# INDIAN INSTITUTE OF TECHNOLOGY KANPUR

**SESSION: 2023-24**


**COURSE: EE687A**

**Topic:Emerging NVM-based Reconfigurable Antennas**

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**Date:27/4/23**

# About Reconfigurable Antennas

Q. What is an antenna?

Q. What is a reconfigurable antenna?

→ Reconfigurable properties

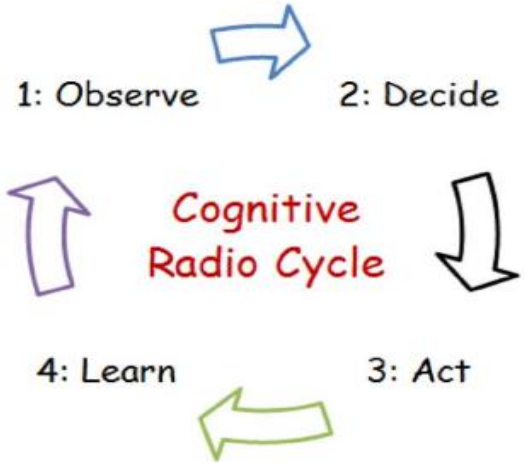
- Freq. of operation → Our focus
- Radiation pattern
- Polarization behaviour
- OR any combination of above mentioned properties

Can be reconfigured but not independently..!

Q. Where do we need reconfigurable antennas?

# Where do we need Reconfigurable Antennas?

- Cognitive Radio




Source:Cognitive radio cycle[2]

- Wireless Communication Systems

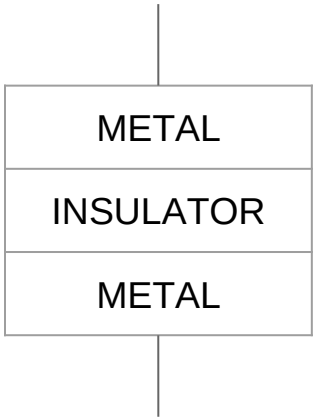
# About Reconfiguration Techniques

Reconfiguration can be achieved by:

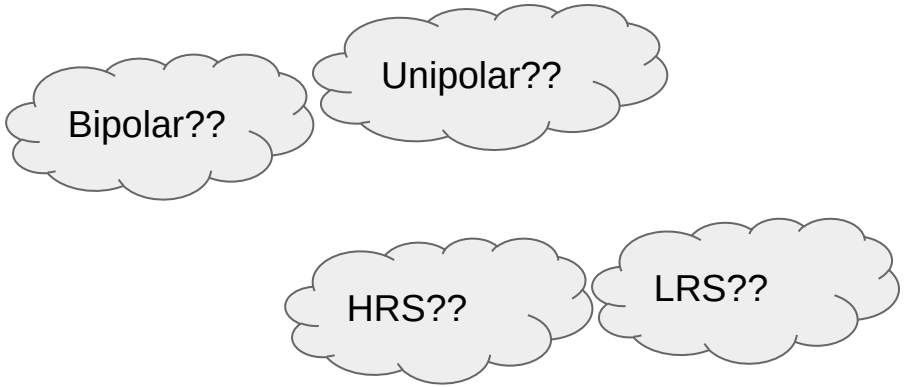
- Mechanical means
- Changing material properties
- Switching ⟹ Our focus

# About RRAMs*

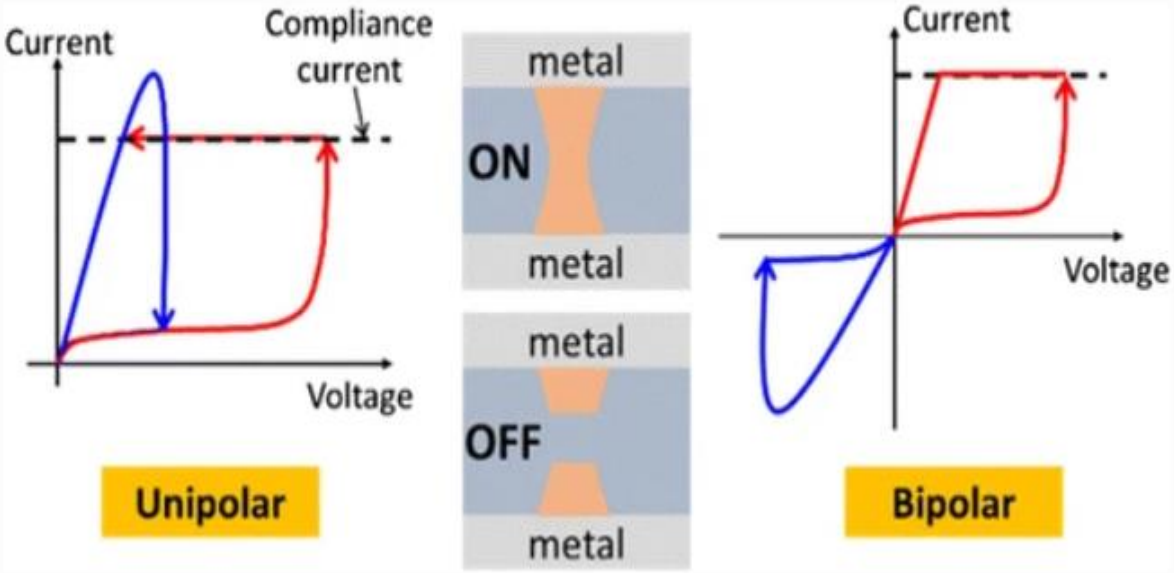
- One of the most promising Emerging-NVM.




- Low operating voltage
- Fast switching



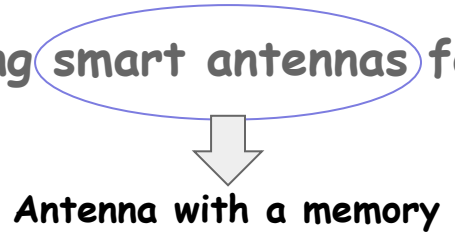

*our choice of NVM for this project




Source:Chen, HY., Brivio, S., Chang, CC. *et al.* Resistive random access memory (RRAM) technology: From material, device, selector, 3D integration to bottom-up fabrication. *J Electroceram* 39, 21–38 (2017). https://doi.org/10.1007/s10832-017-0095-9

# Our Motivation:

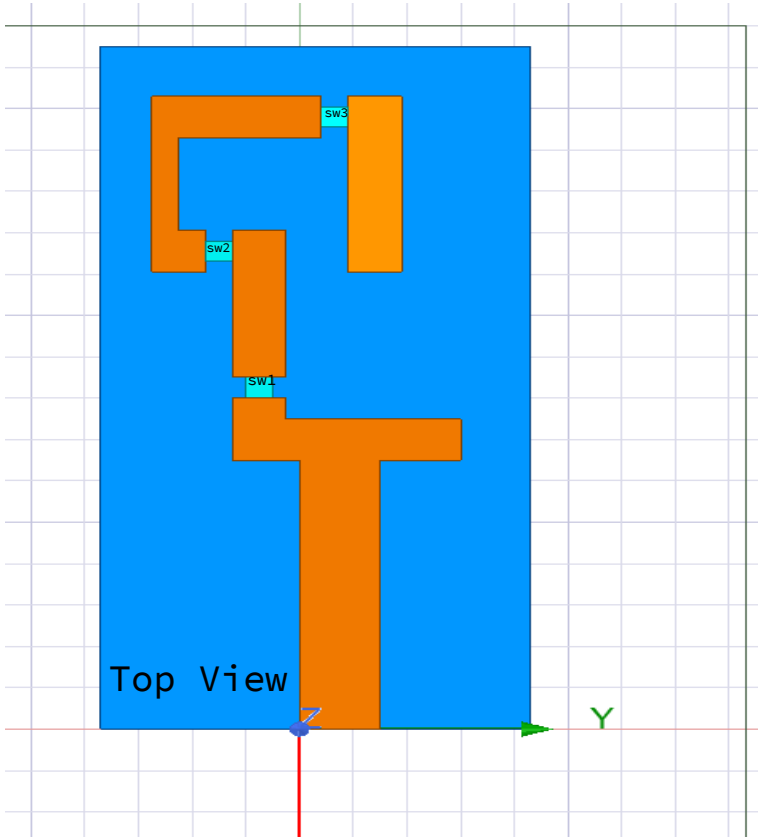
1. Grades* (ofcourse..!)
2. To explore the potential use of NVM in making smart antennas for future communication systems.

