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A Canadian Leaf Shaped Triple Band Patch Antenna with DGS for X and C-Band Applications

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***Abstract*—**A shaped single feed microstrip antenna is realized for C-Band and X-Band applications. The frequency range of C-band and X-band varies from 4 to 8 Gigahertz and 8 to 12 Gigahertz. The antenna operates under three frequency bands, one under C band and two under X-band applications. Defect on the ground called DGS (Defected Ground Structure) is made to enhance the distinctiveness of the antenna parameters. The design consists of DGS provided to improve the antenna performance. The substrate material used is of the Flame Retardant grade-4 (FR4) epoxy having high mechanical and electrical strength. The design and analysis was done using the FEM (Finite Element Method) based Ansoft HFSS (High Frequency Structural Simulator) Version 12. For the resonant frequencies of 5.21, 9.17 and 10.45, a value of reflection coefficient obtained is of -39.0, -16.0 and -30.7 dB respectively. Other constraints of antenna such as bandwidth, gain, directivity and Voltage Standing Wave Ratio (VSWR) are also conferred.

***Keywords*—**Flame retardant-4 epoxy, finite element method, return loss, directivity.

I. Introduction

To act in accordance with the modern-day requirements in communication engineering, wireless antennas are mostly inevitable and hence there is a huge demand for Microstrip Patch Antennas with multiband characteristics under compact nature [6]. Also, the microstrip patch antennas can be applicable in Microwave Monolithic Integrated Circuits and Opto-Electronic Integrated Circuits due to their less weight and low cost nature in terms of fabrication and production. Microstrip patch antenna and Dipole Antennas are highly efficient compared to other antennas particularly in size reduction of rectenna [7]. Usually, an antenna is structured to resonate under single frequency. But the dual band frequency of operation can be achieved by using methods such as providing slots on patch, shorting post or wall inside patch, etc. [1]-[3], [5]. When certain slots are cut along the radiating edge of the conducting patch, they alter the resonant mode characteristics which further results in a dual resonance along with the fundamental mode. Similarly, by introducing four slots in a patch, a nine band antenna was depicted [4]. Several formulations were also done to introduce the slots on the patch for dual and multi-band frequency of operation [9].

C-band and X-band frequency ranges as defined by IEEE definition on letter designation include the scale from 4 to 8 GHz and 8 to 12 GHz correspondingly [16]. The C band frequency ranges have an extensive range of applications in weather radar, Wireless Fidelity devices, cordless phone and for transmission in satellite communications. Also the X-band frequency range has wide application in police radars for vehicle speed detection, weather forecasting, monitoring, civil, and military, etc. Images with discrimination and fine resolution could be obtained from the smaller wavelength of X-band [14]. For satellite and RADAR (Radio Detection and Ranging) communication, an increased operating bandwidth with finest size under X-band frequency range is required [15].

In common, there are various conventional shapes available for patch antenna such as circular, square, dipole, rectangular, disc sector, triangular, etc. But there are various pros and cons in each of the shapes available. Here, a design is used which makes it affordable to resonate under three frequency bands without any additional slots included in the patch. The shape used is named to be Canadian leaf shaped, since it resembles the national symbol of Canada.

DGS is another important parameter used in this depicted model. It is generally an intentional defect added on the ground plane mainly to enhance the desired properties of an antenna [10], [11], [13]. There are various shapes available such as partial ring, dumb-bell, etc. But in this model, a fractal geometry is used which is a combination of hexagon and rectangle to change the distinctiveness of the antenna [8].

II. Design Model

A combination of iterated irregular shaped pentagon is used for the depicted antenna model; it was not made based on any of the conventional shapes such as triangle, rectangular, square, etc. The overall dimension of the antenna is of $25 \times 25 \times 1.6$ mm^3. The design is considered with several iterations as shown in Fig. 1. The first iteration was started from an irregular pentagon shaped structure and is given as Fig. 1 (a). The pentagon is tilted to an angle of 95^o on either side and combined with first iteration to form a fractal shape as the second iteration given by Fig. 1 (b). Similarly, the same is done in a second iteration to make the third iteration as shown in Fig. 1 (c). The Fourth iteration represented in Fig. 1 (d) is done by combining the above said model separated by an angle of 190^o. Fig. 1 (e) is the final design considered in the depicted design model to operate under three frequency bands.

Here, line feeding technique is used to excite the antenna and is a type of direct contact feeding method. This feeding involves the edge of the radiating patch connected or attached to a conducting strip [12]. This gives an advantage of

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providing feed and the patch on the same plane. The breadth or width of the conducting strip acting as the feed has a dimension quite smaller than that of the patch.

