Pattern Reconfigurable Antenna Using Non-uniform Serpentine Flexure Based RF-MEMS Switches

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Abstract— This paper presents the design and analysis of reconfigurable antenna using two circular microstrip patch antenna array with non-uniform RF-MEMS switches in L and S band. It consists of a pair of circular patch antenna with CPW on the same side of Si substrate. This reconfigurable antenna design consists of two RF-MEMS switches, to achieve pattern reconfigurability. Two RF-MEMS switches are used to electrically connect and disconnect the two circular radiating patches. The analysis of reconfigurable antenna using RF-MEMS switch is done using the simulation performed on Ansys HFSS electromagnetic simulator for the frequency range of 1 to 10 GHz. The reconfigurability of the antenna is analyzed for L to S band (2 to 4 GHz) in terms of return loss and radiation pattern. The proposed antenna shows the pattern reconfigurability at 2.3 GHz and 3.4 GHz.

1. INTRODUCTION

In satellite communication, reconfigurable antennas are used to achieve switching capability between two frequency bands. This switching is possible either by using p-i-n diode and FET switches or RF-MEMS switches. Due to the advantages of RF-MEMS switches over semiconductor switches, RF-MEMS switch technology is regarded as a promising technology for future reconfigurable wireless communication systems [1–4].

In this work, two circular microstrip patch antenna array with proposed RF-MEMS switches are used for L and S band. Our recently proposed [5] capacitive non-uniform serpentine spring based RF-MEMS are used in CPW configuration, so they do not require extra bias line, the bias is applied directly to the RF signal line. The lack of bias line for the RF-MEMS switches in proposed reconfigurable antenna design makes the fabrication easier, which in turn improves the radiation performance due to absence of leakage and coupling through the bias lines. This reconfigurable antenna design consists of two RF-MEMS switches, to achieve pattern and frequency reconfigurability. The proposed switch design is scaled up by a factor of 20 in order to achieve the reconfigurability in L and S band.

