Original Article

Simulation of Rectangular Shaped RF MEMS Shunt Switch and Comparing its Isolation Performance with Series Switch at DC - 30 GHz

V.Sri Nandhini[1], Anitha G[2]

[1]Research Scholar, Department of Electronics and Communication Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamilnadu, India. Pincode:602105.
2Project Guide, Corresponding Author, Department of Electronics and Communication Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamilnadu, India. Pincode:602105.

Abstract

Aim: In this paper, isolation performance of rectangular shaped RF MEMS shunt and series switch is described and simulated at up to 30 GHz using HFSS software. **Materials and Methods:** The isolation performance of rectangular shaped shunt switch (n=25) was compared to the isolation performance of rectangular shaped series switch at a frequency range of upto 30 GHz. Beam was built over the two coplanar waveguides. Samples were calculated using sample computation having a pretest power of 80 % where Alpha, Beta are 0.05 and 0.2 respectively. **Results:** The novel shunt switch has better isolation performance (-36.2488 dB) compared to the series switch (-19.4685 dB). The optimized dimensions for maximum isolation performance were L=360 µm, W=100 µm, T=1 µm for beam. The attained significance of isolation performance is 1<0.001 (p<0.05). **Conclusion:** The observed results show that novel shunt switch isolation performance is significantly higher than series switch.

Keywords: Novel Shunt switch, Series Switch, Isolation Performance, Rectangular Shaped RF MEMS, Coplanar waveguide, Microelectronics.

DOI: 10.47750/pnr.2022.13.S04.066

INTRODUCTION

This paper describes the microelectronics based rectangular shaped RF MEMS shunt switch and series switch in which the beam was constructed over the coplanar waveguides at DC-30 GHz using HFSS software to analyse isolation performance. Improvement in microstructures and the performance prevailed by incorporating into devices are the cause for the growth of MEMS structures (Kurmendra, Kurmendra, and Kumar 2020). Due to its compact size, good linearity, low insertion loss, strong isolation, and exceptionally low power consumption, RF MEMS switches are becoming increasingly important in today's society (Rebeiz 2004). Portable wireless and low-power battery-operated devices benefit from MEMS-based switches. MEMS switches have been commercialized successfully as X-Band applications (Sravani and Girija Sravani 2021), 5G Scenario (Ma et al. 2019)), Reconfigurable series-shunt switch based RF MEMS capacitive switch (Angira, Sundaram, and Rangra 2015), Phase shifter (Anitha and Usha Kiran 2018), phased array(Gopalan and Kommuri 2018) applications, low power consumption applications (Chouhan, Agrawal, and Saxena 2018). Rectangular shaped RF MEMS novel shunt switch can be used in the design of dual band antennas(Suman et al. 2021).

In the last 5 years, several research papers of MEMS switches have been published. IEEE Xplore has publications of around 242 and 9570 papers are published directly in Google Scholar. Evolution of Microelectro-mechanical Systems at a rapid rate makes it difficult for designers to improve design, fabrication of different types of microscale systems and devices (Srikar and Spearing 2003). The excellent performance shows the impedance of the ability of integrating the MEMS switches for antenna applications (Jung et al. 2006). A class of new devices can be provided by RF MEMS and companies that display high frequency performance related to the conventional devices which enables good system compatibilities (Brown 1998).

Our team has extensive knowledge and research experience that has translate into high quality publications(Bhansali et al. 2021; Jayanth et al. 2021; Sudhakar, Ravel, and Perumal 2021; Sathiyamoorthi et al. 2021; Deepanraj et al. 2021; Raju et al. 2021; Arun Prakash et al. 2020; Kamath et al. 2020; Shanmugam et al. 2021; Rajasekaran et al. 2020; Adhinarayanan et al. 2020; Rajesh et al. 2020; Aurtherson et al. 2021). Since low isolation has been an issue for RF MEMS switch performance, tremendous research has been done to reduce the issue. This work goes through how to choose the right switch to be constructed on the coplanar waveguide to improve the efficiency of the system. Main aim of this work is to provide a detailed comparison of isolation performance of series and novel shunt switch at DC - 30 GHz frequency.

Materials And Methods

This work was carried out in the Nanoelectronics Lab, Department of Electronics and Communication Engineering at Saveetha School of Engineering, Chennai. Two groups are considered. Each dataset consists of 25 samples, which in total gives the total sample size of 50. Clinical analysis was used to analyse the pretest power. Pretest power is determined to be 80% with Alpha and Beta value of 0.05 and 0.2 respectively (Craig 2019).

For 2 groups, 2 preparation methods are done. In group 1, design of microelectronics based rectangular shaped MEMS shunt switch using HFSS software is carried out. In this, the dimensions are; length, width and thickness are 1090 µm, 600 µm and 525 µm respectively. Similarly dimensions of the beam like length, width and thickness are 360 µm, 100 µm and 1 µm.

Similar to group 1, preparation for group 2 is also done. In group 2, design of microelectronics based rectangular shaped MEMS series switch using HFSS software is carried out. In this, the dimensions are; length, width and thickness are 1090 µm, 600 µm and 525 µm respectively. Similarly dimensions of the beam which is placed over the two coplanar waveguides are length= 235 µm, width= 130 µm and thickness= µm.

