International Journal of Engineering Trends and Technology- Volume4Issue2- 2013

A Review Paper on RF MEMS Switch for Wireless Communication

Gajanan D. Patil[#1], N. R. Kolhare[*2]
[#]Dept. of Electronics and Tele-Communication, Government College of Engineering, Aurangabad (M.S.), India
[*]Dept. of Electronics and Tele-Communication, Government College of Engineering, Aurangabad (M.S.), India

Abstract- **This paper deals with the RF (Radio Frequency)-MEMS (Micro-Electro-Mechanical-System) switch importance in the wireless communication system. Also explains the dominance of RF-Switch over existing devices like PIN Diodes and Field-Effect-Transistors with size, power, isolation, insertion loss, and graphically how Pull-in voltage affects on the tip deflection of the switch.**

Keywords- **RF-MEMS, RF Switch, PIN Diodes, Pull-in voltage, isolation, insertion loss.**

I. INTRODUCTION

Now a day's RF (Radio frequency) MEMS (Micro-electro-mechanical-system) Switches are most important because of their Performance and various researches has been done on this. MEMS switches are dominating over existing semiconductor devices such as PIN Diodes, Field-effect-transistors because of their small size, less power consumption, low insertion loss and high OFF-state isolation. One more advantage of RF MEMS switch is fabrication process is compatible with CMOS technology so these switches can easily interfaced with rest of the circuitry.

Because of electromechanical isolation, RF circuit doesn't leak or couple significantly to the actuation circuit. And electromechanical coupling is done through electro statically through air less power required because power consumes only when actuation occurs. Based on MEMS actuation, MEMS switches can be classified by following three characteristics;

i. RF circuit configuration;
ii. Mechanical structure;
iii. Form of contact.

A. *RF MEMS Switches*

For wireless communication Radio frequency (RF) signals are used, the range of RF signals is huge that is from 9 KHz to 300 MHz, As RF signals exhibits electromagnetic field for this purpose micromachined devices such as filters, oscillators and switches required. For wireless communication applications RF switches are designed at high frequency (1MHz to 60 GHz).RF MEMS circuits leaves huge impact on communication applications such as handset (mobile phones) because of their small in size, low power consumption, less insertion loss and high isolation. With this there are some disadvantages of MEMS switches such as low switching time and high actuation voltage. Commonly series or parallel connected circuit configurations are used. The most used RF MEMS mechanical structures are the cantilever beam and the air bridge structures.

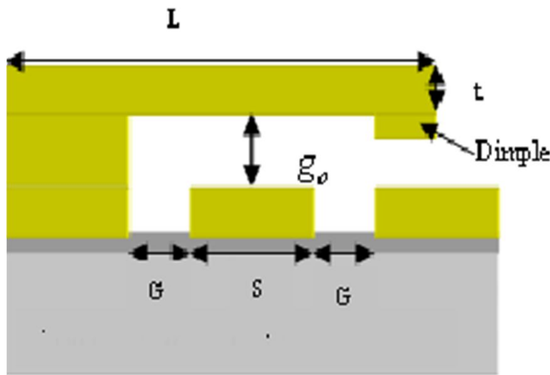
1) Cantilever Type MEMS Switch; In this one end of the beam is fixed and other is free. The voltage is applied at the free end. Working principle is, when voltage is applied across the electrode, the charge developed on the beam causes the electrostatic force on the beam which pulls down. Results the stress in the beam as gap goes on decreases the stress increases. When this applied voltage is removed the equal and opposite force called restoring force develops, helpful to bring the beam to its original position. The Cantilever type switch is as in Fig.1 (a).

The Cantilever type switch is again of two types;

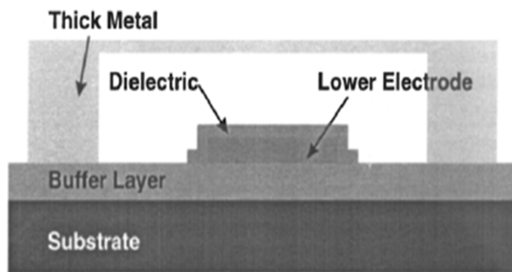
a) Capacitive contact switches; These switches use metal-insulator-metal type contact. Capacitive switches are fabricated by using surface micromaching process. Because of its ease of design and fabrication process these switches are used in reconfigurable bandstop filter development [1]. The figure of merit (FOM) of RF MEMS capacitive switch is calculated as in eq. (1)

$$FOM = \frac{Down\ State\ Capacitance\ (C_d)}{Up\ State\ Capacitance\ (C_u)} \qquad (1)$$

Figure of merit is also depends on the Q factor of the design switch. Performance of the switch is directly proportional to Q factor value that is if Q factor is greater, performance of switch is good and if Q factor value is small then the performance of the switch is poor.