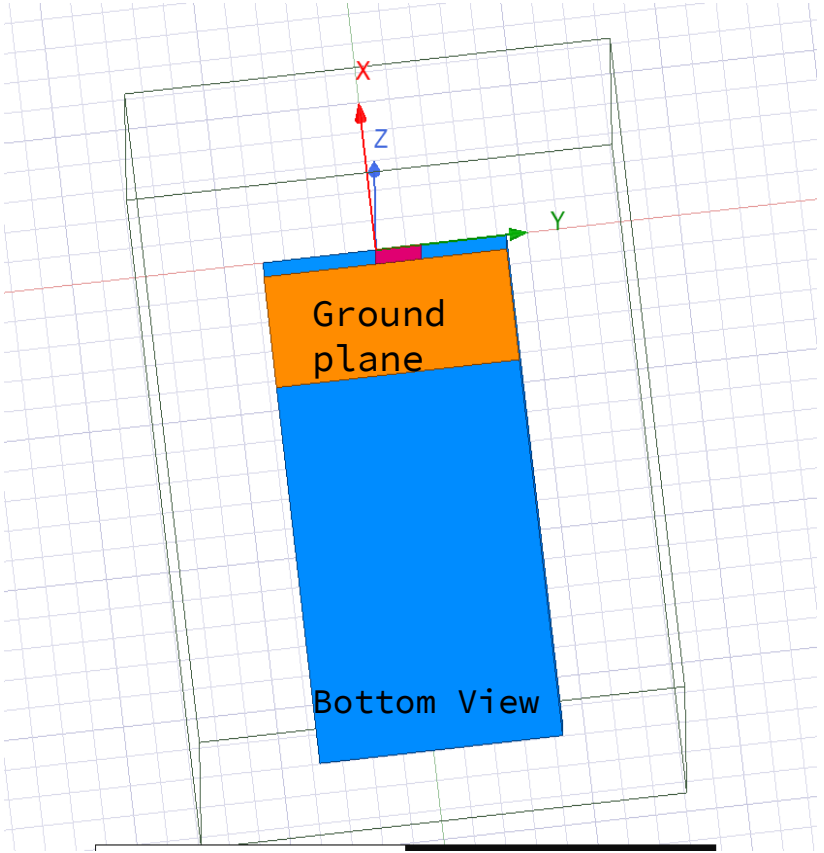





*this is our real motivation

# Designing Reconfigurable Monopole Antennas




Reference: I.A. Shah, S. Hayat, A. Basir, M. Zada, S.A.A. Shah, S. Ullah, S. Ullah, Design and analysis of a hexa-band frequency reconfigurable antenna for wireless communication, AEU - International Journal of Electronics and Communications,Volume 98,2019

- **Switches** → Unipolar RRAM with LRS = 50Ω and HRS = 50KΩ
- **Logic** → ‘0’ == 50Ω & ‘1’ == 50KΩ with RRAM

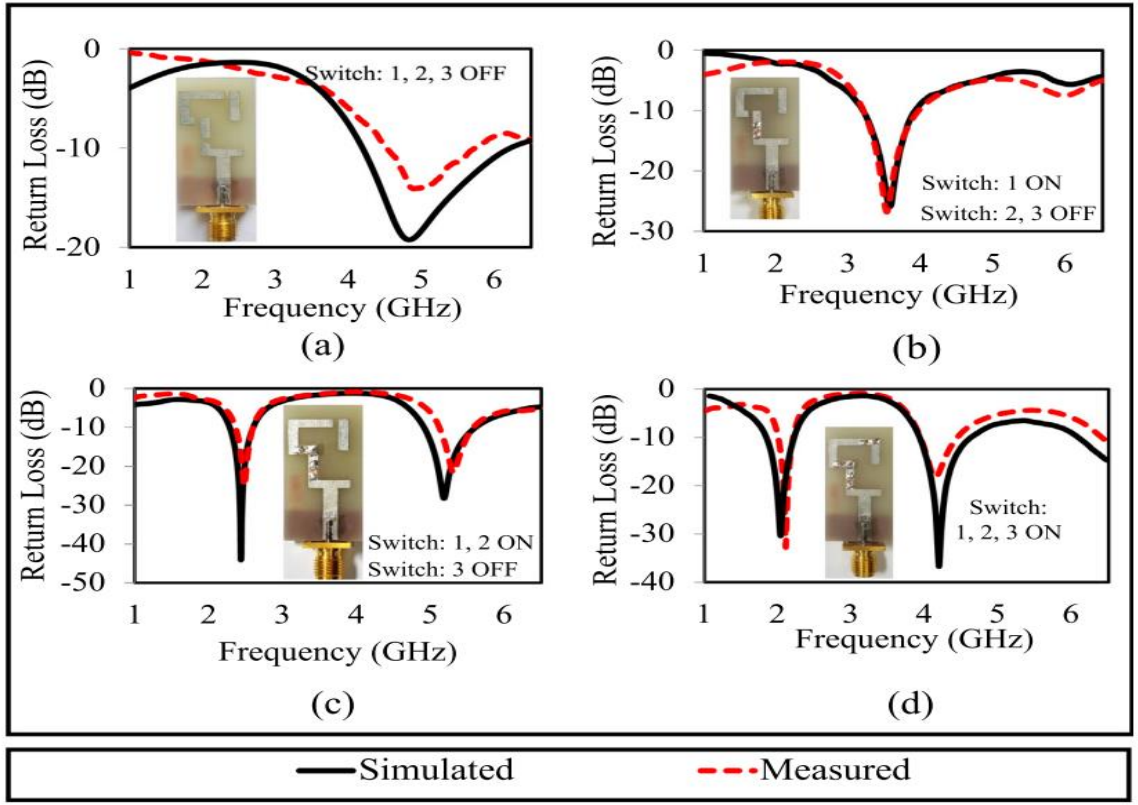
  → {‘0’ == 1uΩ & ‘1’ == 1MΩ with pin diode}

$Au/Nb_2O_5/Nb$ is one such stack

- **3 switches** → $2^3$ combinations

| sw1(MSB) | sw2 | sw3 |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 0 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |
| 1 | 1 | 1 |

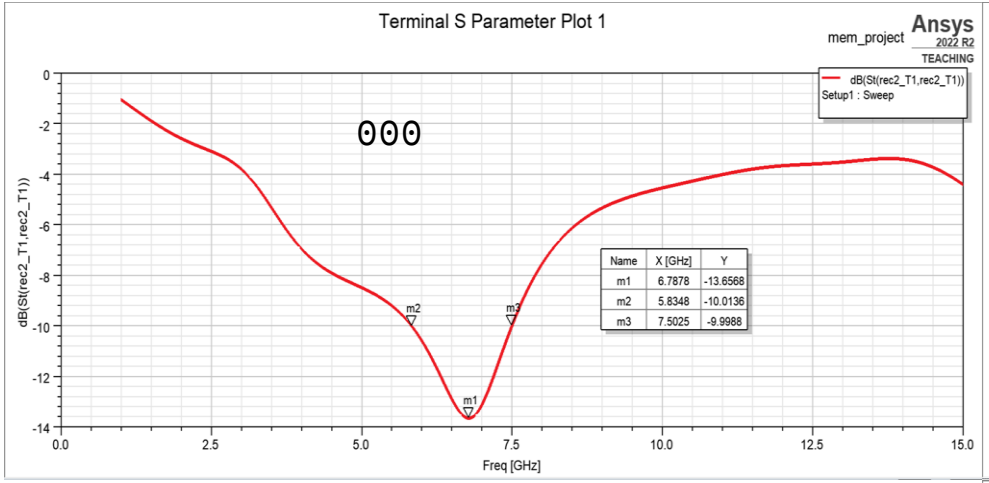
# STATE OF THE ART(with pin diode):

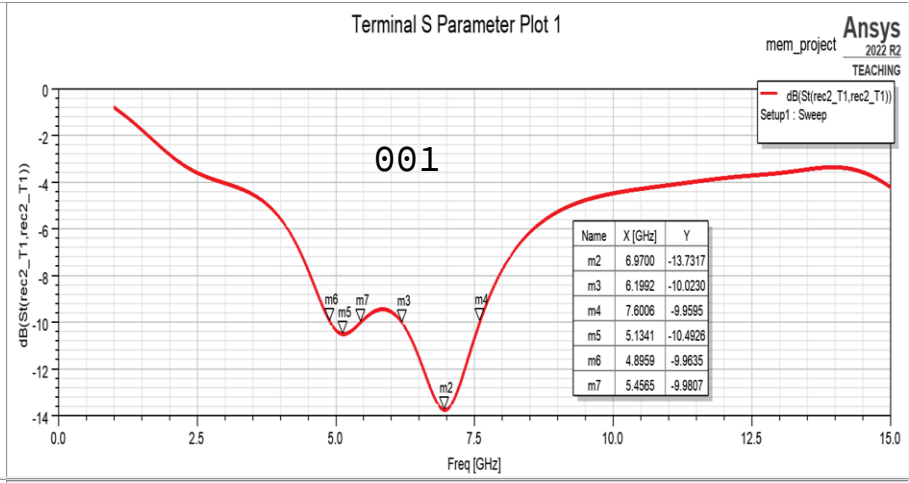


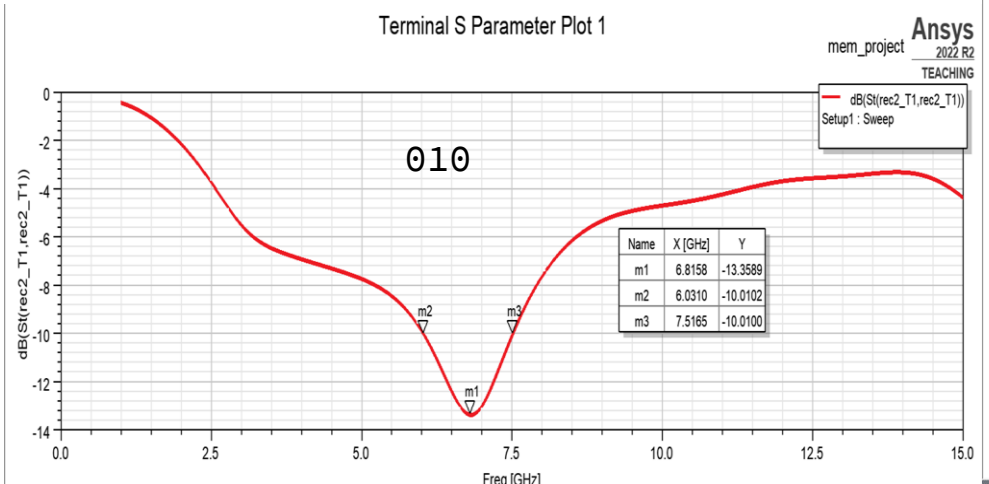

The simulated and measured reflection coefficient for operation states: (a) 4.82 GHz. (b) 3.5 GHz. (c) 2.43 and 5.18 GHz. (d) 2.1 and 4.14 GHz.

