Printed Monopole Antenna Using Inductive Stub and Defected Ground Structure

K. Kumar

Abstract— A new type of triple band antenna is proposed for wireless applications. The proposed structure printed on FR4 substrate with $\varepsilon_r = 4.3$, $h = 1.6$ mm and $\tan \delta = 0.008$. The size of the radiating element is 11.2 x 6.0 mm^2. Both the triple band antenna and the feeding microstrip line are printed on the same substrate, leading to a fully planar structure. The Defected Ground Structure is employed to enhance the bandwidth. 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. The performances of the antenna with optimized parameters are characterized in terms of reflection coefficient, gain, and radiation pattern.

Keywords- monopole antenna; bandwidth; radiation pattern; return loss

I. 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 [1]-[5]. 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

II. ANTENNA DESIGN

The geometry of the proposed antenna is illustrated in Figure 1. A fabricated slotted octagonal shaped monopole antenna shown in Figure 2. is printed on FR4 substrate ε_r = 4.3, h = 1.6 mm, and $\tan \delta = 0.008$. The antenna is fed by 50 ohm co-planar waveguide feed line of width 1.6 mm. The size 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. 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 as shown in Figure 3 is indicated by the length L_1 is 10.4 mm, close to $\lambda_0/4$ 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 0.01λo 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 to $\lambda_0/4$ 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.

Manuscript Received on March 2015.
K. Kumar, with the Department of Electronics and Communication Engineering, Pondicherry Engineering College, Puducherry, India.

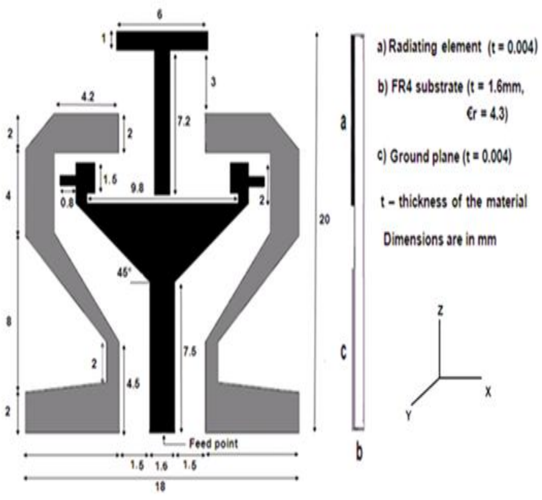

Figure 1. Geometry of the slotted Octagonal shaped antenna front and side view

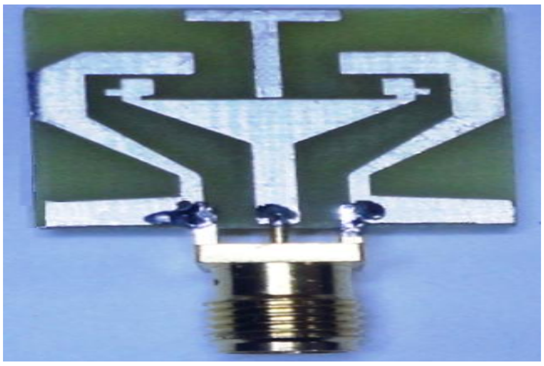

Figure 2. Fabricated slotted Octagonal shaped antenna

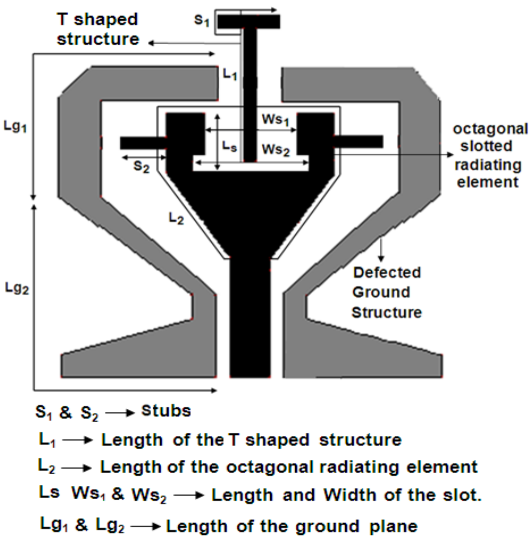

Figure 3 Parameters of octagonal shaped antenna

III. RETURN LOSS

Figure 4 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 5 shows the Return loss measurement using HP 8757D Scalar Network Analyzer for a slotted Octagonal shaped antenna.