The formula used to determine the isolation performance of Rectangular shaped MEMS shunt switch is given in equation 1 (Rebeiz 2004).

$$S_{21} = -20log\left|\frac{2}{2+(j\omega CdZo)}\right| \qquad (1)$$

Where,
Z_0= Characteristic Impedance
Cd= Down State Capacitance

The large ratio of upstate and downstate capacitance gives the isolation performance of rectangular shaped MEMS novel series switch. Capacitance ratio can be given in equation 2 (Sravani et al. 2020).

$$C_{ratio} = \frac{\varepsilon r[g0+\frac{td}{\varepsilon r}]}{td} \qquad (2)$$

Where,
g_0= Air gap
t_d= Thickness of the oxide layer
ε_r= Dielectric material relative permittivity.

HFSS is a solution for electromagnetic structure for finite elements method (FEM) (Kim, Oh, and An 2012). The full form of HFSS is High frequency structure simulation. HFSS is used to design microelectronics devices, antennas, radio frequency electronic circuit elements containing filters, transmission lines and packaging. The testing procedure measures the RF performance of the proposed shunt switch. Frequency was maintained at about 30 GHz and readings for the isolation performance were taken.

The entire work is carried out in Windows 10 pro, Intel core i3, 7th Gen and HFSS software is used for simulation and verification process. At first, HFSS software should be opened. Dimensions for substrate, Dielectric material, Coplanar waveguide, Anchor, Beam should be given. Also, dimensions for rectangular sheet and airbox should also be given. Then, boundaries and radiation should be assigned. Solution setup and frequency sweep should be added. Finally, validation and design analysis should be done. Thus output can be obtained by selecting S Parameters S(1,1), S(2,1).

Statistical Analysis

The data can be exported in the form of excel from the output. This data should be given to the SPSS software (SPSS Inc 2007). Statistical softwares like HFSS and SPSS are used. HFSS is used for simulation and verification whereas statistical analysis of the data can be done using SPSS. Thickness of substrate and dielectric material are independent of isolation performance whereas length and thickness of beam affects the Isolation performance of the switch.

Results

Microelectronics based RF MEMS novel shunt switch was successfully implemented and analysed at DC to 30 GHz. The dimensions are given as input for the testing process. The dimensions of the design are given. The rectangular shaped beam was placed over the two coplanar waveguides. Then boundaries and radiation can be assigned. The output from the graph is exported in the form of an excel sheet. These values are given to the SPSS software from which statistical analysis can be done. Maximum isolation can be obtained with the dimensions L_b=360 µm, W_b=100 µm, T_b=1 µm.

Comparative analysis of isolation performance of microelectronics based rectangular shaped RF MEMS shunt switch and microelectronics based rectangular shaped RF MEMS series switch at DC 30 GHz are tabulated in Table 1. Isolation performance of the rectangular shaped MEMS shunt switch (-25.2370 dB) is better than the isolation performance of rectangular shaped MEMS series switch (-10.3180 dB). Table 2 depicts the group statistics of both the groups with their mean (34.0495), standard deviation (7.32057 & 6.90227) and standard error mean (.95306 & .89860). Table 3 shows the statistical analysis of both the groups with its p value (<0.001), mean difference (16.21826) and standard error difference(1.30988). Descriptive statistics of both the groups is represented in Table 4 with its n value (50), minimum and maximum values (10.30 & 55.01), mean (25.9404) and standard deviation (10.79368)

Fig. 1. (a) and (b) depicts the top view and side view of the rectangular shaped MEMS switch. Fig. 2. shows the graph for the isolation performance of the rectangular shaped shunt switch which was obtained using origin software. Fig. 3. Shows the graph for the isolation performance of a rectangular shaped series switch which was obtained using origin software. Fig. 4. Shows the graph of comparison of isolation performance of rectangular shaped shunt and series switches. It can be observed that the shunt switch has more isolation in comparison to that of the series switch. From Fig. 5. It can be seen that the mean isolation of the shunt switch is better than the series switch. It has p-value <0.001 and error bar 95 % with proper prediction.

Discussion

Isolation performance of rectangular shaped MEMS shunt and series switch using HFSS at 30GHz is simulated and analysed. Based on different findings, it can be observed that isolation performance of the shunt switch is better than the series switch. This data is stored in an excel sheet for further verification using SPSS software.

This paper describes the simulation and comparison of isolation performance of novel shunt switch and series switch at 30 GHz. The article that supports this work is (Shanthi, Srinivasa Rao, and Girija Sravani 2020) in which higher isolation of -42.11 dB is provided. (Ravirala et al. 2018) has similar higher isolation performance in which isolation of -61 dB is provided (Ravirala et al. 2018) The other article that opposes the present work is (Cho et al. 2005) with isolation of around -20.7 dB. Isolation of -28.4 dB was obtained by (Narayana et al. 2017). These findings shows that many studies gave evidence to support that shunt switch has isolation performance better than series switch. The proposed work has an isolation performance of -25.2370 dB which is better than many of the existing works.

