"DESIGN DISK RESONATOR USING MICRO-ELECTRO-MECHANICAL SYSTEM (MEMS) FOR GSM AND RF APPLICATIONS"

[1]MISS. KOMAL S. KSHIRSAGAR
Department of Electronics & Telecommunication Engineering, Prof. Ram Meghe Institute of Technology & Research, Badnera, India
kshirsagarkomal09@gmail.com

[2]DR. P. V. INGOLE
Department of Electronics & Telecommunication Engineering, Prof. Ram Meghe Institute of Technology & Research, Badnera, India

ABSTRACT: *Over the past few years, Micro-Electro-Mechanical system (MEMS) based on-chip resonators have shown significant potential for sensing and high frequency signal processing applications. Due to advanced developments in the MEMS switches, it is desirable to use MEMS switches. MEMS switches offer lower insertion loss and higher isolation, zero power consumption, small size and weight and very low intermodulation distortion. RFMEMS components are mainly used as inductors, tunable capacitors, switches, in VCOs, and resonators MEMS switches for wireless applications include transmit/receive duplexers, band-mode selection, time delay for phased-array antennas, and reconfigurable antennas. By integrating RF MEMS in the entire system, it will enhance the entire operation of the harvester. The size and cost will be reduced to great extent. In this paper proposed the disk resonator using Micro-Electro-Mechanical technology at resonance frequencies between 20 to 24 MHz. This disk resonator replaced the quartz crystal oscillator and filters and it is used for GSM and RF Applications. The disk resonates in out of plane mode. The mode shape is selected such that four electrodes are used to excite the disk in resonance. The COMSOL FEM is used to design disk resonator. The solid mechanics physics has been used to check the stress and displacement of structure. The electro mechanics has been used to excite disk resonator with help of electrodes.*

***Keywords*:** COMSOL, Micro-Electro-Mechanical, *resonators, excite disk resonator.*

1. INTRODUCTION

Due to wide and tremendous increase in usage of wireless technologies, energy transmitted by broadcast stations, cellular stations and Wi-Fi access points can be harvested by operating ultra-low power electronic devices and sensors. It can be accomplished by having antennas, rectifier circuits for conversion of RF signals into DC, super capacitor, boost converters and necessary power management circuits. RFMEMS components are mainly used as inductors, tunable capacitors, switches, in VCOs, and resonators. Popular MEMS switches for wireless applications include transmit/receive duplexers, band-mode selection, time delay for phased-array antennas, and reconfigurable antennas. The efficiency of energy harvester developed in [1] can be improved by modifying the components based on MEMS devices. In addition to the improvement of efficiency the power consumption within the devices are reduced to great extent. RF MEMS technology promises to enable on-chip switches with zero standby power consumption, nano-Joule-level switching power; high quality inductors, capacitors and varactors; highly stable (quartz-like) oscillators; and high performance filters operating in the tens of megahertz-to several gigahertz frequency ranges. The availability of such an arsenal of first rate RF and microwave components will provide designers with the elements they have long hoped for to create novel and simple (but powerful) reconfigurable systems. These MEMS based components and devices are more flexible and compatible with the 'smart' antenna. This integrated system improves the overall performance of the system. The overall system including smart antenna, energy convertor circuits along with WSN module is shown in figure. The entire system is split into two, i.e. Energy harvester circuit and Wireless sensor and control network. The design of energy harvester initiates from antenna and ends in the useable power for the WSN and the second part is the conventional WSN module.

