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Microstrip Antenna for Enhanced Bandwidth.

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Abstract. Introduction: A compact MPA has been presented with an increased bandwidth for X band applications. A 24 mmX15.6mmX1.6mm is designed and fabricated on FR4 substrate with co-axial probe fed excitation. **Methodology**: Here Commercially available integrated electromagnetic 3dimentional (IE3D) is used for simulation. Bandwidth is increased in the desired band by changing the shape of the patch to 'I' and also by placing an inverted L slot on ground plane which generates two adjacent resonances**. Results**: The antenna is resonating at 10.53 GHz &11.71GHz giving a return loss of -28.49dB and -25.74dB. In the desired X-band (8GHz-12GHz) the antenna is giving an impedance bandwidth of 3.99GHz from 8.28GHz — 12.27GHz which is below -10dBi. A maximum peak gain of 7.51 dB at attained at the operating frequency with a good radiation pattern and less cross polarization. The parametric study of the proposed patch antenna is done w.r.t slots, height of the substrate and substrate material. The proposed antenna is fabricated and tested the results using VNA shows in good agreement between simulated and measured. The proposed antenna compared with the existing ones w.r.t results.

Keywords: Coaxial probe, FR4 substrate material, Inverted L slot, MPA, X-band.

1 Introduction

Due to the changes in wireless communication systems, demands for new generation of antenna technoloi MPA is one which will fulfill the demands of Wireless communication due to its attractive advantages li less profile, low weight, low cost, easy to fabricate and conformal design. MPA has a dielectric substrate wi one side patch and on other side ground plane [1-2]. Apart from advantages it has limitations as lower pow handling, lower bandwidth low efficiency. To overcome these limitations many techniques has been propos in literature. Many researches have proposed different techniques to enhance the bandwidth like stacked mu resonator, multi layered, modifying the shape of the patch, modifying the ground plane etc.[3-5].

Among these modifying the shape of the patch and ground plane (by placing slots) are the easier methods wi respect to design and size [6-8]. Due to high data transmission rates, short range and larg- 'dth X bay technology is widely used. A circular and rectangular slot antenna for X-band applicati but tl gives a bandwidth of 1.5 GHz and of 40x4Onun in size [9]. On modified ground p ♦ pat antenna is proposed with a size of 36 x36mm and a maximum gain of 4.1dB [10]. pat antenna is proposed on 30 x 30 is proposed for X band applications [11]. With a wide range of size X70mm is proposed which is too large [12]. An E-slot patch antenna with micro-strip line feed and CPW feed is designed with enhanced BW but dimension is 85x85mm is too large [13].

In this paper by placing an inverted L slot on ground plane and by changing the shape as 4, makes the patch to resonate at nearby frequencies to improve the bandwidth to 3.99GHz an improvement of 82.4% in X-band, with a size reduction of 41.6% [11] and a gain of 60%. Parametric study is done with respect to height and dielectric substrate and is discussed in detail.

2. Antenna Geometry and Design

In order to increase the bandwidth, the shape of the patch is changed to **Ψ**, and also placed an inverted L shaped slots on the ground plane. Fig 1 shows the proposed MPA and a modified ground plane. The design procedure starts with the selection of parameters like Resonating frequency, Dielectric constant of the substrate, height of the substrate, type of feed and size of the ground plane. The patch antenna is tested on a 1.6 mm thick Flame Resistant (FR4) substrate that has relative permeability 1, relative permittivity 4.50, and dielectric loss tangent of 0.025. The proposed antenna is fed with coaxial probe. The SMA connector with 500 impedance is connected at (12, 3.925) as a feeding line to give RF signal as input.

The transmission line model (TEM) approximations used to design micro-strip patch antenna. Using the following below equations the width and length of the MPA can be designed for the given f0.

$$W = C/2f\sqrt{2/\varepsilon_{r}+1} \quad (1)$$

$$\lambda_{g} = c/f\sqrt{\varepsilon_{reff}} \quad , \quad L = \lambda_{g}/2 - 2\,\Delta L \quad (2)$$

Where, W is the width of the radiating patch, L is the length of the radiating patch and is the guided wavelength f0 is the desired resonance, c is used to indicate the light speed in a vacuum. ε_{reff} is the effective dielectric constant is determined using the following equation:

$$\varepsilon_{reff} = (\varepsilon_{r}+1/2) + (\varepsilon_{r}-1/2)\,(1+12h/w)^{-1/2}$$