The air gap is one of the elements that affects the isolation performance and actuation voltage of the shunt switch in this work. If the air gap increases, then the isolation decreases. Different techniques like multi-bridge tuning, capacitive series- shunt design and DC- contact series- shunt switches can be used in future work to improve the isolation and reduce the pull-in voltage.

Conclusion

This article examines and enhances the isolation performance of novel shunt switch and series switch at 30 GHz. It can be seen that the isolation performance of the shunt switch (-25.2370 dB) is significantly better than that of the series switch. It is appropriate for high frequency applications.

DECLARATION

Conflict of interests

No conflict of interest in this manuscript.

Author Contributions

Author VSN was involved in design, Simulation, data collection, data analysis, and manuscript writing. Author AG was involved in conceptualization, data validation and critical review of manuscript.

Acknowledgement

The authors would like to express their gratitude towards Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences (Formerly known as Saveetha University) for providing the necessary infrastructure to carry out this work successfully.

Funding: We thank the following organizations for providing financial support that enabled us to complete the study.

1. Inmitto Solutions, Chennai..
2. Saveetha University
3. Saveetha Institute of Medical and Technical Sciences.
4. Saveetha School of Engineering.

References

1. Adhinarayanan, Rajesh, Aravindh Ramakrishnan, Gopal Kaliyaperumal, Melvinvíctor De Poures, Rajesh Kumar Babu, and Damodharan Dillikannan. 2020. "Comparative Analysis on the Effect of 1-Decanol and Di-N-Butyl Ether as Additive with diesel/LDPE Blends in Compression Ignition Engine." *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, June, 1–18.
2. Angira, Mahesh, G. M. Sundaram, and Kamaljit Rangra. 2015. "Performance Improvement of a Reconfigurable Series-Shunt Switch via Asymmetric Structure Based RF-MEMS Capacitive Switch." *International Journal of Advances in Engineering Sciences and Applied Mathematics*. https://doi.org/10.1007/s12572-015-0146-x.
3. Anitha, G., and K. Usha Kiran. 2018. "Miniaturized Switched Line MEMS Phase Shifter." *Microwave and Optical Technology Letters*. https://doi.org/10.1002/mop.31199.
4. Arun Prakash, V. R., J. Francis Xavier, G. Ramesh, T. Maridurai, K. Siva Kumar, and R. Blessing Sam Raj. 2020. "Mechanical, Thermal and Fatigue Behaviour of Surface-Treated Novel Caryota Urens Fibre–reinforced Epoxy Composite." *Biomass Conversion and Biorefinery*, August. https://doi.org/10.1007/s13399-020-00938-0.
5. Aurtherson, P. Babu, Bhanu Teja Nalla, Karthikeyan Srinivasan, Kulmani Mehar, and Yuvarajan Devarajan. 2021. "Biofuel Production from Novel Prunus Domestica Kernel Oil: Process Optimization Technique." *Biomass Conversion and Biorefinery*, May. https://doi.org/10.1007/s13399-021-01551-5.
6. Bhansali, Karan J., Kamlesh R. Balinge, Subodh U. Raut, Shubham A. Deshmukh, M. Senthil Kumar, C. Ramesh Kumar, and Pundlik R. Bhagat. 2021. "Visible Light Assisted Sulfonic Acid-Functionalized Porphyrin Comprising Benzimidazolium Moiety for Photocatalytic Transesterification of Castor Oil." *Fuel* 304 (November): 121490.
7. Brown, E. R. 1998. "RF-MEMS Switches for Reconfigurable Integrated Circuits." *IEEE Transactions on Microwave Theory and Techniques*. https://doi.org/10.1109/22.734501.
8. Cho, Il-Joo, Taeksang Song, Sang-Hyun Baek, and Euisik Yoon. 2005. "A Low-Voltage and Low-Power RF MEMS Series and Shunt Switches Actuated by Combination of Electromagnetic and Electrostatic Forces." *IEEE Transactions on Microwave Theory and Techniques*. https://doi.org/10.1109/tmtt.2005.850406.
9. Chouhan, Himanshuraj Singh, Vimal Kumar Agrawal, and Ankur Saxena. 2018. "Actuation Voltage Analysis Using FEM of RF MEMS Switch Design for Low Power Consumption Application." *2018 8th IEEE India International Conference on Power Electronics (IICPE)*. https://doi.org/10.1109/iicpe.2018.8709458.
