STUDY AND ANALYSICS OF BANDWIDTH ENHANCEMENT IN A CPW FED PRINTED MONOPOLE ANTENNA

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Abstract

In this paper, a slotted octagonal shaped radiating element with a pair of Z shaped Defected Ground Structure (DGS) is proposed for achieving additional resonances and bandwidth enhancements. The DGS (Defected Ground Structure) refer to certain compact geometrical shapes and they are realized in the form of defects on the ground plane of printed circuits

Introduction

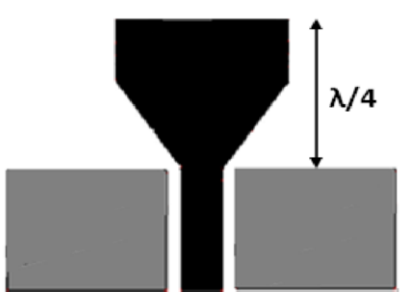
Recently, the demand for the design of an antenna with triple-or multiband operation has increased since such an antenna is vital for integrating more than one communication standards in a single compact system to effectively promote the portability of a modern personal communication system. For this demand, the developed antenna must not only be with a triple/multiband operation but also have a simple structure, compact size, and easy integration with the circuit. Among the known triple/multiband antenna prototypes, the planar monopole antenna with various structures has become a familiar candidate because of its attractive characteristics including low profile and weight, low cost, and versatile structure for exciting wide impedance bandwidth, dual or multiresonance mode, and desirable radiation characteristics. Many techniques have been proposed to increase the bandwidth. Alkanhal (2009) proposed a new triple band small size composite resonator microstrip antenna configurations for wireless communications. The bandwidth achieved is 9.82% in the I band, 8.98% in the II band and 10.64% in the III band. The size of the radiating element is 20x15mm^2. Further, Lin Peng, et al (2010) presented a novel design of compact dual/triple-band microstrip antennas with an asymmetric M-shaped patch. The bandwidth achieved is 12.61%, 9.82% and 10.68% in the I, II and III bands respectively. The radiating strip size is 24 x 21.7 mm^2. Alireza Pourghorban Saghati et al (2010) reported a novel three sickle-shaped slots in the ground plane and three pairs of p-i-n diodes that are soldered between three metal strips inside the slots and the ground plane. The antenna achieves a bandwidth of 11.21%, 10.21% and 10.50% in the

I, II and III bands respectively. The size of the radiating element is 18x10mm^2. Leong et al (2009) presented a tunable monopole antenna using double U-shaped defected ground structure. The antenna achieves a bandwidth of 8.60%. 10.42% and 12.20% in three bands. The size of the radiating element is 20x22mm^2. Piscarreta & Ting SW (2008) proposed a microstrip parallel coupled line bandpass Filter with selectivity improvement using U-shaped defected ground structure. The impedance bandwidth is 8.62%, 11.10% and 9.54% in three bands. The size of the radiating element is 18x16mm^2. The mentioned antennas in the literature have limited impedance bandwidth, complex to manufacture or their size is physically unsuitable for applications requiring low-profile antennas. In this paper, a slotted octagonal shaped radiating element with a pair of Z shaped Defected Ground Structure (DGS) is proposed for achieving additional resonances and bandwidth enhancements. The DGS (Defected Ground Structure) refer to certain compact geometrical shapes and they are realized in the form of defects on the ground plane of printed circuits. The DGS may either comprise a single defect (unit cell), or it may contain a number of periodic and aperiodic configurations. DGS exhibits a band-stop property. DGS was directly integrated with antennas to improve the radiation characteristics. DGS exhibits a band-stop property also.

In our design, DGS (pair of ‘Z’ shaped structure) and the patch are

located in the same plane. When the patch is excited, it perturbs the electromagnetic fields around the defect. Trapped electric fields give rise to the capacitive effect (C), while the surface currents around a defect cause an inductive effect (L). This, in turn, results in resonant characteristics of a DGS, and it is important to determine the equivalent circuits. By introducing DGS in the ground plane, the area of the ground plane is reduced and the bandwidth is improved significantly. The main features of slotted octagonal shaped antenna design are

1. Inductive Stub
2. Defected Ground Structure



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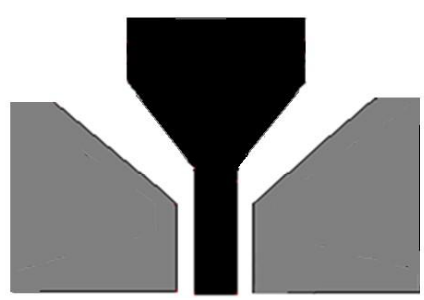

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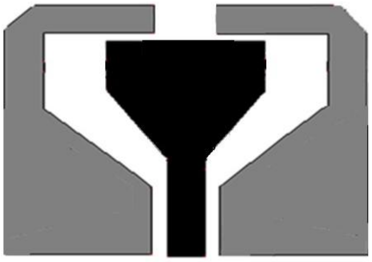

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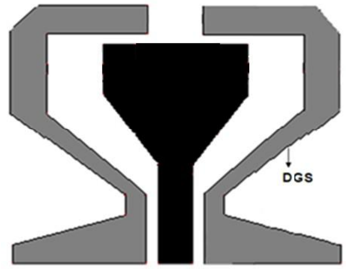

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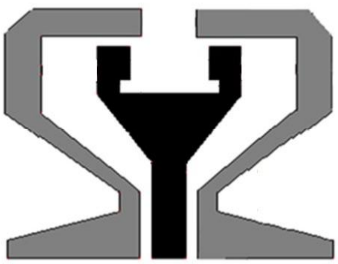

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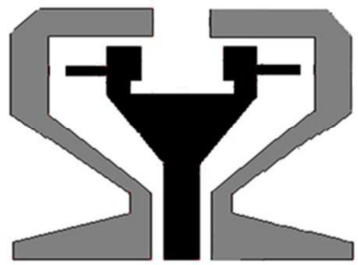

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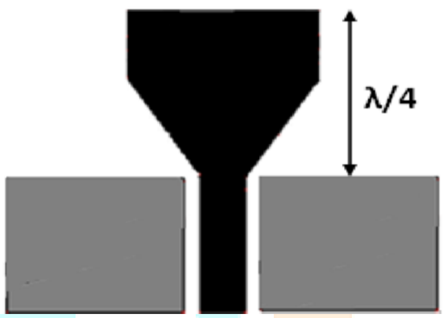