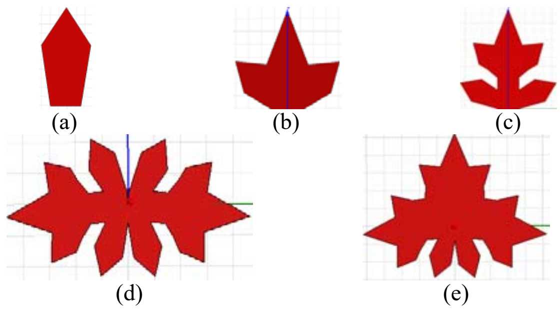

Fig. 1 Iterations of the proposed model

The overall design structure of the depicted antenna is shown in Figs. 2 and 3 in terms of top and bottom view respectively. It consists of a Canadian leaf shaped patch with line feeding technique used for the antenna and it lies above the substrate having a height of 1.6 mm with a loss tangent value of 0.02 and has a relative permittivity of 4.4. The ground structure includes a dimension of 25 × 25 mm with DGS included in it and it is given in Fig 3.

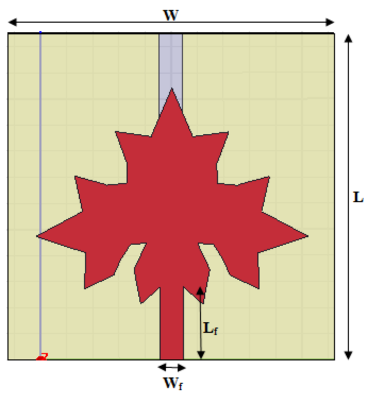

Fig. 2 Proposed Design Model – view at front

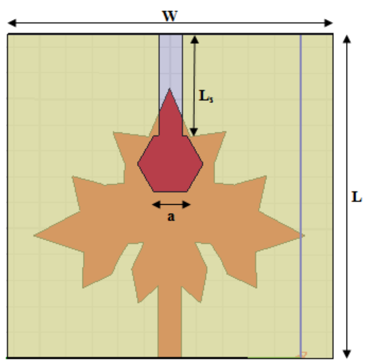

Fig. 3 Proposed Design Model – view from bottom

The DGS included at the ground plane not only helps in improving the antenna parameters, but also effectively changes the effective inductance and capacitance of the patch to provide additional resonant frequency. Table I gives the values of the variables for the depicted antenna shown under Figs. 2 and 3.

TABLE I
PARAMETERS OF PROPOSED PATCH ANTENNA

Symbols	Description of Variables	Values
L_f	Feed length	5.6 mm
W_f	Feed width	1.8 mm
ε_r	Relative permittivity of the substrate	4.4
h	Dielectric Substrate height or thickness	1.6 mm
L	Substrate Length	25 mm
W	Substrate Width	25 mm
L_s	Slot Length at ground	8 mm
a	Side length of hexagonal slot at ground	2.52 mm

The overall design configuration of the depicted model is discussed in the following section.

III. Design Configuration

Under this section, the configuration of the proposed model is explained and is given under Fig. 4. The antenna 1 in Fig. 4 (a) represents the fourth iteration shown in Fig 1 (d) with full ground structure provided to it without any defect in ground plane.

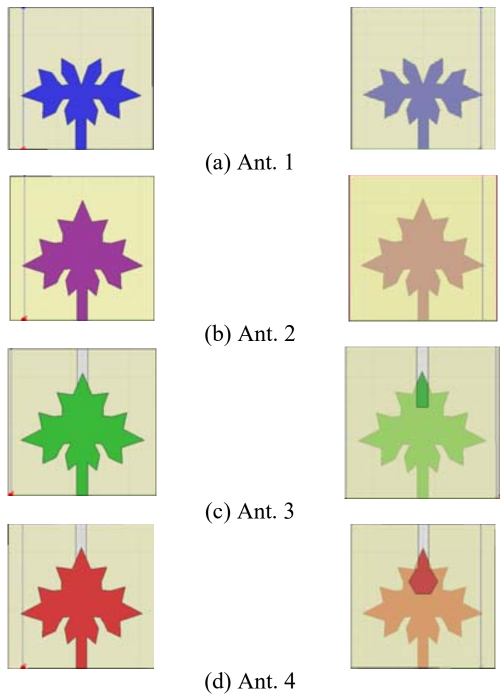

Fig. 4 Design configuration of the depicted model – Front and Back view

Antenna 2 in Fig. 4 (b) represents the fifth iteration shown in Fig. 1 (e) without any change in ground structure. The next configuration consists of the same patch with the inclusion of defect at the ground plane and is signified in Fig. 4 (c). Here, a simple rectangular defect is included as a defected structure in the conducting ground plane. The next configuration is the final depicted model with additional hexagonal shaped defect made on the ground structure, and is shown as antenna 4 in Fig. 4 (d).

