

Simulation of Rectangular Slot MEMS Switch and Comparing its Return Loss Performance with Basic Rectangular Switch at DC-30GHz

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Abstract

Aim: Return loss performance of Rectangular slot MEMS switch and basic rectangular switch is analyzed and simulated at upto 30 GHz using HFSS software is described in this paper. **Materials and Methods:** The return loss performance of rectangular slot MEMS switch (n=25) is compared to that of the basic rectangular switch over a frequency of upto 30GHz. Calculation of 25 samples using sample computation with Alpha of 0.05, Beta of 0.2 and pretest power of 80 % was done. **Results:** Return loss performance of rectangular slot switch is better than basic rectangular switch. Optimized dimensions for improved return loss performance are Lb=160 micrometers, Wb=20 micrometers and Tb=1 micrometer. The attained significance of return loss performance is $p < 0.05$. **Conclusion:** Results show that novel rectangular slot MEMS shunt switch has better return loss performance compared to basic rectangular switch.

Keywords: Novel Rectangular Slot MEMS Shunt Switch, Basic Rectangular Switch, Frequency, Return Loss Performance, HFSS, Microelectronics.

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INTRODUCTION

Return loss performance can be analysed by designing and comparing microelectronics based novel rectangular slot MEMS shunt switch with basic rectangular switch at a frequency of upto 30 GHz. Microelectronics-based rectangular slot MEMS shunt switches have an excellent combination of low power consumption, minimal insertion loss, high isolation performance, and high switching power (Lysenko et al. 2018). There are numerous applications for microelectronics based novel rectangular slot MEMS shunt switch. RF MEMS switches have applications in the field of Telecommunication (Rangra et al. 2005), power applications (Wong and Massachusetts Institute of Technology. Microsystems Technology Laboratories 2000), mobile communication (Kumar et al. 2020), Distributed MEMS transmission line phase shifter (Devi, Maity, and Datta 2014), reconfigurable integrated circuits (Brown 1998), portable applications (Tang et al. 2010) and phase shifter applications (Singh, Anitha, and Usha Kiran 2018).

Several research papers on MEMS switches have been published so far. 65 IEEE journals and 7080 Google scholar publications have been made in recent years. Construction of RF-MEMS Switch Integrated with Circular Microstrip Patch Antenna (Rao et al. 2021) exhibits the design of microstrip circular patch antenna which is combined with microelectronics based RF MEMS switch. Two switches are proposed in this paper. First one is double beam type and the second one is single-beam type. Finite Element Model (FEM) was used to design the switches and obtain the return loss performance. With these switches, return loss performance can be observed as 31.10 dB, 35.46 dB and without these switches, return loss can be seen as 23.65 dB. Thus incorporating the switches with circular microstrip patch antenna enhances the return loss performance. In the work by (Narayana et al. 2017) RF MEMS switch is designed using non-uniform meander's with a membrane structure. Return loss is analysed to be below -16 dB. RF MEMS switch is integrated with uniform meanders in the work by (Gandhi et al. 2021). Meanders are used to reduce actuation voltage and analyse return loss performance. The observed return loss value is -38.60 dB. 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)

The primary issue of the RF MEMS switch performance is return loss. So many research works have been made to improve the return loss performance. The return loss performance can be improved by introducing the slot in the rectangular shaped MEMS switch. The objective of this research is to compare the return loss performance of a novel rectangular slot MEMS shunt switch and a basic rectangular switch at DC - 30 GHz.

Materials And Methods

This work is done in the Nanoelectronics Lab, Department of Electronics and Communication Engineering at Saveetha School of Engineering, Chennai. Two sample groups were taken. The sample size for each group is 25. The overall sample of participants is 50. Using clinical analysis, the pre-test power for continuous testing is determined to be 80% with enrollment ratio 1, alpha value is 0.05, and beta value is 0.2 to the total sample size of proposed work (Torgerson and Miles 2007)

Two preparation methods were carried out for this work. In group 1, design of microelectronics based novel rectangular slot MEMS shunt switch was carried out using HFSS software. The dimensions i.e., length, width and thickness of the substrate are 1090 μm , 600 μm , 525 μm respectively. Likewise, the dimensions of the beam i.e., length, width and thickness are 360 μm , 100 μm and 1 μm respectively.

