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Recent Advancements In RF MEMS Switches

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Abstract

The application of micro electromechanical systems(MEMS) in many current and future radio frequency(RF), microwave and millimeter wave systems are increased, since the focus of area of research in these areas shifted towards consumer applications from the defense related products. These devices are called RF MEMS encompasses all miniaturized devices. These devices are operated micromechanically or fabricated by micromachining or by both. In this paper we discuss about the recent developments in the RF MEMS switches by means of fabrication techniques, comparison of traditional RF semiconductor switches with RF Switches and various applications of RF Switches.

Key Words:

RF MEMS, Capacitance, Mm waves, MIMO, Micromachining

Introduction

The term RF MEMS refers to the design and fabrication of MEMS for RF integrated circuits. MEMS devices in RF MEMS are used for actuation or adjustment of separate RF device or component such as variable capacitors, switches and filters. The RF MEMS development can be classified in three categories, RF extrinsic in which MEMS structure is located outside the RF circuit and actuates or controls other devices in the RF circuit , RF intrinsic in which the MEMS structure is located inside the RF circuit and has the actuation and RF circuit function, RF reactive in which the RF MEMS structure is located inside the where it has an RF function that is coupled to the attenuation.

The RF MEMS switches provides an interface between a system and devices with the capability for automatic redirection of signals, enhancing their flexibility and expandability. A switch in an RF signal path can introduce resistance and capacitance in signal-to-signal and signal to ground paths. RF MEMS switches have shown great potential for the development of low loss, low power, and low cost reconfigurable and smart antenna systems on-chip or on-package by introducing revolutionary phase shifter circuits impedance matching networks and switching matrices for multiple-input–multiple-output (MIMO) systems . RF switching is normally accomplished by using semiconductor devices such as diodes or FETs. Recently, PIN diodes are used for the RF switching of a reconfigurable antenna, for the purpose of beam steering [13]–[15], dual-frequency band operation [16], and dual-polarized radiation [17]. However, these semiconductor devices have low Q (Q< @10 GHz) at high frequencies and therefore exhibit high insertion loss [18]. The use of MEMS switches has provided a reliable alternative to semiconductor devices [19]–[21]. MEMS switches have hiher Q (Q>@ 10 GHz) compared to semiconductor devices[18]. RF micro electronic mechanical systems (MEMS) switch technology has been introduced to replace the conventional GaAs FET and p-i-n diode switches in RF and microwave communication systems, mainly due to their low insertion loss, good isolation, linear characteristics, and low power consumption. It has also provided the way for the development of novel revolutionary RF circuits like low cost reconfigurable and smart antenna systems on-chip that can be used in the next generation of broadband, wireless, and intelligent communication and radar systems.

A mems switched reconfigurable antenna is one that can be dynamically reconfigured within a few microseconds to choose different polarizations (as shown in Fig. 1) or to serve different applications at

drastically different frequency bands, such as communications at L-band (1–2 GHz) and synthetic aperture radar (SAR) at X-band (8–12 GHz). Recently, many researchers have been focusing on the development of miniaturized, low power and low cost RF/microwave circuits with RF MEMS switches [1]–[3].MEMS switches have been used in different RF circuit applications: tunable antennas, tunable microwave filters, tunable phase shifters, and tunable matching networks. Microwave and millimeter wave technology that offers wide tenability is essential for today's cost driven commercial and military industries. In order to meet the above requirements, recently, micro machined tunable capacitors have been shown to have an adequate factor when they are fabricated in either an aluminum [4], [5] or a polysilicon [6] surface micromachining technology. Also, a three-plate structure with a wide tuning range was reported [7]. Tunable capacitors are enabling components for high frequency systems. There are two approaches to make such components. One is a chemical approach that improves properties of the materials, and the other is a physical approach that controls the gap or area of the dielectric layer for variable capacitance. MEMS switch precise, micrometer-level movements are ideal drives for the physical approach. A MEMS-based switching diaphragm could be used as a variable capacitor [8]. The tunability of this component was very impressive because a lossless, Airgap was used for the dielectric layer. However, the range of this variable capacitance was limited when the top membrane collapsed onto the bottom plate.One key factor of MEMS switches is input-output signal isolation in the down state. Traditional MEMS switches use as dielectric material, its lower dielectric constant ( ) limits its application at lower frequency. In order to further improve the performance of MEMS switches, higher ratio and thus larger down state capacitance is required. Emerging barium strontium titanate (BST) thin film technology has been investigated for enhancing RF-MEMS capacitive switches due to its high dielectric constant in [9]. The switch provides better isolation than the nitride switch of the same type, but the isolation value drops considerably ( ) below 5 GHz. In addition, no analog tunning capability was reported in [9].
In this paper, a highly compact low-loss up to 40 GHz and linearly tuned capacitive cantilever MEMS switch using high quality BST as the dielectric layer is reported for the first time. It provides continuous (analog) tunability of the capacitor after the MEMS switch has been pulled down, due to the voltage controlled dielectric constant properties of the BST material.

