Design and Analysis of Sierpinski Carpet Fractal Antenna for UHF Spaced Antenna Wind Profiler Radar

Elluru Jayapal, S. Varadarajan

Abstract-- This paper emphasizes the design of Sierpinski carpet fractal antenna to miniaturize the antenna array of UHF Spaced antenna Wind profiler radar that operates at 445 MHz. The proposed antenna is designed using High Frequency Structure Simulator (HFSS) where aluminium is used as a patch and ground with air as dielectric substrate due to it's zero loss tangent .patch is separated from ground with help of hinges and fed with 50 ohm coaxial probe. The Sierpinski fractal antenna is designed till third iteration so as to reduce its size and weight by 33 percent.

Keywords: Sierpinski carpet, fractal antenna, wind profiler Radar, HFSS, UHF.

I. INTRODUCTION

In the last decade there has been an immense requirement for the design of antennas in crucial sectors like military, remote sensing, biomedical and telecommunication. In general, the designation of antenna consists of certain characteristics which comprises of compact size, low profile, conformal and multiband. There are vivid approaches that has come all through on the antenna design characteristics. Lately, the described characteristics of an antenna can be achieved by using properties of fractal[1][2].

Atmospheric Radars are useful for identifying meteorological changes and weather forecasting. UHF Spaced Antenna Wind Profiler Radar is a one of the type of Atmospheric Radars, which is remote sensing instrument for finding wind velocity components (U, V, W) at different height levels from 0.3 Km to 4 Km with height resolution of 75 m.

Wind profilers working depends on occurring irregularities in refractive index of atmosphere due to variations in Temperature, pressure and humidity of atmosphere [3]. Parameters of Wind profiler Radar are given in Table I.

Revised Manuscript Received on November 30, 2019.
* Correspondence Author
Elluru Jayapal*, Department of Electronics and Communication Engineering, S. V. University College of Engineering, Tirupati,A.P ,India Email: jaijrfscholar@gmail.com
S. Varadarajan, Professor, Department of Electronics and Communication Engineering, S. V. University College of Engineering, Tirupati, A.P, India.

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC-BY-NC-ND license http://creativecommons.org/licenses/by-nc-nd/4.0/

Table I : Wind profiler Radar Specifications

Operating frequency	445MHz
Technique	Spaced Antenna with 3 receive channels
Antenna Sub-Array	18 element Hexagonal Shaped Rectangular Patch Array
Transmit Antenna Array	3 Sub-Arrays (combined)
Receive Sub-Arrays	3 Sub-Arrays (independent Channels)
Transmit Peak Power	4 KW
Pulse width	0.5 to 8 micro seconds
Duty Ratio	10%
Reception	3 Channel Receiver
Radar Control	PC-Based with GUI
Height Coverage	0.3 to 4 Km
Height resolution	75m
Transmit Array Gain	24.8 dBi
Receiver Array Gain	19 dBi
Data outputs	SNR, U,V,W

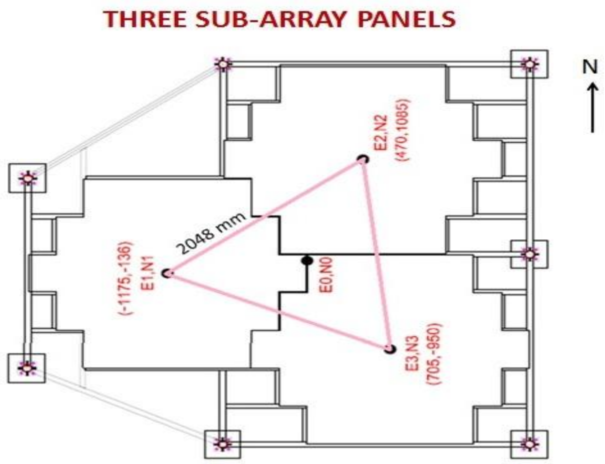

Fig. 1: Three Sub-array for Wind profiler Radar

The Spaced Antenna (SA) technique gives better time resolution over Doppler beam steering(DBS) method due to the beam is pointed in zenith direction only where as DBS method requires at least three beams which are pointed in different directions. Vertical velocity of wind is calculated with help of Doppler Shift, while horizontal velocity of wind is found by using Spaced Antenna Technique [4]. More recently, UHF Spaced Antenna wind profiler Radar has been developed at Sri Venkateswara University, Tirupati, with the help of Spaced Antenna technique to measure velocities of atmospheric wind. The Antenna used in Wind profiler Radar is a three Sub-arrays with each array consists of eighteen elements linearly polarized Rectangular microstrip patch antenna in hexagonal shaped array, as shown in Fig.1.

The below block diagram of 445-MHz Spaced Antenna wind profiler Radar which is shown in Fig. 2. To miniaturize the antenna array, sierpinski carpet fractal antenna is used as an element in the designing of antenna array.