10. Craig, Gloria P. 2019. *Clinical Calculations Made Easy: Solving Problems Using Dimensional Analysis*. LWW.
11. Deepanraj, B., N. Senthilkumar, D. Mala, and A. Sathiamourthy. 2021. "Cashew Nut Shell Liquid as Alternate Fuel for CI Engine—optimization Approach for Performance Improvement." *Biomass Conversion and Biorefinery*, February. https://doi.org/10.1007/s13399-021-01312-4.
12. Gopalan, Anitha, and Usha Kiran Kommuri. 2018. "Design and Development of Miniaturized Low Voltage Triangular RF MEMS Switch for Phased Array Application." *Applied Surface Science*. https://doi.org/10.1016/j.apsusc.2018.02.210.
13. Jayanth, Bellappu Venkat, Melvin Victor Depoures, Gopal Kaliyaperumal, Damodharan Dillikannan, Dilipsingh Jawahar, Kumaran Palani, and Ganesha Prasad Meravanigee Shivappa. 2021. "A Comprehensive Study on the Effects of Multiple Injection Strategies and Exhaust Gas Recirculation on Diesel Engine Characteristics That Utilize Waste High Density Polyethylene Oil." *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, June, 1–18.
14. Jung, C., M. Lee, G. P. Li, and F. DeFlaviis. 2006. "Reconfigurable Scan-Beam Single-Arm Spiral Antenna Integrated With RF-MEMS Switches." *IEEE Transactions on Antennas and Propagation*. https://doi.org/10.1109/tap.2005.863407.
15. Kamath, Manjunath, Subha Krishna Rao, Jaison, Sridhar, Kasthuri, Gopinath, Sivaperumal, and Shantanu Patil. 2020. "Melatonin Delivery from PCL Scaffold Enhances Glycosaminoglycans Deposition in Human Chondrocytes – Bioactive Scaffold Model for Cartilage Regeneration." *Process Biochemistry* 99 (December): 36–47.
16. Kim, Ji-Woong, Joo-Heon Oh, and Beong-Ku An. 2012. "HFSS Based Small Patch Antenna Design." *The Journal of the Institute of Webcasting, Internet and Telecommunication*. https://doi.org/10.7236/jiwit.2012.12.3.133.
17. Kurmendra, Kurmendra, and Rajesh Kumar. 2020. "A Modified Capacitance Model of Shunt Micro Switch Based on MEMS Technology in Actuation Mode: Simulation and Analytical Study." *Journal of Physics: Conference Series*. https://doi.org/10.1088/1742-6596/1432/1/012007.
18. Ma, Li-Ya, Norhayati Soin, Mohamad Hazwan Mohd Daut, and Sharifah Fatmadiana Wan Hatta. 2019. "Comprehensive Study on RF-MEMS Switches Used for 5G Scenario." *IEEE Access*. https://doi.org/10.1109/access.2019.2932800.
19. Narayana, T. Lakshmi, T. Lakshmi Narayana, K. Girija Sravani, and K. Srinivasa Rao. 2017. "Design and Analysis of CPW Based Shunt Capacitive RF MEMS Switch." *Cogent Engineering*. https://doi.org/10.1080/23311916.2017.1363356.
20. Rajasekaran, S., D. Damodharan, K. Gopal, B. Rajesh Kumar, and Melvin Victor De Poures. 2020. "Collective Influence of 1-Decanol Addition, Injection Pressure and EGR on Diesel Engine Characteristics Fueled with diesel/LDPE Oil Blends." *Fuel* 277 (October): 118166.
21. Rajesh, A., K. Gopal, De Poures Melvin Victor, B. Rajesh Kumar, A. P. Sathiyagnanam, and D. Damodharan. 2020. "Effect of Anisole Addition to Waste Cooking Oil Methyl Ester on Combustion, Emission and Performance Characteristics of a DI Diesel Engine without Any Modifications." *Fuel* 278 (October): 118315.
22. Raju, P., K. Raja, K. Lingadurai, T. Maridurai, and S. C. Prasanna. 2021. "Glass/Caryota Urens Hybridized Fibre-Reinforced nanoclay/SiC Toughened Epoxy Hybrid Composite: Mechanical, Drop Load Impact, Hydrophobicity and Fatigue Behaviour." *Biomass Conversion and Biorefinery*, March. https://doi.org/10.1007/s13399-021-01427-8.
23. Ravirala, Akshay Kumar, Leela Koteswari Bethapudi, Jeevani Kommareddy, Bhanu Sai Thommandru, Sateesh Jasti, Prakash Raju Gorantla, Ashok Puli, Girija Sravani Karumuri, and Srinivasa Rao Karumuri. 2018. "Design and Performance Analysis of Uniform Meander Structured RF MEMS Capacitive Shunt Switch along with Perforations." *Microsystem Technologies*.

