A 24 GHz Semi-Passive RFID Tag

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Introduction

- The purpose of this project is to develop a novel Radio Frequency Identification (RFID) tag operating at 24 GHz
- Complete development process including design, simulation, manufacturing, and testing

Background

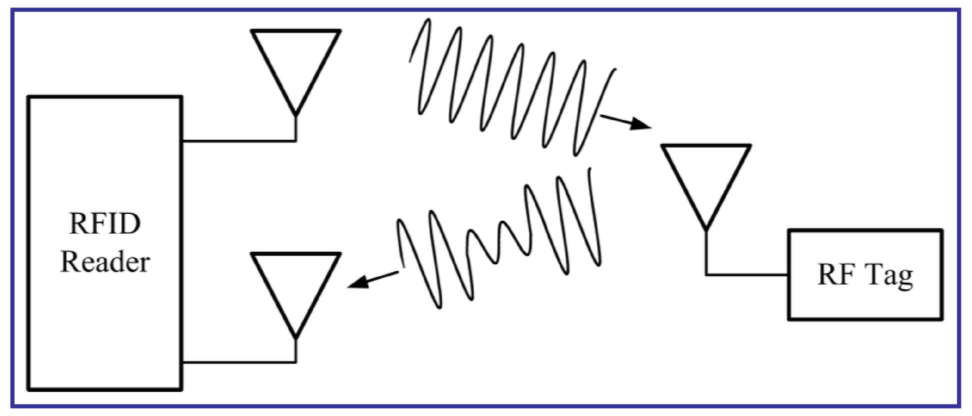

Fig. 1. Diagram of an RFID system [1].

- Current RFID systems operate mostly at around 960 MHz
- Easy to manufacture, but limited bandwidth and data transfer speeds
- Higher frequency RFID tags necessary for next generation devices (5G, Internet of Things)
- Problem: more losses on circuit [2] and in propagation [3]

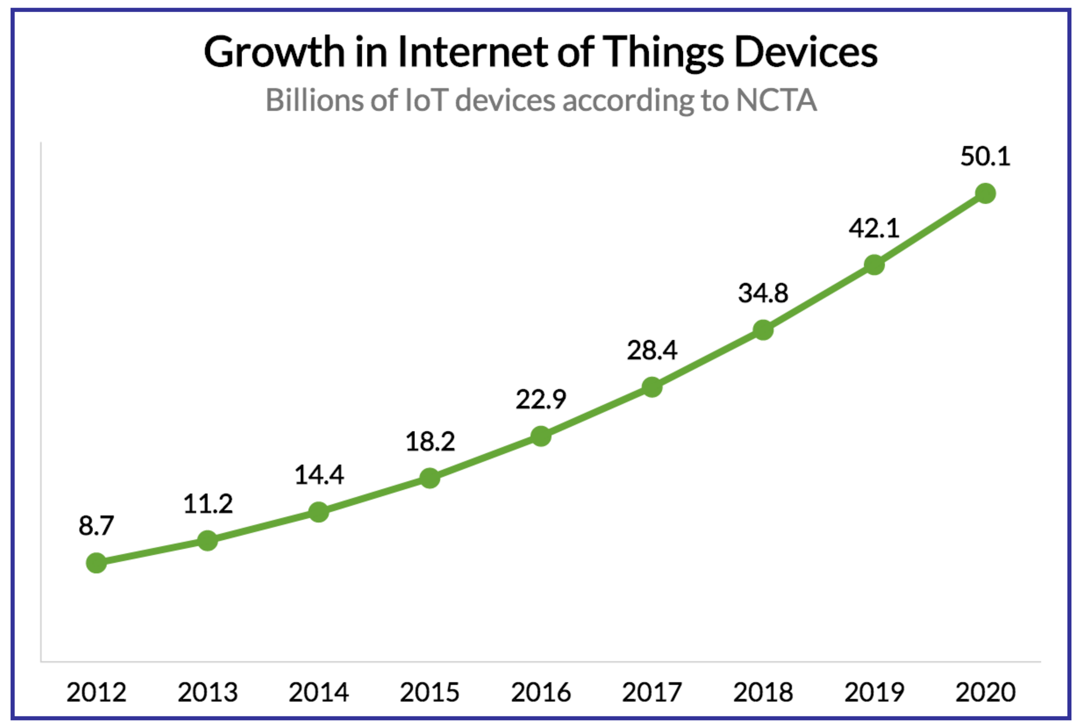

Fig. 2. The number of RFID-equipped IoT devices has grown exponentially this decade [4].