Where, ε_r is the substrate dielectric constant and the substrate thickness is indicated as h. Due to the fringing fields around the periphery of the patch , the antenna looks larger than its physical dimensions Al accounts for this which is given by the following equation

$$\Delta L = 0.412h\left[(\varepsilon_{reff}+0.3)/(\varepsilon_{reff}-0.258)\right]\left[\{(w/h)+0.264\}/\{(w/h)+0.8\}\right] \quad (4)$$

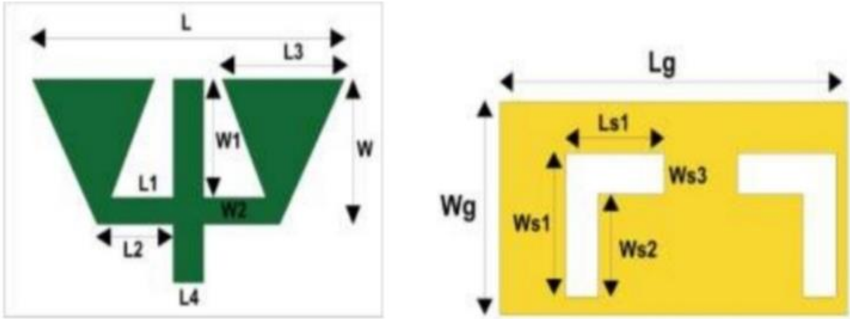
The input impedance of the micro-strip patch antenna is calculated and must be made equal to the probe impedance of 5052. We can calculate the correct co-ordinate of the feeding point using the following equations.

$$Gl = (1/120)(w/\lambda_{0}) \quad (5)$$

$$Y_{in} = 2Gl, \; Z_{in} = 1/Y_{in} \quad (6)$$

$$R_{in} = 1/2Gl\left[\cos^{2}(\pi y_{0}/L)\right] \quad (7)$$

Where Yo is the feed point and Rin =500. Keeping dielectric constant and bandwidth as objectives the antenna is first designed to operate in X band by using above equations then optimized to achieve optimum size and bandwidth of the radiating patch. Finally the satisfactory dimensions have been tabulated in table 1. The geometry of the proposed antenna from simulation software and fabricated one is shown in figure 2.



(a)Top layer (b)Modified ground plane

Figure.1. Geometries of the proposed patch antenna

Table 1. Proposed Antenna Specifications (All units are in mm)

Parameter	W	L	W1	W2	L1	L2	L3	Wg	Lg	Ls1	Ls2	Ws1	Ws2	Ws3
Proposed Antenna	15.6	11.6	11.4	0.6	1.43	3.5	5.3	3.2	24	2.4	1.2	2.4	1.8	0.6

(a)Top layer (b) Bottom layer

Figure 2. Fabricated geometry of the proposed antenna

3. Results and Discussion

In order to get the required performance the patch is simulated using Integrated Electromagnetic dimension (IE3D). Return loss indicates the amount of power reflected back, for MPA's the acceptable value of S 1 1 must be less than -10dB .The patch is resonating at two frequencies to increase the bandwidth. The patch is resonating at 1038 GHz and 11.71 GHz giving a return loss of -28.49dB and -25.74 dB respectively which is shown in figure 3. In X band we got 3.99 GHz (8.28GHz — 12.27GHz) bandwidth. The patch fabricated and tested through Vector network analyzer (VNA) and the results shows that apart from X band the patch are resonating in C band from 5.61 GHz to 6.58GHz due to feed radius variation and fabrication errors.

