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MULTIBAND MSP SPIRAL SLOT ANTENNA WITH DEFECTED GROUND STRUCTURE

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ABSTRACT

Defected ground structures are one of the key important structures to attain multiband characteristics in the microstrip antennas. In this paper, spiral shaped defected ground structures are proposed to improve the performance of different passive circuits, including dual, triple and multiband characteristics and to suppress harmonics in the patch antennas. The proposed defected ground structure monopole antenna is resonating at multiband with size reduction to perform LC resonant property in the operating band. By incorporating defected ground structure in the antenna model, additional resonant frequencies are attained due to the abrupt change in the current path of the antenna. The proposed antenna is prototyped on FR4 substrate and measured results are obtained from ZNB Vector Network Analyser. The simulated results are in good agreement with measured results of the fabricated antenna model.

Keywords: microstrip patch, multiband, spiral slot, defected ground structure, FR4, ZNB 20 vector network analyser (VNA).

INTRODUCTION

There is a never ending demand for compact and multiband antennas in the communication systems. The communication systems became smaller due to greater integration of electronic devices and antenna became a significant larger part of the overall volume [1-4]. In some of the cases, low profile antennas and their designs are very important for fixed wireless communication applications. The microstrip antenna is having numerous applications and advantages over other types of antennas [5-8]. There is a never ending demand for these antennas because of low profile, printed technology and integration with MMIC and RFIC devices. The performance of the antenna mostly depends upon the substrate material that is used in the design of the antenna [9-12]. Choosing a proper substrate material with relevant structure will improve the performance characteristics of these antennas. The microstrip antenna also suffers with narrow bandwidth and low efficiency. To overcome these problems, we have to choose a proper structure with some performance improvement techniques like DGS, FSS and metamaterial like things have to be incorporated in the design [13-18].

Defected ground structures and defected microstrip structures are widely used techniques to enhance the radiation characteristics and bandwidth of the advanced antennas. The defected microstrip structure can be easily integrated with other microwave circuits and effectively reduce the circuit size [19-20]. The DMS exhibits some properties like slow wave, rejecting microwaves at certain frequencies and change in electrical length in certain circuits which are similar to DGS. Generally, DMS is made by etching slots in the microstrip line, so the enclosure problems need not be considered because there is no leakage through the ground plane [21-22]. DMS is generally used to enhance the behaviour of passive circuits and perform LC resonance property in certain frequency and suppress the unwanted signals. This DMS will increase the electrical length of the antenna and disturb the current distribution thereby reducing the resonant frequency operating band from higher frequency to lower frequency [23].

Antenna, geometry and design

In this paper, we experiment three different antenna models with DMS and DGS techniques. Figure-1 shows the proposed antenna models with spiral slots in the structure. Figure-1(a) shows the microstrip antenna with spiral slots on the radiating element. Figure-1(b) shows spiral slots on radiating element as well as slots on the ground plane exactly on the opposite faces. Figure-1(c) shows the spiral slot antenna with defected ground structure on the other side at exactly the centre of the ground plane.

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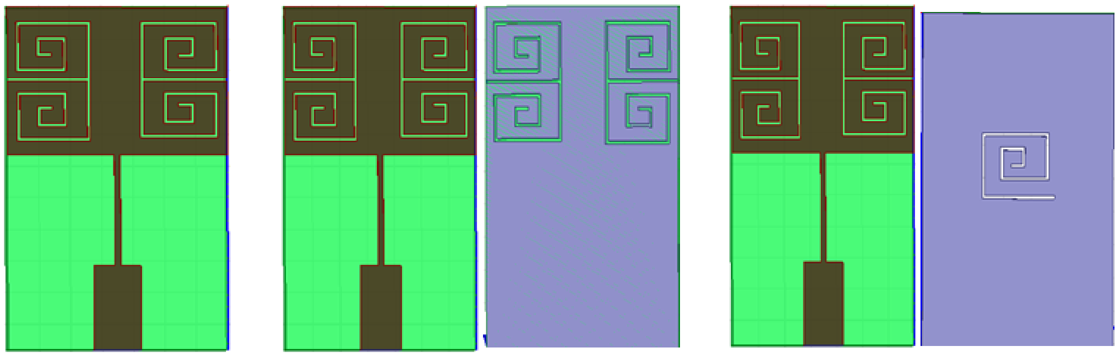

Figure-1(a). Spiral slot antenna, **(b).** Spiral slot with DGS, **(c).** Spiral slot with centre DGS.

From Figure-1(b), we observed that slots are occupying at the same position in two planes (top, bottom) and from Figure-1(c), we can observe spiral slots beneath the feed line on the opposite side of the radiating element.

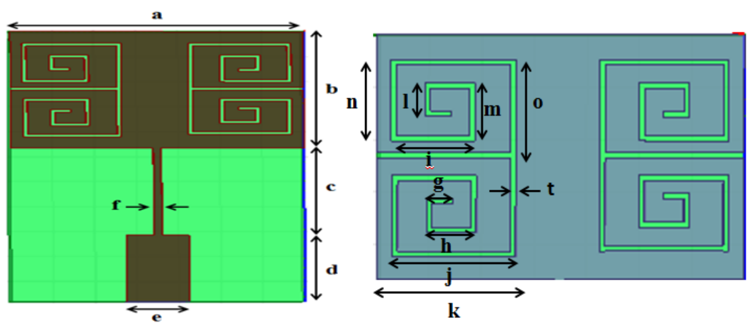

Figure-2. Dimensional representation of spiral slot antenna with DGS.

