Analysis high frequency of RF MEMS switches with electrostatic actuation

Gholamhosein Moloudian*1, Asghar Ebrahimi 2, Nemat allah Monsef 3, Arman Aghajeri4

1,3 . Sama technical and vocational training collage,Islamic Azad University, kazeroun branch, kazeroun, Iran
2. Malek Ashtar University Of Technology
4. Department of electronic, Bushehr Branch, Islamic Azad University, Bushehr, Iran

*Corresponding Author email: gholamhosein_molvudian@yahoo.com

ABSTRACT: High frequency switches wildly have applied in defense aerospace and wireless communication, radar systems application. For the purpose at a suitable RF switch for any kind of application at first should be consider required function features such as band width excited voltage and switching velocity. In this paper, we design and simulate RF MEMS switch in suspension bridge mode. We chose the transmission line of type CPW. First, by using TX LINE2003 software, we have designed and calculated the dimensions of transmission line for having characteristic impedance 50Ω. We have chosen the substrate made of silicon, conductor of transmission line of made of cooper, dielectric layer made of SiO2, and upper electrode (bridge) made of aluminum. We simulate the switch, in Hfss software and calculate the scatter parameters. High frequency analysis shows that the designed switch has low transmission loss and return loss, which endorses the switch performance.

Key words: Electrostatic, Substrate, Switch, Waveguide, High frequency

INTRODUCTION

RF microelectromechanical systems (MEMS) switches have demonstrated outstanding RF performance with very low insertion loss, high isolation, excellent linearity, and very low power consumption, which make them very attractive for modern radar and telecommunication applications (Ming-jeer lee et al. 2010). Fixed–fixed beams and cantilevers are the most popular switch structures (G. M. rebiz et al. 2001). RF MEMS is the application of micro electromechanical systems in radio frequency circuits. The utilization of RF MEMS helps fulfill the increasing demand for more flexible and functional, lightweight, and low-power-consumption wireless systems. RF MEMS switches are one of the applications of RF MEMS (Y. mafinejad et al. 2009).

Radio frequency micro-electro-mechanical systems (RF MEMS) are a technology that offers low insertion loss, high isolation, and low power consumption with improved functionality. Micromachined beam structures are the basic building-block of many RF MEMS devices and components like switch, phase shifter, varactor etc. (Bao 2005; Nathason et al. 1967; Peroulis et al. 2003; Rahman et al.2009; De Los Santos 2004). In past, a large number of papers had been published on the development of RFMEMS switches based on the principle of electrostatic actuation. However, these switches operated at higher voltage than their conventional counterparts (Bao 2005; Nathason et al. 1967; De Los Santos 2004)

RF MEMS Switches

MEMS Switches may be categorized in two categories, as the manufacturing combination point of view, which are: switch with anchor beam or Cantilever, and switch with constant-constant beam or suspension bridge. Both of these groups may be divided into serial and parallel categories, in terms of method of placement across the transmission line. For excitation of mechanical part of RF MEMS Switches, four mechanisms may be used: electro-static, thermal, magnetic and piezoelectric (Haslina Jaafar et al., 2011). One of the Special Applications of RF MEMS Switches is in military and defense industries. MEMS Switches have components with high power handling, but are advantageous in RF and lower frequencies and have low switching speed. A new technology which has advantages of both solid state switch and electromechanical switch, is the MEMS technology(Hyman D.et al ,1999). Parallel RF MEMS Switches on same page waveguide (cpw) are the most applicable type of micro-
electromechanical switches. The schematic of this type of switch is shown in Fig. (1) which is composed of a very thin metal layer which is placed suspended on the central conductor (Katehi, L. P. B et al., 2002).

Without applying excitation voltage, the layer has a greater distance with central conductor and the signal is transmitted by the line. By applying excitation voltage on two lower and upper electrodes, an electrostatic force is created between the electrodes which cause the upper electrode (bridge) to be drawn downwards and be absorbed by the lower electrode which causes short circuit. In terms of connection type, switches are divided as metal-metal connection and metal-insulator-metal (capacitive). Since we use capacitive switch in this paper, thus we must place a dielectric layer of SiO$_2$ or Si$_3$N$_4$ on the lower electrode to create a capacity when the switch is on. The loss in parallel switches is due to impedance mismatch which may be minimized by accurate calculations.

