Microstrip-Patch Antenna Designed with Novel S and Rectangular Slots and Gain Comparison with S Slot Antenna

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ABSTRACT

Aim: The aim of this work is to compare novel S and rectangular slots in comparison with S slot antenna for gain enhancement.

Materials and Methods: The rectangular microstrip patch antenna using novel S and rectangular slots was constructed with the aid of Ansoft High Frequency Structure Simulator (HFSS) version 15.0 software. It was built on a FR4 epoxy material substrate with a thickness of 2.00 mm. The sample size estimation is done using the G Power Statistical tool with probability of 80% and the total sample size of the research is 20 and consists of two groups i.e for each group 10 samples.There is significant difference between the two groups

Results: Simulation is done by using HFSS (High Frequency Structure Simulator) software.The performance of the antenna is analyzed in terms of gain. The enhanced gain of S and rectangular slotted patch antenna is 4.26 dB is significantly better than S slot patch antenna gain of 2.94 dB. From the SPSS analysis the significance obtained is 0.003, ($p < 0.05$) there is statically significant difference between the two groups.

Conclusion: The Novel microstrip with S and rectangular slotted patch antenna appears to be significantly better in terms of gain compared with S slot antenna.

Keywords: Rectangular microstrip patch antenna, S slot, Novel S and rectangular slots, gain, FR4, HFSS.

INTRODUCTION

The research is to enhance the gain of the rectangular microstrip patch antenna by adding the slots of S and rectangular shape in the ground plane. This method is called Novel slotting of Antenna [1]. The importance of using Novel S and rectangular Slot in the ground plane is to shift the resonance frequency towards a lower side [2].The demand for microstrip patch antennas are increasing rapidly due to their advancements such as less weight, low profile and ease of fabrication [3]. These properties make the microstrip patch antennas to be used in mobile communication, satellite applications, and 5G applications [4].

Similar to this work, 824 journal papers are available in Google Scholar and 153 journals published in Sciencedirect from the last 5 years. Nowadays, the use of wireless communication is increasing rapidly due to faster communications across the systems [5]. In wireless communication systems there is a need for high gain antennas for effective signal transmission and reception. The antenna gain can be enhanced by using different techniques. In this research two different types of slots S and rectangular shaped respectively are carved on the patch antenna to bring an optimal output [6]. In satellite communication, the signals need to travel to the longer distances from one base station to the other stations. To communicate with longer range communication points the antenna needs to be well structured and implemented. Because of their good properties, microstrip patch antennas are widely used in satellite communication applications [6], [7]. However microstrip patch antennas also have some limitations such as low gain, narrow bandwidth and larger size [8]. .Our institution is passionate about high quality evidence based research and has excelled in various fields[9]–[16][17]–[26]

The limitations of the existing methods are poor gain and return loss . To improve the gain of microstrip patch antenna different techniques are available such as by slotting the planes with different slots, shorting pins, different feeding techniques [coaxial, proximity coupled, microstrip line feed],and by using different substrate materials. This research work focuses on the design of high gain of antennas by implementing and carving Novel S and rectangular slots on the patch antenna.

MATERIALS AND METHODS

This work was carried over at Antenna and Wave propagation laboratory, Department of Electronics and Communication Engineering in Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences. This work was based on gain improvement of rectangular microstrip patch antenna putting Novel S and rectangular slots in comparison with rectangular microstrip patch antenna S slot. Sample size was calculated as 20 of each group of 10 sample size [27] using clinicalc.com by keeping alpha error-threshold by 0.05, 95% confidence interval, power 80%. In this work to compare the parameter as gain with one sample group from previous literature [28].

The first group refers to the rectangular microstrip patch antenna with S slot containing 10 samples and the second group contains 10 samples of microstrip patch antenna having S and rectangular slots. The sample size estimation is done using the G Power statistical tool with probability of 80 % [1] for the total sample size of S and rectangular slotted patch antenna and S shaped slotted patch antenna. Ansoft HFSS software tool is used to design the structure and validate the antenna design.

In design of rectangular microstrip patch antenna with S shaped slot carved on it. The S slot rectangular microstrip patch antenna consists of Flame Retardant (FR4) as a substrate material. The dielectric constant of FR4 is 4 with 2mm substrate thickness. Fig.1. depicts the design of the S slot microstrip patch antenna. The design setup of a rectangular microstrip patch antenna with S slot was done using Ansoft HFSS software. The length and width of the ground are used as [ground length of 37 mm and width of 25.7 mm].

