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Sandia National Laboratories

Electrically Small Antennas with Minimal Broadband Radio Frequency Threat Coupling

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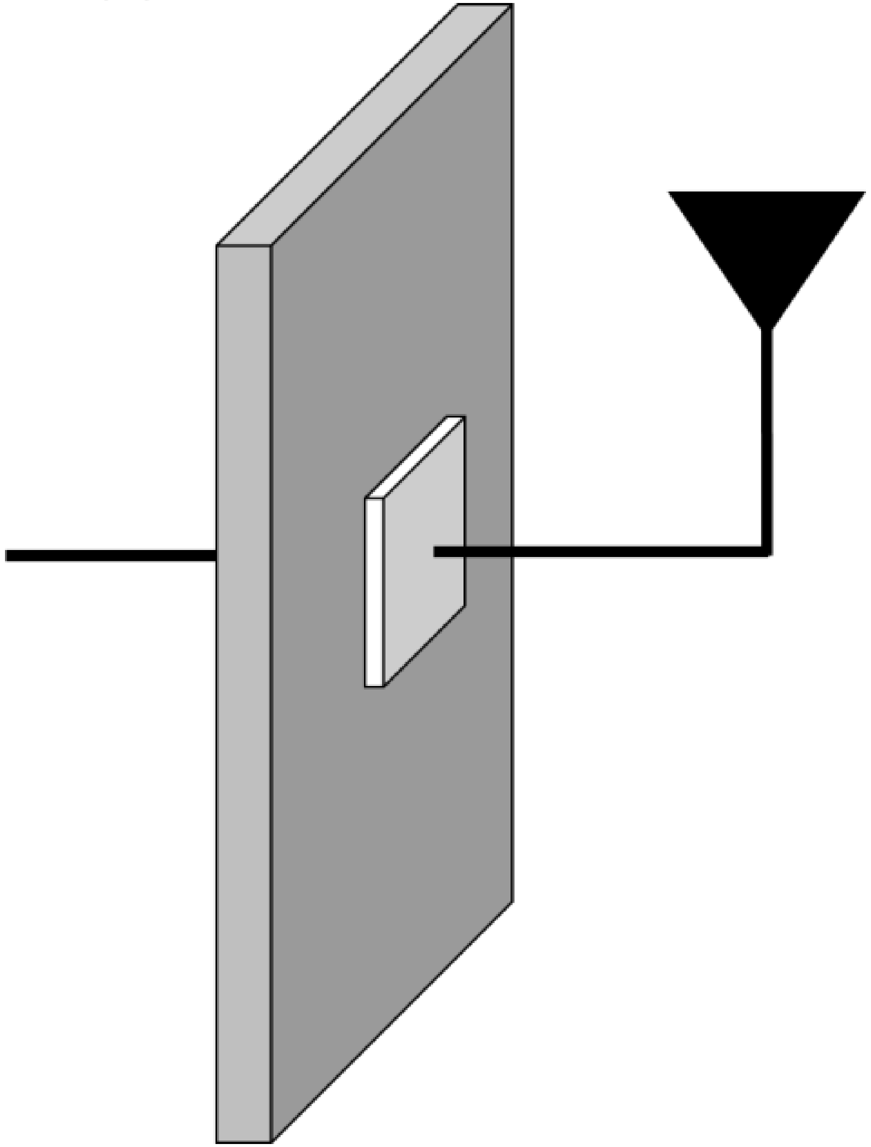
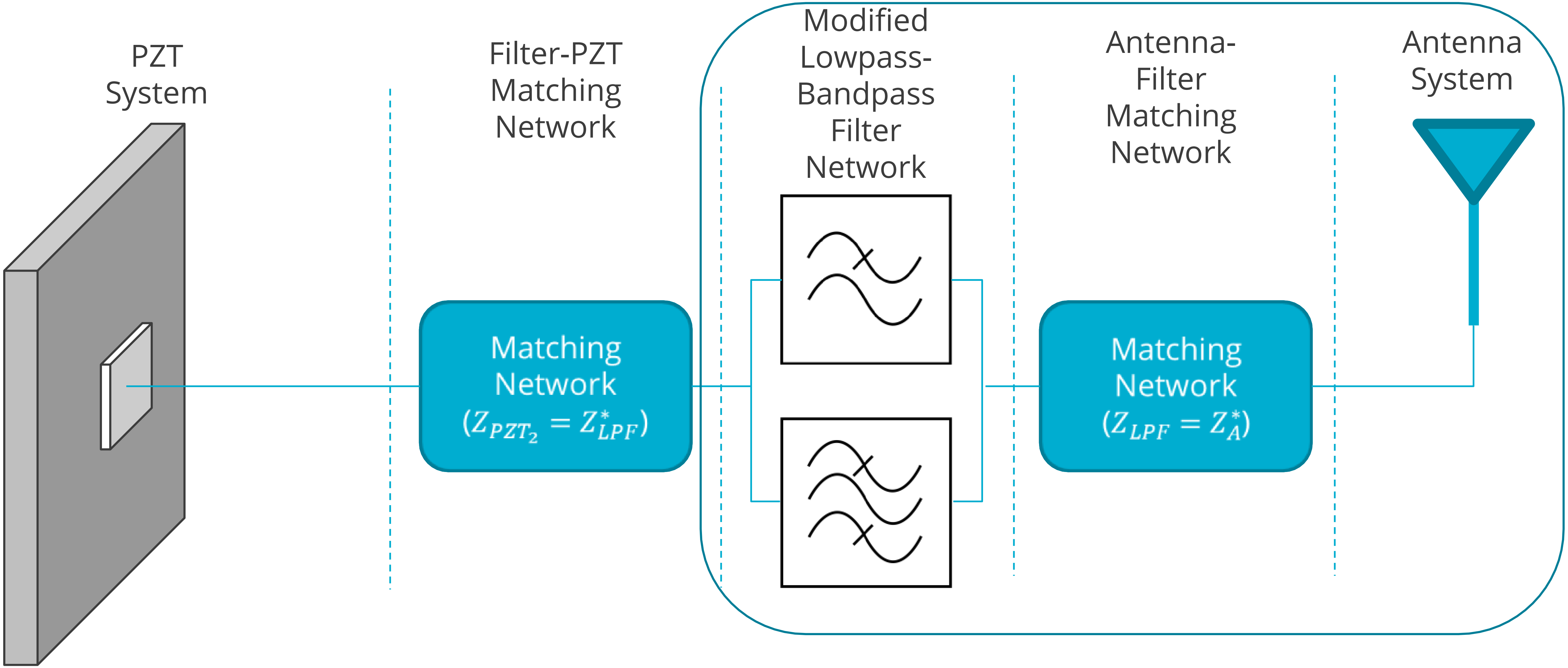
Background – Piezoelectric Tile Interface

Purpose

- In our application we wish to transfer electrical energy through a metallic boundary.
- This metallic boundary will be part of a Faraday cage that will be without any perforations or any kind of RF instrumentation.
- Piezoelectric Tiles (PZT) are of interest because of their ability to act like a mechanical transducer.
- Using PZTs will avoid the need to make any physical alterations to the Faraday cage. This, in return, will maintain the electrical integrity of the Faraday cage.
- Additionally, we will have the ability to communicate with the electronics that are within the Faraday Cage, through the metallic boundary.

