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Multiband Hendecagonal Ring Fractal with Defected Ground Plane Microstrip Patch antenna for UWB Applications

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Abstract: In this current trend, an antenna size and dimension should be simple and multifunction. In this paper a low profile compact microstrip feed Hendecagonal Ring Fractal (HRF) patch antenna is proposed for multiband UWB applications, The effects of fractal iterations and dimensions of the ground plane are optimized to improving the characteristics performance of the antenna. The Return loss, VSWR and radiation properties value for the proposed simulated design further bear out the wireless applications. The low cost dielectric material FR4 (ϵ=4.4) is used as substrate for this design. The proposed antenna is simulated using Ansoft HFSS v.14 and fabricated using photolithography, with the dimensions of 44X30X1.6mm^3 with operating frequency band from 3-10.4 GHz. Multiband (Five Resonance) are measured from -10dB and VSWR is less than 2. Input impedance is 50Ω and it exhibits the unidirectional pattern. Finally it is bring into being that the proposed HRF antenna design suitable for UWB Wireless applications.

Keywords: Hendecagonal Ring Fractal Antenna, Defected Ground Structure, Ultra Wideband, HFSS, Return loss, VSWR.

I. INTRODUCTION

Recent development in wireless applications necessitate antenna to design with small size and low profile to integrate with multiple portable electronic devices. Therefore a assortment of concentrations are given to design UWB antennas, because the size of the antenna significantly affects the bandwidth and gain. [1]. In FCC rules, the owed frequency for UWB is from 3.1-10.6 GHz and it mainly provides high data rates with low energy level for short-range communications [2]. Various compact and multiband techniques have been proposed for WLAN/ WiMAX application using micostrip feed monopole [3], self similar ring radiators [4], and monopole with defected ground plane [5]. To further decrease the size of the antenna element various ground plane radiation modes are excited for multiband applications [6].On the other hand, the fractal geometry is used for improving the antenna parameters, and fractals with self similarity and self affinity in their structure can offer size miniaturization with multiband characteristics [7] and proves to be a better candidate for compact multiband antenna. This geometry allows the electrons to flow through the various lengths that implies in wider frequency spectrum, multiple bands and also minimizes the antenna size by 2-4 times [8]. In this proposed design, a compact Hendecagonal ring fractal iteration concept of miniaturization for multiband operation with optimized ground plane is used for good return loss and bandwidth improvement.

II. ANTENNA DIMENSIONS AND FRACTAL GEOMETRY

Fig. 1 shows the shape and dimension of the proposed Hendecagonal Ring Fractal antenna suitable for UWB applications. The proposed antenna is fed by 50Ω asymmetric microstrip line printed on FR4 substrate ($\in r$= 4.4) of thickness 1.6 mm with area of the substrate as the dimensions of 44X30X1.6mm^3, the size of the ground plane is optimized and reduced ground plane of dimension of 10X20 mm^2 is printed on bottom of the patch. The proposed antenna design is based on concept of self replicate and self resemblance geometry [9-15], where patch is designed with hendecagonal ring fractal loop nested inside the larger hendecagonal ring structure (Initiator) connected to the 50 Ω microsrtip feed line. Width of the hexagon ring strip Ws=1 mm is constant in entire iteration process of simulation and observation. The various dimensions of the proposed HRF antenna are summarized in Table-1. The sides of regular hendecagonal at various stages are related with log periodic concepts and can be determined by following equation [16].

$$S_{n+1} = \tau \times s_n \qquad (1)$$

Where n (=number of Iteration) =1, 2, 3; in the proposed HRF antenna, Initial length of hendecagonal side (Initiator) S_1= 7.88mm. For the further iterations (s_2, s_3, s_4) of the proposed antenna, Initiator is multiplied with scaling factor (τ) which is the controlling parameter in designing the proposed antenna. Scaling factor, τ = 0.734 is parametrically optimized for the proposed design as it controls the design dimension. The progress of the proposed antenna design from initiator geometry of single ring hendecagonal loop with full ground plane shown in Fig.2. To further improve the performance of the proposed HRF antenna the size of the ground plane is optimized. The High Frequency Structure Simulator software (HFSS) has been used to analyze the Performance of the proposed HRF antenna.

