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Design of Micro Strip Stacked Patch Antenna in C-Band for Satellite and Radar Communications

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Abstract: An analytical model of Edge Feed Micro Strip Stacked Patch Antenna (EFMSSPA) with twin slots operating at 5Ghz frequency is proposed and this lies within the microwave C-band (4-8 GHz). Micro strip Patch antennas (MSPA) with simple making procedure are preferred because of light weight , low profile low volume and easy to fabricate. These are used for satellite communication, wireless communication, medical , military systems and microwave radar applications. The antenna parameters like return Loss (S11), Voltage Standing Wave Ratio (VSWR), Gain and Directivity have been studied in this paper. The scale of the antenna 37.2*61.94*1.6mm3 has been increased by applying the Parametric Analysis. A unsighted trial and error means of analysis is take up to study the effects of twin slots on the patches .This Edge Feed Micro Strip Stacked Patch Antenna (EFMSSPA) with twin slots is designed using computer simulation Technology (CST) Microwave Studio. The CST Microwave Studio helps in understanding the features like Gain, Directivity, Return Loss (S_{11}) and Voltage Standing Wave Ratio. The design process of an EFMSSPA and EFMSPA (Edge Feed Micro strip Patch Antenna) is obtained by using FR4 Epoxy having a dielectric constant of 4.3. The Patch width (P_W) and Patch length (P_L) of an antenna are 18.43mm and 13.92mm The twin slots in the patch and stacked Patch placed with 3mm air gap above original patch increases the Return loss (S11), Gain and Directivity. A comparison of EFMSPA and EFMSSPA is considered and proved that EFMSSPA exhibits good results than EFMSPA.

Keywords*: Return Loss, Stacked Patch, Gain, Directivity, Micro strip Patch antennas (MSPA), Edge Feed Micro Strip Patch Antenna(EFMSPA) ,Edge Feed Micro Strip Stacked Patch Antenna(EFMSSPA).

I. INTRODUCTION

Antennas place a crucial role in communication systems. By definition, it is a device used to convert Radio frequency signal into an Electromagnetic wave in free space[1]. The radiating patch can be placed on one side of the dielectric substrate and ground plane on the back of the substrate to achieve the Micro Strip Patch Antenna (MSPA)[2]. The Materials of the patch are copper, gold etc and can be shape like, rectangular, circular or square type [3]. There are numerous feeding types in MSPA. The four types mainly pointed out and mostly used are micro strip line, coaxial probe, proximity coupling and aperture coupling [4]. The proposed antenna is designed using micro strip line. The advantages are more in MSPA when compared with conventional antennas. They have low cost, less weight, low volume and easy to fabricate. Radar communication demands a light weight, low profit, low volume antennas [5].The MSPA are an individual choice. They are used in Satellite communication, wireless communication, medical and military systems. Moreover, there are several disadvantages present in the MSPA. It consists of narrow bandwidth, low efficiency and low gain.

II. PROBLEM FORMULATION

There are several methods to improve to improve efficiency and gain in MSPA. One of the technique is to change the slots and apply stacked patches to the original patch, fractal geometry and defected ground structure [6]. In this paper, twin slots are placed in the patch and stacked patch is introduced with 3mm air gap above the original patch to increase the Return Loss (S_{11}), Gain and Directivity.

III. REVIEW OF MICRO STRIP PATCH ANTENNA[MSPA]

A dielectric substrate and a ground plane are present on the either side and a radiating patch is placed on the top of the substrate and is of any shape (planar or non planar in geometry) [7]. It is a resonant antenna and is popularly printed for narrowband microwave wireless links that are required for semi hemispherical coverage [8]. It is used as elements for an array due to its ease of integration and planar configuration with micro strip technology [9]. Most commonly used micro strip antennas consists of rectangular and circular patches and are used for most demanding applications [10]. The Symmetric pattern of radiation is the main advantage of circular patch antenna and a Rectangular MSPA in its easiest form is shown in Fig 1 [11].

