RECONFIGURABLE PATCH ANTENNA FOR FREQUENCY DIVERSITY WITH HIGH FREQUENCY RATIO (1.6:1)

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ABSTRACT

Reconfigurable patch antenna integrated with RF mircoelectromechanical system (MEMS) switches is presented in this paper. The proposed antenna radiates circularly polarized wave at selectable dual frequencies (4.7 GHz and 7.5GHz) of high frequency ratio (1.6:1). The switches are incorporated into the diagonally-fed square patch for controlling the operation frequency, and a rectangular stub attached to the edge of the patch acts as the perturbation to produce the circular polarization. Gain of proposed antenna is 5 - 6dBi, and axial ratio satisfies 3dB criterion at both operating frequencies. The switches are monolithically integrated on quartz substrate. The antenna can be used in applications requiring frequency diversity of remarkable high frequency ratio.

KEY WORDS

Reconfigurable antenna, RF-MEMS switch, High-frequency ratio.

INTRODUCTION

Microstrip antennas are widely used in wireless communications because of their compatibility, low profile and low cost. In more demanding environments such as military aircraft, circularly polarized antenna is typically used because it mitigates the loss in most of the situations. The capability to select the frequency is essential for diverse missions. A simple idea to adjust the resonant frequency of an antenna is to reconfigure its geometrical structure. This has been made possible with the use of the microelectromechanical systems (MEMS) switches [1, 2]. The MEMS devices can outperform their semiconductor counterparts such as transistors and diodes in lower insertion loss, lower power during operation and higher Q, which inherently fits the antenna element [3].

In this paper, a novel circularly polarized patch antenna using MEMS switches to reconfigure the resonant frequency with remarkable high frequency ratio (1.6:1) is reported. An additional patch is placed near to the main patch. It is convenient to make the patch smaller in order to share the same matching network and the same perturbation stub, which excites the circular polarization mode. Actuating the MEMS switches can connect these two patches and thus increase the effective electrical length, affording a lower frequency operation. In contrast, the higher frequency operation

is achieved when the switches are released. Both simulation and experiments demonstrate that the proposed antenna has the same polarizations and similar patterns at both frequencies.

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Geometry

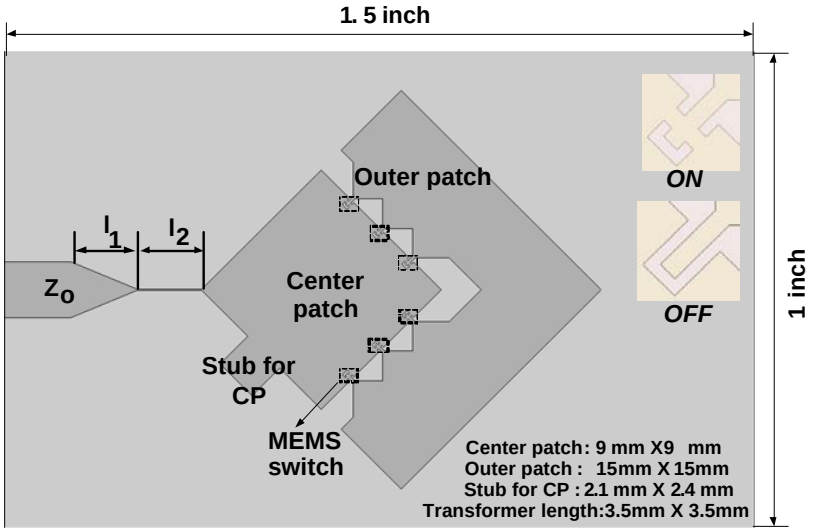
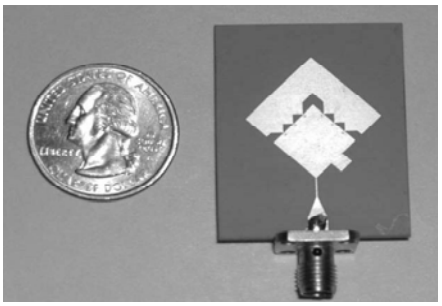