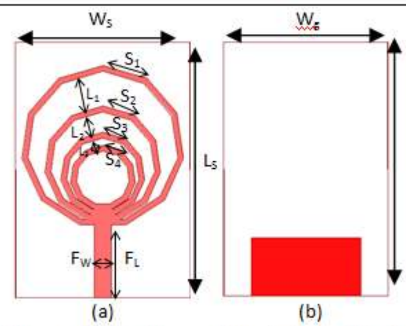
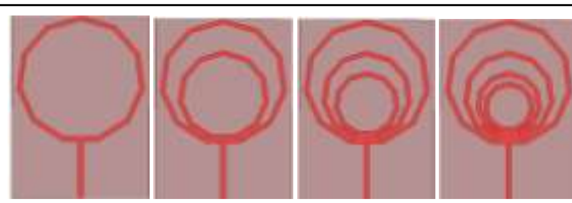


Fig.1. Proposed HRF antenna a) Front view b) Back view



Initiator (a) First fractal (b) Second fractal (c) Third fractal (d)

Figure.2 Design steps of proposed antenna (a) Initiator (b) Second Fractal (c) Third Fractal (d) Fourth fractal.

Table 1: Dimension of Proposed HRF Antenna

Parameters	Dimensions (mm)	Parameters	Dimensions (mm)
Ls	44	S4	3.17
Ws	30	L1	6.0
Lg	10	L2	3.5
Wg	20	L3	1.22
S1	7.88	S_w	1.0
S2	5.6	F_l	12.5
S3	4.08	F_w	3.0

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III. SIMULATION RESULTS

This section discusses the proposed antenna dimension with variations in its design parameters, and the antenna parameters are obtained by simulating it on HFSS Simulation tool. Return loss, VSWR, gain, bandwidth and radiation pattern are measured.

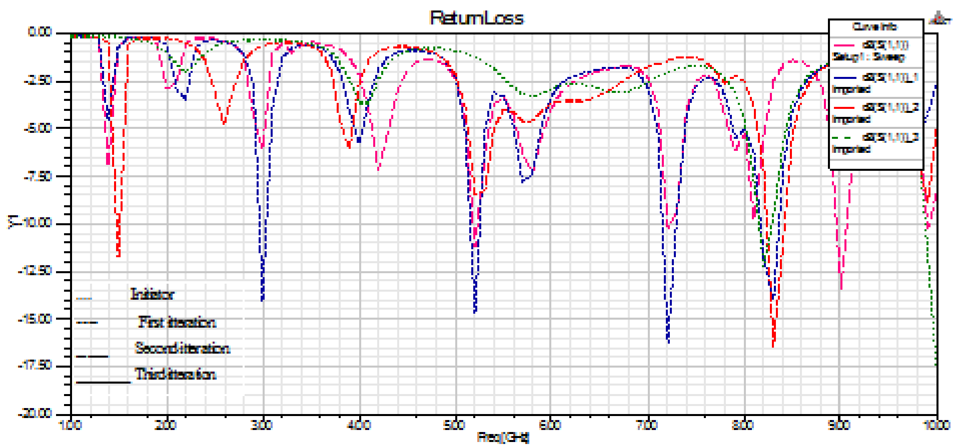


Figure.3. Simulated Return loss of antenna for various design steps as shown in fig.2 (a)-(d).

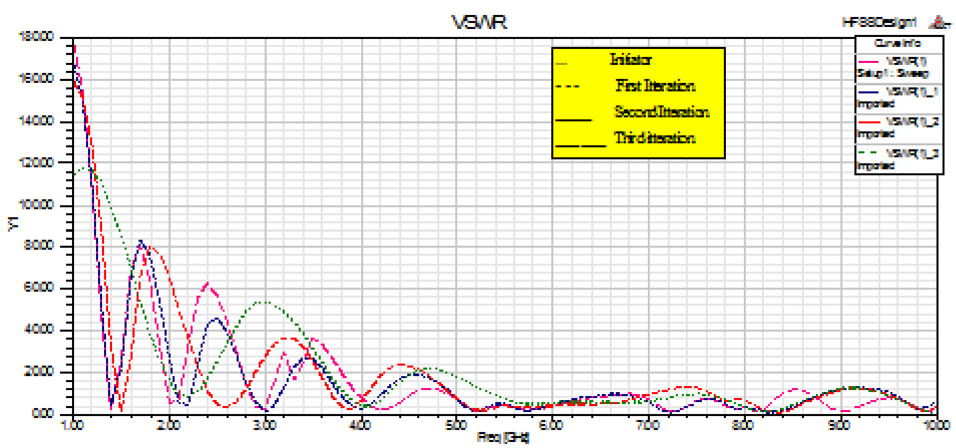


Figure.4 Simulated VSWR of antenna for various design steps as shown in fig.2 (a)-(d).

