Designing and Analysis of Star-Shaped Microstrip Patch Antenna For Wide Band Applications

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Abstract- In this research investigation, the star-shaped wideband microstrip patch antenna has been proposed. The proposed antenna provides the broadband frequency response from the lower cut off frequency f_{low}= 1.98 GHz to higher cut of frequency f_{high} = 4.30 GHz. The impedance bandwidth of 2.32 GHz and the fractional bandwidth of $\mathbf{73.88}$ % have been achieved for $|S_{11}|$ < -10dB. Wide band characteristics has been achieved by designing a star-shaped planner with proper impedance matching between radiating patch element and partial ground element. For the proper physical analysis of the proposed antenna the parametric study has been done. Bi-directional radiation pattern, low VSWR and wide band have been achieved. A prototype of presented antenna has been fabricated on FR-4 substrate ($tan\ (\delta) = .02,\ \varepsilon_r = 4.3$) where as the thickness of 1.6 mm and experimental results validate the performance of proposed antenna.

Keywords – bandwidth Enhancement, DGS, WLAN, WiMAX, Wideband.

I. INTRODUCTION

Current wireless communication systems demand antennas that are low-cost, high-performing, small, wideband, and discrete [1-2]. Modern communication needs the availability of efficient, compact, and portable devices capable of high data rates and low signal power [3.5]. In addition to their larger size, higher cost, and lower gain, microstrip patch antennas frequently have bandwidth limitations, single-frequency operation, and polarisation problems. Traditional microstrip antennas may be improved in many ways, including by stacking, using various feeding systems, frequency selective surfaces, electromagnetic band gaps, photonic band gaps, metamaterial, and others. Because of its straightforward structural design, the microwave component with Defected Ground Structure has obtained popularity among all the techniques documented for increasing the parameters [6-9]. The ground plane of microstrip circuits may include etched slots or defects, which are referred to as "defective ground structure." A single or a slew of faults in the ground plane are referred to as DGS. Filters below the microstrip line were the first to be associated with DGS. To obtain band-stop features and lower higher mode harmonics and mutual coupling, DGS was applied beneath the microstrip line [10-13]. Following its successful implementation in the field of filters, DGS is today in great demand for a wide range of applications. DGS has been applied in the field of microstrip antennas to improve the radiation parameters of the microstrip antenna by enhancing the bandwidth and gain of the microstrip antenna and reducing higher mode harmonics, mutual coupling between surrounding components, and cross-polarization [14-16]. The application of DGS in microwave technology is rising by the day.

In this research work, compact star shaped wideband microstrip patch antenna proposed and fabricated. Micro-strip feed antenna consists star-shaped patch element and partial ractangular ground plane has been presented for wideband Applications (1.98 to 4.30 GHz). The proposed compact antenna occupies a physical size of 32 x 44 x 1.6 mm^3. The designed antenna has been fabricated on FR-4 substrate ($tan\ (\delta) = .02,\ \varepsilon_r = 4.3$) whereas width of 1.6 mm and so low manufacturing cost. The performance of proposed antenna have been investigated using Computer Simulation Technology simulator (CST-Studio) and there after measured results validates the simulation outcomes. The proposed antenna is suitable for integrated within wireless portable devices for wideband applications.

II. ANTENNA GEOMETRY AND DESIGN

Figure 1. shows the geometry of a star-shaped structure wideband microstrip patch antenna. This suggested antenna is placed on the X–Y axis. A star-shaped patch element, a 50 ohm microstrip feed line, and a modified ractangular ground plane make up the suggested arrangement. The structure's l length and w width have been designated as the star-shaped patch's specifications. This radiating patch is intended for applications that require a wideband range of resonance frequencies. The width of the feed (Wf) and length of the feed (Lf) are the parameters of the microstrip feed line (Lf). The bottom of the radiating element is where the microstrip feed line is terminated. The partial ractangular ground element has been modified; these are responsible for the antenna's good return loss and low voltage standing wave ratio (VSWR). The radiating patch is etched on the top edge of the ground element, where the microstrip feed line and radiating patch are inserted. This junction is extremely important in order to have better impedance matching. The proposed antenna has been made on a FR-4 substrate with a dielectric constant of 4.4, a tangent loss of 0.02,

and a thickness of 1.6 mm. The antenna's total dimensions are 32 x 44 mm^2. The rectangular wave guide feed approach has been used to excite the proposed antenna. The copper annealed conductor's thickness (top and bottom layers) is measured (0.035 mm). Parametric analysis has been done to optimise the size of all the components in order to achieve the superwide band impedance bandwidth.