The overall dimensions of the antenna can be observed from Figure-2 and dimensional characteristics from Table-1. The overall dimension of the antenna is around 21.6X14X1.6mm on FR4 substrate with dielectric constant 4.4.

Table-1. Dimensional characteristics of the spiral slot antenna with DGS.

Description	a	b	c	d	e	f
Length(mm)	14	9.3	7	5.3	3	0.4

Description	g	h	i	j	k	l	m	n	o	t
Length(mm)	1	1.7	3.2	4.7	5.3	1.1	2	2.9	3.8	0.2

RESULTS AND DISCUSSIONS

Three antenna models are designed and simulated using commercial HFSS tool and presented in this section. Antenna model 1 is not having DGS but model 2 and model 3 are having DGS on the top and centre of the ground plane. The reflection coefficient of the designed antenna models are presented in Figure (3). Spiral slot antenna model 1 without DGS is resonating at quad band with impedance bandwidth of 14% at fundamental resonating and 26% at second resonating frequency. The antenna model 1 is showing better bandwidth characteristics at higher resonant frequencies compared to lower resonant frequencies. At the third resonating frequency, the antenna is showing a bandwidth of 1.5GHz with an impedance bandwidth of 13.6%. The antenna model 2 is resonating at triple band with low loss at fundamental resonating frequency. Antenna model 2 is showing an impedance bandwidth of 14.2% at the highest resonant frequency. The proposed antenna model 3 is resonating at pentaband with highest impedance bandwidth at 12.5GHz and 14.5GHz.

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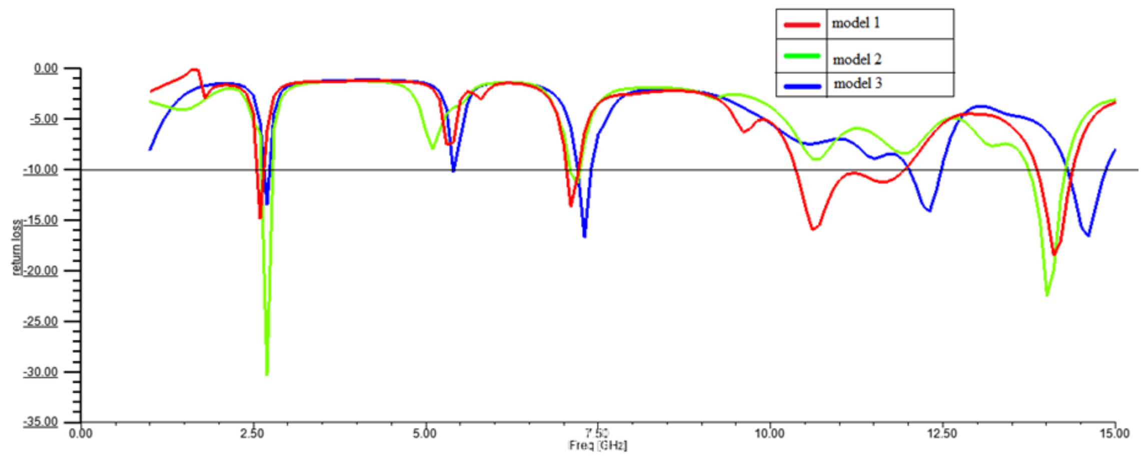

Figure-3. Reflection coefficient of antenna models.

Figure-4 shows the VSWR characteristics of the designed models. It has been observed that the antenna models are showing a 2:1 VSWR at the corresponding resonant frequencies. Figure-5 shows the impedance characteristics of the designed models at their corresponding resonant frequencies. At the resonating frequencies, the antenna is showing impedance nearer to 50Ω.

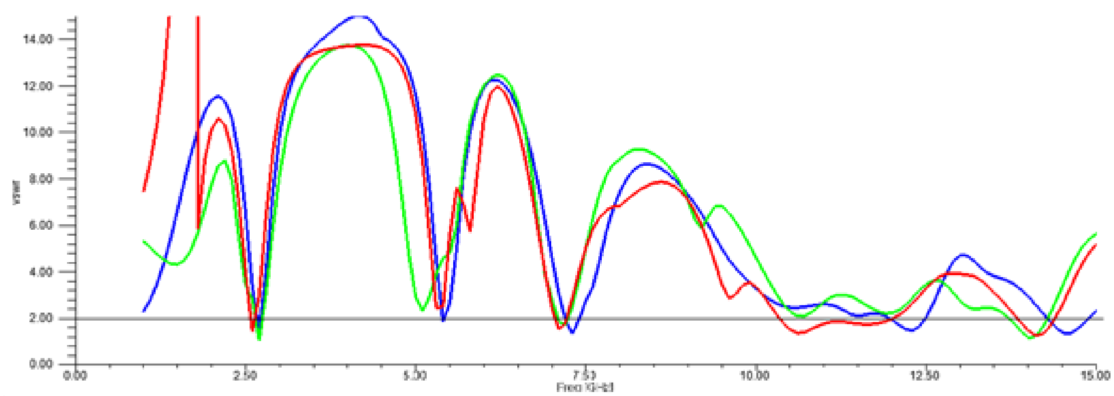

Figure-4. VSWR vs frequency of antenna models.