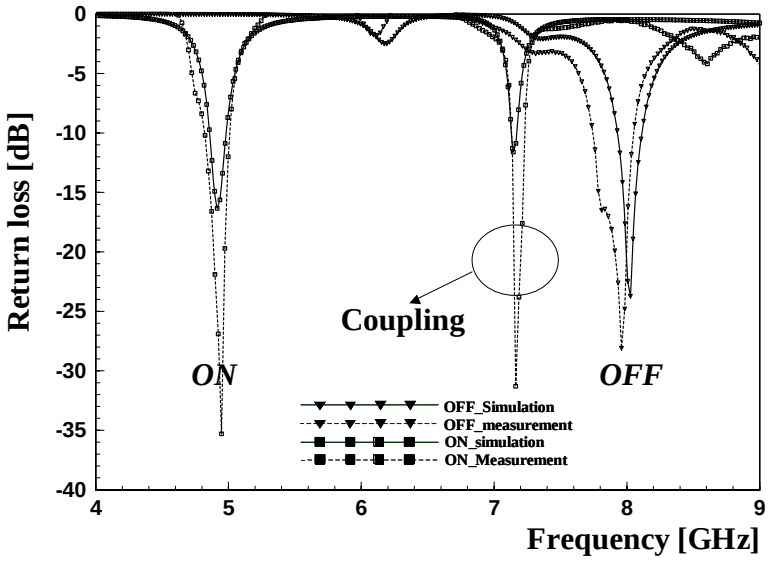
Figure 1 Geometry of reconfigurable patch antenna with 2D-MEMS switch.

The topology of the proposed reconfigurable patch antenna with artificial (2-dimensional) MEMS switches is shown in figure 1. A diagonal-fed center square patch (9mm X 9mm) is printed onto a quartz substrate (38.1mm X 25.4mm). The thickness of quartz is 1.58 mm and relative permittivity is 3.78. The outer patch (15mm X 15mm) is placed in outer part of the antenna. The perturbation stub (2.1mm X 2.4mm) attached at the square patch excites the circular polarization mode. Six-artificial MEMS switches are located between center and outer patches with 2.25 mm spacing. MEMS switches are connecting two patches for the purpose of structure for dual band (4.7 GHz and 7.5GHz) operations. Line of MEMS switch-location from the outer patches is tapered to increase isolation between two patches. Optimized line lengths (l_1 and l_2) are used for matching transformer network at both frequencies.

Simulation and measurement results

The proposed antenna is simulated using full wave analysis, HFSS. Two reconfigurable antennas representing *"ON"* and *"OFF"* states with artificial MEMS (figure 1) are fabricated on printed circuit board as shown in figure 2 (a). Printed circuit board (PCB) has similar dielectric constant and loss tangent (ε_r = 3.28, tan δ= 0.002) with quartz (ε_r = 3.78, tan δ = 0.0004). Thickness of PCB substrate is 1.524mm. Figure 2 (b) shows the comparison between simulated and measured return losses for the antenna. The antenna operates at 4.9GHz (*"ON"*-state) and 7.9GHz (*"OFF"*-state) frequency bands by states of MEMS switches with high frequency ratio (1.68:1). However, coupling band between two frequency bands is inevitable in this design, even though two patches are connected with tapered line to increase isolation. Simulated and measured radiation gain pattern at both operating frequency bands are shown in figure 3. Radiation gain of RHCP is 6.8dBi at 4.9GHz for *"ON"*-state and 5.4dBi at 7.9GHz for *"OFF"*-state, respectively. Axial ratio satisfies less than 3 dB criterions for both states.





(a) (b)

Figure 2 (a) Measured artificial reconfigurable patch antenna fabricated on PCB (printed circuit boards) (b) Comparison of return losses between measurement and simulation results.

