Movable Parallel Plate RF MEMS Switch with Wide Frequency Response

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Abstract—**A novel RF MEMS switch with two parallel suspending bridges is designed for wide frequency range. This paper reports, how change in the area of capacitive actuators can be used to achieve wider bandwidth. Change in parallel plate width from 50 µm to 150 µm, up state switch yields an insertion loss lower than 0.5 dB and return loss down to 25 dB in the range of 15-47.5 GHz. Down state switch yields return loss lower than 0.5 dB and isolation down to 25 dB at the same frequency range.**

I. Introduction

RF Micro-Electro Mechanical Systems (MEMS) Switch with a shunt capacitive switch is increasingly used in different applications including, automatic test equipment, advance telecommunication system, aerospace and satellite communication [1]. RF MEMS switch is used as antenna filter, phase shifter, oscillator and multiplexer [2]. The major advantages of RF MEMS switch are low loss, higher tuning range with higher operating frequency and very compact. However, high activation voltage, low switching speed and weak mechanical strength, etc. are the challenges, which are still to be improved [2-3].

II. Device Design and Analysis

Fig. 1 shows the shunt type RF MEMS switch. It consists of two parallel cantilever beams, suspended above coplanar waveguide (CPW) line with G/S/G (Ground /Signal /Ground) of 100/60/100 µm and characteristic impedance of 50 Ω. It has been built on high resistive silicon substrate with 500 µm thickness. Also, the silicon substrate and the switch are separated by a thin layer of silicon dioxide with 0.1µm thickness. Fig. 1 shows the flexible electrodes of two bridges with fixed flexure suspension. These flexure suspensions are connected to both the ground lines. Bridge is made up of gold with 570 GPa Young Modulus and thickness of 1 µm. It is suspended above G/S/G (Ground /Signal / Ground) electrode with 3.5 µm initial air gap height. The lower electrodes are also made up of gold material. A silicon nitrite layer of 0.2 µm thick with relative permittivity 7.6 covers the lower electrodes to avoid the direct electric contact between metal bridge and the signal line. For a capacitive shunt switch, this dielectric layer is extended to cover the signal line in high capacitance mode (OFF state). In lower capacitance mode (ON state) air gap is higher than the dielectric layer, provides good metal to metal contact.

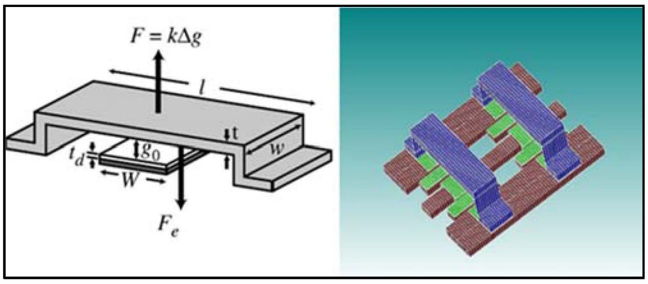


Fig.1 Propose RF MEMS Switch

In the proposed shunt switch, the bias voltage is not applied between signal (centre) conductor and ground conductor, which is a usual practice. In this case DC bias applied across bridge and extra node added between signal line and ground line shown in Fig. 1. This mechanism enables separation of RF and DC signals. This separation of RF and DC signals provides more flexible circuits for practical modeling and analysis.

A parallel plate capacitance (C) is given by (1), where g_0 is beam height above the electrode. The generated electric force (F) given by (2). Here, the electric force is directly related to the electric potential (V) and the capacitance between bridge and the signal line. Under the applied electric field, the cantilever beam moves towards the signal line. In addition to this, spring constant must be associated with the distance moved under the amount of applied force. Beam movement is balanced by the mechanical restoring force due to the stiffness of the beam. Beam becomes unstable when beam height becomes 2/3 of the zero potential beam height (g_o) [3]. So, maximum pull down electric force (Activation Voltage) can be given up to displacement of $(2/3)g_o$ as shown in (3). Activation voltage depends on spring constant (k), beam height (g_0) and width of signal line (W) shown in (3) [3].