The return loss plot comparison of the configurations is represented under Fig. 5. From figure, it is evident that the antenna 1 resonates under single frequency band with -10 dB as reference. Subsequently, antenna 2 and antenna 3 resonate under two frequency bands. The DGS included has an effect of gain and directivity improvement along with increased return loss value. With the inclusion of additional hexagonal shaped defect on the ground, the effectual capacitance and inductance of the antenna changes, in turn the fundamental mode changes, making the antenna to resonate under three frequency bands.

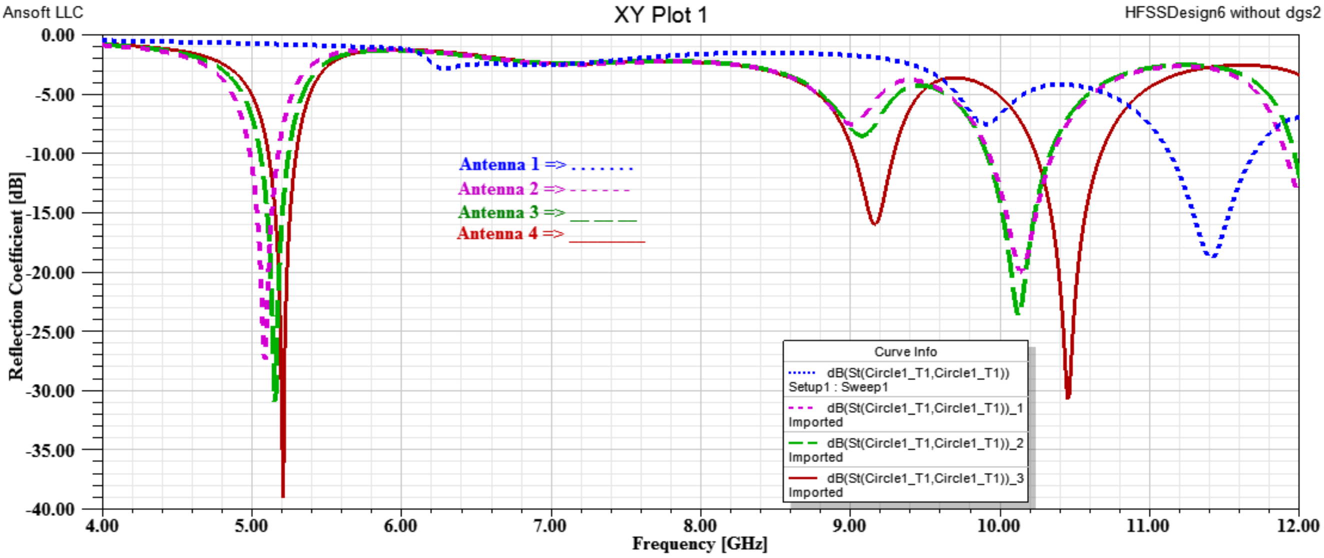

Fig. 5 Return loss comparison

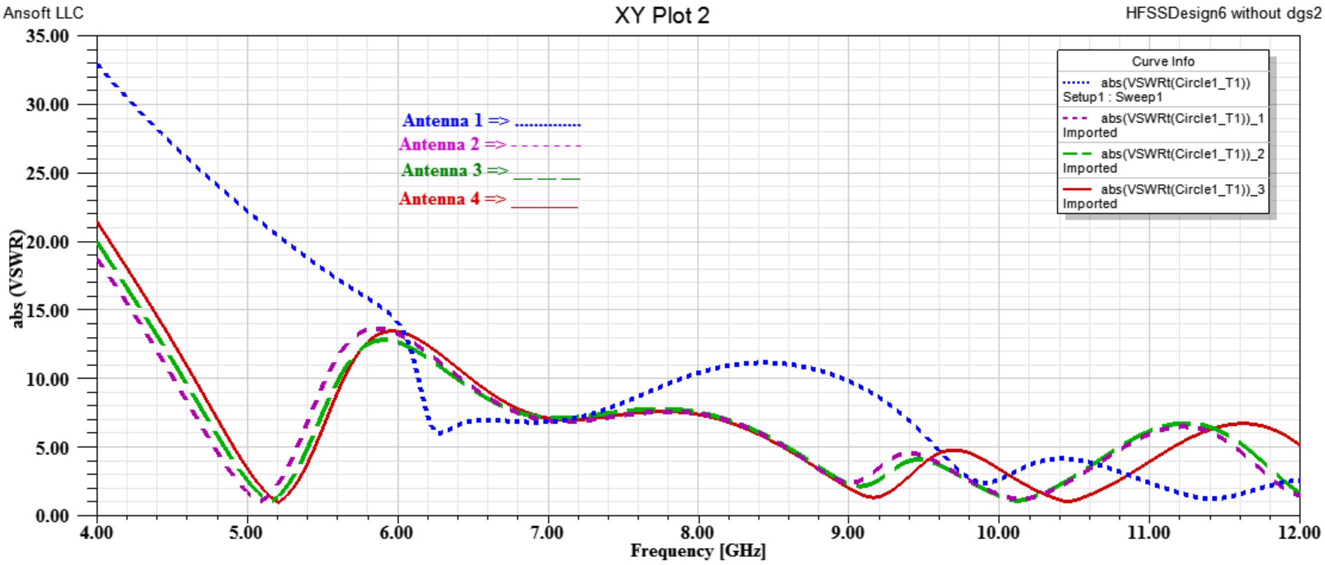

Fig. 6 VSWR comparison

The VSWR comparison in Fig. 6 depicts that for the entire antenna configuration, the VSWR values ranges from 1 to 2.

IV. Results and Discussion

Ansoft HFSS V.12 software is used to design the depicted model and the results simulated using the same is briefly described under this section. The obtained results such as reflection coefficient vs. frequency, surface current distribution, gain, VSWR and directivity for the depicted model are given as follows.

