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DESIGN OF MICROSTRIP PATCH ANTENNA WITH S AND 2 SHAPED SLOTS TO IMPROVE THE GAIN COMPARED TO S SHAPED SLOT ANTENNA

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ABSTRACT :Aim: This study aims to design a rectangular microstrip patch antenna with Novel S and 2 shaped slots at 2.45 GHz and to compare its gain performance with an S-shaped rectangular Microstrip patch antenna. **Materials and Methods**: Two groups, S-shaped microstrip patch antenna and Novel S and 2 shaped microstrip patch antenna are simulated with 10 samples each. Each group is simulated for 8 iterations. Micro-strip patch antenna patch length, width, height, the dielectric constant of the substrate, and resonance frequency are used for gain performance analysis. The alpha error-threshold of 0.05 was kept with a 95% confidence interval and 80% pre-test power.**Results:** The rectangular microstrip patch antenna with Novel S and 2 shaped has obtained the gain value of 7.76dB and the S-shaped antenna 6.1dB at 2.45 GHz with a significance value of $p = 0.002$ ($p < 0.05$). **Conclusion:** Novel S and 2 shaped microstrip patch antenna significantly better in achieving gain performance compared to S-shaped microstrip patch antenna.

KEYWORDS: Microstrip Patch Antenna, Novel S and 2 shaped microstrip patch antenna, S-shaped microstrip patch antenna, Gain, Return loss, Directivity.

1. INTRODUCTION

An antenna is made up of a patch with a metal foil which is usually copper with a specified application with different slots and shapes which the patch is fabricated on a substrate, below that a ground plane which is of copper is known as a microstrip patch antenna (Carver and Mink 1981). Intentionally created error or slot in the patch of a Microstrip patch antenna results in some variations in parameters such as gain, directivity, etc(Bhattacharjee et al. 2015). Owing to their compactness, reliability, and suitability slotted antennas have been the subject of many antenna research efforts and it is being used in many applications such as 5G mobile and Bluetooth technologies, marine or land vehicle navigation (GPS) (Carver and Mink 1981; Hu, Chen, and Chu 2016). An antenna with high gain is needed for effective signal reception in many high-frequency applications such as military and navigation (Ayn et al. 2018).

Twenty-seven articles were published in IEEE and twenty articles published in Google Scholar during the past 5 years. (Nakmouche et al. 2021) designed a rectangular patch antenna with U shaped microstrip patch antenna for Bluetooth/5G technology with horizontal polarization using the HFSS tool. (Patel, Patel, and Thakkar 2012) proposed microstrip patch antenna with an S-shaped slot proved that an antenna with a slot on the patch results in good polarization and the gain is improved. In addition, the article compared the results of a flat ground path antenna with a multiple slotted patch antenna. (Atalah et al. 2018) proposed a circular-shaped ground-fed patch antenna with many limitations. Few are low gain and low efficiency. (Bakry, Abdel-Rahman, and Hamed 2014) proposed a periodic structure of the Complementary G-Shape Split Ring Resonator (CGSRR) to improve the gain of the microstrip patch antenna. An array of shapes on the rectangular patches are loaded to improve the gain and bandwidth of the antenna. The presence of the Clustered gate SRRs around the patch antenna improved the gain by 2.5 dB.(Kannadhasan and Shagar 2017) proposed U Shaped microstrip antennas with improved gain at 3.8 GHz. (Ketkuntod et al. 2017) proposed the microstrip patch antenna with an I-shaped mushroom-like EBG structure for gain improvement. By properly placing the electromagnetic bandgap structure around the radiating patch, the gain of a microstrip patch antenna was improved. They proved the gain of the proposed antenna improved by 2 dB at 5.2 GHz. (Arnmanee 2018) proposed a method for gain improvement of microstrip

patch antenna using octagonal loop superstrate and octagonal-shaped electromagnetic bandgap (EBG) structure for 2.4 GHz band application. The superstrate is suspended in the radiating patch at a distance of 7. 25mm to improve the gain. (Hu, Chen, and Chu 2016) proposed the development of flush-type radiators of the microstrip patch slot and discussed the advantages of slotted microstrip patch. (A. Kumar and Singh 2020) discussed the enhancement of gain using slotted antennas and compared its effect with the yagi-udaantenna.Our team has extensive knowledge and research experience that has translate into high quality publications(Patturaja and Pradeep 2016; Ramesh Kumar et al. 2011; Krishnan, Pandian, and Kumar S 2015; Felicita 2017b, [a] 2017; S. Kumar 2017; Sivamurthy and Sundari 2016; Sathivel et al. 2008; Sekar et al. 2019)
Through the above literature, it is found that many researchers have analysed the use of S-shaped antennas to obtain the gain which appears to be low which cannot be used for long-range distance communication. Usage of an additional slot which is 2 shaped along with S-shaped can attain better gain because of adding slots which helps to radiate the signals in Omni-directional as well as which supports long-distance communications such as GPS. The aim is to improve the gain performance of a microstrip patch antenna using a Novel S and 2 shaped antenna at 2.45 GHz.