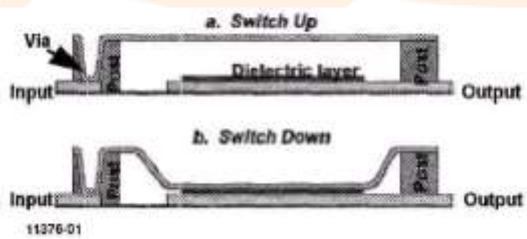

Fig 1. Cross Sectional View Of Capacitive Membrane Switch

The proposed switch can be used to develop very compact digital capacitor banks with enhanced analog tuning for a variety of reconfigurable antenna systems and other networks. A special MEMS design with a separate actuation electrode is considered to provide tunability of the switch and to prevent the breakdown problem of the BST. Clamped-free (cantilever-type) coplanar waveguide (CPW) switches with a contact area of 100 200 and various hinge geometries (solid and meander shaped) were fabricated on sapphire substrates using a five mask process [10]. The measured dc and microwave performance of the cantilever switches for a given hinge geometry has been reported at this stage. High Performance Tunable RF MEMS Switch Using Barium Strontium Titanate (BST) Dielectrics for Reconfigurable Antennas and Phased Arrays.RF MEMS are small mechanical devices fabricated by photolithographic processes, which are used for elemental signal processing functions in rf and microwave frequency circuits. The most ,common RF MEMS control component is a microwave transmission line switch, currently under development for applications requiring low insertion loss, high linearity, moderate switching speeds, and low to moderate power. The RF MEMS switch promises integration onto a variety of substrates, including suhs.trates hearing active semiconductor devices. This paper will discuss.some aspects of the operation of RF MEMS switches and how they may be inserted into microwave circuitry to best advantage.

As of my last knowledge update in September 2023, RF MEMS (Radio Frequency Micro-Electro-Mechanical Systems) switches had been gaining attention for their potential in wireless communication and microwave applications due to their fast switching times, low insertion loss, and small size. Since technology trends evolve over time, here are some potential recent trends and developments in RF MEMS switches up to 2023.They are highlighted as below clearly.

1. **Miniaturization and Integration**: RF MEMS switches continue to shrink in size, allowing for greater integration into complex RF systems. Miniaturization is particularly important for applications like 5G, where small, low-loss switches are required in massive MIMO (Multiple-Input Multiple-Output) systems.
2. **5G and Beyond**: RF MEMS switches are becoming more critical in 5G and beyond 5G (B5G) technologies. They are used in beamforming systems, phase shifters, and other essential components of advanced wireless communication systems.
3. **Increased Frequency Range**: RF MEMS switches are being developed for higher frequency ranges to accommodate the growing demand for millimeter-wave and terahertz applications. This includes switches that can operate at frequencies well above 100 GHz.
4. **Reliability and Packaging**: Researchers and manufacturers are working on improving the long-term reliability of RF MEMS devices, which has been a historical concern. Additionally, new packaging techniques are being developed to ensure better protection against environmental factors and mechanical stresses.
5. **Low Power Consumption**: As energy efficiency becomes more critical in modern electronics, there's a trend towards developing RF MEMS switches with lower power consumption, making them suitable for battery-powered and IoT (Internet of Things) devices.
6. **Multi-Band and Multi-Functional Switches**: RF MEMS switches are evolving to handle multiple frequency bands and serve multiple functions in a single device. This is particularly useful in software-defined radio (SDR) and cognitive radio systems.
7. **Non-Silicon Substrates**: Some research is focusing on using substrates other than silicon, such as gallium arsenide (GaAs) and silicon carbide (SiC), to extend the capabilities of RF MEMS devices, especially for high-temperature and high-power applications.
8. **Advanced Actuation Methods**: The actuation mechanisms in RF MEMS switches are being enhanced. This includes innovations in actuation voltages, actuator materials, and actuation methods like electrostatic, piezoelectric, and magneto motive actuation.
9. **Emerging Applications**: RF MEMS switches are finding new applications in automotive radar systems, aerospace communication, and satellite technology. These switches offer the advantage of high-performance and reliability in extreme environments.
10. **Commercialization and Standardization**: With the maturation of the technology, RF MEMS switches are becoming more widely available, and standardization efforts are gaining momentum to ensure compatibility and interchangeability.

It is essential to note that the development and adoption of RF MEMS technology can vary by region and industry, and there may have been significant advancements in the field since my last update. To stay current with the latest trends in RF MEMS switches, I recommend consulting industry publications, academic journals, and attending relevant conferences and seminars.

Conclusion:

RF Mems switches are widely used in all circuits because of their low insertion loss ,good isolation and low power consumption.Thease advantages are useful to operate any system integrated with RF Mems switches in high frequency of operation with good quality factor.It is widely used in all broadband wireless communication systems.

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