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A Comprehensive Survey on MEMS Technology in RF as Road Map towards Future Research

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Abstract: **-- Since 1980 there have been significant research with MEMS switch in the field of RF (Radio Frequency). In every 3-5 years there have been a break through achieved with MEMS in RF technology. This breakthrough include improvement in the switching voltage, improvement in the overall pass-band, improvement at the insertion loss and improvement at the switching speed. Currently MEMS switch offers a tremendously high frequency around 70GHz in comparison to FET which offers 4GHz, similarly diode offers 20GHz, EMR 5GHz, EMRSMA 40GHz . Even though insertion loss is now reduced to 0.25db, switching voltage has come down to 2 to 4 V, there are areas where MEMS still need significant amount of research in terms of unit cost MEMS switches are significantly high value in comparison to other peers, have present lesser less life time and represent high switching power (even though switching power comedown.**

A dedicated research is needed in the direction of MEMS based RF technology to improve this factor were they lag other semiconductor counterpart. This research requires and understanding of technological advancement in the area of MEMS along with the parameter and factor that have resulted changes and advancement. In this paper we present historical water fall in the advancement of MEMS over RF technology along with comprehensive analysis with the other parallel technology in terms of standard matrices and theoretical foundations.

Keywords: **--RF MEMS, Insertion Loss, Switching Voltage, and Pass-band Frequency.**

I. INTRODUCTION

Radio frequency (RF) is any of the electromagnetic wave frequencies that lie in the range from around 3 kHz to 300 GHz, which incorporate those frequencies utilized for communication or radar signals. RF refers to electrical instead of mechanical oscillations. These frequencies cover a significant part of the electromagnetic radiation range reaching out from kilohertz the most minimal wireless communication frequency to a great many gigahertz (GHz). An RF and microwave switch is a device to course high frequency signal through transmission ways. These are utilized widely as a part of microwave test frameworks for signal routing amongst instruments and device under test.

The remarkable preferences of RF-MEMS switches over traditional RF switches are to a great degree wide band operation, higher isolation, extremely low insertion loss, low power consumption, simple biasing system. RF–MEMS switches work on electrostatic force between two cathodes. So they require low bias current. The power consumption occurs from the dynamic current stream to MEMS bias circuits only when actuation happens. A voltage excitation is needed to actuate the switch, but once actuated, the switches hold their ON/OFF states with next to little dc power.

MEMS switches can be created on any substrate.

In addition to that switches don't contain a semiconductor junction, exhibit inter modulation distortion. The MEMS switches are utilized as a part of testing of equipments, media transmission furthermore in power applications. The measurements of MEMS are extremely from one micron to lower end of spectrum range the distance to mm. The essential ideal in RF MEMS is to utilize smaller than usual mechanical devices and physical movement to accomplish the capacity of a microwave switch or a variable capacitor. The high performance is because of the low capacitance and contact resistance, which can be accomplished by using RF MEMS technology as compared with GaAs PIN diodes or FET's . It is conceivable to manufacture RF MEMS switches with a make sense of legitimacy cut off frequency of 30-80THz, which is around 100 times superior to GaAs transistors. also varactors with a Q of 150 were shown at 30GHz and this is around 5 times better than devices utilizing GaAs methods. MEMS (Micro Electro Mechanical Systems) multidisciplinary technology that includes diverse fields e.g. material and fabrication, procedure and device engineering, microwave engineering, mechanical engineering. A ultimate objective in applying RF MEMS is to propagate the device level advantages as far as possible up to the to attain high system performance[4].

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The innovative progress of bulk and surface micromachining techniques, empowers miniaturized mechanical and electromechanical components. It is the coordination of mechanical components , sensors, actuators, and hardware on a single substrate called integrated circuit, the microelectronic integrated circuit is brain of the system and micromechanical area as arms , eyes of the system to detecting thermal biological , chemical compound , optical and magnetic phenomenon on the earth. In the previous decade have been impressive in both pace of advancement and new applications. The conventional relays converge with MEMS devices prompts new switching device called MEMS switch. While conventional pin diode and FET switches are experiencing slender band width , poor isolation, high insertion loss, high power consumption and significant inter modulation products because of their nonlinear attributes. RF –MEMS show fabulous exchanging qualities over to a great degree wideband(DC - 40GHz and 75-110 GHz) frequencies [2].