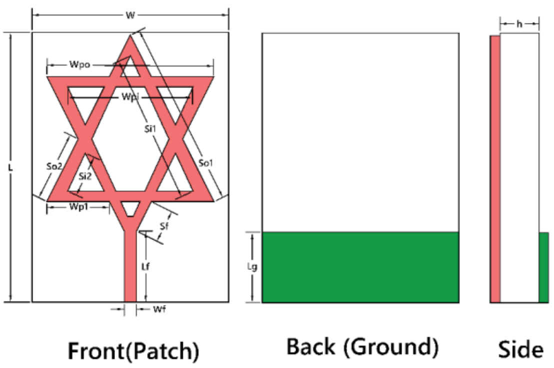


Figure 1. Two-dimensional geometry of a Star-shaped planar antenna.

Table 1: Detailed Dimensions of the Antenna

Dimension	Value(mm)	Dimension	Value(mm)
W	32	L	44
Wpo	27.11	Wp1	10.2
Wio	20.26	Lf	11.6
So1	30.37	Wf	2
Si1	24.29	Lg	11.47
So2	11.4	h	1.6
Si2	6.82	Sf	5.37

III. ANTENNA EVOLUTION

All successive stages to design proposed antenna has been analyzed and designed. Figure 2 shows the two sucessive steges for final geometry of the antenna that is designed. This patch antenna is made up of a microsrtip feed line, a radiating patch element, and a ground plane, all of which are responsible for excellent impedance matching and better reflection coefficient characteristics. The suggested antenna is fabricated on a FR4 substrate with a thickness of 1.6 mm, a dielectric constant of 4.4, and a loss tangent of 0.02. The antenna's overall dimensions are 32 x 44 x 1.6 mm^3, with a feed line width of 2.8 mm, achieving the normal 50 input impedance. The antenna's impedance bandwidth and reflection coefficient were improved by using a star-shaped radiating element and a ractangular partial ground structure. Figure 3 shows the Reflection Coefficient Characteristics S_{11} of Successive stages Antenna 1, 2, 3, & 4. PLanner Antenna 2 provides the efficient wide band reflection coefficient S_{11}.

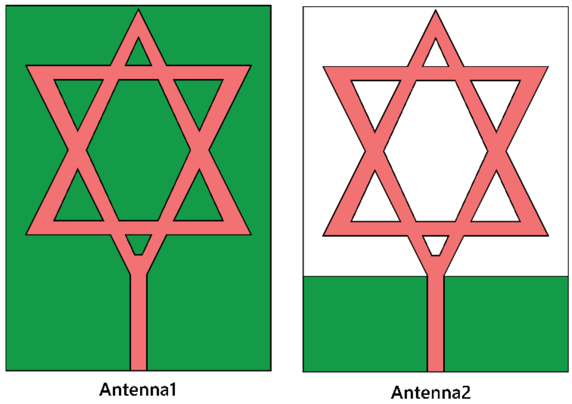


Figure 2 Development of Star-shaped planar Antenna

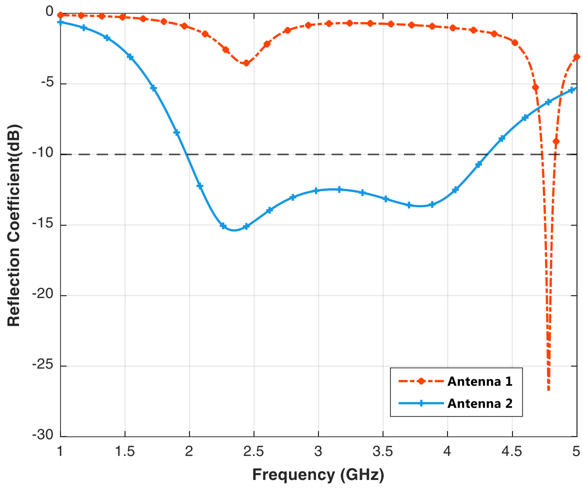


Figure 3 Reflection Coefficient Characteristics S_{11} of Successive stages Antenna 1 and 2.