In design of rectangular microstrip patch antenna with Novel S and rectangular slots carved on it. The carving of two different slots is done to improve the gain of the proposed antenna. The Novel S and rectangular slots rectangular microstrip patch antenna is designed using Ansoft HFSS 15.0 version software with FR4 epoxy substrate with a thickness of 2mm. The rectangular patch is designed and slots were cut into a S and rectangular shape by subtracting the patch and slots. By varying the length / width / height / frequency / radius of the antenna the results shows that there is betterment in gain. Fig.3 shows schematic representation of Novel S and rectangular slots rectangular microstrip patch antenna.

The testing setup used to design the microstrip patch antenna is Ansoft HFSS software. The system configuration used to set up the testing procedure is Intel Core i3 10th gen processor. To obtain the dimensions of the designing antenna, it requires a resonant frequency which is fixed at a certain value. Antenna variables such as L,W,H,F are defined to construct the antenna in Ansoft HFSS Software. Excitations, boundaries and radiation fields are assigned to the antenna. Analysis setup has been done to add the frequency sweep to the antenna. After Validation, Simulation results are analyzed in the HFSS simulation tool.

Statistical analysis

SPSS version 22 was used for statistical comparison of parameters such as gain. The S and rectangular shaped slotted microstrip antenna and S shaped slotted microstrip patch antenna were compared [29].The independent variables are width and Height of the substrate, length and width of patch and operating frequency of Antenna [30]. The dependent variables are gain, directivity, return loss and VSWR of the antenna. The Independent sample t-test was done.

RESULTS

The Microstrip patch antenna by using S and rectangular slots has been designed and simulated results have been obtained by using Ansoft HFSS (High Frequency Structure Simulator) tool.

The gain results have been simulated for innovative S and rectangular microstrip patch antennas. Fig.1 shows the schematic representation of S slot rectangular microstrip patch antenna using HFSS.The simulation parameter of S slot microstrip patch antenna is 25.7mm x 37mm x 2mm as shown in Table 1.

Figure 2 represents the gain (dB) Vs Frequency (GHz) plot of the S shaped slotted microstrip patch antenna. It was observed that the value of gain at different frequencies. The plot shows the variation of gain at different frequencies in Wave shaped patterns . The red color indicates the maximum gain obtained for the designed antenna and the other color indicates the lower values away from the resonance. The maximum gain obtained for the S slot microstrip patch antenna is 2.94dB at the frequency of 2.4GHz.

The dimensions of novel S and rectangular slots microstrip patch antenna is 29.7mm x 37mm x 2mm as shown in Table 1. Fig.3 shows the schematic representation of novel S and rectangular slots microstrip patch antenna designed using Ansoft HFSS 15.

The proposed design of the novel S and rectangular slots microstrip patch antenna has a gain of 4.26dB which was depicted in Fig.4, representing the gain(dB) Vs Frequency(GHz) plot of the novel S and rectangular slots microstrip patch antenna. From Fig.4 it was observed that the value of gain at different frequencies. The plot shows the variation of gain at different frequencies in Wave shaped patterns. The red color indicates the maximum gain obtained for the designed antenna and the other color indicates the lower values away from the resonance. The maximum gain obtained for the S slot microstrip patch antenna is 4.26dB at the Frequency of 2.4 GHz.

The novel S and rectangular slots microstrip patch antenna has a higher mean (4.4911) than the S slot rectangular microstrip patch antenna (3.6370). The descriptive statistical analysis is illustrated in Table 2. The Mean,standard deviation and significance difference of novel S and rectangular slots microstrip patch antenna and S slot rectangular microstrip patch antenna there is a significance difference between the two groups 0.003 ($p<0.05$). The detailed analysis is tabulated in Table 3. Bar chart comparing the mean(+/-1 SD) gain for novel S and rectangular slots microstrip patch antenna and S slot rectangular microstrip patch antenna. Fig.5 shows a bar chart representing the comparison of novel S and rectangular slots microstrip patch antenna. Novel S and rectangular slots microstrip patch antenna appear to produce more consistent results. Table 1 shows the simulation parameters of both S slot microstrip and novel S and rectangular slots microstrip patch antenna.

DISCUSSION

In the overall exploration of proposed work, the antenna gain of the Novel S and rectangular slots microstrip patch antenna is higher than the S slot rectangular microstrip patch antenna and the frequency remains the same at 2.4 GHz [31];[32].The antenna's gain will differ in the material used and the structure of the antenna.The gain of Novel S and rectangular slots microstrip patch antenna is good compared to S slot antenna significantly.