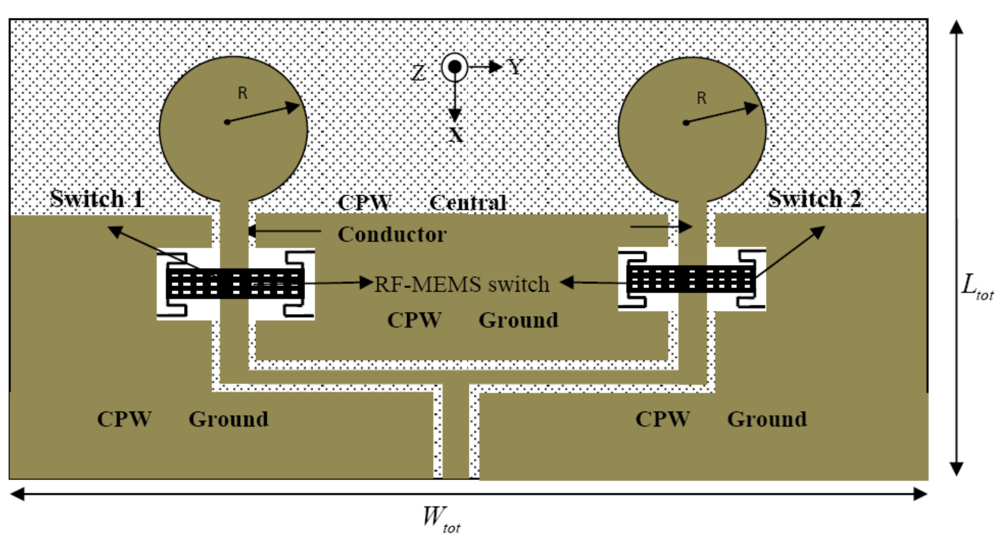


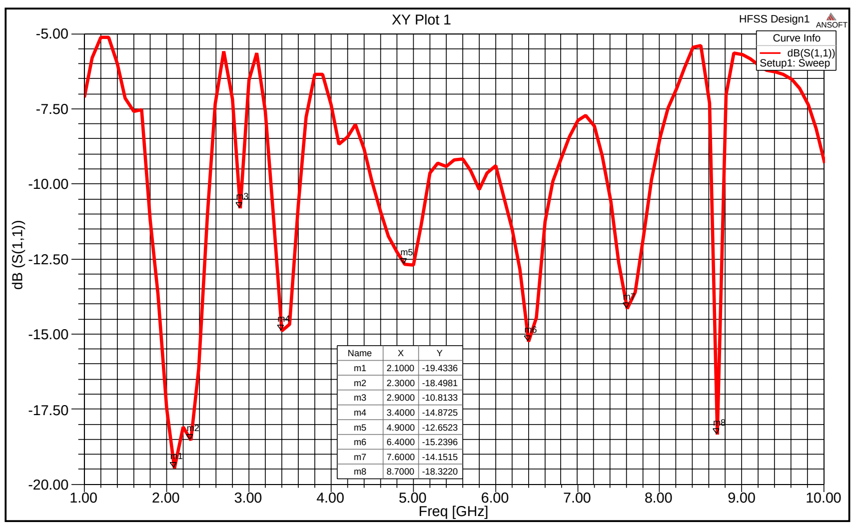
Figure 1: Schematic view of RF-MEMS switch based reconfigurable antenna.

2. DESIGN AND OPERATION

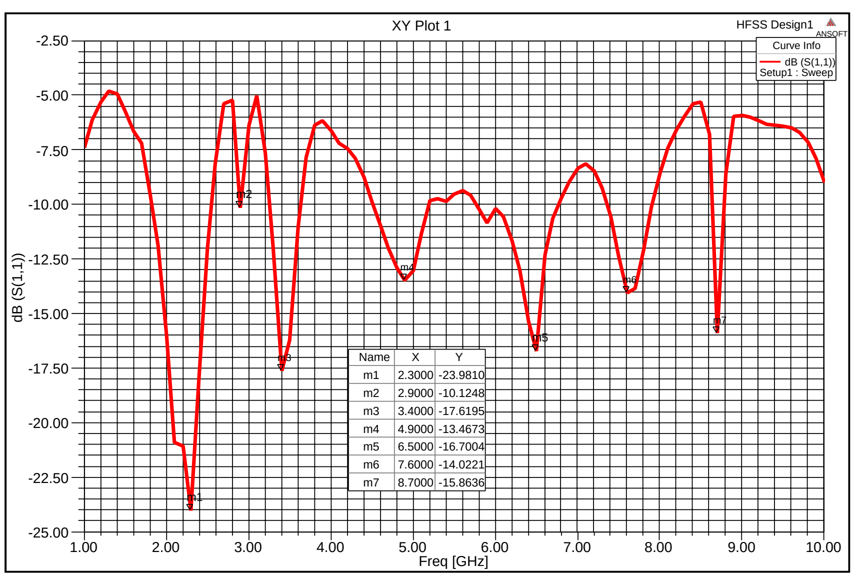
Figure 1 represents the schematic view of reconfigurable antenna with RF-MEMS switch. Two circular patch antenna array with RF-MEMS switches are designed to achieve a reconfigurable antenna characteristics for the frequency band of 1 to 10 GHz. It consists of a pair of circular patch antenna with CPW on the same side of Si substrate. The total width (W_{tot}) and length (L_{tot}) of this antenna are 94 mm and 67 mm, respectively. The radius of the patch is taken as 12.5 mm and the length, width and thickness of RF-MEMS switch are 12.8 mm, 2.08 mm and 0.1 mm respectively.

A CPW feed line with central conductor width $W = 4$ mm and ground signal gap $S = 0.45$ mm is used, resulting in a characteristic impedance (Z_0) of 50 Ω. Two RF-MEMS switches are used to electrically connect and disconnect the two circular radiating patches. These switches are positioned at 6 mm from the circular patch along x axis.

