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Design and Comparison of Broadband Micro Strip Patch Antenna with Different Slots Loaded At the Centre and Fixed Double Cross Slot at the Edges

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ABSTRACT-
A novel method of designing broadband micro strip antenna is proposed in this paper. By embedding Cross-shaped slots placed close to the non-radiating edges and at the centre of a micro strip patch and adding an air layer between the substrate and the ground, the broadband character can be achieved. The measured broad band is achieved with small sizes and the good radiation characteristic for operating frequencies within the impedance bandwidth is also observed. Even by taking additional slots of swastika shaped and H shaped at the centre of the patch the broadband characteristic can be increased more, the dimension remaining the same.

Key words - Broadband, Cross Slot, H slot, Slot Antenna, swastika slot, WLAN

1. INTRODUCTION

Micro strip antennas are the subject of much research activity among scientists due to their unique advantages, especially their low weight simple and low cost of fabrication. Although in early implementations they suffered from narrow bandwidth, several approaches have been proposed to improve the bandwidth. The latest approach resulted in antennas with excellent bandwidths include the double-layer structure, slotted antennas [1,2,3,4], E-shaped patch antennas [4,5] and so on. Then, the structure of E-shaped rectangular_ patch antenna with achievable good impedance bandwidth has been proposed [4, 5]. However, the antenna has a large dimension, and its patch is 1.5-2 times as wide as that of the common microstrip antennas. A broadband rectangular microstrip antenna with a pair of U-shaped slots placed close to non-radiating patch edges was designed [8], but its bandwidth drops to 4.9%. Some antennas with a pair of other shaped slots placed close to non-radiating patch edges were introduced [9, 10], however their bandwidths still don't exceed 7%.Even simple double cross shaped slots at the edges were not sufficient for enhanced bandwidth[11]. In order to overcome these shortcomings, this paper proposes a novel method of designing as well as comparing the broadband microstrip antennas with a pair of slots placed close to fixed non-radiating patch edges, and different slots of shaped H, Swastik and a cross slot placed at the centre of the patch which could achieve the aim of wide bandwidth in a small size to about 37.97%. The IE3D simulation software based on Method of Moments (MoM) is used for simulation [12].

2. ANTENNA DESIGN

Fig.1 depicts the cross-sectional view as well as the top view of the antenna. The novel microstrip antenna consists of a ground plane, an air layer and a substrate-patch. A pair of double cross-shaped slots which consists of two horizontal slots and a vertical slot is embedded on the non-radiating edge and a cross shaped slot is placed at the

centre of the patch. The source is connected to the antenna through an SMA connector mounted on the ground plane. The Q value of microstrip antennas is so high that the bandwidth is hard to increase. Increasing the thickness of the substrate and lowering the relative permittivity can effectively decrease the Q value. An air layer is added between the substrate and the ground, which not only lowers the relative permittivity but also increases the thickness of the substrate. Therefore, using this method the Q value can be decreased. Analysis is performed for rectangular patch antenna using Air ($\varepsilon_r = 1$) as substrate having thickness of 4mm from the ground and another dielectric having thickness of 1mm from the bottom dielectric(Air) having dielectric constant of 2.65 which lowers significantly the effective dielectric to a lower value.
The relative permittivity of the new substrate can be given as [11]

$$\frac{\varepsilon_r}{\varepsilon_r \times \frac{h_1}{h+h_1} + \frac{h}{h+h_1}}$$

For ε_r=2.65, h=1mm and h1=4mm, the relative
Permittivity ε_r' of the new substrate gotten from above equation is 1.14, which is much smaller than ε_r .
The proposed microstrip antenna has patch dimensions of 25x25mm^2 and the finite ground plane of dimension 50x50 mm^2 with double cross slot of dimension 23x6 mm^2 and slots of Cross shaped, H shaped, and Swastik compared. The antennas are considered to be antenna A, antenna B and antenna C.

A. ANTENNA

A rectangular cross slot of dimension 10x1 mm^2 at the centre of the patch. Its geometry is shown in Fig. 1. The microstrip patch antenna probe is fed at (X = 0, Y = 10 mm) from the patch centre and the Antennas parameters like Reflection Coefficient, Gain and Radiation Patterns at the corresponding resonance frequency point is also shown.