Methods

- Designing a 24 GHz Antenna
  - ANSYS HFSS

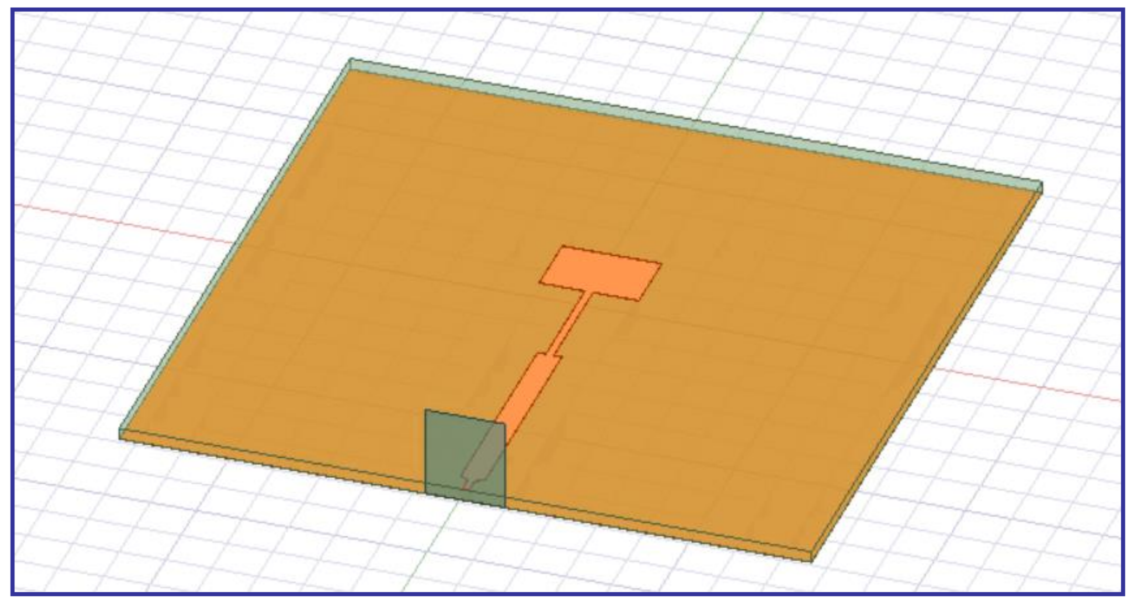

Fig. 3. Antenna design in HFSS with antenna, λ/4 transmission line, feed line, and wave port.

- Simulation/Optimization
  - S_{11} (return loss) and gain
- Manufacturing
  - Layout in Autodesk EAGLE
  - Laser milled on RO4003 substrate
- Testing
  - S_{11} measurement using high-frequency vector network analyzer
- RF Circuit Design/Simulation
  - RF Switch layout in Keysight ADS
  - Measured S-parameters for 24 GHz use case