The RF-MEMS switch activates or deactivates the circular microstrip patches when a DC bias is applied. For two circular microstrip patch element based antenna, the frequency band is selected or removed based on whether the RF-MEMS switches are in up-state (open), or in down-state (short) with the CPW central conductor. The proposed reconfigurable antenna is simulated for two cases, when switch 1 in down-state (ON) and switch 2 in up-state (OFF) and when switch 1 in up-state (OFF) and switch 2 in down-state (ON).



(a)



(b)

Figure 2: Return loss for RF-MEMS switch based two element circular microstrip patch antenna, (a) when first switch is in down-state, (b) when second switch is in down-state.

3. ANALYSIS AND RESULT

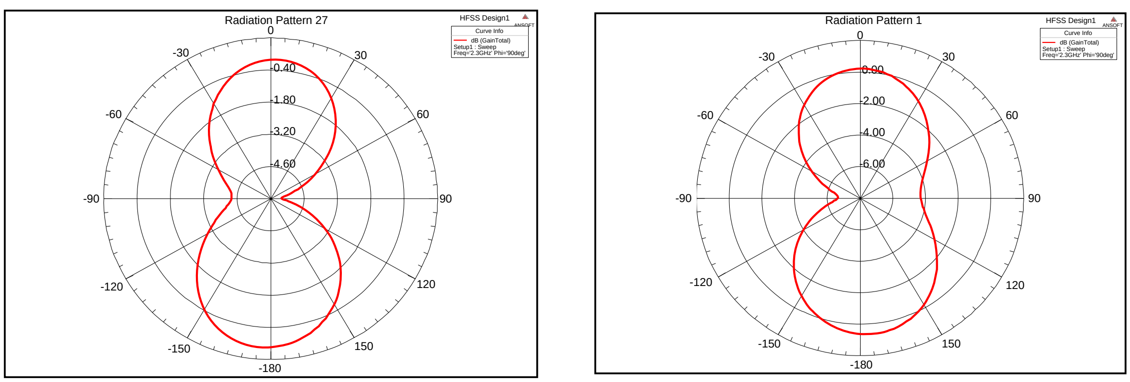
The analysis of reconfigurable antenna using RF-MEMS switch is done using the simulation performed on Ansys HFSS electromagnetic simulator for the frequency range of 1 to 10 GHz. The reconfigurability of the antenna is analyzed for L to S band (2 to 4 GHz) in terms of return loss and radiation pattern. Figure 2(a) shows the return loss (S_{11}) for proposed reconfigurable antenna for frequency ranging from 1 to 10 GHz. In this, an actuation voltage is applied at first switch. This plot illustrates that this antenna provide the resonance at eight resonant frequencies with > -10 dB for the frequency range of 1 to 10 GHz.

When an actuation voltage is applied at second switch, the simulated return losses are shown in Figure 2(b). It shows that this antenna radiate at seven resonant frequencies except 2.1 GHz. So from this graph it can be concluded that this antenna do not radiate at 2.1 GHz by actuating second RF-MEMS switch.

The E-plane (x-y) radiation patterns are simulated ($\varphi = 90$) for different switch positions. When first switch is actuated, this antenna shows a different radiation pattern at 2.3 GHz as shown in Figure 3(a). It shows that radiation pattern can be reconfigured slightly to the left side by switching the first RF-MEMS switch. When second switch is actuated the radiation pattern shifts towards the right hand side at 2.3 GHz as shown in Figure 3(b). It is observed that left and right pattern reconfigurability can be obtained at 2.3 GHz by actuating either first or second switch.

