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Good Performance RF-MEMS SP2T Switches in CPW Configuration for Space Applications

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Abstract: Coplanar (CPW) waveguide based on cantilever or clamped-clamped switches have been developed for use in space applications. All the devices are manufactured on high-resistive silicon using surface micro-machining technology. The SP2T switches provide very good performance in terms of insertion and return loss and isolation over a wide frequency band. These switches are intended to be used as building blocks for large order switching matrices for satellite applications. Full wave simulations and measured RF performances are shown to be in very good agreement, showing high performance for all SPST typologies. Depending on the specific design, insertion loss -20dB, return loss between -5dB and -15dB and isolation between -20dB and -23dB has been obtained in the 0-40 GHz frequency band. In this paper implementation of HFSS (High Frequency Structure Simulator) is done to take desired results.

Keywords: RF MEMS Switch, CPW, insertion loss, Return loss and isolation.

1. INTRODUCTION

For telecommunication systems in space very large order switching matrices are needed, where a great number of inputs is connected with the corresponding outputs. Requirements for such a switching matrix are low insertion loss, high isolation with low coupling between the various transmission channels, low power consumption and a symmetrical transmission behavior. RF-MEMS represent an attractive technology for satellite applications thanks to their low insertion loss in the transmission path, low power consumption, compact size and weight and high integrability [1][3-6]. In the design of large order switching matrices a modular approach using basic switching circuits as building blocks is favorable since it implies the optimization of few components and easily allows to extend the order of the matrix. Different network topologies can be adopted, such as the Clos 3D network, the Planar Benes Network or the 3D Clos/Benes network. In particular, the Clos 3D configuration [2] realizes an N-order switching matrix as a combination of single pole N throw switches. This paper presents the design and realization of Single Pole Double Throw (SP2T) switches in HFSS (High Frequency Structure Simulator). The performance of the different devices will be evaluated in order to identify the configuration which shows the best RF and mechanical performance The external layout of the devices, i.e. size (1126μm x 2010μ), RF and DC pad position, is identical. The technical requirements for the SP2T switches developed in this work are summarized in Table 1.

Table 1

Parameter	*SP2T Switching Unit Requirements*
Frequency band	0-40GHz
CPW	S/W/S(75/90/75)
Series ohmic contact	50Ω
Software implemented	L-Edit, HFSS

2. SP2T DESIGN BASED ON SERIES OHMIC CONTACTS

Figure 2 shows schematic views of the RF MEMS series ohmic contact switch. The series ohmic contact MEMS switch has a CPW line of 75/90/75μm (= S/W/S, 50Ω). The isolation characteristic generally depends on two off-state parameters (C_g and C_c). C_g refers to the off-state signal-line coupling capacitance that is due to the gap between each broken signal line; C_c refers only to the off-state contact capacitance. C_c depends solely on the distance of the overlapping part between the front end of the signal line and the contact metal of the switching part in the membrane. If is an arbitrary value, the isolation feature can be improved by decreasing, which is inversely proportional to the RF open signal line gap. The goal of this design is to enhance the isolation characteristic such that, at the same time, the release process does not affect the RF performance.

The easiest way to realize a SP2T switch is to cascade two SPST switches. This modular approach has the advantage of requiring the optimized design of only a single SPST switch. The main drawback is that it inherently tends to be more space consuming and have high loss. On the other hand a single stage solution can lead to higher RF couplings due to the proximity of the RF paths and it is not always possible. In the following paragraphs configuration of SP2T in coplanar waveguide are presented along with full-wave simulated results.

In the presented circuit, the input signal from port 1 is driven to one out of the 2 output ports, which is selected by activating the series witches of the considered input-output path via the control signals provided by the bias network.

2.1. Design of SPST and SPDT RF MEMS Switches

Switching is the most fundamental function in electronics and plays a vital role in every system. Analog and digital bus switches are used in many industrial instruments and consumer devices to implement test interfaces, multiple peripheral and host selection functions, power and clock management, sample and hold circuits, test and debug interfaces, etc. Single Pole Single Throw (SPST), Single Pole Double Throw (SPDT), and Double Pole Double Throw (DPDT) are some of the switch configurations widely used in the industry today.

