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Comprehensive Study on RF MEMS Technology for Reconfigurable Antenna in Wireless Communication

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Abstract: The main objective of this paper is comparative study of Reconfigurable antennas using RF MEMS. The word 'reconfigure' indicates that to change or alter the characteristics like radiation pattern, polarization, operating frequency of antenna according to our need or application. The reconfigurable antenna is attractive for satellite, military and commercial applications, where it is required to have a single antenna that can be adaptively reconfigurable to transmit or receive on multiple frequency bands and patterns. In this paper RF MEMS switching is proposed for reconfigurability.

Keywords: Reconfigurable, MEMS, FEM

1. INTRODUCTION

In recent years, developments in MEMS (Micro-Electro-Mechanical-System) technology have achieved remarkable advancement for radio frequency (RF) applications, which include switches. Nowadays, Antennas are basic components of any electrical system for transmitting and receiving the signals.

Antennas are employed in different forms based upon the operational characteristics and its performance plays a significant role in communication systems. Wide range of deployable antennas have been successfully used in space and satellite communication applications. Traditionally in space and satellites multiple antennas are used to radiate at different frequencies at different directions to cover various applications. The advancement in the satellite and space technologies enhanced the performance requirements of antennas. The antennas which are used in space and satellite.

The RF MEMS switches are classified into series or shunt type based on the electrical characteristics and capacitive or resistive types based on contact. Capacitive switches are preferably used in high frequency applications. The capacitive switches are mainly used because of high isolation losses which mainly depend on dielectric material between the actuation electrodes hence Si_3N_4, SiO_2 are considered as the dielectric material for most of the RF MEMS switches. The MEMS switch structure can be of bridge type or cantilever or diaphragm type. In electrostatically actuated switches the type of forces effects the deformation of the beam are classified as static forces (Spring, Electrostatic, Contact force) and dynamic forces (Damping, Inertial force). The bridge with four supporting flexures is considered to minimize the actuation. By investigating it is clear that resistive type RF MEMS switches are suitable for low frequency application, but to fulfill the necessity of high frequency application we can use capacitive switches. In this paper an electrostatically actuated shunt type capacitive RF MEMS switch is proposed. The switch performance parameters like spring constant, pull-in voltage, Actuation voltage, switching time (ts), operating frequency, insertion and isolation losses have been studied. The proposed four switches are integrated with patch antenna and reconfigurability in the frequency and radiation pattern have been observed at satellite communication frequency range.

2. REVIEW OF RESEARCH AND DEVELOPMENT IN THE SUBJECT:

As of now, there is big research in reconfigurable antennas. Reconfigurability with respect to radiation pattern, polarization, operating frequency.

Module 1: Design and simulation of fixed–fixed flexure type RF MEMS switch for reconfigurable antenna
Objectives:

Reduce the size of the multiband antenna. While reducing the size of the antenna, the main design considerations, including the resonant frequency, the impedance bandwidth, radiation patterns, gain and structure have to remain unaffected.

Enhance the bandwidth of operating bands without using bias, reactive elements and any additional matching circuit, ground plane etc.

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Module 2: Comprehensive Study on RF-MEMS Switches Used for 5G Scenario.

Objectives

1.The antenna should have a very low profile, ultra-thin and should reduce the interaction with other electronic components.
2.To cover the maximum number of bands in a single design
3.To improve the isolation between two antennas without using any additional isolating elements.
4.To increase the data rate and speed for the forthcoming communication services.
5. Low design complicit.

Module 3: Design, Simulation and Analysis of RF-MEMS Switches for Reconfigurable Antennas.

- Higher the Q Factor low energy loss
- To reconfigure in operating frequency, radiation pattern, polarisation.

Low power consumption.

A comparison of different switching components is provided in Table 1. MEMS switches offer some advantages over PIN diodes or varactors, including high isolation and linearity, wide impedance bandwidth, low noise figure and low power losses. However, compared with other RF switches, it requires a high-control voltage and has a slow switching speed and a limited life cycle. Extensive studies on various kinds of reconfigurable antennas with electronic switching components are given below.

Table 1. A comparison of different switch components

Reconfiguration Technique	Advantages	Disadvantages
PIN-Diodes	Very reliable	High tuning speed
	Extremely low-cost	High DC bias in ON-state
	Common choice for reconfiguration	High power handling capacity
Varactors	Small current flow	Nonlinear
	Continuous tuning	Low dynamic range
	Ease of integration	Complex bias circuitry
RF MEMS	High isolation and linearity	High-control voltage
	Wide impedance bandwidth	Slow switching speed
	Low power losses and low noise figure	Limited life cycle

2.1 Why MEMS ?

1 Smaller in size
2. low power consumption
3.More sensitive to input variations
4. cheaper due to mass production
5. less invasive than larger devices.