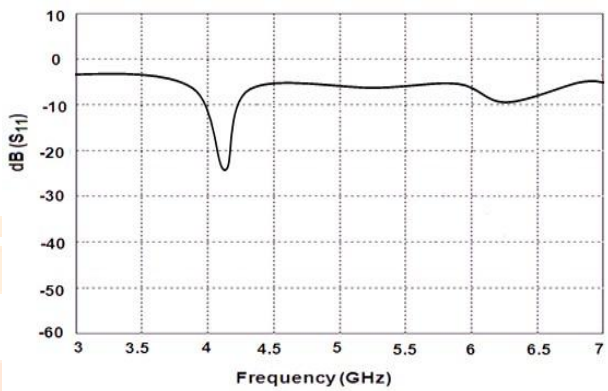

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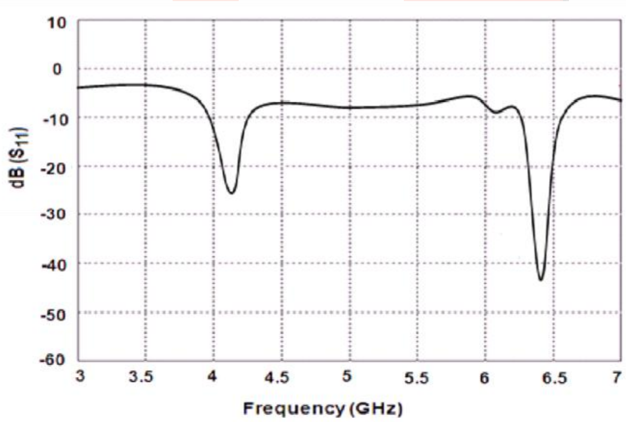

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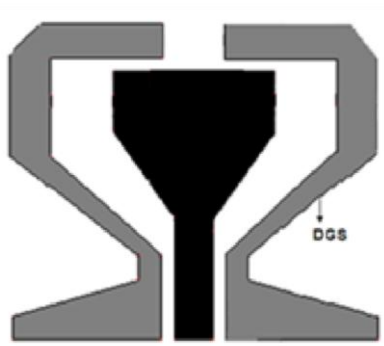

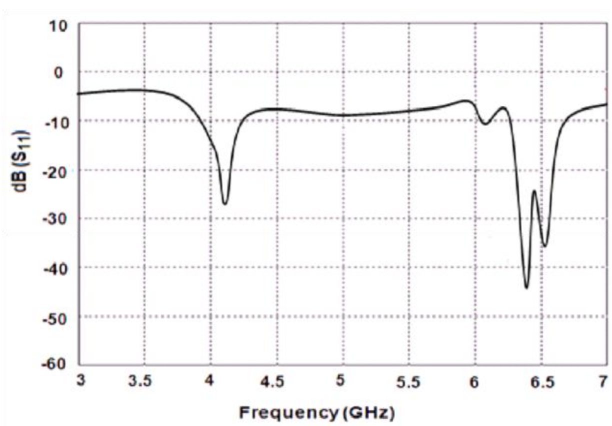

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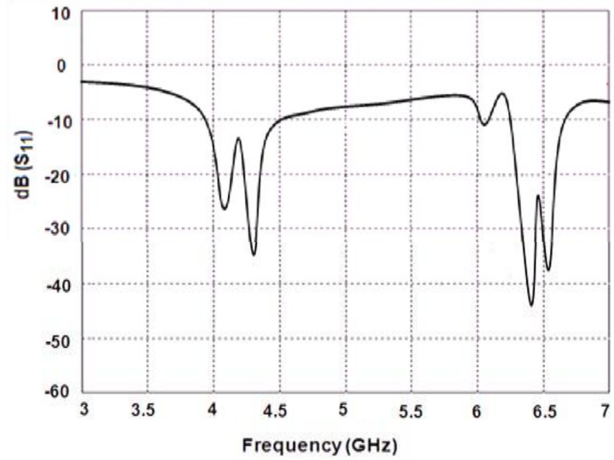

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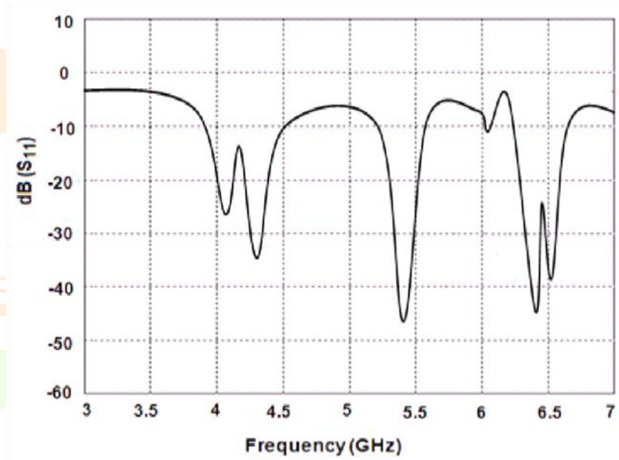

Step 12

Figure Progress of the Geometry of the proposed antenna and its response

Antenna Design

The geometry of the proposed antenna is illustrated in Figure 2. A fabricated slotted octagonal shaped monopole antenna shown in Figure 5.2 is printed on FR4 substrate ε_r = 4.3, h = 1.6 mm, and tan δ = 0.008. The antenna is fed by 50 ohm co-planar waveguide feed line of width 1.6 mm. Thesize of the radiating element is 11.2 x 6.0 mm^2. The octagonal shaped monopole radiating element is close to $\lambda_0/4$ length is about 20.8mm at a frequency of 4.2 GHz is designed. The beveling angle 45° in the octagonal shaped structure results in a smooth transition from one resonant mode to another and ensures good impedance matching. A slot is introduced into the octagonal shaped structure as shown in Figure 3.30. This slot having the dimension Ls x Ws_2 = 2 mm x 9.8 mm is used to increase the excitation of resonant mode. Further, a section of T shaped structure indicated by the length L_1 is 10.4 mm, close to $\lambda/4$ length at a frequency 5.5 GHz is placed above the modified U shaped slot. This section of the 'T' shaped structure provides inductive reactance. To improve the impedance matching, a section 'S_1' is attached to the L_1 shaped section which provides 'capacitive reactance'. The lower part of the vertical arm of the T shaped structure is placed inside the modified U shaped slot so that the slot resonant mode is disturbed. For further tuning of the resonant frequencies, a pair of horizontal stubs S_2 of length $0.01\lambda o$ at 4.2 GHz, (λo is the free space wavelength) is placed on either side of the octagonal shaped radiating element. The length of the stub is varied gently, so that the related frequency is finely tuned. In order to excite one more resonant mode, a pair of Z shaped Defected Ground Structures (Lg_1 = 10.2 mm, Lg_2 = 16.2 mm, close $_0$/4 length at 6.4 GHz and 6.2 GHz respectively) are mirror-symmetrically placed on both sides of the monopole radiating element. The ground plane and the radiating element both are in the same plane. The proposed antenna has been analyzed and optimized by Zeland IE3D simulation software based on the method of moments. First, simulation results are presented followed by experimental verification.