Similar to group 1, preparation methods for group 2 were also carried out. HFSS software is used to carry out the design of the microelectronics based basic rectangular switch. The dimensions are length, width and thickness of substrate which can be given as 1090 μm , 600 μm and 1 μm respectively. Beam dimensions are length- 360 μm , width- 100 μm and thickness- 1 μm .

Return loss of rectangular shaped RF MEMS shunt switch can be determined in equation 1 (Waghmare and Shah 2019).

$$S_{11} = -20 \log \left| \frac{-Z_0}{2Z_s + Z_0} \right| \quad (1)$$

Where Z_s = switch impedance

Z_0 =characteristic impedance

High Frequency Structure Simulation is a solution for electromagnetic structure for FEM. HFSS is used to design antennas, RF circuit elements and microelectronic devices ("ANSYS HFSS" 2015). The testing procedure measures the return loss of the described shunt switch. Frequency of upto 30 GHz was maintained and the readings for isolation were taken. The data was collected from the result and then tabulated.

The work is done in Windows 10 pro, Intel core i3, 7th Gen and for the process of simulation and verification, HFSS was used. In HFSS software, Optimized Dimensions of the substrate, Dielectric material, CPW, Anchor and Beam should be included. Other Optimized dimensions such as rectangular sheets and airbox should also be given. Boundaries, Radiation, solution setup and frequency should be added. Then validate and analyse the design. Finally obtain output by selecting S Parameters.

Statistical Analysis

The data can be exported into excel from the output graph. Data should be input to the SPSS (SPSS Inc 2007)). Statistical analysis of the data can be done by using SPSS. Thickness of the substrate and dielectric are independent of Return loss but length and thickness of the beam are dependent variables.

Results

The dimensions of the design were given. Output graph is exported in the form of an excel sheet. Statistical analysis was done by giving the output values to SPSS. Maximum return loss (-13.0831 dB) can be obtained with the Optimized dimensions like $L_b = 360 \mu\text{m}$, $W_b = 20 \mu\text{m}$, $T_b = 1 \mu\text{m}$.

In Table 1. comparative analysis of return loss performance of rectangular slot MEMS shunt switch and rectangular shaped MEMS shunt switch was tabulated. Return loss performance of the rectangular slot MEMS shunt switch (-13.0831 dB) is better than the return loss performance of rectangular shaped MEMS shunt switch (-11.8533 dB). Group statistics of two groups with its mean (20.7656 & 19.3939), standard deviation (7.05885 & 6.87543) and standard error mean (0.91898 & 0.89510) is shown in Table 2. The statistical analysis of both the groups with its p value of <0.05, mean difference (1.37175) and standard error difference (1.28287) is shown in Table 3. In Table 4. descriptive statistics of both the groups is represented with its n value (50), minimum and maximum values (11.80 & 42.74), mean (20.0798) and standard deviation (6.97201).

Figure 1 (a) and (b) depicts the top view and side view of the rectangular slot MEMS shunt switch. Fig. 2. shows the graph for the return loss performance of the rectangular slot shunt switch which was obtained using origin software. Fig. 3. depicts the graph for the return loss performance of a rectangular slot shunt switch which was obtained using origin software. Fig. 4. Shows the graph of comparison of return loss performance of rectangular slot MEMS shunt switch and rectangular shaped MEMS shunt switch. It can be observed that the return loss performance of a rectangular slot MEMS shunt switch is better than rectangular shaped MEMS shunt switch. From Fig. 5. it can be observed that the mean return loss performance of the rectangular slot shunt switch is better than that of the rectangular shaped MEMS shunt switch. It has p-value <0.05 and error bar 95 % with proper prediction.

Discussion

Simulation and analysis of Return loss performance of Rectangular slot MEMS shunt switch and basic rectangular switch was done at a frequency of 30 GHz. On the basis of various findings, it can be seen that the Rectangular slot MEMS shunt switch has better return loss performance than the basic Rectangular MEMS shunt switch. Data is stored in excel sheets to obtain graphs with SPSS.

Simulating and comparing the return loss performance of novel Rectangular slot MEMS shunt switch and basic rectangular MEMS shunt switch was carried out. The existing article (M, Abirami, and Rajasekar 2016) has a return loss of around -13 dB, the work by (Nafde and Pande 2017) has a return loss of -5.5 dB at 6 GHz. In (Glubokov et al. 2017), the return loss performance is -15 dB. The work (Naji, Farhood, and Ali 2019)10 dB. From these, it can be inferred that the novel rectangular slot MEMS shunt switch has better return loss performance compared to basic rectangular switch. Thus the proposed work has a return loss of -13.0831 dB which is better than many existing works.

