Low Loss High Isolation NEMS Switch (0-80GHz) for RADAR Application

Elangovan. R and Usha Kiran Kommuri
School of Electronics Engineering, Vellore Institute of Technology, Chennai, TamilNadu, India.
elangovan.r2012@vit.ac.in, usha.kiran@vit.ac.in

Abstract

NEMS switches are advantageous in terms of low power consumption, switching times, high isolation, low insertion loss and many more. This paper proposes a NEMS switch with reasonably high isolation and low insertion loss. The model used is a cantilever series switch built on a CPW with a silicon substrate. The switch parameters are optimized for the lowest insertion loss and return loss. An insertion loss values of -0.1305 dB in the down state with return loss of -38 dB and -75dB of isolation have been observed up to 80GHz.

Keywords: NEMS switch, Low Loss, High Isolation, RADAR

I Introduction

Nano-Electro-Mechanical Systems (NEMS) is the future electronics. Two different electrostatic actuation models exist namely the capacitive switch and the metal-metal contact switch. High isolation in the switch OFF position and low insertion-loss in the ON position is expected. The cut-off frequencies obtained may reach a value of 40THz [1]. The actuation voltage is the main feature of the switch.

Micro-Electro-Mechanical Systems (MEMS) technology has grown rapidly and entered into many communication and defense applications. At present, as the development in MEMS technology, Radio Frequency (RF) MEMS is one of the fastest growing areas in commercial MEMS technology. As a novel switch, RF MEMS switches have a myriad application in radar system and wireless communications. Comparing to semiconductor switches widely used in millimeter wave integrated circuits and microwave circuits, the novel device has a low insertion loss, good isolation, low return loss, high frequency, good Q-factor, and a low cost and power consumption.

The components and subsystems used in radar are based on RF MEMS switches, switched capacitors, and varactors. Limiters protect active microwave circuitry from damaging power levels. Anti-stiction treatments involve the application of a molecular film to the micro-machine surface.

II RADAR APPLICATIONS

Radio Frequency Nano-Electro-Mechanical Systems have been proposed to replace the already existing components like the Active Electronically Steerable Antennas, Passive Electronically Scanned Arrays, phase shifters, radomes [3]. A wide bandwidth can be obtained by using RF NEMS switch as phase shifters in RADAR [4-12]. Thou many switches are proposed but detailed study of NEMS switch is not available in the literature.

This paper presents the detailed optimization of parameters of NEMS switch for the RF Characteristics.

III DESIGN

A) Conventional NEMS switch

The proposed NEMS switch is a cantilever beam developed on a 50 Ω Co-planar Wave-guide (CPW) with G/S/G = 150/200/150 nm as shown in Fig. 1. The substrate used is a silicon substrate of thickness 450nm. The whole switch is fabricated on the silicon substrate with a silicon oxide layer on top of it [6]. A layer of SiO2 of about 150nm is layered for the isolation purpose. The anchor for the beam is made of Gold. A dielectric layer made of Silicon Nitride (SiN) is layered between the cantilever and CPW to avoid stiction in the down state.
structures are being changes it is taken care that the cantilever of the switch dimensions remains unaltered.

Substrate height change:

Substrate of the switch is varied from 250nm to 1000nm. As we are aware that as the substrate dimensions changes the CPW G/S/G changes hence altering the substrate and G/S/G to maintain 50Ω impedance various combinations have been considered and tabulated.

Table 1: Substrate height variations.

<table>
<thead>
<tr>
<th>G/S/G</th>
<th>Height</th>
<th>INSERTION LOSS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10GHz</td>
</tr>
<tr>
<td>110/250/110</td>
<td>250nm</td>
<td>-0.094</td>
</tr>
<tr>
<td>100/150/100</td>
<td>470nm</td>
<td>-0.1474</td>
</tr>
<tr>
<td>180/250/180</td>
<td>650nm</td>
<td>-0.0883</td>
</tr>
<tr>
<td>80/130/80</td>
<td>800nm</td>
<td>-0.1684</td>
</tr>
<tr>
<td>125/200/125</td>
<td>1000nm</td>
<td>-0.1091</td>
</tr>
</tbody>
</table>

It is observed from the above table that 1000nm with G/S/G of 125/200/125 is the optimized value for the substrate variations. These values are considered keeping in mind that the overall impedance of the circuit is 50Ω. Although the G/S/G is determined, changing the CPW gap may alter the impedance hence keeping the impedance of 50 ohm in mind the gap is altered accordingly.