2. MATERIALS AND METHODS

This study was conducted in an Antenna and Wave Propagation Laboratory, Department of Electronics and Communication Engineering, Saveetha School of Engineering. There are two groups in this research work. One group refers to a Novel S and 2 shaped antenna (Group 1), the second group refers to an S-shaped antenna (Group 2) (Patel, Patel, and Thakkar 2012). For each group, the sample size is 10. The total sample size is 20. Using clinical analysis, the pre-test power is found to be 80% taken for continuous testing with enrollment ratio 1, alpha value 0.05, and beta value 0.2 for Novel S and 2 shaped microstrip patch antenna.
Figure 1 shows the design view of the top plane and substrate thickness of the Microstrip patch antenna having 36mm width and 40mm length with an S-shaped slot (-26.5,33.2,1.8). The Novel S and 2 shaped slots are constructed on the patch with position of (-26.5,33.2,1.8) & (-37.8,22.1,1.8) and are shown in Fig. 2. The substrate was constructed with 1.8 mm thickness. The gain performance of the Novel S and 2 shaped microstrip patch antenna and S shaped antenna is analysed using HFSS software and are shown in Fig. 3(a) and Fig. 3(b) respectively.To get the results, Create a ground plane and substrate with the dimensions illustrated in Table 1. Assign dielectric material. Create a patch using the measured dimensions using Equations [1-7] (Chen, Wang, and Zhang 2009; Chintakindi et al. 2007) and assign a boundary with perfect electric. In this work, Novel S and 2 shaped slots are created with (-26.5,33.2,1.8) & (-37.8,22.1,1.8) coordinate dimensions on top of the patch.

Design of the Rectangular Micro-Strip Patch Antenna
A Rectangular Microstrip patch antenna is designed using Novel S and 2 shaped antenna at 2.45 GHz.The following parameters mentioned in equation [1-7] are taken into consideration during the design.(Kavas and Kirik 2016)
The width of microstrip patch antenna with DGS is calculated using Equation 1

$$W = \frac{c}{2fr}\sqrt{\frac{2}{\varepsilon r + 1}} \qquad (1)$$

c-Speed of light(3*10^8 m/sec)
W-Width of the patch
f_r-The center frequency

The effective dielectric constant based on antenna height, width, and dielectric constant of substrate is calculated using Equation 2

$$\varepsilon_{reff} = \left[\frac{\varepsilon_r + 1}{2}\right] + \left[\frac{\varepsilon_r - 1}{2}\right]\left[1 + 12\frac{h_L}{w}\right]^{-1/2} \qquad (2)$$

ε_{eff}-Effective dielectric constant
ε_r-Relative permittivity of the substrate
h-height of substrate

The effective length of the antenna (L_{eff}) is calculated using Equation 3

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{reff}}} \qquad (3)$$

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Where,
c is the velocity of the light, **fr**is the resonating frequency and
ris the relative permittivity of the dielectric material.
The length extension of the antenna(ΔL) is calculated using Equation 4

$$\Delta L=\frac{(\varepsilon_{reff}+0.3)\left(\frac{w}{h_L}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{w}{h_L}+0.8\right)} \quad (4)$$

The actual length of patch antenna(L) is calculated using Equation 5

$$\boldsymbol{L} = \boldsymbol{L_{eff}} - 2\Delta L \quad (5)$$

Where the Leff is the effective length of the patch.
The feed line length is calculated using Equation 6

$$L_f=\lambda_g/4 \quad (6)$$

Where λ_g is guided wavelength is given by

$$`\boldsymbol{\lambda_g}=\frac{c}{\sqrt{\varepsilon_{reff}}}$$

Ground plane dimensions $L_g$and $W_g$are calculated as given in Equation 7

$$L_g=6h+L$$
$$W_g=6h+W \quad (7)$$

L_g - length of the substrate andW_g - width of the substrate

A 9th generation Intel core processor (8MB cache, 2.45GHz) and MATLAB R2019a software were used to run the simulation. HFSS (Satheesh et al. 2008) is a software tool used for antenna design and sophisticated RF electronic circuit elements including filters, transmission lines. In this work, a microstrip patch antenna is simulated and tested with two different slots namely Novel S and 2 shaped slots and S-shaped slot with the help of the HFSS software tool. A rectangular microstrip patch antenna with an S and 2 shaped is designed having 1.8mm thickness with slot position of (-26.5,33.2,1.8) & (-37.8,22.1,1.8). Each antenna was simulated with square slots on the patch and 10 samples were collected.

