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Study of RF Microelectromechanical Systems for Microwave Application

Kumar Utpal Kant
M. Phil. Students, Department of Physics, B. R. A. Bihar University, Muzaffarpur-842001, Bihar, India

ABSTRACT

In this paper, we report on analytical study of RF MEMS for microwave applications discussed with the help of BST technology.
Keywords: RF Switch, MOSFET, Spiral Inductor, RF-MEMS, BST.

I. INTRODUCTION

This work is aimed at developing and optimizing aspects of these technology relevant to future commercial application, including device design, fabrication and processing, and microwave circuit demonstrations.
The importance lies in the present study deals with the development of two emerging tuning and control technologies for microwave circuits and antennas applications. Thus, the work mainly focuses on topics- RF MEMS. The motivation for using radio frequency microelectromechanical systems (RF MEMS) technology for the control of microwave circuits and antennas is presented. A brief survey of currently used microelectronic RF switching technologies is presented. RF MEMS switches are compared with conventional semiconductor switches. Microwave circuit and system applications that benefit from the use of RF MEMS switches are listed.
Lastly, we investigate on replacing traditional silicon nitride dielectric with RF MEMS switches for high-isolation and broadband applications. RF MEMS switches using silicon nitride dielectrics was fabricated. Measurements of both devices were compared, followed by discussions on further improving the performance.

II. MATERIALS AND METHODS

The present paper deals with the development of two emerging tuning and control technologies for microwave circuits and antennas applications. Thus, the work mainly focuses on topics- RF MEMS. The motivation for using RF MEMS switch for the control of microwave circuits has been presented. RF MEMS switch has been extensively investigated to increase fabrication yield, reduce insertion loss, and improve isolation performance for various application requirements. RF MEMS switches posses the potential for very low loss, reasonable switching speeds, and operation with no quiescent current consumption. The successfully fabricated RF MEMS switches are used to implement low-cost, high-performance SPDT switches, analog and digital phase shifters, tunable filters. However, in order to commercialize this new technology, there are still many problems that need to be further investigated in future work.

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Finally, MEMS switches need to be packaged in inert atmospheres (nitrogen, argon, etc.) and in very low humidity, resulting in hermetic or near-hermetic seals. Packaging costs are currently high, and the packaging technique itself may adversely affect the reliability of the MEMS switch. Thus, the packaging technique must also be investigated extensively in the future in order to improve performance and reduce the total fabrication cost of the switches.
The present paper involves the mathematical formulation of the problem and related computation using CAD of the results along with the discussion of the result and conclusion.

III. RESULTS AND DISCUSSION

Radio-frequency microelectromechanical system (RF MEMS) is now an emerging technology with great promise for reducing cost and improving performance in certain microwave applications. RF MEMS switches are devices that use mechanical movement to achieve a short circuit or an open circuit in the RF transmission line. The forces required for the mechanical movement can be obtained using electrostatic, magnetostatic, piezoelectric, or thermal designs. To date, only electrostatic-type switches have been demonstrated at 0.1-100 GHz with high reliability (100 million to 10 billion cycles) and wafer-scale manufacturing techniques.

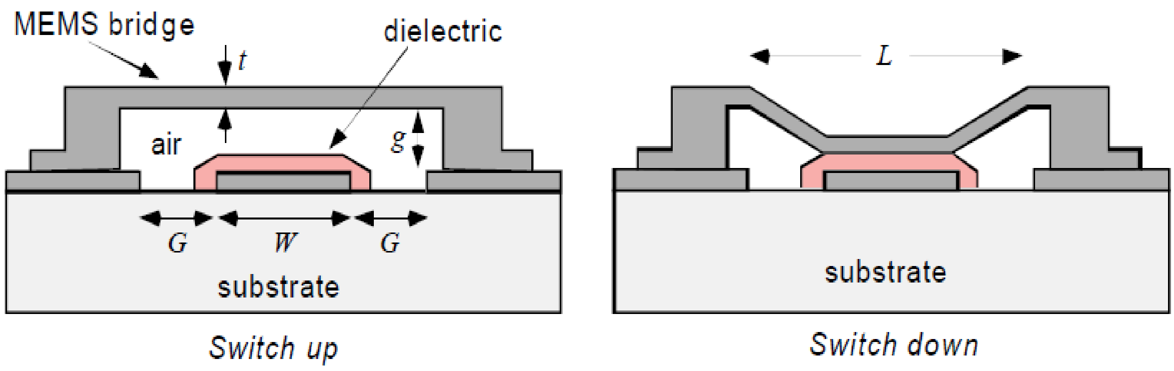

Figure 1: Cross section of a MEMs membrane switch in the up (off) and down (on) state. In this case the switch alternates between a high and low capacitance.

