OELP End Semester presentation

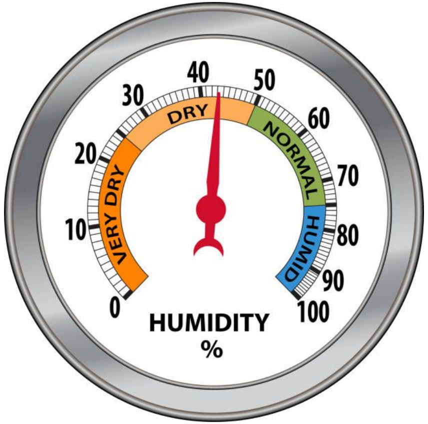
Humidity sensing using Substrate Integrated Waveguide

Supervised by Dr. Sukomal Dey

Pavitra R- 122301031
V.Avighna Kumar- 122301039

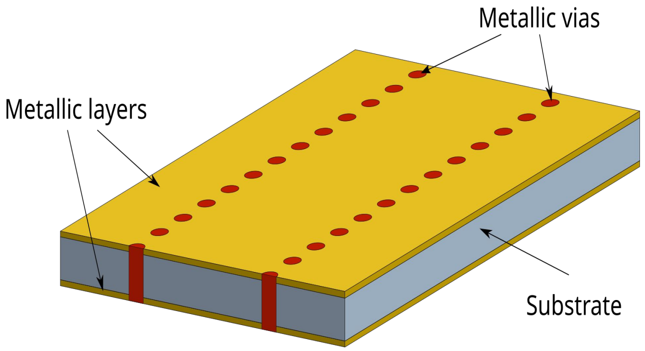
Importance of Humidity Sensing

- Crucial for various applications, including weather monitoring, industrial processes, healthcare, and agriculture.
- It helps in predicting climate changes, ensuring optimal conditions in greenhouses, and preventing damage to sensitive electronics.
- In healthcare, humidity sensors are used in ventilators and incubators to maintain proper air moisture.
- Industries rely on them to prevent corrosion, control manufacturing processes, and ensure product quality. Additionally, they enhance comfort in smart homes and vehicles by regulating air moisture.



Humidity Sensing using SIW

- In an SIW-based humidity sensor, a dielectric-sensitive material is integrated onto the SIW structure. This material absorbs moisture from the surrounding environment, leading to a change in its dielectric constant.
- As humidity increases, the dielectric constant variation alters the propagation characteristics of the SIW, specifically affecting parameters like resonant frequency, phase shift, and attenuation.
- By monitoring these changes, the system can accurately determine the relative humidity (RH%) in real time