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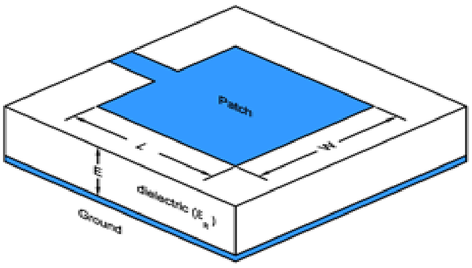


Fig 1. Micro Strip Patch Antenna

IV. DESIGN PROCEDURE

The Edge Feed Micro strip Patch Antenna (EFMSPA) and Edge Feed Micro strip Stacked Patch Antenna (EFMSSPA) with twin slots are shown in Fig 1 and Fig 3 respectively.

The design process of an EFMSPA is obtained by using FR4 Epoxy having a dielectric constant of 4.3. The thickness of the substrate is 1.6mm. The Length and Width of the Substrate are 61.9mm of 37.2mm. The Patch and Ground thickness is 0.2mm and the material for the Patch and Ground is Copper. The parameters are shown in the Table 1.

The design of an antenna is done in two ways to get the better gain and directivity.

Here the frequency considered as C-Band which is in the range of 4-8 GHz and is used in the satellite communication and radar application.

Equations (1) to (6) are the design equations using transmission line model. The following are steps to design the antenna

Step1: consider the frequency of C-Band (4- 8GHz) as resonant frequency $f_r = 5$ GHz, Thickness of the Substrate (ht) and Relativity Permeability s_r=4.3 of the substrate.

Step2: To get the values of patch width (P_W) just place the values of s_r and λ_w

$$P_W = {}^{\lambda_W}\!/_2 \, [(\varepsilon_r + 1)/2]^{-1/2} \qquad (1)$$

Step3: To get Patch Length (P_L) after obtaining

ΔL and s_{reff}

$$p_L = {}^{1}\!/\left[2 f_r (\varepsilon_{ref})^{1/2}\right] \qquad (2)$$

$$\varepsilon_{reff} = [(\varepsilon_r + 1)/2 + (\varepsilon_r - 1)/2][1 + 12(h_t / P_W)]^{-1/2} \qquad (3)$$

$$\Delta L = 0.412 \frac{[(\varepsilon_{reff} + 0.3)(P_W / h_t + 0.264)]}{[(\varepsilon_{reff} - 0.258)(P_W / h_t + 0.8)]} \qquad (4)$$

Where h is the height of the substrate and W is the width of the patch.

Step4: The Location of the feed of MSPA rectangular patch antenna can be given as

$$X_{f1} = [P_L / 2(\varepsilon_{reff})^{1/2}] \qquad (5)$$

$$Y_{f1} = P_W / 2 \qquad (6)$$

Where (X_{fl}, Y_{fl}) is the desired feed location.

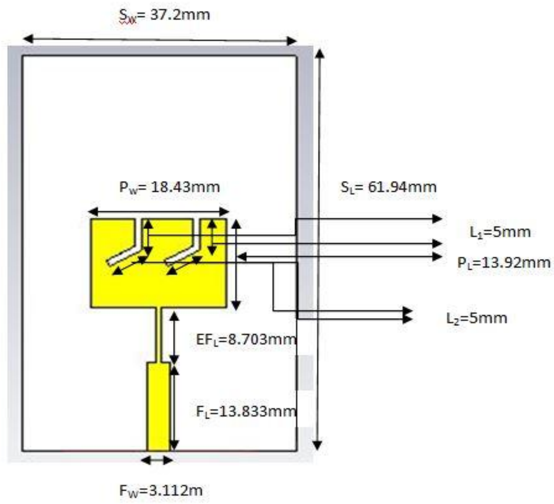


Fig 2. Edge feed MSPA (EFMSPA) with twin slots

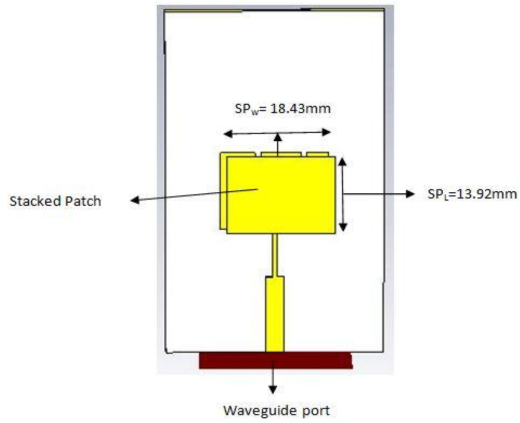


Fig 3. Edge feed Micro Strip Stacked Patch Antenna(EFMSSPA)with twin slots

The design parameters of EFMSPA are shown in Table 1.The Patch width (P_W) and Patch length (P_L) of an antenna is 18.43mm and 13.92mm. The slot lengths L_1 and L_2 are of same values 5mm with an angle of 120^o from the axis XY.

