

# Reconfigurable Dual Frequency Microstrip Patch Antenna Using RF MEMS Switches

Jessica A. DeSignor<sup>1</sup> and Jayanti Venkataraman<sup>2</sup>

<sup>1</sup> Department of Electrical Engineering  
Rochester Institute of Technology, Rochester, NY 14623, USA  
[jad8922@rit.edu](mailto:jad8922@rit.edu)

<sup>2</sup> Department of Electrical Engineering  
Rochester Institute of Technology, Rochester, NY 14623, USA  
[jnveee@rit.edu](mailto:jnveee@rit.edu)

**Abstract:** A reconfigurable dual frequency microstrip patch antenna is created by reconfiguring its size using two rectangular patches that are connected together via RF MEMS switches. This design has been analyzed for two antenna configurations; the case in which the switches are open resonates at 10 GHz and the case in which they are closed resonates at 8 GHz. A reconfigurable double stub tuner has been designed to match each of the antennas with two sets of stub lengths that correspond to each frequency. Finally, the performance of the dual frequency patch antenna is validated through construction and measurement.

**Keywords:** RF microelectromechanical systems (MEMS) switches and reconfigurable microstrip patch antenna.

## 1. Introduction

With the rapid development of the information age of communication systems and networking, there has been a growing demand for new RF technology to improve system capacity. In particular, in the field of wireless communications a very important development is the integration of different applications including cellular phones, satellite communications and wireless local area networks. Seeing how each of these applications operates on a different frequency band, each of these circuits requires different configurations. Due to size constraints in designing such devices, it would be beneficial to have reconfigurable circuitry that operates on each of these different frequencies.

In order to create reconfigurable circuitry, different types of switching techniques have been used including PIN diodes, GaAs field-effect transistor (FET) switches and RF MEMS switches. Although PIN diodes and GaAs FET switches were heavily used in the past, recent technology has allowed for the MEMS switch RF performance to advance past these other switches, and the use of MEMS switches has become more and more common in reconfigurable circuitry. Applications of the MEMS switch include phase shifting networks, antenna arrays, reconfigurable antennas, tunable filters, and reconfigurable power amplifiers. Some key advantages to the RF MEMS switch are near-zero power consumption, very high isolation, and very low insertion loss [1]. These characteristics make the RF MEMS switch an excellent companion to microwave circuitry.

## 2. Simulation Model

### A. Overview

There are two major aspects to this paper; the implementation of the RF MEMS switches into a rectangular patch antenna to obtain desired dual frequency resonance, and the implementation of RF MEMS switches into a double stub tuner impedance matching network to match both frequencies of the antenna to a 100 ohm transmission line as shown in Fig. 1 below.

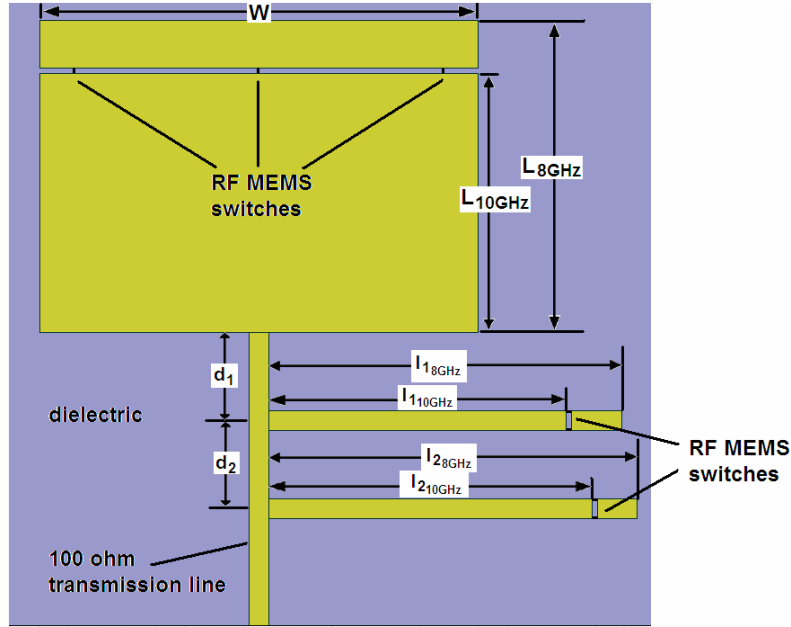


Fig. 1. Dual frequency microstrip patch antenna with reconfigurable impedance matching network.