Fig.3 and Fig.4 shows the comparison result of simulated return loss and VSWR parameter for various iteration stages. The design with only initiator (First Fractal) resonates at the 8.2 GHz with return loss -12db. Addition of first ring as shown in Fig 2(b) resonates at 1.5GHz and 8.3GHz with return loss of -11.7db and -16.49db.Similarly Third fractal (Fig2 c) results in multiband resonance frequencies of 3 GHz, 5.2Ghz,7.2 GHz and 8.3Ghz with return loss of -14.0db,-14.74db,-16.29db and 14.375 db. Similarly in Fourth fractal the number of resonance frequency are decreased one is shifted to the lower frequency side and another one is shifted to the higher frequency side. In this proposed design the iteration stages increase, antenna dimension decreases in Y-direction causing electrical path length to increase that shifts the resonant frequency towards lower frequency side and provides multiple resonances [15].

A. The Effect of Varying the Length of Ground Plane (Lg)

In this proposed design, the length of the ground plane is optimized with constant Width(Wg= 30mm) for maximum performance of the antenna, the effect varying the ground plane length(lg) shown in Fig.3, With the ground plane dimension of 10 x30 mm^2 gives good results of multiband as shown in Fig.5. and Fig.6, From the fig the antenna resonates 2.4 GHz, 3.1GHz ,3.9 GHz,5.4GHz and 9.0 GHz with return loss of -16.90db, -26.0db,-21.12db,11.24db and -34.143db respectively with VSWR less than 2.

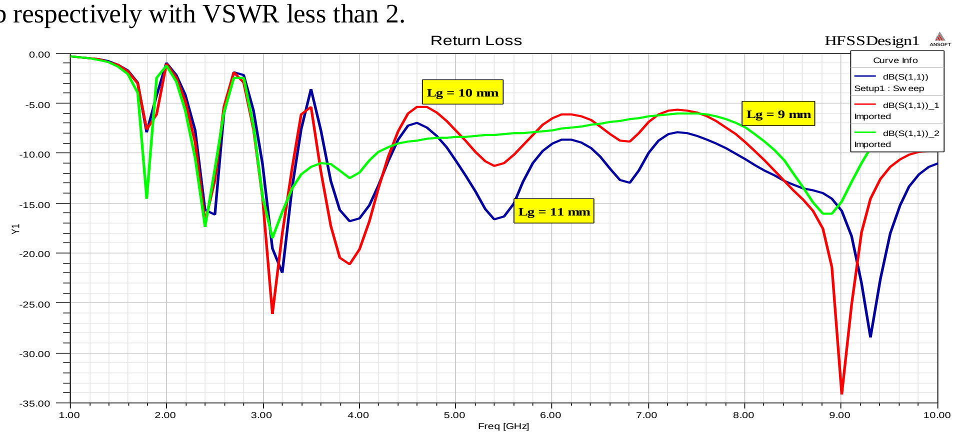


Figure.5. Simulated Return loss for various Length of the ground plane (Lg).

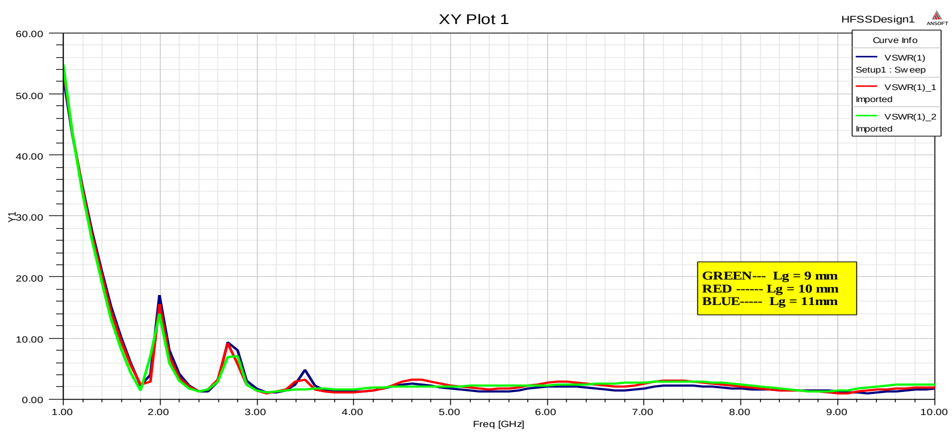


Figure.6. Simulated VSWR for various Length of the ground plane (Lg).