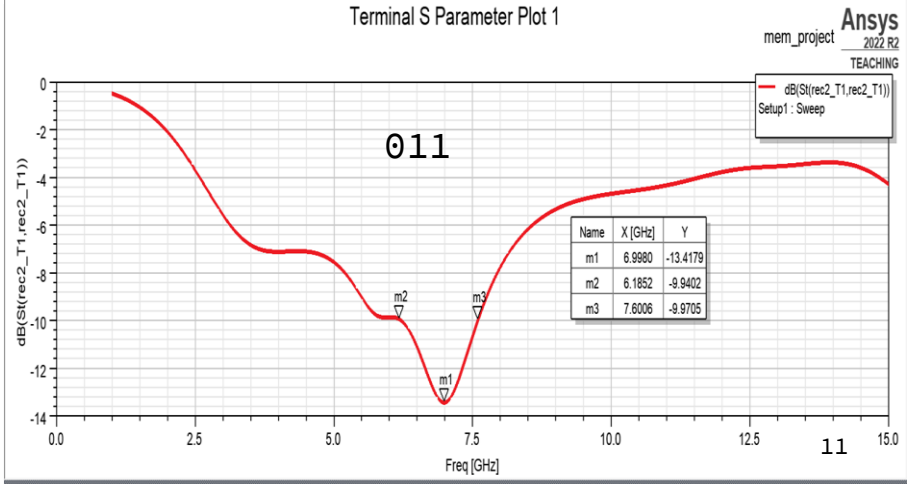

Reference: I.A. Shah, S. Hayat, A. Basir, M. Zada, S.A.A. Shah, S. Ullah, S. Ullah,
Design and analysis of a hexa-band frequency reconfigurable antenna for wireless communication,
AEU - International Journal of Electronics and Communications,Volume 98,2019