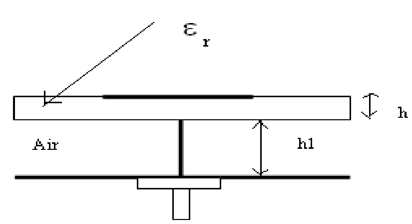


Fig. 1 A general layout of the simple micro strip Patch Antenna

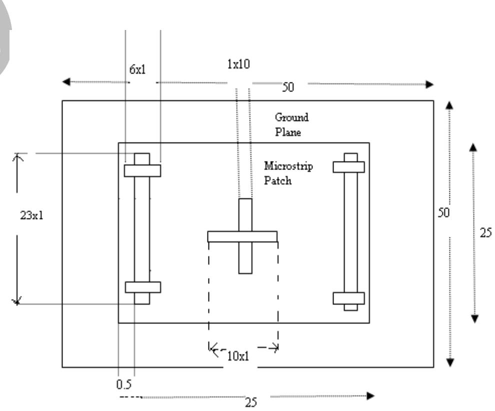


Fig. 2. Dimensions of the double Cross slot with cross slot at the centre of the microstrip Patch Antenna

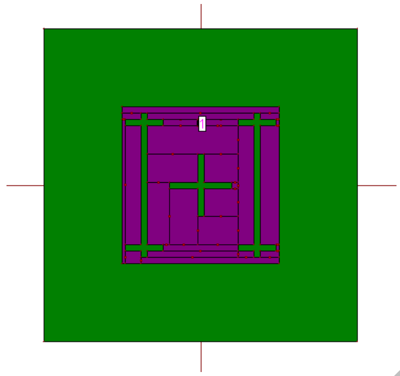
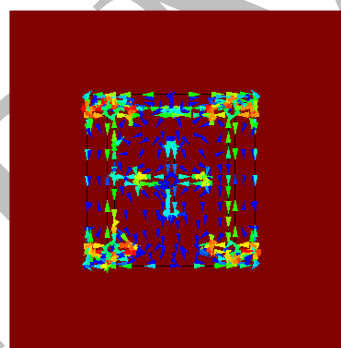
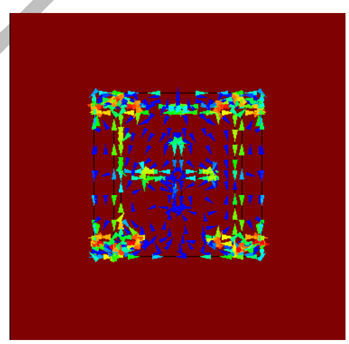


Fig. 3IE3D simulation of the double Cross slot with cross slot at the centre of the microstrip Patch Antenna

The current distributions about the Patch are as shown in figure 4. The current flow in the vertical slot which is parallel to the patch does not affect the current so much but the horizontal slot cut the current which changes its path at the edges and thereby enhances the electrical length of the Antenna. The slot at the centre moreover combines again herewith to give broadband feature.



(a)



(b)

Fig.4.Current distributions of the double Cross slot with cross slot at the centre of the microstrip Patch Antenna at frequency a) 3.23 GHz b) 4.02 GHz.

The return loss of the Antenna 1 shows a very good broad band characterestics maintaining a dual band at 3.23 starting from 3.025 GHz to 3.405 GHz and 4.02 GHz starting from 3.825 GHz to 4.750 GHz .It can be seen that the correspnding bandwidths are 380 MHz and 925 MHz respectively.

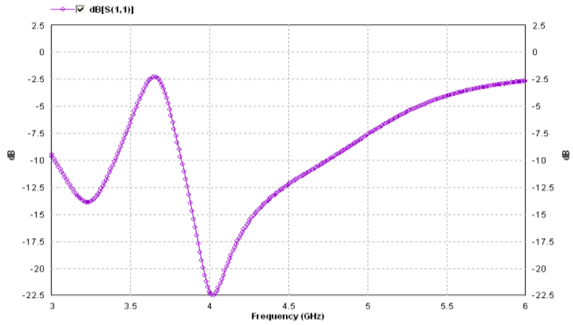
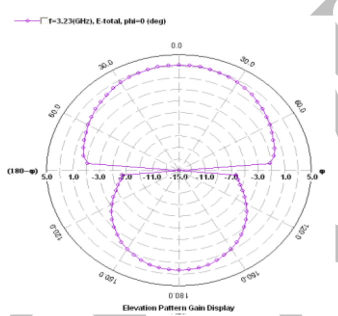
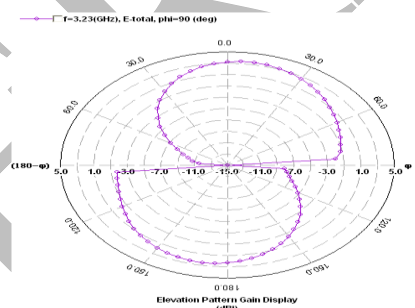