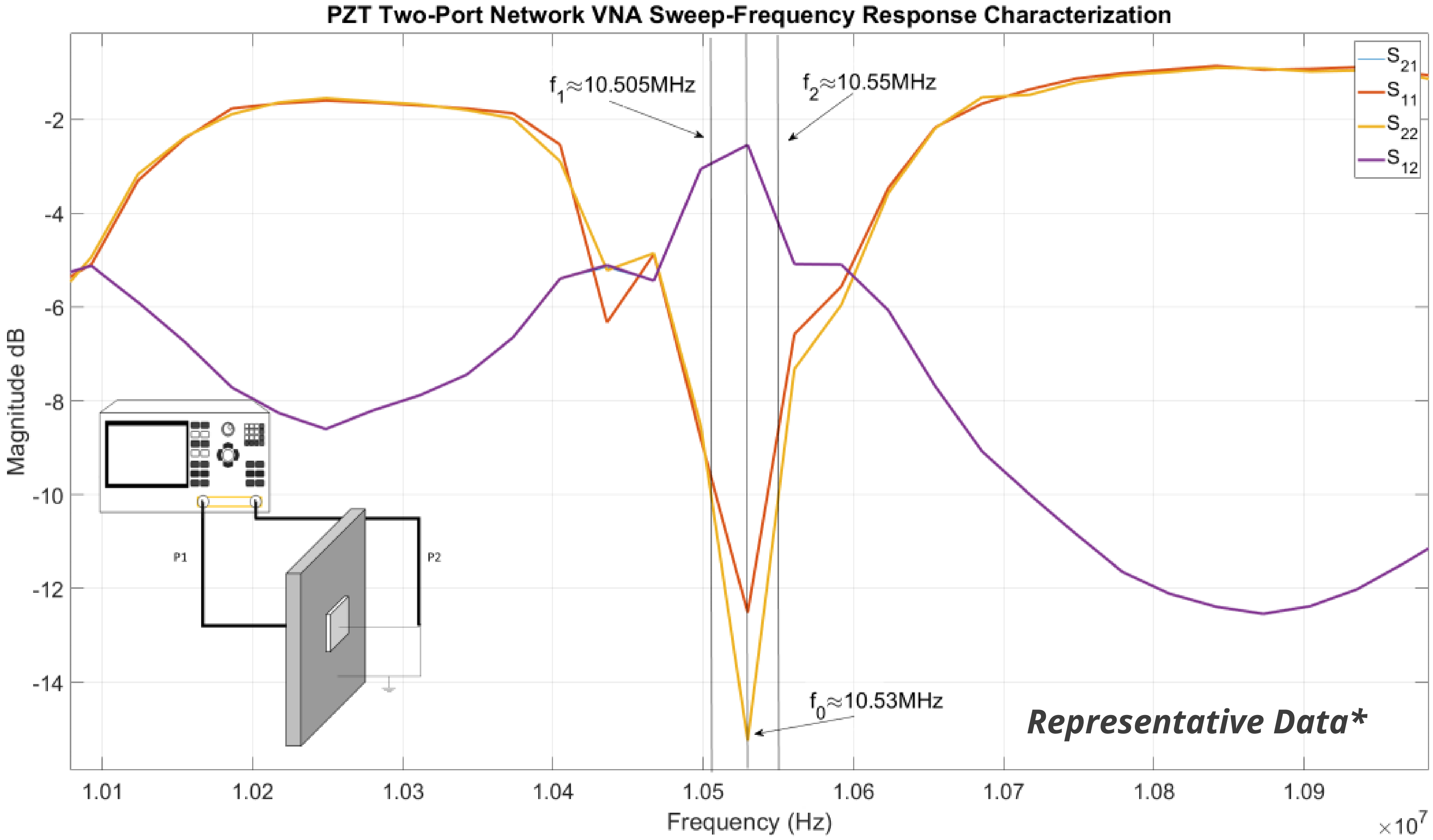


Proposed Layout



Limitations, Characterization & Observations

- Best Match at port 2 was at $f_0 \approx 10.53MHz$ with the lowest return coefficient of $S_{22}[dB] = -15.246\ dB$ and a $BW \approx 45KHz$
- The radiator connected to the PZT will have a height limitation of about 2-3 feet.
- The antenna network will need to be designed to avoid broadband coupling, and to also match to the narrowband frequency response of the PZT network.

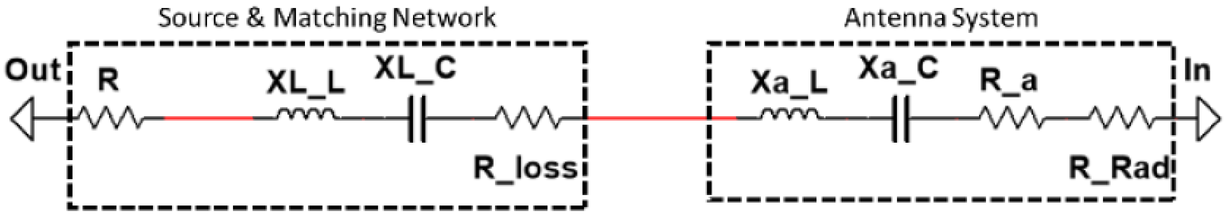


Representative Data*

Electrically Small Antenna (ESA)

Pros:

- As an antenna becomes physically smaller, its Q will increase. High Q networks have a narrow bandwidth frequency response.
- Narrow bandwidth frequency response antenna network (along with RF filter systems) will prevent broadband coupling.
- This will result in a resilient Antenna Network against potential broadband RF threats above 10MHz.
- A physical small antenna will meet the physical constraints.



