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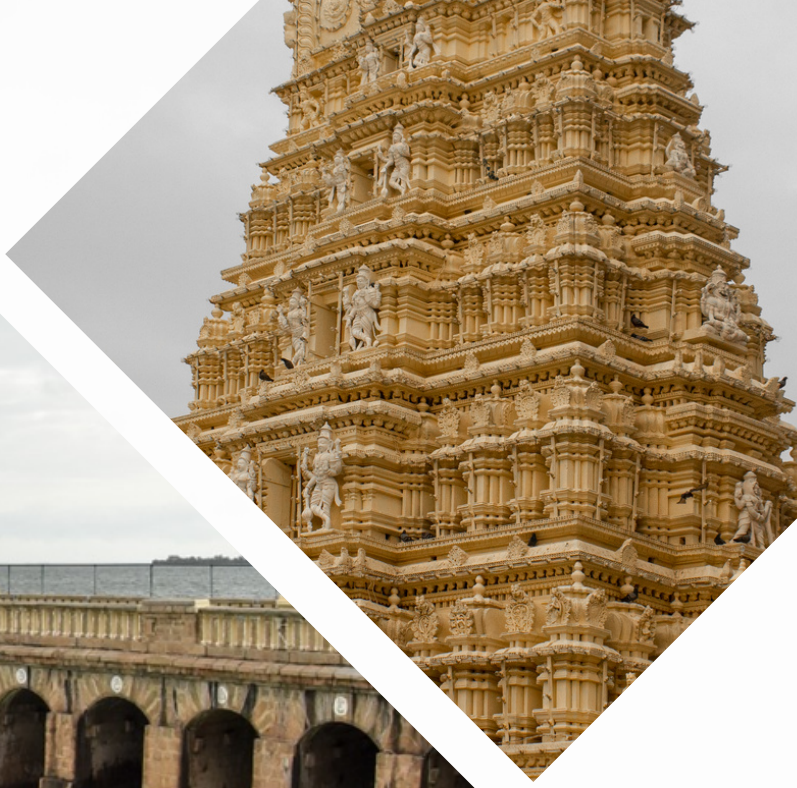

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Design and analysis of microstrip patch antenna

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***Abstract*—This work represents the design of a rectangular microstrip patch antenna resonating at 2.4 GHz to 11 GHz with better notch in the band. The structure of the rectangular microstrip patch antenna consists of the dielectric material in between the patch and the ground plane. The antenna is designed with a suitable substrate such as Flame-Retardant-4 (FR-4) which has a dielectric constant of 4.4, a height of 1.6 mm, and a loss tangent of 0.02. Microstrip feed lines are used for the design. The performance evaluation is measured in terms of return loss, gain, directivity and notch. From the results, this antenna has shown better performance in comparison to other related works.**

***Index Terms*—Microstrip patch antenna, return loss, gain, directivity**

I. Introduction

An antenna can transmit and/or receive electromagnetic waves. Antenna plays an important role in signal communication and is a secure and fast way of transferring data. At the beginning, communication was due to the sound voice. After that, communication was via radio and was the first communication that happened in human history. Later on, this was employed in industrial applications. Hence success in the antenna field came into the picture. Modern communication systems in the digital age require the usage of antenna that are miniaturized, compatible and reasonably priced. Different types of antenna with different shapes and sizes like rectangular, circular, triangular, and annular patches were discovered. Among those antennas, microstrip patch antennas [1] [2] are widely used in modern wireless technology because of many reasons such as low profile, less weight, cost-effectiveness, and conformal design. Microstrip antenna was developed in 1970s and got huge benefits and good performance. Many previous researchers found that patches in antenna arrays can be further improved by changing shapes like rectangular, and circular as well as with different frequencies as per the application. For wireless LAN, it can be operated in the frequency range of 2 to 3 GHz. Rectangular-shaped patch antenna has gained popularity because it can be easily analyzed and output exhibits better results.

