Frequency Reconfigurable Slotted Patch Antenna for Mobile Applications using MEMS Cantilever Switch

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Abstract: This paper presents the design and simulation of a frequency reconfigurable antenna structure which can switch to different frequencies by means of MEMS cantilever switches. A microstrip patch antenna structure is designed which can adjust its frequencies to support various mobile applications like WiFi, WiMaX and GSM by switching series cantilever switches on and off, thereby eliminating the need of multiple antennas to support each frequency. Behaviour of series cantilever switch is analysed using COMSOL MultiPhysics.

Keywords: Reconfigurability, cantilever, MEMS

1. Introduction

Wireless communication has witnessed spectacular advancements over the past few decades. These developments demand reconfigurable antenna technology where several frequencies can be supported in a single platform rather than having separate antennas for each frequency. By electronic reconfiguration mechanisms, switches can be turned on or off to help attain required frequencies.

While optoelectronic switches suffer from low power handling capability, solid state switches like PIN diodes and varactor diodes have poor linearity, high power consumption, high insertion loss, poor isolation and performance degradation at higher frequencies. So MEMS switches with their excellent linearity, low power consumption, low insertion loss and high isolation offer a promising solution as switches to reconfigurable antennas. [1,2].

Here initially, a microstrip slotted patch antenna was designed and on and off switch states were simulated by the presence and absence of copper strips respectively. Then cantilever switches were fabricated and their mechanical and electrical behaviour were studied. We aim at integrating these switches with the antenna structure so as to enable frequency reconfigurability.

2. Antenna Design and Simulation.

Fig.1 shows the geometry of a microstrip patch antenna of thickness 0.035 mm printed on top of an FR4 substrate of thickness 1.6mm and relative permittivity 4.4 and a ground plane of thickness 0.035 mm.

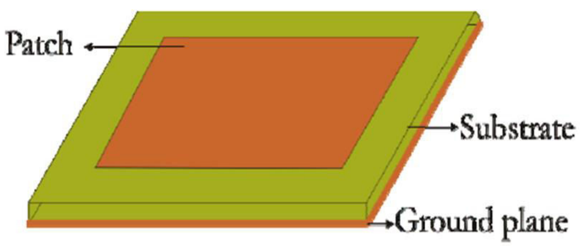

Fig. 1. Microstrip patch antenna

Fig.2a shows the cross sectional view of the proposed frequency reconfigurable antenna structure with notches at the centre of four patch edges and an A-slot through the patch.

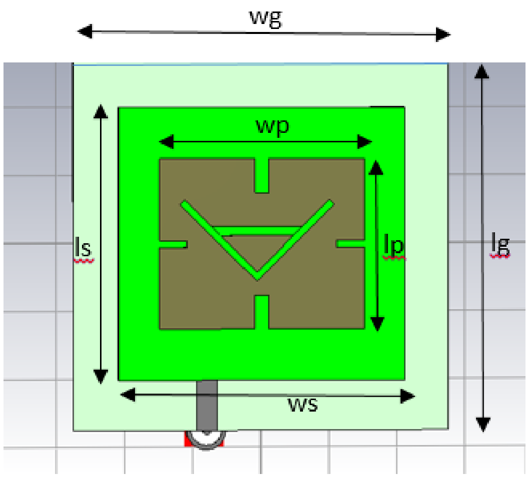

Fig. 2a. Frequency reconfigurable slotted patch antenna with switches in off state

Dimensions of proposed antenna are as follows: lg (length of ground plane) = wg (width of ground plane) = 55 mm, ws (upper substrate width)=42 mm, ls (upper substrate length) =40 mm, wp (patch width)=30 mm, lp (patch length)=25 mm, notch length= 5 mm, notch width=1 mm, A slot slant arms length=16 mm, A slot horizontal arm length= 13 mm, A slot width=1 mm.

In fig.2a, switches are in off state (absence of copper strips). Fig.2b shows the antenna with switches in on state (copper strips present). Location of copper strips represent the location of cantilever switches.