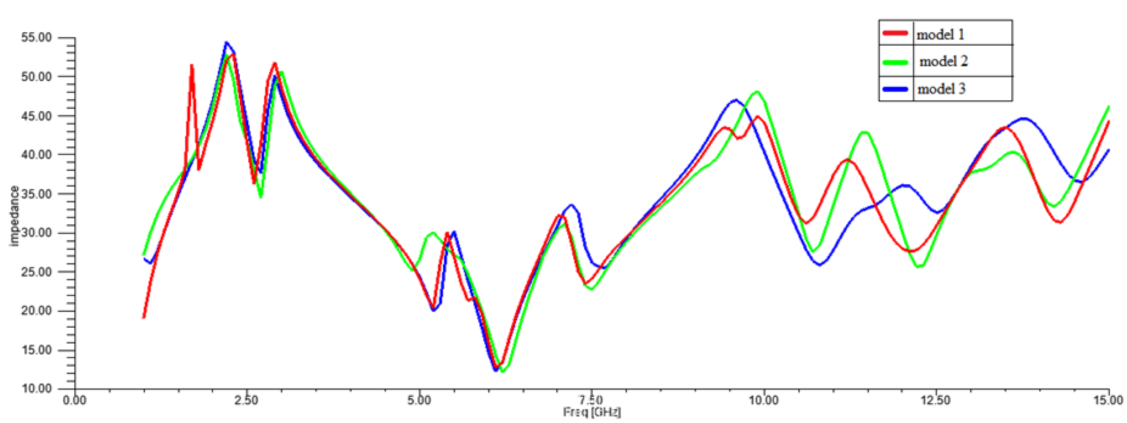

Figure-5. Impedance vs frequency of antenna models.

Figure-6 shows the antenna model 1 radiation pattern at different resonant frequency in E and H plane. Figure-7 shows the three dimensional radiation characteristics of antenna model 1 at corresponding working frequencies. At 5.8GHz, antenna model 1 is showing directive radiation pattern whereas at 10.6GHz, it

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is showing disturbed radiation in YZ plane. At 14.1GHz, antenna is showing directive radiation in XZ plane with back lobes in XY plane.

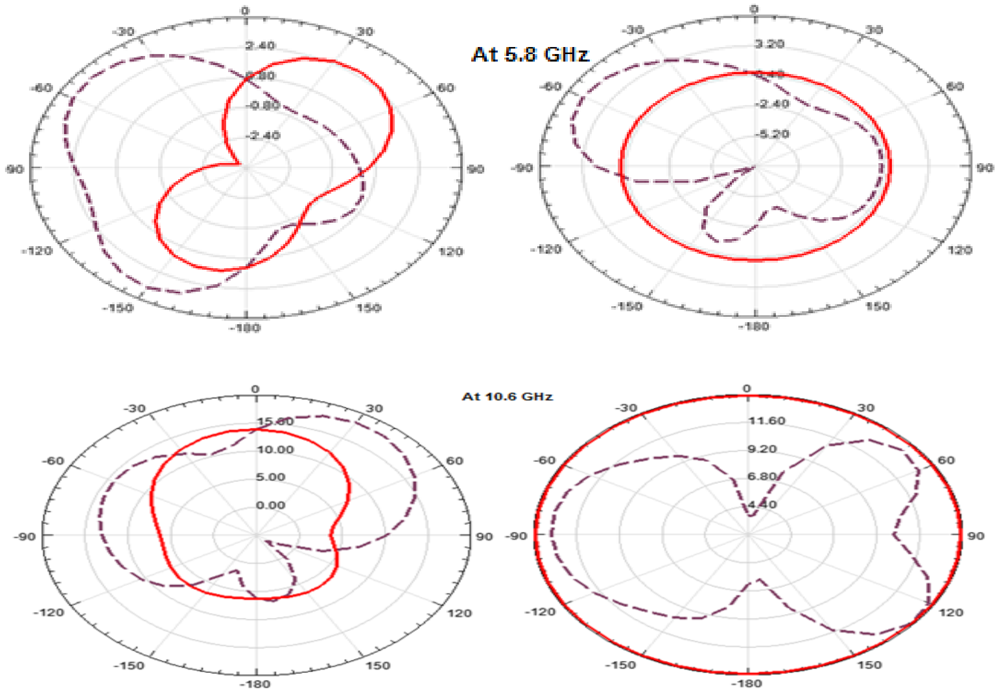

Figure-6. Radiation pattern of antenna model 1 in E & H-plane.

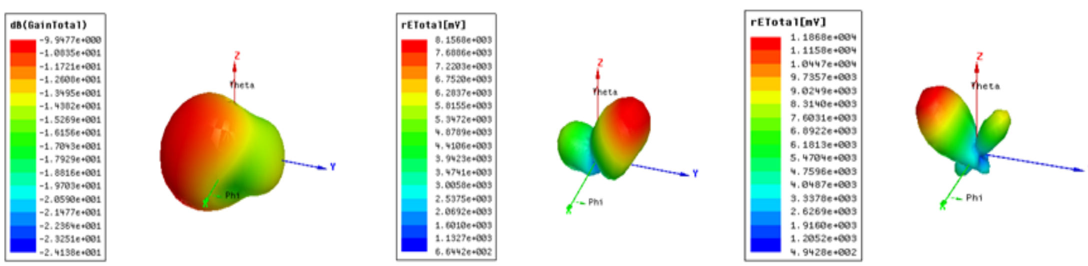

Figure-7. Radiation of antenna 1 in three dimensional view.