II. Background

In relevant to this work few papers [3]–[10] are referred to understand the requirements for an antenna and suitable parameters were selected for the design. The paper [11] suggesting the design of a microstrip rectangular inset-fed patch antenna for Wimax application for a resonating frequency of 2.5 GHz was analyzed. The antenna was designed using CST microwave studio software. The size of the antenna plays an important role while designing. Making of an antenna of a smaller size with better output is always better. Paper [12] on miniature microstrip antenna for IOT application was referred. The antenna was designed such that the resonating frequency was around 5.8GHz. However, the results of that antenna were not up to the mark. The return loss was around -20 dB with a low gain value of 1.83 dB. So main factors to be considered for improving the results of the single-patch rectangular microstrip patch antenna with miniaturizing the size which will be resonating at the frequency of 2.4 GHz - 7 GHz, can be the dimension of the antenna to be varied. Another paper [13] representing a rectangular microstrip patch antenna was designed with slotted patches in it. The antenna had a resonating frequency of 2.4 GHz. The purpose of the antenna was to cover the entire ISM band (2.4-2.49 GHz). The antenna obtained a gain of 3.714dB and a directivity of 5.199 dB. The Table. I represents a comparison of several related papers contributions.

III. Workflow

For designing a microstrip patch antenna several various parameters are chosen carefully. They directly impact the antenna performance characteristics such as bandwidth, gain, and efficiency. The resonating frequency, the dielectric constant of the substrate material, and the height of the substrate material should be known prior to the design. This paper represents the designed microstrip patch antennas resonating at the frequency of 2.4 GHz to 11 GHz. The design of the antenna consists of 3 components such as the ground plane, substrate, and patch design. The substrate material used for the antenna was FR-4 with a dielectric constant of 4.4. The microstrip inset line feeding technique is used while designing

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the microstrip patch antenna as it provides a smooth surface to the antenna. The height of the substrate was 1.6mm. The 3D model of the rectangular microstrip patch antenna is designed using HFSS. Once the design was completed, it was simulated to observe the obtained antenna parameters. If the designed antenna maps up to the marked output, then the antenna is considered for further use. If the production was not up to the mark which is lesser than the expected values, then the antenna was redesigned with modifications. This modified antenna has to be simulated again to check if the requirements are met. The flow of the proposed work is represented by the flow chart in Fig. 1. The antenna parameters such as width and

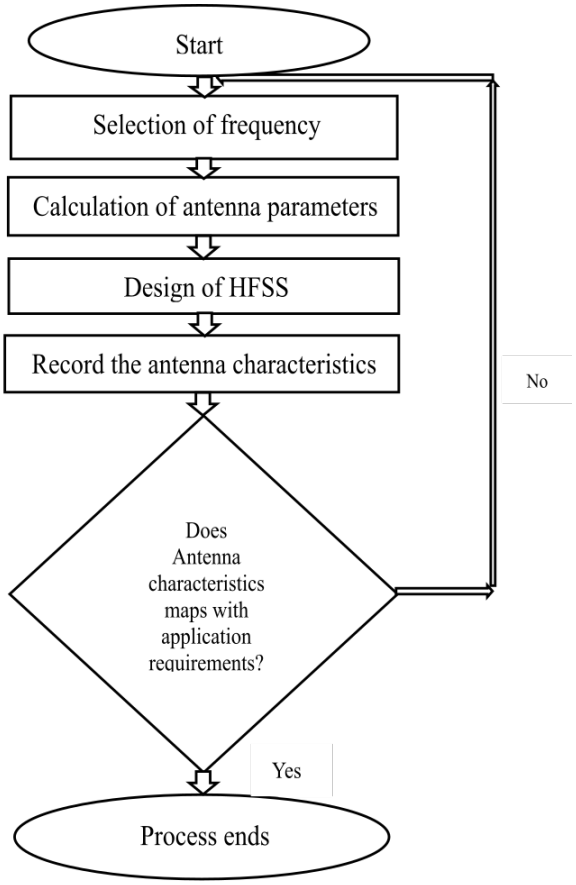

Fig. 1: Flow chart of Proposed antenna design

length (L_p) of the patch (W_p) have been calculated from the given equations.