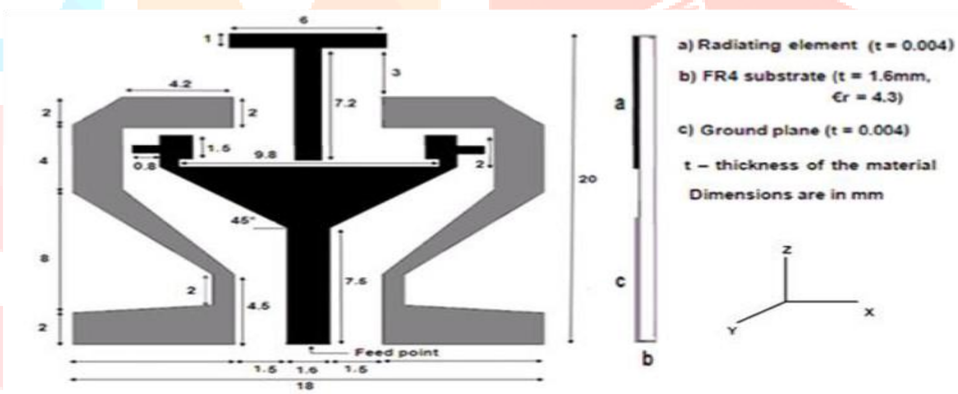

Figure 2 Geometry of the slotted Octagonal shaped antenna front and side view

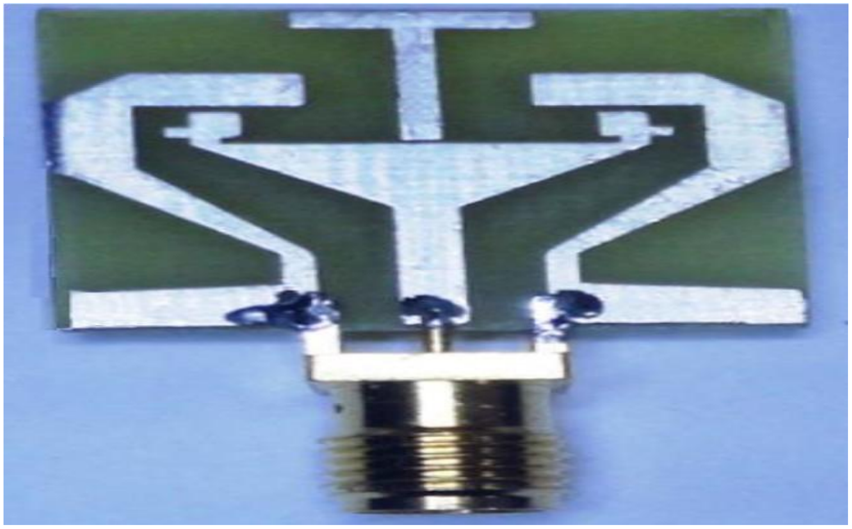

Figure 3 Fabricated slotted Octagonal shaped antenna

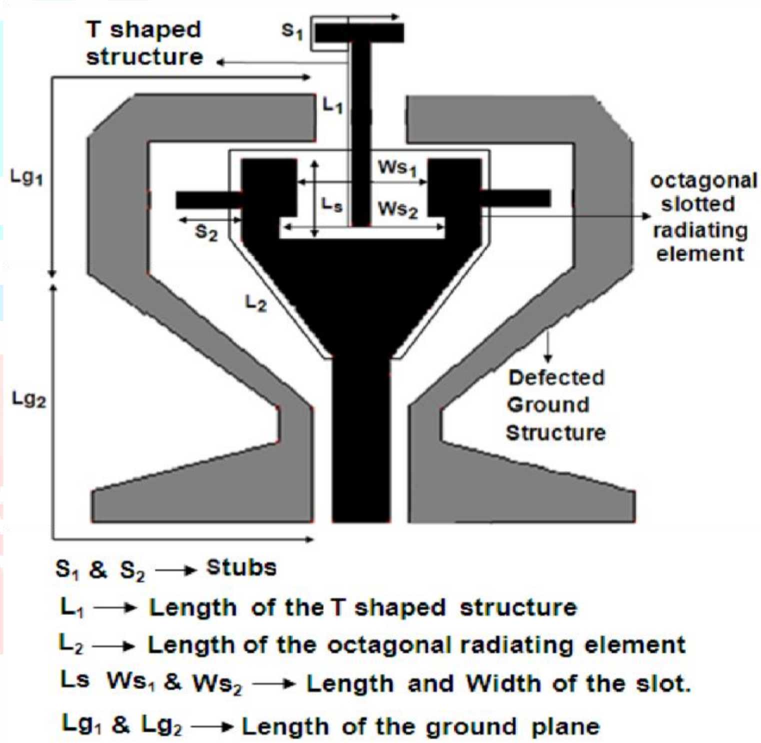

Figure 4 Parameters of slotted Octagonal shaped antenna 5.3 Bandwidth Enhancement

Figure .4 shows the proposed antenna structure with various parameters. Excellent results are obtained with proposed configurations when various dimensions are properly chosen.There are number of parameters that influence the bandwidth: these include the width of the slot in the octagonal shaped monopole, the size of the DGS and the size of the 'T' shapedstructure. Here the DGS is considered as a part of the radiating element

Effect of varying the slot width Ws_1 : A modified 'U' shaped slot is embedded in the octagonal shaped radiating element significantly affect the impedance matching in the first and second bands.The proposed modified 'U' shaped slot creates additional resonance in the first band.Figure 5 (a) shows the simulated results for various width Ws_1 of the slot. The width of the slot is adjusted from 6.8 mm to 9.8 mm in steps of 1mm. In the first band there is an improvement in bandwidth is noticed. In the second band the variation of resonant frequency is moderate. There is no shifting of resonant frequencies is observed in the third band. Further, the two resonances in the first band are not wide enough to provide the -10 dB bandwidth and therefore, a horizontal tuning stub S_2 is placed on either side of the radiating element and it is varied.