Statistical analysis
The SPSS tool (Bright 2020) is used for statistical analysis. The two groups were analysed using an independent sample t-test. For this test, the dependent variables taken were gain and the independent variables taken were Microstrip patch antenna patch length, width, height, the dielectric constant of the substrate, and resonance frequency.

3. RESULTS

The Novel S and 2 shaped patch antenna are designed with the help of above equations 1 to 7 and designed values are listed in Table 1. The gain performance is analyzed for the frequency of 2.45 GHz using the HFSS tool. The analysis is done by changing various types of the slot such as U-shaped, rectangular slot, Novel S and 2 shaped slot antenna to attain better gain performance. From the iterations with different slots where the proposed work is having more gain at the slot position of (-26.5,33.2,1.8) & (-37.8,22.1,1.8). Fig. 3(a) shows the gain plots of the antenna with S-shaped antenna and Fig. 3(b) shows the gain plots of the antenna with Novel S and 2 shaped antenna. From Fig. 3(a) and Fig. 3(b), it is observed that the Novel S and 2 shaped antenna is having a gain of 7.76 dB and the S-shaped antenna is having a gain of 6.1dB which is listed in Table 2 (a). Fig. 5 (a) and Fig. 5(b) shows the 3D rectangular plot of the directivity performance. The red color indicates the maximum directivity obtained for the designed antenna and the other color indicates the lower values away from the resonance. The maximum directivity obtained for the NovelS and 2 shaped antenna is 7.54 dB.
The return loss performance of Novel S and 2 shaped antenna and S-shaped antenna has been simulated at the operating frequency of 2.45 GHz and is shown in Fig. 4 (a) and Fig.4(,b). The return loss values of Novel S and 2 shaped antenna is -21.62 dB and S-shaped antenna is -15.6 dB. These values are listed in Table 2(b).
The obtained gain values of microstrip patch antennas with S-shaped and NovelS and 2 shaped are validated through SPSS statistical tool software and shown in Table 3 and Table 4. From these Tables, it is observed that the mean gain value of the Novel S and 2 shaped is 6.86dB and the S-shaped antenna is 5.98dB. The validated gain values of S-shaped and Novel S and 2 shaped antenna are plotted and shown in Fig. 6.

4. DISCUSSIONS

From the results, it is observed that the microstrip patch antenna with Novel S and 2 shaped antenna is having improved gain performance (7.76 dB) compared to S-shaped antenna (6.1 dB). From Fig. 3(a) and Fig. 3(b), it is observed that the gain of the microstrip patch antenna is improved when the additional 2 shaped slot is implemented with the position of (-37.8,22.1,1.8). By comparing Fig. 4(a,b), it is found that the microstrip patch antenna with Novel S and 2 shaped is having reduced return loss value (-21.6dB) which means less power is required and more gain and high directivity compared to the antenna with S-shaped antenna (-15.6dB).
(Ali et al. 2011) proposed the design of an E-shaped microstrip single patch antenna. The parametric study was included to determine the effect of design on the antenna to improve the gain performance. It is found that the gain of the antenna is 4.9dB. In (Mekki et al. 2015) work, it is shown that the unidirectional antenna has a higher gain and a higher front-to-back ratio than the bidirectional one. This is achieved by using a second flame retardant layer (FR-4) coated with the copper of 0.035 mm at both sides with an air gap of 0.04 as a reflector. A gain of 5.2 dB with directivity of 7.6 dBi, F/B of 9.5 dB was attained in that work. (Li, Zeng, and Denidni 2017) In this design monopole is used as a radiating source and surrounded by four columns of FSS screens and metallic sheets. The metallic sheets are used to improve the gain of the antenna. Simulation results show the gain of the beam switching antenna with metallic sheets has been enhanced 7.2 dB compared to that without metallic sheets.(Midasala and Siddaiah 2016) proposed the design of the microstrip patch antenna with an array in Ku-band which results in the gain of 8.1dB. (Boutayeb and Denidni 2007) proposed parametric analysis using a full-wave method was carried out to design the EBG structure and obtained the gain value of 7.23 dB.
In this work, by using an additional 2 shaped slot, the antennas are designed for gain improvement, which means it has the ability to radiate in Omni-direction. In addition, more slots result in the Fringing Effect. To avoid this, the quality factor such as slot size should be within the limit of the microstrip patch antenna. This work can be extended for multi-band frequencies in satellite communications, GPS for navigation, and wireless communications by using proper slot dimensions suitable for mentioned applications.