In this work the significance and gain were compared with the previous work and the output gain obtained was better in the proposed system[5] the output obtained in terms of gain was 3.3dB. The novel S and rectangular slots antenna gain is obtained as 4.26 dB [27]. In [33] the output produced by the antenna was 3.8dB.The S slot antenna produced a gain of 2.94dB [30]. From this research, the output shows better performances for Wireless Local Area Networks(WLAN) Innovative Microstrip patch antenna for 5G applications that are similar to our research work and their findings are almost related to our study as mentioned above. As it involves 10 samples for each group, significant results are obtained and if the sample size increases.

The proposed Novel S and rectangular slots microstrip patch antennahas a limitation i.e the antenna gives more reflection loss when it is operated at a higher frequency. Future scope of the work can be the design of an antenna with compact size and high gain at specified operating frequency that is suitable for desired application. This is influenced by the feed location, substrate content, and antenna fringing area. The feed direction is combined with a 50-ohm high impedance to achieve a reasonable gain. By obtaining and improving the major lobes for enhancement of gain. In the future, the simulated designed microstip antenna will be fabricated.

CONCLUSION

The gain obtained in the novel S and rectangular slots microstrip patch antenna is 4.26 dB and S slot antenna is 2.94 dB. This shows that novel S and rectangular slots microstrip patch antennas are significantly better than S slot antenna.

DECLARATIONS

Conflict of interests

No conflict of interest in this manuscript.

Authors contribution

Author NM was involved in antenna design, antenna parameters analysis, and manuscript writing. Author VA was involved in antenna validation, a study of simulated results, and a critical review of the 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.Reindeer Technologies Pvt. Ltd.,Chennai

2. Saveetha University

3.Saveetha Institute of Medical And Technical Sciences.

4. Saveetha School of Engineering.

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FIGURES AND TABLES

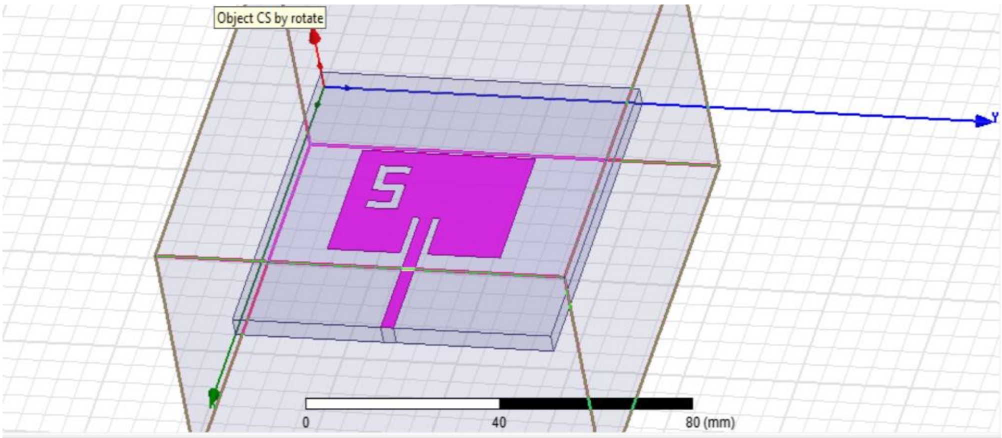

Fig. 1 The representative model of simulated S slot microstrip patch antenna with FR 4 epoxy substrate using Ansoft HFSS tool.