B. The Effect of Varying the Width of the Ground Plane (Wg)

In this proposed design, the length and Width of the ground plane is optimized for maximum performance of the antenna, the effect varying the ground plane length(lg) and Width (Wg) shown in Fig.3, With the ground plane dimension of 10 x20 mm^2 gives good results of multiband as shown in Fig.5. and Fig.6, From the fig the antenna resonates 2.4 GHz, 3.1GHz ,3.9 GHz,5.2GHz and 8.6 GHz with return loss of -15.0 db, -17.50 db,-24.2db,29.16 db and -16.3db respectively with VSWR less than 2.

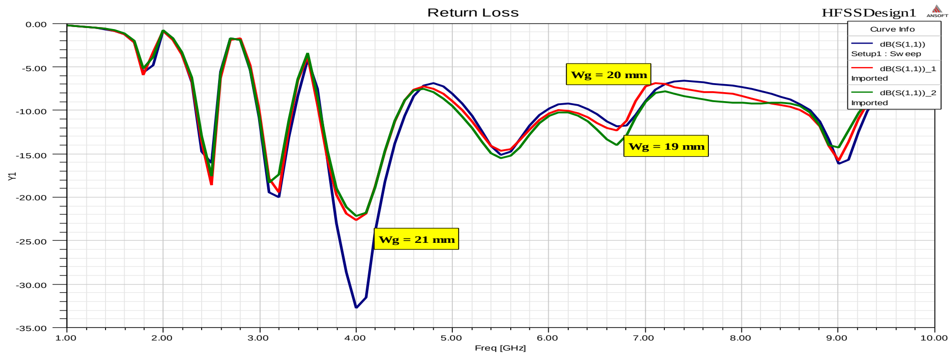


Figure.7. Simulated Return loss for various Width of the ground plane (Wg).

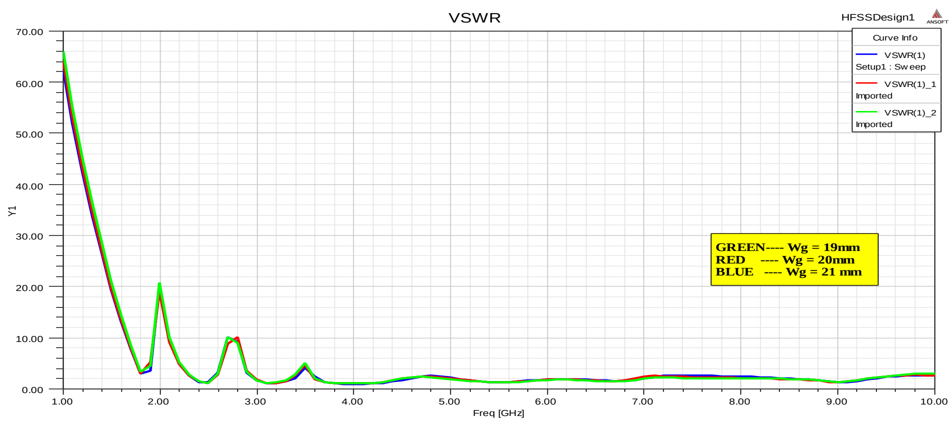


Figure.8. Simulated VSWR for various Width of the ground plane (Wg).

C. Proposed HRF Antenna

The proposed HRF antenna with Optimized ground plane is shown in Fig.1, in this Proposed Design the Dimension of the ground plane is chosen for 10 x 20 mm^2, which will give the good results of multiband with improved bandwidth as shown in Fig.9. and Fig.10, From the fig the antenna resonates 2.4 GHz, 3.1GHz ,3.9 GHz,5.2 GHz and 8.6 GHz with return loss of -15.0 db, -17.50 db,-24.2db,29.16 db and -16.3db respectively with VSWR less than 2. Which meet the bandwidth requirement of DCS1800, Bluetooth and WLAN 2.4/5.2/5.8GHz, WiMAX band at 3.5/5.5GHz frequency. The dimensions of the proposed antenna given in Table I. The simulated performance characteristics of the proposed HRF antenna with Optimized Ground Plane are given in Fig.9. – Fig.11.

