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Advances of RF Mems for 5 G Technology

ShreyaR Pande
Department of Electronics Engineering,
Shri Ramdeo baba College of Engineering and Management, Nagpur 440013.

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Abstract:
The 5 G is next generation of wireless network promising higher data rates and more reliability in comparison to 4 G network. The high data speed would propel the growth of new technologies, including real time cyber physical systems and Internet of Things(IoT). There is need to develop new technology and systems to process high speed data at transceivers with low power requirement. The Radio Frequency Micro-Electro-Mechanical Systems (RF MEMS) passive devices exhibit boosted performance at high frequencies and is potential contender for deployment in 5 G systems.

Introduction: The Fifth generation 5Gmobile communication and wireless network technology is an emerging field promising significant improvement in performance parameters such as high data volume and rate and low latency. Thus 5G will bring significant development in IoT and cyber physical systems such as autonomous vehicles. The implementation of 5G requires new technologies and devices. The greater data rates require new technologies such as higher broadcast frequencies (30-300 GHz) i.e. millimeter waves, smaller cells, advance (Multiple Input Multiple Output) MIMO.

The implementation of new technology requires, devices and components to address and support the new desired requirements. The subsystems in 5G transceivers will include the devices required to exhibit remarkable performance and support high data rates such as wideband switches, phase shifters, filters, reconfigurable filters, resonators, antennas.
The MEMS technology used in RF systems is referred as RF MEMS. RF MEMS has demonstrated performance enhancement, cost reduction and is considered today as emerging technology. The RF MEMS technology has the potential of replacing many RF components such as switches, passive lumped components (inductors and capacitors),variable capacitors, phase shifters, surface acoustic wave devices and ceramic filters. Nguyen [1] had proposed the building blocks of transceivers to be substituted by RF MEMS devices and components.These RF MEMS devices and components are essential building blocks of communication systems. RF MEMS componentssubstantially reduce the power consumption,weight, size, component counts and promise superior performance in comparison with planar semiconductor technologies. These devices are batch fabricated using techniques derived from the semiconductor industry and therefore can be incorporated with integrated circuits (IC).

The recent advances in performance improvement of some RF MEMS devices at very high frequencies in GHz range may be explored for design and development of 5G systems.

RF MEMS passive devices for 5G: The important building block of RF MEMS system is micro-switch.

RF MEMS Switch: The RF MEMS switches are categorized in two types:based on the MEMS technology from contact perspective: metal contacting and capacitive coupling[2]. In the metal contact switch, the connection is established between two metal membranes as an Ohmic contact. The metal membranes act as electrodes. Due to direct metal contacts, the switch can operate from dc to high frequency applications. The significant attribute of metal contact switch is wide

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frequency band operation. Metal contact switches are generally considered for low frequency applications. Another type of RF MEMS switch is capacitive coupling switch. The capacitance between two metal membranes is varied by adjusting distance between plates by electrostatic potential. The metal plates are separated by a thin dielectric film and an air gap. The electrostatic voltage is applied between membranes. One metal membrane will be attracted towards other by electrostatic field. This reduces the distance between metal membranes and subsequently changes the capacitance between them. The capacitance in the absence of electric voltage is 'up' state capacitance and after actuation 'down' state capacitance. The capacitance ratio of 'down' state to 'up' state is an important performance parameter. Higher the capacitance ratio, better is the performance. The high capacitance in down state closes the switch. For high frequency applications, capacitive switch offers good performance. MEMS switches are used in 'series' and 'shunt' topologies. Metal contact switches are used in series configuration and capacitive switches are used in shunt configuration. For RF applications, the power handling capability of switch is important design consideration.

The 5G RF system architecture, characteristics and performance specifications [3] include frequency range of 30 to 100 GHz, switching time lower than 1000 µs, Isolation better than 30 dB, Insertion loss less than 1 dB for broad frequency range, actuation voltage of few volts and greater reliability.

Metal contact MEMS switch: Many metal contact switches are designed, developed and reported [2][4]. The low loss ohmic switch by Iannacci [5] is implemented with suspended Gold membrane by electrostatic actuation [Fig.1][5].The switch performance is satisfactory up-to 50 GHz with good s-parameters. The review of metal contact MEMS switches [4] reports the use of Bi-CMOS technology which may operate up-to 170 GHz. This metal contact switch has less than 10 µs switching time and isolation of18 dB, insertion lossof 1.23 dB. The actuation voltage is however 50 V. The comparative study of metal contact switches [4] indicates that metal contact switches can be deployed in higher frequency band with low power dissipation, high switching time and in many cases compatible to monolithic IC fabrication processes.

RF MEMS Capacitive switch: The RF MEMS capacitive switch structures have been developed. The promising performance parameters are obtained by the scientific community.The review of the capacitive switches [4] reports the development of high frequency low loss devices.These switches operate in the frequency range of 10 MHz to 75 GHz with low insertion loss of 0.6 dB to -0.17dB, high isolation of more than 20 dB to 40 dB. The switches with low actuation voltage and power handling capability of 0.8W are reported. The power handling capability up-to 12W [4] are also developed. The various techniques are used for enhancing the performance of these switches and the requirement of high reliability. Reliability issues[6] have prevented the widespread use and application of RF MEMS switches. The reliability is primarily limited by stiction andmicro-welding. The techniques are developed to address reliability issues [4]. These techniques include reduction in pull in voltage, employing push pull mechanism, use of special material for membrane, reducing temperature sensitivity and optimized structures. Therefore, different techniques in structures, fabrication, and packaging will enable MEMS switches as strong contender for 5G technology.