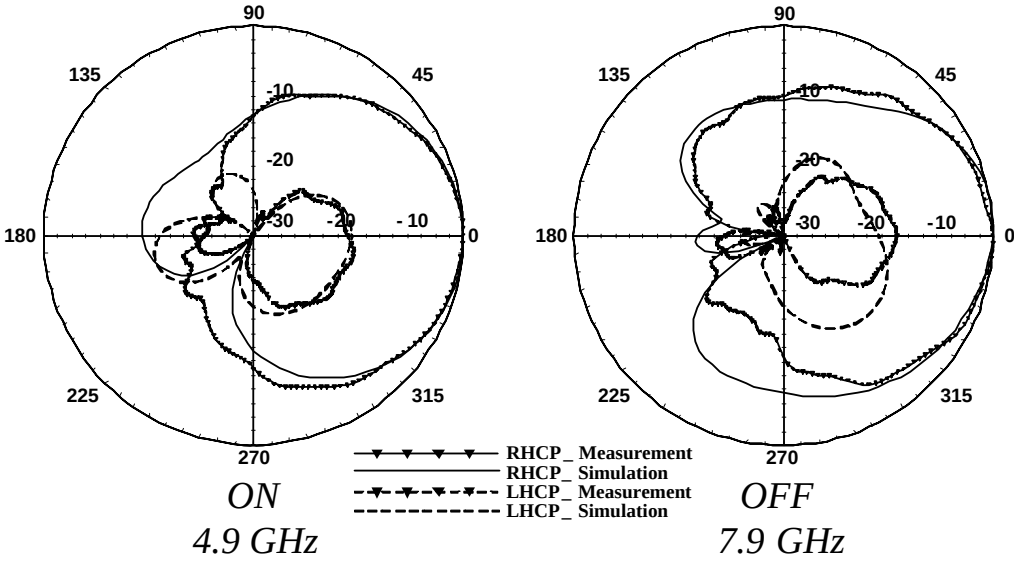


Figure 3 Measured and simulated radiation gain pattern.

Rejection of coupling band by a single open stub

To reject coupling band from previous result of return losses as shown in figure 2 (b), filtering the coupling band by a single open stub is necessary. Therefore, a single quarter-wavelength open stub, which operates at coupling band (6.5GHz), is added to microstrip feeding line as shown in figure 4 (a), (b). The length of single stub is 6.6mm, and width is 0.1mm. Simulation and measurement results show that the reconfigurable patch antenna operates at dual frequencies with high frequency ratio (1.6:1) without intensive coupling band between *"ON"* and *"OFF"* frequency bands as shown in figure 4 (c). To provide isolation between the RF signal and the DC bias signal, an angular open stub is placed in parallel to the quarter-wave length away from the center of the outer patch.