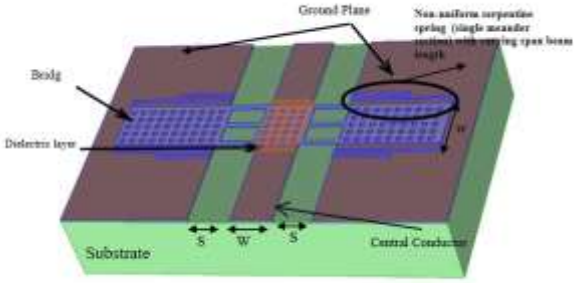

Figure 1: Schematic view of non-uniform serpentine flexure based RF-MEMS switch

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3. DESIGN CONSIDERATION:

Here the design parameters are given which are used to scale the performance of RF-MEMS:

1.RF Power Handling: RF Power handling is a measure of how efficiently a switch passes the RF signal at time of signal transmission.It refers to power at which the MEMS device fails to operate properly.
2.Insertion Loss: Insertion loss of RF -MEMS switch refers to RF signal power dissipated in the switch The insertion loss of RF-MEMS switch refers to the RF signal power dissipated in the switch at the time of signal transmission. Insertion loss occurs at low microwave frequencies as well as at high microwave frequencies. At low frequencies it is due to the resistive loss between the finite resistances of transmission line and switch beam contact area, while at higher frequencies insertion loss occurs because of skin depth effect. For the design aspect, the insertion loss should be minimized for efficient signal transmission.
3.Isolation: The isolation of RF-MEMS switch can be defined as the RF signal power isolation between the input and output terminals in its signal blocking state. A large value (in decibels) of isolation indicates very small coupling between input and output terminals. In RF-MEMS switches, isolation occurs due to capacitive coupling between the moving switch beam and the stationary transmission line as a result of leakage currents. One of the design objectives of the communication system is to achieve a very high isolation at low and high microwave frequencies.
4.Return Loss: The return loss of the RF-MEMS switch refers to the RF signal being reflected back by the device at the input terminal of the switch in its signal transmission state. Return loss occurs due to the matching of the total characteristic impedance between the switch and transmission line.
5.Actuation Voltage: Actuation voltage can be defined as the minimum voltage required to pull down the switch beam of the RF-MEMS switch. One of the design objectives of state of art MEMS technology is to achieve the low actuation voltage , depending on the switch design and application. [1]
Here k is spring constant, is permittivity of free space, W, w and g0 are the length of the pull down electrode, width of beam and gap between the electrode and beam, respectively.
7.Resonant Frequency: The resonant frequency of the switch can be defined in terms of the effective spring constant (k) and resonating mass of the mechanical system (m). At this particular frequency, the stored potential energy and the kinetic energy of the switch tend to resonate. The natural frequency of a simple mechanical system consisting of a weight suspended by a spring can be formulated as [8] The resonant frequency can also be defined for an electrical system in which the resonant frequency can be achieved by using a resonant circuit, which consists of an inductor (L) and capacitor (C) in series configuration. This LC circuit stores an oscillating electrical energy at the circuit's resonant frequency due to the collapsing magnetic field created by the inductor and capacitor.
6.Switching Speed: The switching speed can be defined as the time for toggling from one state of the switch to another. Switching speed can also be called the switching rate. Switching speed of a capacitive RF-MEMS switch can be expressed as switching time required to pull-down the switch membrane (MEMS bridge) [1]:

4. ORIGIN OF THE RESEARCH PROBLEM:

The main issue with any switch integration in reconfigurable antenna design is with biasing the switches without altering the radiation characteristics. In order to avoid this issue, RF-MEMS switches can be used for switching operation because they do not require DC bias lines for actuation. This technique requires a DC short between the central conductor and ground plane of CPW [8].
With existing antenna systems there is restriction on efficiency – bandwidth, gain. There is a need for a compact integrated antenna having reduced costs and reliable performance, high gain. In order to overcome the limitation on conventional antennas using a physical model of PIN diode, RF MEMS is the best choice.
After finding the gap in the work previously done, we came to know that there is the need of design that can focused on compact structure which can increase the, power gain ≥2 dB, bandwidth ≥100%, reduce size ≥50% to create additional frequency bands for multi communication systems.

5. METHODOLOGY

In this study, FEM Technique & HFSS is used.
FEM- Finite Element Method (for Theoretical background)
HFSS- High Frequency Structure Simulation. (For software Background)
1.Numerical Technique
- Computer Based
- Time Domain Solution

2.Modeling of Electromagnetic Phenomenon
- Radiation, Scattering etc.

Proposed Result

The proposed result of system are shown in the graph below.

Fig. 5.3 shows the insertion loss in unactuated state for different up-state capacitance.

This figure illustrate that insertion loss is slightly similar upto 10 GHz thereafter it diverges slowly for lower up-state capacitance. Here it is observed that above 10 GHz, higher up-state capacitance shows higher insertion loss as compared to lower up-state capacitance.