Frequency is one of the elements that affects the return loss in this work. Frequency variation is directly proportional to the return loss. Uniform and non-uniform meandering techniques can be used in future work to enhance the return loss performance for wireless and satellite radar applications.

Conclusion

This article examines and enhances the return loss performance of the novel rectangular slot MEMS shunt switch and basic shunt switch. It can be inferred that the return loss performance of the rectangular slot MEMS shunt switch (-13.0831 dB) is better than the basic rectangular shunt switch (-11.8533 dB). Hence the rectangular slot MEMS shunt switch is significantly better than the rectangular shaped MEMS shunt switch which is most suitable for radar and satellite 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.

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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. "ANSYS HFSS." 2015. Ozen Engineering and Ansys. August 3, 2015. <https://www.ozeninc.com/ansys-hfss/>.
3. 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>.
4. 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>.
5. 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.
6. 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>.
7. 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>.
8. Devi, Thiyam Romila, Subir Maity, and Amlan Datta. 2014. "A Novel Design of 4-Bit Distributed MEMS Transmission Line (DMTL) Phase Shifter Using an RF Shunt Capacitive MEMS Switch for Phased Array Antenna." *International Conference for Convergence for Technology-2014*. <https://doi.org/10.1109/i2ct.2014.7092055>.
9. Gandhi, S. Girish, S. Girish Gandhi, I. Govardhani, M. Venkata Narayana, and K. Sarat Kumar. 2021. "Design and Performance Analysis of Novel Bridge Type RF MEMS Switch for X-Band." *Materials Today: Proceedings*. <https://doi.org/10.1016/j.matpr.2020.11.305>.
10. Glubokov, Oleksandr, Xinghai Zhao, Bernhard Beuerle, James Champion, Umer Shah, and Joachim Oberhammer. 2017. "Micromachined Multilayer Bandpass Filter at 270 GHz Using Dual-Mode Circular Cavities." 2017 IEEE MTT-S International Microwave Symposium (IMS). <https://doi.org/10.1109/mwsym.2017.8058894>.
11. 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.
12. 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.
13. Kumar, P. Ashok, P. Ashok Kumar, K. Srinivasa Rao, and K. Girija Sravani. 2020. "Design and Simulation of Millimeter Wave Reconfigurable Antenna Using Iterative Meandered RF MEMS Switch for 5G Mobile Communications." *Microsystem Technologies*. <https://doi.org/10.1007/s00542-019-04606-w>.
14. Lysenko, Igor, Alexey Tkachenko, Elena Sherova, and Alexander Nikitin. 2018. "Analytical Approach in the Development of RF MEMS Switches." *Electronics*. <https://doi.org/10.3390/electronics7120415>.
15. M. Abirami, M. Abirami, and G. Rajasekar. 2016. "MEMS Reconfigurable Slotted Microstrip Patch Antenna for Cognitive Radio Application." 2016 Online International Conference on Green Engineering and Technologies (IC-GET). <https://doi.org/10.1109/get.2016.7916695>.
16. Nafde, Yogita, and Rajesh Pande. 2017. "Design and Analysis of Resistive Series RF MEMS Switches Based Fractal U-Slot Reconfigurable Antenna." *Wireless Personal Communications*. <https://doi.org/10.1007/s11277-017-4639-8>.
17. Naji, Maham Kamil, Alaa Desher Farhood, and Adnan Hussein Ali. 2019. "Novel Design and Analysis of RF MEMS Shunt Capacitive Switch for Radar and Satellite Communications." *Indonesian Journal of Electrical Engineering and Computer Science*. <https://doi.org/10.11591/ijeecs.v15.i2.pp971-978>.
18. 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>.
19. 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.
20. 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.
21. 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>.
22. Rangra, Kamaljit, Benno Margesin, Leandro Lorenzelli, Flavio Giacomozzi, Cristian Collini, Mario Zen, Giovanni Soncini, Laura del Tin, and Roberto Gaddi. 2005. "Symmetric Toggle Switch—a New Type of Rf MEMS Switch for Telecommunication Applications: Design and Fabrication." *Sensors and Actuators A: Physical*. <https://doi.org/10.1016/j.sna.2005.03.035>.
23. Rao, K. Srinivasa, K. Srinivasa Rao, Ch Gopi Chand, Reshmi Maity, N. P. Maity, and K. Girija Sravani. 2021. "Design of RF-MEMS Switch Integration with Circular Microstrip Patch Antenna." *Transactions on Electrical and Electronic Materials*. <https://doi.org/10.1007/s42341-021-00326-z>.
24. Sathiyamoorthi, Ramalingam, Gomathinayagam 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>.
25. 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.
26. Singh, V., G. Anitha, and K. Usha Kiran. 2018. "Conventional DMTL Phase Shifter Is Designed Without Meta-Material and with Meta-Material." *Lecture Notes in Electrical Engineering*. https://doi.org/10.1007/978-981-10-7293-2_3.
27. SPSS Inc. 2007. *SPSS 16.0 Brief Guide*. Prentice Hall.
28. 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.
29. Tang, Min, Ebin Liao, Cheng Kuo Cheng, Dayong Lee, Rakesh Kumar, Yong Hean Lee, Ravi Shankar, Olivier Le Neel, Giuseppe Noviello, and Francesco Italia. 2010. "A Magnetostatic MEMS Switch Designed for Portable Applications." *Journal of*