$$W_{patch} = \frac{\text{speed of light}}{2f_r\sqrt{\frac{\epsilon_r+1}{2}}} \tag{1}$$

where the speed of light is the speed of the wave in the free space, f_r is the resonant frequency, and ϵ_r is the dielectric constant of the dielectric substrate. The effective dielectric constant ϵ_r is calculated by:

$$\epsilon_{effective} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[\frac{1}{\sqrt{1+12\left(\frac{h_s}{W_{patch}}\right)}}\right] \tag{2}$$

where h_s is the height of the substrate used in the design. The length of the patch is also an important parameter to be taken care of while designing the antenna. It is calculated using the formula:

$$L_{patch} = \frac{\text{speed of light}}{2f_r\sqrt{\epsilon_{effective}}} - 0.824h_s * \ldots \left(\frac{(\epsilon_{effective}+0.3)(\frac{W_{patch}}{h_s}+0.264)}{(\epsilon_{effective}-0.258)(\frac{W_{patch}}{h_s}+0.8)}\right) \tag{3}$$

The length of the ground is found using the equation:

$$L_{gnd} = 2 * L_{patch} \tag{4}$$

The width of the ground is obtained using the equation:

$$W_{gnd} = 2 * W_{patch} \tag{5}$$

IV. PROPOSED ANTENNA DESIGN

The prototype of proposed design is shown in Fig. 2. Parameters of the antenna are varied in each of the proposed designs to achieve better return loss characteristics. The Patch width for design 3 was changed to 36 mm from 38 mm as was in design 2, which resulted in 50 ohm impedance.

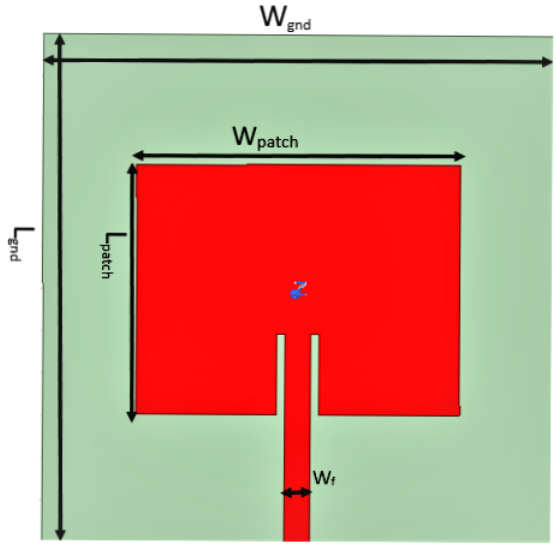

Fig. 2: Prototype of Proposed antenna design

A. PROPOSED DESIGN 1 AND RESULTS

Fig. [3]-[9] represents the notch in return loss, Gain, directivity, Modal Analysis, Surface current, Co and x pol, 2d radiation pattern of the proposed design1. It can be observed from Fig. 3 that the antenna has notch notch in return loss at -17.8025 dB to -20.2112 dB.