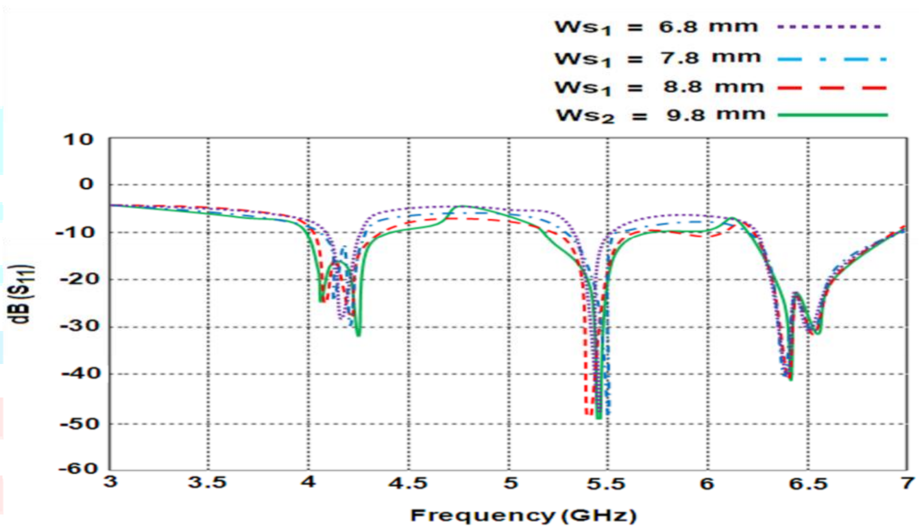

Figure 5(a) Simulated graph for various slot width Ws_1

Effect of varying the length L_1: Figure .5 (b) shows the simulated results for various length ofT shaped structure. A section of the length L_1 of the T shaped structure is designed close to $\lambda_0/4$ length at 5.5 GHz. This will act as an inductive stub. To obtain the optimal dimension of the strip, the effects of the strip length L_1 on the impedance matching of the proposed antenna have been studied. When the length L_1 is varied from 6.2 to 7.2 mm in steps of 0.5 mm it is observed that the first band resonances are affected since a lower part of the 'T' shaped structure disturb the resonance of the slot. In the second band the resonant frequency is shifted towards right and hence the bandwidth is improved. But the third band resonances remain fixed. By increasing the length there is an improvement in bandwidth in each band is noticed. However, when $L_1$is increasedfrom 7.2 mm to 7.7 mm exhibits bandwidth deterioration in the first and second bands. Hence the optimized value is selected for the parameter L_1 is 7.2 mm.

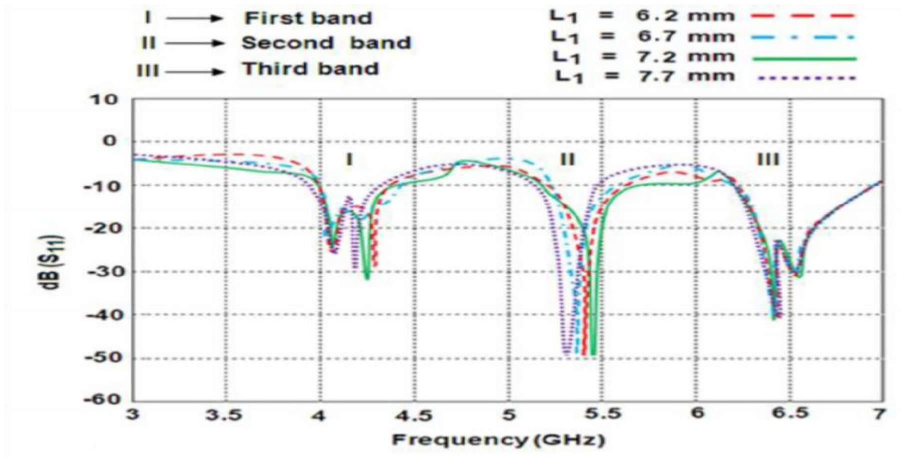

Figure 5(b) Simulated graph for various Length L_1

Effect of varying the length Lg_1 in the Ground plane: Figure 5 (c) shows the simulated graph for various ground plane length Lg_1. To improve the bandwidth of the proposed antenna, the ground plane is modified in the form of a pair of Z shaped structure. It is shown that, the variation in the length Lg_1 and Lg_2 of the Defected Ground Structurehelps in generating additional resonances and hence increase in impedance bandwidth is noticed.Variation of Length Lg_1 affects the length of Lg_2 also. By varying the length of Lg_1 4 mm to 10.2 mm, it not only affects the resonance points in the third band but also affects the resonance points in the first and second bands since DGS is placed close to the monopole radiating element and the 'T' shaped structure. However, the resonance point in the second band is less affected only compared to third and first bands. The resonance points in all the bands are shifted towards right and hence improvement in bandwidth is noticed. Therefore, in this case, the parameter of Lg_1 is set to about one quarter wavelength at the new generated resonant frequency of operation. Compared to the antenna having conventional ground plane, the antenna with defected ground structure can enhance the bandwidth considerably.