Table showing comparison of switches with MEMS Relays

	Characteristics	MMR	GaAs FET	PIN diode	EMR PCB	EMR SMA
1	Size	Small	Very small	Small	Medium	Large
2	On state resistance	0.5Ω	1-5Ω	1-5Ω	0.1Ω	0.5Ω
3	Operating frequency	Upto 70GHz	Upto 4GHz	Upto 20GHz	Upto 05-GHz	Upto 40GHz
4	Switching power	2W CW	0.5W CW	5W CW	10W CW	35W CW
5	Breakdown voltage	Low	Low	Varies	High	High
6	Insertion loss (db)	0.25	0.5	0.5	0.4	0.1
7	Operating speed	0.5-200µs	10-100ns	10-100ns	0.8-10ms	1-40ms
8	Power consumption	Very low	Low	Low	Medium	High
9	Isolation loss(db)	40	30	30	40	80
10	Drive voltage	5V,28V,48V	3V,5V,12V	3V,5V	5V,12V	12V,18V
11	Life cycle	100 million+	Billion	Billion	0.5-5 million	0.1-2 million
12	Integration capability	Very good	Very good	Very good	Average	Difficult
13	Cost – SPDT type	$8 to $20	$0.5 to $4.50	$0.9 to $8	$0.85 to $12	$38 to $90

Source:

A broad literature review has been under taken and key papers have been referred to from these, the inspirations behind different RF MEMS innovations are discussed. The use of MEMS technology for radio applications was begun in the year of 1971 utilizing cantilever switches. Several researchers have been discussed about the improvement of cantilever and MEMS switches using metal membrane, which shows the great switching voltage, insertion loss, fast switching speed and incredible linearity.

- Charlles L Goldsmith,Zhiminyal et..al (1998) "performance of Low-Loss RF MEMS capacitive switches" proposed performance of RF MEMS switches at micro and milli -wave frequency have possesses low loss with good isolation of 15db at 10GHz improves to 35db at 35 GHz by using surface micromachining technique to fabricate the switch. It also shows actuation voltage of 30 to 50Vand better performs then electronic devices

- Shyh-chiang sehn and millon Feng –(1999) "Low actuation voltage of RF MEMS switches with signal frequencies from 0.25 to 40GHz." Proposed surface micromachining technique for performance of RF MEMS switch shows a promising low voltage operation and excellent RF performance over frequency band from 0.25 GHz to 40GHz was achieved along with low insertion , high isolation with switching voltage of 14-17 V.

- Sargio Pacheco , Linda PB katchi - (2000) "Design of Low Actuation voltage RF MEMS switch" has proposed fabrication via surface micromachining technique using PI2545 polymide as sacrificial layer. The switch is composed of electroplated nickel and the serpentine folded suspensions. achieved actuation voltage of 9V with on-off ratio of 48 and isolation of -26 db at 40GHz.

- Jae. Y. Park , Geun H kim, Ki W chung – korea – (2000) " Fully integrated micro machined capacitive switches for RF applications" has present RF switch using electroplating technique with strontium titanate oxide($SrTiO_3$) has achieved high switching ratio , actuation voltage of 8V with insertion loss of 0.08db at 10GHz and isolation of 42 db at 5GHz.

- Dimitros peroluis, serigio Pacheco(2003), "Electromechanical considerations in developing low voltage RF MEMS switch", has reports design , fabrication and testing of high frequency MEMS switch has actuation voltage of 6V , switching speed of 50nsec.with superior performance as compared to evaporated films

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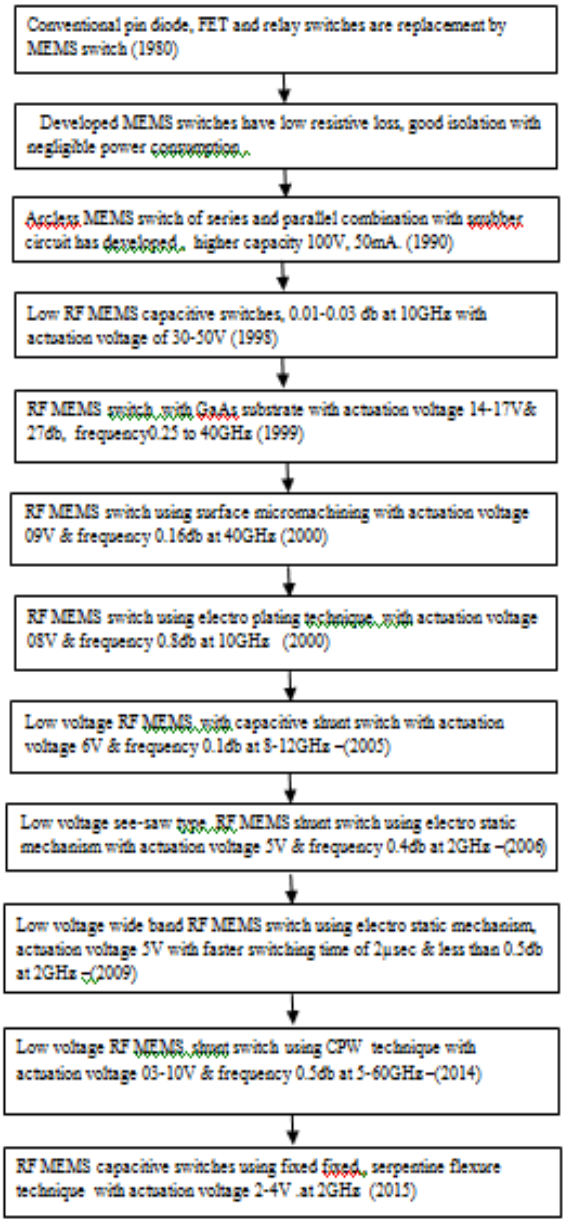
- Y. Mafenejad , A.Z. Kouzai ,Iran –(2009) "Design and simulation of low voltage wide band RF MEMS switch" has proposed electrostatic shunt capacitive RF MEMS switch with two high impedance transmission lines at its input and output using electrostatic mechanism , has achieved the actuation voltage of 5V with , less cost and fast switching time of 2mciro sec. then other switches.

