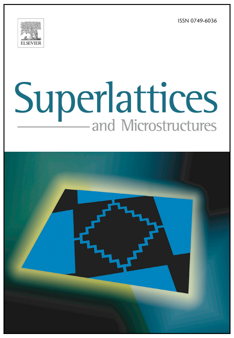

# Modeling and analysis of capacitance in consideration of the deformation in RF MEMS shunt switch

Saurabh Agarwal, Richik Kashyap, Koushik Guha, Srimanta Baishya

PII: S0749-6036(16)30580-8

DOI: 10.1016/j.spmi.2016.10.022

Reference: YSPMI 4567

To appear in: *Superlattices and Microstructures*

Received Date: 28 July 2016

Revised Date: 10 October 2016

Accepted Date: 12 October 2016

Please cite this article as: S. Agarwal, R. Kashyap, K. Guha, S. Baishya, Modeling and analysis of capacitance in consideration of the deformation in RF MEMS shunt switch, *Superlattices and Microstructures* (2016), doi: 10.1016/j.spmi.2016.10.022.

# Modeling and Analysis of Capacitance in Consideration of the Deformation in RF MEMS Shunt Switch

Saurabh Agarwal, Richik Kashyap, Koushik Guha, and Srimanta Baishya
*Department of Electronics and Communication Engineering, National Institute of Technology, Silchar*
*Assam 788010, India*

---

## Abstract

**This paper deals with the modeling of capacitance in an actuated RF MEMS switch where the beam layer forms tilted contact at the edges and touches completely with the dielectric layer at the center. The tilted and overlapping sections of the beam are modeled separately and combined with the effect of etched holes to estimate the overall capacitance formed between the beam and central part of coplanar waveguide. Effects of beam width, dielectric thickness, and the air gap between beam and dielectric layer on total capacitance of the switch are analyzed. RF analysis and beam length optimization has also been done to ensure an efficient grounding of signal in the transmission line. Model and simulated values using Coventorware MEMS plus 4.0 are compared in different configurations and percentage of errors are also estimated. For beam height variation of 1 to 2.25 µm, the error is within ± 8 %, while for varying dielectric thickness of the layer from 0.15 to 0.3 µm and beam width variation of 40 to 70 µm shows an accuracy within ± 6 %.**

*Keywords*: *Microelectromechanical Systems, Modeling, Capacitance, Capacitive Shunt Switch, RF MEMS*

---

## I. INTRODUCTION

As compared to FET based switches, RF MEMS (Radiofrequency Microelectromechanical systems) switches demonstrate better electrical performance as they have the potential to provide better high frequency performance, with ultra-low power consumption [1-2]. Simulation and modeling studies of various structures of RF MEMS switches have been carried out to find the capacitance of beam, pull in voltage, and spring constant of the beam [3-4]. The performance of RF MEMS Switch is determined by the capacitance in the model of the beam, and helps in analyzing the RF parameters of the switches [5-6].

Some of the literature presents numerical methods to find out the performance parameters of switch. Such analyses are no doubt accurate enough but are bound to consume sufficient computation time [7-9]. There are techniques to eliminate the problem of stiction in between the two plates in down state. Depositing a dielectric layer on lower plate is one, which brings down the problem of stiction and also enhances the capacitance in down state [10]. Many of the capacitance models have ignored the effect of dielectric layer on capacitance in actuated position [11-13]. Wang [14] proposed a rigorous capacitance model in up and down states for trapped charges in dielectric layer. However, the inclusion of etched holes on the structure, which also shows impact on the performance parameters, has been ignored. Moreover, the variations of the beam parameters and their effects on the overall capacitance have also not been looked into. Lee in [15] reported an excellent analysis of the deformation due to electric field in the upper plate and its effect on down state capacitance, but the analysis did not include the capacitance due to the tilting part. Although, Binzhen [16] and Cevher [17] have considered the effect of tilted plate but the effect of etched holes due to the deformation in the beam with the application of potential, in turn of electric field is missing from their analysis. Bendali and Rabinov, in [18-19] separately discussed the effects of etched holes in calculating the RF parameters of beam.

In this paper, we present a model for the capacitance in RF MEMS fixed-fixed capacitive switch and presents its significance in calculating the RF parameters of switch. The model takes care of the parallel plate and tilted plate sections separately, in addition to the impact of perforated holes in down-state position. Furthermore, we have also incorporated the deformation effect of upper plate utilizing the model reported in [15]. Using the model, the various components of the capacitance are analyzed for different beam configurations. To obtain a complete ideal beam-signal line contact with no tilts, and to gain complete isolation of the signal in the transmission line, we have further optimized the beam length based on yield point strain of gold film. The developed capacitance model is validated with FEM simulation results using Coventorware MEMS plus 4.0 for varying width, dielectric thickness, and air gap between beam and signal line. Our model calculations show a close match with the FEM results.

## II. SWITCH DESIGN

Fig. 1 shows the RF MEMS Fixed-Fixed shunt capacitive switch on coplanar waveguide line configuration. In theoretical analysis of RF MEMS switch, it is assumed to have complete contact between the beam layer and coplanar waveguide signal line. But in reality, beam doesn't make complete contact with the signal line as shown in Fig. 2. Actuation of shunt switch is due to applied potential across