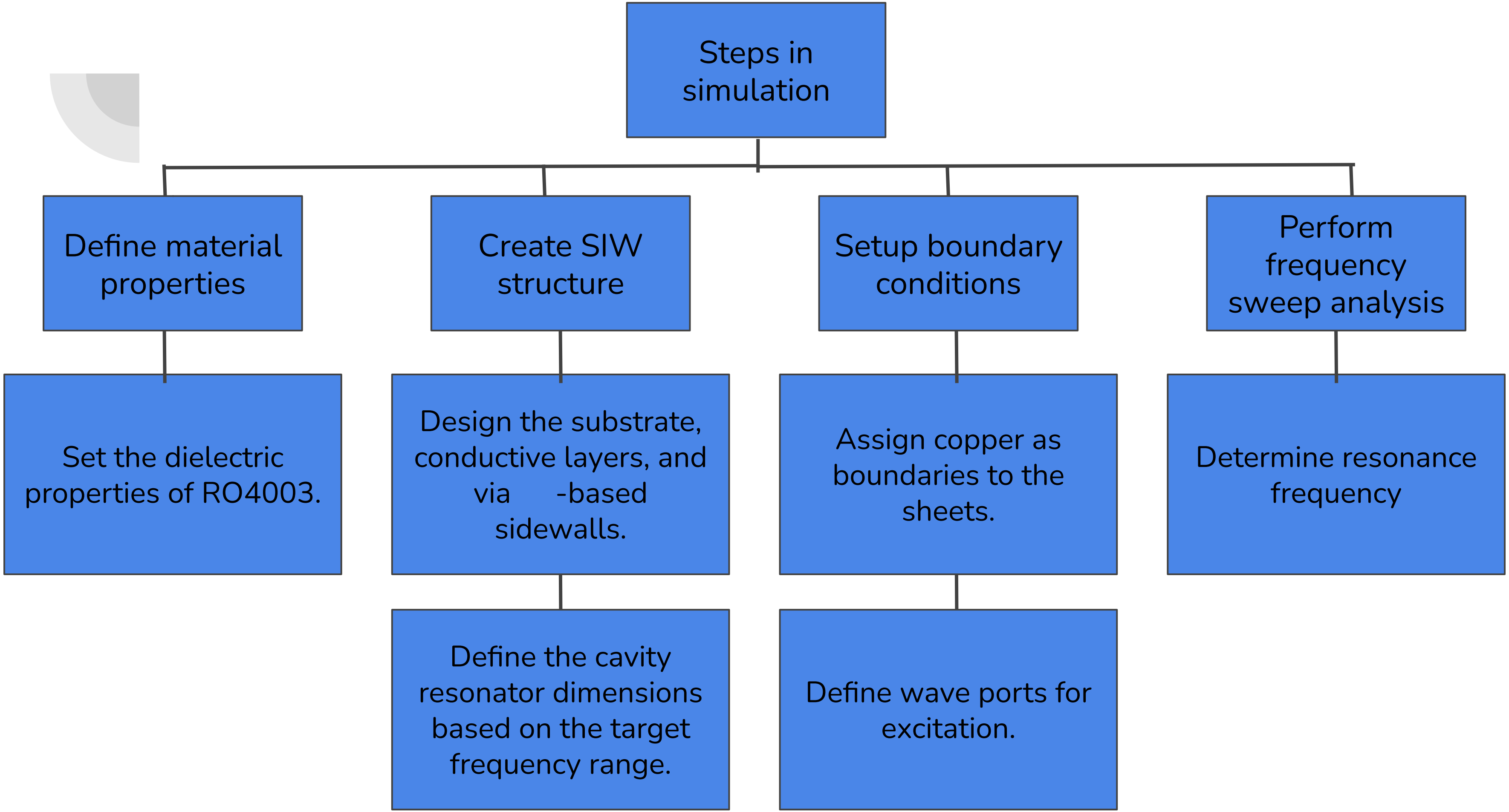
Challenges in Humidity Sensing

- Accuracy and Calibration
- Response Time and Hysteresis
- Long-term Stability and Aging
- Temperature Dependence
- Condensation Issues
- Low Humidity Sensing
- Material Selection
- Energy Consumption
- Interference from Contaminants
- Integration with Other Systems

Specific Technical Challenge in Humidity Sensing Using SIW

- **Material selection**: The substrate must be highly sensitive to humidity changes.
- **Design optimization**: SIW structures must be tailored for maximum sensitivity.
- **Measurement accuracy**: Noise and external factors can affect readings.

Proposed Solution – Design Approach


Steps in simulation
Define material properties
Create SIW structure
Setup boundary conditions
Perform frequency sweep analysis
Set the dielectric properties of RO4003.
Design the substrate, conductive layers, and via -based sidewalls.
Assign copper as boundaries to the sheets.
Determine resonance frequency
Define the cavity resonator dimensions based on the target frequency range.
Define wave ports for excitation.