Fig.5. Return loss characteristics of the double Cross slot with cross slot at the centre of the microstrip Patch Antenna.

A 2-D Radiation Pattern of the double Cross slot with cross slot at the centre of the microstrip Patch Antenna is as shown below.



(a)



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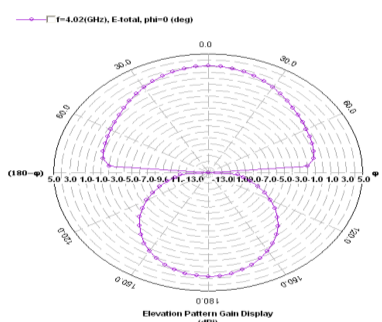
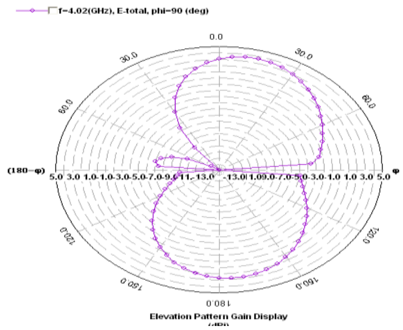


(c)



(d)

Fig. 6. Radiation Pattern of the double Cross slot with cross slot at the centre of the microstrip Patch Antenna for $\varphi=0^0$ and $\varphi=90^0$ (a and c) for the frequency 3.23 GHz and 4.02 GHz respectively) and $\varphi=90^0$ (b and d) for the frequency 3.5GHz and 4.21 GHz respectively.

The proposed antenna having broadband showed fairly good gain of about 3.35 dBi at low frequency and 4.83 dBi at the frequency about the resonating frequency.

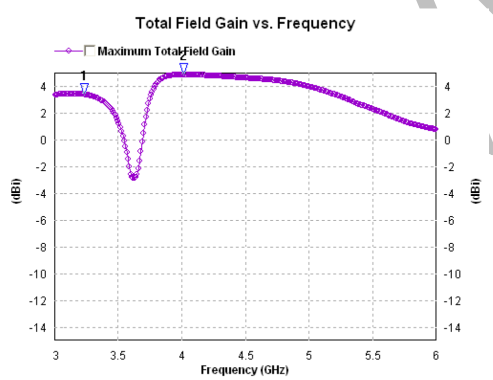


Fig.7. Gain of the double Cross slot with cross slot at the centre of the micro strip Patch Antenna.

B. ANTENNA 2

The same antenna is having swastika shaped slot at the centre of the patch having dimension 10x10 $mm^{2.}$

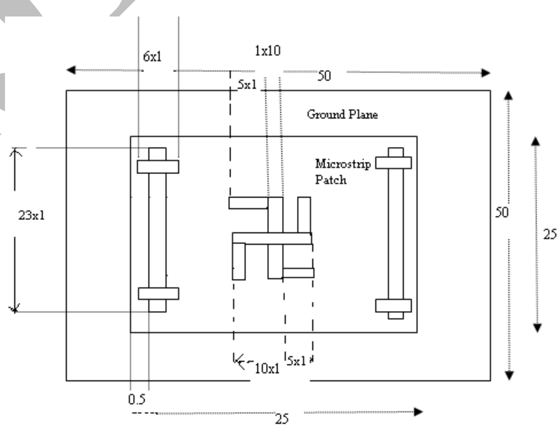


Fig.8. Dimensions of the double Cross slot with Swastika at the centre of the micro strip Patch Antenna