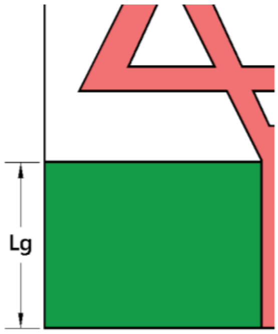
IV. PARAMETRIC ANALYSIS

The impact of parameters on the antenna performance in terms of the reflection coefficient characteristics (S_{11}) curve has been examined in this section, and optimal values for these parameters have been produced to improve the antenna's overall performance. For the best modification, a parametric sweep is used to do a parametric analysis on numerous structural characteristics of the antenna. Optimal antenna parameter dimensions are necessary to improve its frequency response performance and provide appropriate impedance matching for bandwidth expansion. In this part, the basic parameters are modified within a specific range. The adjustment is carried out one parameter at a time to identify the actual impact on antenna performance.

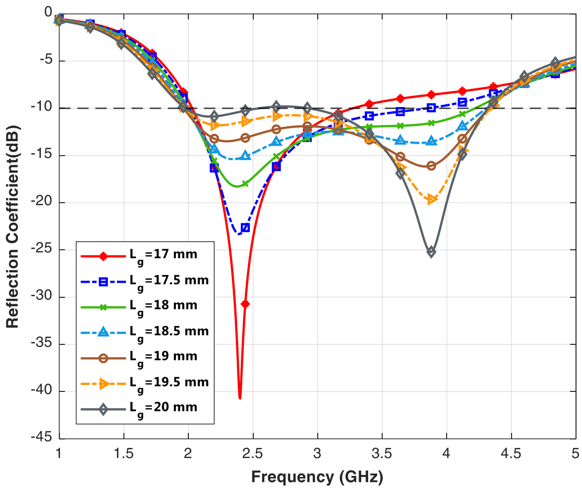
4.1 Effect of ground height ($L_g = 10\ mm\ to\ 13\ mm$)

Figure 4 (a) Ground height L_g parameter has been varied in actual that vary the gap between patch bottom and ground top and by doing this the impedance matching between radiating patch and ground has been achieved.

To see the impact of L_g a large variation has been observed on reflection coefficient (S_{11}) depicted in Figure 4. (b). Only on Hg = 10- and 13-mm value gives a large band as shown by blue and orange curve and for other value gives low bandwidth. Ground height Hg =11.5 mm makes better impedance matching and so better S_{11}.



(a)

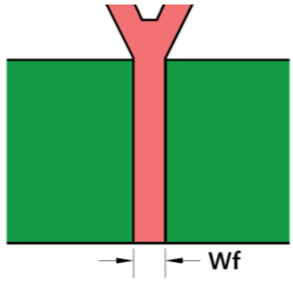


(b)

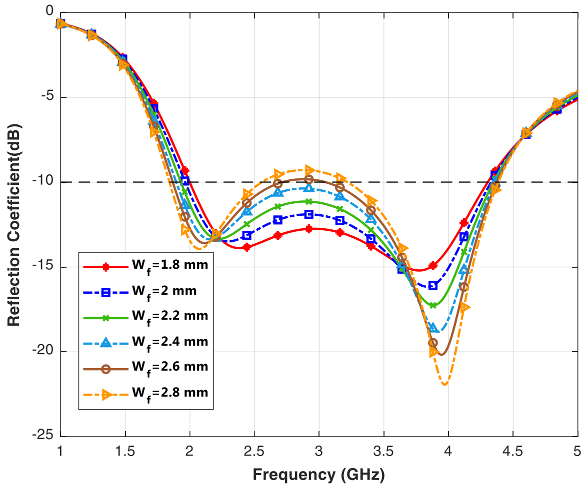
Figure 4. (a) Ground height (L_g) and (b) the effect of ground height (L_g) on S_{11}

4.2 Effect of feed width (W_f = 1.8 *mm to* 2.8)

To see the impact of feed width parameter (W_f) on reflection coefficient other antenna parameter, feedline width (W_f), was changed to examine how it affected the antenna's performance. W_f is the width of the feedline on the patch plane (see Figure 5). (a). The features of return loss with variations in W_f have been observed and depicted in Figure 5. (b). W_f varies between 1.8 and 2.8 mm. W_f is increased further, resulting increase the effective S_{11}. As a result, it can be determined that a feedline width of 2 mm is the ideal width for matching the antenna's correct impedance.