A. Return Loss

Fig. 7 represents the plot of the reflection coefficient (dB) vs. frequency (GHz) for the depicted model. It resonates under three frequency bands with a return loss value of -39.04, -16.01 and -30.74 dB for the first, second and third resonant frequency correspondingly. A bandwidth of 190, 270 and 440 MHz is obtained for the resonant frequencies of 5.21, 9.17 and

10.45 GHz respectively.

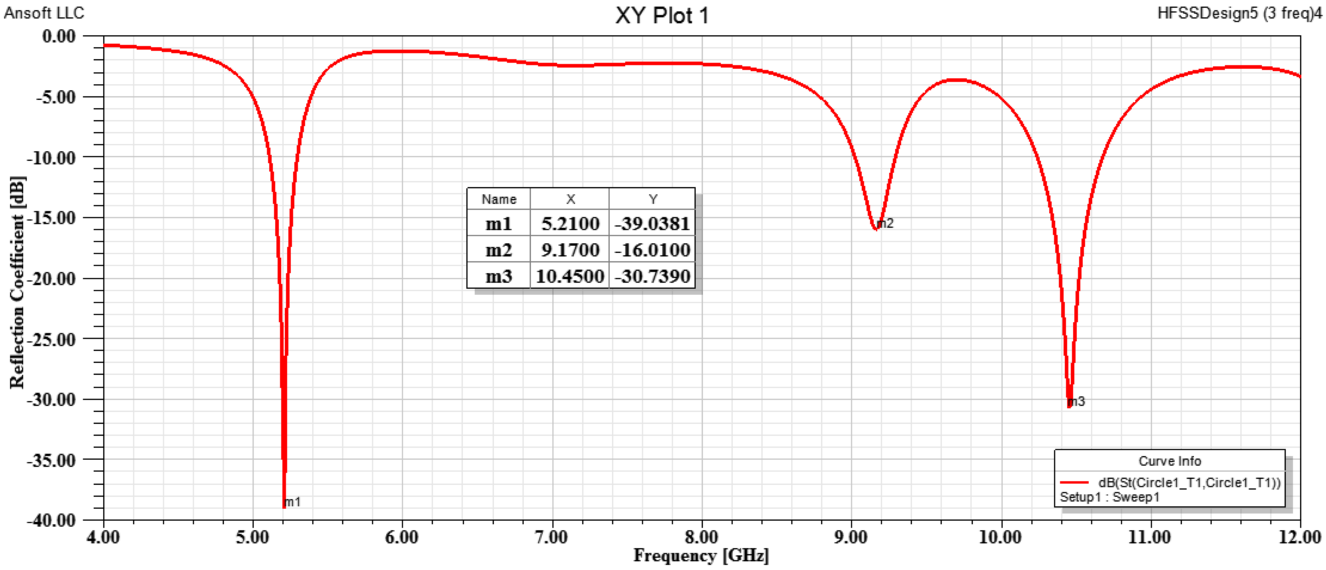

Fig. 7 S-parameter for the Proposed Model

B. Surface Current Distribution

The entire characteristics of the antenna for a particular resonant frequency can be easily predicted by the surface current distribution in a clearer manner. Figs. 8-10 represent the current distribution (A/m) for the entire resonant frequencies. From figures, it is evident that for the first resonant frequency, the antenna radiates along the top edges of the patch. And for the second resonant frequency, it radiates along the perimeter or edges of the patch as given under Fig. 9. Finally, for the third resonant frequency, it resonates along the bottom surface of the patch.