Calculations

The relation between humidity and air permittivity:

$$\varepsilon_r = 1 + \frac{211}{T}\left(P + \frac{48P_s}{T} RH\right) \times 10^{-6}$$

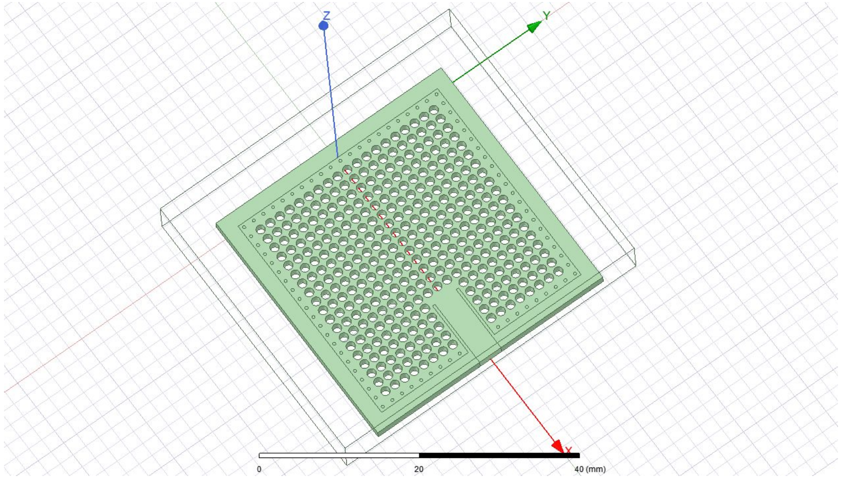
Where P is the pressure of air in mmHg, T is temperature in Kelvin, Ps is the pressure of saturated water vapor in mmHg, and RH is humidity percentage.

The relation between resonance frequency and relative permittivity:

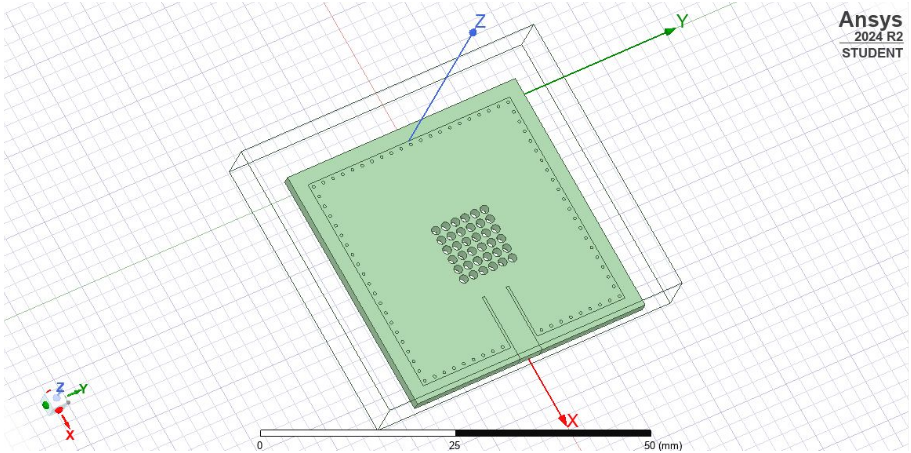
$$f_{R,mn} = \frac{c}{2\sqrt{\varepsilon_{r,eff}}} \sqrt{\left(\frac{m}{W_{eff}}\right)^2 + \left(\frac{n}{L_{eff}}\right)^2}$$

$$\delta f_r = \left|\frac{\partial f_r}{\partial \varepsilon_r}\right| \delta\varepsilon_r = \left|\frac{\partial f_r}{\partial \varepsilon_r}\right| \left(\left|\frac{\partial \varepsilon_r}{\partial P}\right|_{P_0} \delta P + \left|\frac{\partial \varepsilon_r}{\partial T}\right|_{T_0} \delta T + \left|\frac{\partial \varepsilon_r}{\partial H}\right|_{H_0} \delta H \right)$$