5. CONCLUSION

Micro-Strip patch antenna with Novel S and 2 shaped is designed and simulated for gain improvement. It is observed that the mean gain performance of Micro-Strip patch antenna with Novel S and 2 shaped slot antenna is having significant improvement (6.97%) compared to S-shaped antenna.

DECLARATIONS

Conflict of interests

No conflict of interest in this manuscript.

Authors Contributions

Author AUK was involved in the design of Microstrip patch Antenna with Novel S and 2 shaped slots to improve the gain and its simulation. Author KC was involved in performance analysis, performance validation, and the review of manuscript.

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Tables and Figures

Table 1. Simulation Parameters of Novel S and 2 Shaped Microstrip patch antenna showing the details of patch width, length, and substrate thickness.

SI.No	PARAMETER	SPECIFICATION
1	Frequency of the patch	2.45 GHz
2	Dielectric constant	4.4
3	Width of the patch	36 mm
4	Length of the patch	40 mm
5	Thickness of the substrate	1.8 mm
6	Passes	10
7	Sweep	1 to 5 GHz
8	Feed Position	12.5 ,3,1.8
9	Position of S and 2 shaped slot	(-15.2,41,1.8)&(-16,5,1.8)

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Table 2(a). Comparison of the Gain (in dB) of Microstrip patch antenna with Novel S and 2 shaped is having 7.76dB and S-shaped antenna is having 6.1dB.

Parameter	Gain (dB)
S and 2 shaped	7.76
S-shaped	6.1

Table 2(b). Comparison of the return loss of S-shaped antenna which is having -15.6dB and Novel S and 2 shaped Microstrip patch antenna is having -21.6dB

Parameter	Return loss (dB)
S-shaped	-15.6424
S and 2 shaped	-21.6237

Table 3. Group statistics of Independent sample -t-test for Microstrip patch antenna with S-shaped and Novel S and 2 shaped antenna. Novel S and 2 shaped microstrip patch antenna is having significant improvement in mean gain compared to S-shaped Microstrip patch antenna

Group Statistics

	Group	N	Mean	Std.Deviation	std.Error Mean
Gain	With S and 2	10	6.8660	2.15427	.60451
	With S	10	5.9830	1.54934	.55684

Table 4. Independent sample T-test for significance and standard error determination. Novel S and 2 shaped Microstrip patch antenna are having significant improvement in mean gain compared to S-shaped Microstrip patch antenna.

Independent Samples Test								
		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Gain	Equal variances assumed	.892	.002	.508	18	.538	.35200	.73193

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	Equal variances not assumed			.508	16.345	.538	.35200	.73193