- Microelectromechanical Systems. <https://doi.org/10.1109/jmems.2010.2067434>.
30. Torgerson, David J., and Jeremy N. V. Miles. 2007. "Simple Sample Size Calculation." *Journal of Evaluation in Clinical Practice*. <https://doi.org/10.1111/j.1365-2753.2006.00776.x>.
31. Waghmare, Surendra K., and Dilip D. Shah. 2019. "Design and Analysis of RF MEMS Capacitive Shunt Switch and Impact of Geometric Trade-Offs on RF Performance." *HELIX*. <https://doi.org/10.29042/2019-4992-4999>.
32. Wong, Jo-Ey, and Massachusetts Institute of Technology. Microsystems Technology Laboratories. 2000. Analysis, Design, Fabrication, and Testing of a MEMS Switch for Power Applications.

Tables and Figures

Table 1. Represents the comparison of return loss performance of rectangular slot MEMS series and shunt switches 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.	SLOT SHUNT	10	-22.5035	-0.1022	-21.3565
		20	-16.4525	-0.2191	-31.8794
		30	-13.0831	-0.3895	-38.0175
2.	SWITCH SHUNT	10	-21.1214	-0.1135	-36.2488
		20	-15.1867	-0.2554	-29.6459
		30	-11.8533	-0.4699	-25.2370

Table 2. Representation of group statistics for both sample groups, mean (20.7656), standard deviation (7.05885) and standard error mean (0.91898)

GROUP	N	MEAN	STD. DEVIATION	STD. ERROR

SLOT SHUNT	25	20.7656	7.05885	0.91898
SWITCH SHUNT	25	19.3939	6.87543	0.89510

Table 3. Representation of statistical analysis of independent sample tests for both the sample groups. p value (0.05), mean difference (1.37175) and standard error difference (1.28287)

		ONE-SIDED P	TWO-SIDED P	MEAN DIFFERENCE	STD. ERROR DIFFERENCE
RETURN LOSS	EQUAL VARIANCES ASSUMED	0.05	0.287	1.37175	1.28287
	EQUAL VARIANCES NOT ASSUMED	0.05	0.287	1.37175	1.28287

Table 4. Representation of descriptive statistics for both the sample groups. n value(50), minimum and maximum values (11.80 & 42.74), mean (20.0798) and standard deviation (6.97201)

	N	MINIMUM	MAXIMUM	MEAN	STD. DEVIATION
RETURN LOSS	50	11.80	42.74	20.0798	6.97201

FIGURE



(a)



(b)