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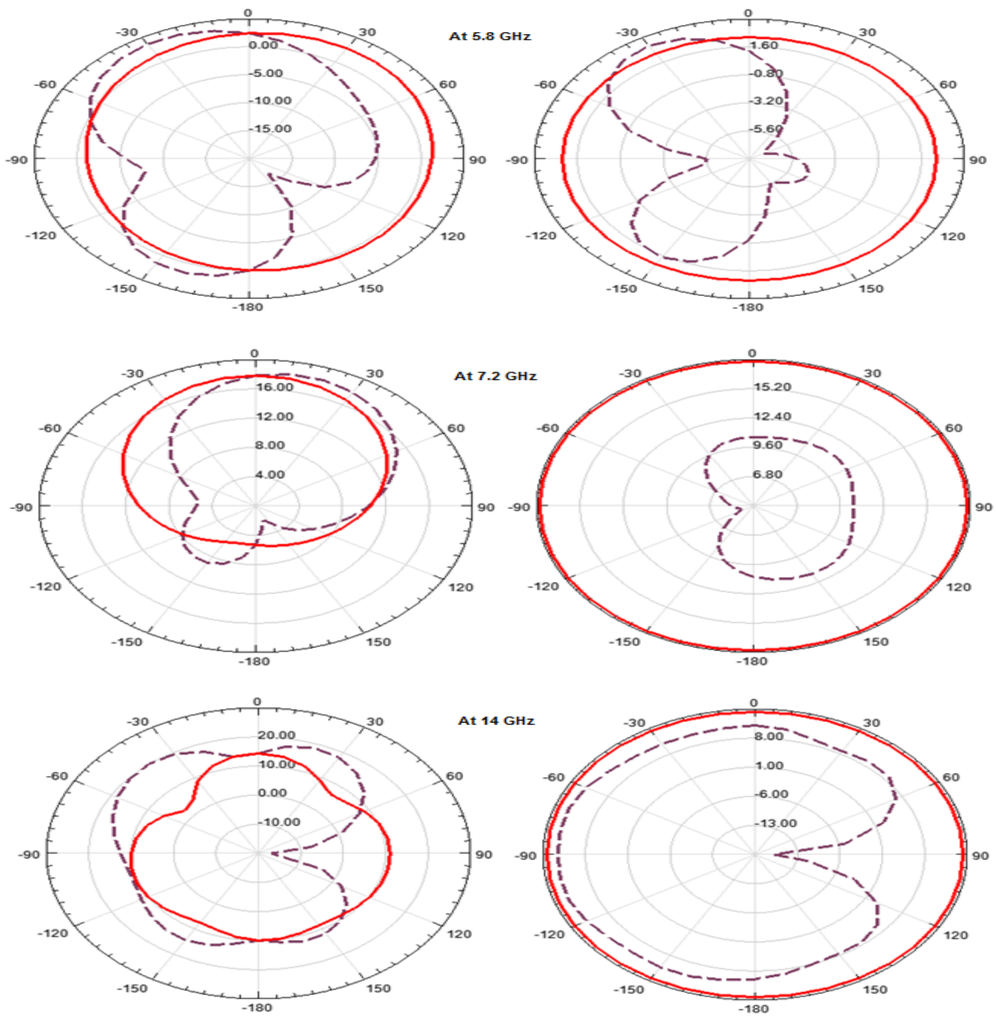

Figure-8. Radiation pattern of antenna model 2 in E & H-plane.

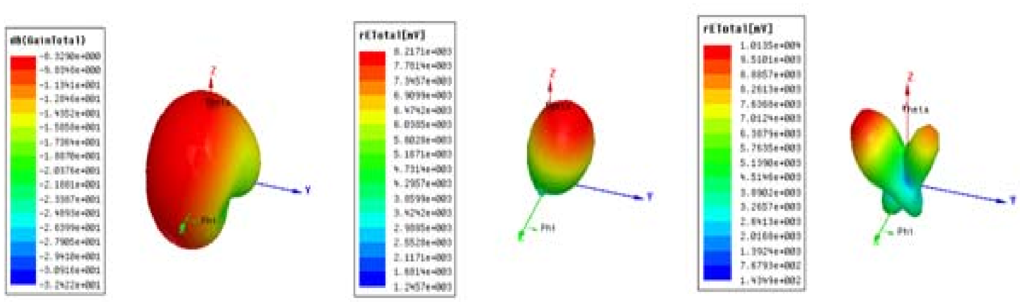

Figure-9. Radiation of antenna 2 in three dimensional view.