https://doi.org/10.1007/s00542-017-3403-z.
24. Rebeiz, Gabriel M. 2004. *RF MEMS: Theory, Design, and Technology*. John Wiley & Sons.
25. Sathiyamoorthi, Ramalingam, Gomathinayakam Sankaranarayanan, Dinesh Babu Munuswamy, and Yuvarajan Devarajan. 2021. "Experimental Study of Spray Analysis for Palmarosa Biodiesel-diesel Blends in a Constant Volume Chamber." *Environmental Progress & Sustainable Energy* 40 (6). https://doi.org/10.1002/ep.13696.
26. Shanmugam, Rajasekaran, Damodharan Dillikannan, Gopal Kaliyaperumal, Melvin Victor De Poures, and Rajesh Kumar Babu. 2021. "A Comprehensive Study on the Effects of 1-Decanol, Compression Ratio and Exhaust Gas Recirculation on Diesel Engine Characteristics Powered with Low Density Polyethylene Oil." *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects* 43 (23): 3064–81.
27. Shanthi, G., K. Srinivasa Rao, and K. Girija Sravani. 2020. "Design and Analysis of a RF MEMS Shunt Switch Using U-Shaped Meanders for Low Actuation Voltage." *Microsystem Technologies*. https://doi.org/10.1007/s00542-020-04864-z.
28. SPSS Inc. 2007. *SPSS 16.0 Brief Guide*. Prentice Hall.
29. Sravani, K. Girija, and K. Girija Sravani. 2021. "Optimization and Analysis of Bridge Type RF MEMS Switch for X-Band." *Microsystem Technologies*. https://doi.org/10.1007/s00542-020-05152-6.
30. Sravani, K. Girija, K. Girija Sravani, Koushik Guha, and K. Srinivasa Rao. 2020. "Analysis of a Novel RF MEMS Switch Using Different Meander Techniques." *Microsystem Technologies*. https://doi.org/10.1007/s00542-019-04703-w.
31. Srikar, V. T., and S. M. Spearing. 2003. "A Critical Review of Microscale Mechanical Testing Methods Used in the Design of Microelectromechanical Systems." *Experimental Mechanics*. https://doi.org/10.1007/bf02410522.
32. Sudhakar, M. P., Merlyn Ravel, and K. Perumal. 2021. "Pretreatment and Process Optimization of Bioethanol Production from Spent Biomass of Ganoderma Lucidum Using Saccharomyces Cerevisiae." *Fuel* 306 (December): 121680.
33. Suman, Maloji, S. Deepika, S. Jagadeswari Sai Priya, and M. Prasanth. 2021. "Design of Dual Band Antenna with Asymmetric Microstrip-Fed Dual U-Shaped for Wireless Applications." *2021 3rd International Conference on Signal Processing and Communication (ICPSC)*. https://doi.org/10.1109/icspc51351.2021.9451727.

TABLES AND FIGURES

Table 1. Comparison of isolation performance of rectangular shaped MEMS novel shunt and series switches with L_b=360 µm, W_b=100 µm, T_b=1 µm at up to 30 GHz.

S. No.	SWITCH	FREQUENCY (GHz)	ON STATE RETURN LOSS(dB)	ON STATE INSERTION LOSS(dB)	OFF STATE ISOLATION(dB)
1.	Shunt	10	-21.1214	-0.1135	-36.2488
		20	-15.1867	-0.2554	-29.6459
		30	-11.8045	-0.4699	-25.2370
2.	Series	10	-40.1670	-0.0592	-19.4685
		20	-33.6729	-0.0976	-13.5769
		30	-30.1059	-0.1430	-10.3180

Table 2. Representation of group statistics for both sample groups, mean (34.0495), standard deviation (7.32057 & 6.90227) and standard error mean (.95306 & .89860) at up to 30 GHz

GROUP	N	MEAN	STD. DEVIATION	STD. ERROR
SHUNT	25	34.0495	7.32057	.95306

SERIES	25	17.8312	6.90227	.89860

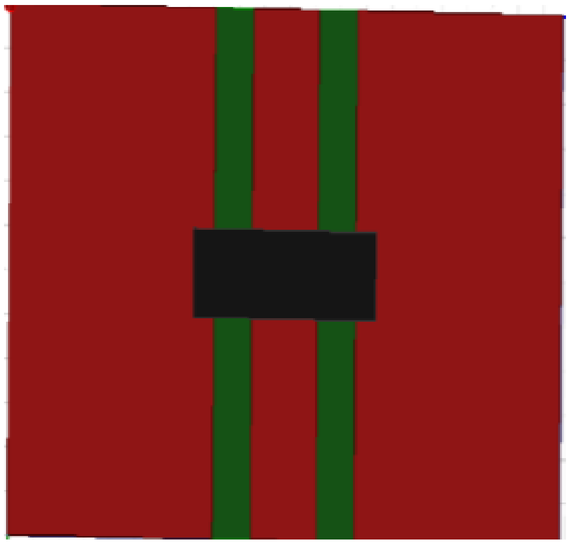
Table 3. Representation of statistical analysis of independent sample tests for both the sample groups. p value (0.001), mean difference (16.21826) and standard error difference (1.30988) at up to 30 GHz.