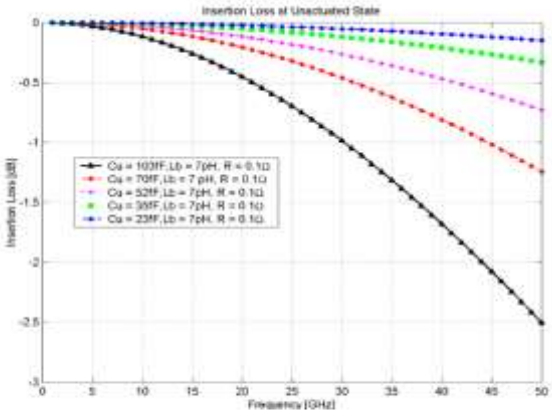

Figure 2: Insertion loss of RF-MEMS switch in unactuated state.

Fig. 5.4 shows the return loss in unactuated state, which illustrate that smaller up- state capacitance, leads to better return loss as compared to higher up-state capacitance. At 10 GHz up-state capacitance with 103 fF shows the return loss of -15 dB, whereas up-state capacitance with 23 fF shows the return loss of -30 dB. This shows that better return loss can be achieved with lower up-state capacitance.

Figure 1: Insertion loss of RF-MEMS switch in unactuated state.

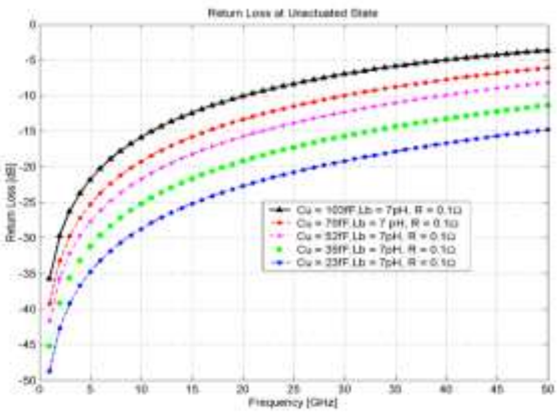

Figure 3: Return loss in unactuated state for different up-state capacitance.

CONCLUSIONS:

The paper presented a comprehensive study on RF MEMS technology in reconfigurable antennas. including their function, classification, reconfiguration techniques, and applications. Reconfigurable antennas were mainly classified into frequency reconfigurable, radiation pattern reconfigurable, polarization reconfigurable, and compound reconfigurable by using electrical, optical, mechanical, and smart material based tunable structures. A detailed comparison between different techniques used to implement reconfigurable antennas was presented. The applications of reconfigurable antennas such as cognitive radio, MIMO systems, satellite communications, and biomedical devices were discussed.

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REFERENCES:

1. T.Galla.Basics of RFSwitches.AnalogICTips.Accessed:Feb.25,2019. [Online].Available:https://www.analogictips.com/basics-of-rf-switches/ [5]
2. J. Iannacci, ''RF-MEMS technology as an enabler of 5G: Low-loss ohmic switch tested up to 110 GHz,'' Sens. Actuators A, Phys., vol. 279, pp. 624–629, Aug. 2018.
3. S. Shekhar, K. Vinoy, and G. Ananthasuresh, ''Low-voltage high reliability MEMS switch for millimeter wave 5G applications,'' J. Micromech. Microeng., vol. 28, no. 7, p. 075012, 2018.
4. J.Iannacci,''InternetofThings(IoT);Internet Of Everything(IoE);tactile Internet; 5G—A (not so evanescent) unifying vision empowered by EHMEMS (energy harvesting MEMS) and RF-MEMS (radio frequency MEMS),'' Sens. Actuators A, Phys., vol. 272, pp. 187–198, Apr. 2018.
5. Keysight Technologies, ''RF/microwave switching solutions,'' in The Coree of Test Systems—RF/Microwave Signal Routing Without Compromise. Santa Rosa, CA, USA: Keysight Technologies, 2017.
6. Skyworks, ''General purpose RF switches,'' in Select RF Switches AvailableFromStockforPrototypeorHigh-VolumeProduction.Woburn,MA, USA: Skyworks Solutions, 2017.
7. Narayana TL, Sravani KG, Rao KS (2017) Design and analysis of CPW based shunt capacitive RF MEMS switch. Cogent Eng 4(1):1363356
8. Rao KS, Thalluri LN (2016) Review on analytical design, simulation, fabrication, characterization, and packaging aspects of micro electro mechanical switches for radio frequency applications. J Biosens Biomark Diagn 1:1–6
9. Ashish K. Sharma and Navneet Gupta, " Material Selection Approach for Dielectric Layer in RF-MEMS Switch", International Conference on Emerging Technologies - Micro to Nano; ETMN-2013, BITS, Pilani - KK Birla Goa Campus, India, February 23-24
10. Ashish K. Sharma and Navneet Gupta, "Impedance Matching for RF-MEMS Based Microstrip Patch Antenna" ECTI-CON-2014, Suranaree Univ. of Tech., Nakhon Ratchasima, Thailand, May 14-17, 2014.
11. Mulloni V, Margesin B, Farinelli P, Marcelli R, Lucibello A, De Angelis G (2015) Cycling reliability of RF-MEMS switches with
12. gold-platinum multilayers as contact material. Microsyst Technol. https://doi.org/10.1007/s00542-015-2782-2