Cons:

- Electrically small antennas will have a low efficiency, η.

$$\eta = \frac{R_{rad}}{R_{rad}+R_{\ell}+R_{a}+R}$$

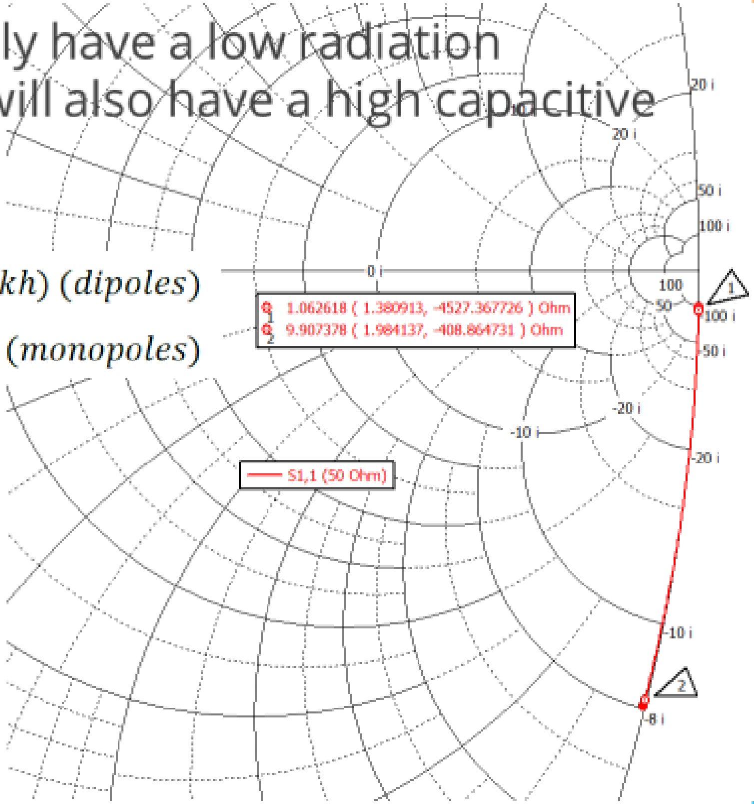
$$R_{rad} = 20k^2\left(\frac{L}{2}\right)^2 \ (dipoles)$$

$$R_{rad} = 10k^2\left(\frac{L}{2}\right)^2 \ (monopoles)$$

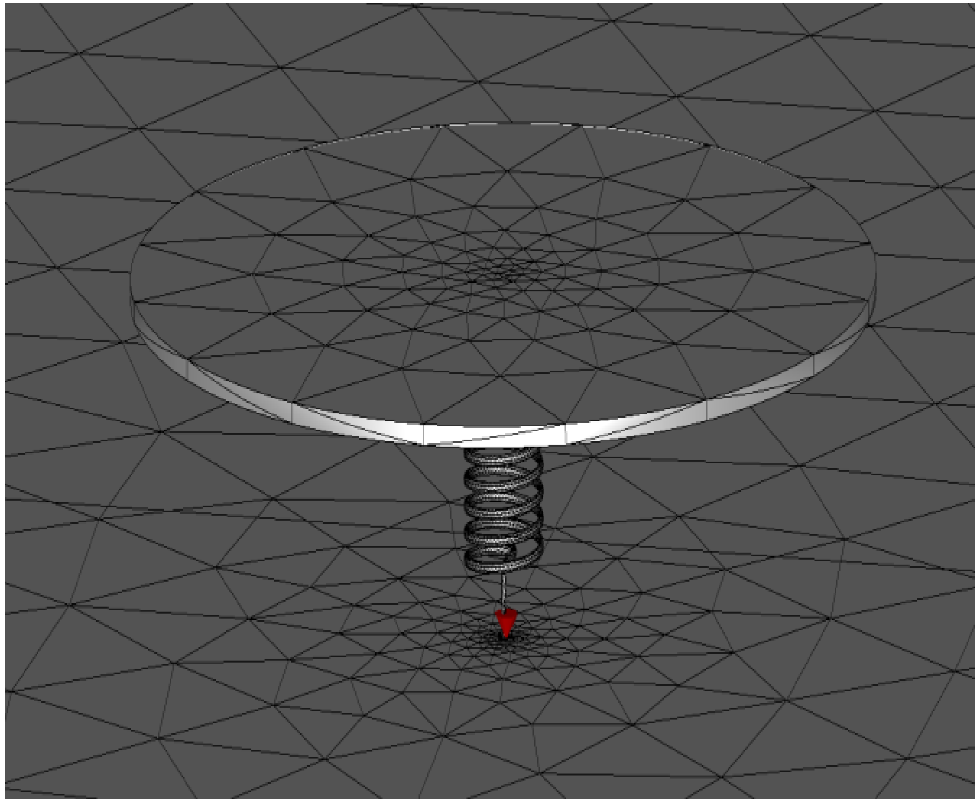
- ESAs will not only have a low radiation resistance but will also have a high capacitive reactance.

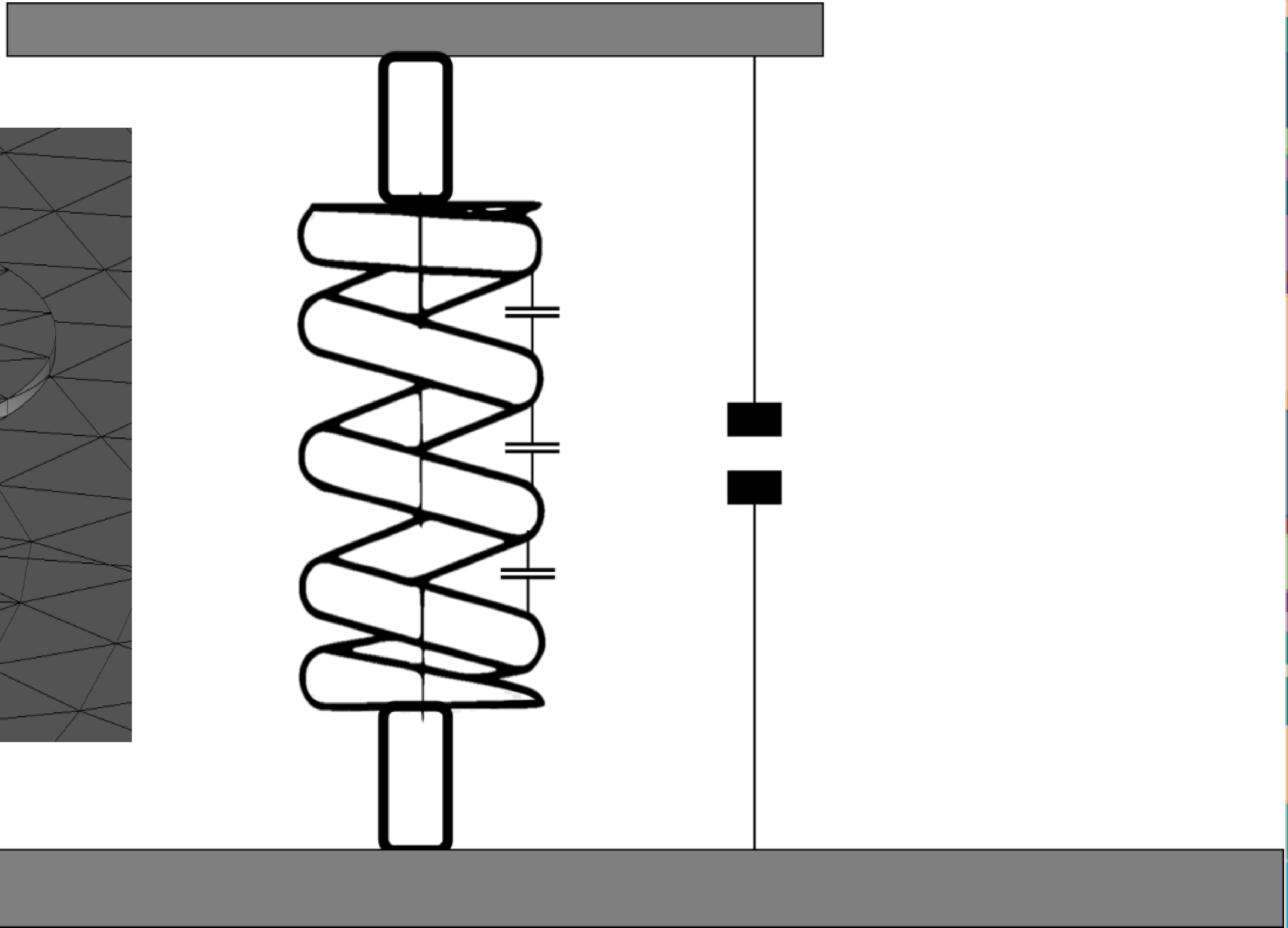
$$X_a = 120\left(1 - \ln\left(\frac{L}{2a}\right)\right)\cot(kh) \ (dipoles)$$

