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A Wideband Microstrip Patch Antenna for KU-Band Applications

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Abstract

In this paper, the design of wideband microstrip patch antenna is proposed for applications working at the operating frequency in the range of KU - band. The design is created with related to above 12 GHz of resonant frequency. The structure is consist of a perfect conductor patch plane with a triangular slot, (infinite and finite) ground plane in two separate studies in this paper, substrate layer with dielectric constant 1.001 as a sandwich between them and coaxial cable feed line for excitation. An achievement of the design has been carried out using FEKO simulation software. Antenna was analyzed in terms of reflection coefficient, bandwidth, gain and VSWR to verify performance efficiency. The maximum simulated bandwidth is 13.3% is achieved at 12.57 GHz resonant frequency with VSWR<2 in the case of using infinite ground plane. On the other hand the maximum bandwidth is 12.9% at 12.128 GHz resonant frequency with VSWR <2 in the case of using finite ground plane with certain sizes.

Keywords: bandwidth; gain; VSWR; finite; infinite; FEKO.

1. Introduction

Satellite communication is unaffected to a large extent by the communication distance or configuration of the ground [1]. The operation in Ku Band is generally used for satellite data communication systems [2]. A compact microstrip antenna such as VSAT systems is one of the most suitable applications to support high mobility satellite communication devices. Ku-band (12-18 GHz) is one of the most preferred choices in VSAT systems [3]. There have been a lot of developments in the field of antenna design in recent years. The researchers are focusing on Increasing gain and impedance, bandwidth and decreasing dimensions of microstrip antennas while keeping the antenna at low cost and easy to fabricate [4].

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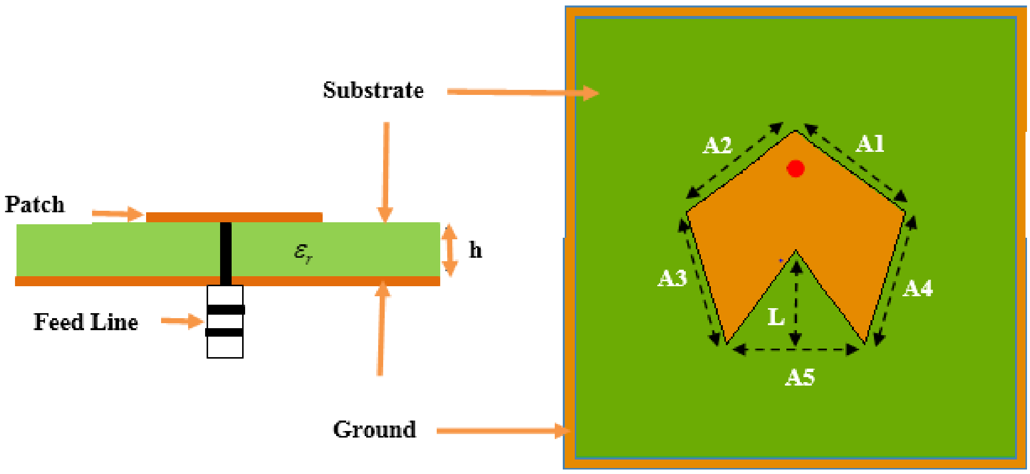
The patch has different shapes such as circular, triangular, rectangular, elliptical, etc., The microstrip antennas have wide advantages and due to their good characteristics such as light weight, easy fabrication, and low cost, they have been used in various applications [5-6].

Many antenna configurations have been proposed to enhance bandwidth requirements [7]; in this paper, the microstrip patch antenna is simulated to achieve high bandwidth in the range of KU-band. FEKO software version 7.0 is used in simulation process, which it is a comprehensive electromagnetic simulation software tool for the electromagnetic field analysis of 3D structures. It offers multiple state-of-the-art numerical methods for the solution of Maxwell's equations, enabling its users to solve a wide range of electromagnetic problems encountered in various industries [8].

2. Antenna Configuration

Figure 1 show that the structure of the proposed antenna included a perfect conductor plane as a patch, substrate layer with dielectric constant and thickness and (infinite or finite) ground plane under them. A coaxial cable is connected with the antenna at the position. In this configuration, a triangular slot with a dimensions base and high has been cutting from the lower part of the quintuple patch design which is consist of arms. All parameters valuable are listed in the Table 1.