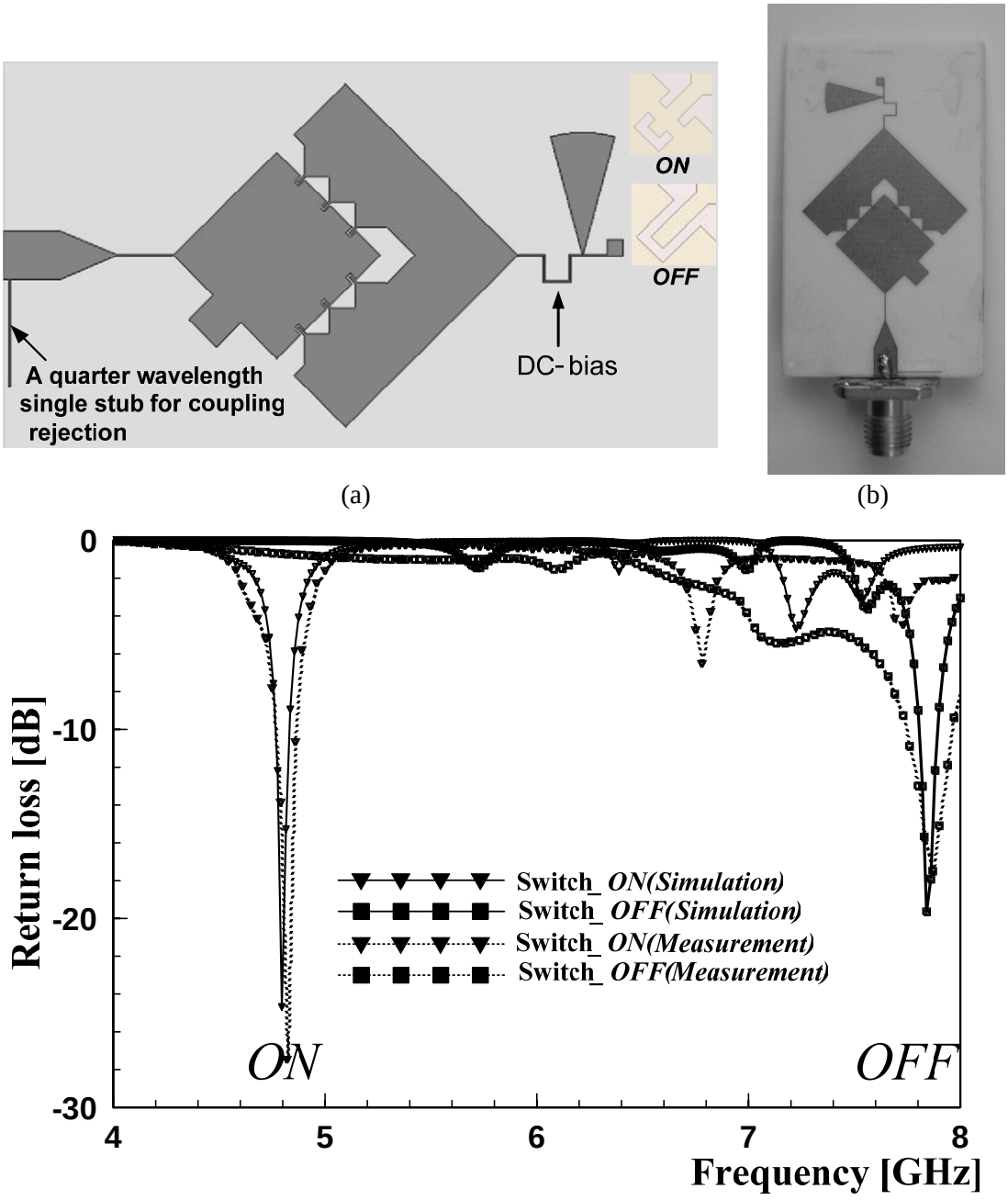


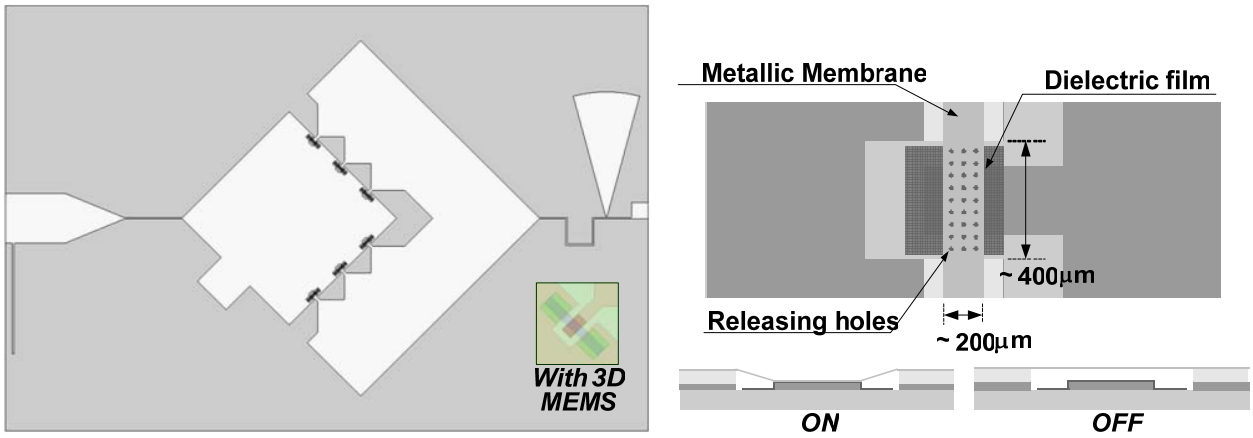
Figure 4 (a) Reconfigurable antenna with a single open stub to reject coupling band (6.5GHz) (b) Fabricated antenna for the measurement (c) Simulation result of return loss without coupling band by a single open stub.