$$X_a = 60\left(1 - \ln\left(\frac{L}{2a}\right)\right)\cot(kh) \ (monopoles)$$

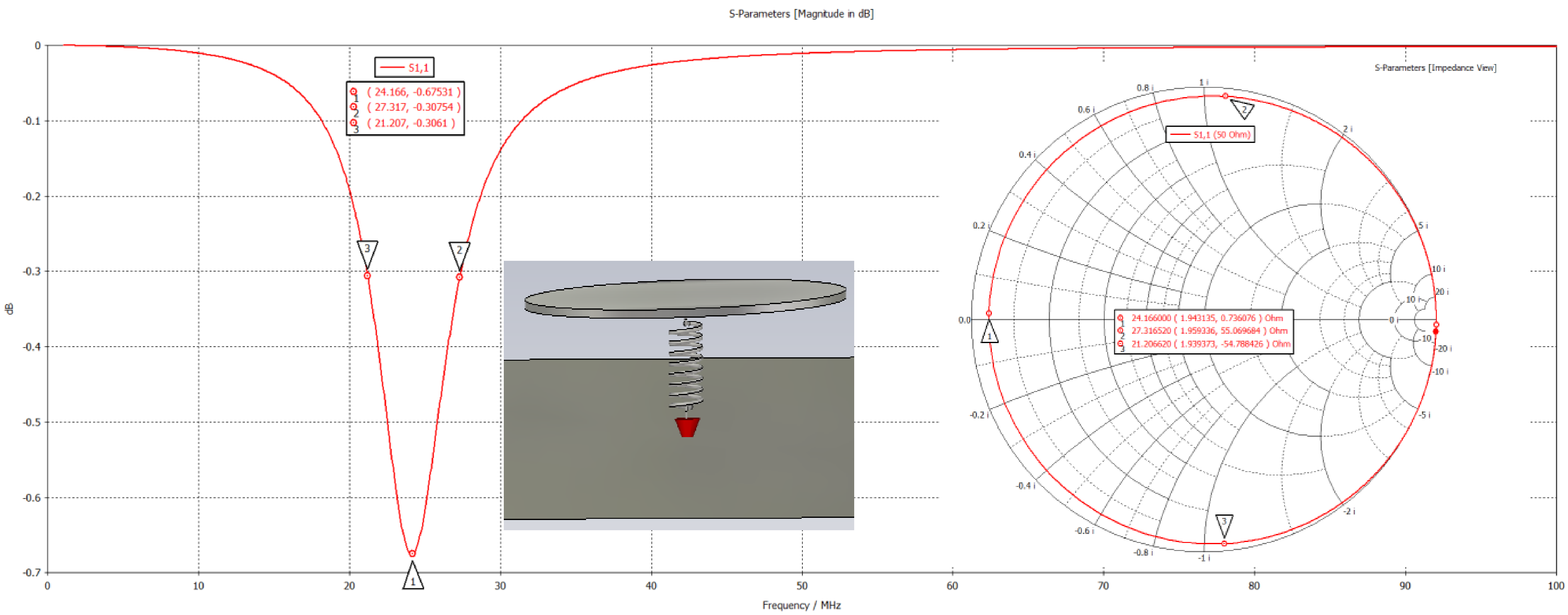


Antenna System: Preliminary Design (Dimensions in cm)