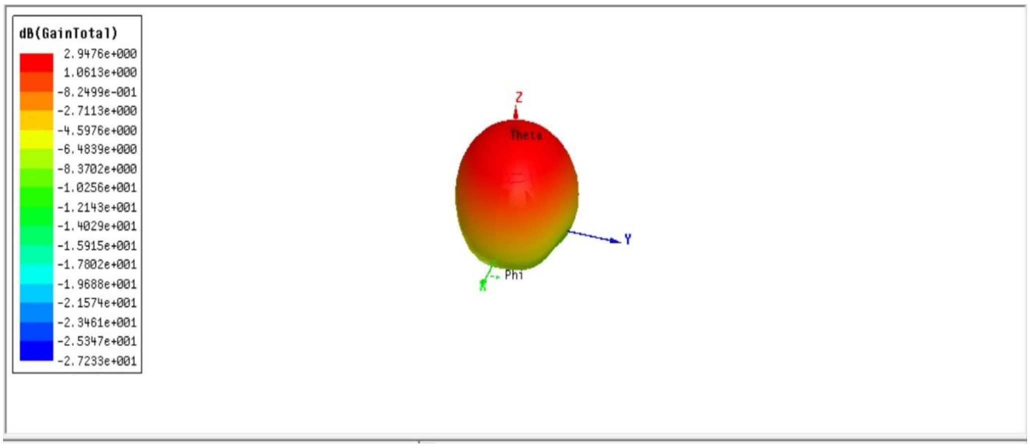

Fig. 2 Frequency at 2.4GHz shows the gain value of the S slot microstrip patch antenna by varying the frequency of (1GHz to 3 GHz) and the gain is 2.9476 dB (X-axis:Phi;Y-axis:dB and Z-axis:Thetha). Red color indicates the maximum gain and other colors indicate the reduction of gain from maximum resonance of the antenna.

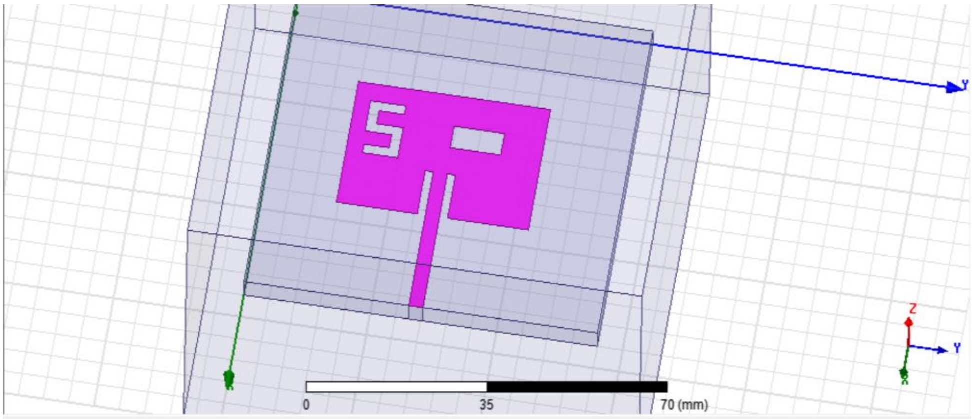

Fig. 3 The schematic representation of novel S and rectangular slots microstrip patch antenna with FR4 substrate designed using Ansoft HFSS tool.

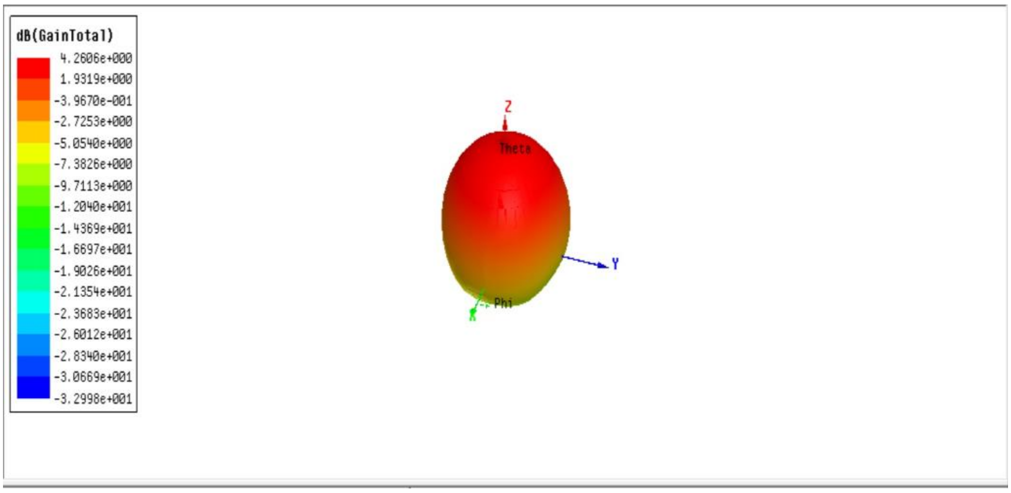

Fig. 4 Frequency at 2.4GHz shows the gain value of the novel S and rectangular slots microstrip patch antenna by varying the frequency of (1GHz to 3 GHz) and the gain is 4.2606 dB.(X-axis:Phi;Y-axis:dB and Z-axis:Thetha). Red color indicates the maximum gain and other colors indicate the reduction of gain from maximum resonance of the antenna.