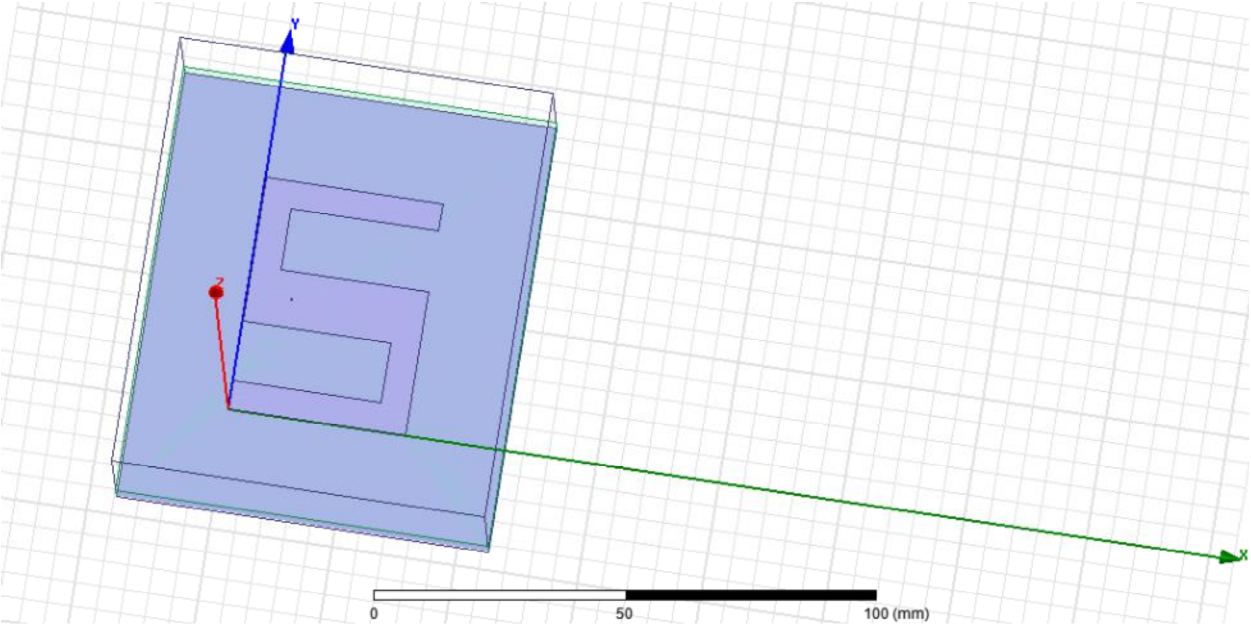

Fig. 1. Design view of Ground plane and Substrate of S-shaped micro-strip patch antenna, Thickness of the substrate --1.8mm, with the length of 36mm & 40mm width.

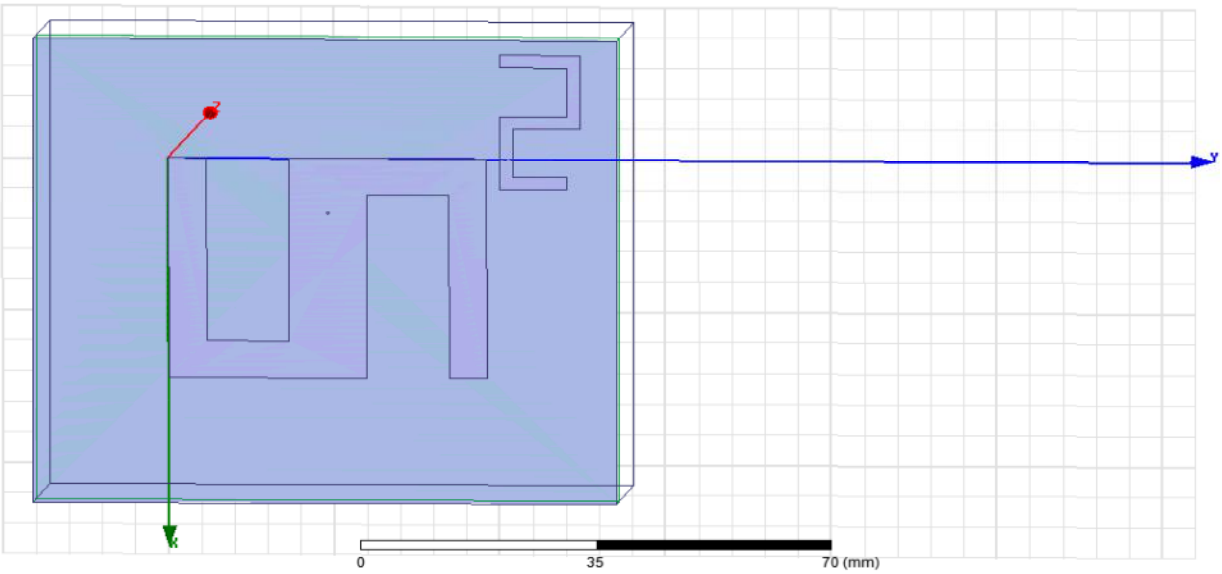

Fig. 2. Design view of Ground plane and Substrate of Novel S and 2 shaped microstrip S-shaped patch antenna, Thickness of the substrate --1.8mm, with the length of 36mm & 40mm width.