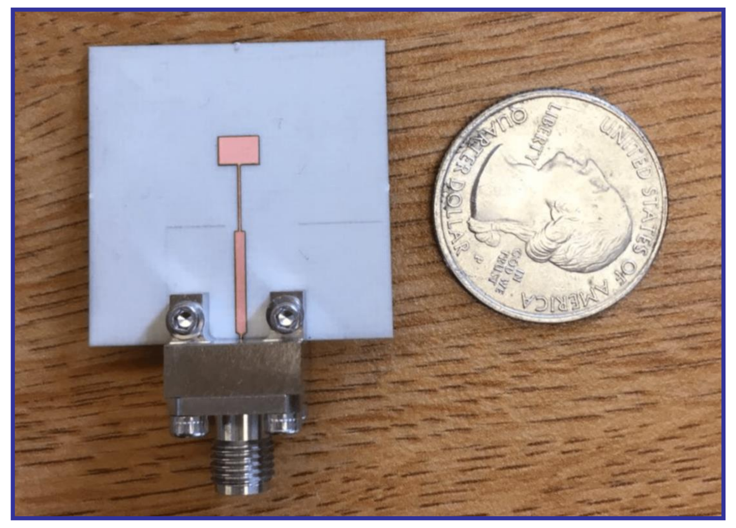

Fig. 4. Manufactured 24 GHz antenna, with a quarter for size reference.

Results

- Antenna Optimized for 24 GHz
  - S_{11} (return loss) below -10 dB across entire 24-24.25 GHz bandwidth (90% efficiency)
  - Gain of 6.9 dBi

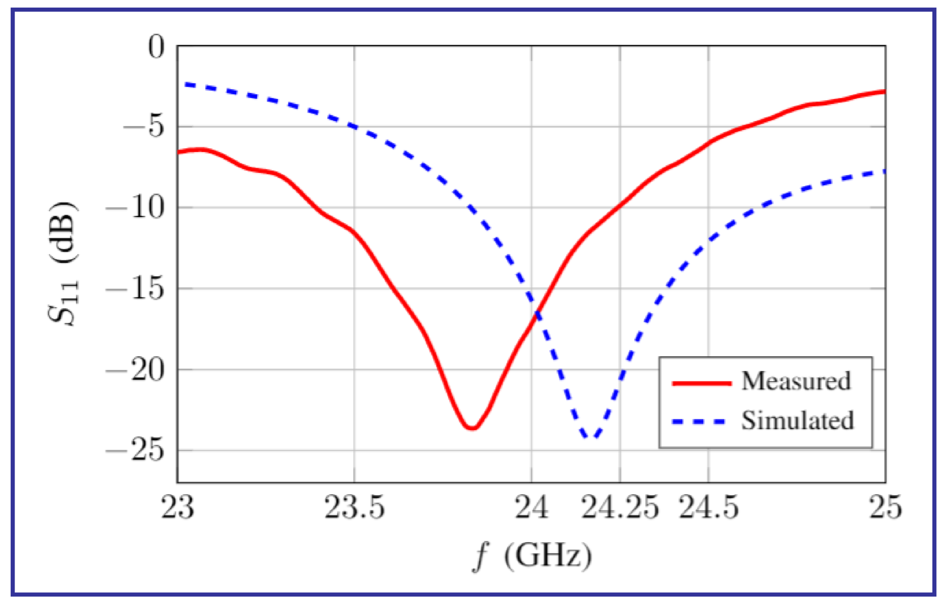

Fig. 5. Simulated and measured S_{11} (return loss) for the manufactured 24 GHz patch antenna.

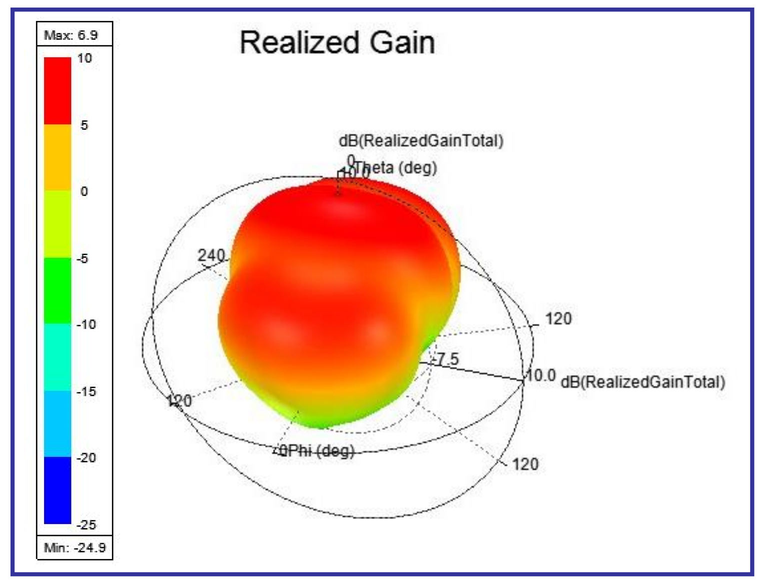

Fig. 6. Simulated gain for the 24 GHz antenna.