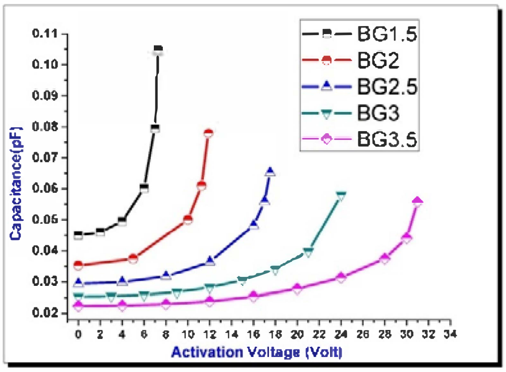
$$C = \frac{\varepsilon_0 A}{g_0} = \frac{\varepsilon_0 Ww}{g_0} \tag{1}$$

$$F_e = \frac{1}{2}V^2\frac{dC(g_0)}{dg_0} = -\frac{1}{2}\frac{\varepsilon_0 wWV^2}{{g_0}^2} \tag{2}$$

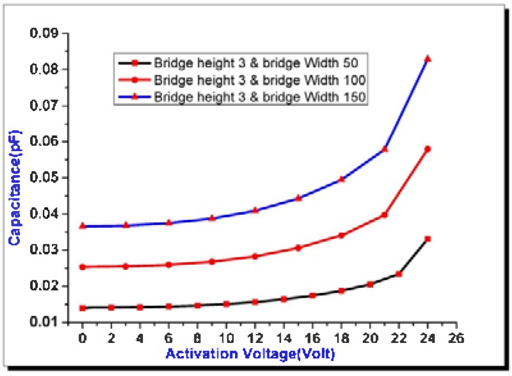
$$V_p = V\frac{2g_0}{3} = \sqrt{\frac{8k}{27\varepsilon_0 Ww}{g_0}^3} \tag{3}$$

III. Results and Discussion

Fig. 2 shows how capacitance varies with the different bridge heights. Range of capacitance is from 0.05 to 0.15 pF by changing bridge height from 3.5 to 1.5 µm. This variation of capacitance is used for different required operation of frequency of the RF MEMS switch.



(a)



(b)

Fig. 2 Effect of activation voltage on capacitance with changing of bridge height and bridge width

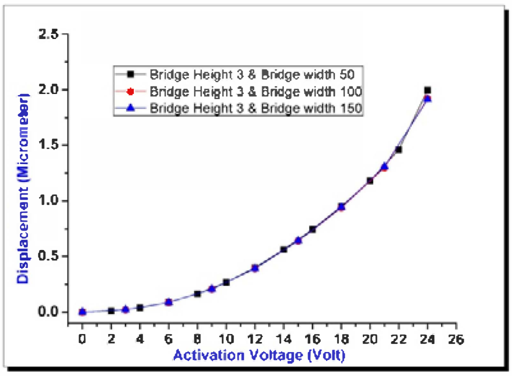


Fig. 3 Effect of activation voltage on displacement with different bridge width

Fig. 3 shows that bridge width changes from 50 µm to 150 um with constant bridge height 3 µm. The activation voltages are constant but the shunt plate area changes the capacitance as shown in Fig. 2(b). Different capacitances give variation in the frequency response. The simulated results shows in Table I that, variation in bridge widths can result into different frequency response. The bridge width of 50 µm gives better response in the frequency range of 40-47.5 GHz. Similarly, for different bridge width the change in frequency responses are summarized in Table I.

Bridge width (µm)	UP State		DOWN State		Actual Operation range of the Switch (GHZ)
	Frequency range over which Return Loss is better than25dB (GHz)	Frequency range over which Insertion Loss is less than 0.5 dB (GHz)	Frequency range over which Return Loss is less than 0.5 dB (GHz)	Frequency range over which Isolation is above 25dB (GHz)	
50	40-47.5	3-59.5	16-92.5	26-67	40-47.5
75	32.5-41	2.5-53.5	15-92.5	20-73	32.5-41
100	22.5-35	2-48	12.5-94.5	15.5-82	22.5-35
125	2.5-27.5	2-42	12.5-94.5	14.5-85.5	22.5-35
150	2-21	3-37.5	11-94	14-89.5	14-21

TABLE I: Frequency Response in UP/DOWN State for Different BridgeWidth (Bridge height 3µm)

IV. Conclusion

In the proposed paper, design of a Movable Parallel Plate RF MEMS Switch is discussed. The switch parameters are optimized to obtain the maximum wide frequency response. The switch can be used for many practical applications in the microwave domain.

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