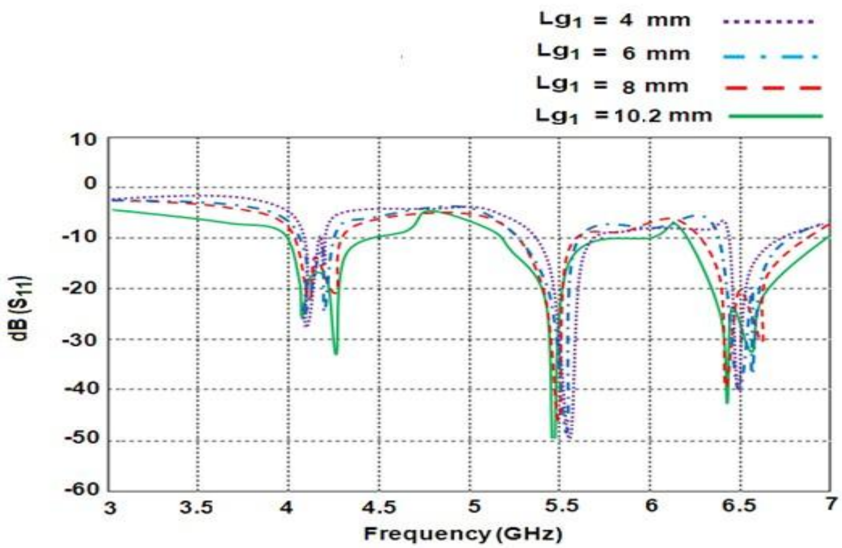

Figure 5 (c) Simulated graph for various ground plane length Lg_1 5.4 Return

Loss

Figure .6 shows the Return loss Characteristics of a slotted Octagonal shaped antenna. The measured -10 dB return loss impedance bandwidth for the first band is about 4.0 - 4.5 GHz (11.76%) with a resonance mode excited at 4.2 GHz, for the second band is about 5.2 - 5.8 GHz (10.90%) with a resonance mode excited at 5.9 GHz and for the third band is about 6.2 - 7 GHz (12.12%) with a resonance mode excited at 6.5 GHz. Comparison of the simulated and measured results shows a reasonable agreement for all the three bands.Figure .7 shows the Return loss measurement using HP 8757D Scalar Network Analyzer for a slotted Octagonal shaped antenna. Figures .8 (a) to .8 (e) show the Return loss and VSWR measurement graphs.

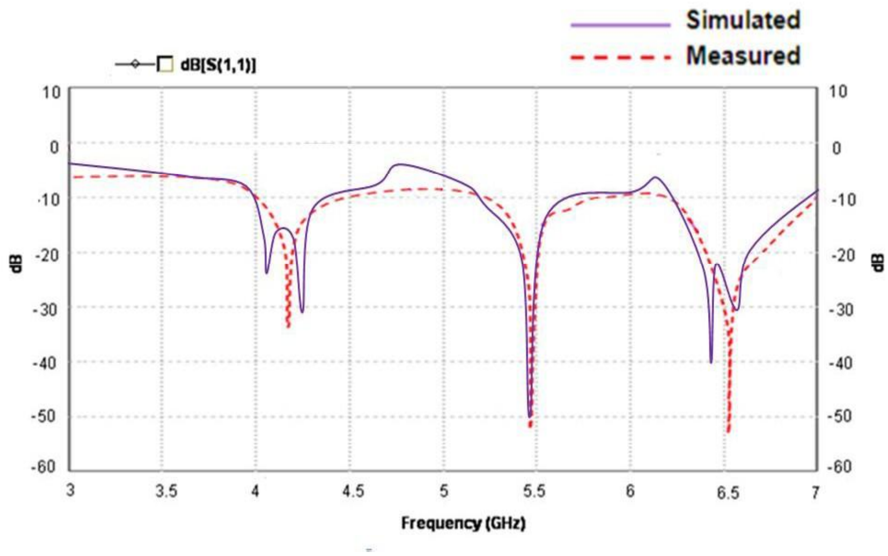

Figure 6 Return loss Characteristics of a slotted Octagonal shaped antenna

Figure 7 Return loss measurement using HP 8757D Scalar Network Analyzer for a slotted Octagonal shaped antenna