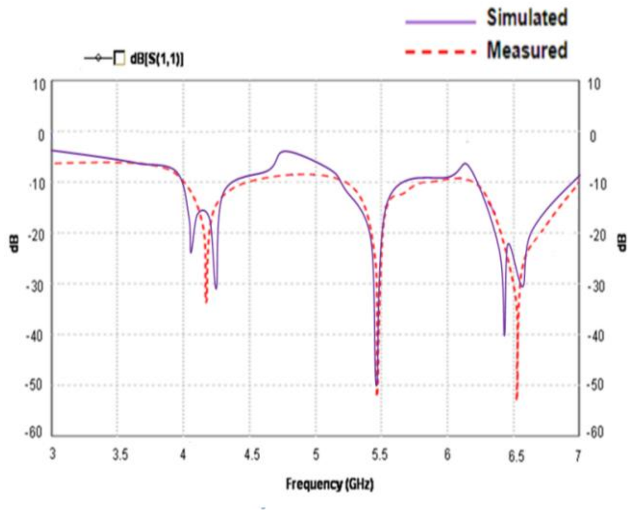

Figure 4. Return loss Characteristics of a slotted Octagonal shaped antenna

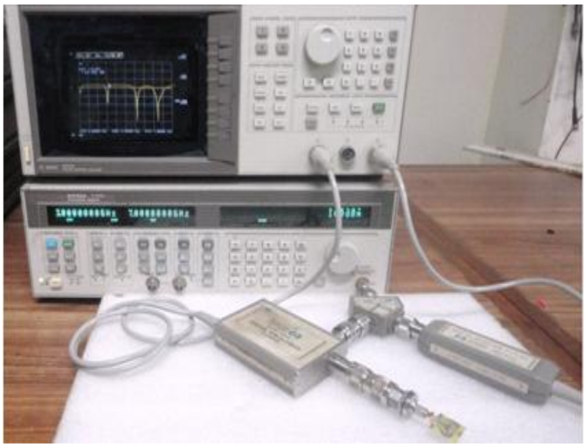

Figure 5. Return loss measurement using HP 8757D Scalar Network Analyzer for a slotted Octagonal shaped antenna.

I.
II.
III.
IV.
V.

IV. CURRENT DISTRIBUTION

The simulated surface current distribution at three frequencies 4.3, 5.5 and 6.4 GHz are given in Figures 6 (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.

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication Pvt. Ltd.

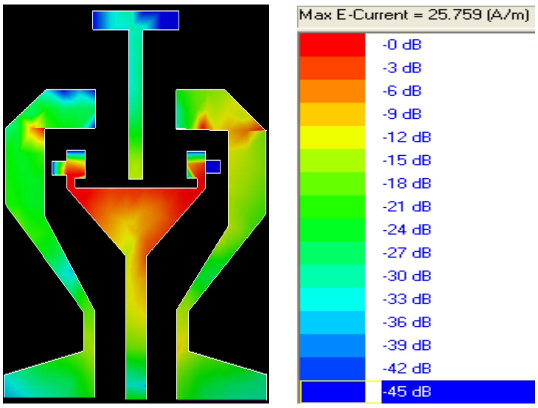

Figure 6 (a) Surface Current Distribution at 4.3 GHz

Figure. 6 (b) Surface Current Distribution at 5.5 GHz

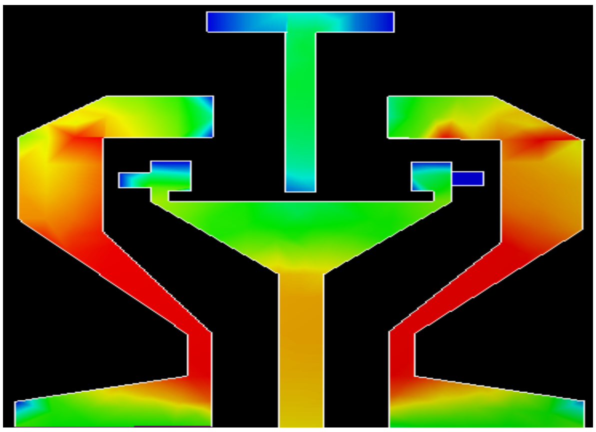

Figure. 6 (c) Surface Current Distribution at 6.4 GHz

V. RADIATION PATTERN

The E-plane and H-plane radiation patterns are shown in Figures 7 (a) & 7 (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.