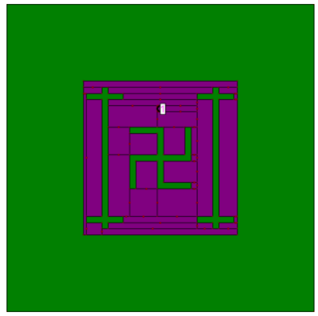
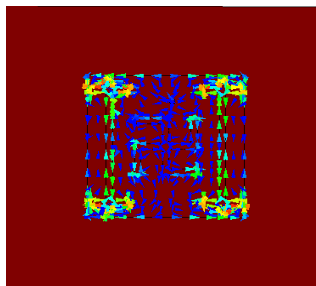
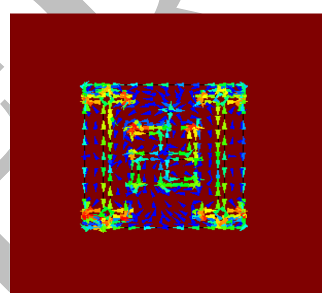


Fig.9. IE3D simulation of the double Cross slot with Swastik shaped slot at the centre of the microstrip Patch Antenna

The current distributions about the Patch are as shown in figure 10. At the high frequency the Electrical length is more compared to the low frequency as shown in the figure which results in the Broadening of the high resonant frequency band and shortening of the low frequency band compared to the Antenna 1.



(a)



(b)

Figure 10: Current distributions of the double Cross slot with Swastik shaped slot at the centre of the microstrip Patch Antenna at a frequency (a) 3.5 GHz and (b) 4.21 GHZ.

The return loss of the Antenna 2 shows a very good broad band characterestics resonating at 3.5 GHz having a bandwidth of 80 MHz starting from 3.46 GHz to 3.54 GHz and 4.21 GHz having bandwidth of 1.02 GHz starting from 3.935 GHz to 4.955 GHz .It can be seen that the higher resonant frequency band comparatively to Antenna 1 is remarkely increased to 1.02 GHz .But the total bandwidth decreases even after introduction of the added horizontal and vertical slots in the cross shaped slots.This is because at low frequency very low current density can be seen across the Swastik slot which results to the decrease in bandwidth compared to Antenna 1.So some other method is even required to increase the electrical length of the Antenna.This is achieved by adding a H Slot loaded at the centre of the double cross slot loaded at the edge as shown in Antenna 3.

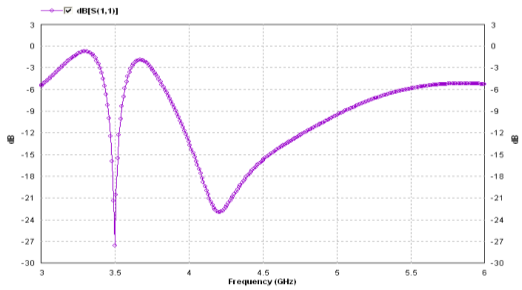
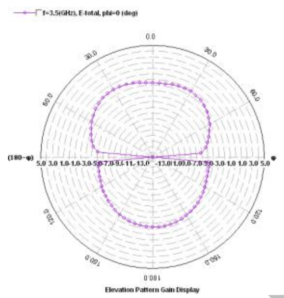
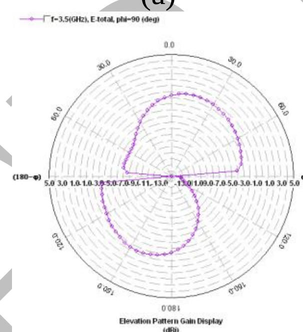


Fig.11 Return loss characteristics of the double Cross slot with Swastik shaped slot at the centre of the micro strip Patch Antenna

A 2-D Radiation Pattern of the double Cross slot with Swastik shaped slot at the centre of the microstrip Patch Antenna is as shown in figure 12.



(a)



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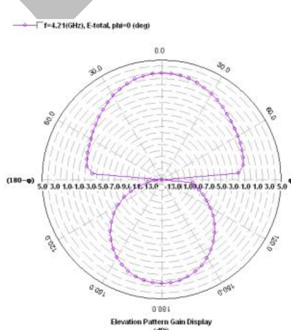

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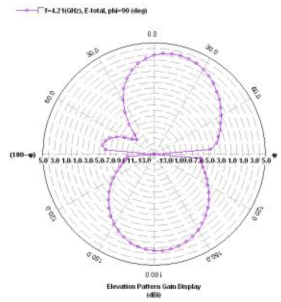


(d)

Fig.12. Radiation Pattern of the double Cross slot with Swastik shaped slot at the centre of the microstrip Patch Antenna for φ=0^0 (a and c)for the frequency 3.5GHz and 4.21 GHz respectively) and φ=90^0 (b and d)for the frequency 3.5GHz and 4.21 GHz respectively .