- RF Switch Simulated at 24 GHz
  - Phase balancing for Binary Phase Shift Keying (BPSK) implementation

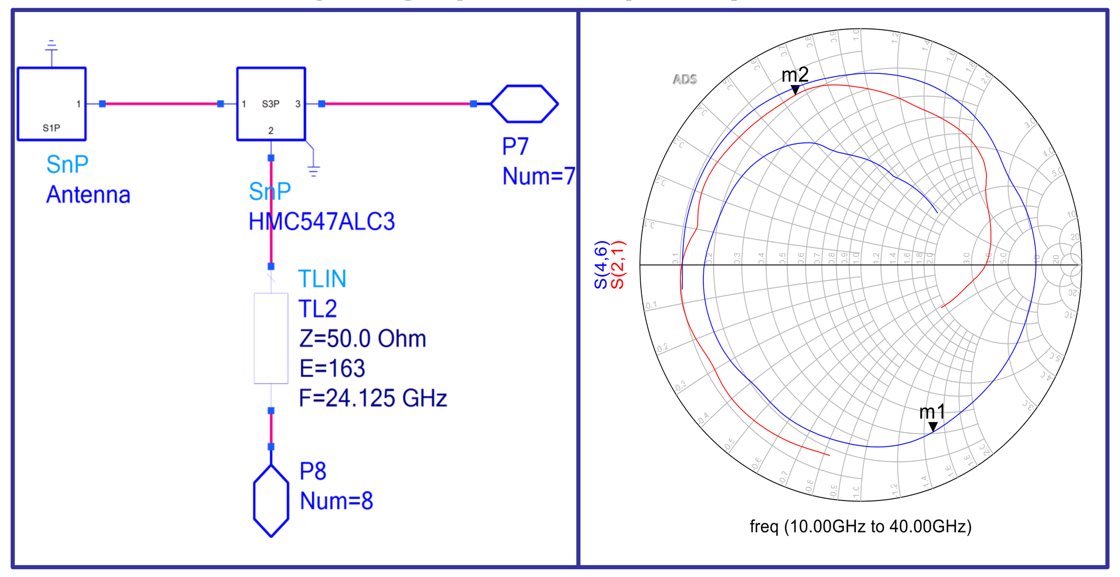

Fig. 7. (Left) Circuit layout with RF Switch. (Right) Smith chart showing 180° offset at 24.125 GHz between the two outputs.

Conclusions

- 24 GHz RFID tags are feasible with acceptable lossyness
- Cost/manufacturing difficulty must be addressed before successful commercial implementations
- The small size/large bandwidth of a 24 GHz tag makes it ideal for implementation in next-generation RFID devices

Future Work

- Manufacture prototype 24 GHz RFID tag with complete circuitry
- Implement multiple input-multiple output (MIMO) communication with multiple antennas on a tag

References

[1] Valenta, C. (2014). *Microwave-energy harvesting at 5.8 GHz for passive devices*. [Online]. Available at: https://smartech.gatech.edu/handle/1853/52295 [Accessed: 1 Oct. 2018].

[2] M. Slovic, B. Jokanovic, and B. Kolundzija, "High Efficiency Patch Antenna for 24 GHz Anticollision Radar," *TELSIKS 2005 - 2005 uth International Conference on Telecommunication in Modern Satellite, Cable and Broadcasting Services*, Oct. 2005.

[3] E. E. Altshuler, "Millimeter Wave Propagation," *Wiley Encyclopedia of Telecommunications*, 2003.

[4] Priceonomics. (2019). *The IoT Data Explosion: How Big Is the IoT Data Market?*. [Online] Available at: https://priceonomics.com/the-iot-data-explosion-how-big-is-the-iot-data/ [Accessed: 26 Mar. 2019].

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