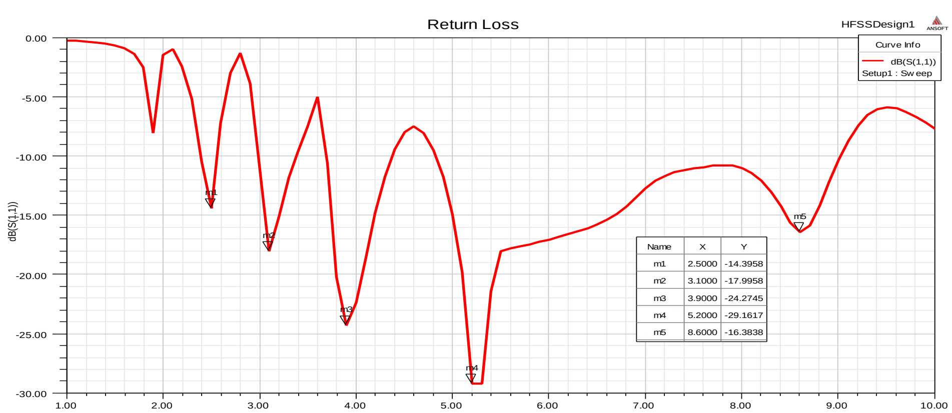


Figure.9.Simulated Return loss of proposed HRF antenna.

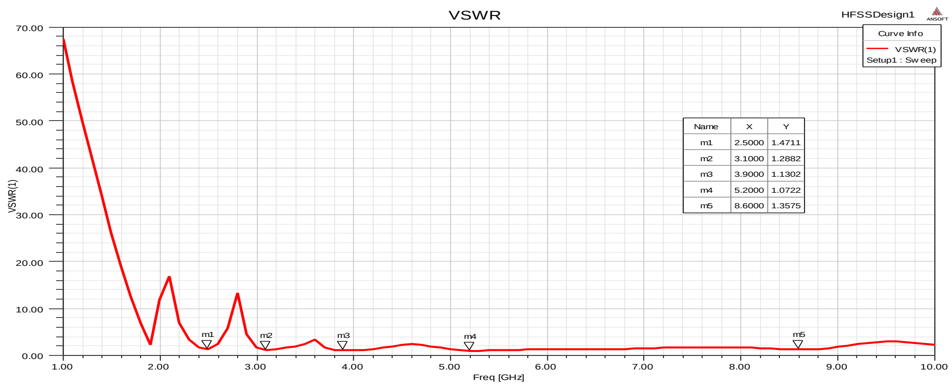
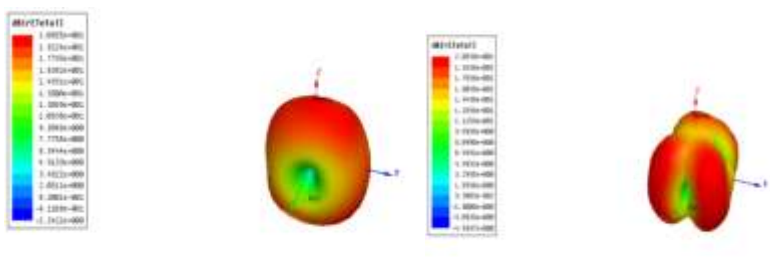


Figure.10.Simulated VSWR of proposed HRF antenna



(a) (b)

Figure.11.Simulated Gain of proposed HRF antenna at a) 5.2 GHz b) 8.6 GHz.

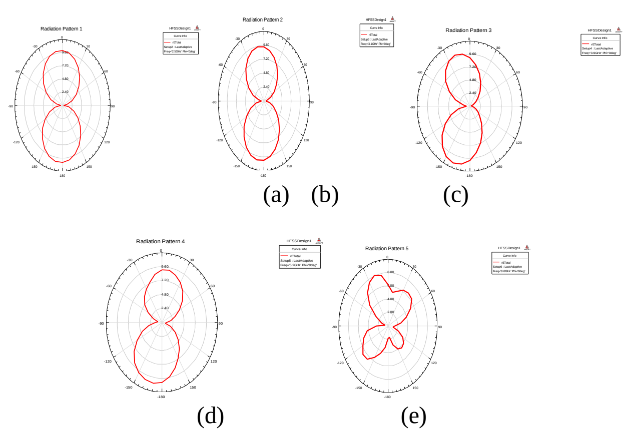


Figure.12.Simulated Radiation Pattern of proposed HRF antenna at a) 2.5GHz b) 3.1 GHz c) 3.9 GHz d) 5.2 GHz and e) 8.6 GHz.