2. RELATED WORK

A. A. Zainuddin et.al. [1] present the design and analysis result of a low power, low noise, 20 MHz CMOS-MEMS oscillators. To perform oscillator circuit simulations, the CMOS-MEMS resonator (Clamped-Clamped beam) was modeled using its RLC equivalent circuits. For a MEMS resonator to be able to function as an oscillator it needs to be coupled with supporting amplifier circuits. The MEMS beam resonator has 73dB insertion loss which translates to motional resistance of Rx=3M, capacitance, Cx=4.58aF and inductance, Lx=14.5H respectively. The amplifier design is based on the requirement for oscillation, which is, the loop gain of one and the zero phase shifts. For this work, the pierce circuit topology was chosen due to its simplicity and high frequency stability. Both the amplifier and beam resonators were designed using Silterra's CMOS technology. The design of the amplifier comprises of 6 transistors, which are integrated with the

MEMS beam resonator to form an oscillator. The proposed CMOS-MEMS oscillators are capable of generating 20 MHz clocks. The beam resonators require approximately 40VDC and 400mV, VAC to vibrate. The actuation was simulated and measured using Finite modeling software, FEM and Cadence to obtain the desired design parameters. The design of 20MHz oscillator produces output power –1.45dBm by using 1.8V power supply.

Alexandr Kuzmin et. al. [3] provides a comparison of energy consumption in WSN with different criteria and modeling of lifecycle networking. Description of routing algorithms - Directed Diffusion and Geographic Adaptive Fidelity, which was based WSN. The simulation results showed that the method of routing Directed Diffusion more energy-intensive than the method Geographic Adaptive Fidelity.

Jong-Wan Kim et. al. [4] presents the development of monolithically integrated RF transmitters and antennas for MEMS sensors such as accelerometers. Integrating wireless communication ability on-chip micro sensor, sensors can communicate the sensing data with information network by wireless. Integration technology of MEMS sensors and RFCMOS including RF passive components is required to realize highly integrated smart micro sensors. CMOS oscillators with 315MHz carrier frequency are designed and fabricated by our CMOS/MEMS integration technology. Spiral inductors for resonators and monolithic antennas have been realized with IC metallization process. Each essential component have been fabricated and evaluated.

Yanzhu Zhaoa et. al. [5] presents a radio-frequency (RF) evanescent-mode cavity resonator for passive wireless sensor applications. The evanescent-mode resonator is composed of a cavity with a center post. The resonant frequency of the resonator is determined by the dimension of the cavity, the gap between top membrane electrode of the cavity, and the center post. They proposed the top electrode of the cavity resonator is deformed when airflow is applied. This results in a resonant frequency shift. A coplanar waveguide (CPW) coupling method has also been proposed for the sensor structures. The proposed coupling method has demonstrated low transition loss with a relatively simplified signal feeding structure, resulting in easy integration of sensing elements and RF antenna. The fabrication of the proposed flow sensor is realized by a simple molding technology. Measurements of airflow velocity using the proposed flow-sensor have been demonstrated with sensitivity of 0.37 GHz/(m/s). Passive wireless interrogation has also been achieved by integrating the sensor with a pair of ultra-wide-bandwidth (UWB) antennas.

3. SYSTEM DESIGN

To find the effectiveness of the proposed method implemented in COMSOL Simulation software.

3.1 Analysis

The Materials used in MEMS resonator:

- Poly Silicon (Disk structure with anchor and beam)
- Gold (electrode)
- Air (Dielectric)

3.2 Solid Mechanics

The first step is to study free disk vibration using this COMSOL Multi-physics Software. This study gives the behavior of free disk at different eigen frequencies. All edges boundary of this disk are free which is shown in figure. The solid mechanics Physics is selected for this study. This physics give insight of modes of vibration produced due to application of mechanical stress. The stress in structure produces deformation which can be simulated by solid mechanics physics.