ISOLATION		**ONE-SIDED P**	**TWO-SIDED P**	**MEAN DIFFERENCE**	**STD. ERROR DIFFERENCE**
	Equal variances assumed	<0.001	<0.001	16.21826	1.30988
	Equal variances not assumed	<0.001	<0.001	16.21826	1.30988

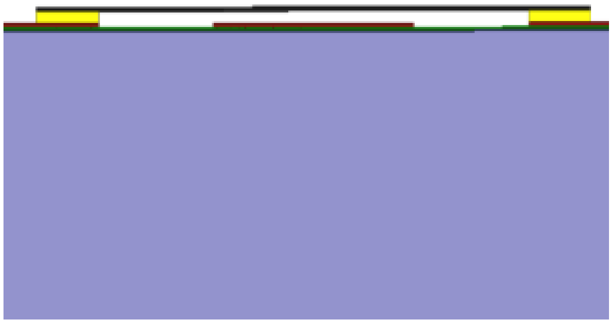
Table 4. Representation of descriptive statistics for both the sample groups. n value (50), minimum and maximum values (10.30 & 55.01), mean (25.9404) and standard deviation (10.79368)

PARAMETER	**N**	**MINIMUM**	**MAXIMUM**	**MEAN**	**STD. DEVIATION**
ISOLATION	50	10.30	55.01	25.9404	10.79368

FIGURES



(a)



(b)

Fig. 1. Design of RF MEMS switch using HFSS (a) Top view and (b) side view (X-axis : Width of feedline and substrate, Y-axis: Length of the substrate and Z-axis: Thickness of the substrate).

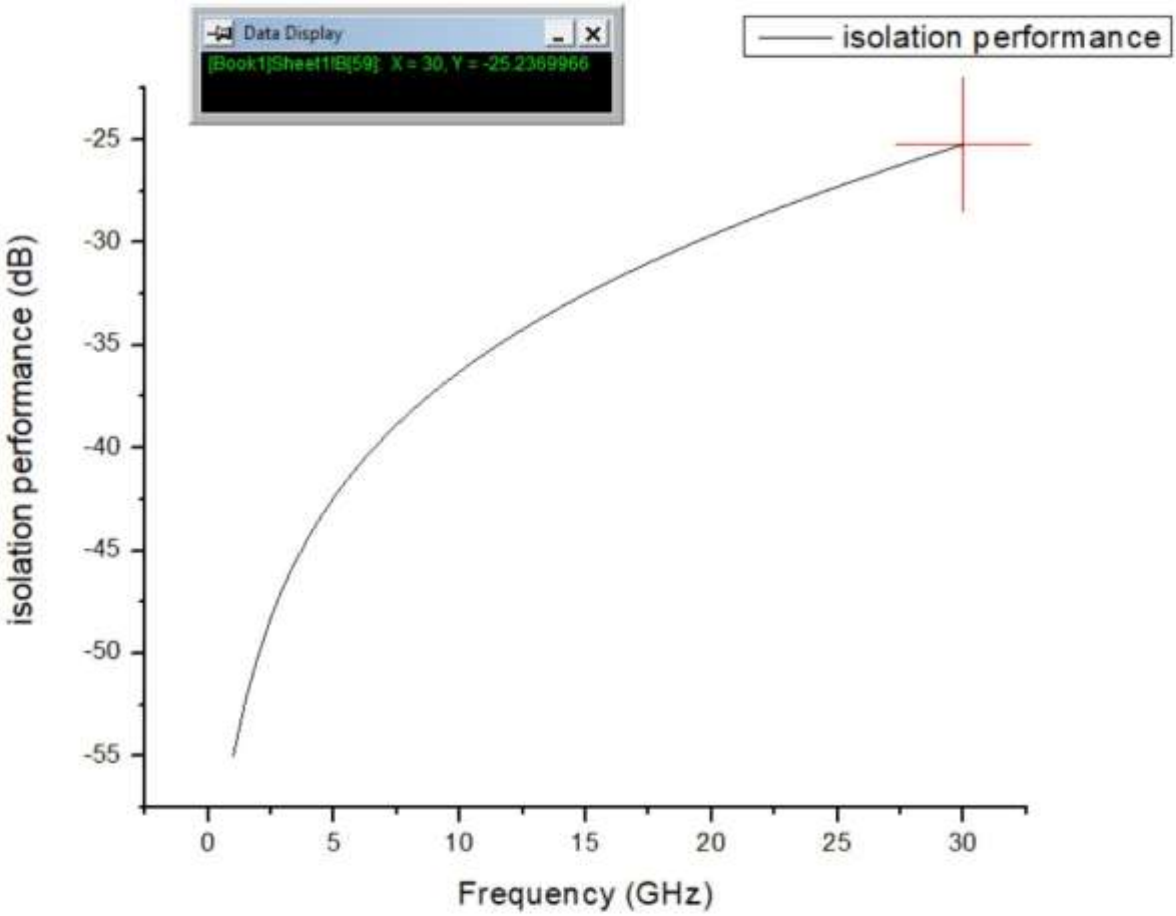


Fig. 2. Isolation performance (-25.2369 dB) of rectangular shaped MEMS shunt switch at up to 30 GHz.

