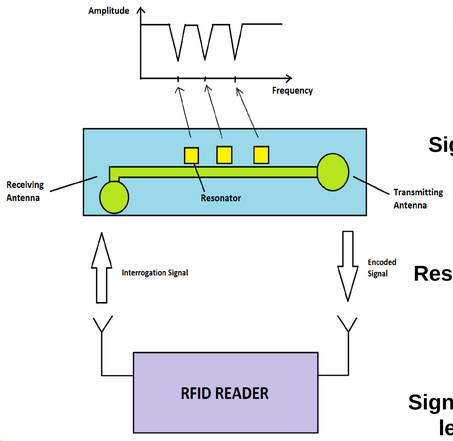
Printable Passive Chipless RFID for Low Cost Humidity Sensing

Naeem Safdari, Simon Krafft, Daniel Dominic, Prof. Sharmistha Bhadra

Motivation and Objective

- Existing wireless humidity sensors are active devices, and have the following limitations:
  - Require semiconductor chips → Costly.
  - Requires a power source → Batteries need to be recharged or changed.
- Limitations can be avoided by using:
  - A passive system → No power source on the sensor.
  - RFID [1] technology → Makes it amenable to low cost mass production using printed electronics.
- In this project, we design, build and investigate a low cost **chipless RFID humidity sensor**, consisting of:
  - Microstrip line
  - Receiving and transmitting antenna.
  - Three spiral resonators, one of which is coated with a humidity sensitive polymer, PVA.

Idea of the Passive Chipless RFID



High Level Block Diagram

Interrogation signal received at receiving antenna

Signal passes through microstrip coupled to resonators

Resonators modify signal according to their spectral signature.

Signal carrying relative humidity data leaves through the transmitting antenna.

The Resonators and HFSS Simulation

- Simulated in HFSS software
- Resonators are coupled to the 50 Ω microstrip [2]
- Obtained different resonant frequencies by changing the parameters of the resonators. [3]

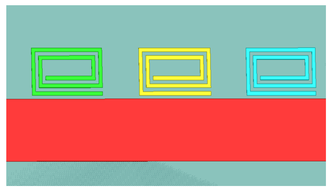
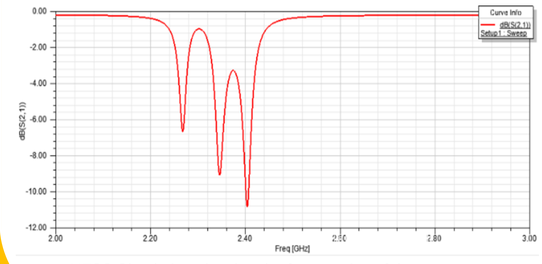


Diagram showing resonators coupled to microstrip



HFSS Simulation showing the frequencies of the resonators

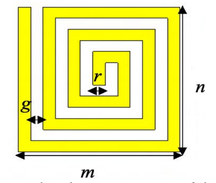
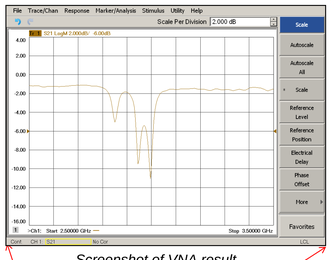


Diagram showing parameters of the resonator

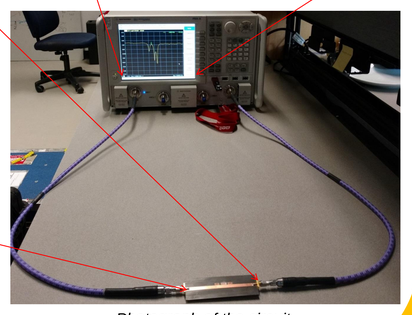
VNA Tests

- The Resonant frequency can be observed clearly from the VNA results.
- The observable frequency shifts are due to the imperfections in fabrication.
- VNA tests conclude that the humidity sensor works as designed on HFSS



Screenshot of VNA result

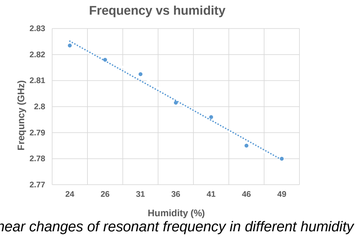
The board under test



Photograph of the circuit.