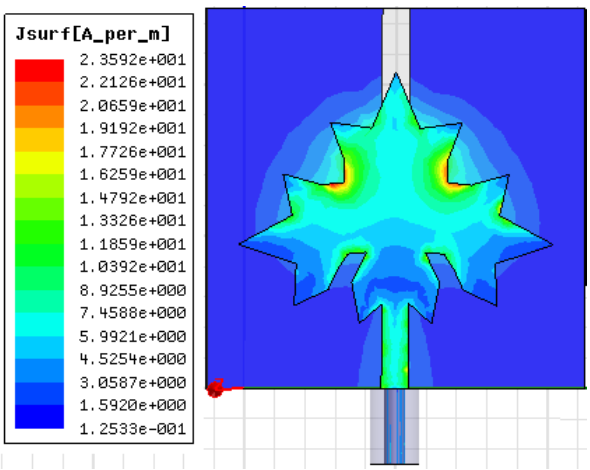

Fig. 8 Current Distribution at 5.21 GHz

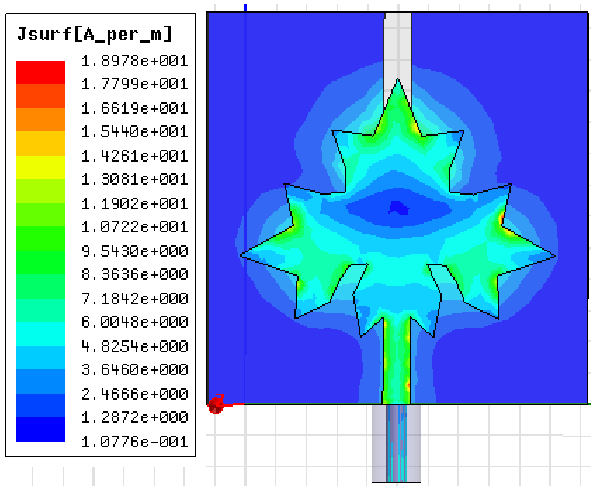

Fig. 9 Current Distribution at 9.17 GHz

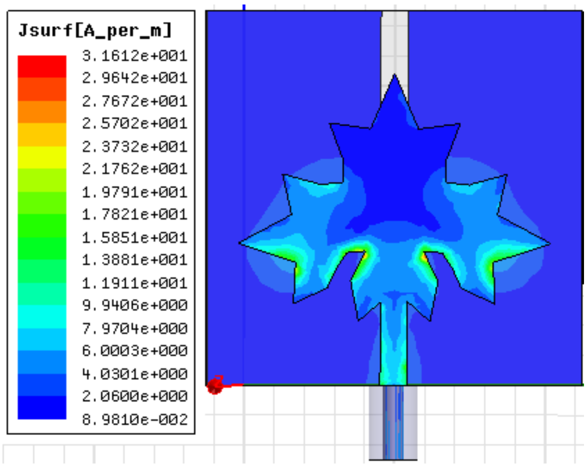

Fig. 10 Current Distribution at 10.45 GHz

C. Gain

An overall gain value of 1 dBi to 5 dBi is obtained for all of the resonant frequencies. The 3D polar plot of gain for each of the resonant frequency is shown in Fig. 11 for the first, Figs. 12 and 13 for the second and third correspondingly. A gain value of 1.38, 4.5 and 1.16 dBi is obtained for the operating frequency of 5.21, 9.17 and 10.45 GHz respectively.

D. VSWR

VSWR is a function of Reflection Coefficient and has no units. It represents the power returned back by the antenna due to impedance mismatch by itself. A suitable value of VSWR must be positioned from 1 to 2. Fig. 14 depicts the VSWR value of 1.02, 1.38 and 1.06 for the first, second and third resonant frequencies.