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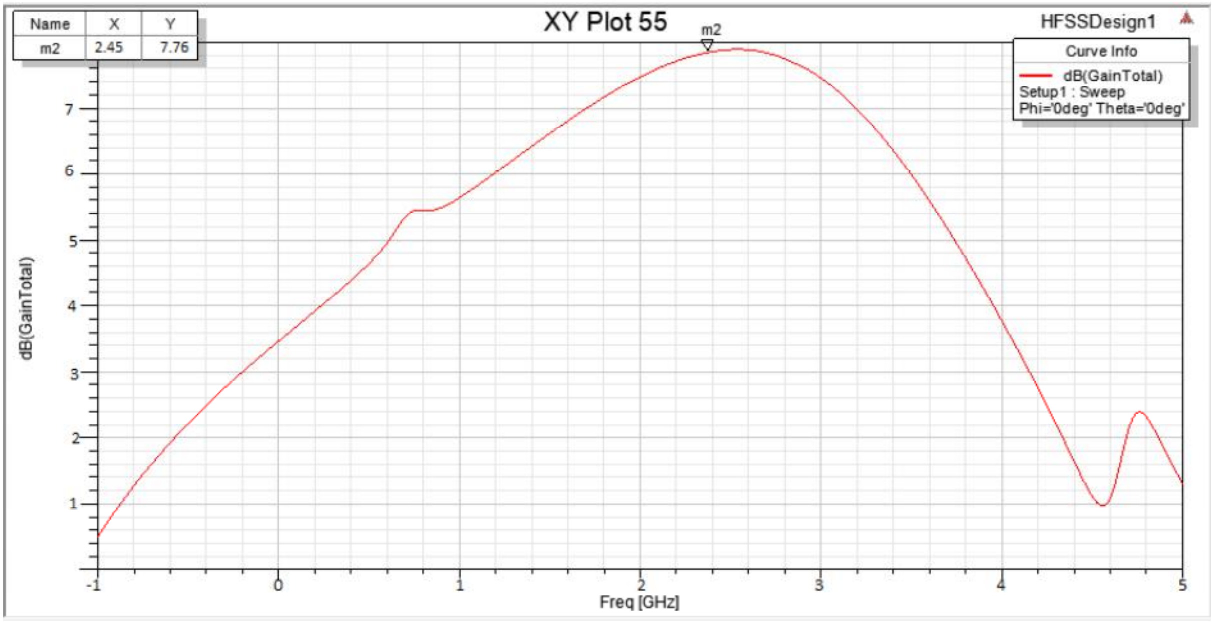
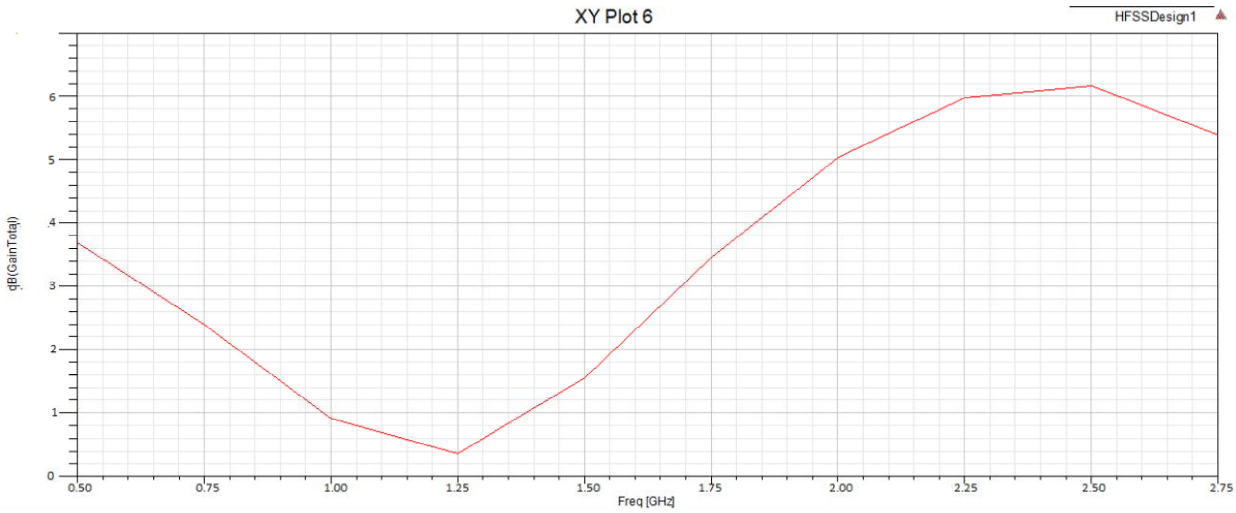


(a)



(b)

Fig. 3. Gain performance of Novel S and 2 shaped Microstrip patch antenna and S-shaped microstrip patch antenna (a) With Novel S and 2 shaped microstrip patch antenna = 7.76dB b) With S-shaped microstrip patch antenna = 6.1dB at 2.45GHz. X axis: Frequency in GHz, Y-axis: gain in dB.