A single patch by itself has a width,  $W$ , and a length,  $L$ . In this design,  $W$  is fixed to half the free space wavelength at 10 GHz and  $L$  is variable depending on the state of the switches. When the switches are in the open or up position the patch length will be  $L_{10\text{GHz}}$  and thus resonate at 10 GHz. When the switches are in the closed or down position the patch length will be  $L_{8\text{GHz}}$  and will resonate at 8 GHz.

In order to match the input impedance of the antenna to a 100 ohm transmission line a double stub tuner is proposed. For this design, the distances between the stubs  $d_1$  and  $d_2$  are fixed, and the stub lengths  $l_1$  and  $l_2$  are variable to the state of the switches. When the switches are open the stubs will be the shorter lengths,  $l_{1,10\text{GHz}}$  and  $l_{2,10\text{GHz}}$  which correspond to the matching of the 10 GHz antenna. When the switches are closed the stubs will be the longer lengths,  $l_{1,8\text{GHz}}$  and  $l_{2,8\text{GHz}}$  which correspond to the matching of the 8 GHz antenna.

### B. RF MEMS Switch Model

The RF MEMS switch is modeled the same way as in [2] using Ansoft HFSS and shown below in Fig. 2. As shown in Fig. 2, the switch lies between two copper patches which are printed on a dielectric material with a dielectric constant of 2.32. Copper pads are used to keep the switch from being connected to the patch and allow for the dc bias voltage to be applied. Unlike previous applications of the MEMS switch, in this design there is no thin dielectric slab separating the bridge from the patch. The idea of this design is that when the switch is in the down position it is in contact with both copper patches, and when it is in the up position there is no connection between the switch and the patches. As in [2] the RF MEMS switches are fabricated using gold with a width of 50  $\mu\text{m}$  and a thickness of 2  $\mu\text{m}$ .

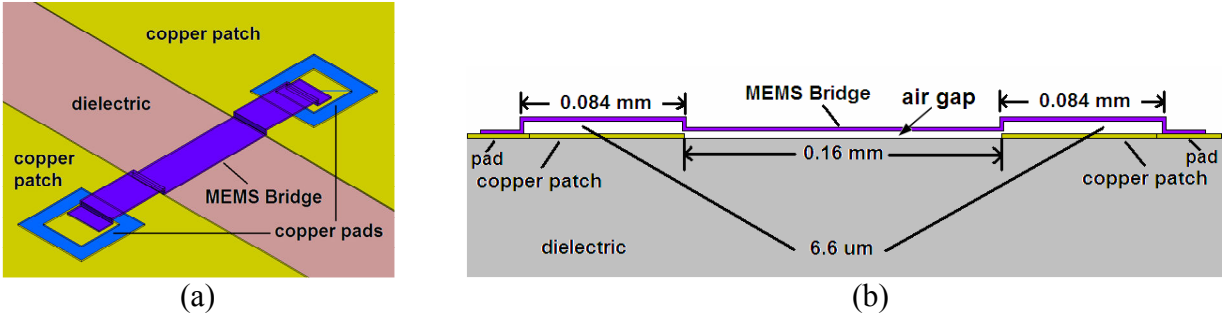


Fig. 2. RF MEMS switch modeled in HFSS a) angled view b) side view.

C. Design of Dual Frequency Microstrip Patch Antenna

Since the resonant frequency of a microstrip patch antenna is largely dependent on the dimensions of the patch, increasing the area of the patch will reduce the frequency at which the antenna resonates. By integrating RF MEMS switches into the design, a dual frequency patch antenna may be designed as shown in Fig. 3. Depending on whether the switches are closed or open they alter the patch size and thereby the resonant frequency of the antenna.