Table I:Parameters of EFMSPA with Twin Slots

Description	Parameters	Dimensions(mm)
Substrate Width	S_W	37.2
Substrate Length	S_L	61.94
Patch Width	P_W	18.43
Patch Length	P_L	13.92
Slots	L_1	5
	L_2	5
Width of Feed Line	F_W	3.112
Length of Feed Line	F_L	13.833
Effective Feed Length	EF_L	8.703
Effective Feed Width	EF_W	0.753
Ground Width	G_W	37.2
Ground Length	G_L	61.94
Stacked Patch Length	SP_L	13.92
Stacked Patch Width	SPW	18.43
Air Gap Patch & Stacked Patch	AG	3
Height of the Substrate	ht	1.6

V. SIMULATION RESULTS

CST Microwave Studio is used as a design tool for MSPA. The CST tool designer can implement the antenna and it also helps in understanding the features like Gain, Directivity, Return Loss (S_{11}) and Voltage Standing Wave Ratio. Fig 4 shows the Return Loss (S_{11}) of Edge Feed Micro strip Patch Antenna (EFMSPA) with twin slots at 4.56GHz is -21.5179. Fig 5 shows the Return Loss (S_{11}) of Edge Feed Micro strip Stacked Patch Antenna (EFMSSPA) with twin slots at 4.53GHz is - 32.7604.

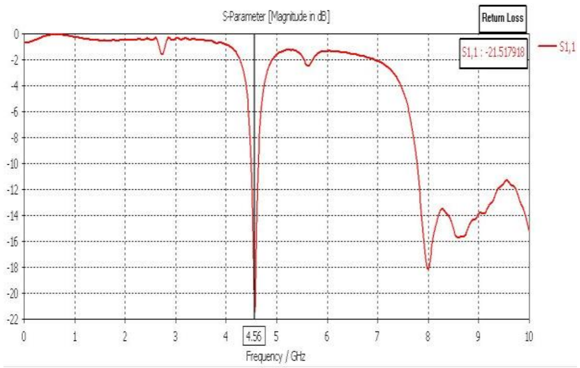


Fig 4. Return loss (S11) of EFMSPA with twin slots

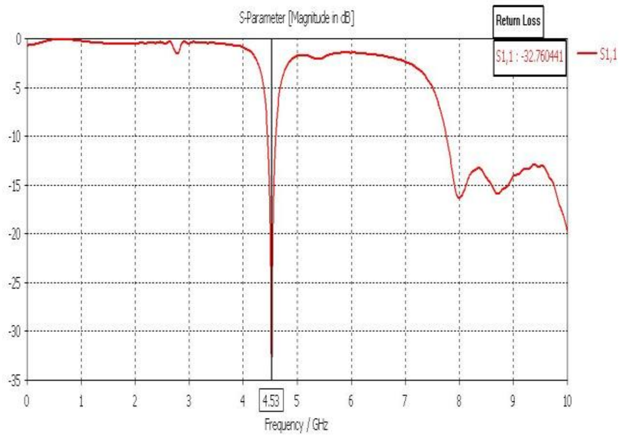


Fig 5. Return loss (S11) of EFMSSPA with twin slots

The Comparisons of both EFMSPA and Edge Feed Micro strip Stacked Patch Antenna with twin slots are shown in Fig 6.