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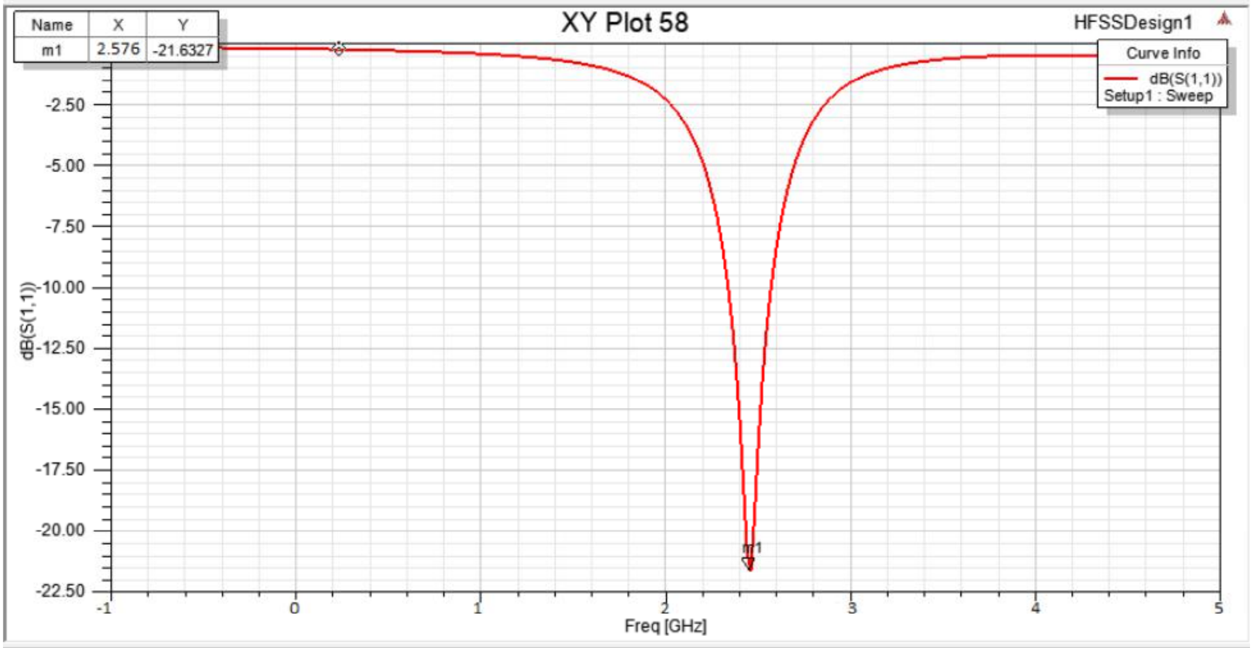
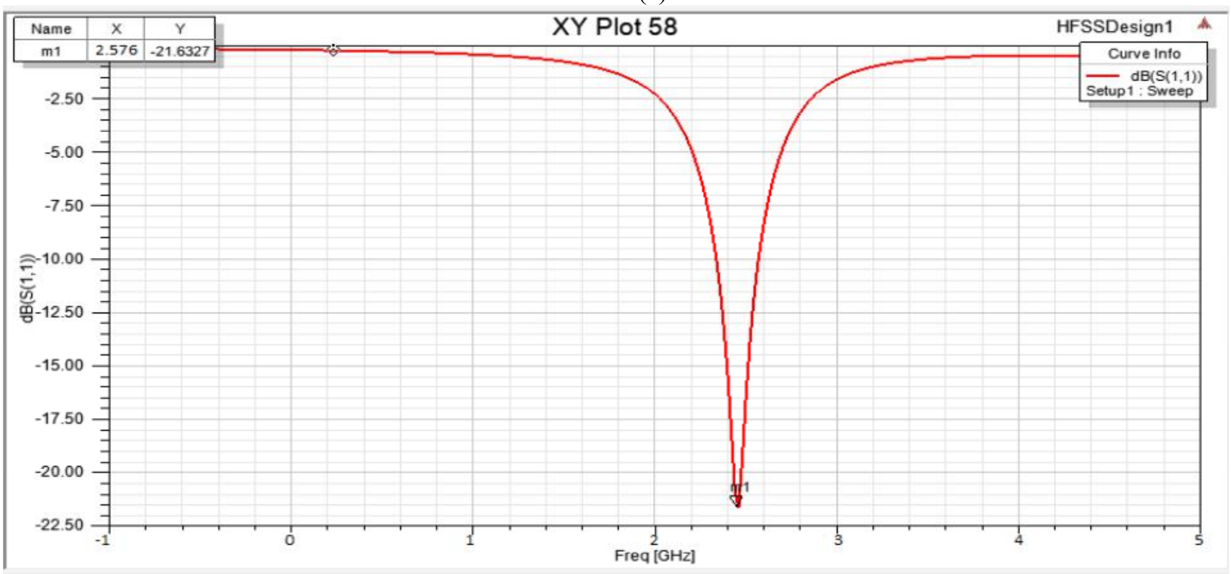
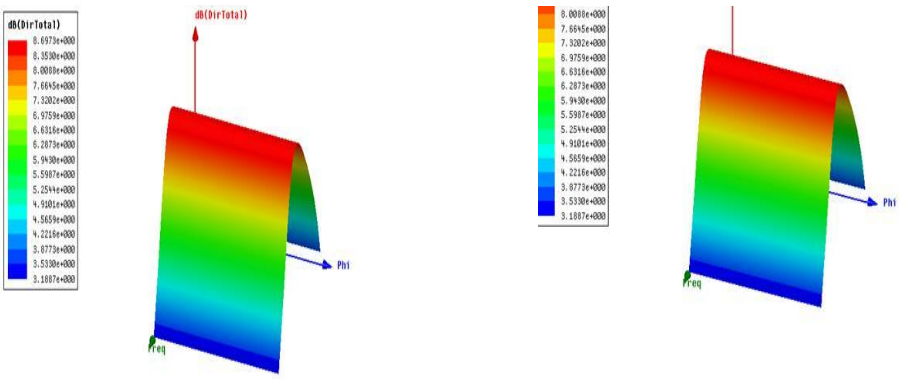