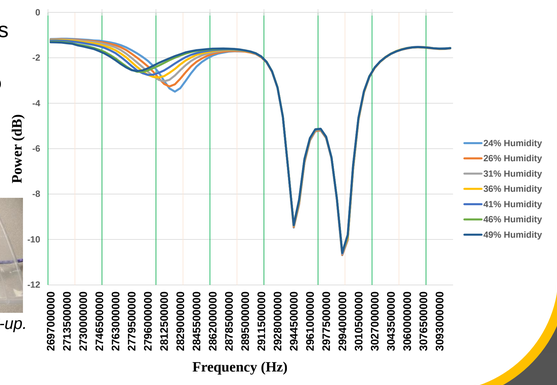
Humidity Measurement Results

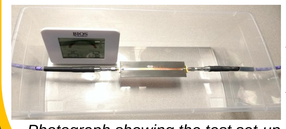
- We observe that the VNA results are as expected and very similar to the HFSS results.
- The shift in one of the peaks is due to the application of the humidity sensing polymer, PVA.
- A limit of operation was observed, which was between 21% and 51%



Linear changes of resonant frequency in different humidity

Frequency Response for Different Humidity Levels

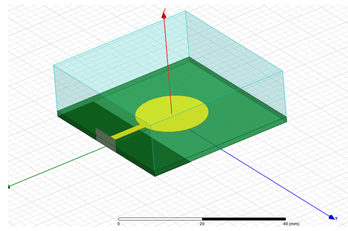


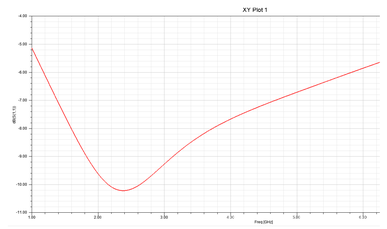


Photograph showing the test set-up.

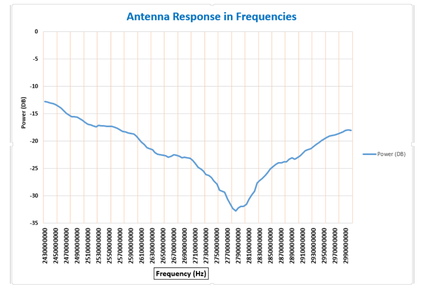
The Antenna and HFSS Simulation

- Receiving and transmitting cross-polarized monopole antennas.
- Operating frequency: 2.4 GHz – 3.0 GHz
- The VNA result of physical antenna correspond very closely to HFSS software result of antenna
- A little bit shift in physical antenna result by VNA is due to finding a right angle of measurement and perfect condition of testing.





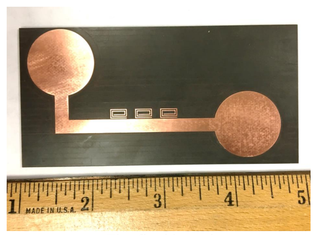
HFSS Simulation of the Antenna.



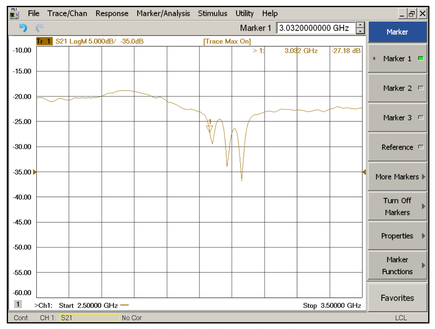
VNA results of the Antenna.

Results

- Results from the wireless testing are as expected despite the use of non-commercial antennas.
- The observed shifts in the resonance frequencies are due to imperfections in fabrication.



The final board



Screenshot of the final board under VNA testing

Conclusion

- Increase in humidity was appropriately depicted in VNA results.
- However the reversing was considerably slower. This can be attributed to the quality of the polymer.
- From the results, both simulated and physical testing, we can conclude that the prototype is a success.
- Design is amenable to inexpensive mass production using printed electronics technology and holds potential for low cost humidity sensing.

Team Contribution

Literature Review and design formulation: All
Selection of substrate: Simon and Naeem
Selection of Polymer: Daniel and Simon
Selection of design parameters: All
Design on HFSS: Naeem, Simon
PVA Application: Naeem, Daniel
Testing Resonators: Simon and Naeem
Testing Antenna: Daniel and Simon
Testing integrated circuit: All

References

[1] Preradovic, Stevan, and Nemai C. Karmakar. "Multiresonator based chipless RFID tag and dedicated RFID reader." *Microwave Symposium Digest (MTT), 2010 IEEE MTT-S International*. IEEE, 2010.
[2] http://yoksis.bilkent.edu.tr/pdf/files/10.1109-TMTT.2007.909611.pdf
[3]http://www.rfcafe.com/references/electrical/microstrip-eq.htm