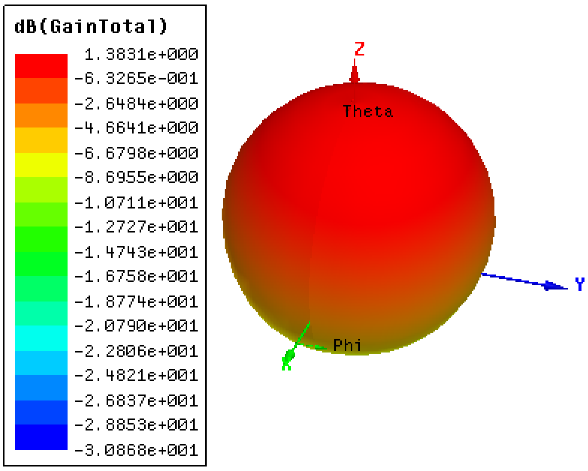

Fig. 11 Gain at 5.21 GHz

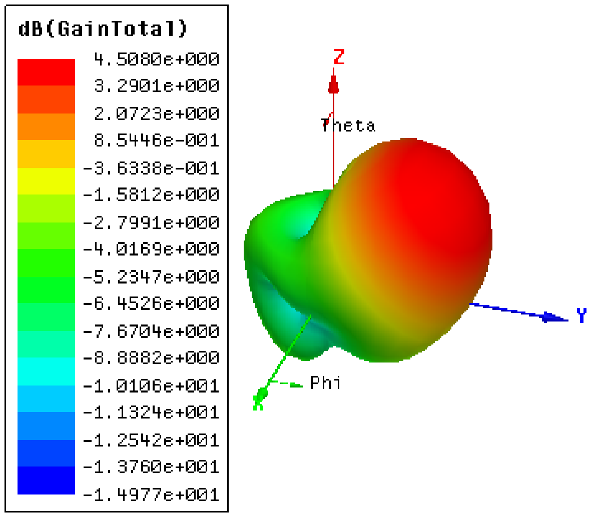

Fig. 12 Gain at 9.17 GHz

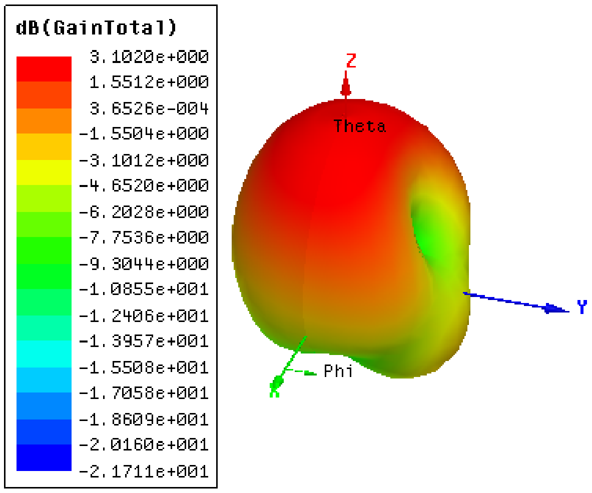

Fig. 13 Gain at 10.45 GHz

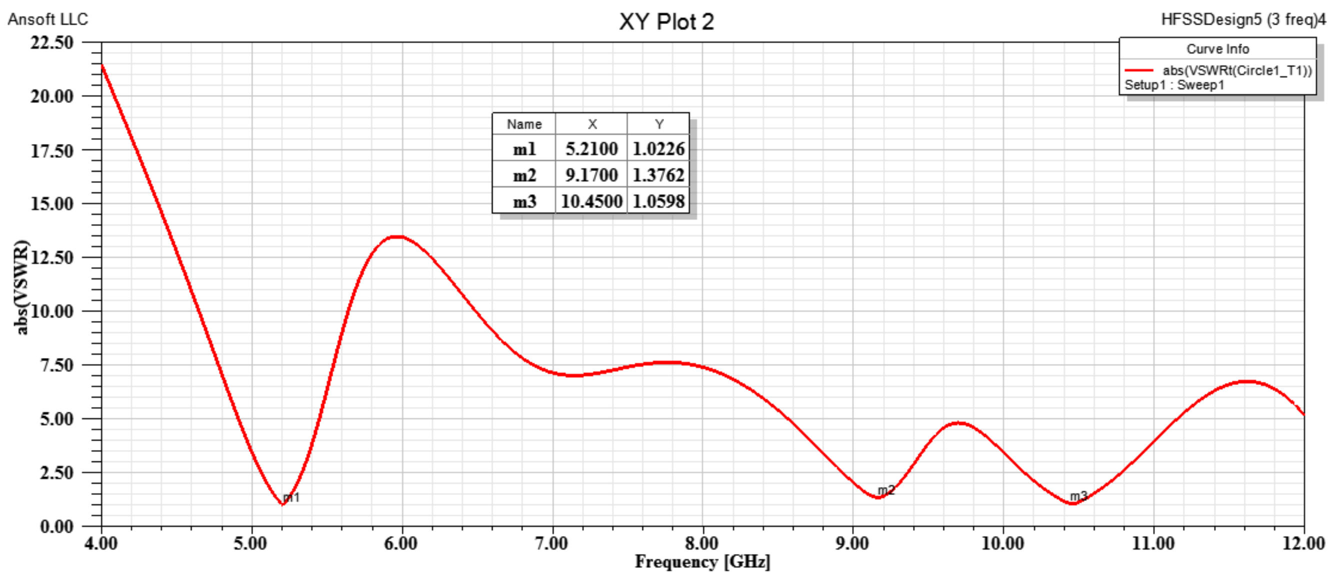

Fig. 14 VSWR plot for the proposed model

E. Directivity

The directivity is one of the radiation characteristics of the antenna that defines the directional pattern or property of the antenna, for a particular operating frequency. The range of directivity obtained for the depicted model is between 3 dB and 7 dB and is given in Figs. 15-17.