(a) **(b)**

Figure 1: Geometry of patch Antenna (a) Side View (b) Top View

3. Analysis Results (Using Infinite Ground Plane)

Through a process of simulation using FEKO, the proposed antenna is analyzed in three cases of varying the high of triangular slot (L). Discussion on the results is also provided in this section in terms of return loss, bandwidth, VSWR, gain and current distribution.

Table 1: Dimensions of the proposed antenna

Parameter	Value
First Arm A1	10 mm
Second Arm A2	10 mm
Third Arm A3	10 mm
Fourth Arm A4	10 mm
Fifth Arm A5	10 mm
Dielectric Constant ε_r	1.001
Feed Point (x, y)	(-6, 0) mm
Substrate Thickness h	2.2 mm
High of Triangular L	7 mm

3.1. Reflection Coefficient and bandwidth

Figure 2 shows the reflection coefficient characteristics of the designed antenna. The simulation work is done as follows. In the first case L=7 mm, the return loss of 32.56 dB is obtained at the resonant frequency 12.57 GHz. After that this losses is reduced to 12.61 dB at 12.61 GHz when increase the high of the triangular slot by one (L=8 mm). On the other hand, it is observed that at L=9 mm, the minimum value of return loss is achieved at 12.62 GHz, which it has been 46.6 dB because the current length obviously will be lengthened. The range of frequencies is described by bandwidth, which it is another fundamental parameter of the antenna. The bandwidth of the antenna is calculated as follows:

$$BW = \frac{2(f_H - f_L)}{f_H + f_L} \quad (1)$$

Where f_H is the highest frequency of the band and f_L is the lowest frequency of the band. It is noticed that, the value of bandwidth has been reduced gradually from (13.3 - 13) % by increasing the high of the triangular slot (L). Table 2 shows the reflection coefficient and bandwidth results.

3.2. VSWR and Current Distribution

"VSWR is defined as the ratio of the maximum radio frequency (RF) voltage to the minimum RF voltage along the line", in another meaning is a way to find out the transmission line defects. It is clear that through the simulation results, the minimum value of voltage standing wave ratio of 1.01 has been obtained at the resonant frequency 12.62 GHz, while it found that this value has been 1.03 and 1.04 at 12.61 and 12.57 GHz respectively. Figure 3 and Table 3 shows the relation between the resonant frequency and VSWR.

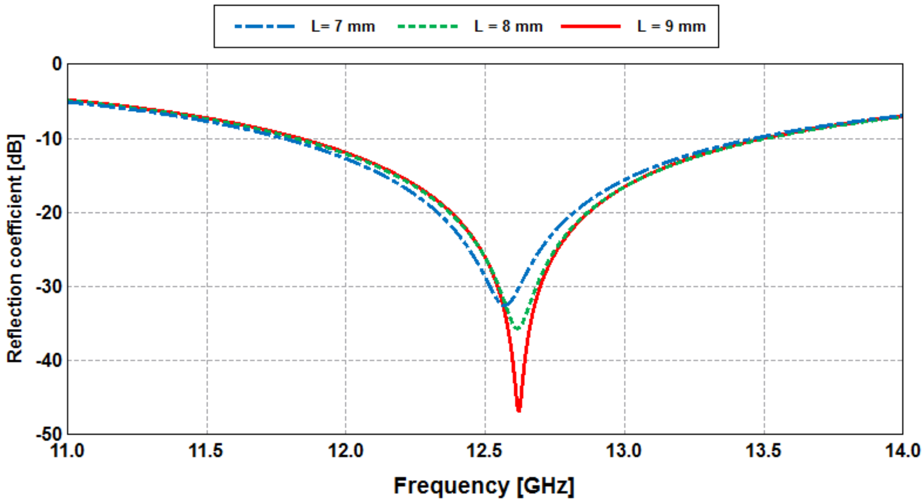


Figure 2: Reflection coefficient results produced by FEKO at L= (7, 8 and 9) mm

Table 2: Reflection coefficient and Bandwidth Results

Case	Resonant frequency (GHz)	Reflection Coefficient (dB)	f_H (GHz)	f_L (GHz)	BW %
(L=7 mm)	12.57	-32.56	13.46	11.781	**13.3**
(L = 8 mm)	12.61	-35.66	13.505	11.826	13.2
(L = 9 mm)	12.62	**-46.6**	13.485	11.838	13