(a)



(b)

Fig. 4. Return loss performance of Novel S and 2 shaped Microstrip patch antenna and S-shaped microstrip patch antenna (a) Return loss value of the Novel S and 2 shaped microstrip patch antenna is -21.6dB b) S-shaped microstrip patch antenna return loss value is -15.6dB.



(a) (b)

Fig. 5. 3D rectangular plot shows the directivity performance of NovelS and 2 shaped Microstrip patch antenna and S-shaped microstrip patch antenna. a) Novel S and 2 shaped antenna gain value is 7.54dB, (b) S-shaped microstrip patch antenna gain value is 6.6dB.

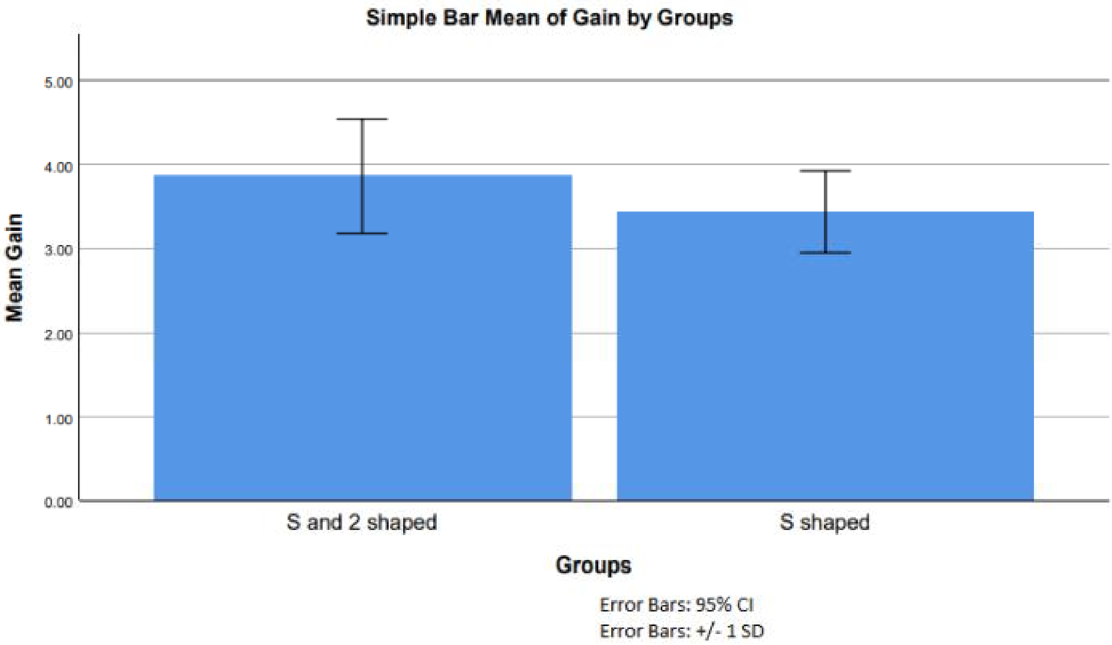


Fig. 6. The Bar Chart represents the Mean gain of the antenna with a NovelS and 2 shaped microstrip patch antenna and an S-shaped microstrip patch antenna. The mean gain performance of the antenna with a Novel S and 2 shaped microstrip patch antenna is having high accuracy when compared to the S-shaped microstrip patch antenna. Mean accuracy with Error Bars +/- 1 SD