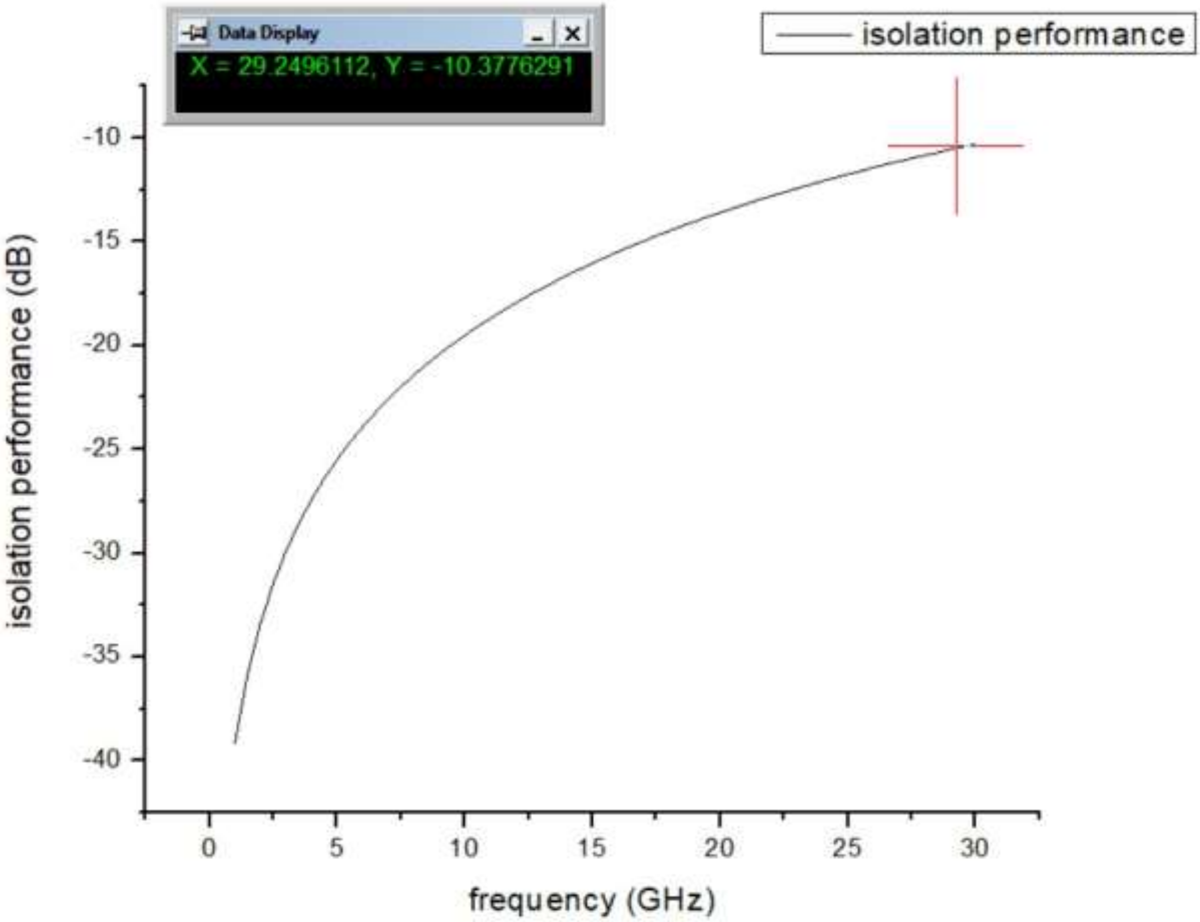


Fig. 3. Isolation performance (-10.3776) of rectangular shaped MEMS series switch at upto 30 GHz

