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Simulation of Capacitive Shunt RF MEMS Switch for Low Actuation Voltage using Coventorware 2012.000

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Abstract: **The design of capacitive shunt RF MEMS switch for low actuation voltage is described. The switching element is a thin metallic membrane which has two states: up and down. A RF signal can be transmitted or blocked through these states. Electrostatic actuation mechanism is used to actuate the membrane by applying a voltage bias to actuation electrode. The actuation voltage is reduced by using meander structure and reducing the air gap between electrode and membrane. The optimized actuation voltage comes out to be 5.3 volts which is comparable to contemporary MOS switches. Major advantage over MOS switch is negligible power dissipation.**

Keywords: **RF MEMS switch; Actuation voltage; Anchors; Air gap.**

1. INTRODUCTION

As early as 1979, microelectromechanical switches have been used to switch low frequency electrical signals. Since then, switch designs have utilized cantilever, rotary and membrane topologies to achieve good performance at RF and microwave frequencies [7]. Radio frequency (RF) microelectromechanical systems (MEMS) switches have found applications in several communication systems. These applications require signal conditioning circuitry which is usually fabricated on low resistivity silicon using IC fabrication technique [8]. RF MEMS switches are low cost, high performance devices used for radio frequency switching now days because of their potential benefits over contemporary switching devices. Development in technology has made possible switching of high frequency signal through these devices. The moving metal contacts have low parasitics at microwave frequency hence become beneficial to achieve high on state capacitance [3]. RF MEMS switch has many advantages over FET switches like negligible power consumption, very high isolation, very low insertion loss etc. RF MEMS switches have a lot of advantages over their counter parts, however they have their own set of problems. The major shortcomings include the switching time, high actuation voltage and reliability.

2. SWITCH OPERATION

The switch is actuated using electrostatic actuation by applying a dc voltage bias on actuation electrode. This type of switch works opposite as compared to its counterparts. When no bias is applied to actuation electrode switch is in up state and transmission of RF signal takes place through the coplanar waveguide transmission line. On other hand when sufficient voltage bias called actuation voltage is applied to actuation electrode the membrane snaps down and switch is in down state then RF signal is capacitively shunted to the co-planar grounds through the metallic membrane and transmission is off, hence, it require zero or negligible power for operation. The two states of switch operation are as shown in the figures 1 and 2.

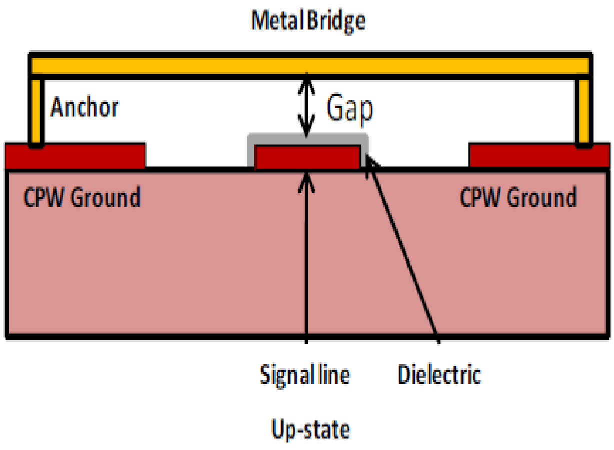

Figure 1. Up state of switch

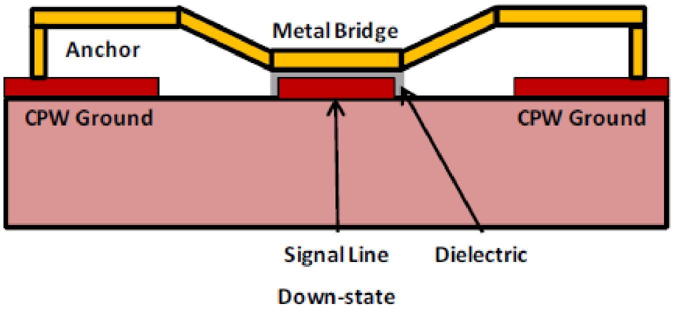

Figure 2. Down state of switch

The formula for calculating pull-in voltage (Vp) for device is as follows:

$$V_P = \sqrt{\frac{8K_Z g^3}{27\varepsilon_0 A}}$$

The actuation voltage depends upon spring constant (K) of membrane, air gap (g) between beam and pull-in electrode and actuation area (A) of switch [2]. In current case the actuation voltage is 5.3 volts and when this voltage is applied the membrane is pulled-in to touch the dielectric surface and RF signal get shunted to CPW grounds. Thus the transmission stops.

