Reconfigurable Antennas for RFID/GPS/WiMAX/WLAN Applications Using RF MEMS Switches

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1 Introduction

The demand for innovative wireless communication applications is drastically increasing day by day [1, 2]. To fulfill this demand, there is a necessity for novel and optimized communication devices like reconfigurable antennas, phase shifters, and RF isolators with low power consumption. Especially in 5G technology, there is a significant demand for reconfigurable antennas with multi-operating frequencies and low interferences [3, 4]. The researchers are investigated with intense curiosity to propose the optimized solution and to design a reconfigurable antenna with best performance. In this era, MEMS technology is shown great potential in the design of communication devices with low power consumption and high linearity.

This is the major motivated factor to design reconfigurable antennas by using RF MEMS switches other than traditional solid-state electronic switches (PIN diode and FET transistor) [5–7]. MEMS technology has recently received significant attention due to its ability to enhance the performance of RF switches. Despite the best

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Table 1 Wireless
applications based on
frequency bands [14–16]

Frequency range (GHz)	Application
0.9–5.2	RFID
1.2–1.6	GPS
1.85–1.9	GSM
2.39–2.4 and 5.2–5.6	WLAN
3.4–3.69	WiMAX
3.7–4.2 and 5.1–6.25 and 6.7–7.1	Few satellites

performance, decreasing the pull-in voltage, increasing the reliability, and improving
the switching time are significant research challenges in RF MEMS switches.
Improving the capacitance ratio and achieving the best RF performance are the
potential challenges in capacitive RF MEMS switches [8–10]. RF MEMS switch-
based reconfigurable antennas are offering the best performance when compared
with structure-based reconfigurable antennas [11–13].

In this paper, we have presented an investigation and design analysis on the
performance of reconfigurable antennas using shunt capacitive RF MEMS switches.
These configurations aim to provide the following bands: GPS bands (1.2–1.6 GHz),
WLAN bands (2.39–2.4 and 5.2–5.6 GHz), RFID (0.9–5.2 GHz), some satellite bands
(3.7–4.2, 5.1–6.25, and 6.7–7.1 GHz), and GSM bands (1.85–1.9 GHz) (Table 1).

2 Reconfigurable Antenna

In this paper, we have designed a reconfigurable microstrip patch antenna using shunt
capacitive RF MEMS switches. The antenna is aimed to serve multiple applications
like RFID, WLAN, GPS, and WiMAX applications.

2.1 RF MEMS Switches

The shunt capacitive RF MEMS switches are used as the basic switching elements
used for making the antenna as reconfigurable. The switch is designed with serpentine
structure membrane of gold (Au) material of 1 μm thickness (Table 2; Figs. 1, 2 and
3).

The membrane is perforated with 5 μm × 5 μm size square shape holes. Elec-
trostatic actuation is used to deform the membrane. The RF MEMS switch designed
using COMSOL tool is offering good performance i.e., the required actuation voltage
is 4.5 V, the switching time of the switch is 45 μs. We have done a wide range of
analyses on the serpentine membrane in terms of max/min actuation voltages points,
max/min displacement points, isolating surface for electric potential, displacement
direction, and contour for electric potential, principal stress points.

Table 2 RF MEMS switch materials and dimensions

Parameter		Material	Dimension
Serpentine membrane thickness		Gold (Au)	1 µm
Perforation		–	5 µm × 5 µm
Dielectric		AlN	0.5 µm
Meander 10 µm uniform width	1	Gold (Au)	20 µm
	2		60 µm
	3		70 µm
	4		80 µm
	5		30 µm
Air gap		–	1.5 µm