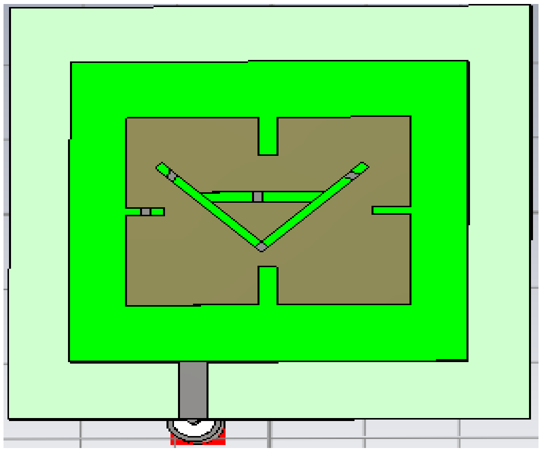

Fig.2b Slotted patch antenna with switches in on state.

Proximity coupled feeding technique has been used here. Two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. Advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth due to increase in the electrical thickness of microstrip patch antenna.

3. Simulation of cantilever switch using COMSOL and fabrication.

3.1 Cantilever simulation

Cantilever beam is a micro-electromechanical switch where one side is fixed and the other side is free to move. Fig. 3 shows a series cantilever switch simulated using COMSOL MultiPhysics with the following dimensions:

Beam length= 300 μm, width=20 μm, thickness= 200 nm and air gap=2 μm.

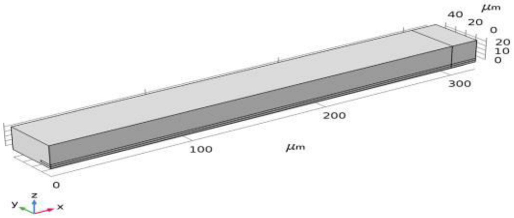

Fig. 3 Simulated cantilever beam

Initially, in the absence of any applied voltage, beam stays in upright position and there is no signal transfer across the beam. This is equivalent to off condition of the switch. When dc bias is applied between the beam and bottom electrode, after a certain threshold value called pull-in voltage, stress forces can no longer balance he electrostatic force and the beam falls to the bottom electrode.

3.2 Cantilever Fabrication

Fabrication of cantilever was done from NNFC, CENSE of IISc Bangalore which proceeded through various steps as follows:

a) Initially silicon wafer was cleaned in Piranha bath.
b) Thin sacrificial layer of SiO_2 was formed on silicon wafer by chemical vapour deposition.
c) Here cantilever beam material is Aluminium, so aluminium device layer was formed on top of SiO2 by low pressure chemical vapour deposition technique.
d) Cantilever patterns were prepared on mask which were transferred to positive photoresist layer coated on device layer by exposure to UV light in photolithography bay.
e) On immersing the samples in developer solution, exposed parts get dissolved and replica of mask cantilever pattern was formed on photoresist layer.
f) Anisotropic plasma etching was done for ions in plasma to etch away the exposed device layer so that cantilever pattern was formed on aluminium.
g) Photoresist layer was removed from sample surface by dipping in Piranha solution.
h) The buried SiO_2 was selectively etched away from exposed areas with Buffered Hydrofluoric acid at specified etch rates. Some portion of sacrificial layer remains under the beam as anchor, which prevents stiction or beam sticking to the substrate.
i) Samples were loaded into Critical Point Dryer in which liquid CO_2 was purged in. Once critical conditions were reached, cantilever beams were released with minimal stress.

Fig.5 shows the photolithography stage of cantilever fabrication and the final fabricated cantilever beam and anchor.

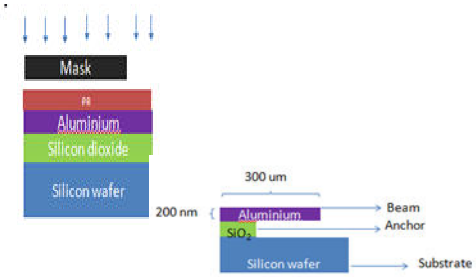

Fig.5 Photolithography and final cantilever structure

Samples were then taken to Laser Doppler Vibrometer which has probes for applying variable ac voltage across the beam and bottom electrode. Beam displacement was noted on applying ac voltage. Maximum displacement was observed for pull-in voltage=6 Volts.