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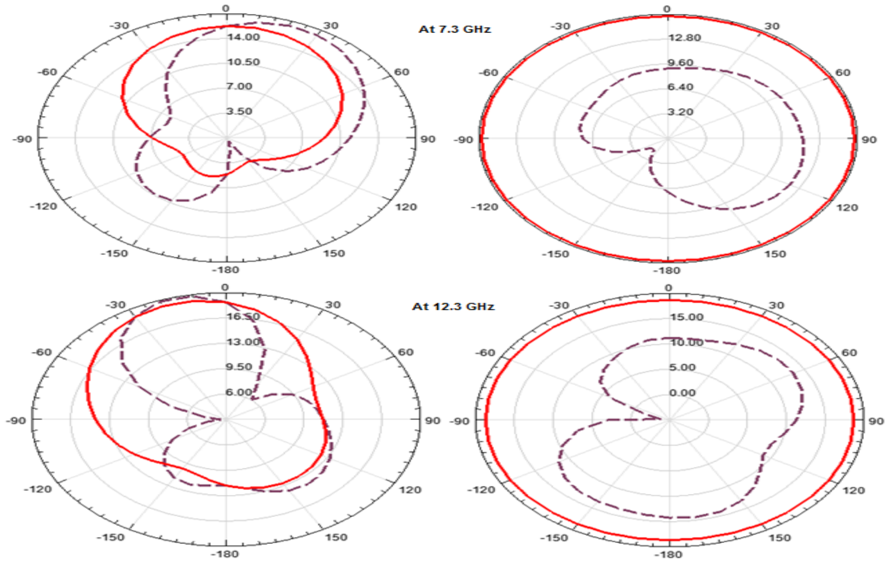

Figure-10. Radiation pattern of antenna model 2 in E and H-plane.

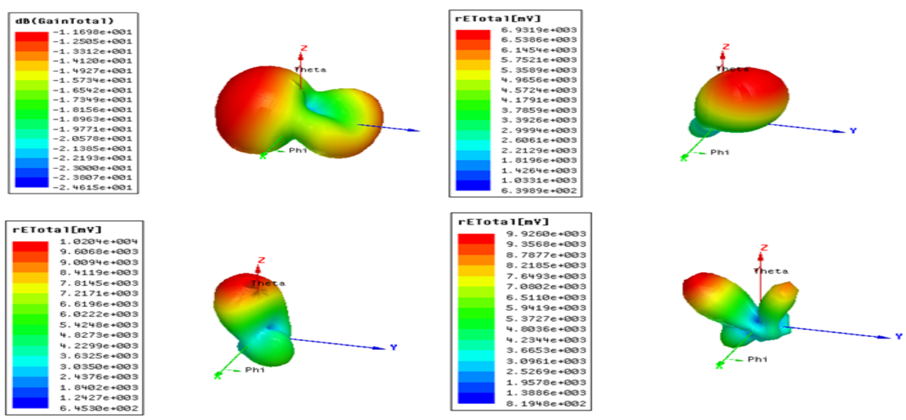

Figure-11. Radiation of antenna 3 in three dimensional view.

Figure-8 shows the radiation characteristics of antenna model 2 at corresponding triple band resonant frequency. Figure-9 shows the three dimensional radiation characteristics of antenna model 2 at corresponding resonant frequencies. Figure-10 shows the radiation characteristics of antenna model 3 in polar coordinates at resonant frequencies. Figure-11 shows the same radiation pattern of antenna 3 in three dimensional view. At fundamental resonant frequency, the antenna is showing a dumbbell like radiation pattern in Y direction and directive radiation pattern at other frequencies. The current distributions of the designed antenna model 1 are presented in Figure-12.

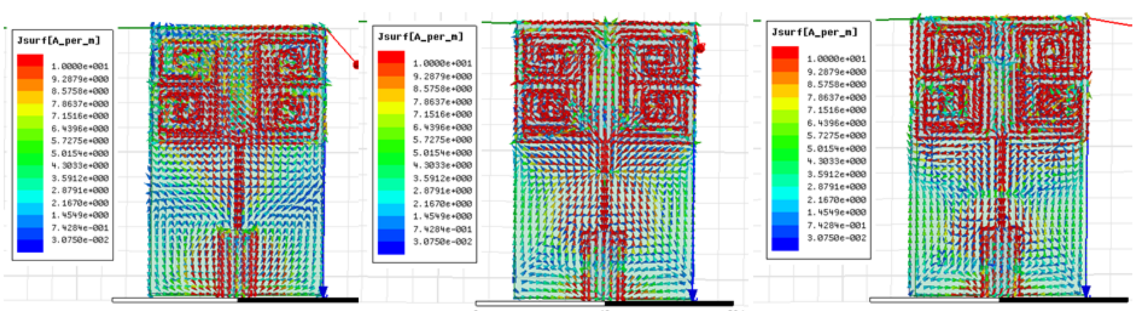

Figure-12. Current distribution of the antenna model 1 at resonant frequencies.