Variation in CPW G/S/G:

After varying the substrate thickness, CPW G/S/G is varied accordingly.

Effect of CPW length:

Keeping the G/S/G variations as derived earlier, the CPW length is altered to be tabulated as below.

Table 2: Variation of CPW length.

<table>
<thead>
<tr>
<th>CPW LENGTH</th>
<th>INSERTION LOSS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10GHz</td>
</tr>
<tr>
<td>3µm</td>
<td>-0.093</td>
</tr>
<tr>
<td>4µm</td>
<td>-0.1194</td>
</tr>
<tr>
<td>5µm</td>
<td>-0.146</td>
</tr>
</tbody>
</table>

Based on the tabulated values it is observed that 3µm is the corrected length of CPW for the switch.
Effect of CPW thickness:

The thickness of the CPW also varies the overall impedance of the switch. Hence it is carefully observed that 50Ω impedance is observed.

**Table 3: Isolation layer variation characteristics**

<table>
<thead>
<tr>
<th>SiO₂ thickness</th>
<th>INSERTION LOSS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10GHz</td>
</tr>
<tr>
<td>140nm</td>
<td>-0.1152</td>
</tr>
<tr>
<td>130nm</td>
<td>-0.1121</td>
</tr>
<tr>
<td>150nm</td>
<td>-0.1137</td>
</tr>
<tr>
<td>120nm</td>
<td>-0.1129</td>
</tr>
<tr>
<td>160nm</td>
<td>-0.114</td>
</tr>
</tbody>
</table>

A few carefully selected values of the isolated layer have been portrayed in the form of a table above to bring about the best of the characteristics in an RF NEMS switch.

**IV FINAL OPTIMIZED RF NEMS SWITCH**

After analyzing various parameters and dimensions a final optimized result is simulated. The optimized dimensions are found out to be:
- Substrate thickness: 1000nm
- G/S/G: 125/210/125
- CPW length: 3µm
- CPW thickness: 130nm
- Isolation thickness: 140nm

Therefore the Insertion loss and the Return loss characteristics of the NEMS switch are as shown in Fig. 4.
From the analysis performed for the optimized switch characteristics, a return loss of -75dB and an insertion loss of -0.1352dB is observed at 80GHz which is in the RADAR range.

CONCLUSION

A high isolation NEMS switch from 0-80GHz has been proposed. The effect of various parameters is studied and presented. The NEMS switch is optimized for the best performance. An insertion loss values of -0.1305 dB in the down state with return loss of -38 dB and -75dB of isolation has been observed up to 80GHz. The obtained range covers many applications of the radar.

REFERENCES


BIO DATA OF AUTHOR(S)

Mr. Elangovan.R Pursued Bachelors of Engineering from Jawaharlal Nehru Technological University, Hyderabad, Andhra Pradesh. Currently pursuing M.S (by Research) in Vellore Institute of Technology (VIT), Chennai, Tamil Nadu.

Dr. Usha Kiran K Completed her Ph.D on Microwave Antennas from Gulbarga University, Karnataka in 2007. Then she joined as Project Associate to Microwave Lab, ECE, Indian Institute of Science (IISc), Bangalore.Developed several RF MEMS SPDT & SPST switches from 2007-2009. Worked at Indian Institute of Technology (I.I.T), Delhi as Project Scientist working on RF MEMS from 2010-2012. At present working in Vellore Institute of Technology (VIT), Chennai from 2012 till date. She has above 50 papers published in Journals and Conferences on Microwave Antennas and RF MEMS.