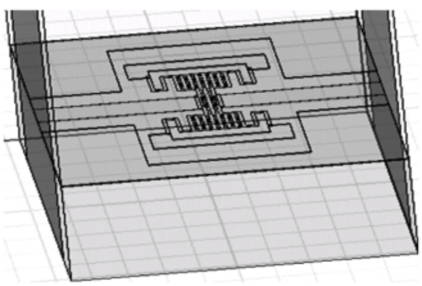

Figure 1: Design of the SPST Switch (HFSS)

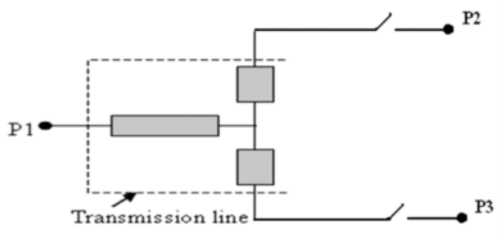

Figure 2: Schematic for the SP2T MEMS Switch Based on Metal–contact RF MEMS Switch

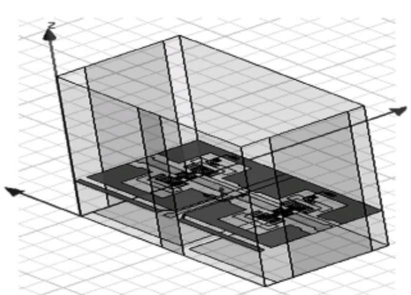

Figure 3: 3D View of SP2T Switch (HFSS)

3. RESULTS AND DISCUSSIONS

In this paper we discuss the simulations results and performance of SP2T RF MEMS Switch using CPW with configuration of S/W/S (75/90/75) and also the performance of the CPW itself. We have analyzed the performance under two scenarios:

- One scenario is when the switch is in ON state (Return Loss, Insertion Loss).
- 2nd scenario is when the switch is in OFF state (Isolation Loss).

The comparisons are done on the basis of various performance S-Parameters (dB) that is, frequency GHz. The evaluation is done by means of simulations using HFSS (High Frequency Structure Simulator). We take RF frequency range in between 40-50GHz. The CPW lines are designed for a nominal characteristic impedance of 50Ω with a signal track width W = 90μm and a line spacing S =75μm. The Silicon substrate of e_r = 11.9 was chosen, and CPW center conductor width w =90 μm and ground spacing s = 75 μm, nearly thickness is 5 μm Microwave parameters that should be optimized for any RF switch are the insertion loss, isolation, and switching frequency and return loss. As shown in Figure 4, RF response of CPW using rectangular ports (a) return loss (b) insertion loss. The return loss and insertion loss is minimum in case of rectangular ports as comparison to coaxial ports. The insertion loss is due to mismatch the characteristic impedance of the line and switch. The contact resistance and beam metallization loss will also contribute to the insertion loss [7-8].

3.1. Simulations for CPW

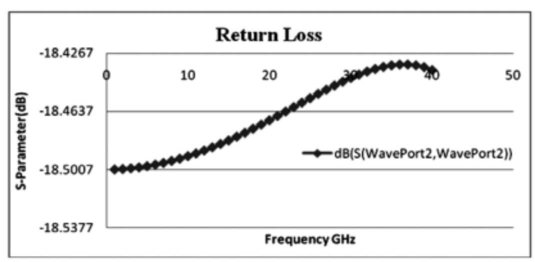

Figure 4: RF Response of CPW Using Rectangular Ports at 40-50GHz with S/W/S (75/90/75 μm) for the 1016 μm Long CPW Line

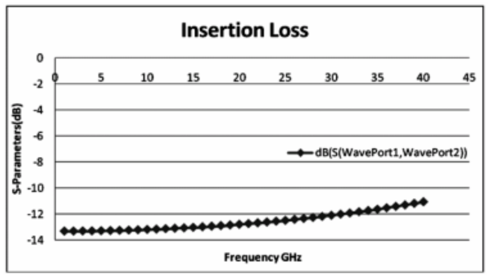

Figure 5: RF Response of CPW Using Rectangular Ports at 40-50GHz with S/W/S (75/90/75 μm) for the 1016 μm long CPW Line

Table 2
Simulated RF Performances of the CPW (Return Losses, Insertion Loss) at 40GHz (75/90/75 µm) for the 1016 µm Long CPW Line

Pass	*Return Loss(dB)*	*Insertion Loss(dB)*
Port2-Port2	-18.43dB	
Port-Port2		-11.04dB

3.2. EM Simulations for SPDT RF MEMS Switch

The EM simulations in Figure 6 reveal that depending on which port is turned on, the SP2T switch exhibits return-loss response. This is something that is not predicted by the equivalent-circuit model. return loss, the transmission-line model matches EM simulations very closely for both the input and output ports. There is some parasitic coupling that affects the input-output match.

