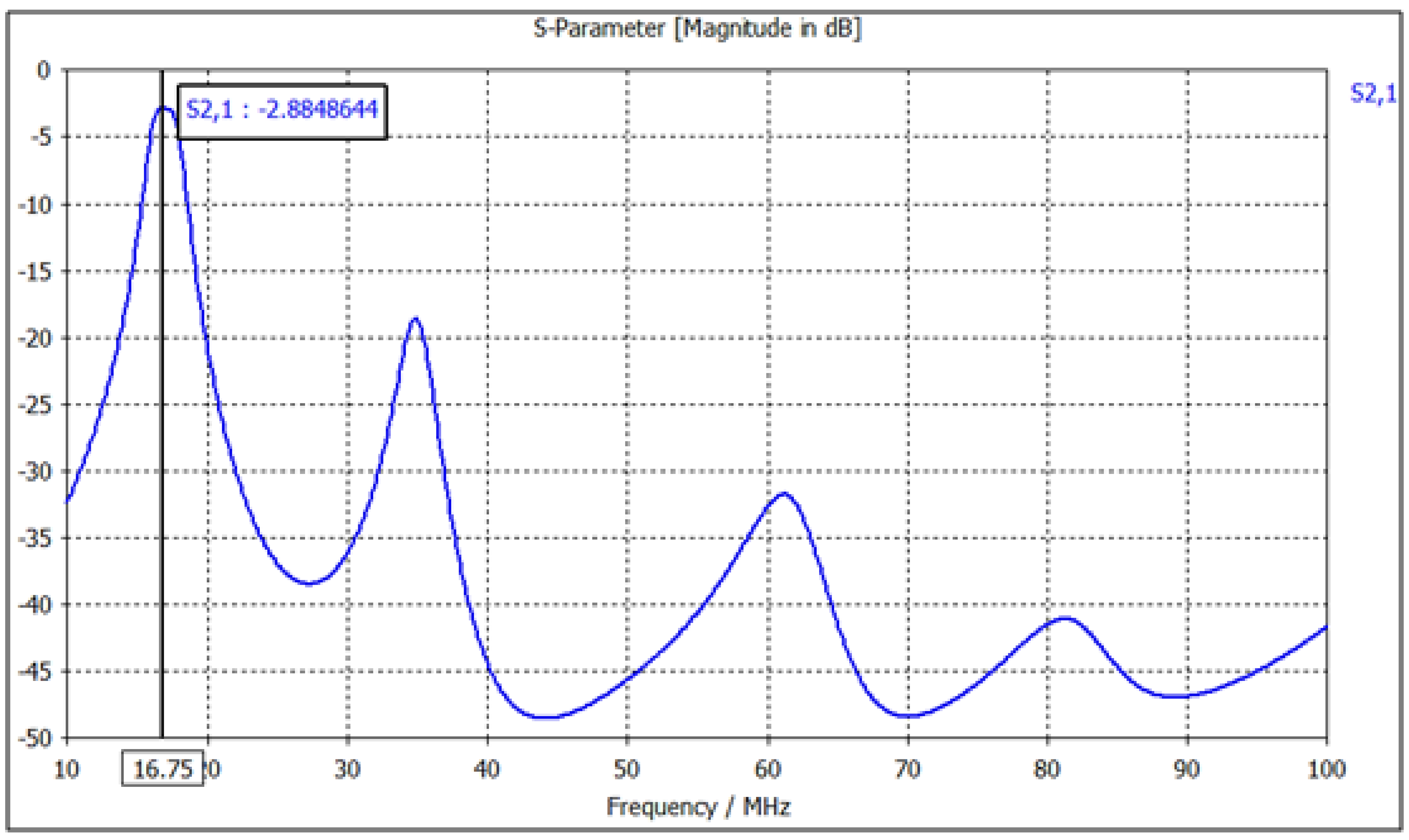

Figure 5 Simulation Results

The maximum point of the transmission curve ($20 * logS21 = -2.88dB$) has a linear value of S21=0,717.