(a)

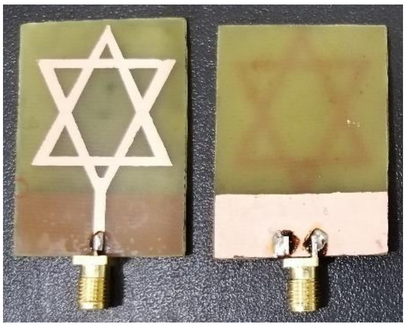


(b)

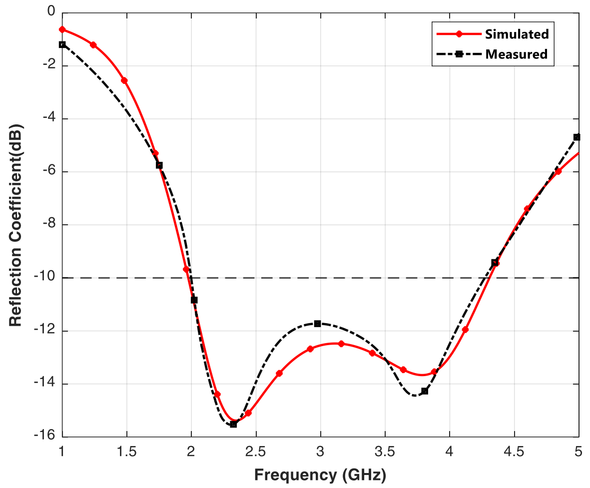
Figure 5. (a) Microstrip feed line width parameter (W_f) and (b) Significance of microstrip feedline width (W_f) on (S_{11})

V. RESULTS AND DISCUSSION

In this section the overall antenna performance parameters has been analyzed through the simulation and measured results. The return loss curve shows in Figure 6 that a wideband impedance bandwidth has been achieved. The lower cut off frequency f_{low} is 1.98 GHz and a higher cut of frequency f_{high} is 4.30 GHz whereas the impedance bandwidth of 2.32 GHz has been achieved.



(a)



(b)

Figure 6. (a) Fabricated antenna (b) Reflection Coefficient characteristics (S_{11}) of optimized proposed antenna

5.1 Fractional Bandwidth (dB)

The fractional bandwidth 73.88 % of proposed antenna has been mathematically derived given below in equation1. Table 2 shows the frequency response of planner antenna.

$$\text{Antenna FBW} = 2 \times \left(\frac{f_H - F_L}{f_H + F_L}\right)\% \qquad (1)$$

$$= 200 \times \left(\frac{4.30 - 1.98}{4.30 + 1.98}\right)\%$$

$$= 200 \times \left(\frac{2.32}{6.28}\right)\%$$

$$\text{Antenna fractional Bandwidth} = 73.88\ \%$$

Table 2 Frequency response of planner antenna.

Frequency (GHz)	**Reflection Coefficient (dB)**
f_{low}= 1.98	-10
f_{r1} = 2.344	-15.3839
f_{r2} = 3.784	-14.8186
f_{high} =4.30	-10

5.2 Current Distribution

Current distribution of proposed antenna has been analyzed at the obtained at resonance frequencies 2.344 and 3.784 GHz frequency. In the Figure 7 (a) and (b) it has been observed that the current vectors are concentrated at the junction where the ring and feed line has been joined with the high magnitude and normal and low intensity current vectors are distributed through the patch and ground structure.