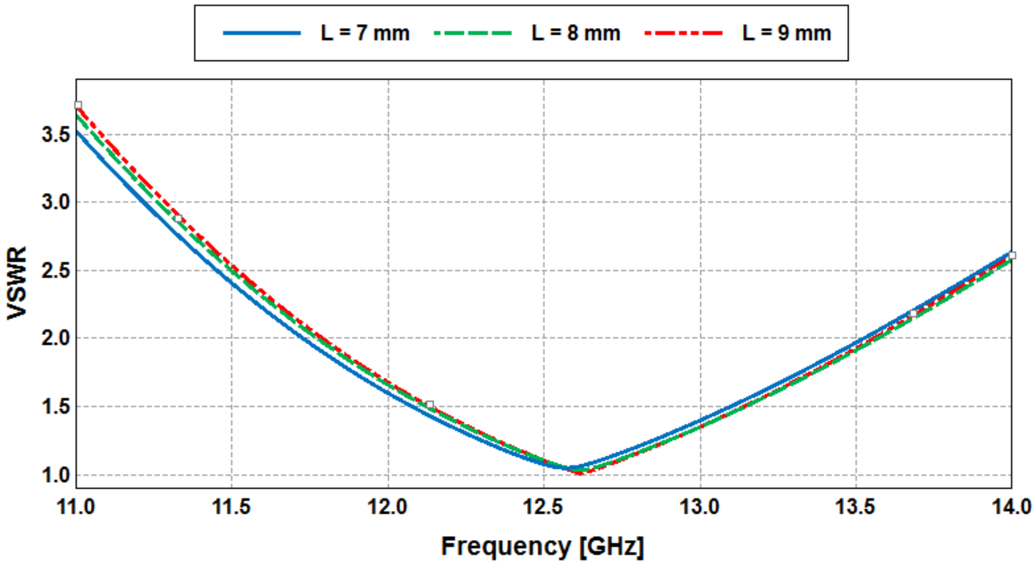
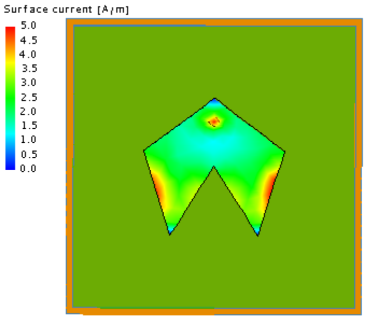


Figure 3: VSWR results produced by FEKO at L= (7, 8 and 9) mm

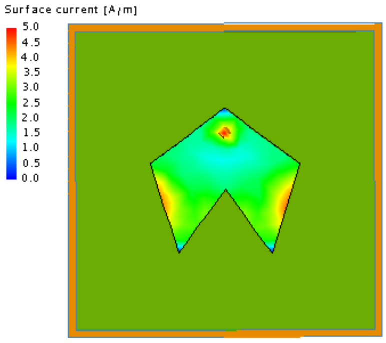
Table 3: VSWR Results

Case	Resonant frequency (GHz)	VSWR
Step 1 (L=7 mm)	12.57	1.04
Step 2 (L = 8 mm)	12.61	1.03
Step 3 (L = 9 mm)	12.62	**1.01**

On the other hand, it is important to know how the current has been distribute on the surface of the patch in each case because the current distribution on the patch is used to specified the properties of the microstrip antenna as shown in Figure 4.



a)



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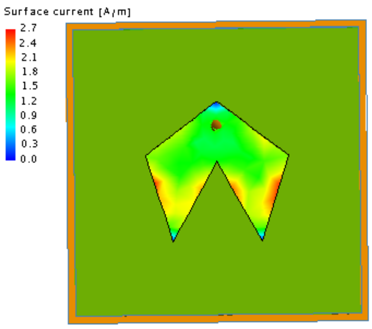
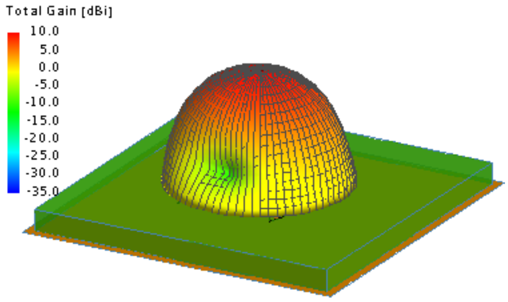