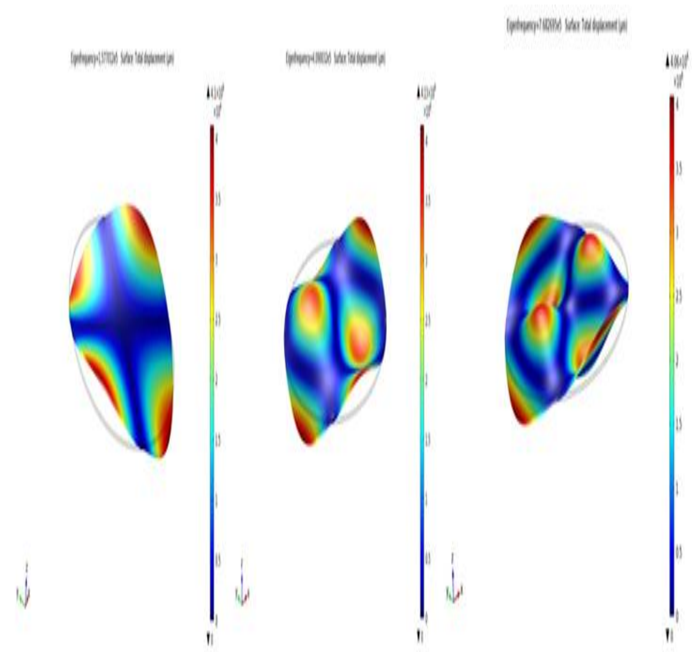


Figure 1: Free Disk vibration at various Eigen frequencies

After this study of behavior of different Eigen frequency, we selected frequency in between 20 to 24 MHz which is used for Frequency Domain Analysis. We did Frequency domain analysis in Solid mechanics. In Frequency Domain Analysis, We selected mode shape for next process which is show in fig. The force is applied to disk quarter's surfaces such that it vibrates in mode shape given in Eigen frequency analysis. The 1 nN forces is applied upwards to two disk surfaces and other two have down ward surfaces.

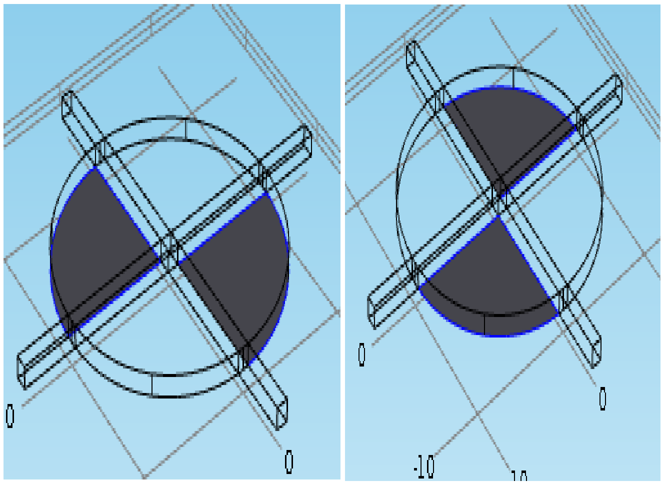


Figure 2: Boundary load apply on disk

Then we observed the behavior of the resonator disk in solid mechanics physics when we give them external force.

3.3 Electro-Mechanics domain

In this domain there are different nodes to design the resonator. Free deformation node is comes with physics. It models structure which can deform. Second is the linear elastic Material mode which includes the deformation of disk ,beam and anchor. This node adds the necessary equation for deformation of disk and beams. In the Fixed mesh node, the electrodes we used for design are not deformed. Fixed constraint node, the boundaries of the disk which is connected to anchor beam is fixed. We design the resonator in electro mechanics physics. In electro mechanics, we apply the electrical potential to the disk resonator on either side of the quarter's surfaces. In which we maintain the same frequency i.e.20 to 24 MHz.

4. CONSTRUCTION

The geometry of disk resonator in electro-mechanics is shown in figure. The resonator is placed at middle, the electrode are connected at the bottom of the disk resonator. The anchors are connected to the supporting beam. And anchors are used for hanging purpose because the fixed part of disk does not deformed. After that we placed the resonator to the air box at temperature 2930 K. We apply the 1V electric potential to the disk resonator diagonically which is shown in below.