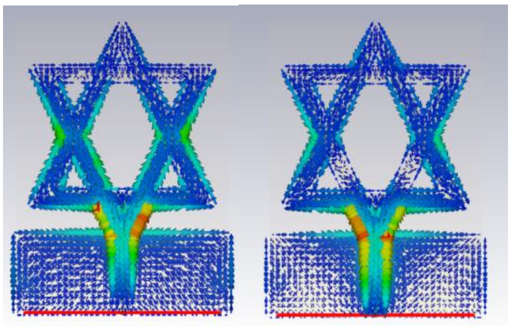
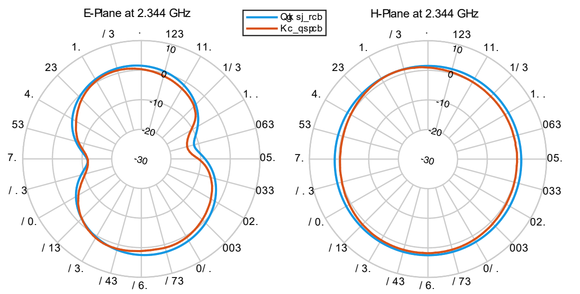


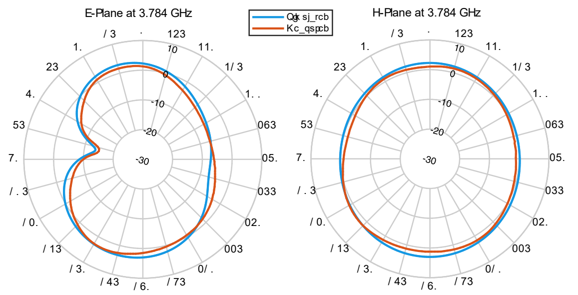
Figure 7. Current distribution at resonance frequencies (a) 2.344 GHz and (b) 3.784 GHz

5.3 Two Dimensional Radiation Pattern

Two dimensional radiation patterns at the resonance frequency of 2.344 and 3.784 GHz have been represented in Figure 10. The radiation patterns at 2.344 GHz is bidirectional in E-field and quasi-omni directional in H-Field from. At the frequency 7 GHz is bidirectional in E-field and H-Field have been achieved.



(a)



(b)

Figure 8. 2D Radiation Field (a) E-Field and (b) H-Field at 2.344 GHz and 3.784 GHz

5.4 Three Dimensional Radiation Pattern

Three dimensional radiation patterns view at the resonance frequencies of 2.344 and 3.784 GHz have been represented in Figure 9. 3D views have been simulated through the CST simulator. It has been analyzed that the radiation patterns are bidirectional in E-field and H-Field at 2.344 GHz and 3.784 GHz.