Model

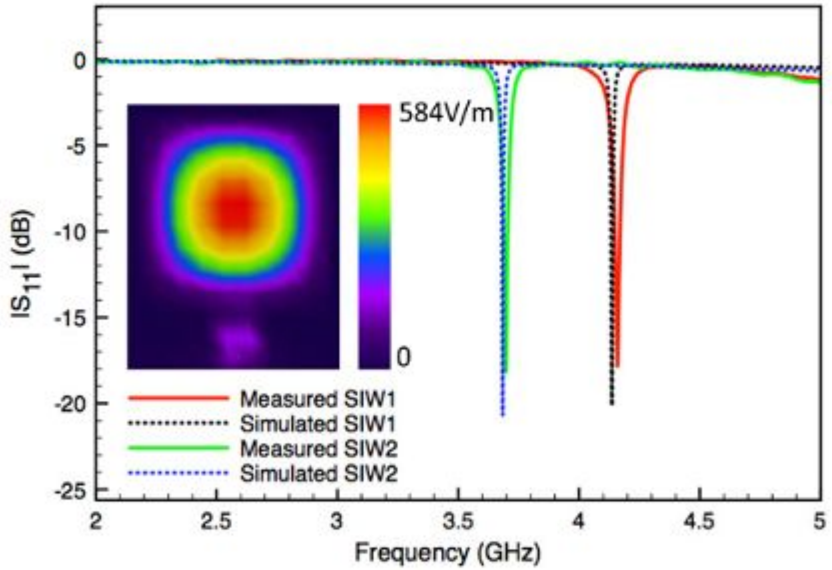


SIW1



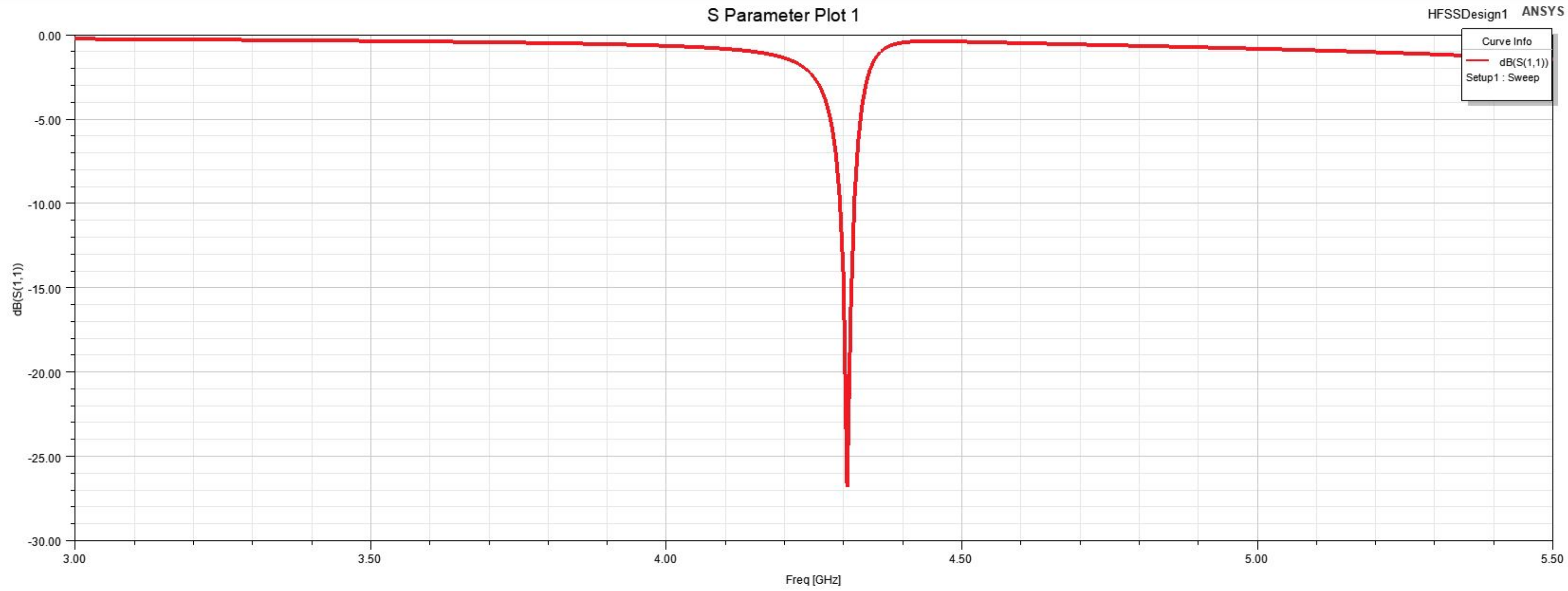
SIW2

Expected Result