# Results(with RRAM):

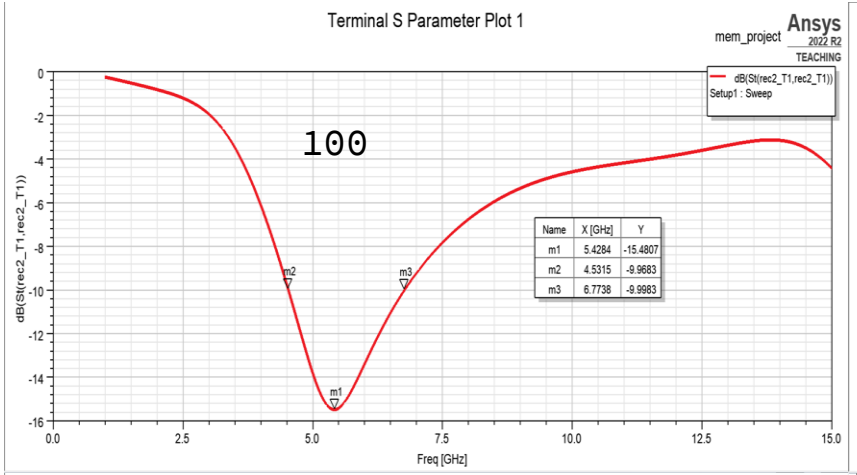


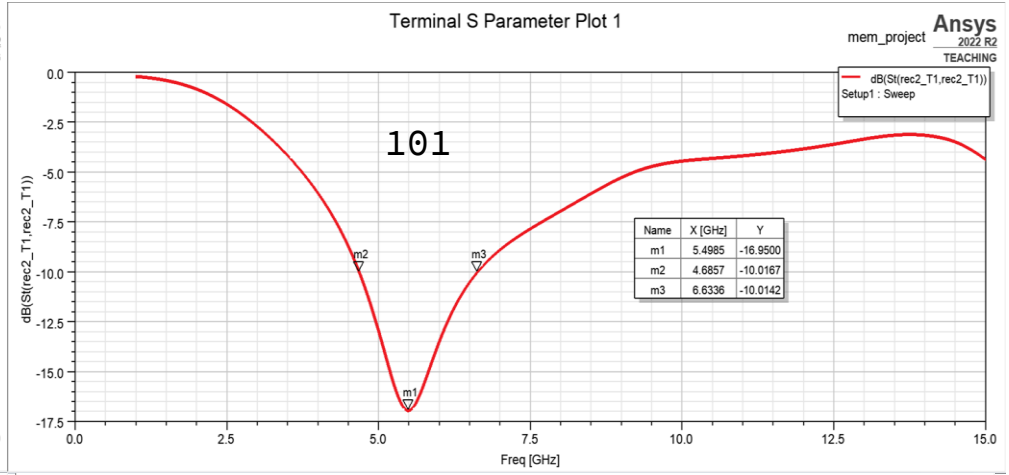



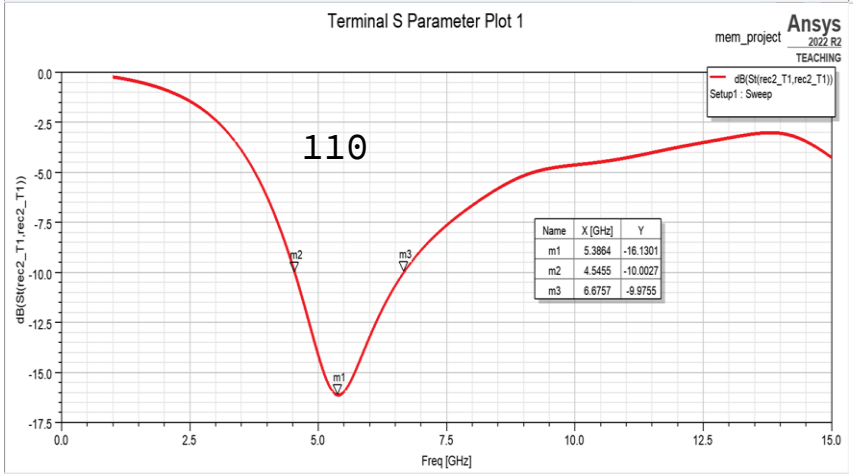



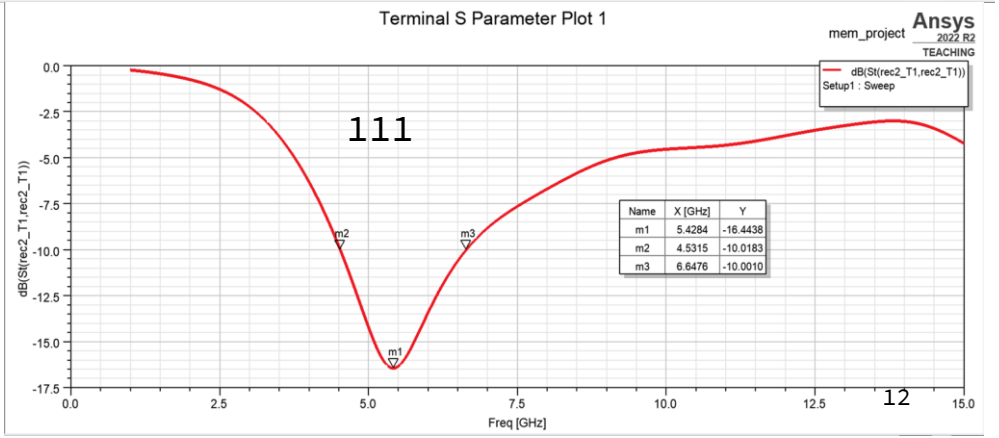



# Results(with RRAM):



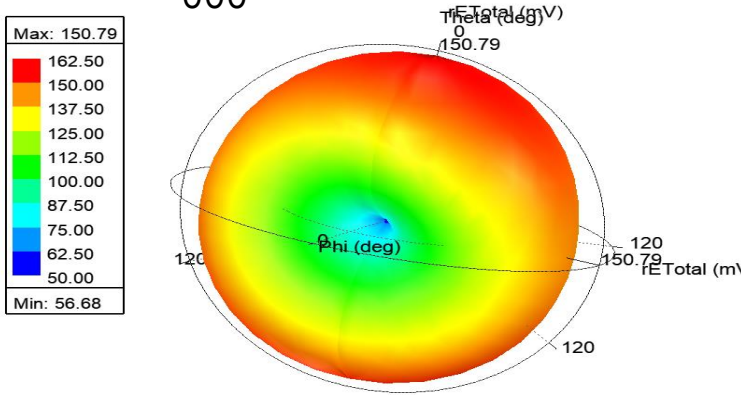



# Results(with RRAM):

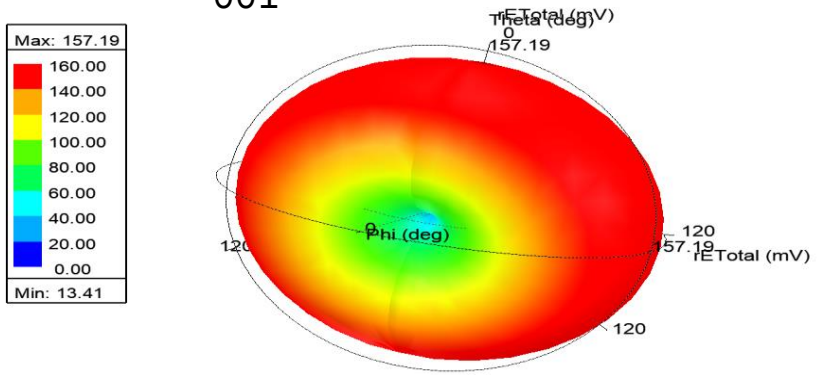
rE Plot 2

000



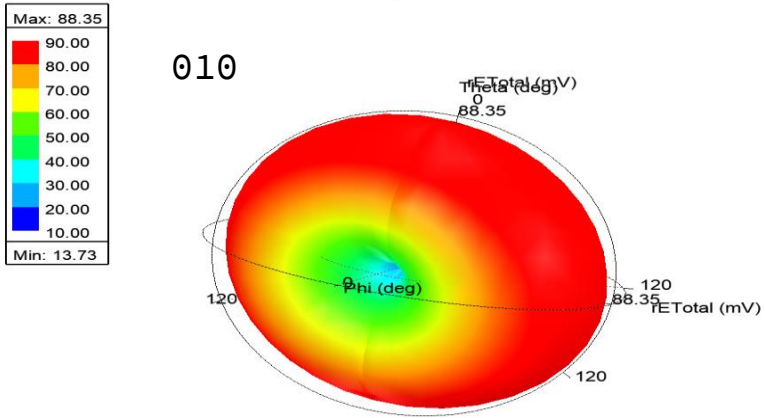

rE Plot 2

001



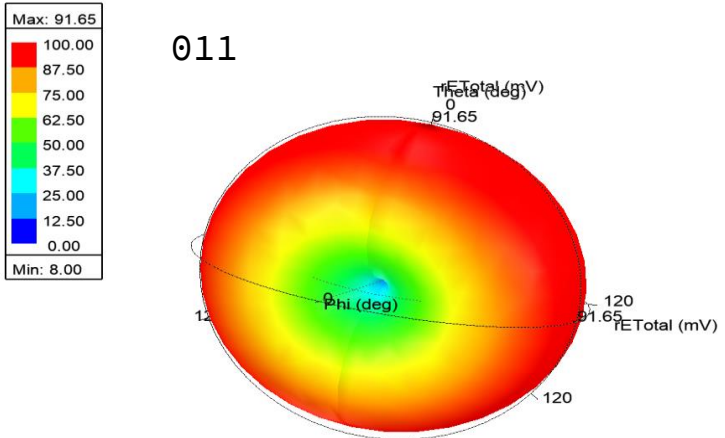

rE Plot 2

010

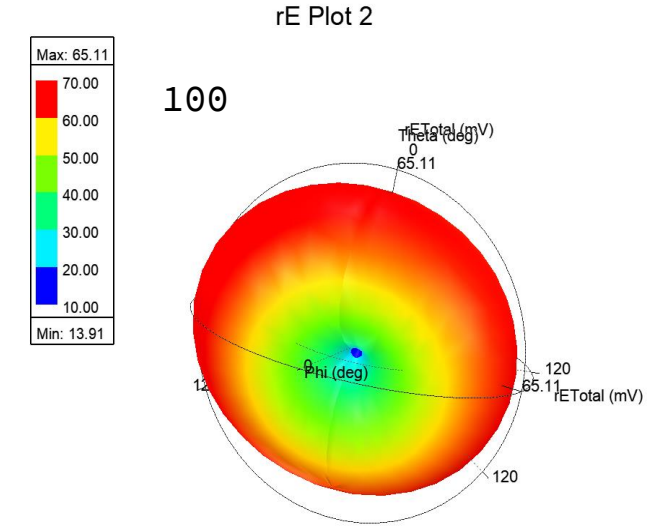


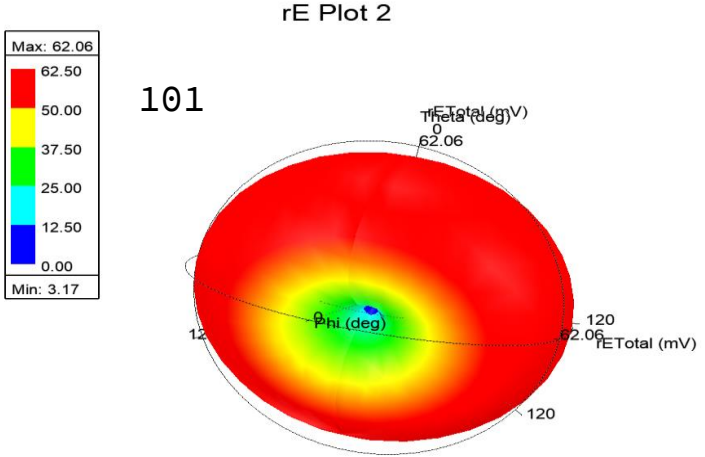

rE Plot 2

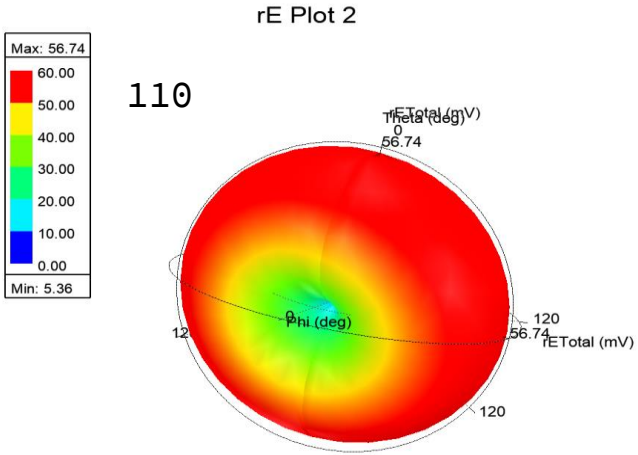
011

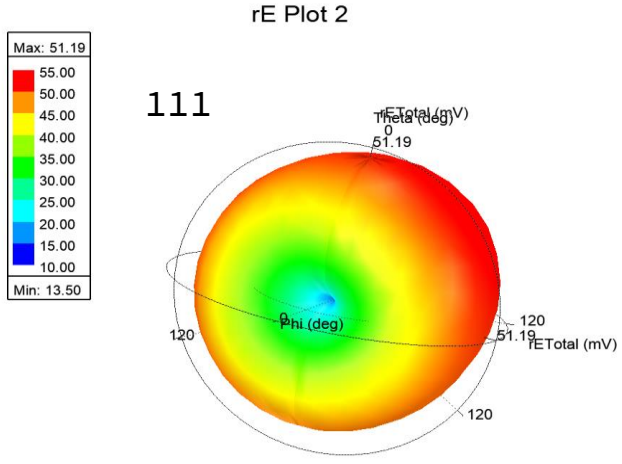


# Results(with RRAM):



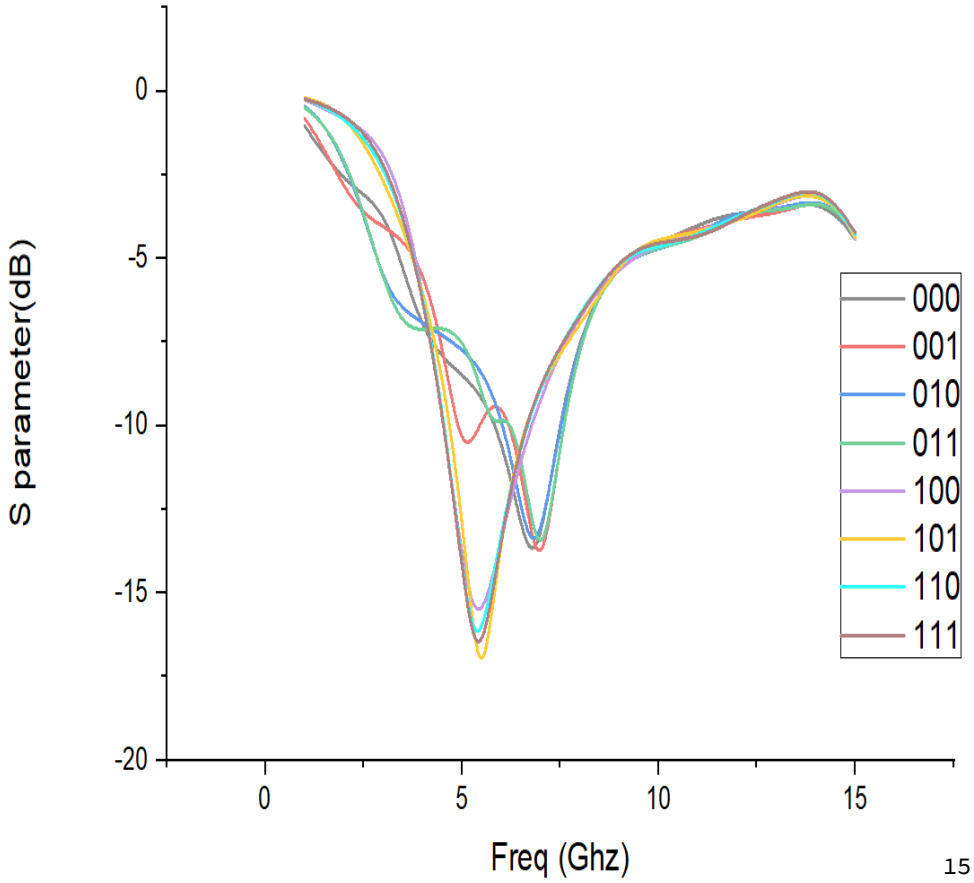



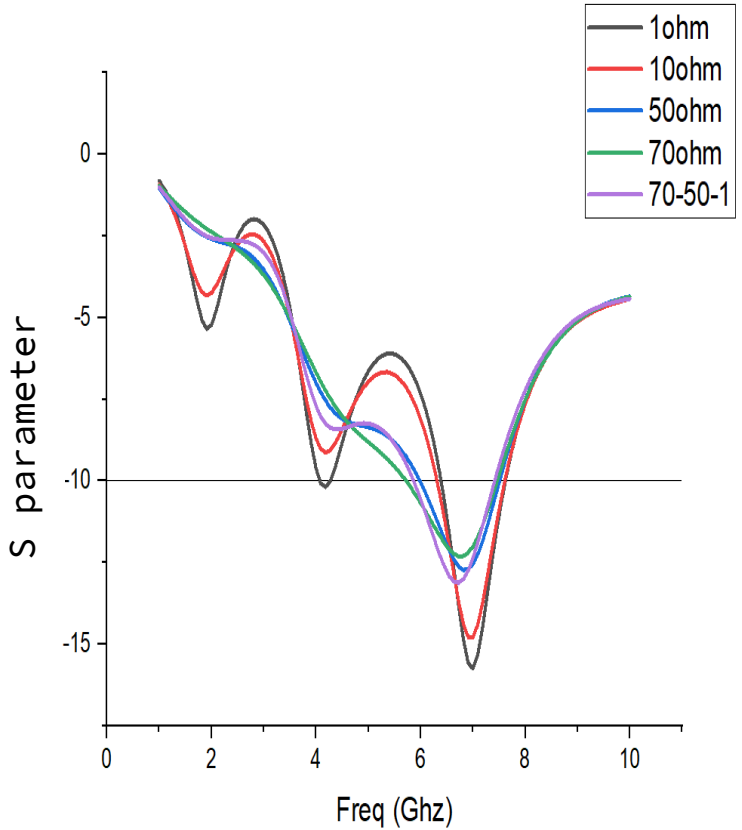