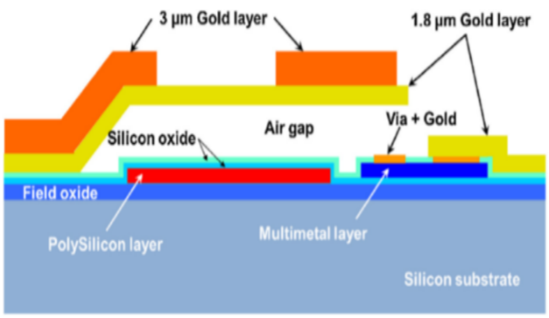

Fig.1. RF MEMS Switch.

RF MEMS variable capacitors: Conceptually, RF MEMS capacitive switch can act as variable capacitor (varactor)[2]. The actuation voltage can be used for tuning. The

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newer structures and fabrication techniques are used to increase C_{down}/C_{up} ratio. Several contributions are reported [7] about development of low actuation voltage varactors suitable for high performance applications.

RF MEMS inductors: The MEMS technology allows the separation of inductor with ground plane. The air gap between suspended inductor and ground plane reduces the parasitic capacitances primarily responsible for low quality factor.The parasitic capacitance also limits maximum operating frequency by creating a self resonance frequency. The suspended MEMS inductors [Fig.2][8]reduce the parasitic effects substantially, increasing Q factor [9]and facilitates operation at high frequency typically up-to 30 GHz. The tunable inductors are developed paving the way use in 5G systems.

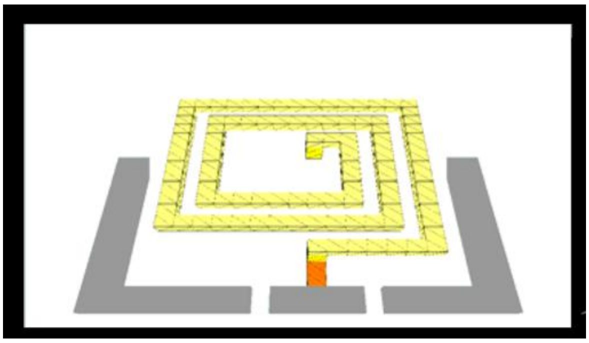
Fig.2. RF MEMS Inductor.

RF MEMS Filters: The MEMS lumped elements may be used for designing filters.In addition to lumped component filter, [2][10]some geometrical structures such as, the hairpin geometry filter uses the inductive contribution of bends and their capacitive coupling to have band-pass characteristics.

RF MEMS Resonators: The RF MEMS technology allows the design and fabrication of on- chip resonators. The RF MEMS resonators are being used for signal processing and sensing applications. The demands of high speed wireless communication service may be full-filled by MEMS resonators to be used in filters, oscillators of transceivers. MEMS resonators with high resonant frequency in GHz range with high quality factor and low motional resistance are developed. Yang et al[11] reported Ka band resonators with high Q of more than 400 suitable for implementation in high speed wireless communication systems. Ansari et al [12] developed 8.7GHz GaN micromechanical resonator with Q of 330.

Other devices, components and systems developed with RF MEMS technology include device RF MEMS impedance matching tuners,RF-MEMS programmable power attenuators, programmable phase shifters[10] are few other examples which are ready to get deployed in 5G systems.

ConclusionThe Development of RF MEMS technology in recent years with enhanced performance indicates that the RF MEMS devices and componentsare strong contenders for deployment in5G systems.

References:

1. C. Nguyen, "Vibrating RF MEMS for next generation wireless applications,"Proceedings, Custom Integrated Circuits Conference, Piscataway, NJ: IEEE Press, 2004, pp. 257-264.
2. J Jason Yao, “RF MEMS from a device perspective,” J.Micromech. Microeng.2000, Vol.10, pp R9- R38.
3. J. Rodriguez, “Fundamentals of 5G Mobile Networks,” NJ, USA, Wiley, 2015.
4. Li-Ya Ma, NorhayatiSoin, MohamadHazwanMohdDaut, SharifahFatmadiana Wan MuhamadHatta,” Comprehensive Study on RF-MEMS Switches Used for 5G Scenario,” IEEE Access, Vol.7 2019.
5. Jacopo Iannacci, “RF MEMS technology as an enabler of 5G: Low-loss ohmic switch tested upto 110 GHz,” Sensors and Actuators A: Physical, 279(2018) pp 624-629.
6. Jefiiev DeNatale, Robert Mihailovich, “RF MEMS Reliability,” The 12th International Conference on Solid State Sensors, Actuators and Microsystems, Boston. June 8-12, 2003.
7. H.-H. Yang, H. Zareie, and G. M. Rebeiz, ‘‘A high power stress gradient resilient RF

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MEMS capacitive switch,'' J. Microelectromech. Syst., vol. 24, no. 3, pp. 599–607, Jul. 2015.
8. Rajesh S. Pande, R.M. Patrikar, "Finite element analysis and optimization of RF MEMS devices," International conference on computer aided engineering, IIT Madras India, Dec. 2007, pp 375-383.
9. Vijay K Varadan, KJVinoy and K.A. Jose, "RF MEMS and Their Applications," John Wiley & Sons, Ltd. 2003.
10. Jacopo Iannacci, "RF MEMS technology for high performance passives," IOP Publishing Ltd 2017.
11. Yansong Yang, R Lu, Tomas Manzaneque, Songpin Gong," Toward Ka Band Acoustics: Lithium Niobate Asymmetrical Mode Piezoelectric MEMS Resonators," IEEE International Frequency Control Symposium (IFCS), Olympic Valley, CA, USA, 2018.
12. Azadeh Ansari, Mina Rais-Zadeh," An 8.7 GHz GaN Micromechanical Resonator with an Integrated AlGaN/GaN HEMT, Solid State Sensors, Actuators and Microsystems Workshop, Hilton Head Island, South Carolina, June 2014.