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Table 2: Summary of Parametric Study

Performance characteristics	Simulated Results			Measured Results		
	Resonance Frequency (GHz)	Return Loss(dB)	VSWR	Resonance Frequency (GHz)	Return Loss(dB)	VSWR
Proposed HRF Antenna	2.5	-15.0	1.4	1.2	-31.72	1.1
	3.1	-17.90	1.2	3.9	-17.8	1.3
	3.9	-24.20	1.1	4.5	-17.7	1.3
	5.2	-29.16	1.0	5.6	-31.2	1.0
	8.6	-16.30	1.3	6.4	-25.8	1.0

Table 2. Shows the Comparison of Simulated and Measured results of the proposed HRF antenna. Simulation and Measured results prove the effectiveness of the proposed HRF antenna. The radiation pattern is bidirectional and the gain value is 9.6 dB. Five numbers of resonant frequencies have been observed. The return loss values are minimum and the VSWR values are less than two. This reduced size and enhanced performance of the HRF antenna makes it an expensive candidate for a number of wireless applications in UWB region.

IV.EXPERIMENTAL RESULTS

The proposed HRF antenna was fabricated on FR4 substrate with dielectric constant ϵr is 4.4 and height (h) = 1.5 mm as shown in Fig. 12. The Return loss and VSWR are measured by using Agilent E5071C network analyzer with SAC-26G-0.5 using 50 Ω Cables. The measured and simulated Return loss graphs for the proposed HRF antennas are shown in Fig. 13 and 14.The Measured E-Plane Radiation Pattern of the Proposed HRF antenna at 3.2 GHz, 3.9 GHz and 5.2 GHz is shown in Fig.15. From the Radiation Pattern it has been observed that the Proposed HRF antenna E plane radiation has bidirectional pattern with small cross polarization. Measurement results corroborate the UWB characteristic as predicted in the simulation results with a small shift in the lower and upper edge frequencies. The inconsistency between the measured and the simulated results is mostly ascribed to the tolerance in fabrication and welding the SMA connector, which are not taken into account through simulation. As well as the dielectric loss tangent of the FR4 substrate is kept constant during simulation, where actually it is a function of frequency.