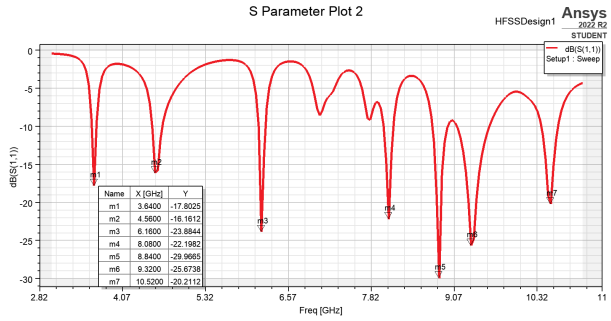

Fig. 3: Return Loss1

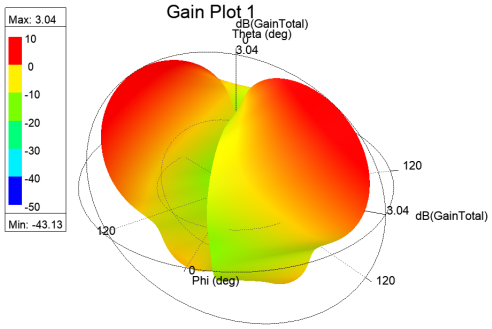

Fig. 4: Gain1

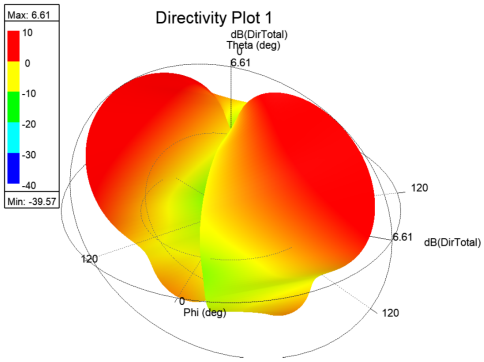

Fig. 5: Directivity1

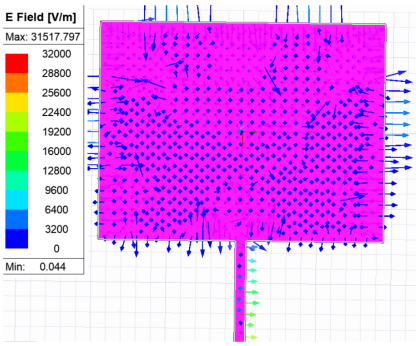

Fig. 6: Efield1

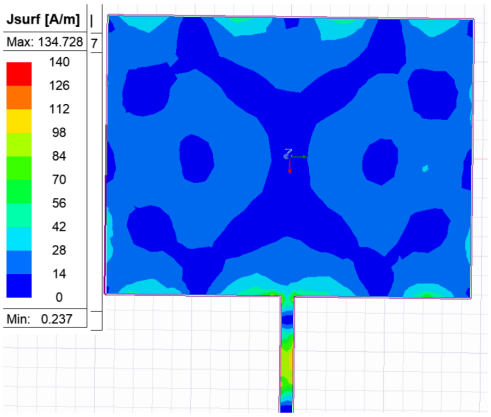

Fig. 7: Surface Current1

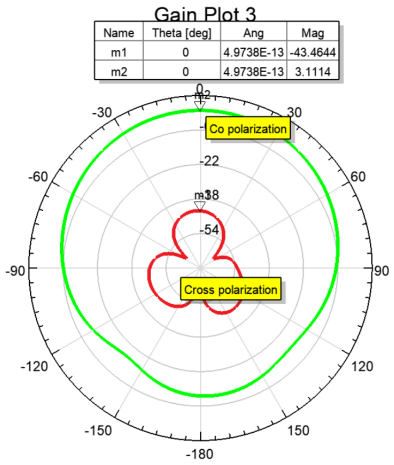

Fig. 8: Co and X pol of the antenna1

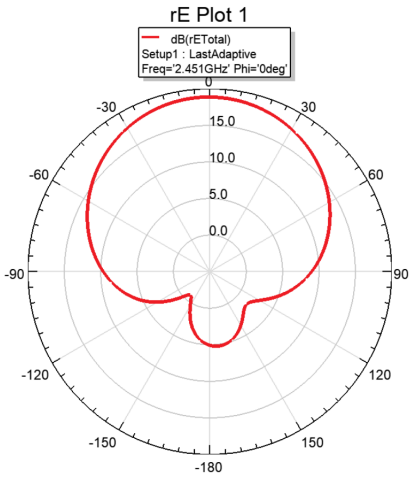

Fig. 9: 2D radiation pattern1

B. PROPOSED DESIGN 2 AND RESULTS

Fig. [10]-[16] represents the notch in return loss, Gain, directivity, Modal Analysis, Surface current, Co and x pol, 2d radiation pattern of the proposed design2.