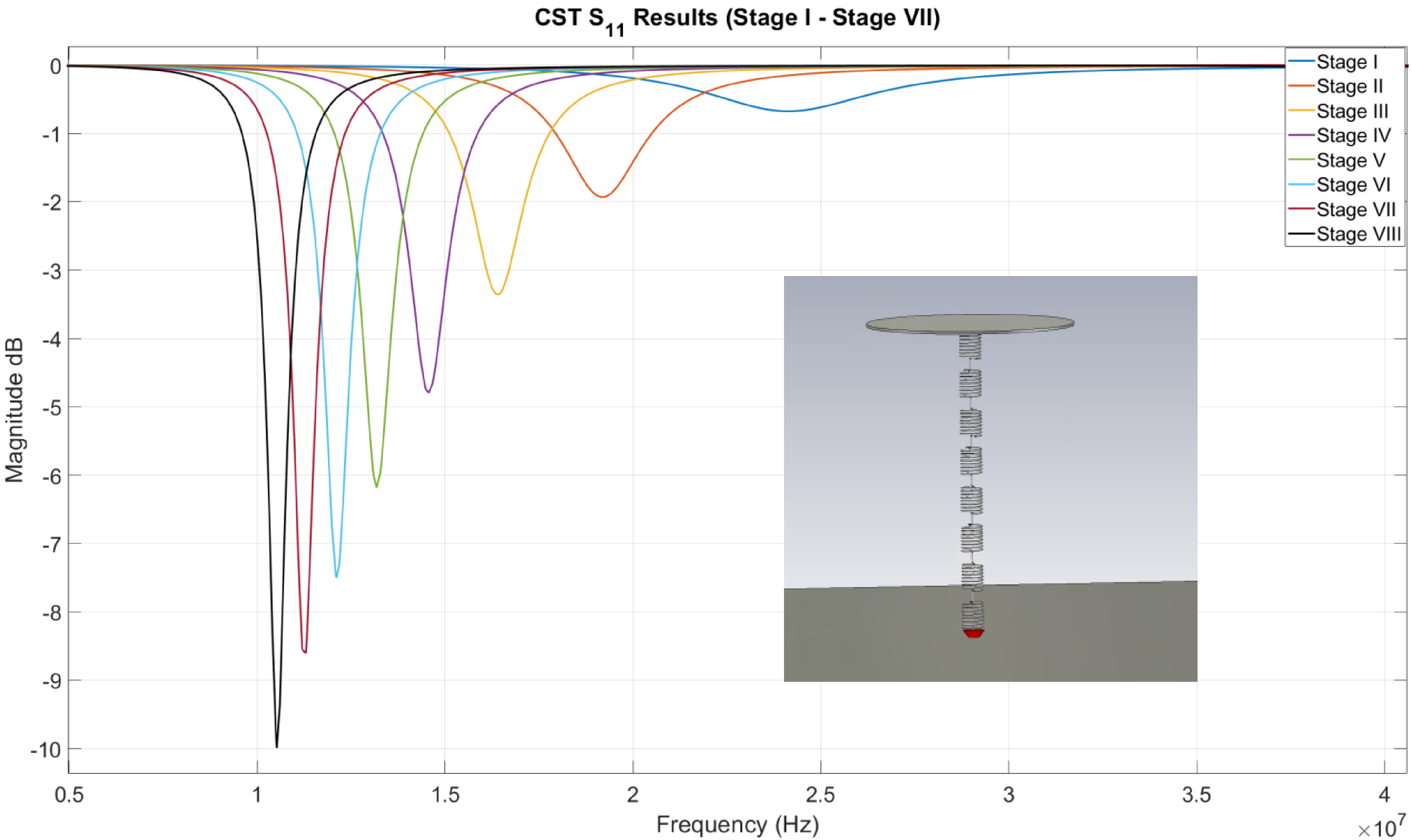




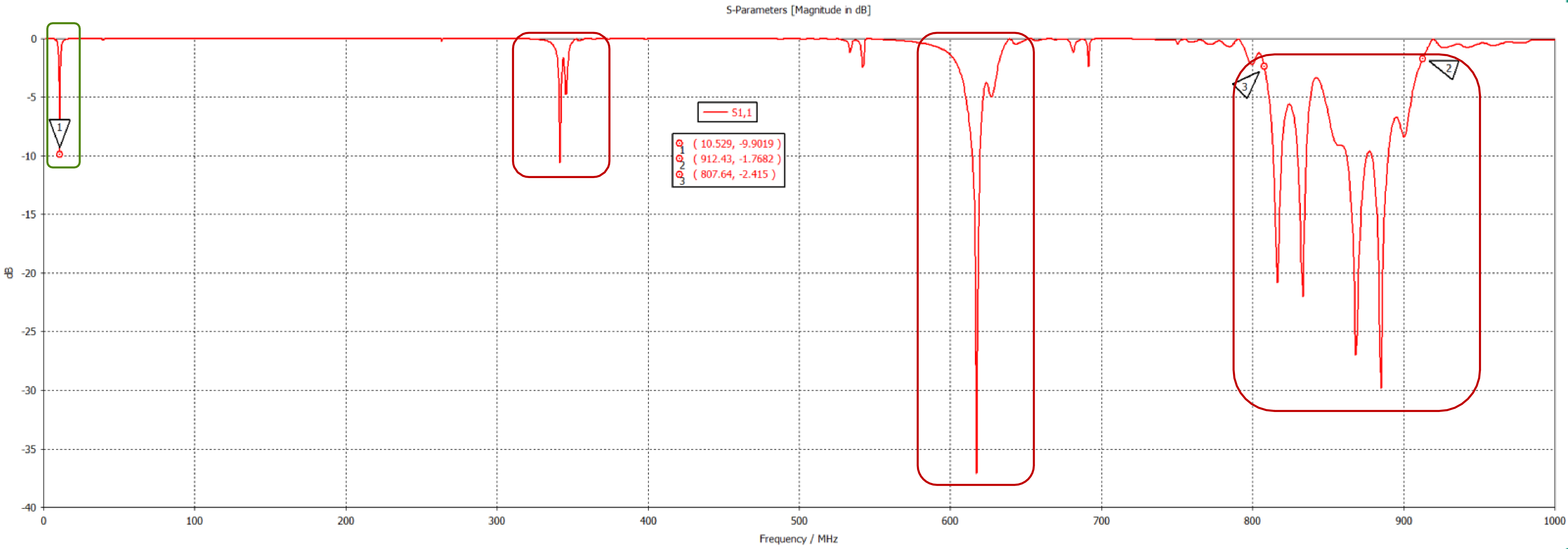
Antenna System: Preliminary Results Simulation (Stage I)



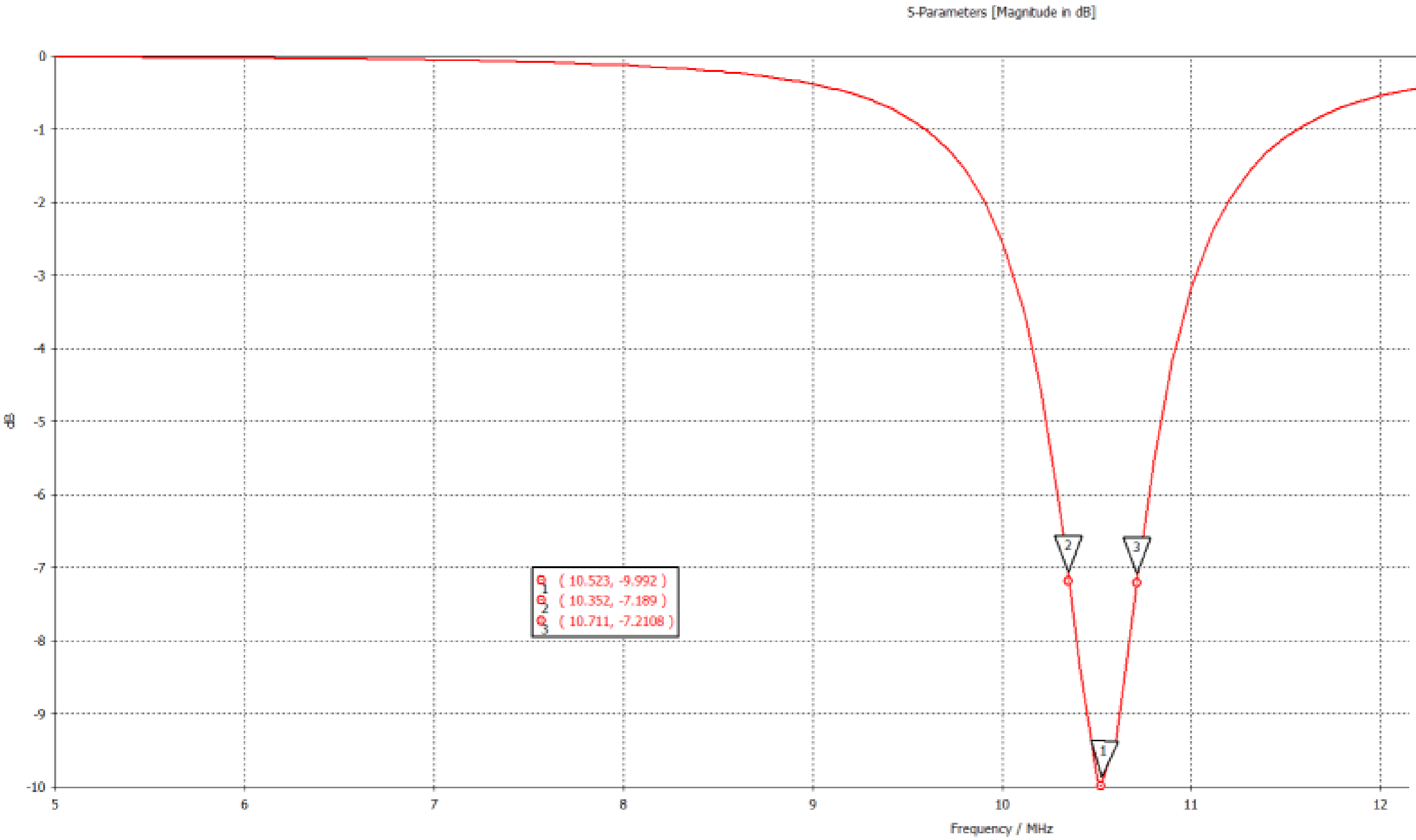
Antenna System: Stages I through VIII Simulation Results