ANTENNA WITH MEMS

Design of antenna with MEMS

The control voltage is applied between the coaxial center conductor and the bias pad. When the voltage is applied, all the switches (M1 ~ M6) are activated (*"ON"*-state) simultaneously, providing the connection between the two patches. Then antenna radiates RHCP wave at 4.7 GHz. When no voltage is applied, the switches are in the *"OFF"*-state, therefore only the center patch is

active while the outer patch serves as parasitic element. Then antenna radiates RHCP wave at 7.5 GHz.



(a) (b)

Figure 5 (a) Reconfigurable antenna with MEMS (b) Schematic view of MEMS switch in reconfigurable antenna.

Basically, dimension of antenna is the same with artificial antenna, which introduced previous chapter. In addition, 3-dimensional MEMS switch structure is included in full wave simulation as shown in figure 5 (a). The dimension of MEMS switch is shown figure 5 (b). Width of metallic membrane is 200 μm, and length is 400 μm. The height of membrane from the bottom electrode is set to 5μm to provide 30 ~ 40 (V) pull down voltage. Capacitance in "*OFF* "-state is 50fF, and in "*ON*"-state is 3.7pF from our previous measurement of capacitive RF-MEMS switch, which is fabricated on printed circuit board substrate. These capacitances provide 70 ~80 of *ON/OFF* - capacitance ratio. It is typical in capacitive RF-MEMS switch.

Monolithic fabrication

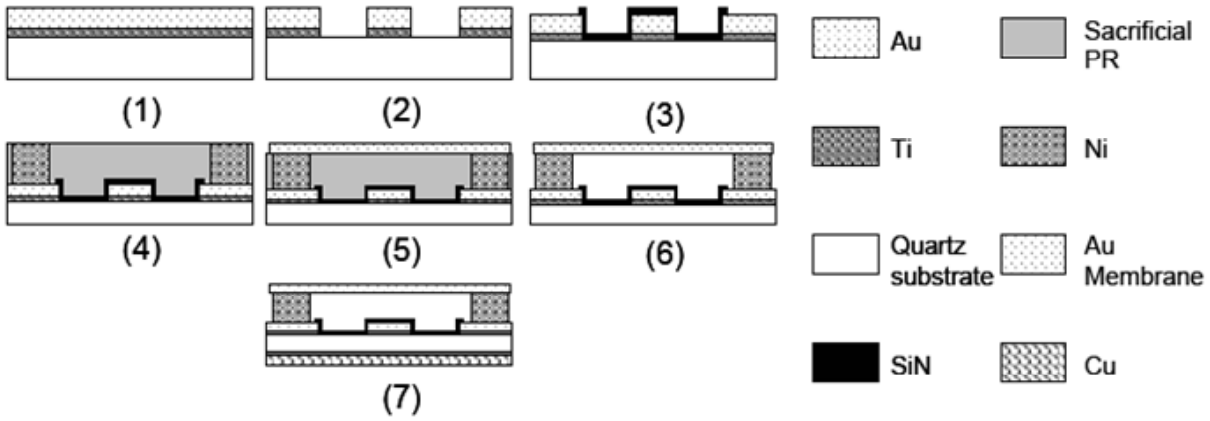


Figure 6 The process flow of a reconfigurable patch antenna fabricated on quartz substrate.

