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Performance Study of RF MEMS Ohmic Series Switch

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Abstract: Most of the MEMS switch designer uses different software tools such as COMSOL, ANSYS, COVENTORWARE etc. for electromechanical modeling of these switches. The various results for RF MEMS resistive series switches using software tools Coventorware is presented in this paper. RF MEMS series resistive switches are used extensively in the frequency range of DC-40 GHz. These switches exhibit low insertion loss and better isolation at sufficiently high frequencies. The switch is optimized by considering different trade-offs between these parameters.

Keywords: RF MEMS series resistive switch, cantilever beam, Insertion loss, Isolation, geometrical parameters.

I. INTRODUCTION

MICRO-ELECTRO-MECHANICAL switches for RF and microwave applications have been the subject of extensive research in recent years. Depending on the design, RF-MEMS switches can operate at frequencies from 0.1 GHz up to 40 GHz. MEMS stands for Micro-Electro-Mechanical Systems where Micro is for small size micro-fabricated structures [1] , Electro defines electrical signal/control, Mechanical define mechanical functionality and Systems stands for structure or devices. MEMS are very small devices or groups of devices that can integrate both mechanical and electrical components MEMS switches combining the advantageous properties of both mechanical and semiconductor switches. MEMS can be constructed on one chip enabling the batch fabrication.

The micro-fabrication of MEMS devices is based on two major micro-machining techniques-bulk micromachining and surface micromachining. In bulk micromachining, the mechanical parts are formed onto the substrate whereas in surface micromachining several layers i.e. structural and sacrificial layers are formed and the mechanical parts are formed by etching of the layers. RF MEMS Switches are the miniaturized device which is used to make or break a contact. MEMS switches can be designed using different configurations based on actuation mechanism, contact type, movement and circuit configuraion [2] .

II. RF MEMS SERIES RESISTIVE SWITCH

Ohmic switch is based on metal-to-metal contacts. A series switch is in series with the power line and either closes or opens the line to turn it ON or OFF. A series switch is open when the MEMS is “OFF” (rest position or when no bias voltage is applied or in the up-state position) and is closed when the MEMS is “ON” (actuated position or when a bias voltage is applied or in the down-state position). In series contact switch the contact surface is usually at the end of a singly supported cantilever beam [3] with a control electrode under the beam. By applying a voltage to the control electrode the beam can be pulled down to complete the connection between two conductors.

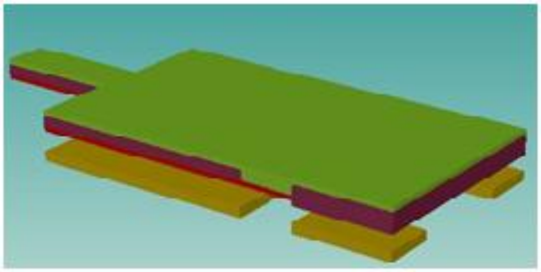

Fig 1: Ohmic contact series switch

In Fig. 1, a MEMS-series switch is shown with its one end fixed, and the other end is covered with a metal-layer to open/connect the microwave signal line. In addition there is a metal-layer in the middle of cantilever beam to make it the top pole of the capacitor. When a control voltage is applied between the top pole and the bottom pole, electrostatic force will make cantilever beam to distort. When the control voltage is bigger than the threshold voltage, the metals layer connects the signal line. When a broadside MEMS-series [4] switch closes, the signal crosses the part of the switch only, not the whole cantilever beam. The series switch is designed using 400 µm thick silicon substrate having a relative dielectric constant of 11.6.The silicon is then coated with 1 µm thick gold layer to form the actuation pads. The switch is designed on the transmission line using gold having width of 25 µm and length of 45 µm and thickness of 1 µm. The anchor with 2 µm height, 55 µm length and 22 µm width is connected to ground plane and the cantilever beam is connected to this anchor at one end.

III. SIMULATION RESULTS

A. Electromechanical Analysis of RF MEMS Switch

The electromechanical behavior of the switch is examined by examining pull-in, contact force, mechanical resonant frequencies, switching times, and other transient effects. We can vary the length of beam connected to the substrate anchor to compute the electromechanical behavior. In this section, we have used" Sweeping the Voltage by Running a DC Transfer" method to sweep the actuation voltage to close the switch and observe the contact force of the closed contacts .

