Design of MEMS Switch for RF Applications

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Abstract

Components like passive electronically scanned (sub) arrays, T/R modules, reconfigurable antennas etc., in RF applications are in need of MEMS switches for its re-configurability and polarization. This paper presents the analysis, design and simulation of a MEMS switch. The switch proposed in this paper is intended to work in the frequency range of 4–8 GHz. The proposed switch fulfils the switching characteristics concerning the five requirements loss, linearity, high switching speed, small size/ power consumption, low pull down voltage following a relatively simple design, which ensures reliability, robustness and high fabrication yield. The switch implemented in this paper is based on the integration mode of operation and widely used in RF applications.

1. Introduction

Technological advances in radio-frequency (RF) front-ends made all the things to work under RF applications. Great effort is made in developing high frequency–low scale designs to follow the trends of the market for smaller, technologically more advanced applications. In the frequency range between 4 and 8 GHz in which we intend to work at, there are three kinds of switches that can be used for multiple element reconfigurable micro strip antenna implementations (Cetiner et al. 2004). They are pin diodes, GaAs FETs and RF MEMS.

Comparing the performance in terms of isolation, insertion loss, linearity and switching speed, RF MEMS excels in all these categories. The electrostatic RF MEMS switches are divided in two main categories, capacitive and Ohmic (also referred to as direct or resistive contact, respectively). Capacitive RF MEMS switches operate on frequencies beyond 4 GHz due to the low dielectric constants of the insulating layers which are available today. This makes them inappropriate for the frequency range we intend to work. The design of RF MEMS switches could be implemented either based on the hybrid mode or integration mode. In general, the cost of a single RF MEMS switch is very low and thanks to the similar to VLSI design and batch processing methodology and tools. In addition to that, there are real estate problems due to the relatively great size of the packaging and the large number of the switches which have to be used for the complete antenna configuration (Pringle et al. 2004). Using the integrated mode we eliminate problems regarding cost, since the fabrication process needs only one packaging procedure for the whole application, real estate problems, due to the small size of the RF MEMS switches without the packaging cells and matching as the switches are parts of the micro strip antenna structure (McKillop et al. 2006).

2. Structure Design

The presented MEMS switch is intended to be used to control a microstrip antenna array built on PCB (Chang et al. 2005). The advantage of these types of antennas is the ability to beam forming according to the requirements of any application. The following considerations are to taken into account while designing the structure:

1. Very low insertion loss in the “ON” condition;
2. Very high isolation in the “OFF” condition;
3. Good linearity over a wide frequency range.

In addition, the structure of the switch should be as simple as possible, to reduce the possibility of failure during the manufacturing process, maintaining high yield.

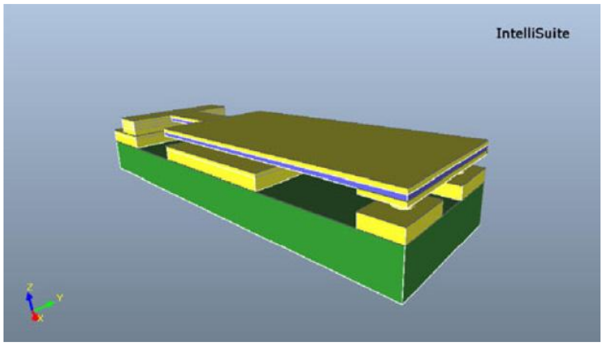

Fig. 1 RF MEMS switch.

3. The MEMS Switch

The MEMS switch is shown in Fig. 1. The design is using two different materials, i.e., gold for the actuator and the conducting regions and silicon nitrate for the insulator.

The actuator designed here reduces the design complexity. Examining the trade-offs of each one of them, it has been decided that Gold was the most appropriate material for the following reasons:

1. The conductivity of Gold (Au) is better than Aluminium (Al) and better conductivity implies less skin depth, which is an important parameter for the lossless RF signal transmission via the cantilever. (0.452.106/ cm for Au, 0.377.106/cm for Al and 0.596.106/cm for Cu).
2. The Young's modulus of Au is similar to that of Al and much smaller than that of Cu. Consequently, the stiffness of the cantilever made by Au will be lower fulfilling the requirement for lower pull down voltages of the cantilever (Scardelletti et al. 2008). The pull down voltage of the switch must be as low as possible and it depends on the dimensions of the cantilever (length and height), the distance from the electrode and the stiffness of the gold. The stiffness in turn mainly depends on the shape of the cantilever and the existence of perforation. The contact area of the switch had to be kept relatively small to maintain high isolation during the OFF state, in the highest operating frequency (Spasos et al. 2009). Simultaneously, it should be large enough to provide good conductance in the ON state. In addition contact pads are provided at the contact position to improve the operation of the RF MEMS switch which is shown in the Fig. 2. This contact pads improves the contact efficiency and reduces distortions produced during the switching operations (Zhang et al. 2006).

The Actuator which is present above the silicon substrate also helps in reducing the pull down voltage which is applied to the cantilever beam.

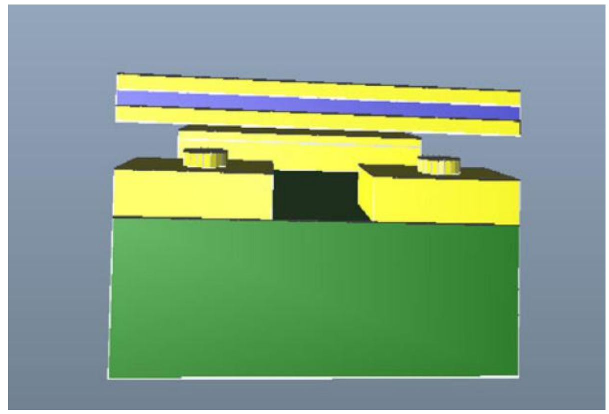

Fig. 2 Contact pads

4. Simulation Results

The design and evaluation of the proposed RFMEMS switch has been carried out using the Intellisuite Software package. A 3D view of the new design, produced in the 3D Builder, with the switch in deformed shape is shown in the Fig. 3.

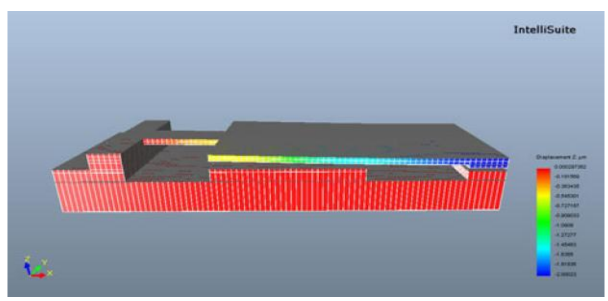

Fig. 3 Deformed shape of RF Switch.

5. Conclusions

The RF MEMS Switch is designed and analyzed using various modules in Intellisuite 8.5. The displacement result shows that RF MEMS Switch enjoys various features like low pull down voltage and high switching speed. This shows that the designed switch can be used for many RF Applications like passive electronically scanned (sub) arrays, T/R modules, reconfigurable antennas, GPS etc.

6. References

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