The microstrip antenna and MEMS switches are monolithically fabricated onto the same quartz substrate. The fabrication process flow is shown in figure 6. There are seven key process steps. 1) Titanium (1000 Å) and Gold (5000 Å) are deposited onto the substrate by E-beam evaporation. 2) Patterns are defined by lithography and chemical etching. 3) 2000Å SiN is deposited by plasma enhanced chemical vapor deposition (PECVD) and then patterned by reactive ion etching (RIE). 4) Ni is electroplated in a thick (5~6 um) photoresist (PR) layer coating. 5) Gold

(5000 Å) is deposited on to the post. 6) Switch is wet released using acetone. To minimize the stiction, boiling methanol is applied right after acetone releasing. 7) Thick metal films (Ti/Au or Ti/Cu) are deposited on the backside of the quartz substrate as the ground plate. An optical microscopy picture of the released MEMS switch is shown in figure 7 (a) and scanning electron microscopy picture of releasing hole is shown in figure 7 (b).

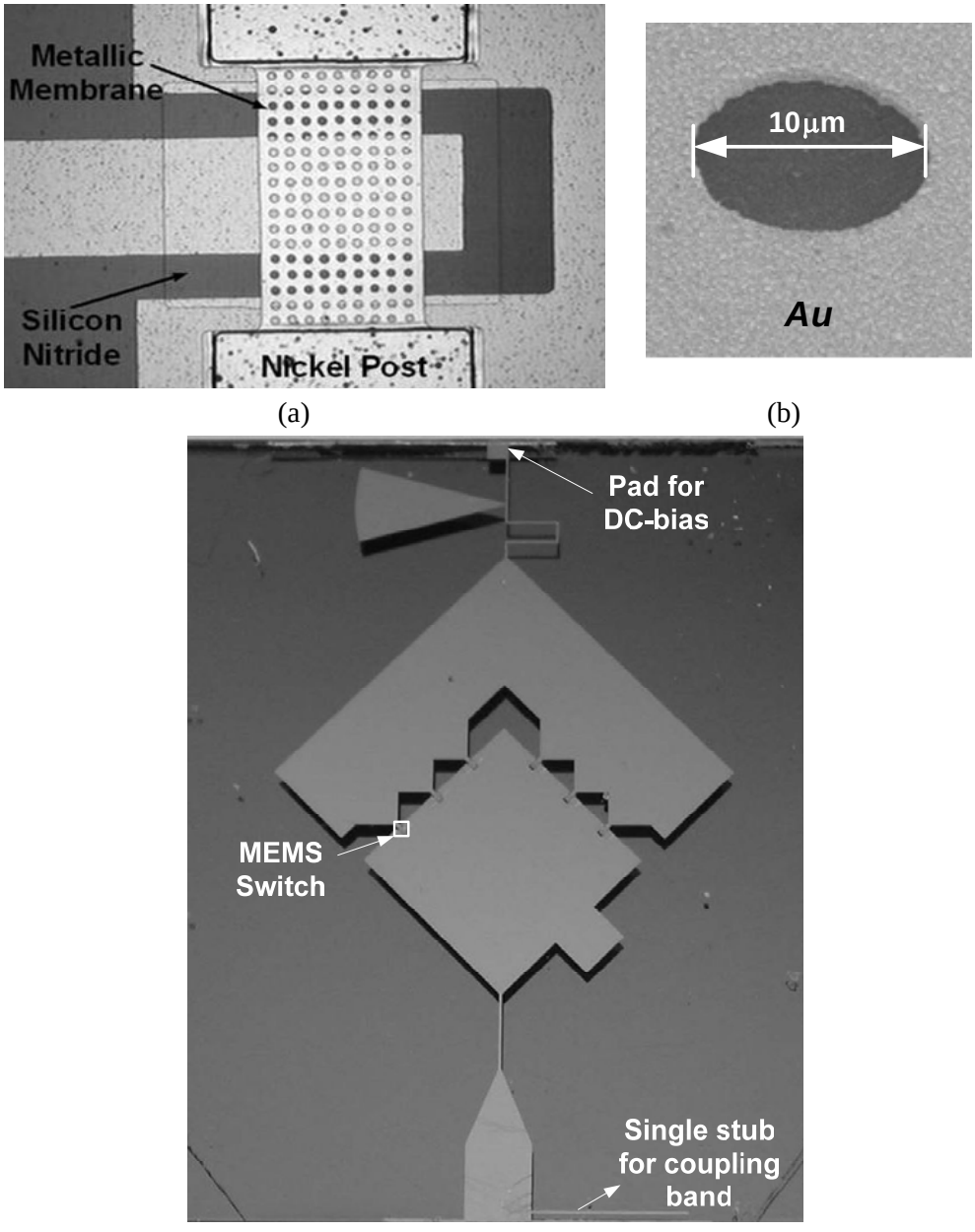


Figure 7 (a) Microscopic picture of MEMS switch in reconfigurable antenna (b) Scanning electron microscopy (SEM) picture of a releasing hole (c) Fabricated antenna with MEMS switches.

Simulation result of antenna with MEMS

Figure 8 shows simulation result of return loss for reconfigurable patch antenna with MEMS as shown in figure 5 (a). Return losses are under -10dB (VSWR < 1.925) at both frequency bands (4.8 and 7.5 GHz) by each switch state. Frequency ratio is 1.6:1. From the previous our work, a bias of 30 volts with negligible current consumption is required to actuate the switches. The

measured and simulated radiation patterns are shown in figure 9. In both cases, axial ratio is less than 3 dB in the main direction (perpendicular to the patch) of RHCP-radiation pattern. Gain is 6.6dBi at 4.8GHz of switch *"ON"*-state and is 5.5dBi at 7.5GHz of switch "*OFF"*-state.

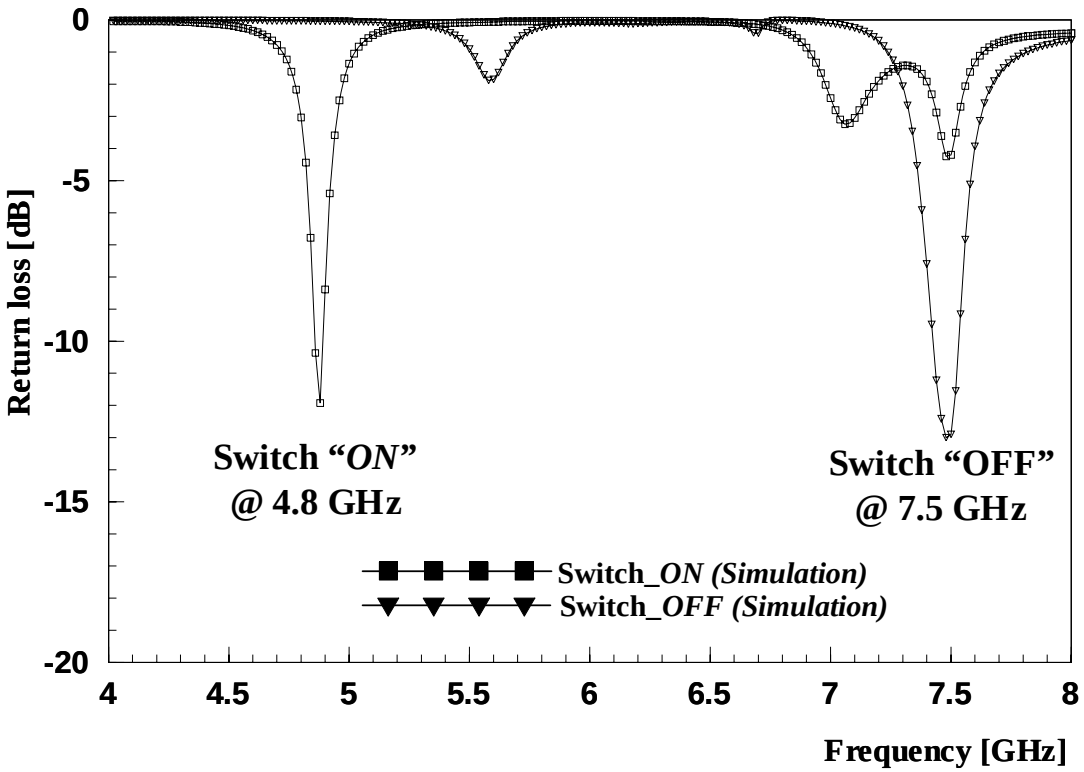


Figure 8 Return loss of reconfigurable patch antenna with MEMS.