1) Pull in voltage: In DC transfer sweep method, to determine the contact voltage, a DC transfer analysis on the voltage source connected to the actuation pad is done from 0 to 20 volts in steps of 0.1.

In Fig 2, the Z node displacement represents the contact voltage of RF switch which is 13.6 V. The tip of the switch pulling down between 13.6 and 13.8 volts. The total displacement towards negative z direction is 1.5106 µm.

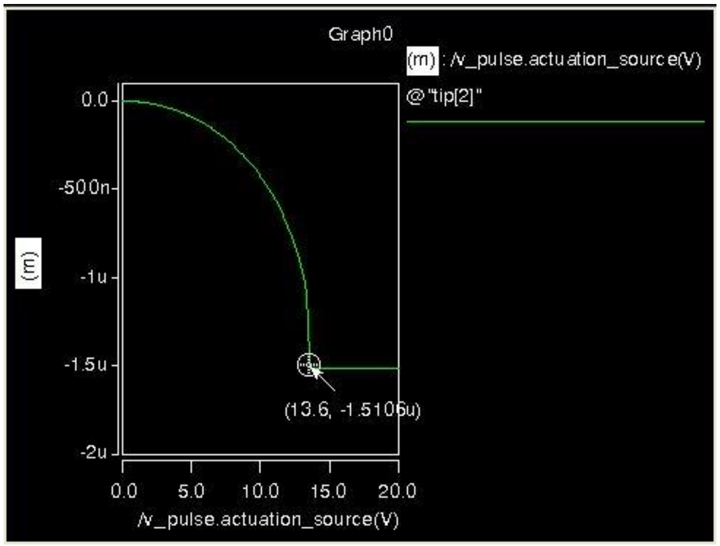

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Fig 2: Plot showing contact voltage of RF MEMS.

DC transfer simulations run quickly into convergence issues at the moment of pull-in and pull-out. There are two different techniques available that both provide similar performance: running a slow transient simulation and using the arc length continuation voltage source. Transient simulations provide a robust alternative to DC transfer simulation if convergence in a DC transfer simulation is hard or even impossible to achieve.

2) Frequency Response: AC analysis was performed by varying all small signal sources from starting frequency of 1 KHz to end frequency 40 KHz. Fig 3 shows the resonance frequency plot (both magnitude as well phase) that do not have a sharp peak because the frequency magnitude response is softened by the damping value defined with modal damping parameter.

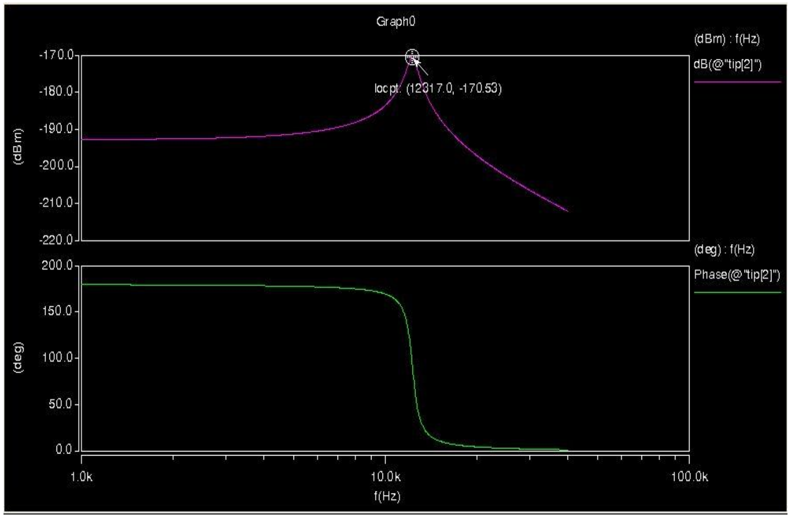

Fig 3: Resonant Frequency and phase plot by using small signal AC response.