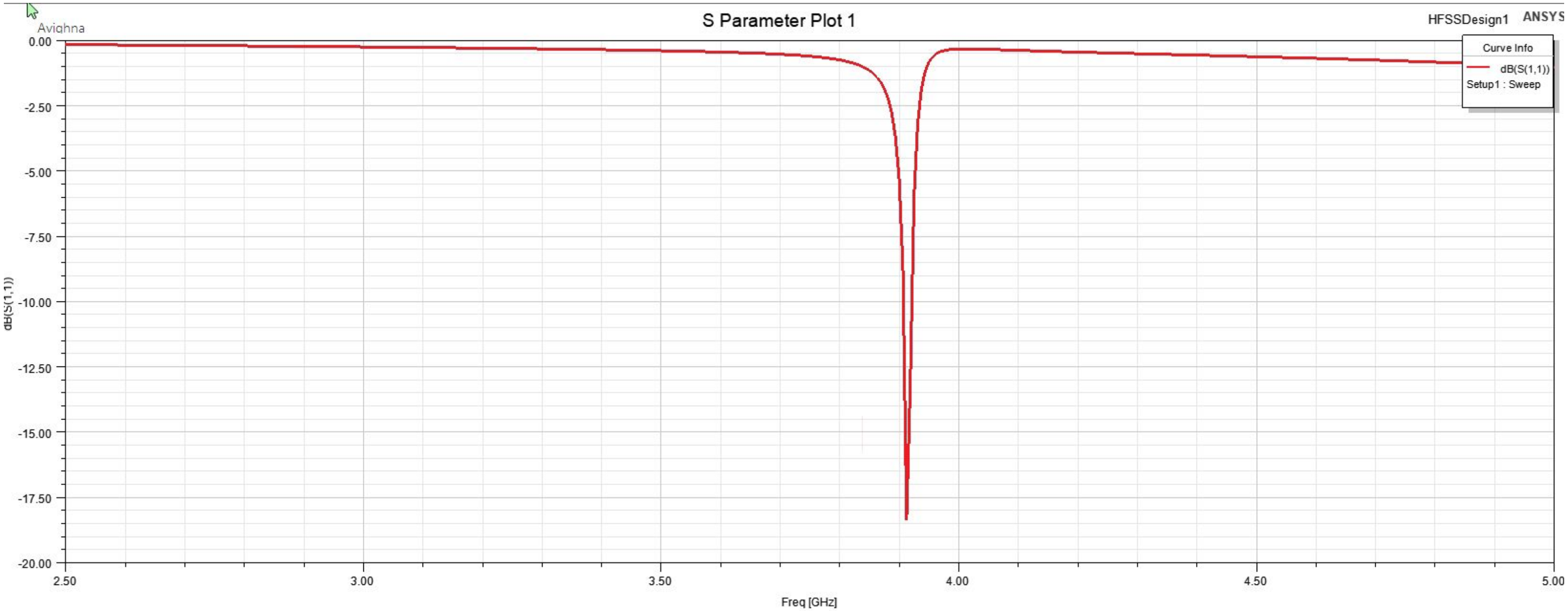


Source: Passive Microwave Substrate Integrated Cavity Resonator for Humidity Sensing(Reference - 1)