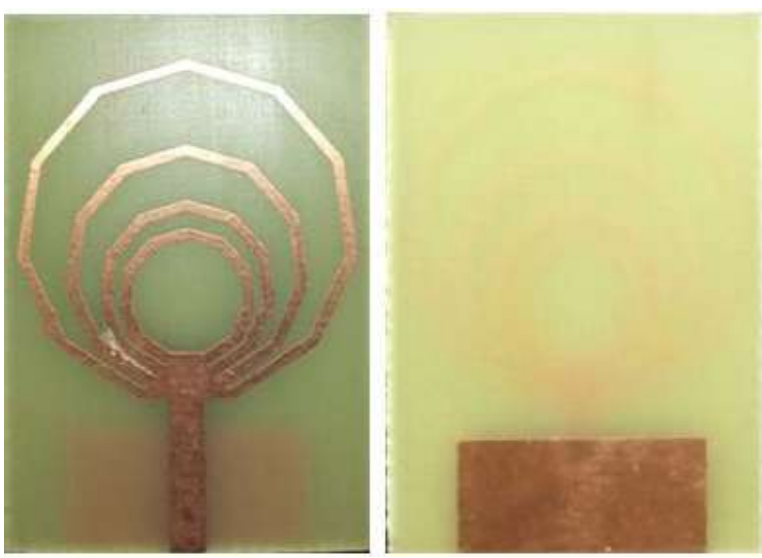


Fig.12.Prototype of Proposed HRF antenna a) Top view b) Bottom view

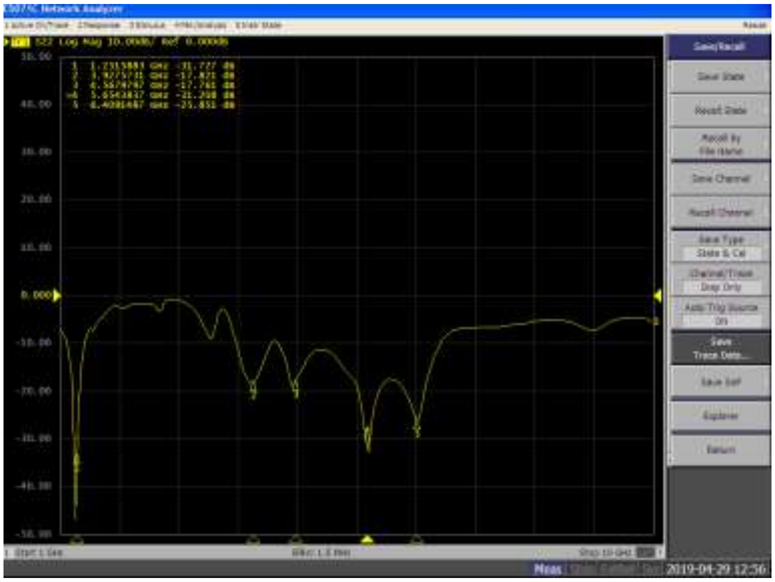


Figure.13.Measured Return loss for the proposed HRF antenna

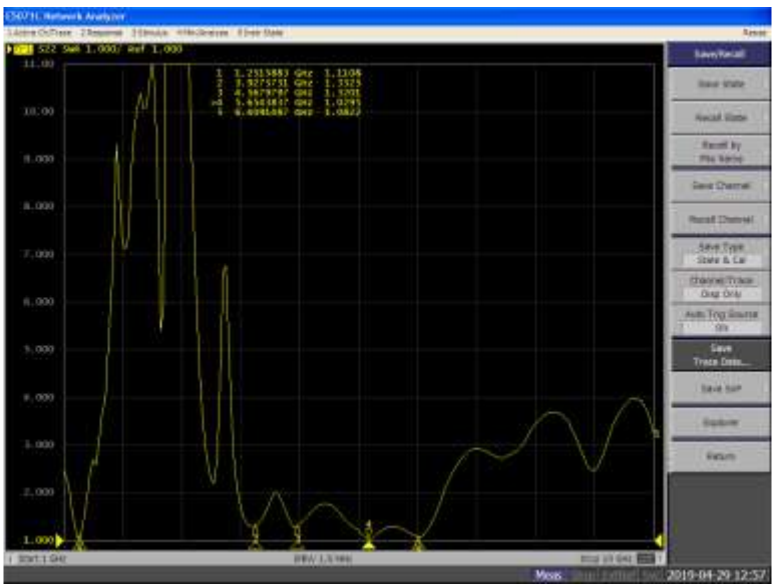
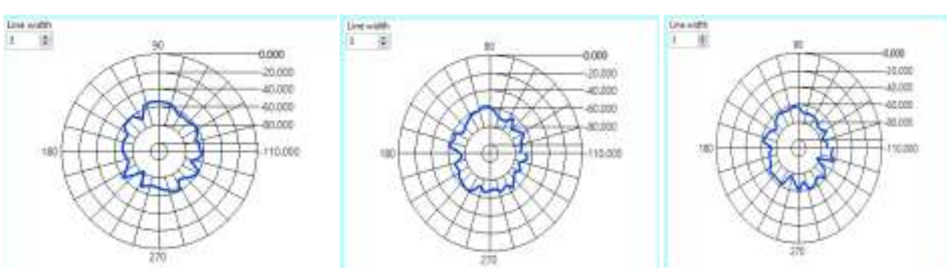


Figure.14.Measured VSWR for the proposed HRF antenna



(a) (b) (c)

Figure.15.Measured E-plane radiation patterns of proposed HRF antenna at (a) 3.2 GHz (b) 3.9 GHz (c) 5.2 GHz

V. CONCLUSIONS

A compact Hendecagonal Ring Fractal (HRF) patch antenna has been designed and fabricated using FR-4 substrate with overall dimension of 40X30X1.6 mm^3; this proposed antenna has been simulated using Ansoft HFSS simulation and measured by using Agilent E5071C network analyzer for DCS1800, WLAN 2.4/5.2/5.8GHz, and 3.5/5.5GHz WiMAX band of operation. Multiband resonant frequencies are obtained by optimizing the number of hendecagonal ring fractal as well as by changing the size of the ground plane. The return loss and VSWR plot shows the step by step improvements and fourth iteration of the fractal structure and length of the ground plane (Lg) 10 mm proves the high bandwidth impedance, The proposed hendecagonal antenna is operating in five different frequency bands with resonating frequency of 1.25,3.9,4.5, 5.6, and 6.4 GHz and provides good return loss of -31.77 db, -17.82 db,-17.76db,31.20 db and -25.85db with reasonable gain which makes the proposed antenna a appropriate candidate for wireless applications. The measurement results are of the same estimation well with the simulation results with a slight shift in the lower and upper side frequencies.