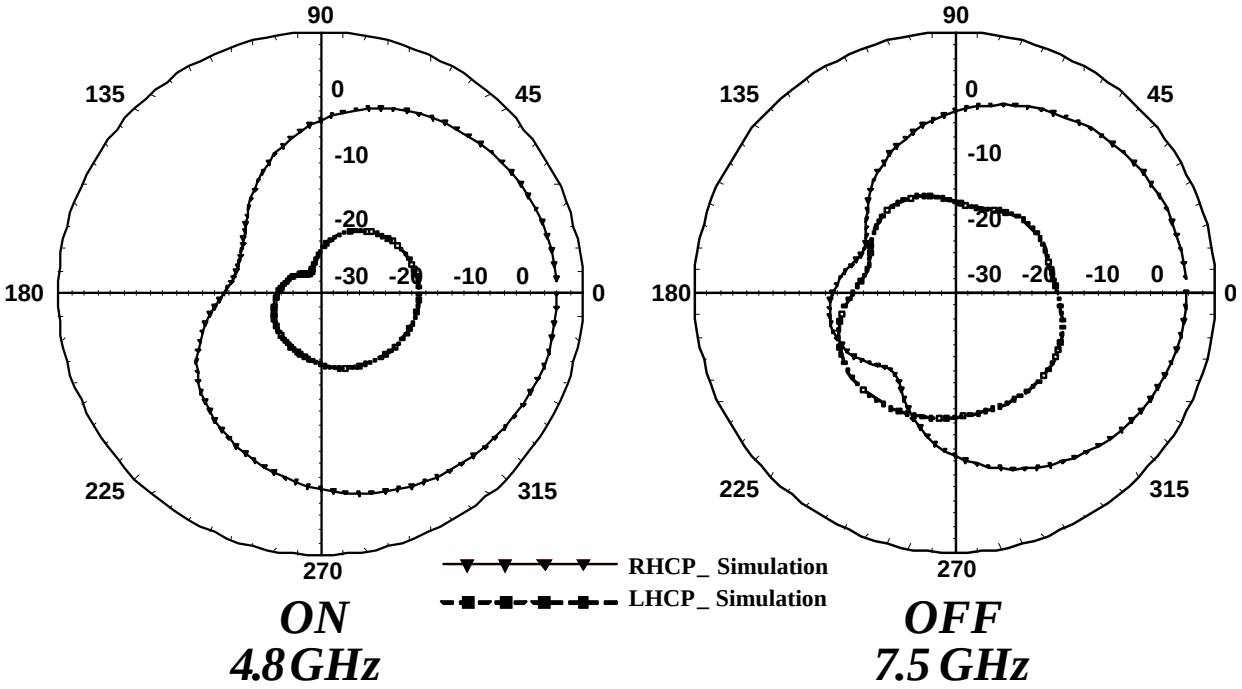


Figure 9 Radiation gain pattern of reconfigurable patch antenna with MEMS.

CONCLUSION

A novel reconfigurable antenna capable of changing frequency operation with high frequency ratio (1.6:1) using RF-MEMS switches is presented. The antenna can be used in applications requiring frequency diversity. A quarter wavelength open stub in feeding removes coupling band. Antenna with MEMS switches operates in two-frequency bands with gain of 5-6dBi with under 3dB of axial ratio. Phased array antenna with butler matrix is applicable to advanced frequency and pattern re-configuration using RF-MEMS switches in communication systems.

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