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Design, Simulation of RF MEMS series switch upto S band

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***Abstract*— A broadside series switch of cantilever type has been designed and analysed in microstrip line using Electromagnetic simulation software and MATLAB. The switch is modelled using microstrip discontinuity and a MATLAB code was written for calculation of insertion loss and isolation. An insertion loss smaller than -0.18db, an isolation greater than 32dB and a return loss less than -30dB has been achieved upto 4 GHz. The electromechanical simulation has been done using coventor software and a pull down voltage of 28 V has been achieved. In this paper, efforts has been done in simulating various shapes of the cantilever using High frequency structure simulator (hfss) and coventorware software. A broadside series switch is in series with the power line and either closes or opens the line to turn it ON or OFF[1]. The ideal series switch results in an open circuit in the t – line when no bias is applied (up state position) and it results in a short circuit in the t – line when a bias voltage is applied (down state position). Ideal series switch have infinite isolation in the up – state position and have zero insertion loss in the down state position [2].The cantilever used in the RFMEMS switch is of silicon dioxide and the dimple below the cantilever is made up of gold which is used for making through contact between the input and output part of the transmission line. The bias lines made are of chrome. This type of switch can be used in communication in S band.**

***Index Terms*— Isolation, Insertion loss, Return loss, Pull down voltage, Switching Time.**

I. INTRODUCTION

RF MEMS switches are micromechanical switches that are designed to operate at RF-to-millimeter wave frequencies (0.1 to 100 GHz). MEMS switches are devices that use mechanical movement to achieve a short circuit or an open circuit in the RF transmission line. The various forces like electrostatic, magneto-static, piezoelectric, or thermal required for the mechanical movement of the switch. MEMS are formed by the integration of mechanical elements, sensors, actuators, analog and digital integrated circuits and power management components on a common substrate using integrated circuit process sequences. The MEMS switch has a lot of advantages as compared with the traditional switch (FET and PIN switch), such as low power consumption, low insertion loss at ‘close’ and high isolation at ‘open’, easy compatibility with the IC, and high reliability etc. These switches have important applications in system designs for both military and commercial telecommunications at microwave and millimeter wave frequencies. MEMS series switches are extensively used for 0.1 – 40 GHz applications. Series switches are more suited for lower frequencies.

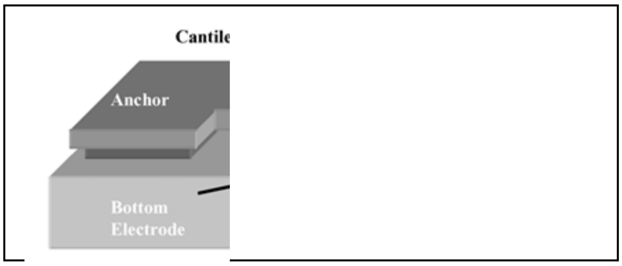

Fig1 : Layout of Broadside series switch

II. ELECTROMECHANICAL DESIGN OF THE SWITCH

The electromechanical parameter includes switching time, pull down voltage and the stability of the switch. The geometrical dimensions of the switch are given in table 1.

Table I

1	l (Beam length)	140µm
2	L(Anchor length)	125 µm
3	g (signal line gap)	90-130 µm
4	W (beam width)	g+10 µm
5	Actuation pad	12 µm away from the signal line

The spring constant due to a uniform force applied over the entire cantilever is given by the formula:

$$k = \frac{3Ew}{12}\left(\frac{t}{l}\right)^3 \quad (1)$$

Where E is the young modulus, w is the beam width and l is the beam length. It is seen that the cantilever spring constant is much smaller than a fixed-fixed beam with the same t/l ratio.

The pull down voltage is given by:

$$V_p = v\left(\frac{2g_0}{3}\right) = \sqrt{\frac{8kg_0^{\,3}}{27\varepsilon_0 wW}} \quad (2)$$

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III. ELECTROMECHANICAL SIMULATION

The electromechanical simulation done in coventor ware software shows that on varying the width of the cantilever there is no variation of pull down voltage. The width of the cantilever varied from 90um to 130um and pull down calculated is shown in table 2.