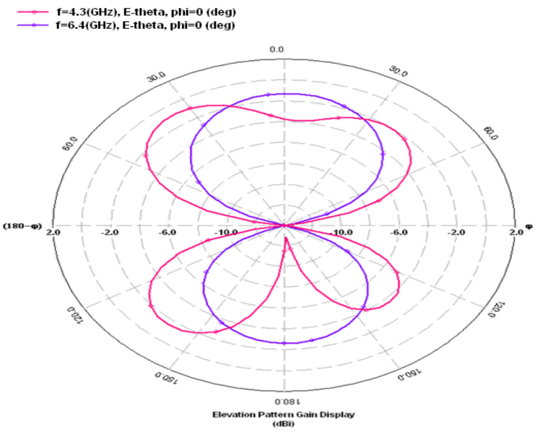

Figure 7(a) Simulated Elevation Pattern (E theta at 4.3 GHz & 6.4GHz)

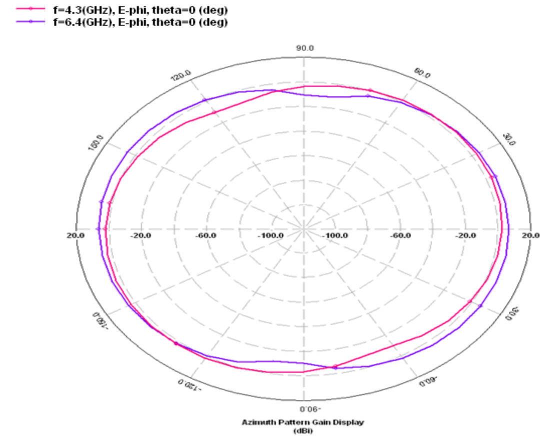

Figure 7(b) Simulated Azimuth Pattern (E phi at 4.3GHz & 6.4 GHz)

VI. GAIN

Figure 8 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 arefrom 1.8-6 dBi.

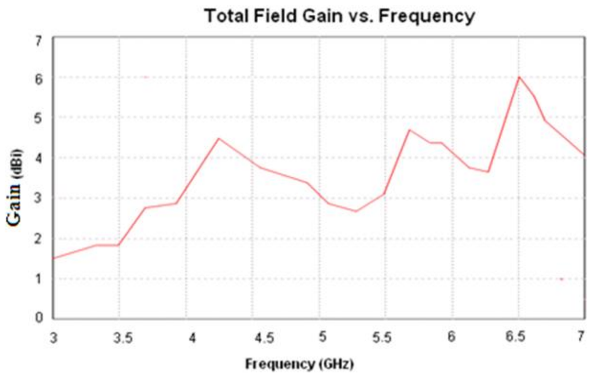

Figure 8. Gain curve

VII. 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

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

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

REFERENCES

[1] Liu, W.-C., C.-M. Wu, and Y. Dai, "Design of triplefrequency microstrip-fed monopole antenna using defected ground structure," IEEE Transactions on Antenna and Propagation, Vol. 59, No. 7, 2457–2463, July 2011.

[2] Kumar C & Guha D 'A new look into the cross-polarized radiation form a circular microstrip antenna and suppression using dot shaped DGS', IEEE Antennas and Propagation Symposium Digest. 2010,

[3] Liu WC, Wu CM, & Dai Y , 'Design of triple-frequency microstrip-fed monopole antenna using defected ground structure', IEEE Trans. Antennas and Propag., vol. 59, no. 7, pp. 2457-2463. 2011

[4] Kang, L., H. Wang, X. H. Wang, and X. Shi, "A Compact ACS fed antenna with rectangular SRRs for tri-band operation," *Electron. Lett.*, Vol. 50, No. 16, 1112-1114, Jul. 2014.

[5] G. Teni, N. Zhang, J. Qiu, and P. Zhang, "Research on a novel miniaturized antipodal Vivaldi antenna with improved radiation," IEEE Antennas and Wireless Propagation Letters, vol. 12, pp. 417–420, 2013.

K.Kumar-Received his B.E. degree (Electronics and Communication Engineering) and M.E. degree (Microwave and Optical Engineering) from the Madurai Kamaraj University (1990 & 1993), Madurai, India. He received his Ph.D degree in Microstrip Antennas from College of Engineering, Guindy, Anna University in the year 2014 Chennai, India. He published technical papers in International & National Journals and Conferences. He is currently working as Associate Professor in the Electronics and Communication Engineering Department at Pondicherry Engineering College, Pondicherry, India. His area of interest is electromagnetics, waveguides, microwave Engineering and Antennas. He has acquired Membership in ISTE and IEEE.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.