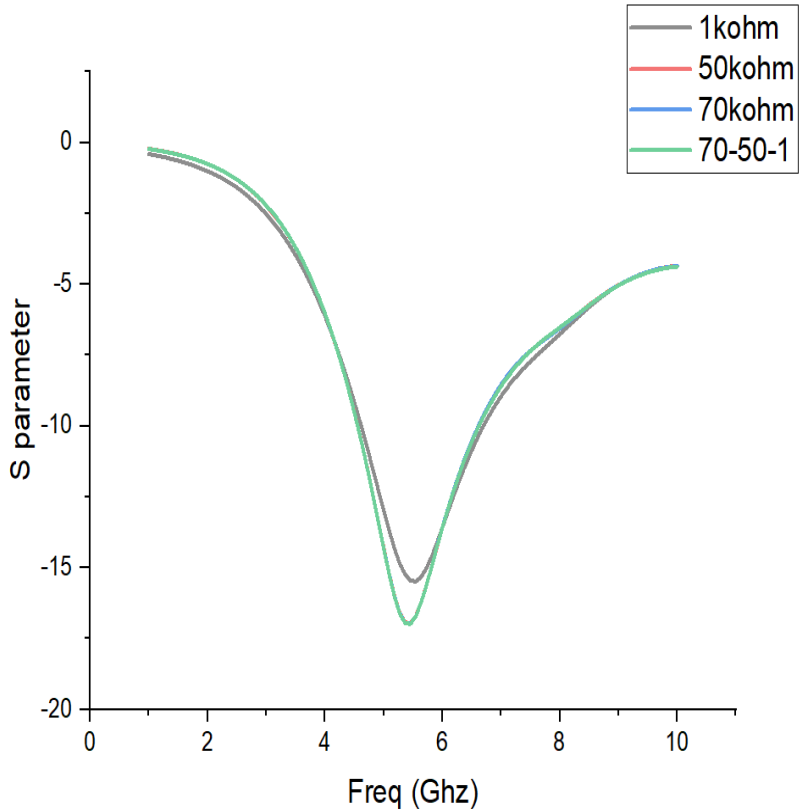
# Results(with RRAM):

| sw1 | sw2 | sw3 | $f_{op}$(in GHz) | BW (in GHz) |
|---|---|---|---|---|
| 0 | 0 | 0 | 6.78 | 1.67 |
| 0 | 0 | 1 | 5.13<br>6.97 | 0.56<br>1.41 |
| 0 | 1 | 0 | 6.8 | 1.47 |
| 0 | 1 | 1 | 7 | 1.42 |
| 1 | 0 | 0 | 5.42 | 2.24 |
| 1 | 0 | 1 | 5.49 | 1.95 |
| 1 | 1 | 0 | 5.38 | 2.13 |
| 1 | 1 | 1 | 5.42 | 2.11 |



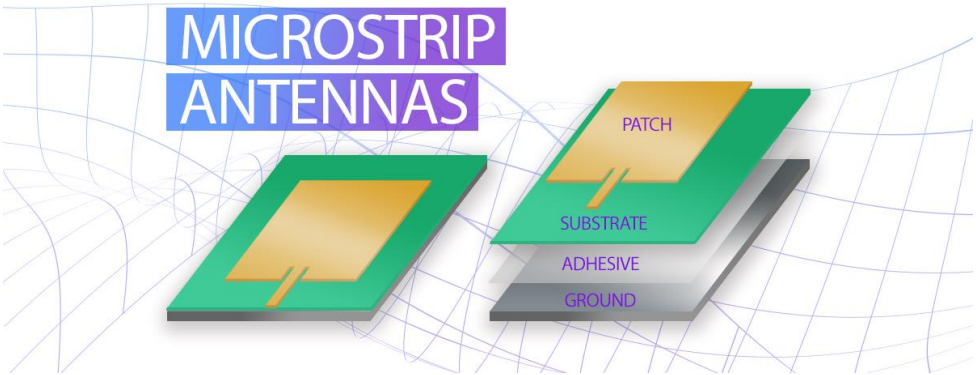
# How variations in RRAM will affect the $f_{op}$?



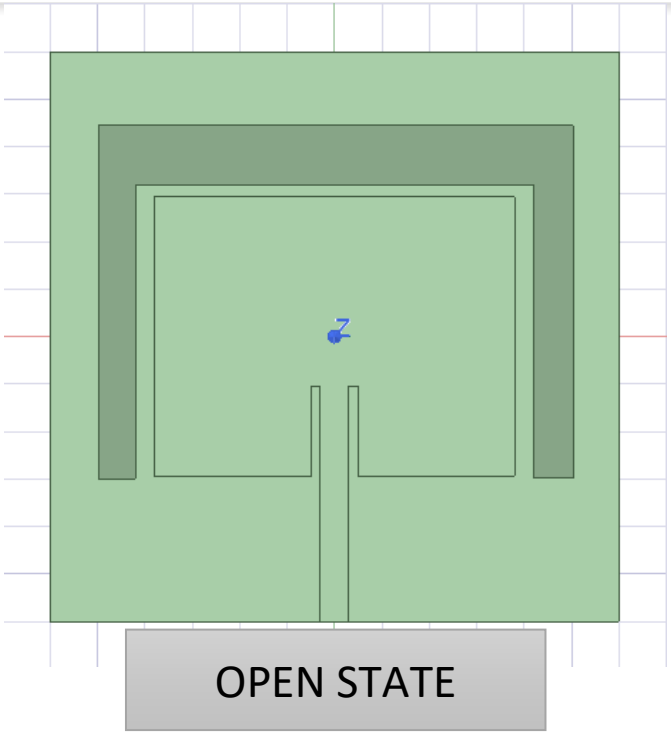



# Designing Reconfigurable Antennas

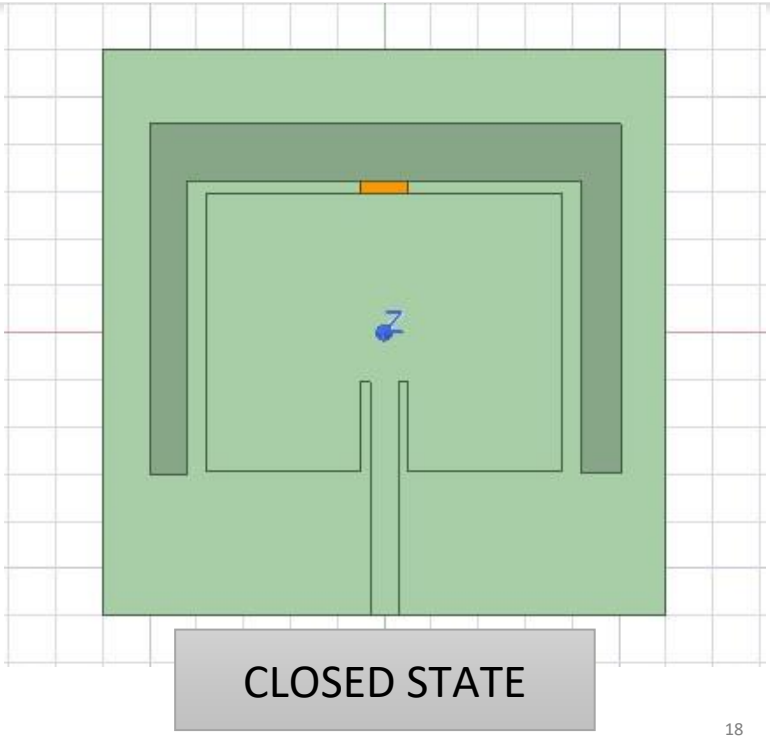
- From Monopole Antenna to Patch Antenna
- But Why?
- Small size
- Its applications spacecraft, satellite, mobile & many more