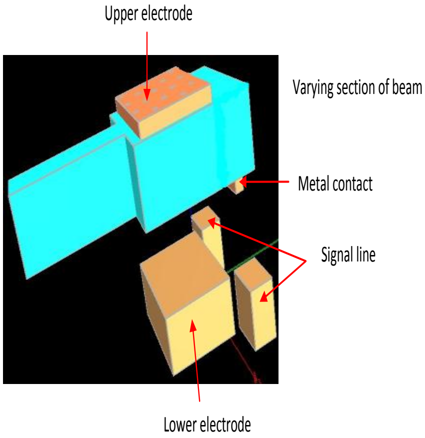

Fig 2 : 3D view during switch OFF state.

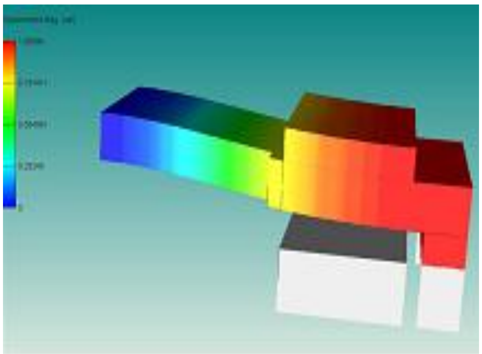

Fig 3 : 3D view during switch ON state.

Table II

Beam Width (g+10) µm	Pull down voltage (V)
90	~28
100	~28
120	~28
130	~28

IV. ELECTROMAGNETIC MODELLING OF THE SWITCH

The switch is made on a Silicon substrate using a suspended silicon dioxide microbeam as the cantilevered arm, a gold electrical contact, and electrostatic actuation as the switching mechanism. In the “ON” state, the insertion loss of switch is dominated by the resistive loss of the signal line which includes the resistance of the signal line and the contact resistance between the signal lines and the contact. The switch can be viewed as a discontinuity of microstrip corresponded to an equivalent circuit [3][4] , parallel with a metal cantilever. So the electrical performance of the switch can be modelled by the parallel connection of equivalent circuit of discontinuity microstrip gap with resistance of metal cantilever circuit. In the “OFF” state, the equivalent circuit, similar to the “ON” state, can be constructed by the parallel connection of discontinuity microstrip with the series of resistance of metal cantilever and two capacitor. The Zs is the characteristic impedance of the microstrip, Rcon is the contact resistance between the end of the cantilever and the microstrip for the “ON” state, Rmw is the microwave resistance of the metal cantilever, l is the length of the microstrip, and C1 is the capacitance between the end of the cantilever and the microstrip. In the equivalent circuit of discontinuous microstrip, the capacitance C2 arises from the coupling between the strip conductors constituting the gap, and the capacitance C3 is the result of the disorder in electric field distribution at the edge of the strip. The capacitance C1, gap capacitance C2 and capacitance C3 can be expressed as

$C1 = \varepsilon 0 WLlap / d$ (3)

$C2 = (2C0 – Ce) / 4$ (4)

$C3 = Ce /2$ (5)

where ε0 is the vacuum dielectric constant, W the width of microstrip, d the distance between the end of cantilever and microstrip, and Llap is the overlap length between the end of the cantilever and signal line. The calculations of Ce and C0 are given in Appendix A[5][6][7]. The microwave resistance Rmw of the metal on the end of the cantilever can be expressed as $Rmw = \rho L / (2b)\delta s$ (6) where ρ is the resistivity of the metal, δs is the skin depth, L and b are the metal length and width, respectively. Based on the equivalent circuit, the scattering parameters matrix S of the switch can be obtained [5][6].Therefore insertion loss in “ON” state can be expressed as :$IL = - 20 \log|S21|$. (7) and isolation in “OFF” state can be expressed as :$IS = - 20 \log|S21|$.

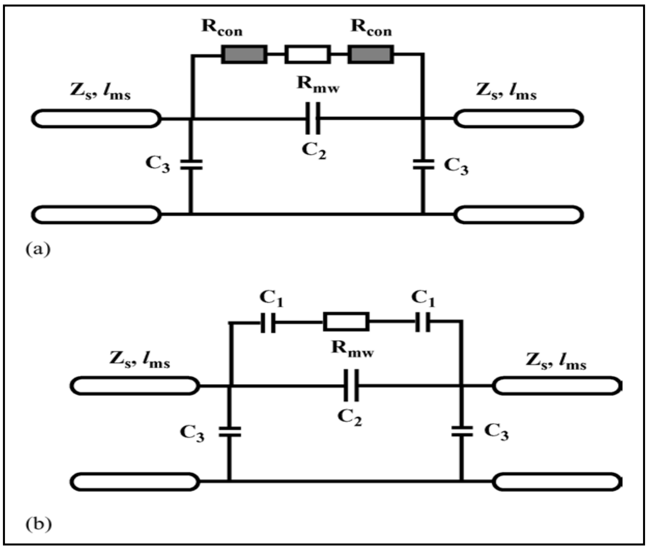

Fig 4. The equivalent of series cantilever switches in ON state (a) and in OFF state (b)