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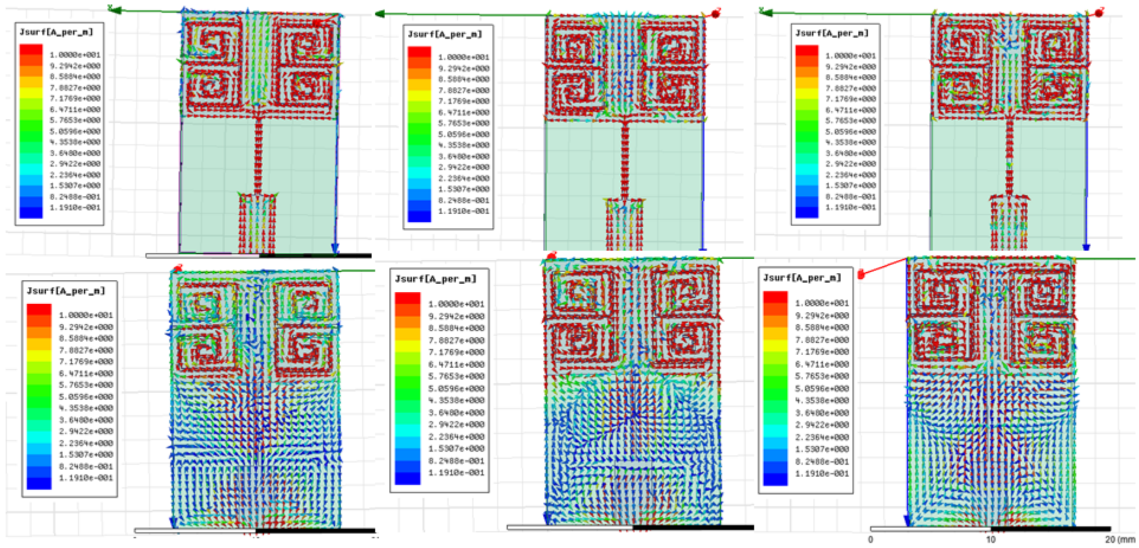

Figure-13. Current distribution of the antenna model 2 at resonant frequencies.

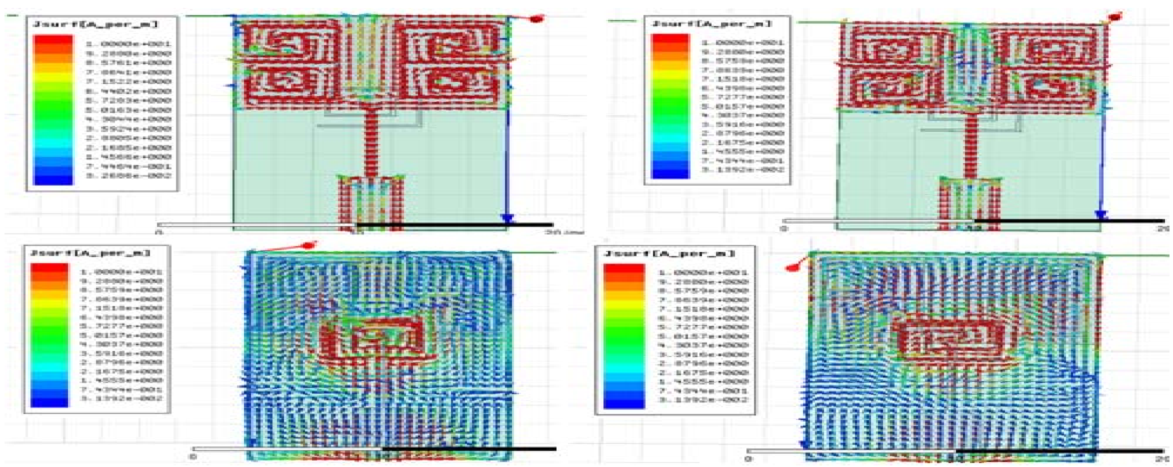

Figure-14. Current distribution of the antenna model 3 at resonant frequencies.

Compared to lower resonant frequency, antenna model 1 is projecting more radiation at higher resonant frequency and most of the current distribution is focussed around slot on the patch and the electrical length of the antenna is increased with slot radiation current path. Figure-13 shows the current distribution of antenna model 2 at their corresponding resonant frequency with top and bottom view. From top view current distribution, we observed that the maximum current intensity is obtained at the second resonating frequency at 7.2GHz whereas for bottom view, it is from the highest resonating frequency 14GHz. Figure-14 shows the current distribution characteristics of antenna model 3 at all resonant frequencies. At the highest resonant frequency, current distribution over the patch is in opposite direction with same magnitude. The resultant of this type of distribution at higher resonating frequency will be cancelled.

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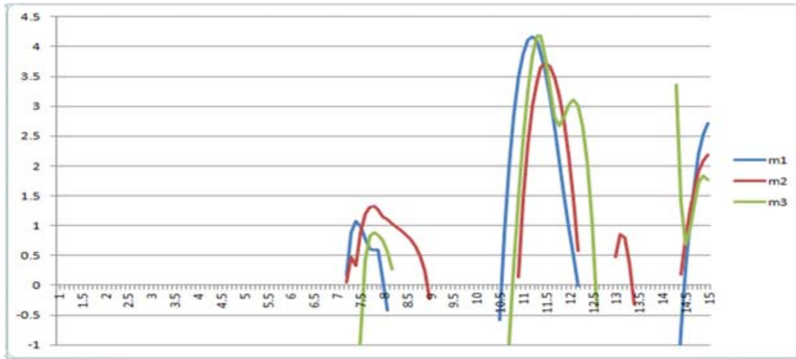

Figure-15. Frequency vs gain of antenna models.

Figure-15 shows the gain characteristics of the antenna models at corresponding operating frequencies. A maximum peak realised gain of 4.2dB is attained for the case of antenna model 3 at the centre resonant frequency.