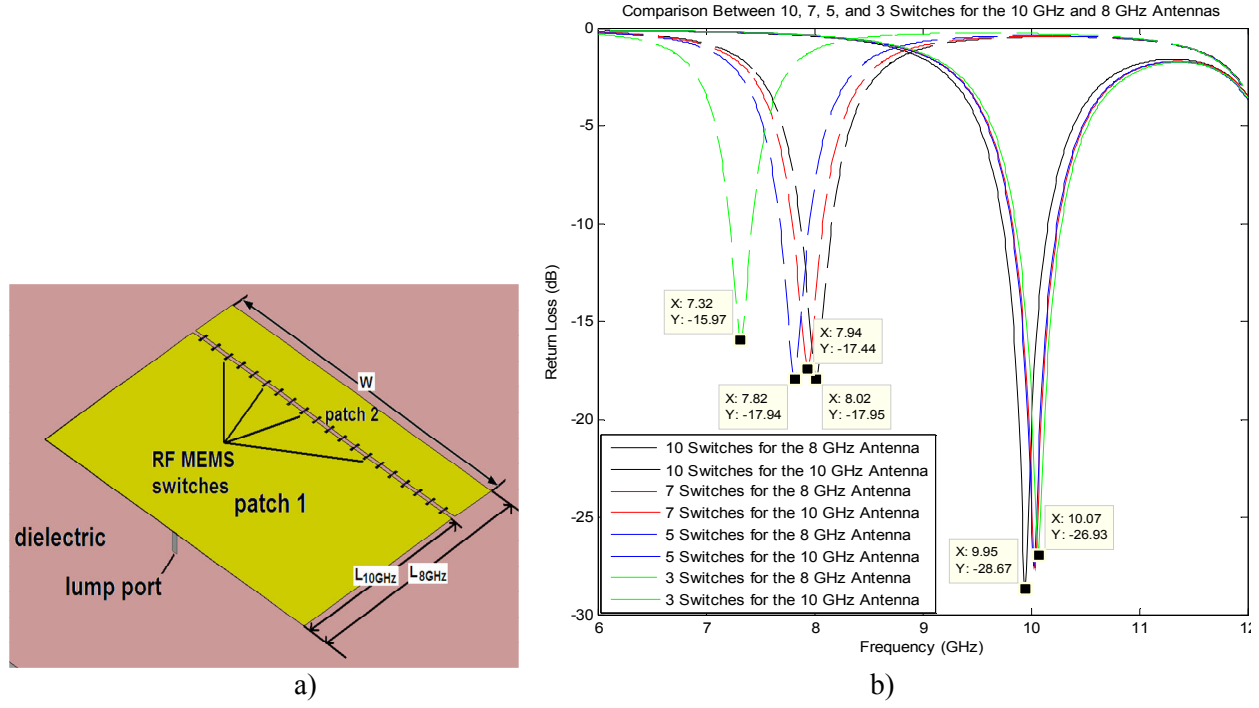


Fig. 3. Dual frequency microstrip patch antenna a) simulation model b) return loss for 10, 7, 5 & 3 switches.

The dielectric material used in this design is Rogers Duroid 5870 which has a dielectric thickness of 0.793 mm, a dielectric constant of 2.32 and a dielectric loss tangent of 0.01. Fig. 3 shows 20 RF switches connecting the two patches together. As discussed above, when the switches are in the open state the antenna has length  $L_{10GHz}$  and resonates at the frequency of patch 1 which is designed to be 10 GHz. When the switches are in the closed state the antenna has length  $L_{8GHz}$  and resonates at the frequency of the two patches combined which is designed to be 8 GHz. The optimum number of switches for dual frequency behavior is investigated and found to be three switches placed evenly along the gap between the two patches. As shown in Fig. 3b, the resonant frequencies obtained for the three switch configuration are 10.07 GHz and 7.32 GHz which is the farthest spread in frequency out of all the configurations.