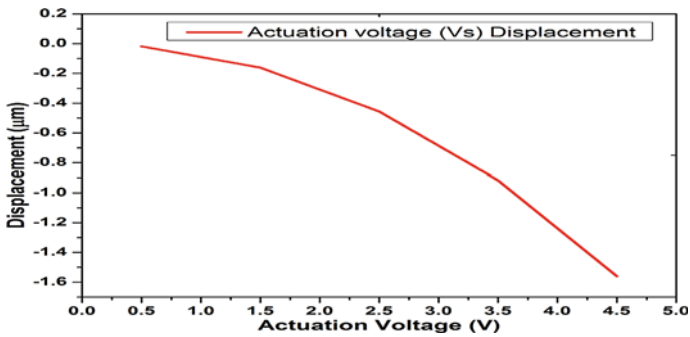**Fig. 1** Serpentine membrane electrostatic actuation

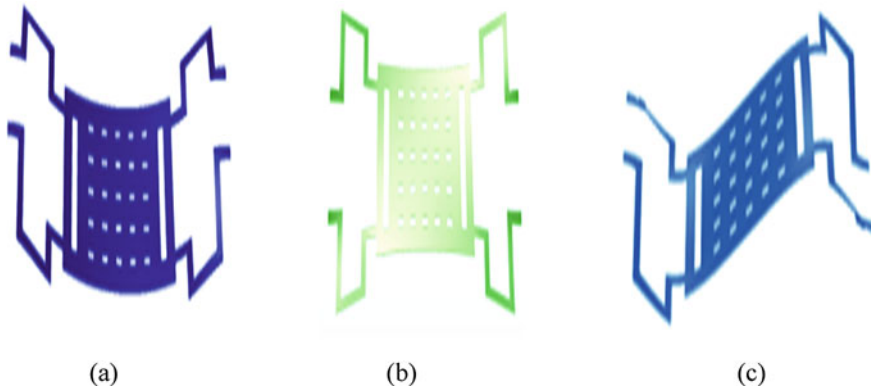

Fig. 2 Actuation voltage (Vs) displacement

Fig. 3 Serpentine membrane resonant frequencies, **a** 4608 Hz, **b** 7772 Hz, 12244 Hz

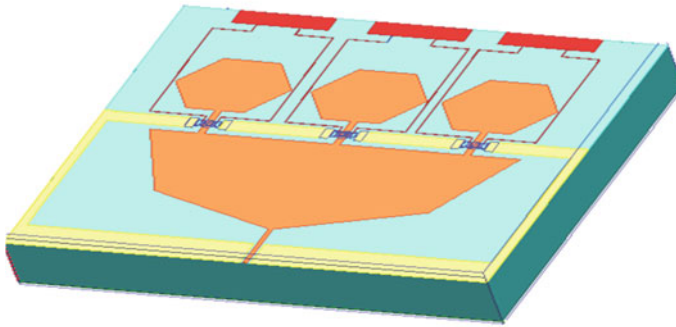## 2.2 Reconfigurable Antenna Using RF MEMS Switches

The reconfigurable microstrip patch antenna is designed by placing three identical shunt capacitive RF MEMS switches i.e., S_1, S_2, and S_3 (Fig. 4).

All three switches are individually connected to biasing pads. Silicon is used as a substrate. Silicon dioxide is used as an insulating material on the top of the silicon substrate (Figs. 5 and 6).