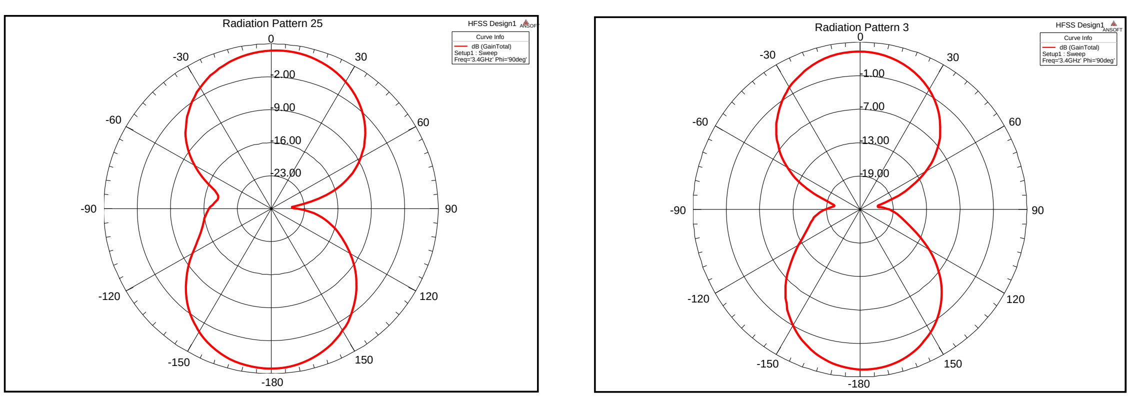
Figure 4(a) shows the antenna radiation pattern at 3.4 GHz when first switch is actuated. This radiation pattern gets changed at 3.4 GHz when second switch is in down-state as shown in Figure 4(b).

From these plots it is observed that the radiation pattern at 2.3 GHz get significantly changed in left side or in right side after actuating the first or second switch. On the other hand it shows the pattern reconfigurability at 3.4 GHz when first switch or second switch are actuated.



(a) (b)

Figure 3: 2-D E-plane radiation plot at 2.3 GHz for RF-MEMS switch based two element circular microstrip patch antenna, (a) when first switch is actuated and when second switch is actuated.



(a) (b)

Figure 4: 2-D E-plane radiation plot at 3.4 GHz for RF-MEMS switch based two element circular microstrip patch antenna, (a) when first switch is actuated and when second switch is actuated.

4. CONCLUSION

The use of circular microstrip resonating elements integrated with RF-MEMS switches were implemented for reconfigurable microstrip antenna for the frequency band ranging from 1 to 10 GHz. Simulations are performed on Ansys HFSS electromagnetic simulator. This reconfigurable antenna shows pattern reconfigurability at 2.3 GHz and 3.4 GHz, when either first or second switch is actuated.

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REFERENCES

1. Erdil, E., K. Topalli, M. Unlu, O. A. Civi, and T. Akin, "Frequency tunable microstrip patch antenna using RF MEMS technology," *IEEE Transactions on Antennas and Propagation*, Vol. 55, 1193–1196. Apr. 2007.
2. Nikolaou, S., N. D. Kingsley, G. E. Ponchak, J. Papapolymerou, and M. M. Tentzeris, "UWB elliptical monopoles with a reconfigurable band notch using MEMS switches actuated without bias lines," *IEEE Transactions on Antennas and Propagation*, Vol. 57, 2242–2251, 2009.
3. Genovesi, S., A. Monorchio, M. Borgese, S. Pisu, and F. M. Valeri, "Frequency-reconfigurable microstrip antenna with biasing network driven by a PIC microcontroller," *IEEE Antennas and Wireless Propagation Letters*, Vol. 11, 156–159, 2012.
4. Sung, Y. J., "Frequency and polarisation reconfigurability from an open-loop square ring antenna," *IET Microwave Antennas Propagation*, Vol. 6, 505–509, 2012.
5. Sharma, A. K. and N. Gupta, "An improved design of MEMS switch for radio frequency applications," *Int. J. of Applied Electromagnetics and Mechanics*, Vol. 47, 11–19, IOS Press, Japan, 2015.