(a)



(b)

Fig. 1 The functional diagram of (a) Cantilever MEMS switch and (b) Air bridge MEMS switch.

The insertion loss of the capacitive switch is lower than 1.2 dB up to 40 GHz, the extracted up-state capacitance is 30 PF and isolation is 1.3dB, 26dB, and 27dB at 1GHz, 20GHz, and 40GHz respectively. As one end is free it requires lower actuation voltage compared to Air Bridge MEMS switch [2]. The capacitive MEMS switch is as shown in Fig.2.

b) Resistive contact switches; These switches use metal to metal contact for ohmic contact between signal line and contact beam. Fabrication process used for such switches is either bulk micromaching or surface micromaching process. The dc bias is applied between ground and the cantilever beam, electrostatic force pushes the cantilever beam to move laterally and contact the signal line. Such type of switch used for an X-band reconfigurable impedance tuner development [3]. The Resistive MEMS switch is as in Fig.3.

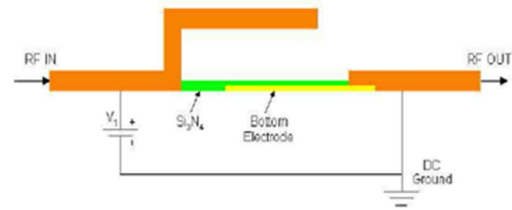


Fig. 2 The cross section of cantilever beam capacitive MEMS switch

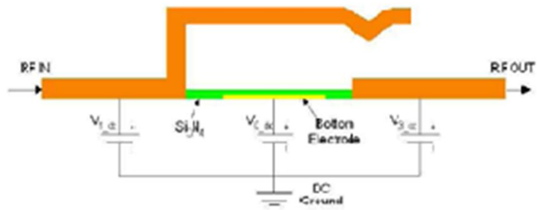


Fig. 3 The cross section of the resistive MEMS switch

Depending on where and how MEMS actuation is carried out in RF circuit, MEMS switches are classified in following three classes; a) RF extrinsic: MEMS structure is located outside the circuit but controls other devices in the circuit, b) RF intrinsic: MEMS structure is located inside the circuit and perform dual role in the circuit but decoupled with actuation and c) RF reactive: MEMS structure is located inside the circuit and coupled to the actuation function.

2) Air Bridge Type MEMS Switch; In this beam is fixed at both the ends and voltage or pressure is applied in the middle of the beam and note down the displacement of the beam towards substrate. The displacement is maximum in the middle region when we go on increase the applied voltage. The Air bridge MEMS switch is as shown in Fig.1 (b)

II. RF PERFORMANCE

For designing cantilever beam as an actuator we should know the pull-in voltage, hold down voltage, spring constant for cantilever and the resonant frequency for cantilever. Also switching lifetime and switching time need to consider.

A. *Actuation Voltage*

The actuation voltage or applied voltage or pull in voltage is the maximum voltage at which the electrostatic force becomes superior over mechanical restoring force, causes MEMS device pull down towards the ground plane. For cantilever type or resistive type switch pull in voltage is calculated as,

$$V_s \cong \sqrt{\frac{8K_{eff}g^3}{27\epsilon_0 A}} \quad (2)$$

Where, K_{eff} is the effective spring constant, g is the distance between the membrane and the bottom electrode switch is in off state, and A is the area of the pull down electrode. At equilibrium as the applied voltage increases the plate moves lower and the gap decreases corresponds to increases the electric field, causes increase in the electrostatic force which pushes plate further lower. At certain value that is pull-in voltage the plate or actuator beam suddenly collapses and allows signal to pass [6].

The electrostatic and release forces are

$$F_e \propto \frac{A.V_s^2}{g^2}, \quad F_r \propto K_{eff}.\Delta x \quad (3)$$

Where, x is the displaced contact-point distance upon actuation. Due to the small actuation area and low spring constant MEMS switches have low contact and release forces [5]. As the applied voltage to the RF MEMS switch is varies the respective displacement of membrane changes for different dimensions of switch [4], is shown in Fig.4.

Initially as the applied voltage goes on increases the gap between the beam and ground electrode gradually reduces, after the gap becomes 1/3 of original gap cause the beam suddenly pull downs, is shown in Fig. 5.