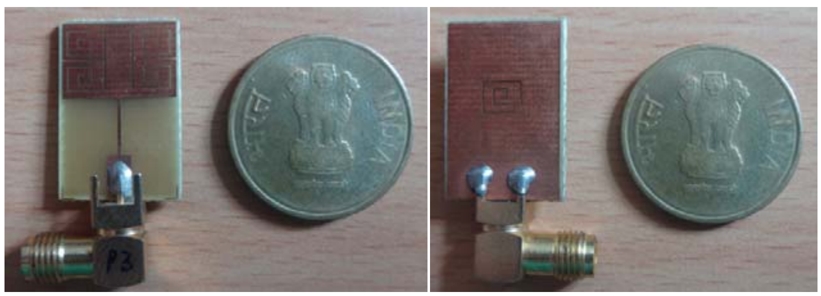

Figure-16. Fabricated antenna, **(a)** Front view, **(b)** Bottom view.

The proposed spiral slot antenna with defected ground structure is fabricated on FR4 substrate and the prototyped antenna is presented in Figure-16. The front view of the prototyped antenna model consisting of spiral slots on patch element and back view consisting of spiral defected ground structure. The measured S11 of the designed model is presented in Figure-17. Measured results are in good agreement with simulation results of HFSS. The multiband characteristics from measured results can be observed from this Figure, which is similar to simulated resonant frequencies.

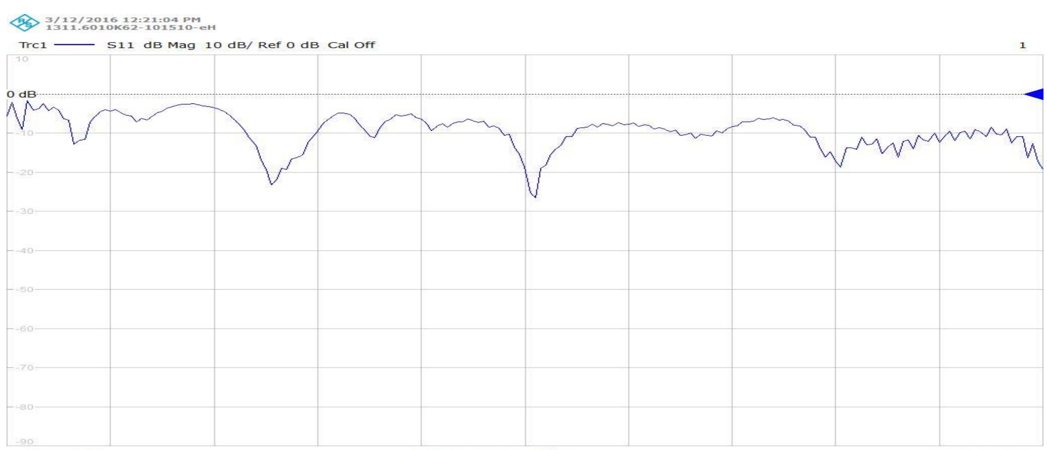

Figure-17. Measured S11 on ZNB 20 VNA.

CONCLUSIONS

A spiral slot multiband antenna is designed and analyzed with defected ground structure in this work. The defected ground structure is responsible for additional resonant frequencies in the multiband. The slot structure on the patch surface creating long path for the current and increasing the electrical length of the antenna, which intern shifting the resonant frequency towards lower band.

The proposed antenna is fabricated on FR4 substrate and the measurements of S11 are taken on ZNB 20 vector network analyzer. The simulation results are having good correlation with measured results on the VNA. Proposed antenna is showing excellent radiation characteristics with peak realized gain of 4.2 dB at resonating frequency.

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REFERENCES

[1] Elftouh, H., N. A. Touhami, M. Aghoutane, S. El Amrani, A. Tazon, and M. Boussouis. 2014. Miniaturized microstrip patch antenna with defected ground structure. Progress in Electromagnetics Research C. 55: 25-33.

[2] B.T.P. Madhav, D. Ujwala, Habibulla Khan, Atluri Lakshmi Tejaswani, Sriram Guntupalli and Atluri Bala. 2013. Substrate Permittivity Effects on the Performance of Slotted Aperture Stacked Patch Antenna. International Journal of Applied Engineering Research, ISSN 0973-4562, 8(8): 909-916.

[3] Arya, A. K., A. Patnaik, and M. V. Kartikeyan. 2011. Microstrip patch antenna with skew-F shaped DGS for dual band operation. Progress in Electromagnetics Research M. 19: 147-160.

[4] B T P Madhav, Krishnam Naidu Yedla, G.S., Kumar, K.V.V., Rahul, R. 2014. Fractal aperture EBG ground structured dual band planar slot antenna. International Journal of Applied Engineering Research, ISSN 0973-4562, 9(5): 515-524.

[5] B T P Madhav, Harish Kaza, Thanneru Kartheek, Vidyullatha Lakshmi Kaza, Sreeramineni Prasanth, K S Sanjay Chandra Sikakollu, Maneesh Thammishetti, Aluvala Srinivas, K V L Bhavani. 2015. Novel Printed Monopole Trapezoidal Notch Antenna with S-Band Rejection. Journal of Theoretical and Applied Information Technology, ISSN: 1992-8645, 76(1): 42-49.

[6] A. Nouri and G. R. Dadashzadeh. 2011. A Compact UWB Band-Notched Printed Monopole Antenna with Defected Ground Structure. IEEE Antennas and wireless Propogation letters. Vol. 10.