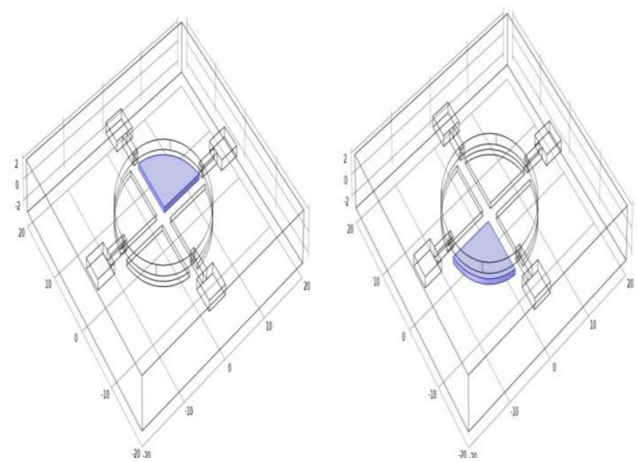


Figure 3: structure of disk resonator indicates apply voltage to input electrodes

In electromechanical interface, an electrical signal at the input port gets transducer into a mechanical signal (force on the resonator) which is filtered by the mechanical response of the beam giving displacement of it. when electric potential are applied to resonator ,then the gap between disk and electrodes are changes then displacement will changes due to this capacitance is changed at that instant current will generated. This mechanical response is translated back to the electrical domain by the output transducer.

4.1 Working Analysis of Disk Resonator Using MEMs System:

Firstly, we select the electro-mechanics physics to design disk resonator and we selected the resonance frequencies in between 20 to 24MHz.we apply the electrical potential dc is 1.5v and ac both to input terminal of the disk, because dc potential is used to actuation in disk and ac potential is used to excitation to pass electrical signal from one side into another side in system. Due to both potential the mechanics force is generated and then stress is enduced in the system and we get the maximum displacement in output electrode of the disk at selected resonance frequency.

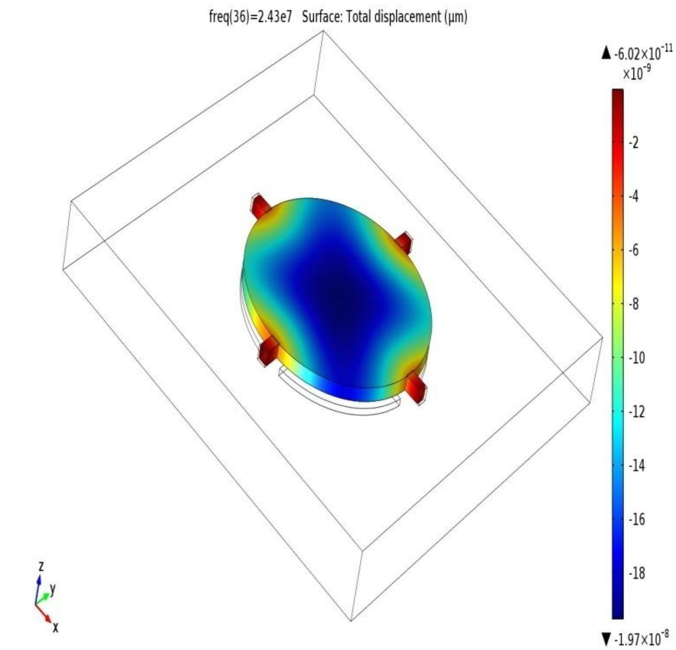


Figure 4: Disk Resonator

4.2 Working of Two Disk Resonator Array:

We take two disk resonators having the same dimension and same resonance frequency only we add between them is beam which coupled them. This 2 disk resonators are coupled by mechanical coupling. The resonators vibrates simultaneously in same manner which is called as two disk resonator array and this is used to improve the power/current handling capacity .If any system required more current then multiple resonator are required for that system due to limited current is pass through them .The coupling beam act as transmission line which exchange energy between two resonators. The one resonator is driven in resonance by electric potential other can be used as output as resonance in that resonator induces current in electrodes. The design of 2 disk resonator array is given below.