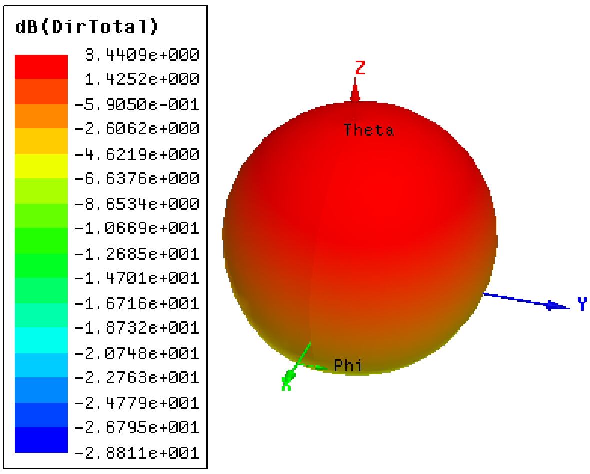

Fig. 15 Directivity at 5.21 GHz

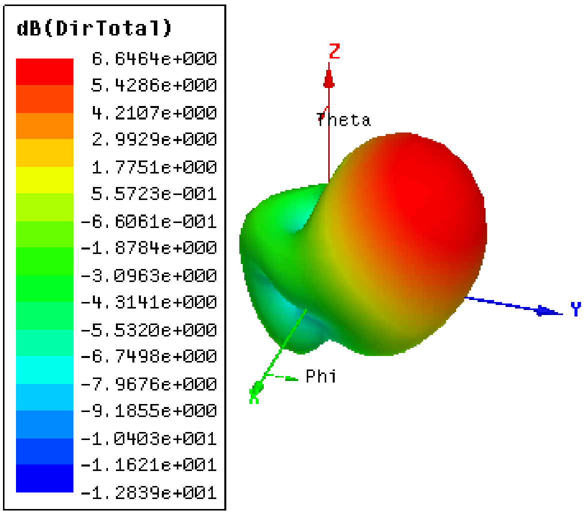

Fig. 16 Directivity at 9.17 GHz

Table II represents the overall result comparison of the Canadian leaf shaped structure.

TABLE II
RESULT S OF THE DEPICTED ANTENNA

Parameters	AT 5.21 GHZ	AT 9.17 GHZ	AT 10.45 GHZ
Return Loss (dB)	-39.04	-16.01	-30.74
Bandwidth (MHz)	190	270	440
Gain (dB)	1.38	4.51	3.10
Directivity (dB)	3.44	6.65	4.93
VSWR	1.02	1.38	1.06