The proposed antenna having broadband in case2 showed fairly good gain of about nearly2.06 dBi and 3.92 dBi for 3.5 GHz and 4.21 GHz respectively about the resonating frequency.

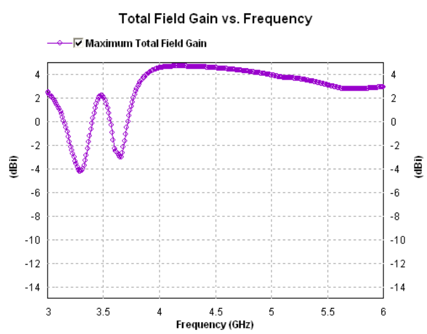


Fig.13. Gain of the double Cross slot with Swastik shaped slot at the centre of the microstrip Patch Antenna.

C. ANTENNA 3

The same antenna is having an H shaped slot at the centre of the patch having dimension 10x10 mm^2.

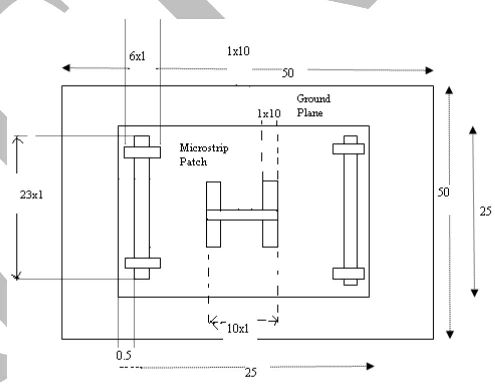


Fig.14. Dimensions of the double Cross slot with H shaped slot at the centre of the microstrip Patch Antenna

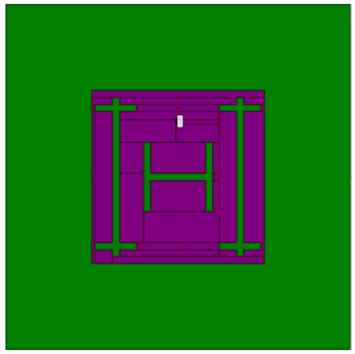


Fig.15.IE3D simulation of the double Cross slot with H shaped slot at the centre of the microstrip Patch Antenna.

The current distributions about the Patch are as shown in figure 16. The current distribution in this case is greatest as can be seen from the figure. Intense distribution can be seen by loading the H shaped slot at the centre all across its boundary and even at the edges of the double cross shaped slot resulting in most widening of the band in this case.

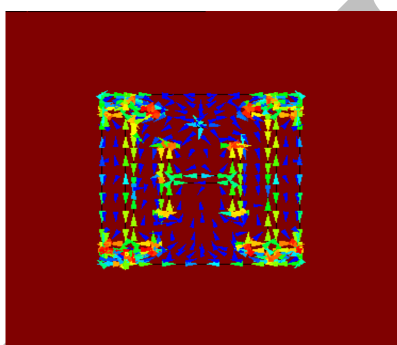


Fig.16 Current distributions of the double Cross slot with H shaped slot at the centre of the microstrip Patch Antenna at a frequency 3.99 GHz.

The return loss of the Antenna 3 shows a very good broad band characterestics resonating at 3.99 GHz and maintaining a broadband starting from 3.815 GHz to 5.33 GHz.It can be seen that the current distributes very densly all along the H shaped slot and thus bandwidth is increased even more than Antenna 1 and Antenna 2 to 1.515 GHz which clearly shows that the electrical length is fairly increased if a H shaped slot is loaded in the centre of the Antenna.