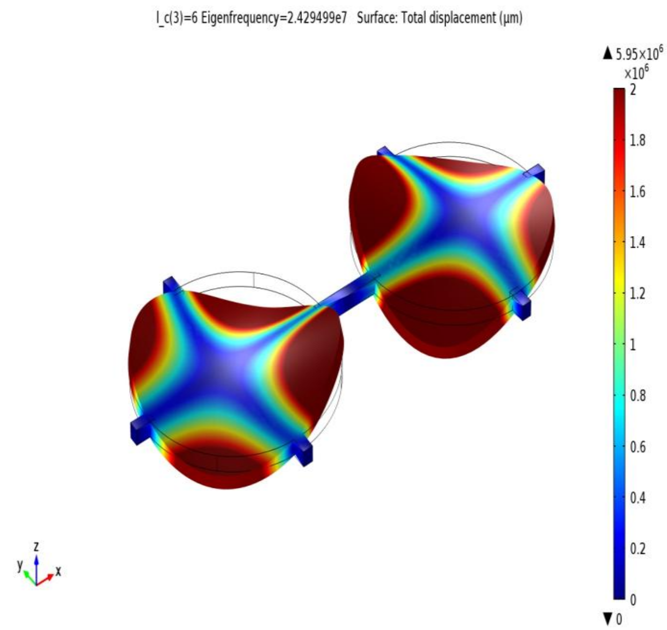


Figure 5: Two- Disk resonator Array design

5. EXPERIMENTAL RESULTS

Output of Frequency Domain Analysis in solid mechanics:

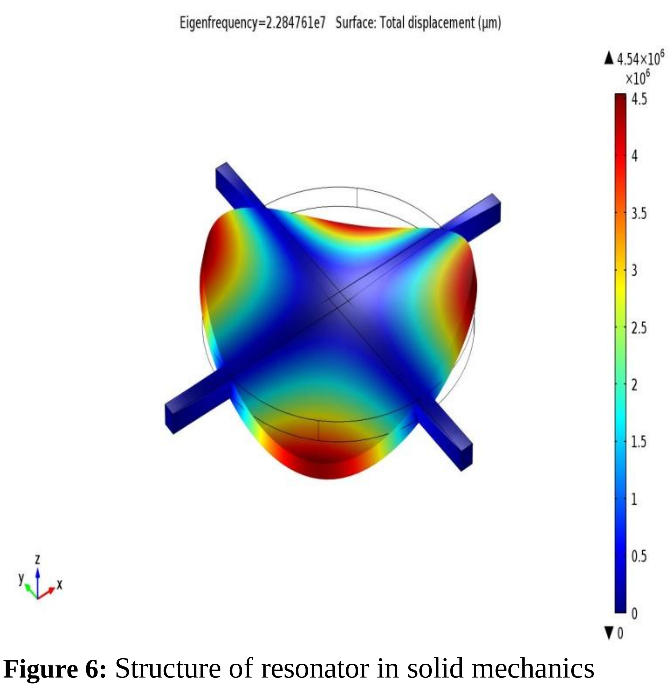


Figure 6: Structure of resonator in solid mechanics

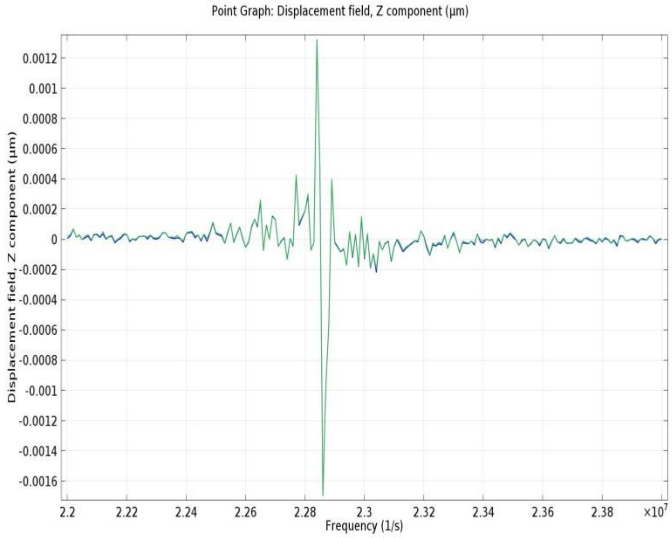


Figure 7: Point graph between the displacement and frequency in solid mechanics physics