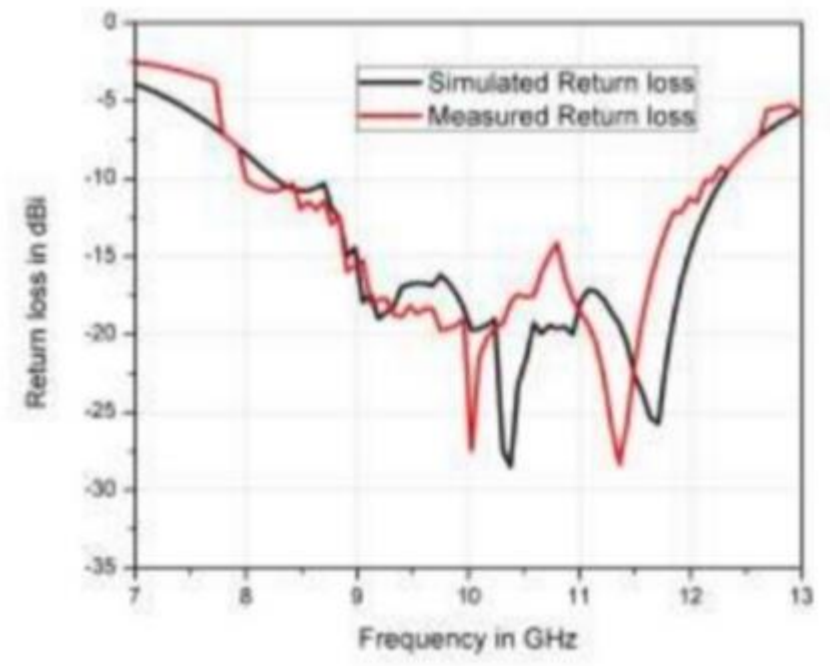


Figure 3: Return Loss of the proposed antenna simulated and measured

3.1. Parametric Evaluation:

To investigate the effect of parameters on antenna performance, some parameters are identified and studied based on design. Parametric study have been performed with respect to (a) Presence of inverted L slot on ground plane (b) Effect of thickness of the substrate (c) Effect of dielectric constant of the material. This simulation has been carried out by using IE3D simulator.

3.1.1 Presence of an inverted L slot on ground plane:

To study the effect of an inverted L slot on ground plane on antenna performance, keeping all other parameters fixed a simulation is carried out without an inverted L slot is presented in Fig 4. It can be observed that an inverted L slot has a significant effect on the bandwidth. The ψ patch without an inverted u slot on ground plane resonates at 10.44 GHz and 11.56 GHz. In X band we got 2.08 GHz (10.15GHz — 12.23GHz) bandwidth. The same antenna with an inverted L slot on ground plane is resonating at 1038 GHz and 11 GHz; we got an impedance bandwidth of 3.99 GHz (8.28GHz — 12.27GHz). On comparing the effect of slot without slots patch is giving a small bandwidth. With slots at proper positions resonates at nearby multiple frequencies which increases the bandwidth.

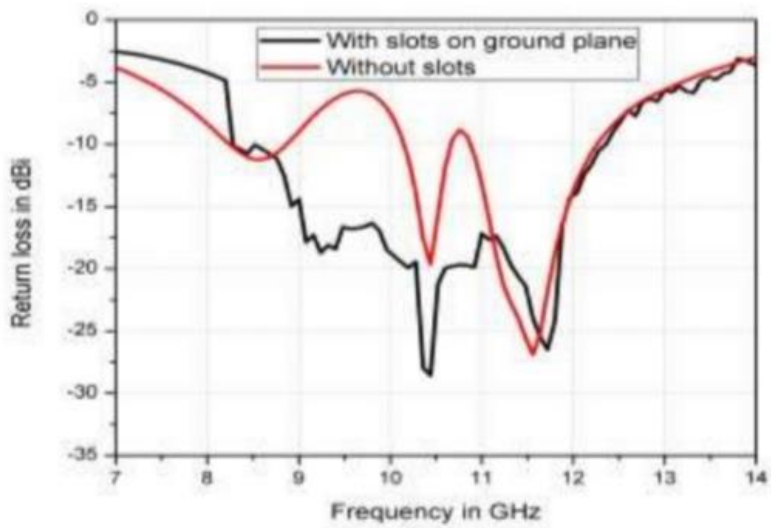


Figure 4: Return Loss of the proposed Antenna with and without slots on ground plane

3.1.2. Variation of height of the substrate:

Considering the same structure, by decreasing the height of the substrate the antenna 1 is giving S 11 less than -10dB from 11.9 GHz to 16.1 GHz giving a bandwidth of 4.2GHz which is shown in figure 5. Considering the same structure again, by increasing the height of the substrate the antenna 2 is giving Sll less than -10dB from 8.11 GHz to 10.15 GHz giving a bandwidth of 2.04 GHz. This shows that the resonating frequency is inversely proportional to the height of patch.