3) Switching Time of Switch

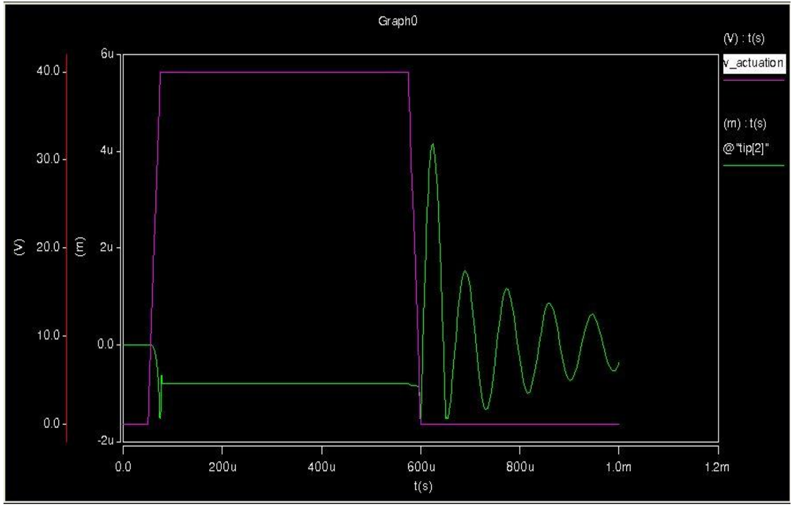

Fig 4: Switching response

B. Effect of Anchor Length on S-Parameters

Fig 5 shows the effect of varying the anchor length on both the parameters; insertion loss and isolation. The results from the open switch show S_{11} near 1, and S_{12} near 0 shows good isolation as expected. That is, most of the energy is reflected and very little is transmitted. As the frequency rises, slightly more energy does pass through as the result of the capacitive coupling between Upper X Line and Lower X Line in the discontinuity model, as well as from the coupling to the common cantilever above. There is no variation with anchor length because the geometry at the tip does not change with anchor length.

The results from the closed switch show S_{11} near 0 and S_{12} near 1 because now most of the energy is transmitted. We also see that S_{12} as a measure of insertion loss shows improvement with increasing anchor length. This makes sense because a longer anchor means that for a given voltage, there is less restoring force pulling the beam back up. Thus the contact force is greater, leading to a smaller resistance and thus less insertion loss**.**

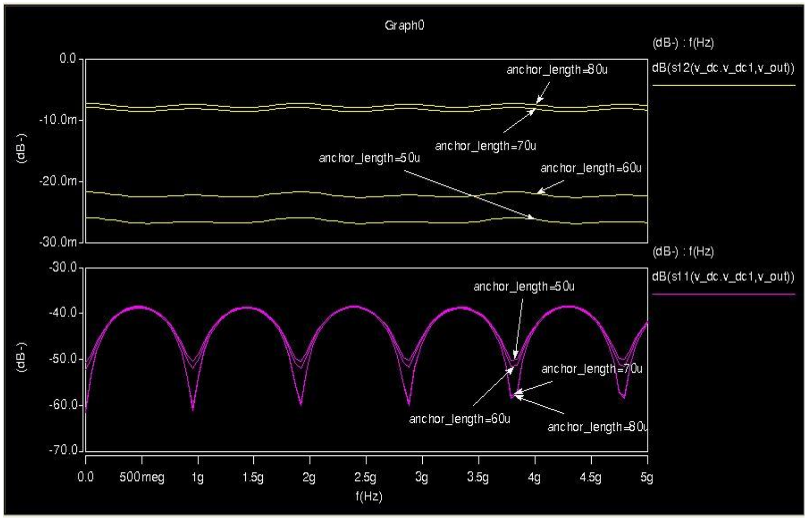

Fig 5: Effect of varying the Anchor Length on S-Parameters.

IV. CONCLUSION

The performance of RF MEMS ohmic series switch in the frequency range of 1 - 40 KHz has been studied. The switch cantilever beam is connected to anchor at only one end. The effect of different geometrical parameters is studied and simulated using Coventorware. This paper shows that varying anchors length improves the contact force thereby reducing the insertion loss. So we can say that there is trade-off between the parameters and switch performance can be enhanced by maintaining these parameters.

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