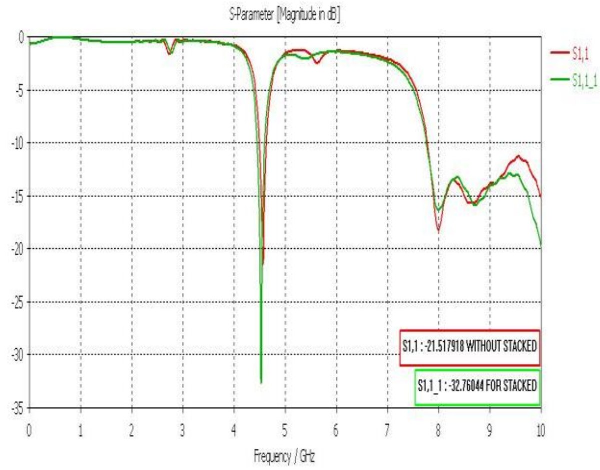


Fig 6. Return Loss comparison of EFMSPA and EFMSSPA with twin slots

The VSWR Results for EFMSPA and Edge Feed Micro strip Stacked Patch Antenna (EFMSSPA) with twin slots are shown in Fig 7 and Fig 8 respectively.

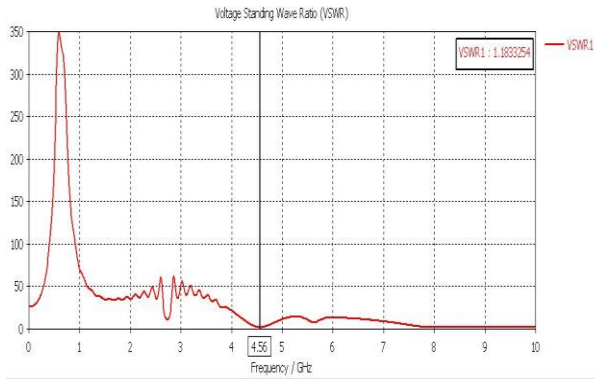


Fig 7. VSWR for EFMSPA with twin slots

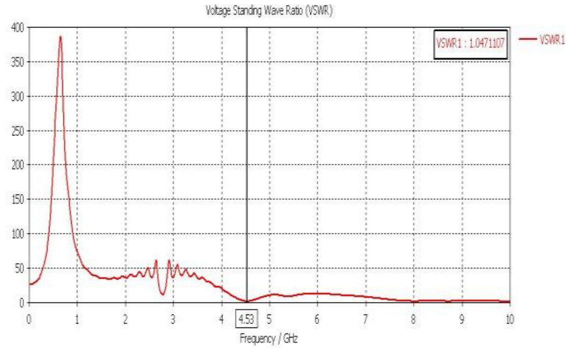


Fig 8. VSWR for EFMSSPA with twin slots

Comparisons of VSWR for both the results are shown in Fig 9.

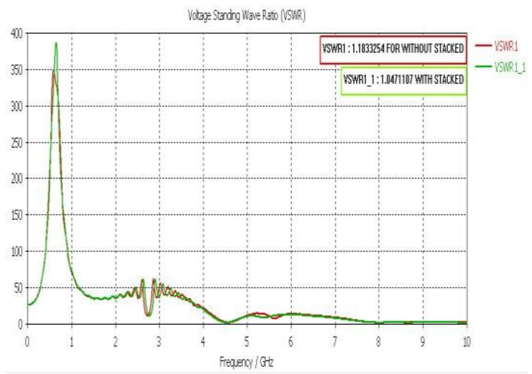


Fig 9. Comparison results of VSWR EFMSPA and EFMSSPA with twin slots

The Three Dimensional Radiation Pattern of Gain is shown in Fig 8. The high Gain obtained for Edge Feed Micro strip Stacked Patch Antenna (EFMSSPA) is 5.04db compared with EFMSPA having twin slots is 3.28db. These are shown in Fig 10 and 11:

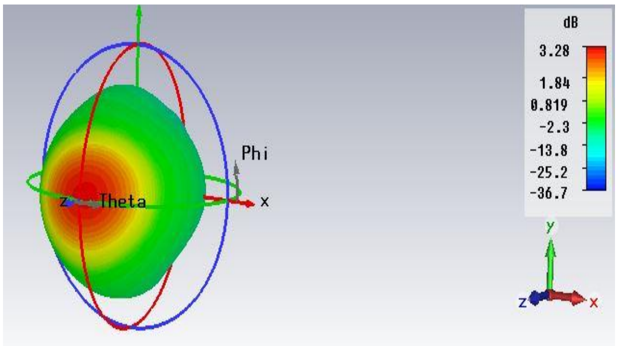
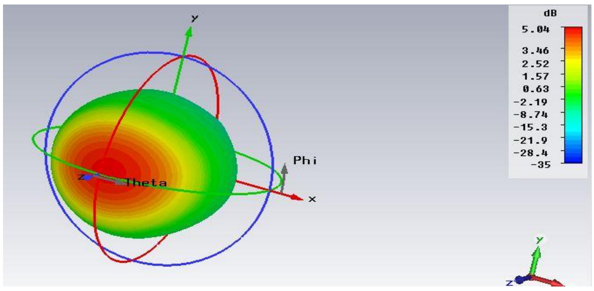