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

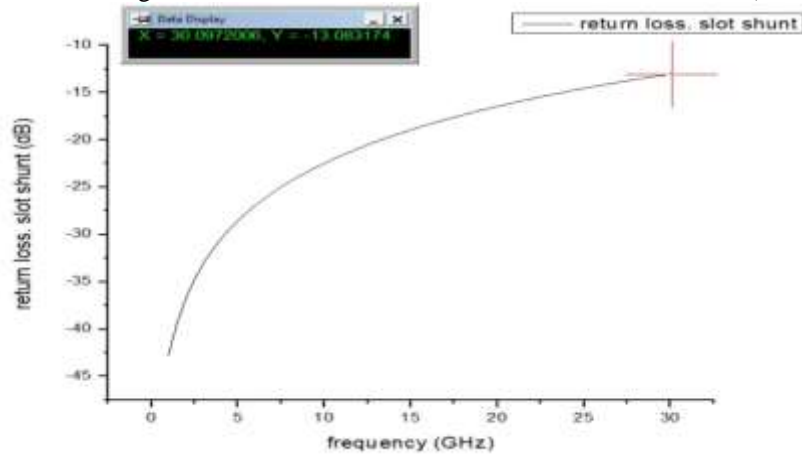


Fig. 2. Return loss performance (-13.0831) of rectangular slot MEMS shunt switch at up to 30 GHz.

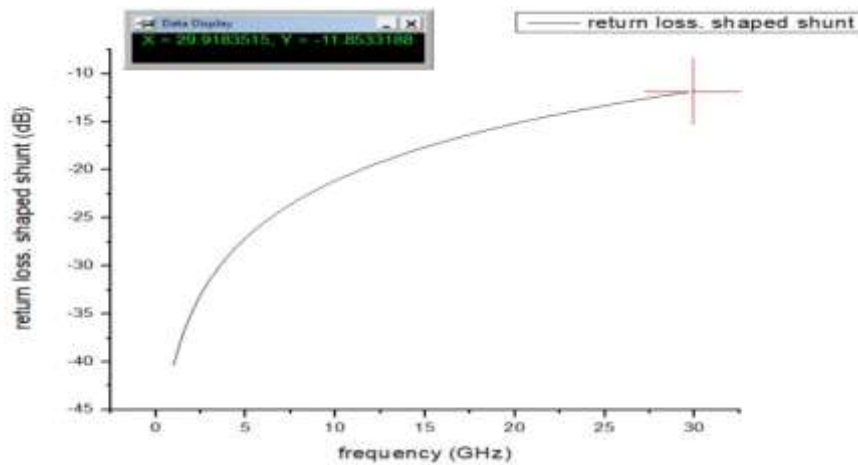


Fig. 3. Return loss performance (-11.8533) of rectangular shaped MEMS shunt switch at up to 30 GHz.

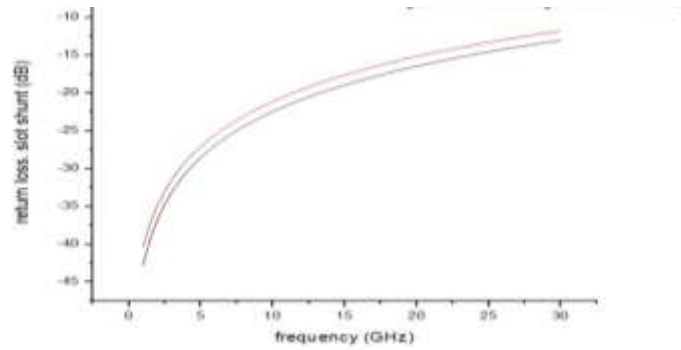


Fig. 4. Comparison of return loss performance of rectangular slot MEMS shunt switch (-13.0831) with rectangular shaped MEMS shunt switch (-11.8533) at up to 30 GHz.

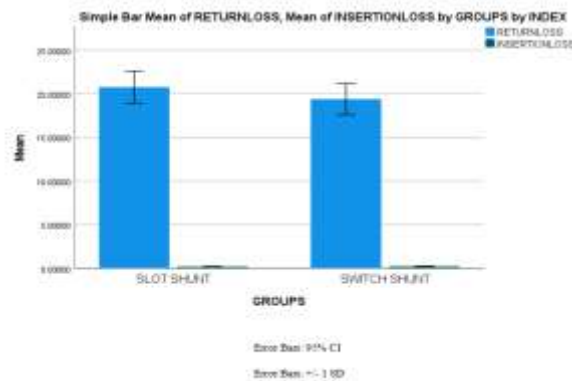


Fig. 5. A comparison of return loss performance of rectangular slot RF MEMS shunt switch and rectangular shaped RF MEMS shunt switch. The Bar graph shows (blue bar - return loss, green bar - Insertion loss) the comparison of both the groups. A rectangular slot MEMS shunt switch has better return loss performance compared to rectangular shaped MEMS shunt switch. X axis: Slot shunt and basic shunt switch, Y axis: Mean return loss with detection of +/- 1 SD and error bar 95 % CI.