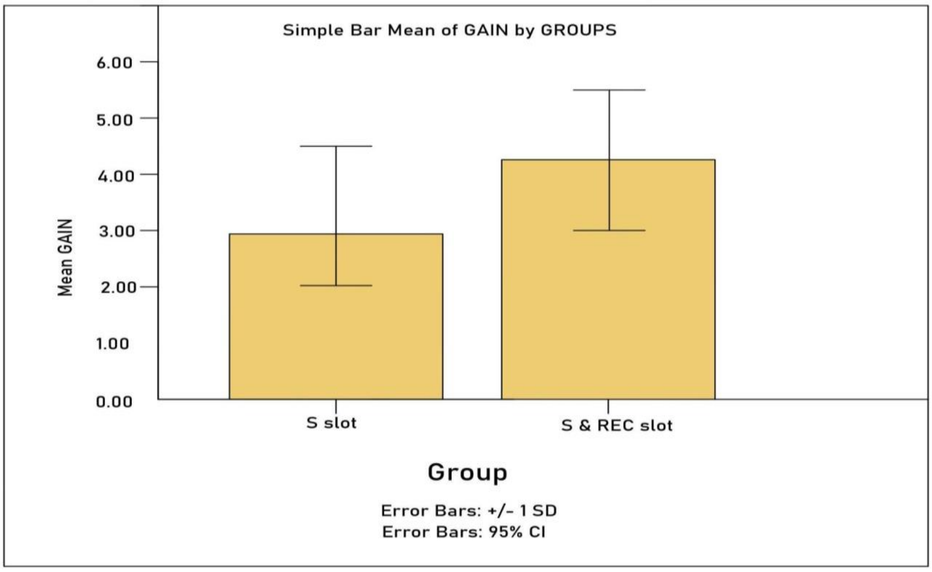

Fig. 5 Bar Graph represents the Comparison of novel S and rectangular slotted microstrip patch antenna and S slot microstrip patch antenna in terms of gain. Analysis on mean gain of FR4 epoxy with S and rectangular slotted microstrip patch antenna and FR4 epoxy with S slot microstrip patch antenna in SPSS tool, significance difference of ($p > 0.05$). Mean accuracy of detection (±1 SD). X axis : FR4, Y axis: Mean, Error bar: 95%. By comparing the S and rectangular microstrip patch antenna and S slot microstrip patch antenna, the S and rectangular microstrip patch antenna performs better than the S slot microstrip patch antenna.

Table 1 Simulation parameters of S slot microstrip patch antenna and Novel S and rectangular slots microstrip patch antenna

S.NO	Parameter	Dimensions (mm)of S slot microstrip patch	Dimensions (mm) of novel S and rectangular

		antenna	slots microstrip patch antenna
1	Solution Frequency	2.4 GHz	2.4GHz
2	Width of the patch	25.7mm	29.7 mm
3	Length of the patch	37mm	37mm
4	Substrate thickness	2mm	2mm
5	Passes	6	6
6	Sweep	1 to 10 GHz	1 to 10 GHz
7	Sweep type	Fast	Fast

Table 2 Statistical analysis of Mean, Standard deviation, and Standard error of gain for S slot microstrip and novel S and rectangular slots microstrip patch antenna. There is a statistically significant difference between the groups. The novel S and rectangular slots microstrip patch antenna has a higher mean gain (4.4) than the S slot microstrip patch antenna mean of (3.6).

Group	**N**	**Mean**	**Std. Deviation**	**Std.Error Mean**
S slot S and Rec slot	10 10	3.6370 4.4911	1.97067 2.14812	.39413 .42962

Table 3 Represents an independent sample T-test which shows the significance in which the gain for Novel S and rectangular slots microstrip patch antenna(.003) is found with statistical significance ($p<0.05$) when comparing S slot microstrip patch antennas.

Leven's Test for Equality of Variance				**t-test for Equality of Variance**					**95% Confidence Interval of the difference**	
Gain		**F**	**sig.**	**t**	**dif**	**sig(2-tailed)**	**Mean difference**	**Std.Error Difference**	**lower**	**upper**
	Equal Variance assumed	.195	.003	-1.465	48	.003	-.85414	.58303	-2.026391	.318111

	Equal variance not assumed			-1.465	47.648	.003	-.85414	.58303	-2.026615	.318335