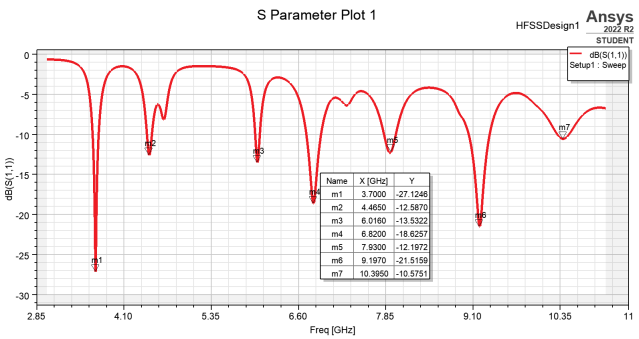

Fig. 10: Return Loss2

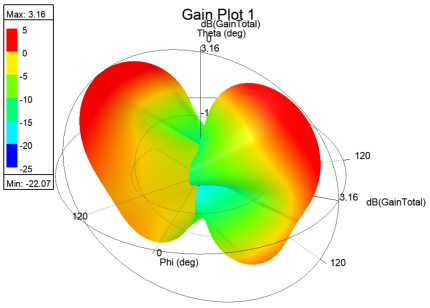

Fig. 11: Gain 2

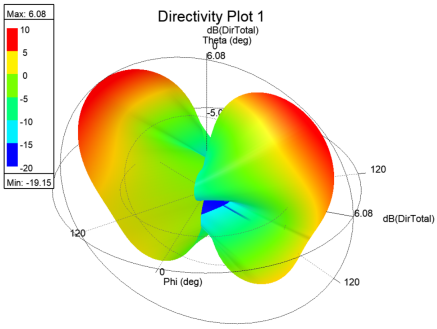

Fig. 12: Directivity2

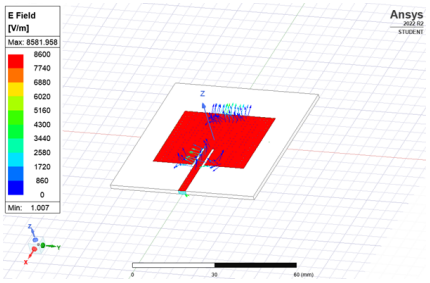

Fig. 13: Efield2

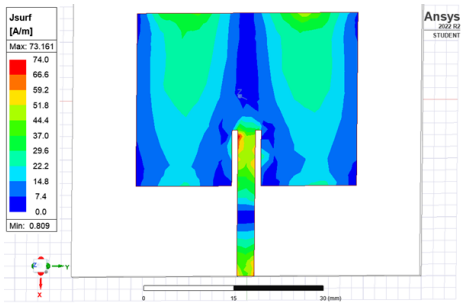

Fig. 14: Surface current2

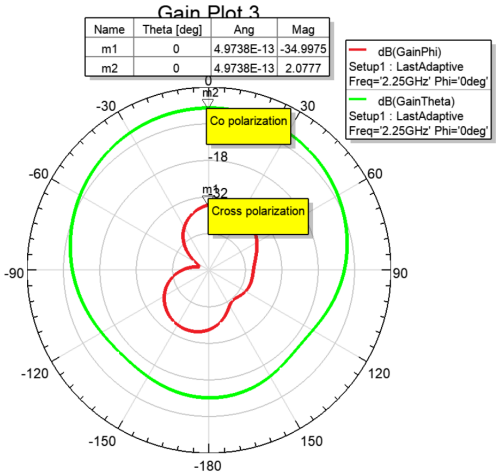

Fig. 15: Co and X pol of the antenna2

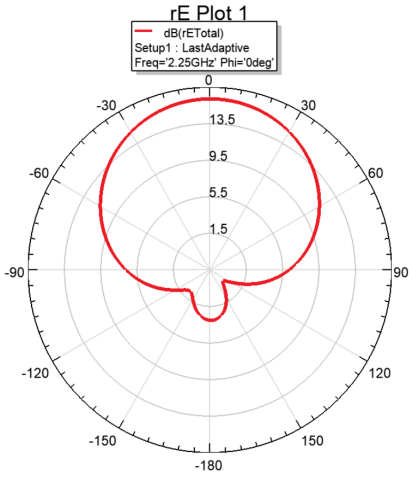

Fig. 16: 2D radiation pattern2

C. PROPOSED DESIGN 3 AND RESULTS

Fig. [17]-[23] represents the notch in return loss, Gain, directivity, Modal Analysis, Surface current, Co and x pol, 2d radiation pattern of the proposed design3.