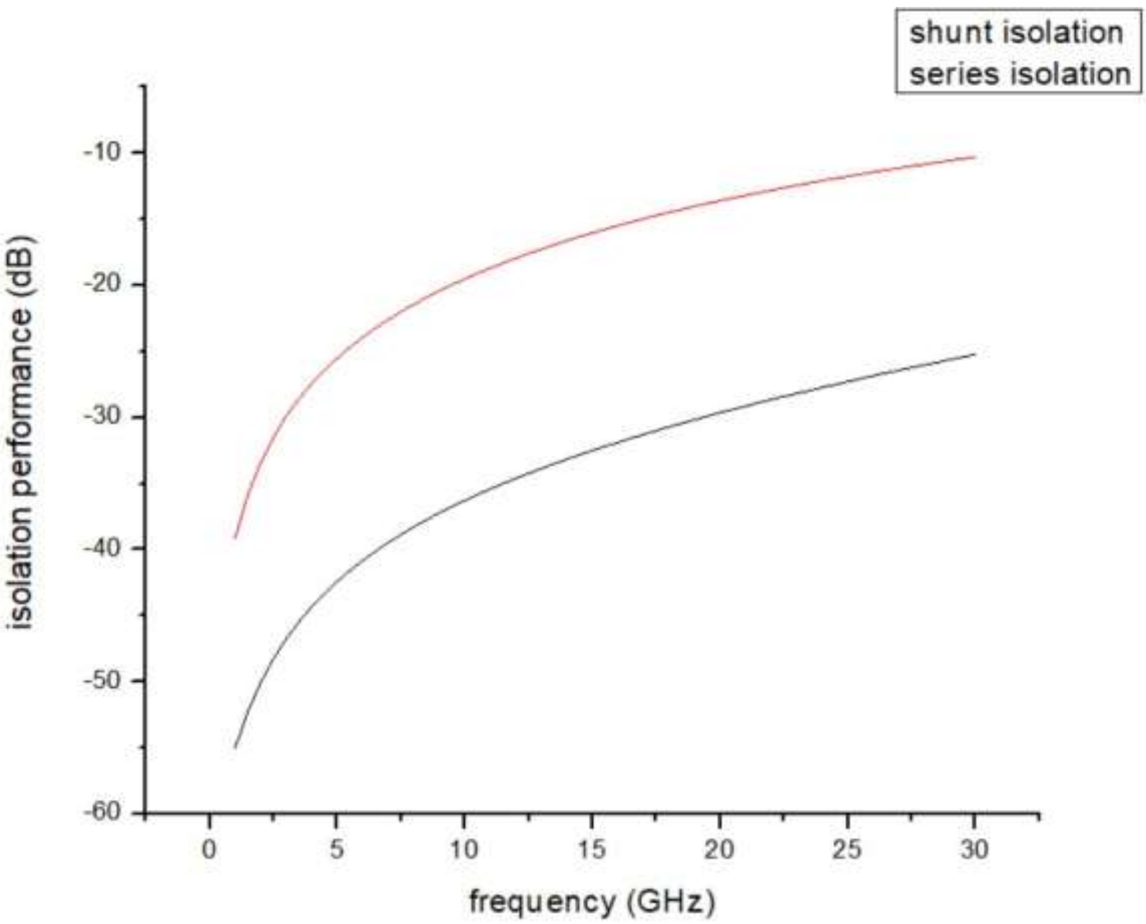


Fig. 4. Comparison of isolation performance of rectangular shaped MEMS shunt switch (-25.2369 dB) with rectangular shaped MEMS series switch (-10.3776) at upto 30 GHz

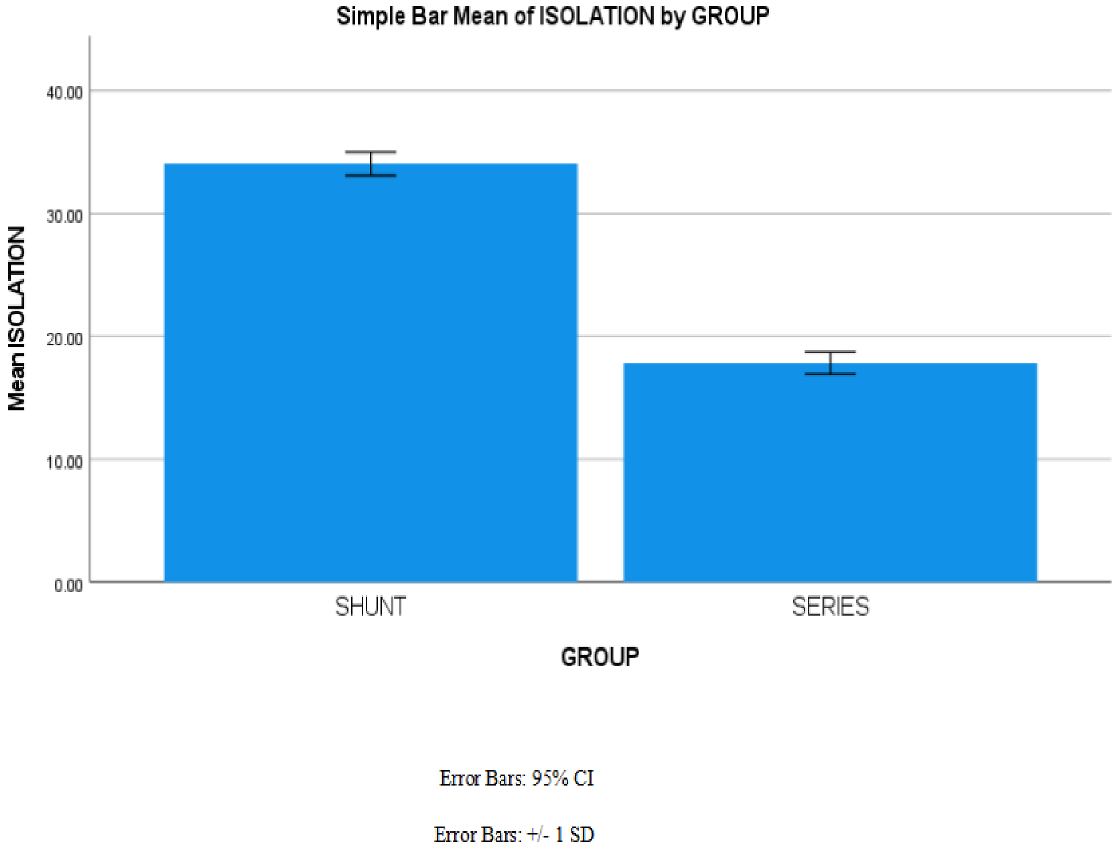


Fig. 5. A comparison of isolation performance of rectangular shaped RF MEMS shunt switch and series switch(shunt switch has higher isolation compared to series switch). Bar graph for comparison of both the groups (X axis) & isolation (Y axis) with error bar (95 % CI) and mean accuracy detection (+/- 1SD).