Result obtained for SIW1

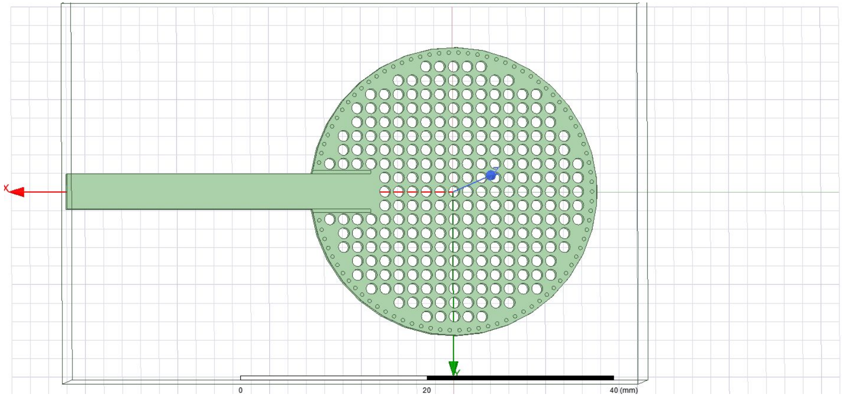


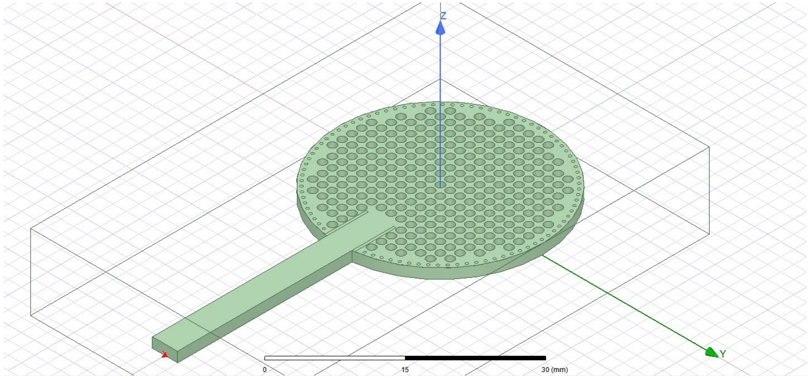
Result obtained for SIW2



Further modifications

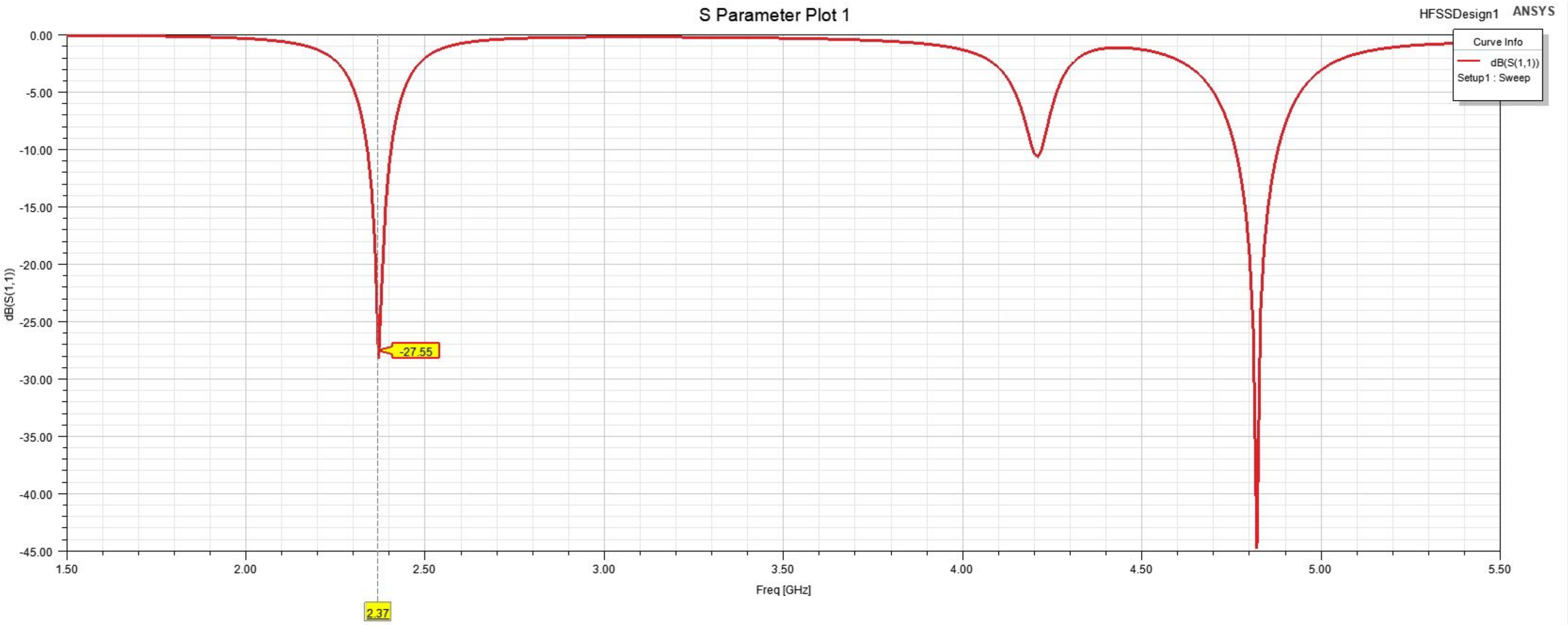
Model



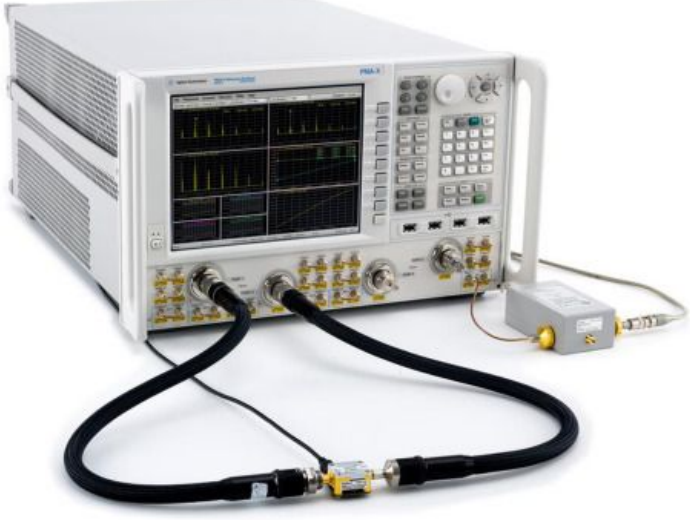


Sent for fabrication.

Result obtained for Circular SIW



SubMiniature version A



Vector Network Analyzer

Inferences

- The resonance frequencies were experimentally determined as 4.3 GHz for SIW1 and 3.9 GHz for SIW2.
- Resonance frequency for the circular waveguide = 2.37 GHz.
- The difference in resonance frequencies suggests variations in structural or material properties.
- A lower resonance frequency in SIW2 may indicate higher effective permittivity when compared with SIW1.
- The results confirm that the SIW waveguide structure interacts with humidity, affecting its resonance characteristics.

Conclusion

- The resonance frequency shift confirms the feasibility of SIW-based humidity sensing.
- SIW2, has a lower resonance frequency, but it has less number of air holes because of that the results that we get from it may not be accurate.
- The study provides insights into design optimization for improved humidity sensing performance.
- Further analysis can help in refining the sensor for better accuracy and sensitivity.

References

1. H. El Matbouly, N. Boubekeur, and F. Domingue, "Passive Microwave Substrate Integrated Cavity Resonator for Humidity Sensing," *IEEE Transactions on Microwave Theory and Techniques*, vol. 63, no. 12, pp. 4150-4156, Dec. 2015
2. S. E. Mohsir and M. Joodaki, "Design and Implementation of SIW Cavity Oscillators for Humidity Sensing Applications," *2020 28th Iranian Conference on Electrical Engineering (ICEE)*, 2020, pp. 1-6.
3. N. S. Khair, N. A. T. Yusof, Y. A. Wahab, B. S. Bari, N. I. Ayob, and M. Zolkapli, "Substrate-integrated waveguide (SIW) microwave sensor theory and model in characterising dielectric material: A review," *Sensors International*, vol. 4, p. 100244, 2023

Thank you