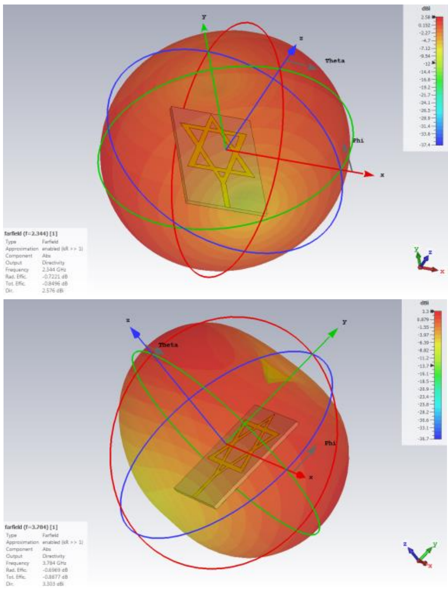


Figure 9. 3D Radiation Field at 2.344 GHz and 3.784 GHz

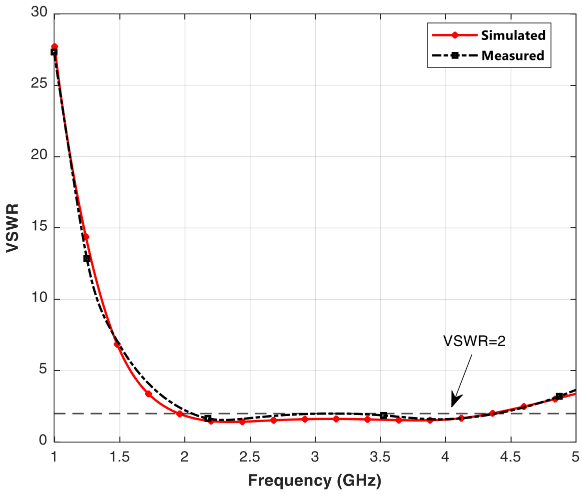


Figure 10. VSWR of proposed antenna

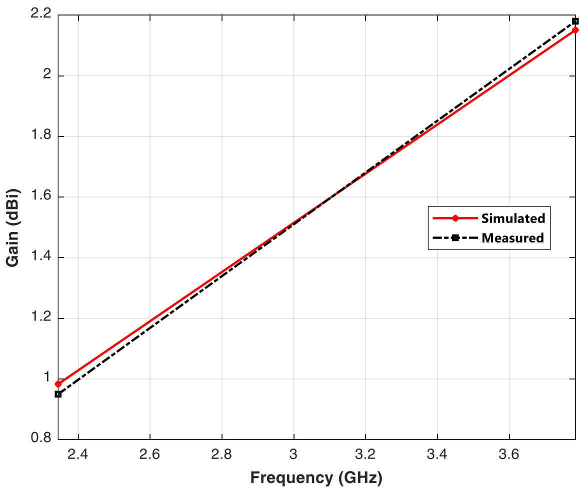


Figure 11. Gain of Planer Antenna

The Voltage standing Wave Ratio (VSWR) curve has been shown in Figure 10. It has been observed that the value of VSWR is below 2 throughout from 1.98 GHz and goes up to 4.30 GHz. The gain and directivity of proposed antenna have been shown in Figure 11 and Figure 12 respectively. The peak gain of 2.1 at 3.7 GHz and maximum directivity of 2.8 GHz at 3.7 GHz have been noticed. Figure 13 shows the antenna's radiation and total efficiency.

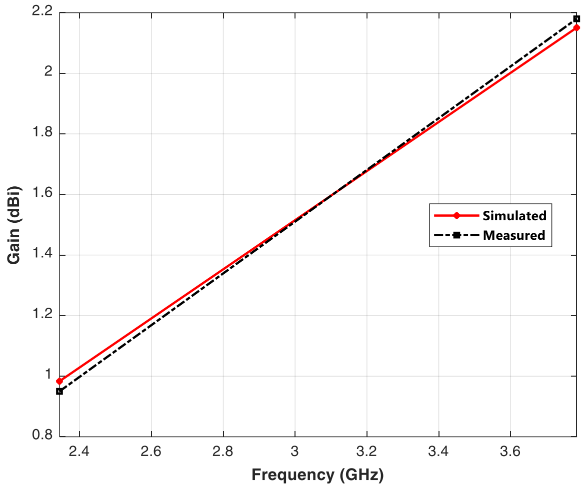


Figure 12. Directivity of Planer Antenna

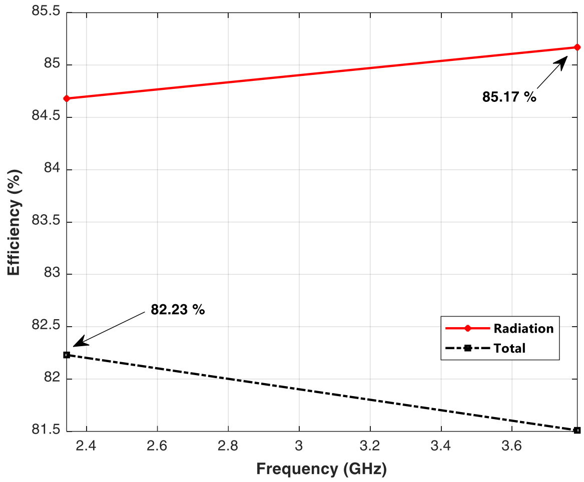


Figure 13. Efficiency of Antenna

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Pramod Kumar had completed B.Tech in year 2006 from Barkullah University, Bhopal, India in Electronics and Communication. He had completed M.Tech in year 2011 from RKDF Institute of Science and Technology, Bhopal in Digital Communication. He is currently perusing Ph. D. from Mewar University, Rajasthan, India. He is an expert in antenna designing, fabrication, CST simulation software. He is currently working on bandwidth enhancement of Microstrip Antenna using hybrid structure.

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