3. Results and discussion

Cantilever beam simulation results in COMOL were analysed for observing beam displacement and pull-in voltage. Fig.4 shows the z displacement of beam as a function of position.

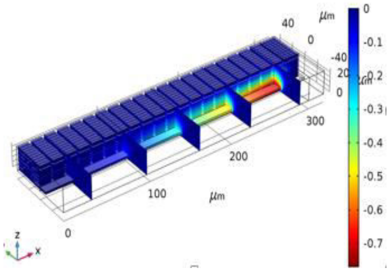

Fig.4 Beam displacement as a function of position.

Fig.5 shows the displacement of cantilever tip for various applied voltages. Pull in voltage was found to be 6.1 Volts from simulation at which significant beam displacement could be observed.

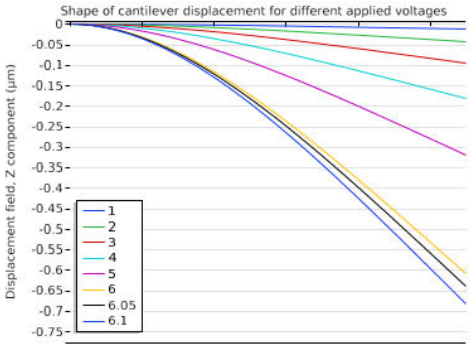

Fig.5 Cantilever tip displacement for various applied voltages.

Antenna simulation with the absence and presence of metal strips yielded the following results.

a) When switches were in off state, reflection coefficients or S11 were:

:-30.5 dB at 1.8 GHz (GSM frequency)
: -40.9 dB at 5.4 GHz (Wifi frequency) as shown in fig.6a).

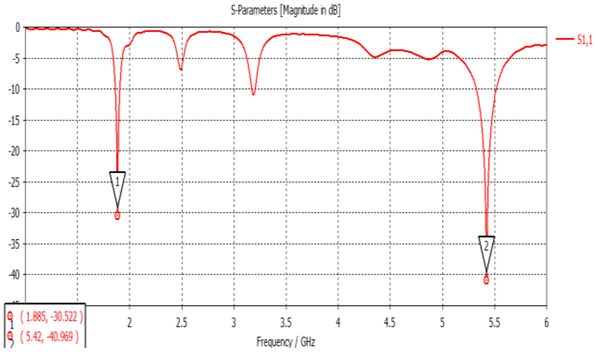

Fig.6a) Reflection coefficients for switches in off state.

a) When switches were in on state, reflection coefficients or S11 were:

S11:-12 dB at 2.4 GHz (Wifi frequency)
: -21 dB at 3.26 GHz (WiMaX frequency)
: -15.5 dB at 5.6 GHz (Wifi frequency) as shown in fig 6b).

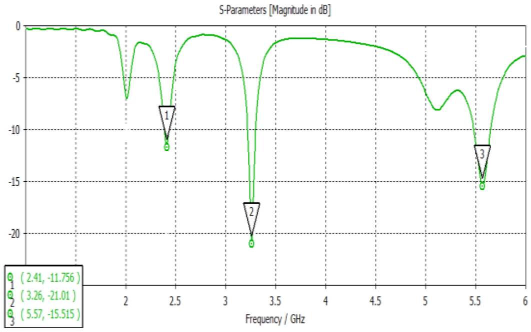

Fig.6b) Reflection coefficients for switches in on state.

So by changing states of cantilever switches to on and off, different frequencies for mobile applications like WiFi and WiMaX could be radiated from a single antenna structure. Also unidirectional radiation patterns could be obtained in both cases.

4. Conclusion

A frequency reconfigurable microstrip patch antenna structure was designed and simulated by electronic reconfiguration mechanism, whereby simulation of on and off switch conditions was done with the presence and absence of copper strips respectively. Cantilever MEMS switches are excellent candidates for RF switches[3,4] due to their linearity, low insertion loss and high isolation when compared to solid state switches like pin diodes and varactor diodes. Changing the states of switches made the antenna to resonate at various frequencies allocated for mobile applications. Cantilever switches were fabricated to study their electrical and mechanical behaviour. As future work, we aim at integrating the cantilever switches with the antenna structure and also to extend the work to higher frequencies.

References

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