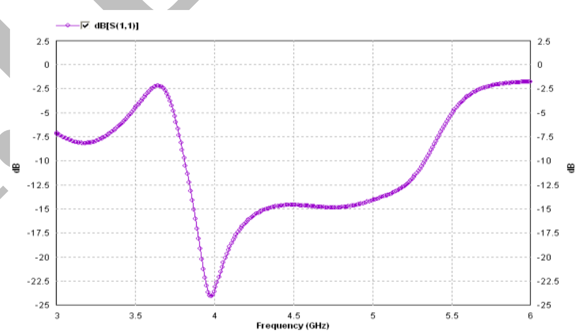


Fig.17. Return loss characteristics of the double Cross slot with H shaped slot at the centre of the microstrip Patch Antenna.

The proposed antenna having broadband showed fairly good gain of about nearly 4.71 dBi about the resonating frequency which is fairly good in comparison to the other two Antennas.

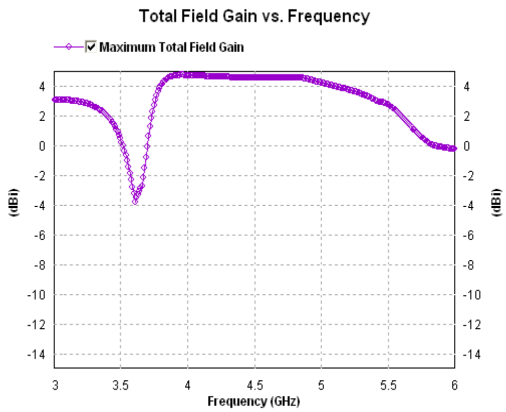
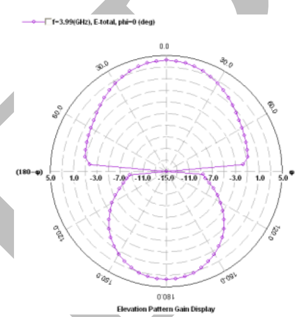
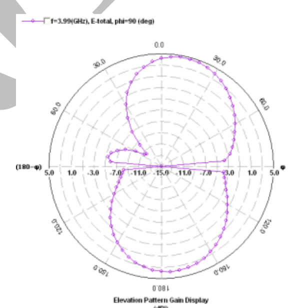


Fig.18. Gain of the double Cross slot with H shaped slot a t the centre of the microstrip Patch Antenna.

A 2-D Radiation Pattern of the double Cross slot with H shaped slot at the centre of the microstrip Patch Antenna is as shown in figure 19.



(a)



(b)

Fig.19. Radiation Pattern of the double Cross slot with H shaped slot at the centre of the microstrip Patch Antenna for φ=0^0 and φ=90^0 at a frequency 3.99 GHz.

3. RESULTS AND DISCUSSION

The return losses of Antenna 1.Antenna 2,Antenna 3 are as given in figure below clearly demonstrate the fact that Antenna 3 that is the H shaped slot at the centre of the patch is having greater bandwidth of 1.5 GHz compared to the other two Antennas. Even there is the fair amount of increase in Gain.

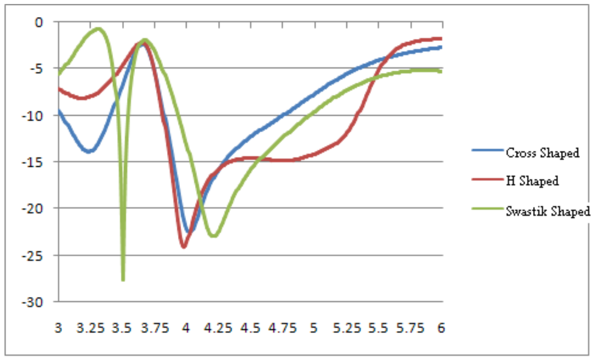


Fig.20. Comparison of the return losses of the Antenna 1, Antenna 2 and Antenna 3 microstrip Patch Antenna

4. CONCLUSION

In this paper, a new method of improving the bandwidth of the microstrip antenna is proposed. The bandwidth broadening method is based on using a pair of slots placed close to non-radiating patch edges and an air layer between the substrate and the ground. The slots can generate a new resonant frequency, and the air layer can decrease the Q value. Therefore, the antenna has a very wide bandwidth of about 37.97% for Antenna 1 which is only about 15.2% in some other literature [11] with a high gain. Because of its simple structure, it will be widely used in communication system.

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12. IE3D Software Release 9 developed by M/S Zeland Software, Inc.

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