Electomagnetic Simulation: The electromagnetic simulation has been done using high frequency simulation software (hfss).The layout of the RF MEMS switch is shown in fig 5 .

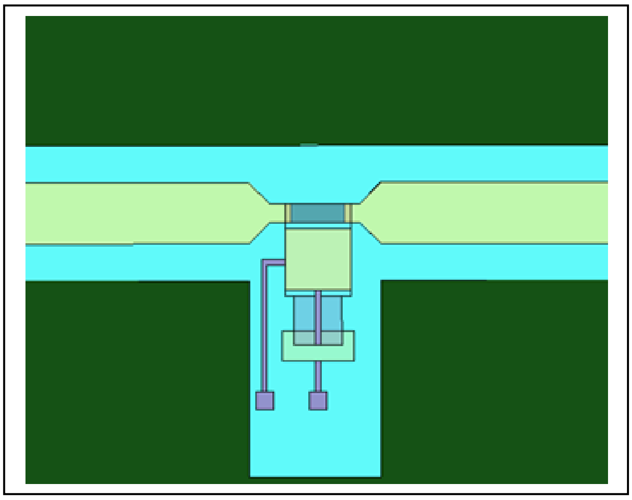

Fig 5 : layout of the RF MEMS Switch

The table 3.0 shows the comparison of insertion loss and isolation has been obtained from matlab and hfss simulation. The structure was simulated from 1Ghz to 4 GHz. An isolation of -30.6 db was found at 4Ghz from hfss and -31.5 dB was obtained by modeling the structure using MATLAB. The insertion loss and isolation upto 4 Ghz has been tabulated in table III .

Table III.

f (GHz)	Isolation loss(dB) MATLAB	Isolation loss(dB) hfss	Insertion loss(dB) MATLAB	Insertion loss(dB) Hfss
1	-37	-42.5	-0.045	-0.001
2	-34.25	-36.5	-0.9	-0.015
3	-32.5	-33.5	-0.13	-0.019
4	-31.5	-30.6	-0.18	-0.02

The isolation in table 3.0 shows that as the frequency increases the isolation decreases. This is so because of the coupling of the field lines from from the input signal line to the one end of the dimple and through the other end of the dimple to the output part of signal line in OFF state. The insertion loss is better at lower frequency as compared to the higher frequency because of the increase in loss at higher frequencies.