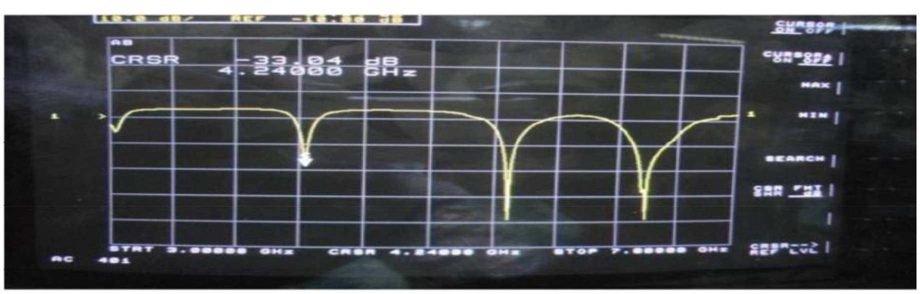

Figure 8 (a) Return loss measurement at 4.2 GHz

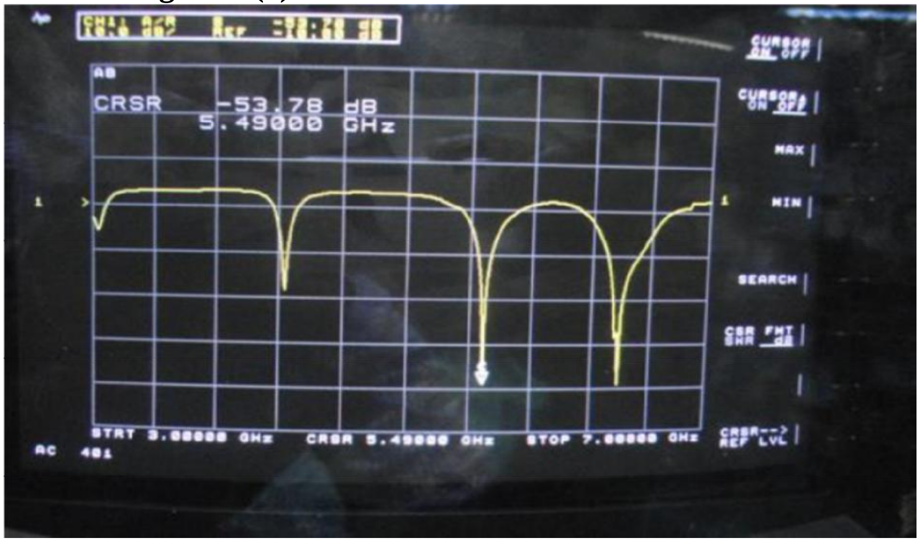

Figure 8 (b) Return loss measurement at 5.4 GHz

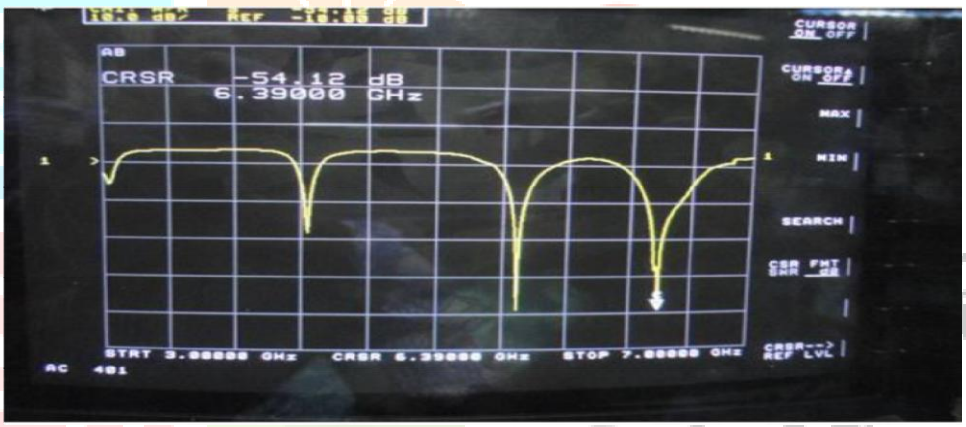

Figure 8 (c) Return loss measurement at 6.3 GHz

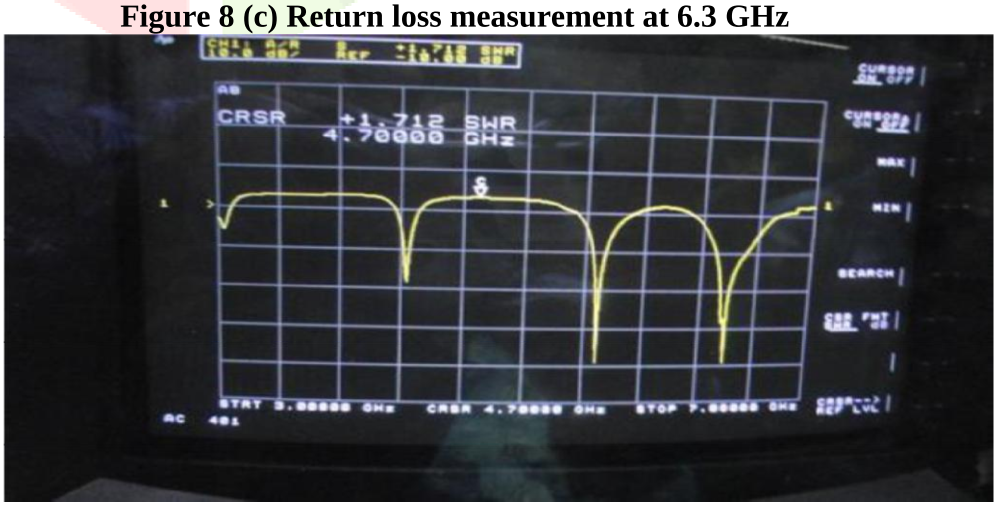

Figure 8 (d) SWR measurement at 4.7 GHz

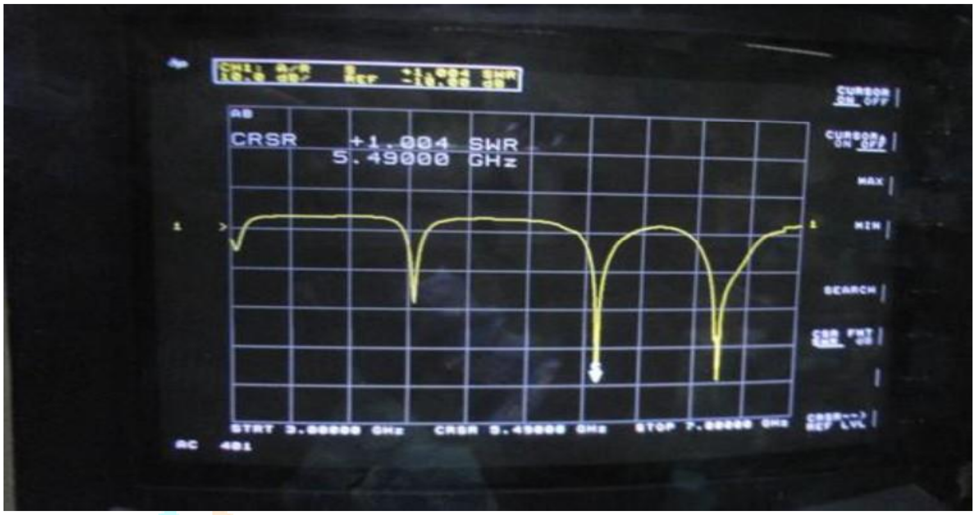

Figure 8 (e) SWR measurement at 5.4 GHz

Current Distribution

The simulated surface current distribution at three frequencies 4.3, 5.5 and 6.4 GHz are given in Figures 9 (a), (b) & (c). At 4.3 GHz, the maximum current flow occur at the centre of the orthogonal shaped structure and at the edge, the current flow tend to decrease. This shows the short and open circuit like behaviour and hence, the radiating element acts like a monopole.

At 5.5 GHz, maximum current flow is observed in the vertical arm of the T shaped structure shown in red colour and in the horizontal arm, the current flow is minimum shown in blue colour at the end. This shows that the T shaped structure operates at a resonant length of $\lambda_0/4$. At 6.4 GHz, the current distribution is observed in the Defected Ground Structure. Each section of the DGS (Lg_1& Lg_2) shows the current distribution which reflects monopole like characteristics. If these two sections are combined together, it can be seen that the 'Z' shaped DGS, behaves like a dipole.