5.1 Output of Frequency Domain Analysis in Electro-mechanics

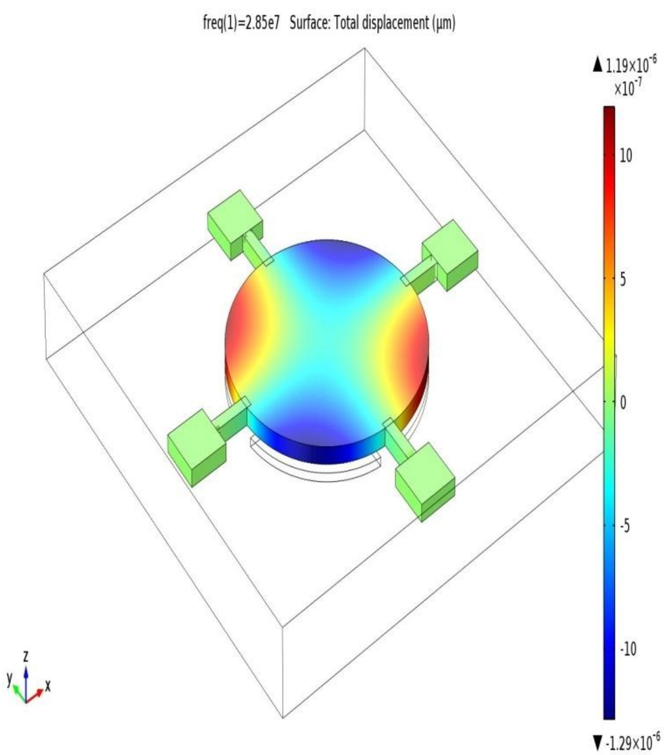


Figure 8: Structure of disk resonator in frequency domain in electro-mechanics

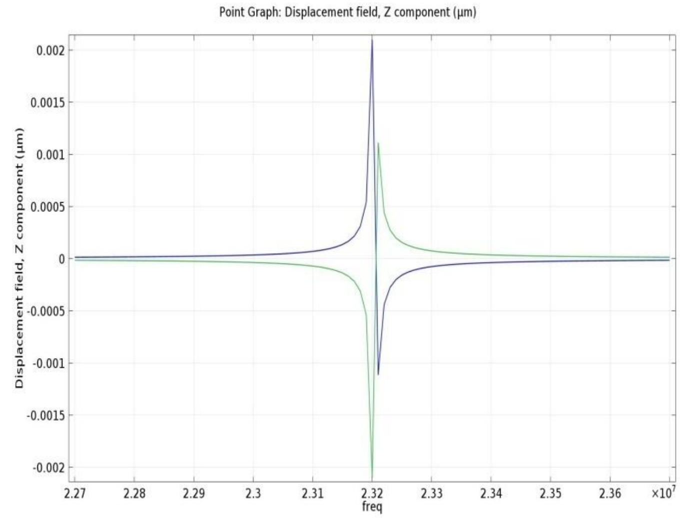


Figure 9: Point graph between the displacement and frequency in electro-mechanics physics at I/O

5.2 Graphical Analysis:

MODE 2: We select the mode two domains for analysis:

5.2.1 Plot of Eigen Frequency Vs Radius

In this mode we can see the graph between eign frequency verses radius of disk, if the radius is increases then eigen frequency is decreases. The increasing radius reduces the stiffness of structure and also increases the mass. Hence frequency of resonance increases with reduction of radius. The lower radius are used to achieve resonance frequency in range MHz to GHz. Therefore we take the minimum radius to get maximum eigen value for the disk.