3. DEVICE DIMENSIONS

Various Dimensions of the device and its individual parts are described in the table 1. The air gap between dielectric layer and membrane plays an important role in determination of the actuation voltage. In this study the air gap is kept 0.2 µm.

Table 1. Device specifications

Parameter	Dimension
Beam Thickness	0.3µm
Beam Length	17µm
Beam Width	15µm
Air Gap	0.2µm
Electrode Thickness	0.3µm
Dielectric Thickness	0.15µm
Device Thickness	6.45µm
Device Length	32µm
Device Width	32µm

4. MATERIALS USED

Silicon is used as substrate for the device with a passivation layer of silicon nitride on it. Aluminium metal is used as material for the membrane and co-planar waveguide. Silicon nitride (Si_3N_4) is used as dielectric due to its high dielectric constant as compared to thermal oxide of silicon thus improving the capacitance ratio. Properties of these materials are quoted in table 2. A thin polyimide layer is used as sacrificial layer which is removed later on in order to achieve the desired air gap between dielectric layer and membrane.

Table 2. Material properties

Property	Al	Si_3N_4
Density (kg/µm^3)	2.3e-15	2.7e-15
TCE (1/K)	2.31e-5	1.6e-6
Electrical Cond. (pS/µm)	3.659e13	1.0e4
Thermal Cond. (pW/µmK)	2.37e+8	2.40e+7
Specific Heat (pJ/kgK)	8.98e+14	1.70e+14
Young's Modulus (MPa)	7.70e+4	2.22e+5
Poisson's Ratio	3.00e-1	2.70e-1

5. DESIGN

Initially a switch is designed with solid membrane and straight anchors with device dimensions described above. The actuation voltage comes out to be 11.2 volts which is higher as compared to MOS switches. The 3D model of initial design is as shown in figure 3.

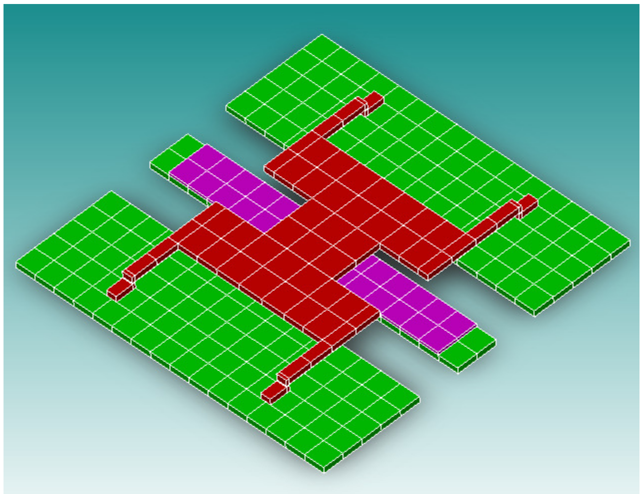

Figure 3. 3D model of initial design

To optimise this result the membrane structure is modified as porous structure while keeping all the dimensions similar to the initial design. The 3D model of modified design is as shown in figure 4.