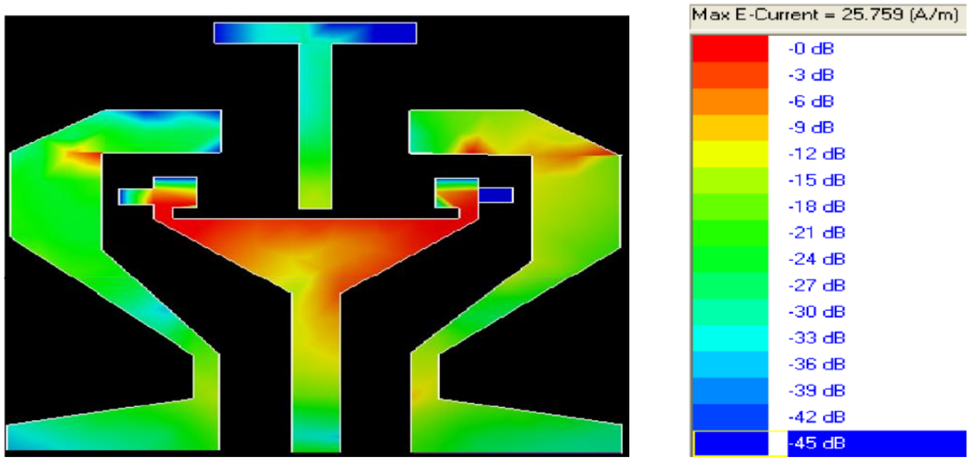

Figure 9 (a) Surface Current Distribution at 4.3 GHz

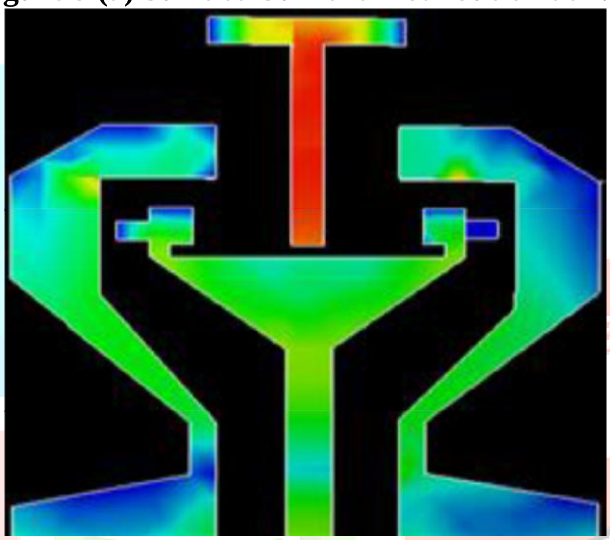

Figure 9 (b) Surface Current Distribution at 5.5 GHz

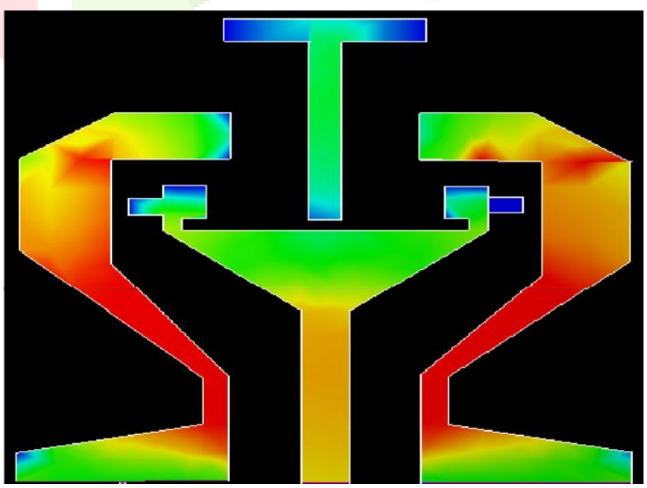

Figure 9 (c) Surface Current Distribution at 6.4 GHz

Radiation Pattern

The E-plane and H-plane radiation patterns are shown in Figures 10 (a) &10 (b) at 4.3 and 6.4 GHz.At 4.3 GHz, the E-plane has monopole like radiation pattern. At 6.4 GHz, though the antenna is monopole, it shows dipole like bidirectional pattern. The H-plane radiation pattern at 4.3 GHz and 6.4 GHz is not a perfect omnidirectional because of the variation of current flow in the octagonal shaped structure and in the DGS. Figure 11 shows the radiation pattern measurement in the anechoic chamber for the slotted octagonal shaped antenna. The corresponding measured E-plane and H-plane radiation patterns are shown in Figures 12 (a) &12 (b).Slight deviations in the simulation and measued radiation patterns are observed in both the planes, because during simulation infinite ground plane is used and during measurement finite ground plane is used.

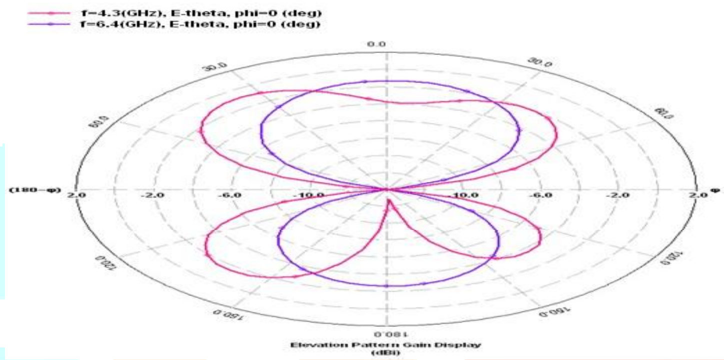

Figure 10 (a) Simulated Elevation Pattern (E theta at 4.3 GHz & 6.4GHz)

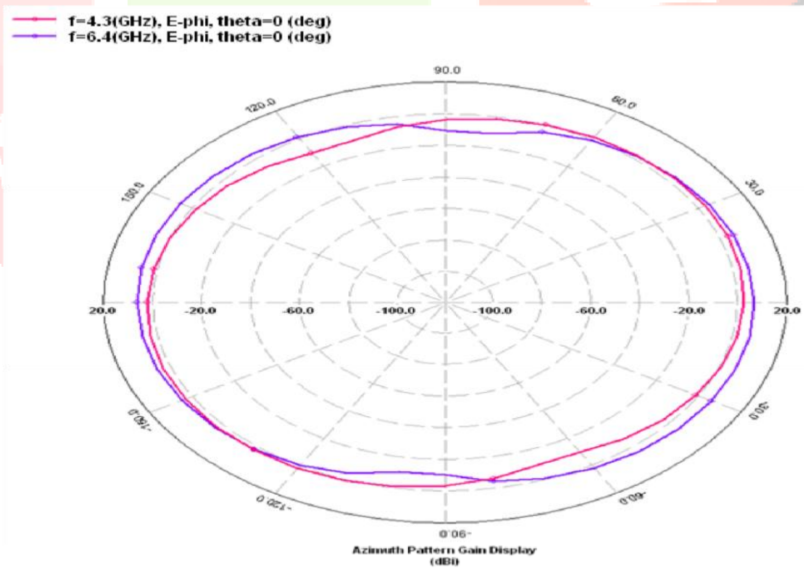

Figure 10 (b) Simulated Azimuth Pattern (E phi at 4.3GHz & 6.4 GHz)