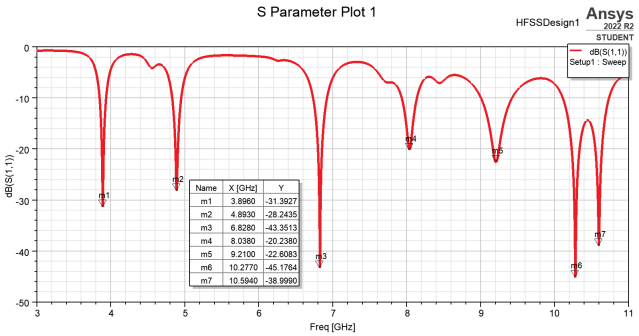

Fig. 17: Return loss3

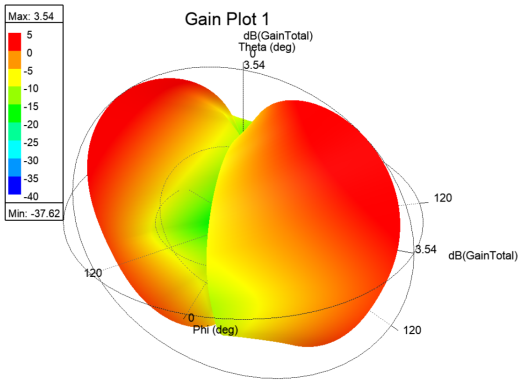

Fig. 18: Gain 3

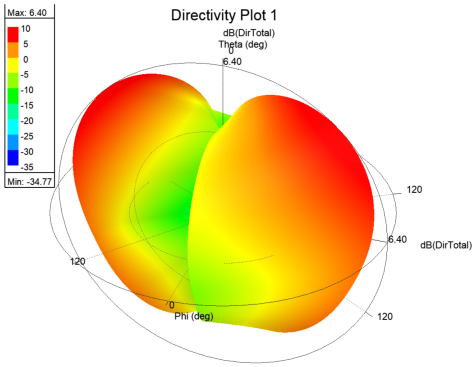

Fig. 19: Directivity3

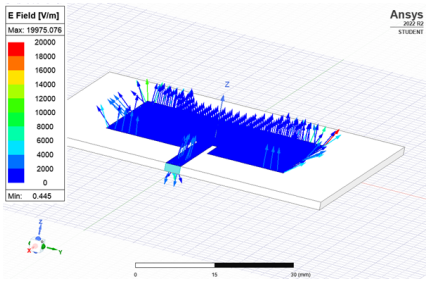

Fig. 20: Efield3

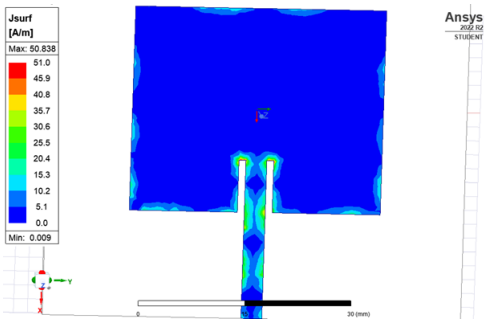

Fig. 21: Surface current 3

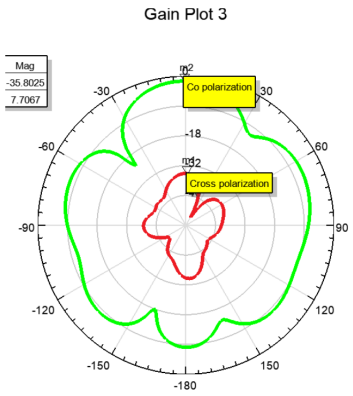

Fig. 22: Co and X pol of the antenna3

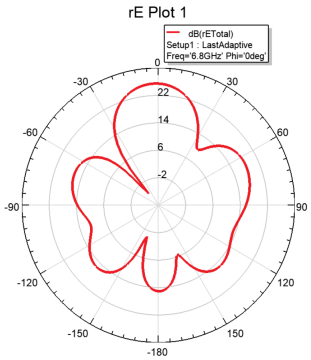

Fig. 23: 2D radiation pattern

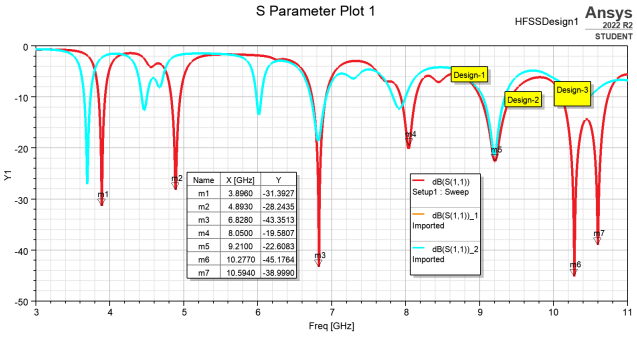

Fig. 24: Comparison of return losses of 3 designs

V. Comparison of simulated results

Fig. 24 represents the comparison of return losses for three proposed designs. The Table. II represents dimension and Table. [III]-[IV] represents all the results obtained.

TABLE I: Comparison of several author's contributions and their results

Sl No	Year	Title of the paper	Tool Used	Return Loss	Gain	Directivity	Conclusion
1	2004	[2]	FDTD method	—	–	3.4	MPA was mounted on a dielectric chip and it has been analyzed
2	2019	[12]	CST	-19.5	6.4	–	The 5G antenna was used for future 5G mobile applications because of its compactness.
3	2019	[13]	CST	-38.4	2.6	5.4	The proposed inset fed slotted MPA was found effective for ISM band applications
4	2020	[1]	–	–	–	–	Based on the number of patches on the antenna
5	2020	[11]	CST	-20.3	1.3	6.7	The single patch antenna obtained the return loss of -20db,directivity directivity was 6.75 and gain was 1.36