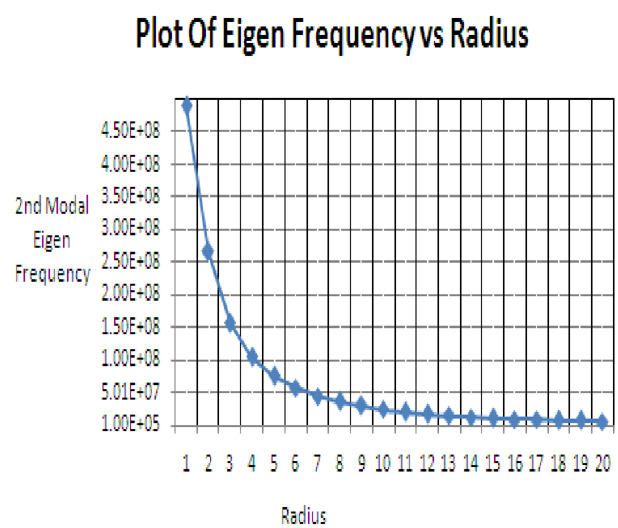


Figure 10: Graph between radius and eigen frequency

5.2.2 Plot between eigen frequency and thickness:

if the thickness of disk is maximum then eigen frequency is also maximum linearly in second mode.

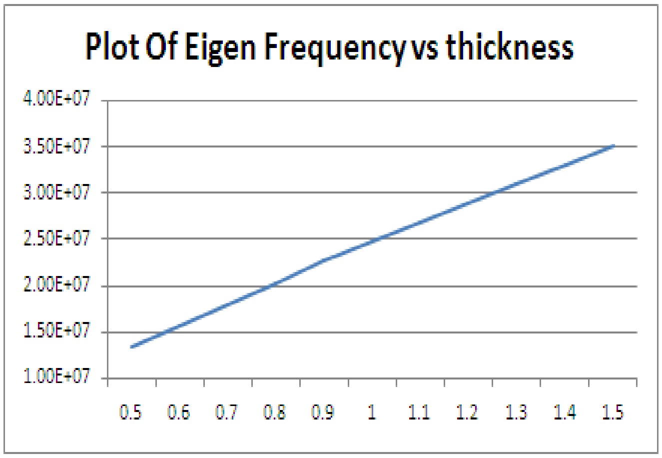
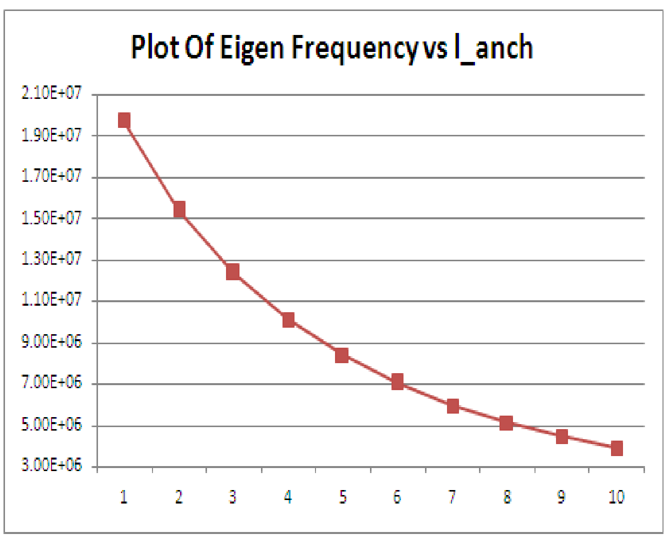


Figure 11: Graph between thickness verses resonance frequency

5.2.3 Plot of Eigen frequency vs anchor length:

The anchor beam dimension governs the resonance frequency as well the quality factor of structure. The increasing anchor length reduces the resonance frequency. This is because of reducing stiffness of structure which also reduces quality factor. If we increase the anchor length during the design of disk resonator then the resonance frequency we got is minimum as shown in below graph.