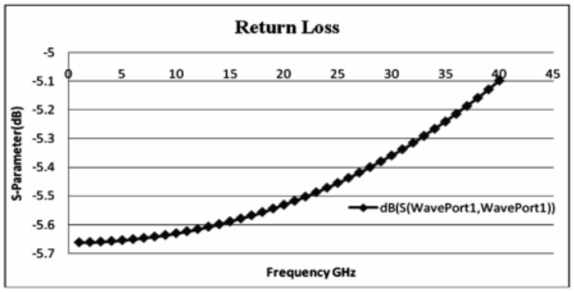

Figure 6: Simulated RF Performance in 'ON-state' of the SP2T Topology while Transmitting from Input 1 to Output 1, Device Size Device size 1126 µm x 2010 µm

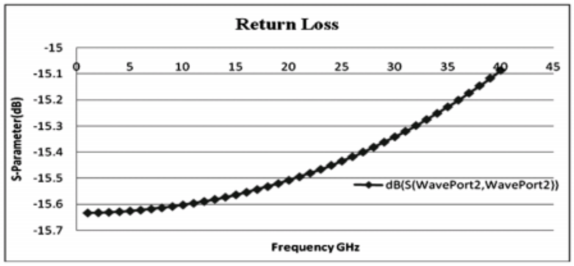

Figure 7: Simulated RF Performances in 'ON-state' of the SP2T Topology while Transmitting from Port 2 to Port 2, Device Size Device Size 1126 µm x 2010 µm

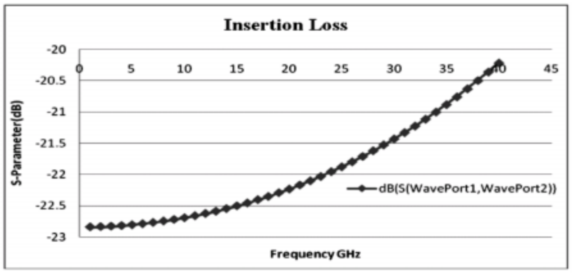

Figure 8: Simulated RF Performances in 'ON-state' of the SP2T Topology while Transmitting from Port 1 to Port 2, Device Size Device Size 1126 µm x 2010 µm

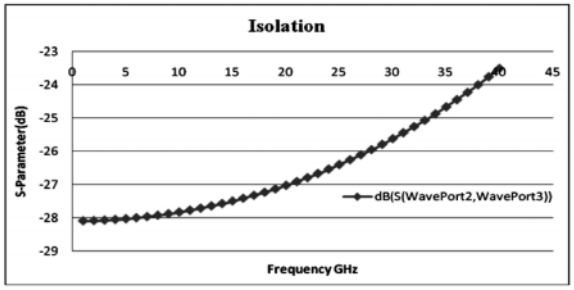

Figure 9: Simulated RF Performances in 'OFF-state' (Isolation) of the SP2T Topology Port2-Port3 having Device Size 1126 µm x 2010 µm

Table 3
Simulated RF Performances in 'ON-state' of the SP2T MEMS Switch (Return Losses) at 40GHz (Device Size 1126 µm x 2010 µm)

Pass	*Return Loss (dB)*
Port1-Port1	-5dB
Port2-Port2	-15dB

Table 4
Simulated RF Performances in 'ON-state' of the SP2T MEMS Switch (Insertion Losses) at 40GHz (Device Size 1126 µm x 2010 µm)

Pass	*Insertion loss(dB)*
Port1-Port2	-20dB

Table 5
Simulated RF Performances in 'OFF-state' of the SP2T MEMS Switch (Isolation) at 40GHz (Device size 1126 µm x 2010 µm)

Pass	*Isolation(dB)*
Port2-Port3	-23dB

The simulated return loss of the SP2T switch is -15dB up to 40 GHz, with an associated insertion loss of -20dB at 40 GHz with device size 1126µm x 2010µm.

4. CONCLUSION

The present research work is concerned with the study of electro statically actuated RF MEMS Single pole four throw switch (SP2T). The current state of the art RF MEMS switches mostly, have been developed for high value defense oriented applications, with excellent RF characteristics. However the commercial applications are still under investigation mainly because of operational voltages, long term reliability and the prohibitive cost in comparison to solid state devices.

A good RF performance has been achieved in the designed and manufactured SPDT switch based on MEMS ohmic switches. They are suitable to be used as standing alone devices or in complex configurations. Their performance meets the strict requirements needed for space applications. The life time test performed up to now show a good reliability. Based on these SPDTs different ring matrices have been developed. The obtained performances make them suitable to be used as building blocks for complex switching networks combining several inputs and outputs.

The main goal of the present work thus, is to explore the design feasibility of RF MEMS SP2T switch having low actuation voltage and optimization of SP2T for S and C band. As a conclusion, it can be stated that switch structure has been optimized by the dependence of pull-in voltage on the material properties of the switch and geometrical sizes and various spring dimensions. This work demonstrated the low actuation voltage ranging from 3V to 20V with acceptable RF response, in the frequency range of 30-40 GHz (S, C and Ka Band).

5. FUTURE WORK

- Further optimization of SP2T switch to get better isolation and less insertion loss.
- Design of single and multi bit phase shifter.
- Design of filters using SP2T.

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