# Design Details With PIN DIODE



OPEN STATE

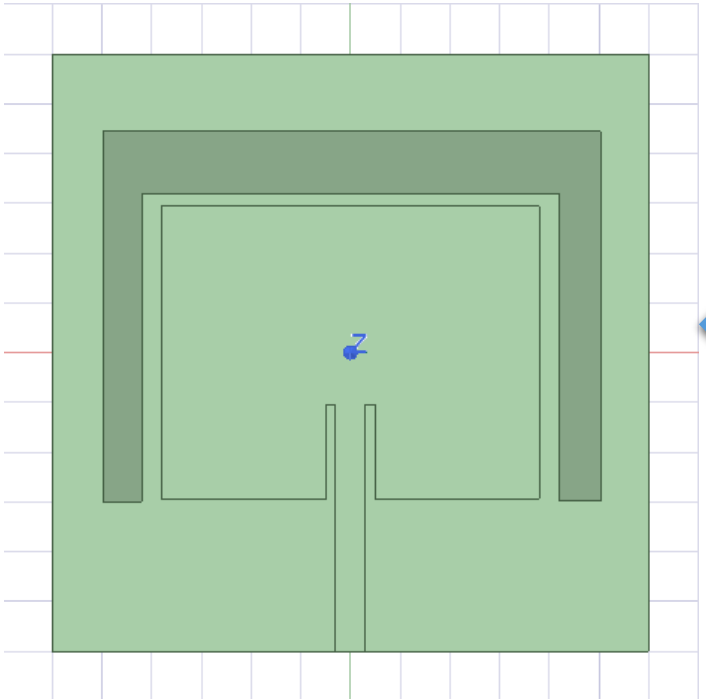


CLOSED STATE



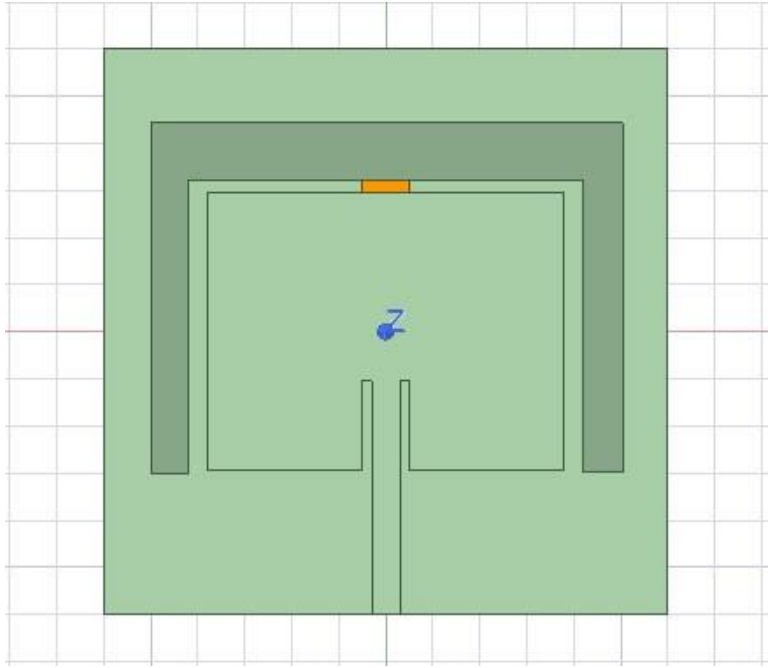
**Reference:** Anuradha A. Palsokar, S.L. Lahudkar,Frequency and pattern reconfigurable rectangular patch antenna using single PIN diode,AEU - International Journal of Electronics and Communications,Volume 125,2020,153370,ISSN 1434-8411