**Electrostatic excitation**

The basis of this excitation is that by applying the voltage between panels and creating opposite charges in both panels, based on the gravity available between panels of an electric field and finally, an electrostatic force is created which causes the panels to be absorbed by each other. By applying the voltage between two panels, we create an electric force which causes the moving panel to be drawn downward and causes short circuit in the transmission path. The voltage in which, the distance between two panels is equal to 0.66 of total distance, is called pull-down voltage or $V_S$. This voltage is one of the most important parameters in switch parameters.

$$V_S = \left\{ \begin{array}{ll} \frac{8kh_{up}^2}{27\varepsilon_0 A} & \text{for suspension Bridge} \\ \frac{128Et^2h_{up}^2}{27\varepsilon_0 L^3} & \text{for Cantilever} \end{array} \right. \tag{1}$$

In which $K$ is the effective spring constant, $h_{up}$ is the initial height of beam when the switch is off, $\varepsilon_0$ is the Permeability of vacuum, $E$ is the Young's modulus, $A$ is the area of two electrodes which are placed in front of each other, $W$ is the width of electrode, $L$ is the length of the electrode and $t$ is the thickness of the electrodes.

**CPW transmission line**

Same page waveguide is a one-way transmission line with 3 conductors. Same page waveguide includes two earth conductor and one central conductor. The schematic this type of transmission line is shown in Figure 2. This Figure has been designed in 3Dbuilder environment of Intellisuite software.
One of the most important characteristics of transmission line is characteristic impedance. In this paper, our purpose is to design switch dimensions in order to have characteristic impedance of 50 Ohms. For this purpose, by using TX-Line 2003 software, the switch dimensions are measured.

As it may be observed with input dimensions, the characteristic impedance of cpw transmission line is 52 Ohms. We simulate switch, with Hfss software and calculate scatter parameters in two modes of On and Off. Designed switch schematic in Hfss Software is shown in Figure 4.
One important parameter in designing RF MEMS switches, is characteristic impedance of transmission line. Characteristic impedance of transmission line must be a standard impedance. In this paper, we designed and calculated cpw transmission line for having characteristic impedance of 50 Ohms. We calculate switch characteristic impedance in Hfss software. Figure 5 shows this case.

**S parameters**

One of the most important parameters in high frequency analysis is S parameter. For 2-port systems, these parameters are calculated as follows.
a1 is radiation wave to port 1, b1 is return wave to port 1, a2 is radiation wave to port 2 and b2 is the transmitted wave to port 2. S parameters are defined as bellow.

\[
\begin{align*}
S_{11} &= b_1 / a_1 & S_{12} &= b_1 / a_2 \\
S_{21} &= b_2 / a_1 & S_{22} &= b_2 / a_2
\end{align*}
\]

Results of high frequency analysis of cpw transmission line in Hfss software is shown in below Figure. When the switch is in off mode, applied signal to port 1 is conducted to port 2 by central conductor. If switch is designed correctly, it must transmit all the wave applied to port 1 to port 2 and the amount of return wave to port 2 must be minimum.

![Figure 7. S parameters when switch is Off](image)

According to fig.7, it is observed that when switch is off, it has very little ohm loss, about 0 db and return loss is -18 db for frequency 200GHz. Very little transition loss means that signal applied to port 1 is transited completely to port 2 and it has how return loss. So the switch in Off mode, shows a very proper performance, when the proper excitation is applied to the switch, switch is put in the On mode, and makes short circuit in the transition line, and prevents signal transition from port 1 to port 2. S parameters of this case are shown in Figure 8.

![Figure 8. S parameters when switch is On](image)
According to Figure 8, it is observed that when switch is on, no signal is transited from port 1 to port 2. Switch shows a very suitable performance in On mode. Thus, we could design a switch which shows proper performance in terms of theoretical manufacturing, mechanical analysis and high frequency analysis.

**CONCLUSION**

In this paper, first we designed and calculated dimensions of same page waveguide for having characteristic impedance of 50 ohms in Tx-Line software. Then, we simulated the switch in Intellisuite software and performed thermo-electromechanical analysis. Finally, we simulated the switch with Hfss software and obtained its scatter parameters. High frequency analysis shows that the designed switch shows proper performance in terms of transition loss and return loss.

**REFERENCES**