- Prof.Laxmi S, Ajithkumar bachipale, MSRIT-Bangalore-Karnataka(2015), "Design, simulation and electromechanical modelling of RF MEMS capacitive switches" , proposed that the design, model mainly reduces the actuation voltage which is an important parameter for RF and microwave applications. By using Fixed-Fixed beam , Fixed-Fixed flexure beam and serpentine flexure techniques. The actuation voltage is achieved in the range of 2-4V for these design.

Historical Water Flow Diagram of MEMS:



The technological improvement in the MEMS has made blend with advanced circuit brakers for power distribution. It has capacity to rapid changing when contrasted with mechanical breakers with change in power handling breakers. An arrangement and parallel blend of isolated bridge of MEMS switch is utilized along with snubber circuit (RCD) to shield from high current. The start of the century has contracting electronic devices and expanding in costs of fossil fuel price. Both of these require for handling of complex

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power necessity. Research on the MEMS application to energy system has steady going momentum and regularly referred as power MEMS. MEMS plays essential role in 21st century to take care of the expanding demand for convenient and exceptionally proficient technology. Sensors and actuators are appropriate for energy harvesting and power generation and also relevant for large scale power applications. It has wide opportunities in compact and portable and energy productions.

1) Chemical energy battery: Lithium ion batteries have generally utilized for giving high voltages and energy densities and less release as contrast with different batteries. The electromechanical properties of the anode material utilizing carbon-MEMS structure batteries gives better results.

2) Super capacitors: Micro –super capacitors have ability to store the energy and deliver it quickly than batteries under power requirement. Integrating micro super capacitor with energy harvesting device, gives high power density by catching and same energy can utilize later.

3) Nuclear –Micro battery: the nuclear batteries uses radioisotope energy through cantilever, than it gives thousand time more than energy of lithium battery .

4) Micro fuel units: It is electromechanical device with a two electrode compassed by electrolyte. MEMS technology based power devices have enhanced their performance by fluid management and device seals the other basic difficulties can be improved utilizing MEMS. Microfuel cells are fit to produce high power up to a several hundreds of mwatts/cm.

5) MEMS for energy production and distribution: Large scale energy production and distribution are the principle objectives to enhance the power generation to reduce the ecological impact and boost the dependability. But as per survey, the power grids are several decade old, which diminishes the efficiency. A MEMS based system of wise "smart sensor" ready to screen different parts of power generation and at the same time caution the administrator, if there is an issue, these smart sensors are "self aware" and they can ready to convey between sensors to take care of the issues consequently without obstruction of individual. Such MEMS based sensors are the appropriate possibility for flawless execution of grid supply. There fore power generation sensor based technology in RF innovation could be adopted.

CONCLUSION

In this survey paper we focused on drawing historical waterfall model depicting improvement MEMS technology in RF alongside parametric elaboration of the matrices. This helps us to understand not only about the use of MEMS in the RF technology, but at the same time the switching gives us with the detailed overview of the direction of the technological advancement in this area. It shows that even though the development in this direction has achieved tremendous performance gained of reducing switching voltage about 50 times, the frequency band 35 times, and insertion loss , Still the scope of improvement. Our analysis and reading in various other areas of MEMS such as power generation helps us to understand the over all research in this area. From this knowledge we can conclude that MEMS in RF can become smarter and more efficient by adopting smart switching with sensing model. Such a system which is now widely adopted in smart grid can lead to MEMS adaptation in next generation communication systems like cognetic radio, 4G network and so on. where hybrid frequency band is adopted by the system which is pre requisite of changing and tuning of different band at the switching level without compromising on switching latency and passband gain.

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