# Design Details With RRAM

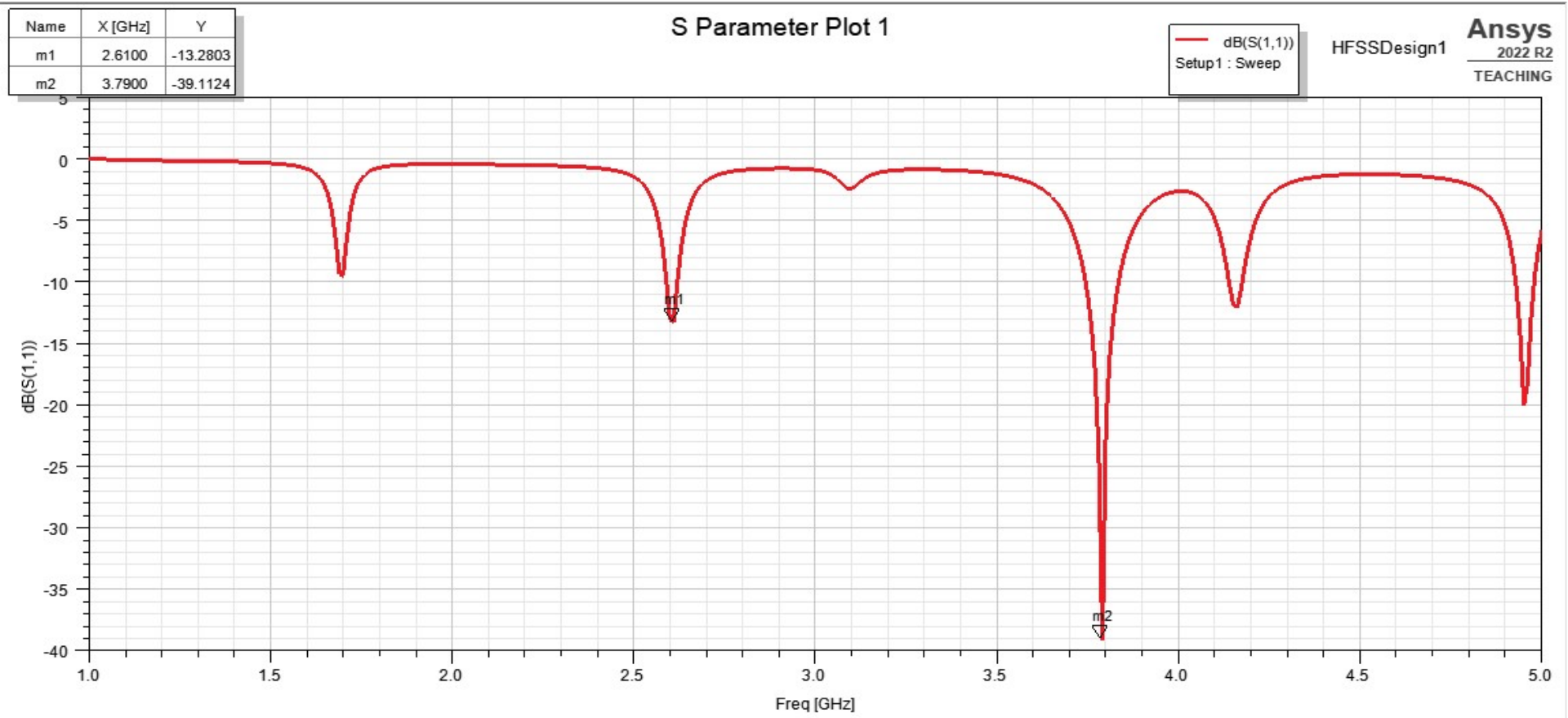


RRAM

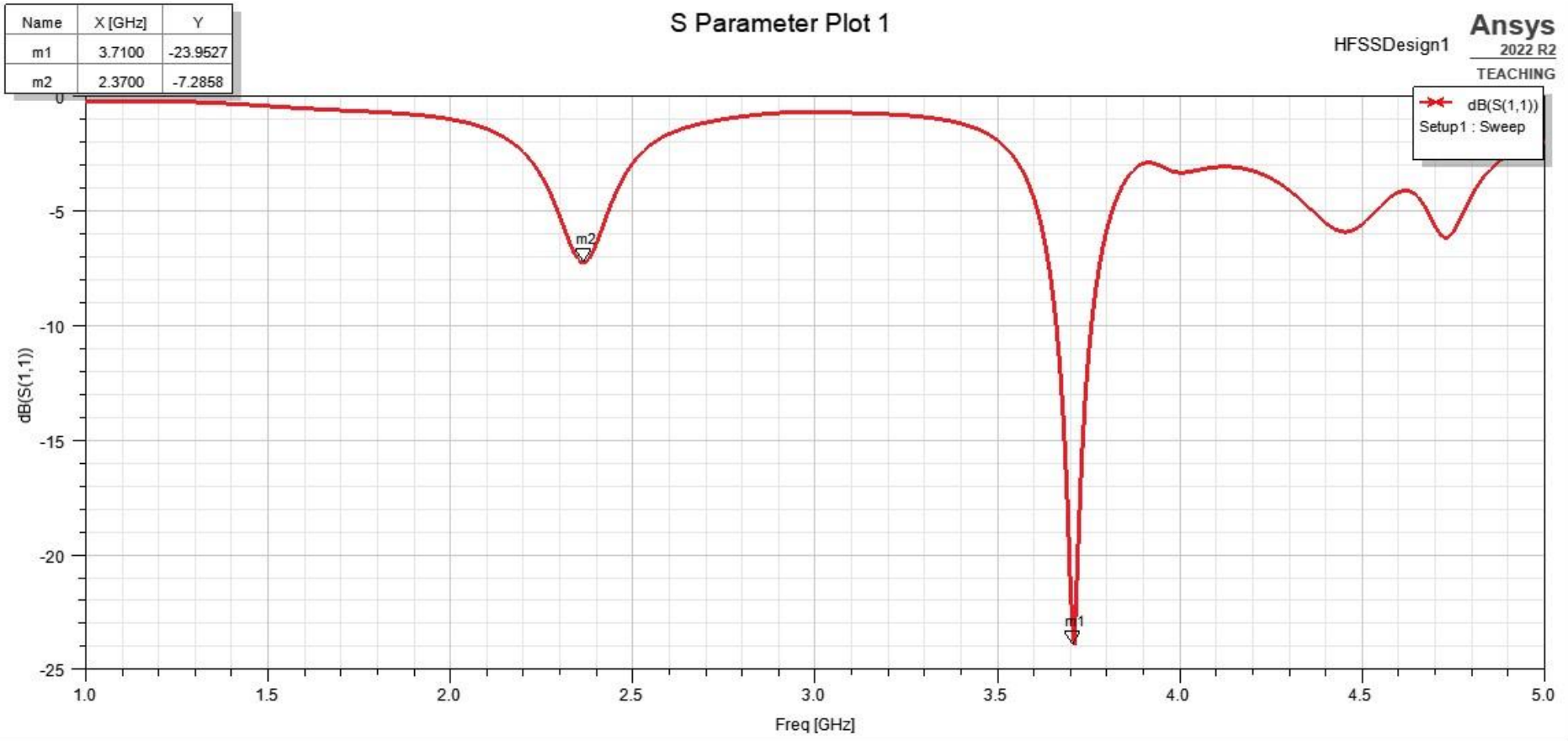
Intermediate Stage



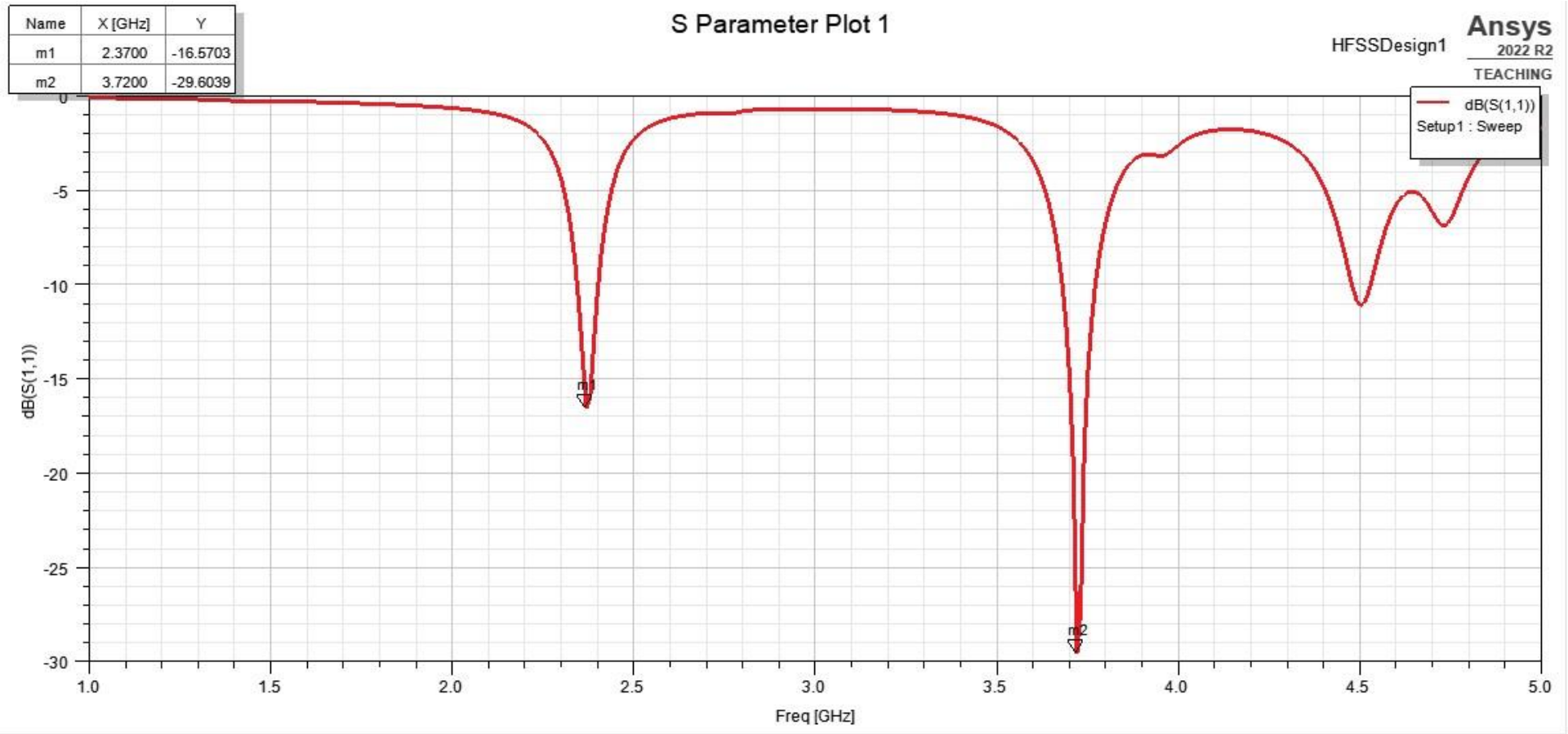
# Result at 1 micro ohm pin diode on



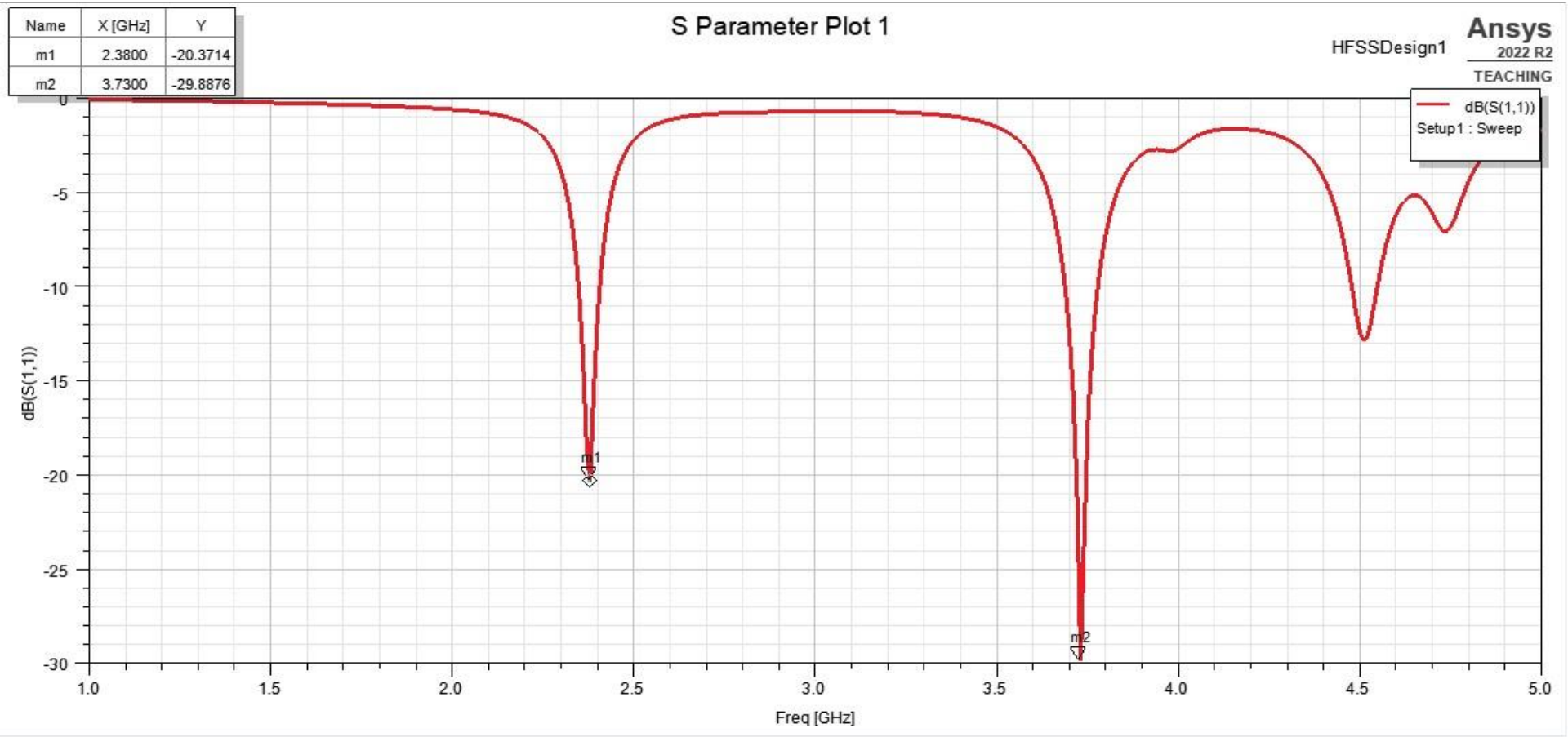
# Result at 100 ohm



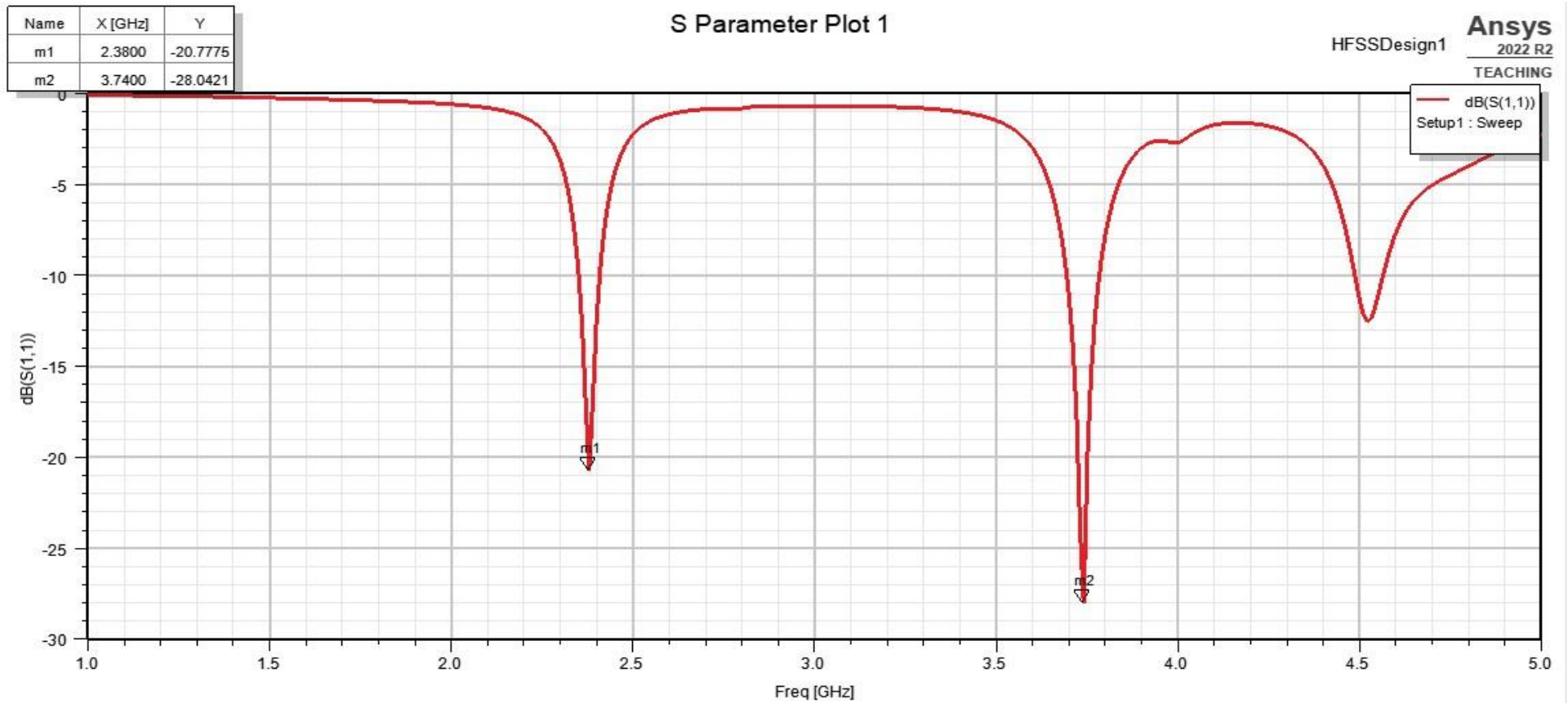
# Result at 1 Kohm



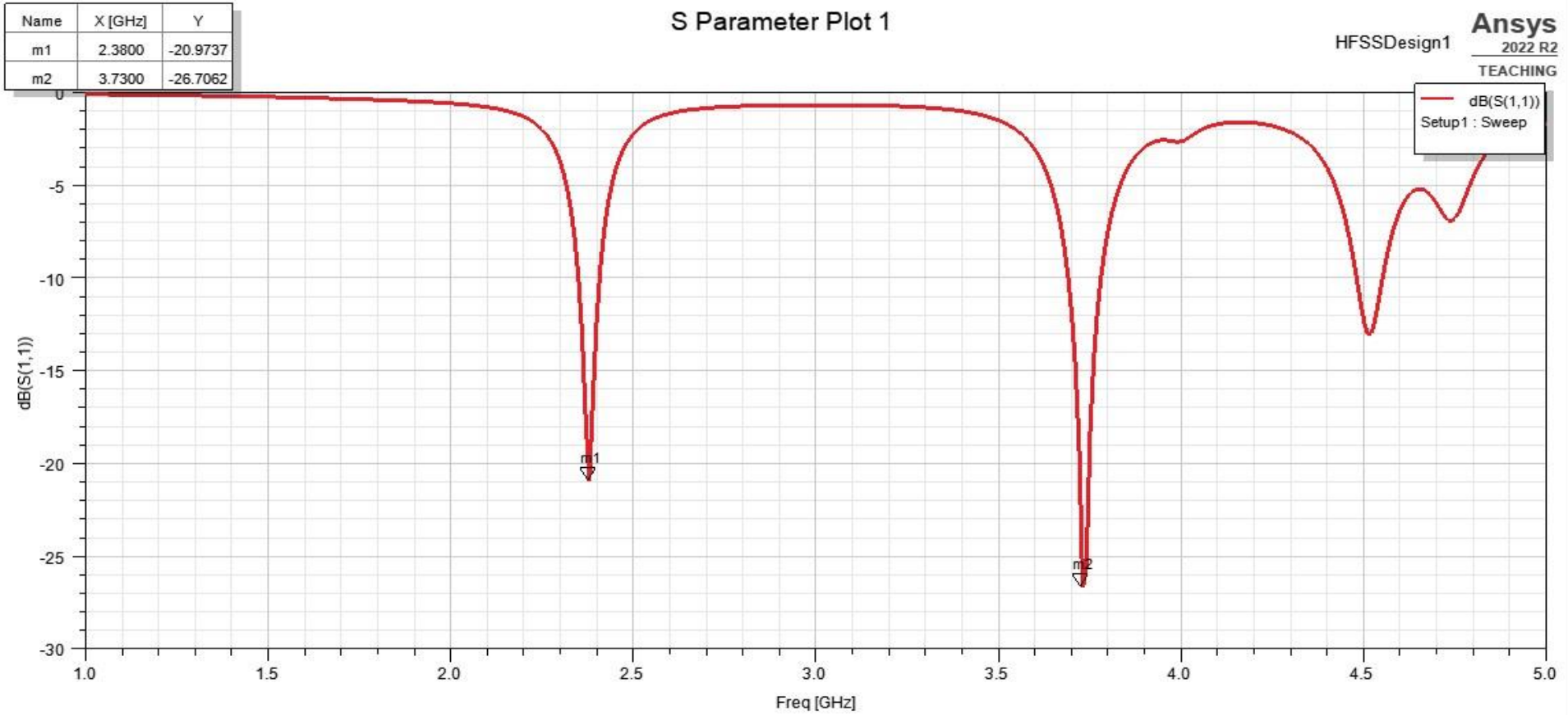
# Result at 10 Kohm



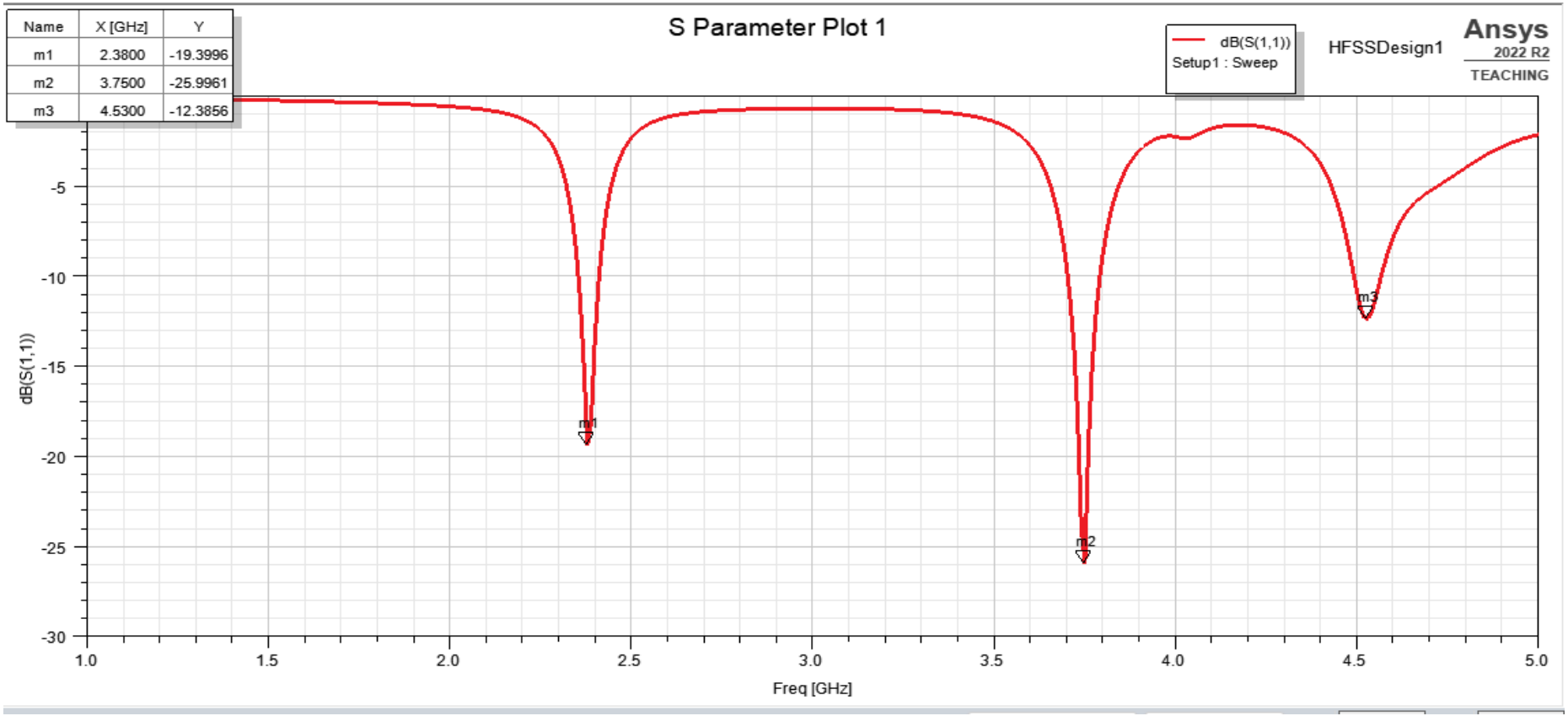
# Result at 1 Mohm



# Result at 10 Mohm



# Result at 10 Gohm pin diode off



# Conclusions & Future Work

- RRAM with low LRS(<10Ω) can be used as a RF switch (with low losses) to design a Reconfigurable Antenna.
- Compared to PIN diodes, RRAM offers the advantage of lower power consumption.
- To design a more realistic model of RRAM for accurate measurements through simulations.
- To incorporate NN with Reconfigurable Antennas to train it various for communication scenarios.

# References:

1.Rutschlin, Marc and Vratislav Sokol. “Reconfigurable Antenna Simulation: Design of Reconfigurable Antennas with Electromagnetic Simulation.” *IEEE Microwave Magazine* 14 (2013): 92-101.

2.Costantine, Joseph et al. “Reconfigurable Antennas: Design and Applications.” *Proceedings of the IEEE* 103 (2015): 424-437.

3.I.A. Shah, S. Hayat, A. Basir, M. Zada, S.A.A. Shah, S. Ullah, S. Ullah,Design and analysis of a hexa-band frequency reconfigurable antenna for wireless communication,AEU - International Journal of Electronics and Communications,Volume 98,2019.

4.Anuradha A. Palsokar, S.L. Lahudkar,Frequency and pattern reconfigurable rectangular patch antenna using single PIN diode,AEU - International Journal of Electronics and Communications,Volume 125,2020,153370,ISSN 1434-8411

5.Kundozerova, T. V., Grishin, A. M., Stefanovich, G. B., & Velichko, A. A. (2012). Anodic Nb2O5 Nonvolatile RRAM. IEEE Transactions on Electron Devices, 59(4), 1144-1148.

# Thank you..!