CPW type feeding is used with G/S/G value 50 μm/100 μm/50 μm. The structure of the reconfigurable antenna is designed by connecting the four patches i.e., P1, P2, P3, and P4. The P1 patch is conned with P2, P3, and P4 through three switches S1, S2, and S3, respectively. If S1-OFF, S2-OFF, and S3-OFF, the antenna is resonating at 5.4 GHz. If S1-OFF, S2-OFF, and S3-ON, the antenna is resonating at 0.9 GHz. If S1-OFF, S2-ON, and S3-ON, the antenna is resonating at 1.5 GHz. If S1-OFF, S2-ON, and S3-ON, the antenna is resonating at 3.5 and 8.4 GHz. Based on the switching of the RF MEMS switches, the antenna is resonating at 0.9, 1.5, 3.5, and 5.4 GHz. So, the proposed antenna is suitable for multiple applications like RFID, GPS, WiMAX, and WLAN (Table 3).
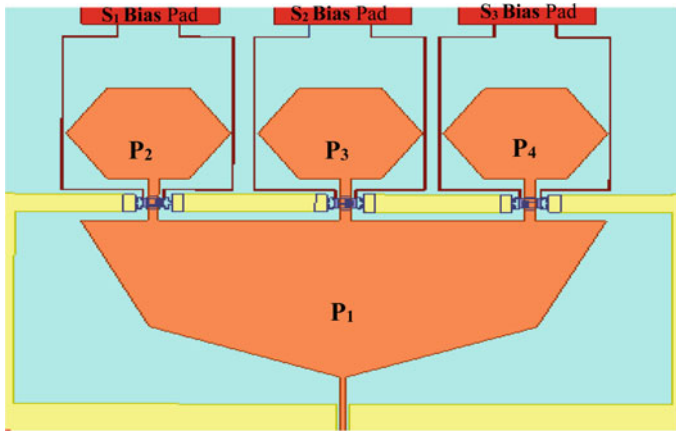
Fig. 4 Reconfigurable antenna with three identical RF MEMS switches, **a** top view, **b** side view
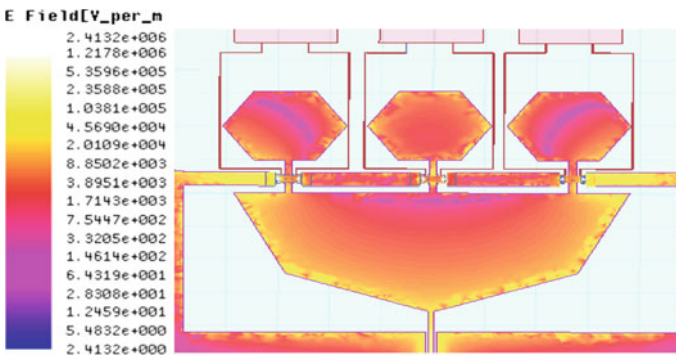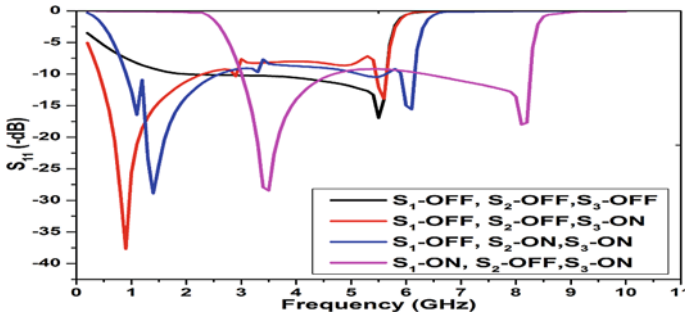

Fig. 5 Flow of current

Fig. 6 Reconfigurable antenna resonating at multiple frequencies under different switching conditions

Table 3 Antenna resonating frequencies under different switching conditions

Switching condition	Antenna resonating frequency (GHz)	Application
S_1-OFF, S_2-OFF, S_3-OFF	5.4	WLAN
S_1-OFF, S_2-OFF, S_3-ON	0.9	RFID
S_1-OFF, S_2-ON, S_3-ON	1.5	GPS
S_1-OFF, S_2-ON, S_3-ON	3.5 and 8.4	WiMAX

3 Conclusion

The demand for the reconfigurable antenna is increasing day by day. In this paper, we have designed a reconfigurable microstrip patch antenna for low-frequency communication applications using shunt capacitive RF MEMS switches. The RF MEMS switch used is offering high performance. The reconfigurable antenna is designed with three RF MEMS switches. Based on the switching of the RF MEMS switches, the antenna is resonating at 0.9, 1.5, 3.5, 5.4 GHz. So, the designed antenna is suitable for multiple applications like RFID, GPS, WiMAX, and WLAN.

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