6	2020	[10]	CST	20.32	1.83	–	The attained operating frequency of 5.755 GHz is suitable for IOT applications

TABLE II: Comparison of dimensions

Parameter	Symbol	Values for design1 (mm)	Values for design 2 (mm)	Values for design3 (mm)
Ground width	W_{gnd}	80	60	60
Ground lengths	L_{gnd}	60	60	60
Substrate height	hs	1.6	1.6	1.6
Patch widths	W_{patch}	38	38	36
Patch length	L_{patch}	28.8	29.4	29.4
Feed width	W_f	1.4	3	3

TABLE III: Comparison of the design results1

Antenna	Resonant Frequency (GHz)	Return (dB)	Gain (dBi)	Directivity (dBi)
Design1	3.6400 to 10.5200 BW= 6.88	-17.8025 to -20.2112	3.04	6.61
Design2	3.700 to 10.3950 BW = 6.695	-27.1246 to -10.5751	3.16	6.06
Design3	3.8960 to 10.5940 BW= 6.698	**-31.39 to -38.9990**	3.54	6.40

TABLE IV: Comparison of the design results2

Antenna	Axial ratio(dB)	CO and X	E field(V/m)	current(A/m)
Design1	23.3312, 23.8684, 24.5158	-43.4644 to 3.1114	3200	14
Design2	33.5488, 21.1272, 15.8690	-34.9975 to 2.0777	860	7.4
Design3	52.1946, 33.5448, 17.2238	-35.8025 to 7.7067	2000	5.1

VI. Conclusion and Future Scope

In this paper design of rectangular microstrip patch antenna is proposed. Based on the results, proposed design 3 has shown better performance with 10.2770 GHz for operating frequency within 2.4 GHz to 11 GHz with better notch.This antenna can be optimized to achieve better return loss below -10 dB for wide band application.

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