(c)

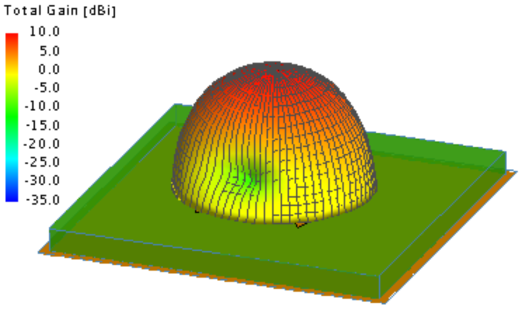
Figure 4: 3-D dimensionresults of current distribution produced by FEKO at f =12.5 GHz in x-y plane (a): L = 7 mm (b): L = 8 mm (c): L = 9 mm

3.3. Gain

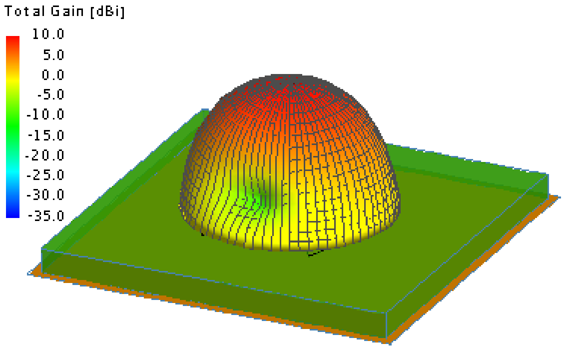
Gain is the radiation efficiency in the far field which efficiency is defined and represented as a ratio of the radiated power p_r to the input power p_i . In Figure 5, it is observed that the value of the gain is maintained constant in all three cases, which is equal 10 dB as illustrated in Table 4.



(a) L =7 mm



(b) L =8 mm

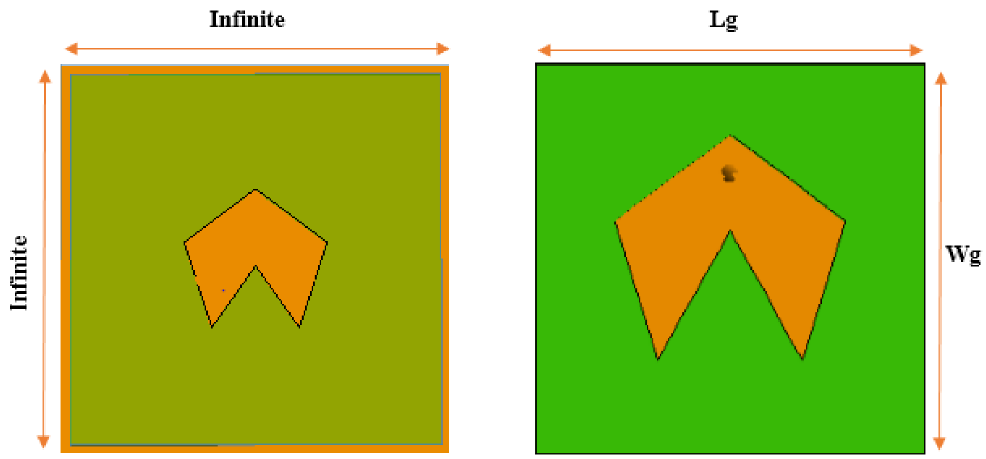


(c) L = 9 mm

Figure 5: 3-D dimension results of gain produced by FEKO in x-y plane at resonant frequency (a): f = 12.57 GHz (b): f = 12.61 GHz (c): f = 12.62 GHz

4. Analysis Results (Using Finite Ground Plane)

Instead of using infinite ground plane in Figure(6-a) as explained in previous sections, finite ground plane with certain dimensions Lg X Wgis proposed as shown in Figure (6-b).



(a) (b)

Figure 6: Antenna structure with (a): Infinite ground plane (b): Finite ground plane

By taking certain sizes of ground plane, It is observes that the maximum parameters are : bandwidth of 12.9 % , VSWR of 1.008, reflection coefficient 52.4 dB and the value of gain is not maintain constant but it is varying from 10 to maximum value of 15 dB. All the results are illustrated in Figures 7, 8, 9 and Table 4.