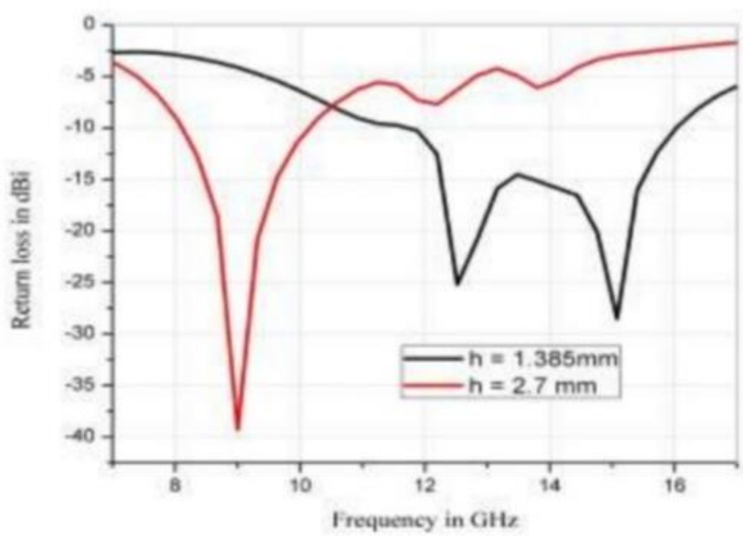


Figure 5: Return Loss of the proposed Antennas with respect to the variation of height

3.1.3. Variation of dielectric constant of the substrate material:

Considering the same structure , by changing the material of substrate i.e choosing RT Duriod with dielectric constant as 2.22 and loss tangent of 0.0009 and a height of 2.72mm the antenna 3 is giving S11 less than -10dB from 8.49GHz to 10.49GHz giving a bandwidth of 2 GHz which is shown in figure 6. Considering the same structure again, by choosing LCP substrate with a dielectric constant of 3.1 and loss tangent of 0.002 and height of 1.385 antennas 4 is designed and is giving S11 less than -10dB from 11.06GHz to 14.76GHz giving a bandwidth of 3.16GHz which is shown in figure 6. This shows that this patch antenna is sensitive variation of dielectric substrate material.

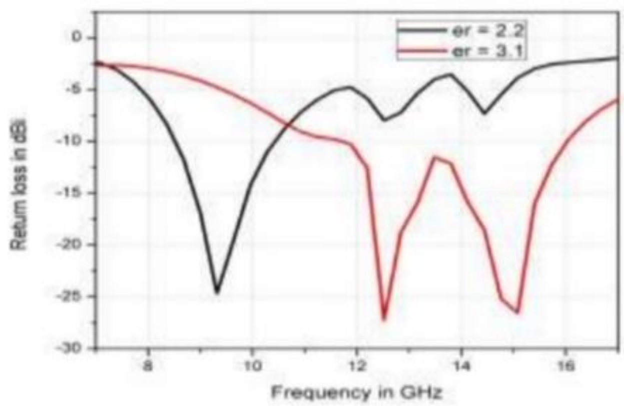


Figure 6: Return Loss of the proposed Antennas with respect to the variation of dielectric substrate.

Voltage standing wave ratio must be between 1 & 2 indicates a minimum reflection. Antenna 1 is giving a minimum VSWR of 1.03 at 9.98 GHz frequency and Antenna 3 is giving a minimum of 1.12 at 9.42GHz frequency. The proposed antenna and antenna 1 is giving a maximum gain Of 7.54 dB and 3.12dB at their resonating frequencies.

Table2: Comparison Results of the Proposed Antennas with respect to height and Ɛr.

Antennas	Bandwidth in GHz	Dielectric Constant (Ɛr)	Size in mm	Maximum Gain in dB	Resonating Frequency fo in GHz
Pro.Ant	3.99	4.5	24 X 15.6X 1.6	7.51@11.76 GHz	10.38 & 11.71
Ant1	4.2	4.5	24 X 15.6X 1.385	5.56 @14.95GHz	12.56 &14.95
Ant2	2.04	4.5	24 X 15.6X 2.7	3.12 @ 9.01 GHz	9.01
Ant3	1.91	2.22	24 X 15.6X 2.7	4.24 @ 9.28GHz	9.28
Ant4	3.16	3.1	24 X 15.6X 1.385	4.15@13.81 GHz	13.16 &13.81

When excitation is applied to a radiating patch antenna the current distribution over the surface is shown in figure 7. Current distribution indicates the mode generation and is given by an arrow sign. The Co and cross Polarization components of one of the proposed antenna 1 in E-plane is shown in figure 8. Cross polarization must be less than - 20dB for practical antennas, from figure it is shown that cross polarization is-49.58dB.