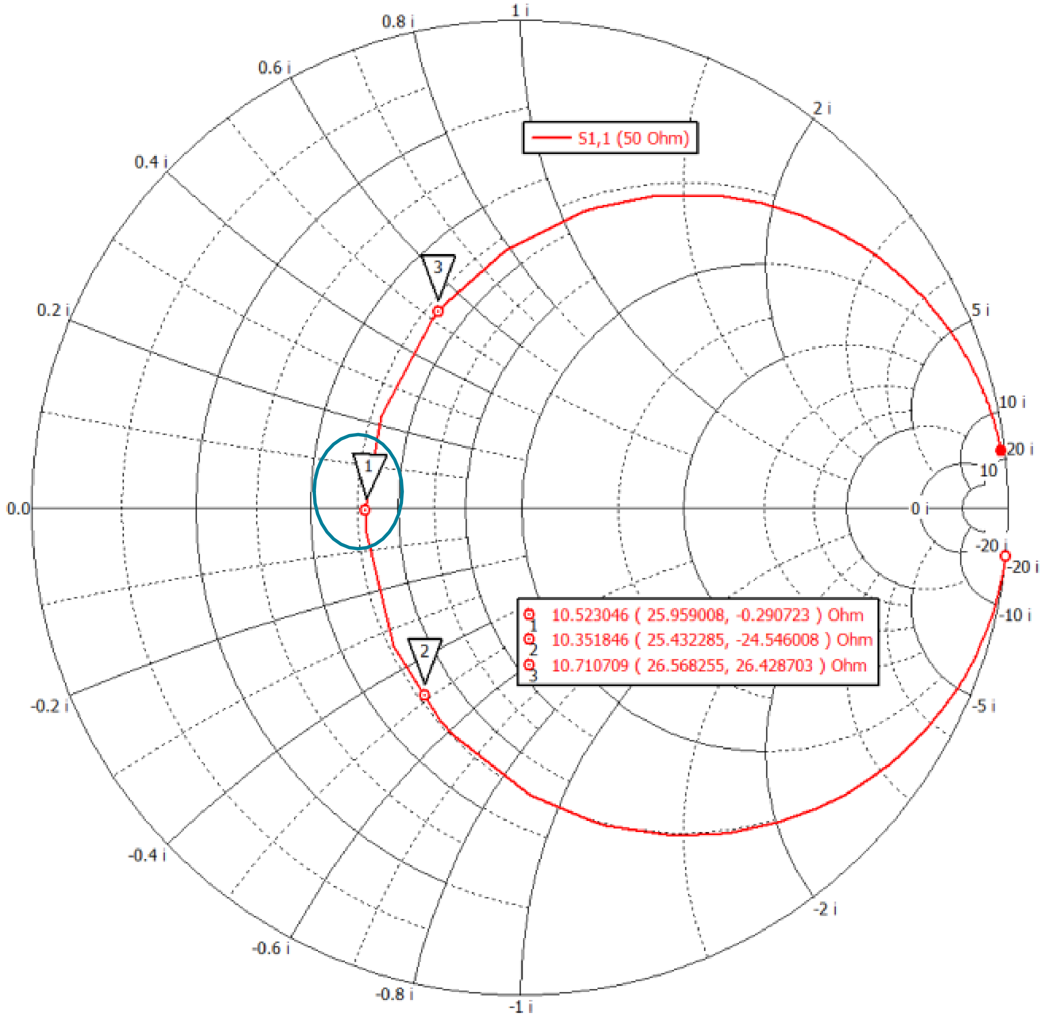


Broadband Frequency Response – Before Matching and Filtering

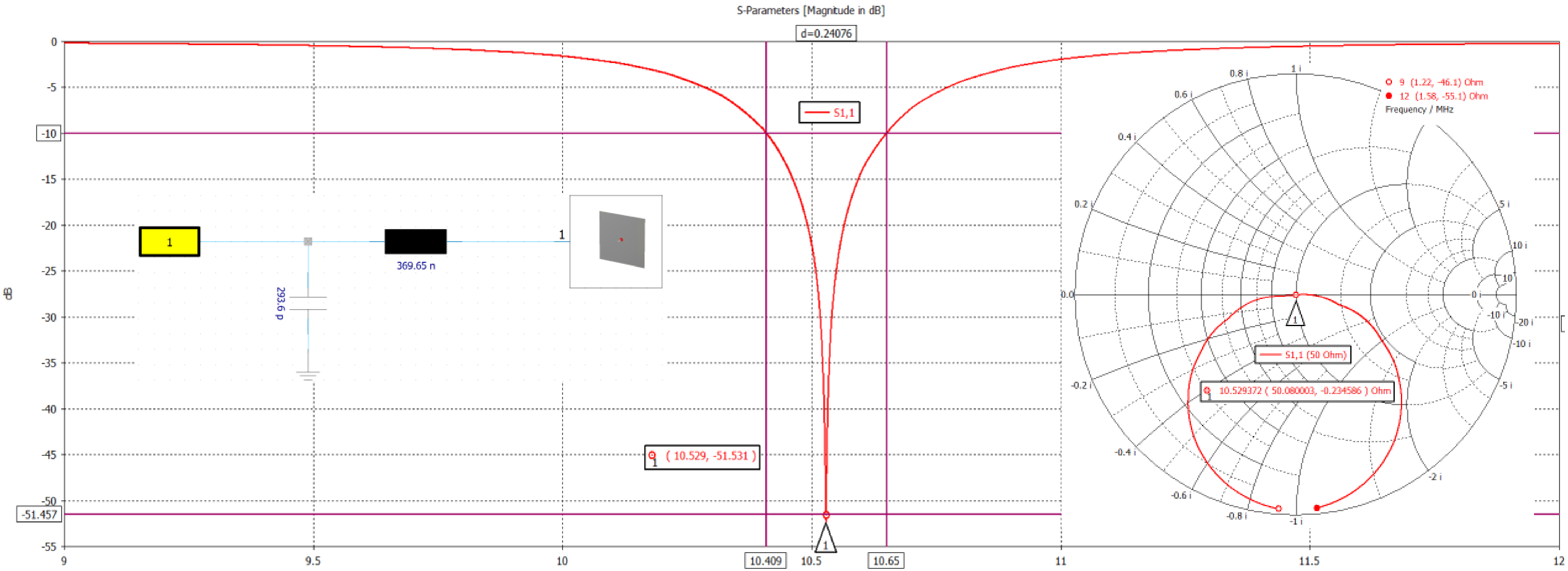


Stage VIII – S11 & Impedance Simulation Results



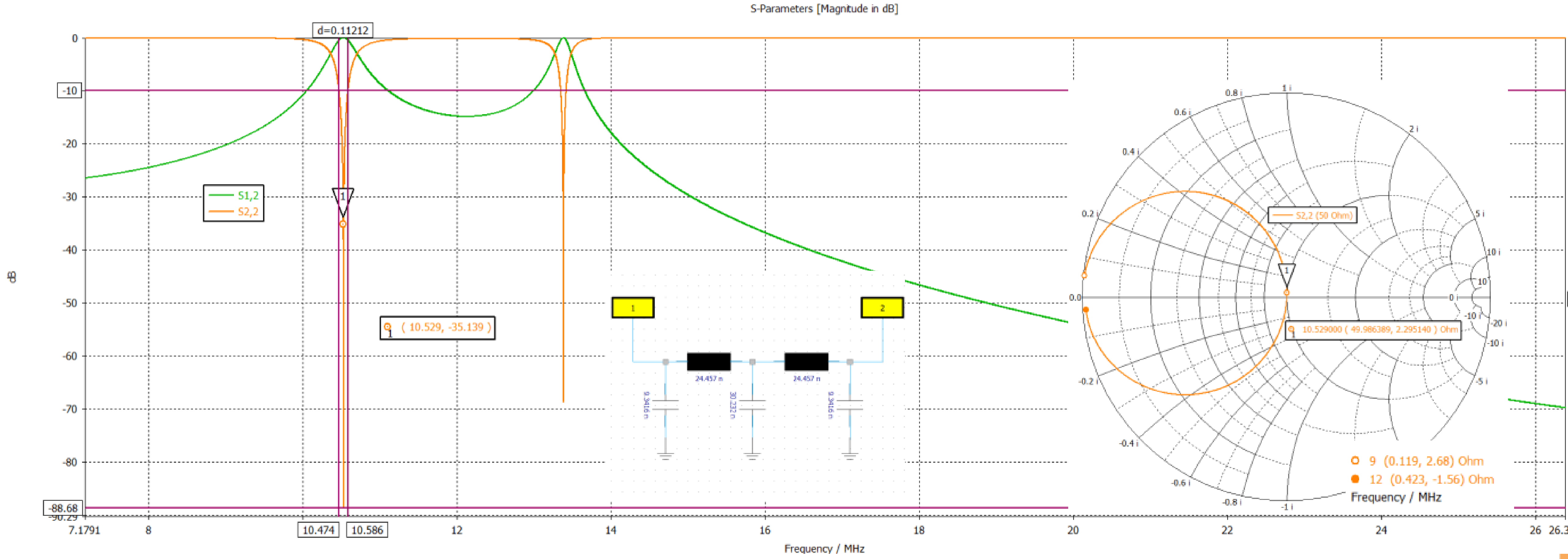


Antenna-Filter Matching Network



$$BW \approx 241\,kHz$$

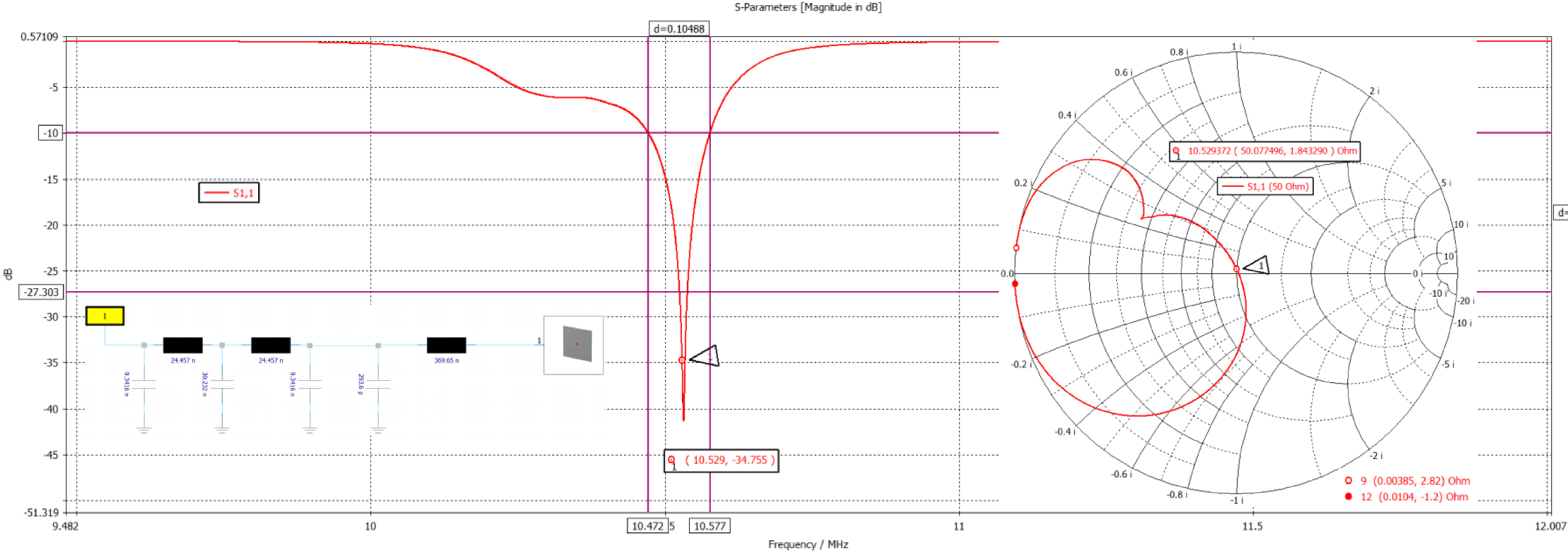
Modified LP Filter - Pi Filter Design