The physical structure of the electrostatic-type MEMS switching device is shown in figure (1). Here a thin metal membrane of thickness *t* is suspended a short distance *g* above a conductor. When a DC potential is applied between the two conductors, charges are induced on the metal which tend to attract the two electrodes. Above a certain threshold voltage, the force of attraction is sufficient to overcome mechanical stresses in the material, and the membrane snaps down to the "closed" position shown on the right of figure (1).

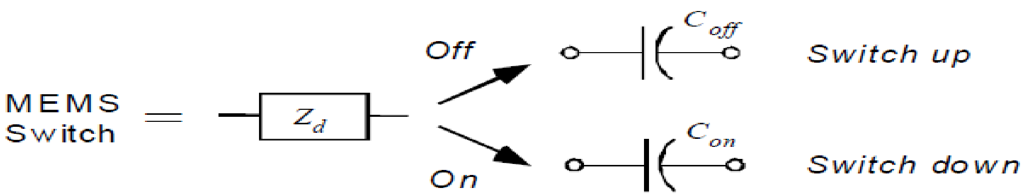

Figure 2: Equivalent circuits for the MEMs switch in the two states shown in figure 1.

Although a true conducting on/off switch appears possible with this technology, it has proved difficult to achieve reliable metal-to- metal contact in the down position. Therefore, the prevailing MEMS switching technology employs a thin dielectric coating over the center conductor, as shown in figure (1), so that the device essentially switches between two capacitance states. Typically, an h=1000 Å thick silicon nitride (SiN) film is used with ε_r =7.5. The equivalent circuit for the device is therefore summarized in figure (2). The capacitance in the two states can be accurately computed using parallel plate formulas, requiring only knowledge of the electrode geometries and the dielectric material.

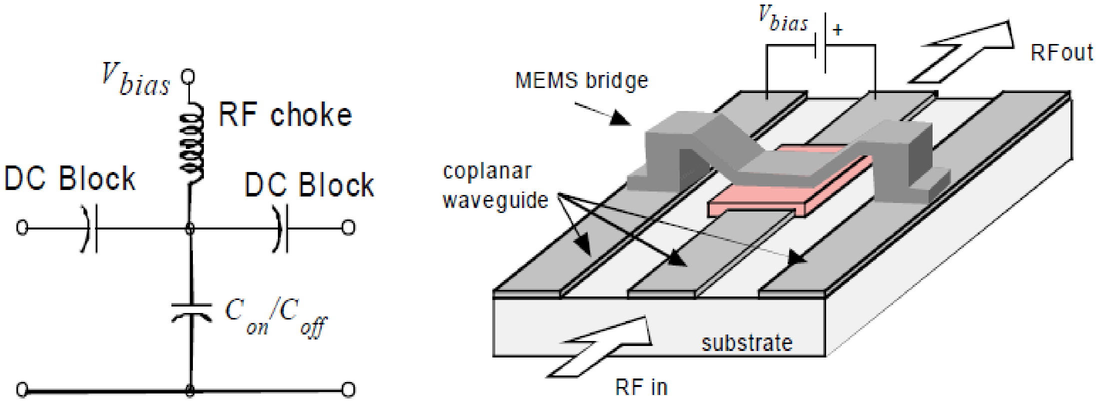

Figure 3: MEMS shunt capacitive switch, and a coplanar waveguide implementation.

A perspective view of a MEMs switch in a coplanar waveguide configuration is shown in figure 3. The main application areas of MEMS switches are:

- *Radar Systems for Defense Applications (5-94 GHz)*: Phase shifters for satellite-based radars, missile systems, long-range radars. *Automotive Radars*: 24, 60, and 77 GHz.
- *Satellite Communication Systems (12-35 GHz)*: Switching networks for antenna applications. Switched filter banks. Also, phase shifters for multibeam satellite communication systems.
- *Wireless Communication Systems (0.8-6 GHz)*: Switched filter banks for portable units and base stations, general SPDT to SP4T switches, transmit/receive switches, and antenna diversity SPDT switches.
- *Instrumentation Systems (0.01-50 GHz)*: These require high-performance switches, programmable attenuators, SPNT networks, and phase shifters.

IV. CONCLUSIONS

The successfully fabricated RF MEMS switches are used to implement low-cost, high-performance SPDT switches, analog and digital phase shifters, tunable filters. However, in order to commercialize this new technology, there are still many problems that need to be further investigated in future work. The main challenge is still the reliability of the RF MEMS devices. Though effective switching control of these MEMS capacitive switches has been demonstrated in research lab, future work should concern the reliability of the switch for long-term applications. For high power applications, the power handling capability of the switch is the major concern.

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