B. Switching Times

Using 4-point resistance measurement and the laser vibrometer the electrical resistance and mechanical displacement of the switch is measured as a function of time. The closing time depends on the actuation voltage and the opening time depends on the mechanical properties of the switch. By scaling the MEMS devices the switching time is also scale downs, as

$$t_s \approx 3.67\frac{V_p}{V_s\omega_0}, \quad f_0 = \sqrt{\frac{K}{m}} \quad (4)$$

Where (ω_0, f_0) is resonant frequency, V_p is pull-in voltage and V_s is applied voltage.

The Deflection of the beam ΔZ is,

$$\Delta Z = \frac{4Fl^3}{Ebt^3} \quad (5)$$

Where l, t is beam length, thickness and E is young's modulus.

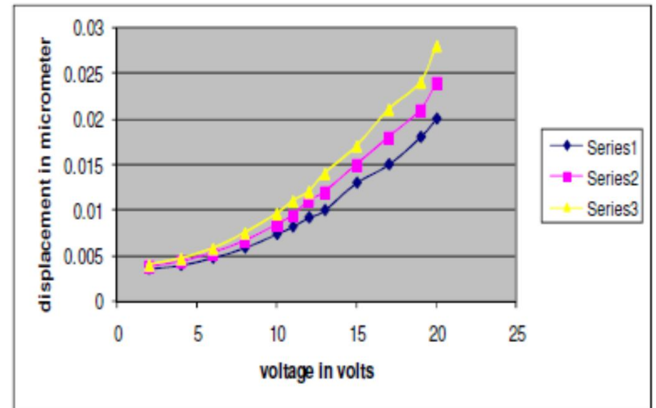


Fig. 4 Graph of displacement verses voltage.

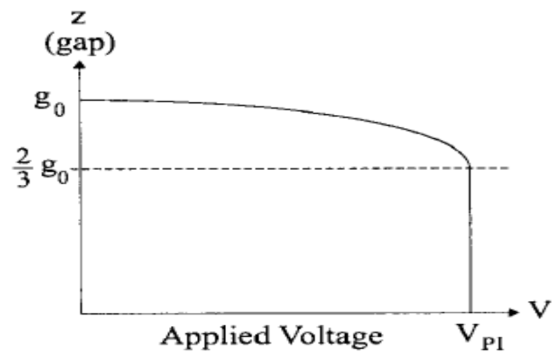


Fig.5 Graph between actuator deflection and applied voltage.

III. CONCLUSION

In this paper we have seen the different types of RF MEMS switches with its structure. Further how the RF MEMS switch is superior to other existing devices In comparison with Size, required power, Isolation and insertion loss. Also seen how applied voltage effects the actuator deflection with different sizes of cantilever beam.

ACKNOWLEDGMENT

Thanks to my Departmental staff for their assistance and I would like to thanks to all my friends and especially to my parents for encouraging me for this work whenever needs.

REFERENCES

[1] G.Zheng, J. Papapolymerou, *“Monolithic reconfigurable bandstop filter using rf mems switches”*,In J RF Microvave CAE, no. 14, pp. 373-382, Jan-2004.
[2] E. R. Brown, *“RF MEMS Switches for Reconfigurable Integrated Circuits”*, IEEE Transactions on Microwave Theory and Techniques, Vol. 46, no.11, November-1998.
[3] G. Zheng, P. Kirby, S.Pajic, A.Pothier, P.Blondy, J.Papapolymerou, Z.Popovic, *“A Monolithic reconfigurable tuner with ohmic contact mems switches for efficiency optimization of x-band power amplifiers”*, in silicon monolithic integrated circuits in RF systems, Atlanta, GA, pp. 159-162, sept-2004.
[4] S. N. Naduvinamani, B. G. Sheeparamatti, S. V. Kalalbandi, *“Simulation of Cantilever Based RF-MEMS Switch Using Coventerware”*, World Journal of Science and Technology 2011, 1(8): 149-153.
[5] R. Stefanini, M. Chatras, P. Blondy, Member, IEEE and G. M. Rebeiz, Fellow, *“Miniature MEMS Switches for RF Application”*, Journal of Microelectromechanical Systems, Vol.20, No.6, December 2011.
[6] E. S. Hung, S. D. Senturia, Fellow, *“Extending the Travel Range of Analog-Tuned Electrostatic Actuators”* Journal of Microelectromechanical Systems, Vol.8, No.4, December 1999.
[7] C. H. Ko, C. I. Lee, T. C. Huang,*”RF Characteristics of Dual-Actuation CMOS-MEMS RF Switches”*, Electronics Components And Technology Conference, 2009.
[8] G. M. Rebeiz, *”RF MEMS Theory, Design and Technology”*.