$BW \approx 112\,kHz$

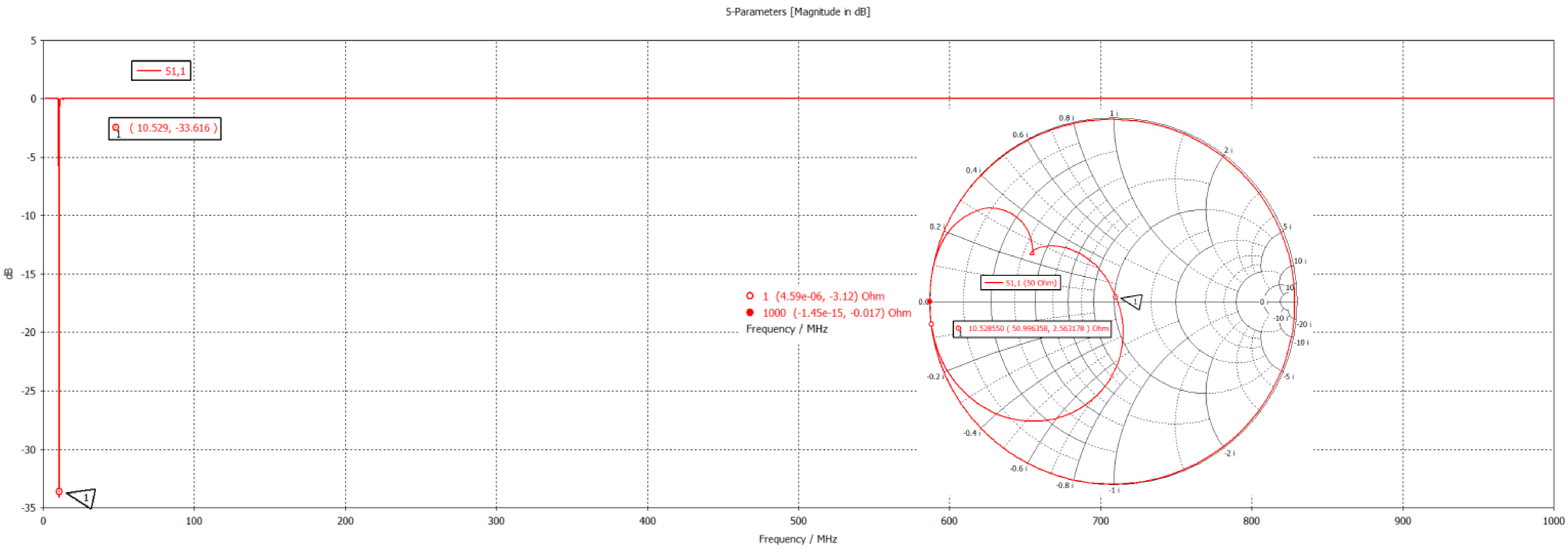
$Q \approx 94$

Pi Filter, Matching Network and Antenna System



$BW \approx 105 kHz$

Broadband Frequency Response – After Matching and Filtering

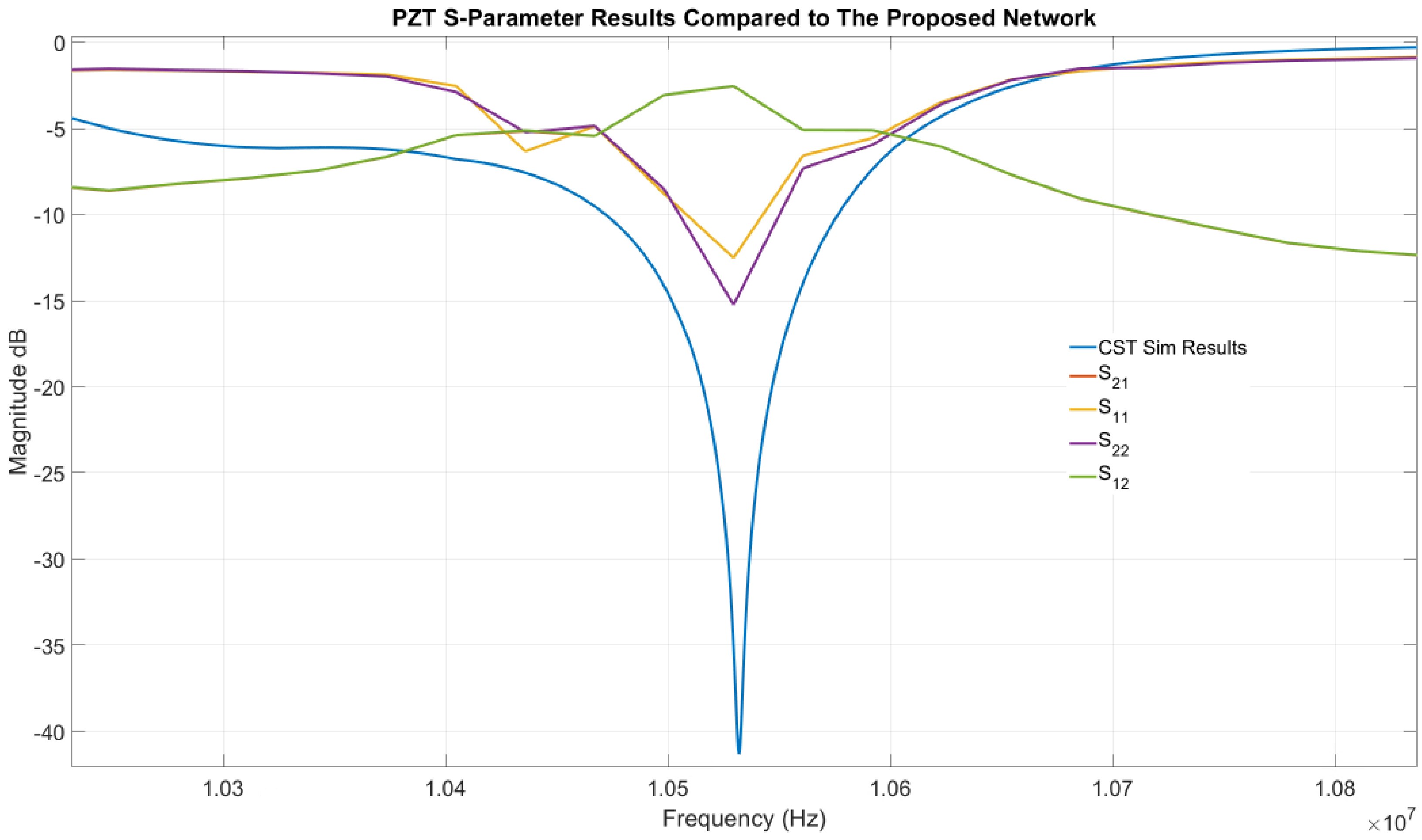


Conclusions & Future Work

- The filter network and matching network constrained the ESA's electrical properties to operate at a narrow band of frequencies.

Next steps

- Fabricate Antenna
- Fabricate RF Boards
- Design an EMC enclosure to house the RF boards and mate with the antenna.
- Test and Characterize the system inside an EM Chamber (i.e Reverberation Chamber)
  - At the front end level (i.e. Antenna Coupling)
  - At the individual circuit component level



Questions?