### 3. Results

To simplify the simulation model, in this project the MEMS switches have been replaced by transmission lines for the “closed” state and for the “open” state the switches are simply removed as shown in Fig. 4 below. Under these conditions a correction method has been developed for tuning the patches to the desired frequencies of 10 GHz and 8 GHz and the results are shown in Fig. 5.

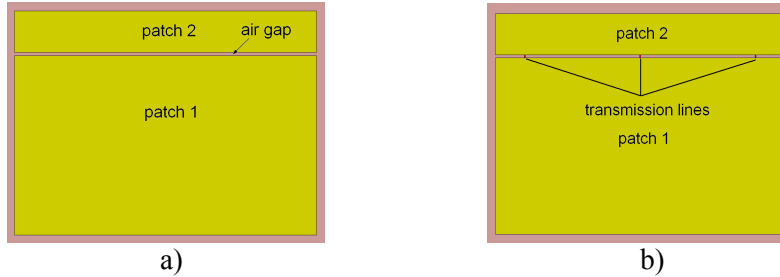


Fig. 4. Microstrip patch antenna with transmission lines in place of switches  
a) 10 GHz antenna b) 8 GHz antenna.

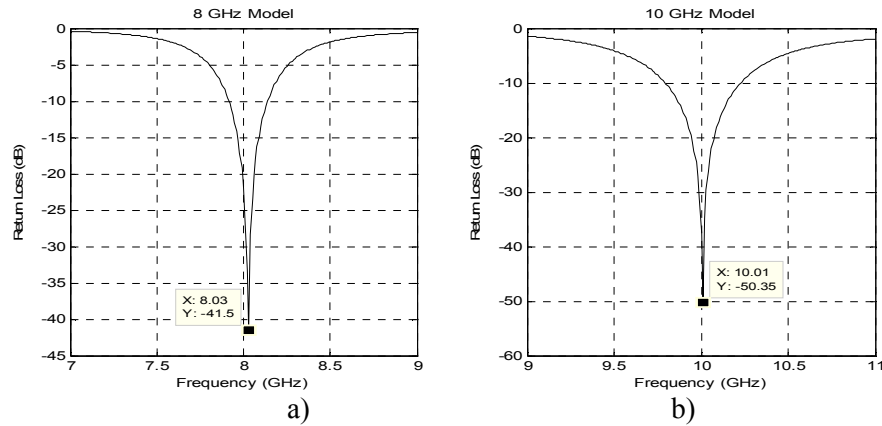


Fig. 5. Performance of dual frequency antenna from HFSS a) 8 GHz antenna b) 10 GHz antenna.

With a  $100\ \Omega$  feed transmission line added to the antenna, a reconfigurable double stub tuner for impedance matching has been implemented. Fig. 6 shows a comparison of the simulated return loss using HFSS with and without matching at the two frequencies. When the switches are open in the antenna and in the two stubs the antenna resonates at 10 GHz with a return loss of -21.87 dB and when they are closed it resonates at 8 GHz with a return loss of -20.86 dB.