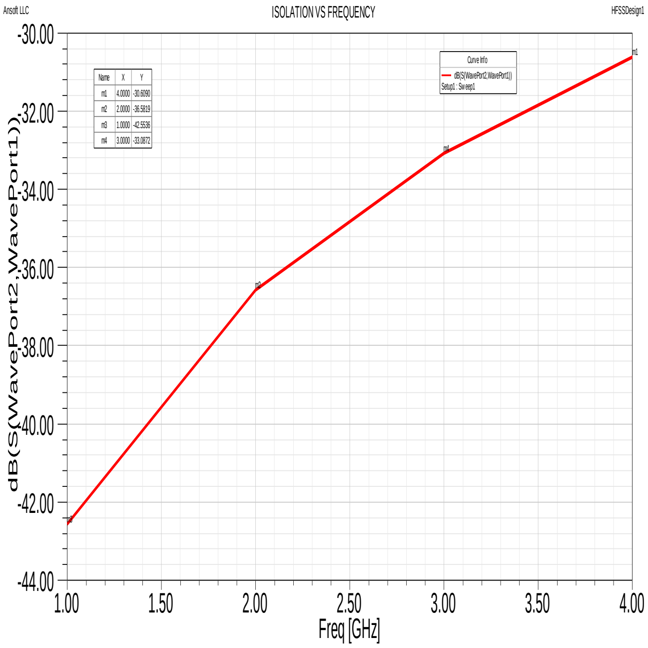

Fig 6 : Isolation vs frequency by HFSS

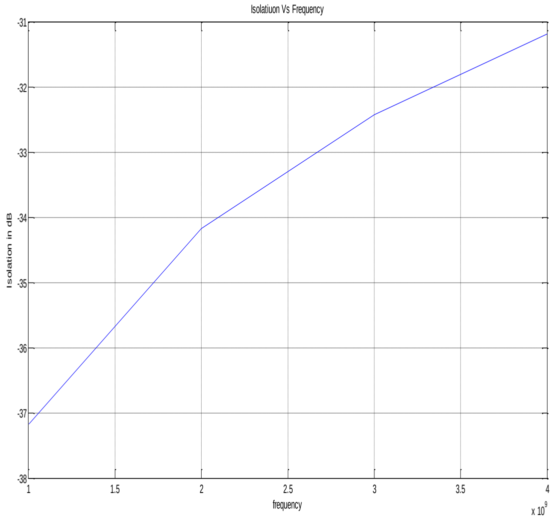

Fig 7: Isolation vs frequency by MATLAB

V. CONCLUSION

An effort has been made for modeling the cantilever [8] based structure using Matlab code and the results has been compared with the results obtained by electromagnetic software hfss.The switch is modelled using microstrip discontinuity[9][10][11] and a Matlab code has been written for calculating insertion loss and isolation. An insertion loss smaller than -0.18db , isolation of 32 dB and a return loss better than -30dB has been achieved upto 4 Ghz. The electromechanical simulation [12] has been done and a pull down voltage of 28 V has been achieved.

Appendix ‘A’

$$C_0 = W\left(\frac{g}{W}\right)^{m_0} \exp(k_0)$$

$$C_0 = W\left(\frac{g}{W}\right)^{m_e} \exp(k_0)$$

$$\mathrm{m}_0 = \left(\frac{W}{h}\right)\left(0.619\log\left(\frac{W}{h}\right) - 0.3853\right), \quad for\, 0.1 < ({}^{g}\!/\!{}_{W}) < 1$$

$$k_0 = 4.26 - 1.453\left(\frac{W}{h}\right), \quad for\, 0.1 < ({}^{g}\!/\!{}_{W}) < 1$$

$$m_e = \frac{1.565}{\left(\frac{W}{h}\right)^{0.16}} - 1, \quad for\; 0.1 < ({}^{g}\!/\!{}_{W}) < 1$$

$$k_e = 1.97 - \frac{0.03}{\frac{W}{h}}, \quad for\; 0.1 < ({}^{g}\!/\!{}_{W}) < 1$$

REFERENCES

[1] Design, simulation of a novel rf mems switch, updesh sharma, manoj kumar, k k jain,solid state physics laboratory, lucknow road, delhi, india

[2] RF mems theory design and technology,Reibez

[3] Modeling microwave behaviors of series cantilever MEMS switch, B. Peng , W.L. Zhang, G.H. Chen, W.X. Zhang, H.C. Jiang

[4] School of Microelectronics and Solid-State Electronics, University of Electronic Science and Technology of China,No. 4, Section 2, North Jianshe Road, Chengdu 610054, PR China

[5] Modeling and Design aspects of the MEMS switch, S. Simion, Military Technical Academy

[6] Foundation for Microstrip Circuit Design, T. C. Edwards.

[7] Handbook of Microwave Integrated Circuits, Reinmut K. Hoffmann.

[8] Novel Beam Design for Compact RF MEMS Series Switches, King Yuk (Eric) Chan'2, Mojgan Daneshmand2, Raafat R. Mansour2, Rodica Ramer'.

[9] Design and Simulation of Simple and Varying Section Cantilever and Fixed-Fixed End Types MEMS Switches, Saeid Afrang Electrical Engineering Department,Urmia University,Urmia, Iran;Ghader Rezazadeh Mechanical Engineering Department Khoy Azad University,Khoy, Iran

[10] Microstrip antenna design handbook,Ramesh Garg

[11] Design and analysis of series and shunt mems switches,Muldavin.

[12] Topical review rf mems from a device perspective, J Jason Yao, J. Micromech. Microeng.10 (2000) R9–R38. Printed in the UK.