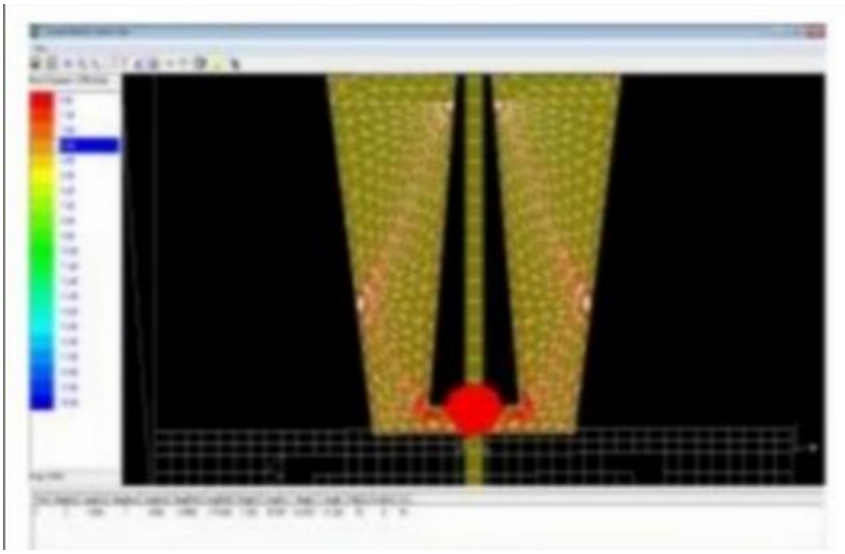


Figure.7 Current Distribution of the proposed antenna

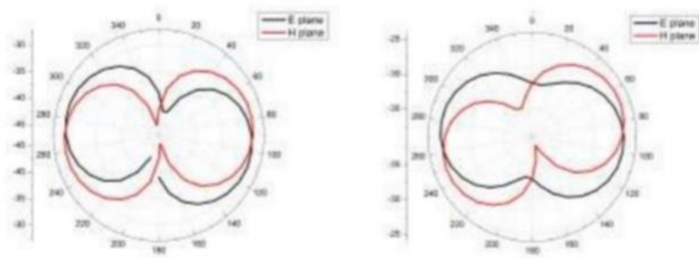


Figure .8 co-polar radiation patterns of proposed ψ-shape patch in E & H planes at 9.32GHz and 13.7GHz

Table 3. Work Comparison

Parameters	[9]	[10]	[11]	[12]	Our Work
Resonating Frequency in GHz	10.25 &11.54	7.9 , 5.5 &10.5	9.5	8.95, 11.06, 11.85	10.53 &11.76
Bandwidth in GHz	1.59	6	1.56	0.45, 1.01	3.99
Radiating Patch Size including ground plane in mm	40 x40 x 1.6	36 x 36 x 1.6	30 x 30 x1.6	20 x 17.2 x 1.6	24 X 15.6X 1.6
Return Loss at resonating frequencies in dB	-17.14 &-14.29	-15 ,-25 & -18	-24	-24	-28.49 & -25.74
Peak Gain in dB	4.31	4.1	4.5	4.45, 3.99, 4.17	7.51

4. Conclusion

For X- band applications a compact micro-strip patch antenna with Enhanced bandwidth is presented here. As the antenna layout is simple, Fabrication is easier. The patch is resonating at two adjacent frequencies which increased the bandwidth. The antenna is resonating at 10.53 GHz &11.76GHz giving a return loss of -28.49dB and -25.74dB, with a bandwidth and maximum gain of 3.99GHz & 7.51dB respectively. Antenna is fabricated and tested through VNA and them is a good agreement of results between simulated and measured. Parametric study of the proposed antenna is also done with respect to slots, height and substrate material and the results are tabulated. Comparison study reveals that the attractive results of low cross polarization, good radiation patterns with high gain , improved bandwidth and compact in size proves that the proposed antenna can be used for X band applications.

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