[7] B. Sadasivarao, B. T. P. Madhav. 2014. Analysis of Hybrid Slot Antenna based on Substrate Permittivity. ARPN Journal of Engineering and Applied Sciences, ISSN 1819-6608, 9(6): 885-890.

[8] P Syam Sundar, Sarat K Kotamraju, T V Ramakrishna, B T P Madhav, T Sravya Sruthi, P Vivek, J Jaswanth Kumar, M Dileep. 2015. Novel Miniatured Wide Band Annular Slot Monopole Antenna, Far East Journal of Electronics and Communications, ISSN: 0973-7006, 14(2): 149-159. http://dx.doi.org/10.17654/FJECJun2015_149_159.

[9] M Ajay babu, B T P Madhav, D Naga Vaishnavi, P Radhakrishna, N Bharath, K Madhuri, K Bhavani Prasad, K Harish. 2015. Flared V-Shape Slotted Monopole Multiband Antenna with Metamateril Loading, International Journal of communications Antenna propagation, ISSN: 2039-5086, 5(2): 93-97.

[10] Habibulla Khan, B.T.P. Madhav, K. Mallikarjun, K. Bhaskar, N. Sri Harsha and Muralidhar Nakka. 2014. Uniplanar Wideband/Narrow Band Antenna for Wlan Applications. World Applied Sciences Journal, ISSN 1818-4952, 32(8): 1703-1709, DOI: 10.5829/idosi.wasj.2014.32.08.990.

[11] Nashaat D., H. A. Elsade, E. Abdallah, H. Elhenawy, and M. F. Iskandar. 2009. Multiband and miniaturized inset feed microstrip patch antenna using multiple spiral-shaped defect ground structure (DGS). IEEE Antennas and Propagation Society International Symposium, APSURSI'09.

[12] B.T.P. Madhav, Harish Kaza, Jagadish Kumar Vaka, K. Sravan Kumar, N. Sriharsha, J. Jaswanth Kumar, D.S. Siddharth and D. Sai Teja Reddy. 2015. Design and Analysis of Compact Coplanar Wave Guide Fed Asymmetric Monopole Antennas. Research Journal of Applied Sciences, Engineering and Technology. 10(3): 247-252.

[13] M S S S Srinivas, T V Ramakrishna, B T P Madhav, N Bhagyalakshmi, S Madhavi, K Venkateswarulu. 2015. A Novel Compact CPW Fed Slot Antenna with EBG Structure. ARPN Journal of Engineering and Applied Sciences, ISSN 1819-6608, 10(2): 835-841.

[14] T V Ramakrishna, B T P Madhav, G Manmohan, M Pavithra. Triple Band linearly polarized Square Slotted Micro strip Antenna for X-Band Applications. Far East Journal of Electronics and Communications, ISSN: 0973-7006, 15(2): 99-110.

[15] Parui S. K., S. R. Choudhury, A. Roy, L. Murmu and S. Das. 2011. Bandstop filtering characteristics of a new spiral defected microstrip structure (DMS). International Symposium on Devices MEMS, Intelligent Systems and Communication (ISDMISC).

[16] M. L. S. N. S. Lakshmi, B. T. P. Madhav. 2015. Analytical Study on Folded-Slot Koch Fractal Antenna. Indian Journal of Science and Technology, ISSN 0974-6846, 8(17): 66573-66578.

[17] Hosseini S. R., R. Sarraf Shirazi and G. Moradi. 2012. A novel defect microstrip structure (DMS) coupled line bandpass filter in C band. PIERS Proceedings, 845-848, Moscow, Russia.

[18] S S Mohan Reddy, P Mallikarjuna rao, B T P Madhav. Asymmetric Defected Ground Structured Monopole Antenna for Wideband Communication Systems, International Journal of Communications Antenna and Propagation, ISSN: 2039-5086, 5(5): 256-262.

[19] K V L Bhavani, Habibulla Khan, B T P Madhav. 2015. Multiband Slotted Aperture Antenna with Defected Ground Structure for C and X-Band Communication Applications, Journal of Theoretical and Applied Information Technology, ISSN: 1992-8645, 82(3): 454-461.

[20] Kazerooni, M., A. Cheldavi and M. Kamarei. 2009. Comparing the performance of defected microstrip structure (DMS) and defected ground structure (DGS) in microstrip miniature circuits. Iranian Conference on Electrical Engineering.

[21] B. T. P. Madhav, Habibulla Khan, Sarat K. Kotamraju. 2016. Circularly Polarized Slotted Aperture Antenna with Coplanar Waveguide Fed for Broadband Applications. Journal of Engineering Science and Technology, ISSN: 1823-4690, 11(2): 267-277.

[22] El-Shaarawy, H. B., F. Coccetti, R. Plana, M. El Said, and E. A. Hashish. 2008. Compact bandpass ring resonator filter with enhanced wide-band rejection characteristics using defected ground structures. IEEE Microwave and Wireless Components Letters. 18: 500-502.

[23] B T P Madhav, A Manikanta Prasanth, Sreeramineni Prasanth, Batchu Mohan Sai Krishna, Devani Manikantha, Usirika Sharmila NagaSai. 2015. Analysis of Defected Ground Structure Notched Monopole Antenna. ARPN Journal of Engineering and Applied Sciences, ISSN 1819-6608, 10(2): 747-752.