IV. References

[1] Gopal M. Dandime and Veeresh G. Kasabegoudar. “Slotted circular monopole antenna for wireless Applications” International *Journal of Wireless Communications and Mobile Computing.*Vol. 2(2), pp. 30-34A, 2014.

[2] http://en.wikipedia.org/wiki/Ultra- wideband

[3] Ghatak R., Mishra R.K and Poddar D.R. “Perturbed Sierpinski Carpet Antenna with CPW feed for IEEE 802.11 a/b WLAN Application,” *IEEE Antennas Wireless Propag Lett,* pp.742-744.2008.

[4] Liu W.X., Yin.Y.Z and Xu W.L. “Compact self similar triple band antenna for WLAN/WiMAX applications,” Microw Opt Technol Lett, Vol. 54 (4), pp1084-1087, 2012.

[5] Abutarboush H. F., Nasif .H, Nilavalan R and Cheung W. “Multiband and Wideband Monopole Antenna for GSM900 and Other Wireless Applications,” *IEEE Antennas Wireless Propag Lett,*Vol. (11), pp. 539-542, 2012.

[6] Anguera J., Andújar.A and Garcia C. “Multiband and small coplanar antenna system for wireless handheld devices,” *IEEE Transactions on Antennas and Propagation,* Vol 61(7); pp.3782-3789, 2013.

[7] Werner D.H and Ganguly S. “An overview of fractal antenna engineering research,” *IEEE Antennas Propag Mag,* Vol (45), pp.38–57, 2003.

[8] Sivagnanam.S, Rameshkumar.S and Kailasapathi.P. **“**Design of Nanogonal Ring Fractal Antenna for UWB applications.” *Bioscience Biotechnology Research Communications,* Vol 12(2), pp 42-49, 2019.

[9] http://www.fractenna.com/nca_faq.html.

[10] Werner D.H and Ganguly S. “An overview of fractal antenna engineering research,” *IEEE Antennas Propag Mag,* Vol (45), pp.38–57, 2003.

[11] Borja C. and Romeu J. “On the behavior of Koch island fractal boundary microstrip patch antenna,” *IEEE Trans. Antennas Propag*, Vol. 51, pp. 1281–1291, 2003.

[12] Gianvittorio J.P. and Samii Y.R. “Fractal antennas: a novel antenna miniaturization technique and applications,” *IEEE Antennas Propag Mag,* Vol. (44), pp. 20–36, 2002.

[13] Hwang K.C, “A Modified Sierpinski Fractal Antenna for Multiband Application, *IEEE Antennas Wireless , Propag Lett,* Vol.(6), pp.357-360, 2007.

[14] Pourahmadazar J., Ghobadi C., Nourinia J. and Shirzad H. “Multiband ring fractal monopole antenna for mobile devices,” *IEEE Antennas Wireless Propag. Lett,* Vol. (9), pp.863–866, 2010.

[15] Beigi P., Nourinia J., Zehforoosh Y. and Mohammadi B. “A compact novel CPW-fed antenna with square spiral patch for multiband applications, *Microwave Opt Technol Lett,* Vol. (57), pp.111-115, 2015.

[16] Beigi P. and Mohammadi P. “A novel small triple-band monopole antenna with crinkle fractal-structure,” *Int Journal Electron Commun (AEÜ),* Vol. (70), pp. 1392-87, 2016.

[17] Gupta. A., Dutt. H and Khanna, R. “An X- shaped fractal antenna with DGS for multiband applications,” *International Journal of Microwave and Wireless Technologies*, Vol. 9(5), pp. 1075-1083, 2017.

[18] Sivagnanam.S, Rameshkumar.S and Kailasapathi.P. **“**Multislot Rectangular Patch Antenna with Defected Ground Structure for UWB Wireless Applications.” *Journal of Emerging Technologies and Innovative Research* , Vol. 6(5), pp 311-319, 2019.