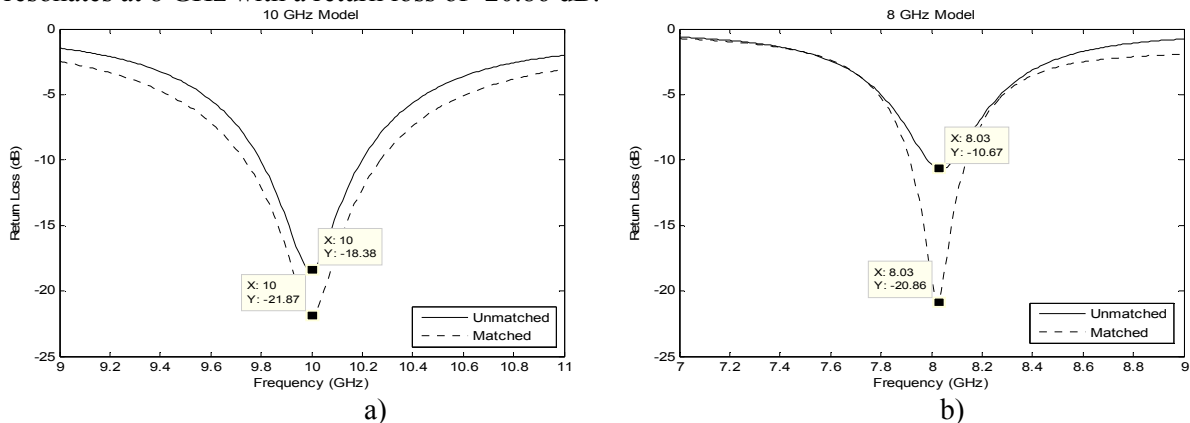


Fig. 6. Performance of dual frequency antenna with impedance matching network from HFSS  
a) 10 GHz antenna b) 8 GHz antenna.

## 4. Experimental Validation

The dual frequency microstrip patch antenna has been constructed using transmission lines in place of the RF MEMS switches and the experimental results are shown in Fig. 7 where the 10 GHz antenna resonates at 9.85 GHz and the 8 GHz antenna resonates at 7.99 GHz.

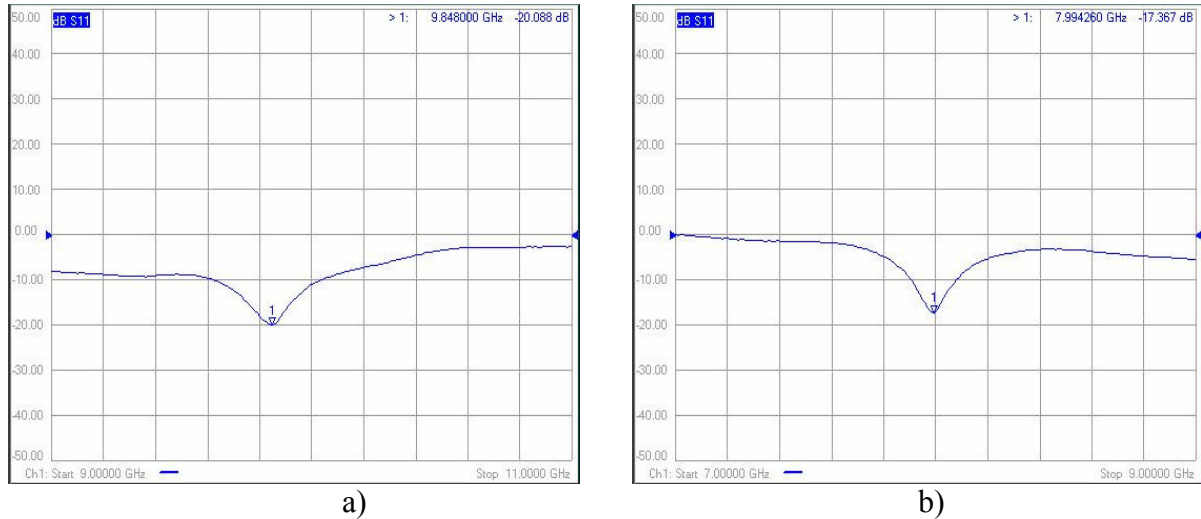


Fig. 7. Measured return loss a) 10 GHz antenna. b) 8 GHz antenna.

## 5. Conclusions

The design of a reconfigurable dual frequency microstrip patch antenna using RF MEMS switches has been established and the minimum number of switches required has been determined. Two antenna configurations that resonate at 8 GHz and 10 GHz have been designed and with a reconfigurable double stub tuner each has been implemented. For ease of computational time and for construction, the switches have been replaced by transmission lines to represent the closed state. The performance has been validated through simulation, construction and measurement.

## References

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