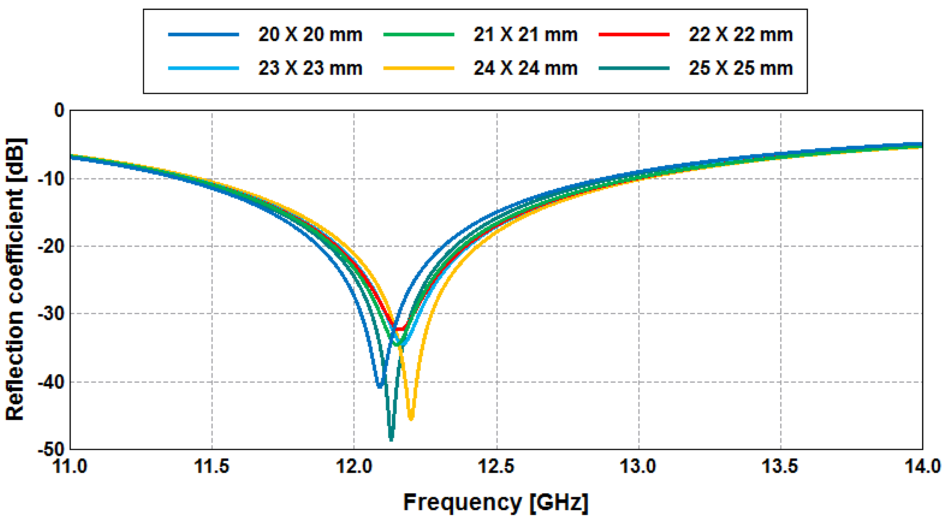


Figure 7: Reflection coefficient at different sizes of ground plane – part 1

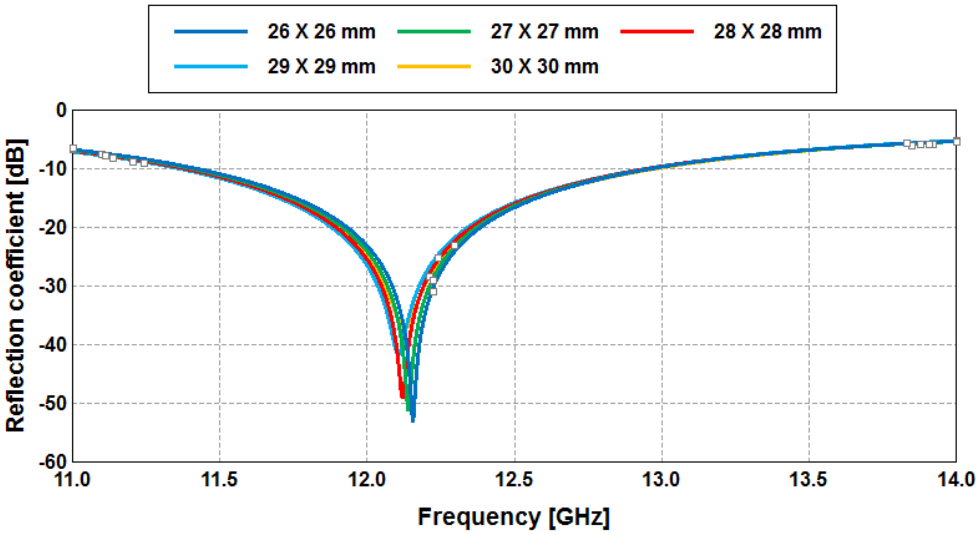


Figure 8: Reflection coefficient at different sizes of ground plane – part 2

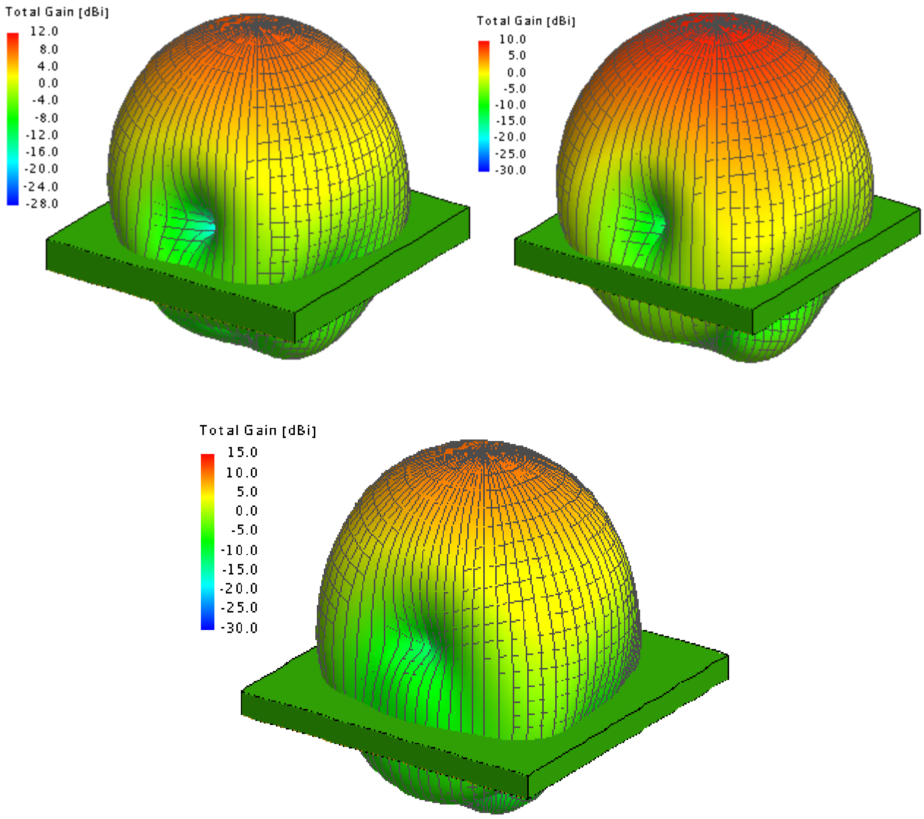


Figure 9: 3-D dimension results of gain produced by FEKO in x-y plane at different sizes of ground plane

Table 4: All parameters results of a microstrip antenna with certain sizes of ground plane

Ground Size Lg X Wg	Resonant frequency (GHz)	Reflection Coefficient (dB)	VSWR	Gain dB	f_H (GHz)	f_L (GHz)	BW %
20 X 20 mm	12.091	40.8	1.37	12	12.876	11.384	12.3%
21 X 21 mm	12.153	34.49	1.03	12	12.974	11.429	12.6%
22 X 22 mm	12.165	32.32	1.04	12	12.986	11.433	12.7%
23 X 23 mm	12.173	34.37	1.03	10	12.986	11.441	12.6%
24 X 24 mm	12.202	45.3	1.01	10	13.003	11.474	12.4%
25 X 25 mm	12.132	48.1	**1.008**	12	12.901	11.425	12.1%
26 X 26 mm	12.157	**52.4**	**1.008**	12	12.941	11454	12.1%
27 X 27 mm	12.14	51.2	**1.008**	12	12.937	11.437	12.3%
28 X 28 mm	12.124	47.8	1.009	12	12.929	11.421	12.3%
29 X 29 mm	12.108	41.45	1.01	12	12.921	11.384	12.6%
30 X 30 mm	12.128	37.17	1.02	**15**	12.958	11.38	**12.9%**

5. Conclusion

A wideband microstrippatch antenna is designed for KU **-** band applications. Presented results show that the following:

1- Maximum bandwidth of 13.3% is achieved at resonant frequency 12.57 GHz in the case of using infinite ground plane and 12.9% at 12.128 GHz in the case of using finite ground plane.

2- Minimum return loss of 46.6 dB is achieved at resonant frequency 12.62 GHz in the case of using infinite ground plane and 52.4 dB at 12.157 in the case of using finite ground plane.

3- Minimum VSWR of 1.01 is achievedin the case of using infinite ground plane and 1.008 in the case of using finite ground plane.

4- In all the steps we have noticed that the gain maintains a constant value of 10 dB in the case of using infinite ground plane but in the case of using finite ground plane the gain is varying from 10-15 due to changing in ground size with certain dimensions.

From the results, it is concluded that the structure has acceptable performance over a range of bandwidth, which has been computed in this paper. Therefore, the proposed antenna can be used for many useful applications.

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