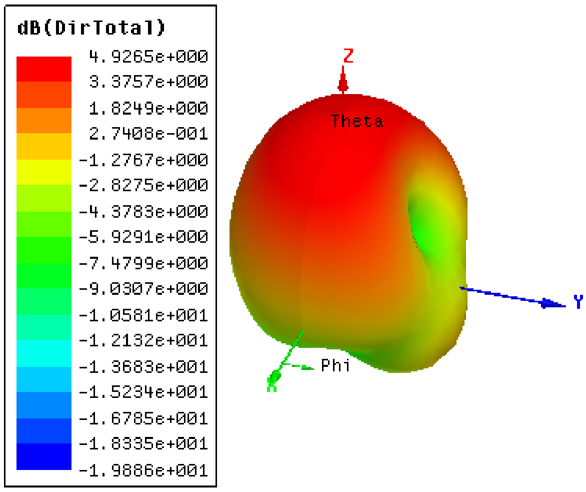

Fig. 17 Directivity at 10.45 GHz

V. CONCLUSION

The depicted Canadian leaf shaped Microstrip Patch Antenna (MPA) resonates under three frequency bands with DGS included in it. The resonating frequencies are under C and X-band frequency range. The applications are of Mobile Services (WLAN), Police radar and Terrestrial Communication & Networking for each of the operating frequency. The radiation parameters such as gain and directivity obtained are well suited for the above said application. Also, the impedance matching parameters such as Return loss and VSWR are in good agreement for all of the operating frequency with acceptable bandwidth.

REFERENCES

[1] Kumar G and Ray K P, "Tunable & Dual Band Circular Microstrip Antenna with Stubs," *IEEE Trans. on Ant. & Propg*, 48, 1, pp. 1036-1039, Jan 2000.

[2] Lee K F, Chair R, Mak C L, Kishk A A and Luk K M, "Miniature Wide-band Half V-Slot & Half E-Patch Antennas," *IEEE Trans. on Ant. & Prop.*, 52, 8, pp. 2645-2652, Aug 2005.

[3] Swain N, Chattoraj N, and Roy J S, "Short Circuited Microstrip Antennas for Multi-Band Wireless Communication," *Microw. & Opt. Tech. Lett.*, 48, 12, pp.2372-2375, December 2006.

[4] Massey P J and Boyle K R, "Nine-Band Antenna System for mobile Phones," *Electr. Lett.*, 42, 5, pp.265- 266, 2006.

[5] Ray K P and Deshmukh A A, "Half V-Slot Loaded MultiBand Rectangular Microstrip Antennas," *Int. J. of Microw. and Opt. Tech., 2*, 2, pp. 216-221, 2007.

[6] Balanis C A, "Ant. Theory: Analysis & Design", 2nd edi. New Delhi, India, *Wiley*, 2007

[7] Shanmuganantham T, Sheik Mohammed S and Ramasamy K, "A 2.45GHz Sierpinski Carpet Edge-fed Microstrip Patch Fractal Antenna for WPT Rectenna", *7th Int. Multi-Conference on Systems, Signals & Devices*, 2010.

[8] Waterhouse R, Itoh T and Chi P L, "Antenna miniaturization using slow wave enhancement factor from loaded transmission line models", *IEEE Trans. Antennas Propag.*, 59, (1), pp. 48–57, 2011.

[9] Amit A. Deshmukh and K. P. Ray, "Formulation of Resonance Frequencies for Dual Band Slotted Rectangular Microstrip Antennas", *IEEE Ants. and Propg. Magazine*, Vol. 54 (4), Aug 2012.

[10] Guha D and Kumar C, , "Linearly polarized elliptical microstrip antenna with improved polarization purity & bandwidth characteristics", *Microw. Opt. Tech.. Lett.*, 54, (10), pp.2309–2314, 2012.

[11] Ishak S H and Ismail K: "Sierpinski gasket fractal antenna with DGS", *Proceedings of Int. Conf. on ICT Convergence*, pp. 441–446, 2012.

[12] Jaget Singh and Gurdeep Singh, "Comparative Analysis of Microstrip

Patch Antenna (MPA) with Different Feeding Techniques", *Int. Conf. on Recent Advances & Future Trends in Info. Tech. (IRAFIT), Proc. published in Int. J. of Computer Apps (IJCA)*, 2012.

[13] Guha D, Biswas S and Kumar C, "Control of higher harmonics & their radiation in microstrip antennas using compact DGS (defected ground structures)", *IEEE Trans. Ant. & Propg.,* 61, (6), pp. 3349–3354, 2013.

[14] Priyali Verma, Kirti Sharma and Anand Sharma, "I-Slot Loaded Microstrip Antenna for C and X-Band Applications", *Int. Conference for Convergence of Tech.*, 2014.

[15] Satbir Singh, Naveen Kumar and Rupleen Kaur, "A Review of Various Fractal Geometries for Wireless Appls", *Int. J. of Electrical & Elect. Engg*, pp 34-36, 2015.

[16] Abhishek Thaukar, Amanpreet Kaur, Rajesh Kumar, Naveen Kumar and Hardeep Saini, "A Parametric Analysis of Ground Slotted Patch Antenna for X-Band Appls", *3rd Int. Conf. on Sig. Processing & Intg. Net.*, 2016.