Fig 10: EFMSPA 3D Gain pattern with twin slots



FFig 11 : EFMSSPA 3D Gain Pattern with twin slots

The Directivity of the EFMSPA and Edge Feed Micro strip Stacked Patch Antenna (EFMSSPA) with twin slots are 7.61dbi and 8.29dbi and are shown in Fig 12 and 13.

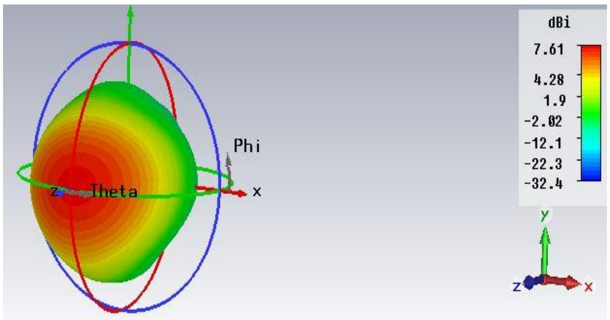


Fig 12 : EFMSPA Directivity Pattern with twin slots

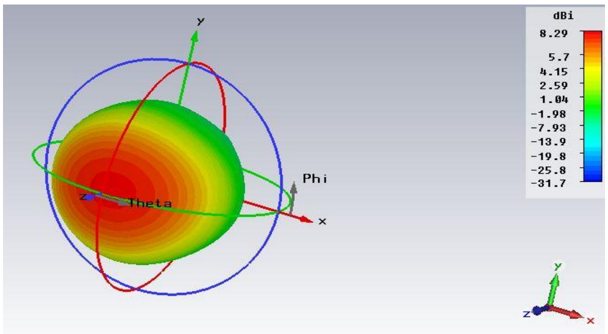


Fig 13: EFMSSPA Directivity Pattern with twin slots

From the Graphs, the values can be easily de- scribed. The central frequency of an antenna is around 5GHz which is lies in the C-band. The return loss of the EFMSPA is -21.5179dB and Edge Feed Micro strip Stacked Patch Antenna (EFMSSPA) with twin slots is -32.7604.

It can be stated that the Return Loss (S11) is improved. The VSWR has also improved by 1.1833 to 1.047. Maximum Gain 5.04db and is obtained by Stacked EFMSA. Directivity is also increased with 8.29dbi.

VI. COMPARATIVE ANALYSIS

The Performance Comparison of Return Loss (S_{11}), VSWR, Gain and Directivity for EFMSPA and Edge Feed Micro strip Stacked Patch Antenna with twin slots are tabulated as follows in Table 2.

Table 2. Comparison of S_{11}, VSWR, Gain and Directivity

Parameters	EFMSPA with twin slots	Edge Feed Micro strip Stacked Patch Antenna with twin slots
Frequency	4.56GHz	4.53GHz
Return Loss (S_{11})	-21.5179	-32.7604
VSWR	1.1833	1.047
Gain	3.28db	5.04db
Directivity	7.61dbi	8.29dbi

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VII. CONCLUSION

Here in this project the Stacked Edge Feed Micro strip Patch Antenna operating at C-band with 5GHz as central frequency has given the desirable features. The twin slots in the patch and stacked Patch placed with 3mm air gap above original patch increases the Return loss (S11), Gain and Directivity. A comparison of EFMSPA and EFMSSPA is considered and proved that EFMSSPA exhibits good results than EFMSPA. Gain and directivity values of these antennas are 5.04db and 8.29dbi at 4.53GHz frequency. The Return Loss (S_{11}) of Edge Feed Micro strip Stacked Patch Antenna is -32.7604. Hence it can be used in the Satellite Communication and Radar Applications. Endower

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