Figurev12: Graph between anchor length and resonance frequency

5.2.4 Output Displacement of disk resonator

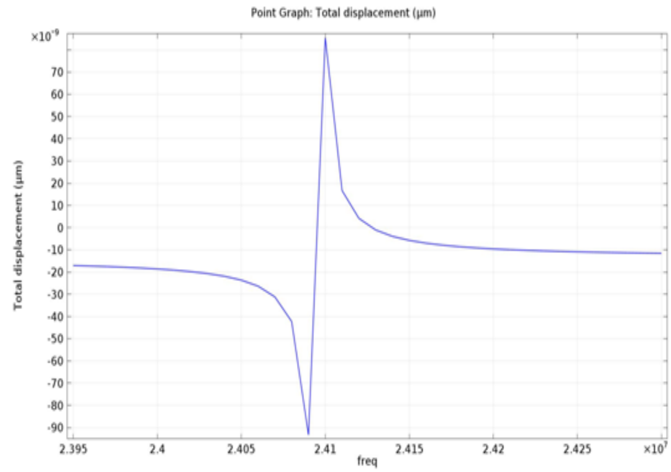


Figure 13: Displacement of the disk resonator at the output electrodes

6. CONCLUSION

In this paper proposed the disk resonator using Micro-Electro-Mechanical technology at resonance frequencies between 20 to 24MHz.this disk resonator replaced the quartz crystal oscillator and filters and it is used for GSM and RF Applications. The disk resonates in out of plane mode. The mode shape is selected such that four electrodes are used to excite the disk in resonance. The four electrodes are circles quarter. These four electrodes give additional freedom of excitation to disk resonance which can cancel noise in differential mode. The anchor beam length is selected such that quality factor is improved for desired eigen frequency. The two resonators are coupled so that they vibrate on single frequency. This coupling mechanism improves the current handling capacity. This makes disk resonator promising device for replacement of off chip component like crystal oscillators.

The COMSOL FEM is used to design disk resonator. The solid mechanics physics has been used to check the stress and displacement of structure. The electro mechanics has been used to excite disk resonator with help of electrodes.

7. REFERENCES

[1] A. A. Zainuddin, J. Karim, A. N. Nordin, M. S.Pandian, S. Khan, "Design and Simulation of 20MHz Oscillator using CMOS-MEMS Beam Resonators", RSM2013 Proc. , Langkawi, Malaysia, 2013.

[2] Hongwei Qu, "Review CMOS MEMS Fabrication Technologies and Devices", Micromachines 7, 14, 2016.

[3] Alexandr Kuzmin, Vasyl Fedeka, "Comparison Energy Cost Wireless Sensor Networks Built on Two Routing Algorithms-directed Diffusion and Geographic Adaptive Fidelity", MEMSTECH, 20-23 April, 2017, Polyana-Svalyava (Zakarpattya), UKRAINE, 2017.

[4] Jong-Wan Kim, Hidekuni Takao, Kazuaki Sawadal, Makoto Ishidal, "Evaluation of Monolithically Integrated Antennas and RF Transmitters for Silicon Smart Micro Sensors with Wireless-Communication Ability", IEEE, SENSORS, EXCO, Daegu, Korea, October 22-25, 2006.

[5] Yanzhu Zhaoa, Yuan Li a, Bo Pana, Seong-Hyok Kima, Zhan Liub, Manos M. Tentzerisa, John Papapolymeroua, Mark G. Allena, "Sensors and Actuators A: Physical", Elsevier, pg 322–328, 2010.

[6] V Amirtha Raj, "Wideband Energy Harvesting Using MEMS for WSN Applications", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 5, Issue 3, March 2016.

[7] O. Brand, "Fabrication Technology", Advanced Micro and Nanosystems. Vol. 2, 2005.

[8] Smith, J.H.; Montague, S.; Sniegowski, J.J.; Murray, J.R.; McWhorter, P.J. Embedded micromechanical devices for the monolithic integration of MEMS with CMOS. In Proceedings of the International Electron Devices Meeting, Washington, DC, USA, 10–13 December 1995; pp. 609–612.