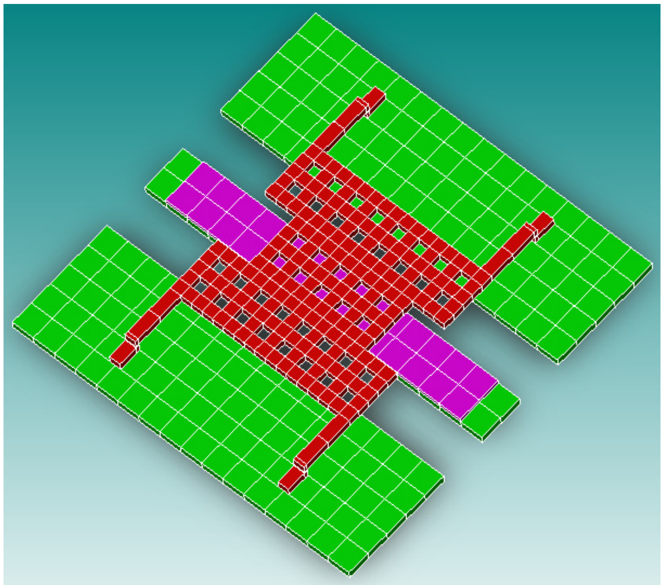

Figure 4. 3D model with straight anchors

Through above design the actuation voltage is reduced to 9.6 volts. This reduction is result of reduced mass and increased capacitance ratio. Since the air gap cannot be reduced to large extent as this will lead to stiction and charge injection problem thus to further optimize the actuation voltage anchors are modified and meander structure is used. The actuation voltage reduces to 5.3 volts which is comparable to MOS switches. The 3D model is as shown in figure 5.

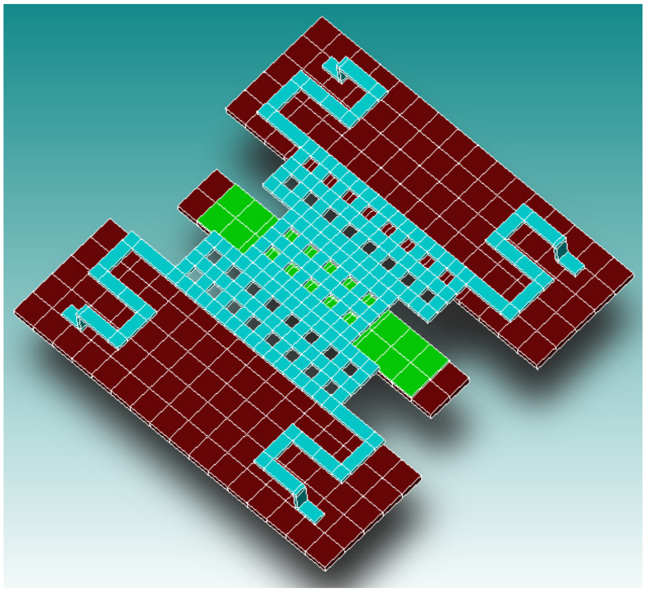

Figure 5. 3D model of optimized switch

6. SIMULATION RESULTS

Simulations are done using CoventorWare software. The difference between actuation voltages achieved with different designs is shown in table 3

Table 3. Actuation voltage

Design	Actuation Voltage
Solid membrane	11.2 V
Straight anchors	9.6 V
Meander anchors	5.3 V

The displacement versus voltage graphs for three designs are also plotted using visualizer tool of coventorware. These graphs are shown below:

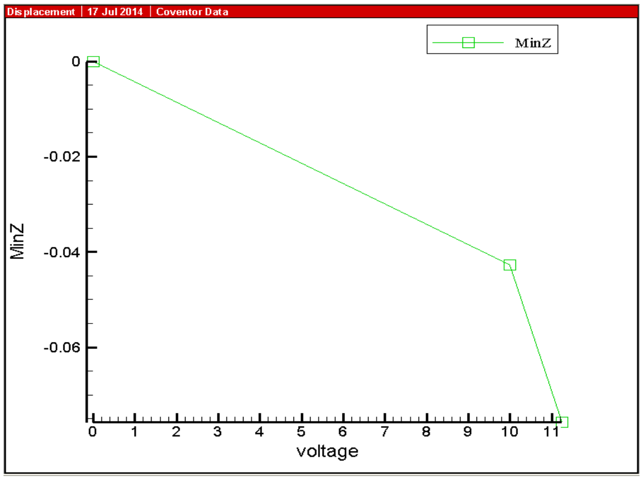

Figure 6. Displacement v/s V plot for solid membrane design

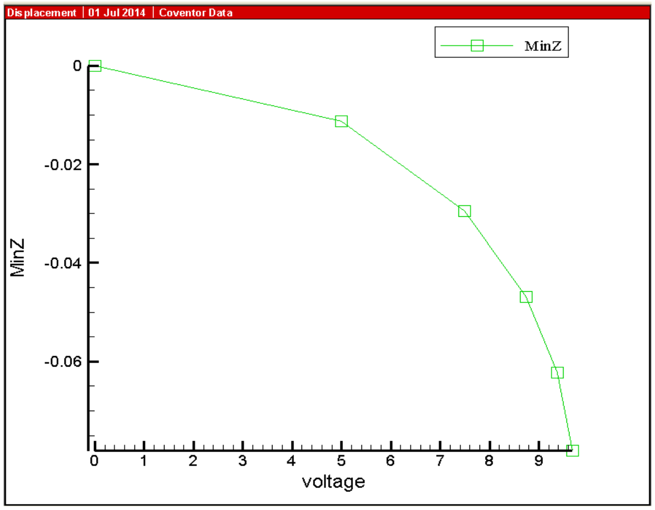

Figure 7. Displacement v/s V plot for straight anchor design

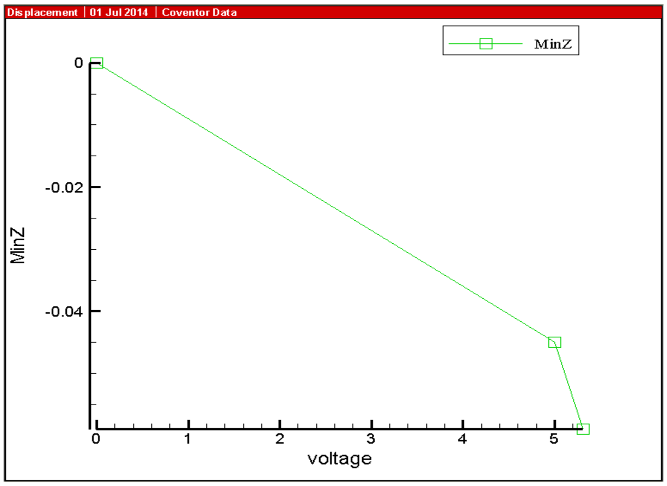

Figure 8. Displacement v/s V plot for meander anchor design

7. CONCLUSION

A low actuation voltage, low loss RF MEMS shunt capacitive switch has been designed suitable for X-band (8-12GHz) applications. Actuation voltage of 5.3V is achieved with an air gap of 0.2µm between CPW conductor and membrane. These characteristics make the switch a perfect choice to be used in applications such as radars, phase shifters, satellites etc.

8. ACKNOWLEDGEMENTS

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REFERENCES

[1] Z. Jamie Yao, Shea Chen, Susan Eshelman, David Denniston and Chuck Goldsmith,“Micromachined Low-Loss Microwave Switches”,IEEE Journal of Microelectromechanical System, Vol. 8, No. 2, June 1999.

[2] Gagandeep Heer, Vijay Kumar Anand, Dinesh Kumar and B.Prasad,“Design and Simulation of Capacitive RF MEMS Switches using Tuned Dual Beam”,Advance in Electronic and Electric Engineering. ISSN 2231-1297, Volume 3, Number 2 (2013), pp. 205-210.

[3] Maninder Kaur (2009),“Study of Capacitive Type RF MEMS Switches”,Ph.D Dissertation, Kurukshetra University, Kurukshetra.

[4] Jeremy B. Muldavin, Student Member, IEEE, and Gabriel M. Rebeiz, Fellow, IEEE,“High-Isolation CPW MEMS Shunt Switches - Part 1: Modeling”,IEEE Transactions on Microwave Theory and Techniques, Vol. 48, No. 6, June 2000.

[5] Chuck Goldsmith, Tsen-Hwang Lin, Bill Powers, Wen-Rong Wu, Bill Norvell,“Micromechanical Membrane Switches for Microwave Applications”,IEEE Microwave Theory Tech. Symp. Digest, May 1995.

[6] C. Goldsmith, J. Randall, S. Eshelman, T. H. Lin, D. Denniston, S, Chen, B. Norvell,“Characteristics of Micromachined Switches at Microwave Frequencies”, IEEE Microwave Theory Tech. Symp. Digest, 1996.

[7] B. Pillans, J. Kleber, C. Goldsmith, M. Eberly,“RF Power Handling of Capacitive RF MEMS Devices”,IEEE MTT-S 2002

[8] Sharma Jaibir, Krishanapura Nagendra and DasGupta Amitava, “Fabrication of low pull-in voltage RF MEMS switches on glass substrate in recessed CPW configuration for V-band application”, Journal of Micromechanics and Micro engineering, IOP Publishing Ltd 22, pp. 9-18 2012