Figure 11 Measurement of radiation pattern for a slotted Octagonal shaped antenna in an anechoic chamber

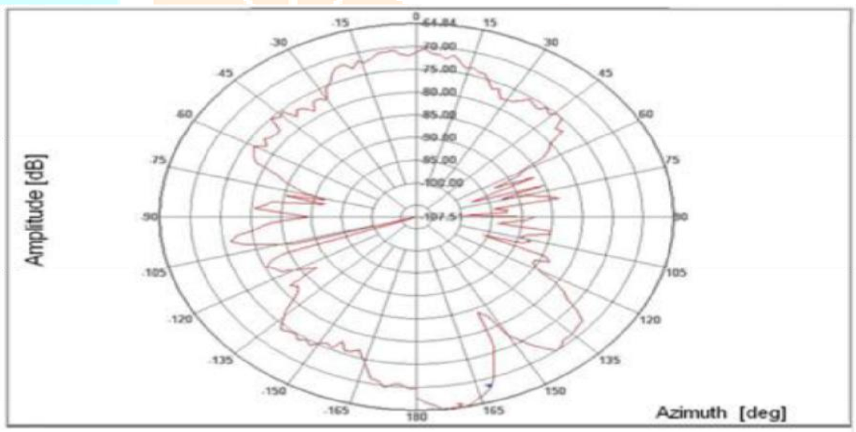

Figure 12 (a) Measured E-plane (XZ) pattern at 6.4 GHz

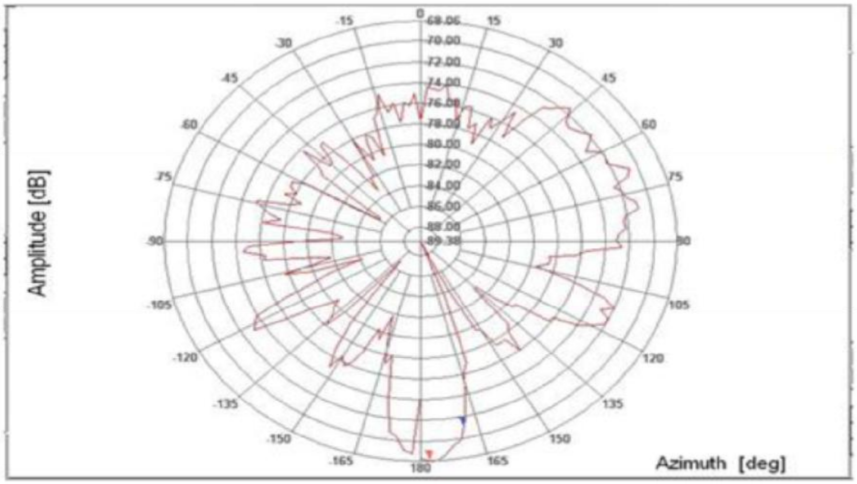

Figure 12 (b) Measured H-plane (XY) pattern at 6.4 GHz

Gain

Figure 13 shows the gain characteristics of a slotted Octagonal shaped antenna at various frequencies. The peak gain is around 6 dBi at 6.5 GHz. For lower frequencies the gain variations are from 0-3 dBi, for the middle frequencies 0-3.8 dBi and for the upper frequencies the variations are from 1.8-6 dBi.

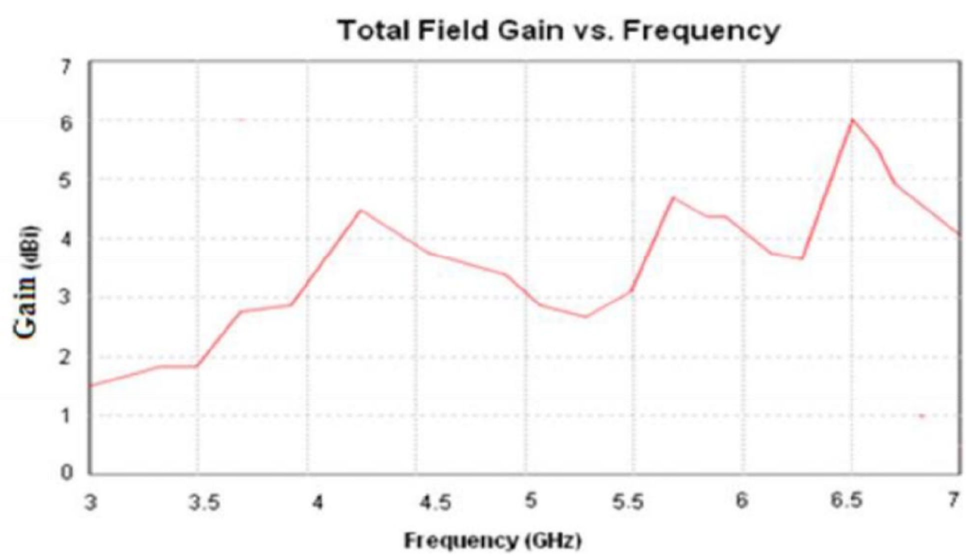

Figure 13 Gain characteristic of a slotted Octagonal shaped antenna

Conclusion

The proposed antenna with compact size and relatively good radiation characteristics. By employing a 'Z' shaped Defected Ground Structure and a T shaped structure, additional resonances are excited. Experimental results indicates that the enhanced impedance bandwidth can reach 4.0 - 4.5 GHz (11.76%), 5.2 - 5.8 GHz (10.90%) and 6.2 - 7 GHz (12.12%). In addition, the proposed antenna exhibits nearly omnidirectional radiation pattern in the H-plane over the operating frequency range. The peak gain is around 6 dBi at 6.5 GHz. The proposed antenna, which has a simple structure, excellent performance and is fabricated easily, suitable for various wireless applications.

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