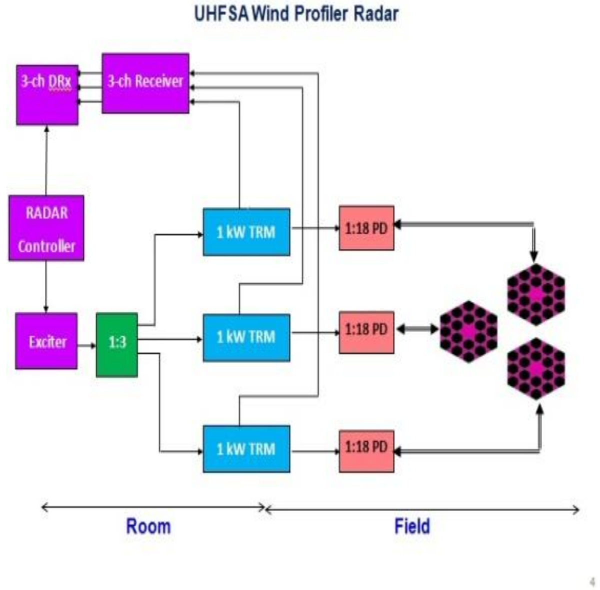

Fig. 2: Block diagram of UHF SA Wind profiler Radar

II. FRACTAL ANTENNA

French mathematician Mandelbrot entitled the term fractal which means broken or irregular elements that acquires deep rooted self-similarity in respective geometric structures .fractal antenna serves an effective purpose with multi band and low profile. There are some fractal geometries that are useful in developing new antenna designs. These include sierpinski gasket, cantorset, Koch curve, sierpinski carpet et al. Which are shown in Fig.3 [5-7].

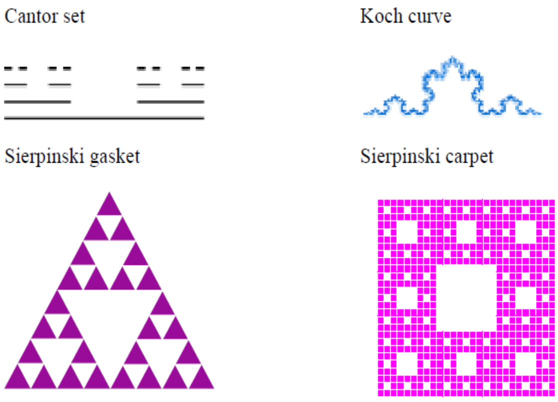

Fig. 3: Some common examples of fractals.

III. SIERPINSKI CARPET FRACTAL ANTENNA DESIGN

The design of Sierpinski carpet fractal antenna begins firstly with design of conventional microstrip patch antenna as iteration 0. The very next step in the design process as iteration 1 is to remove middle square portion by considering scale factor of 1/3. This process is repeated for the eight remaining square microstrip patch portions as to get iteration 2 which is shown in Fig.6. The Sierpinski Carpet fractal is generated by doing iterative process many number of times [8-11]. In the design of conventional Rectangular microstrip patch antenna with sierpinski carpet geometry, aluminium metal is used as patch as well as ground with air used as dielectric substrate which is shown in Fig. 4. The design considerations are given[12][13] in Table II.

Table II: Design Considerations

Dielectric Substrate (Air)	$\varepsilon_r = 1$, $\tan\delta = 0$
Substrate height (h)	*2.5 cm*
Width $(W) = \frac{c}{2f_0}\sqrt{\frac{2}{\varepsilon_r+1}}$	*33.71 cm*
$\varepsilon_{r\ eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2}$	1
$L_{eff} = \frac{C}{2f_0\sqrt{\varepsilon_{reff}}}$	*33.70 cm*
$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)}$	*1.736 cm*
$L = Leff - 2\Delta L$	*30.228 cm*
$Lg = L + 6h$	*45.23 cm*
$Wg = W + 6h$	*48.71 cm*

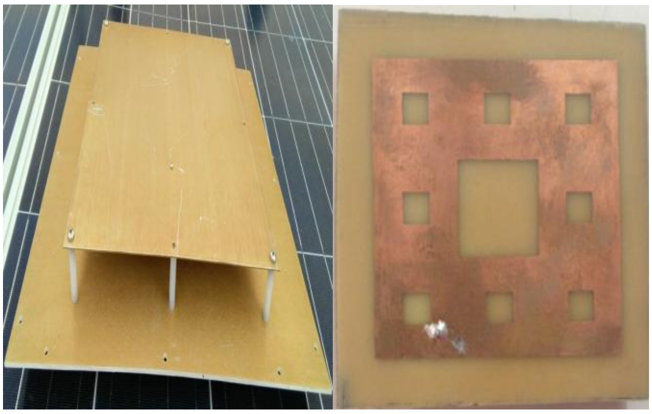

Fig.4: Fabricated Microstrip Patch Antenna element as an iteration 0(left) and Fabricated Prototype of the square Sierpinski carpet fractal antenna (right)

IV. DEVELOPMENT MODEL FOR SIERPINSKI CARPET FRACTAL ANTENNA

A model is created for Sierpinski Carpet Fractal Antenna in HFSS software by the following flow chart which is shown in Fig.5.

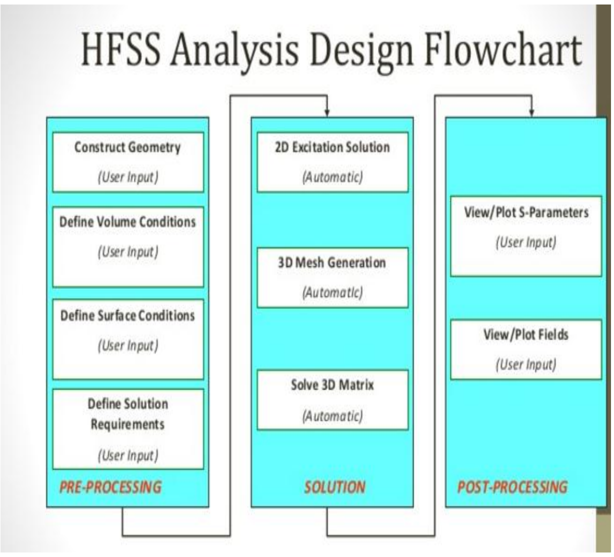

Fig.5 HFSS Design flow chart for Sierpinski Carpet fractal antenna

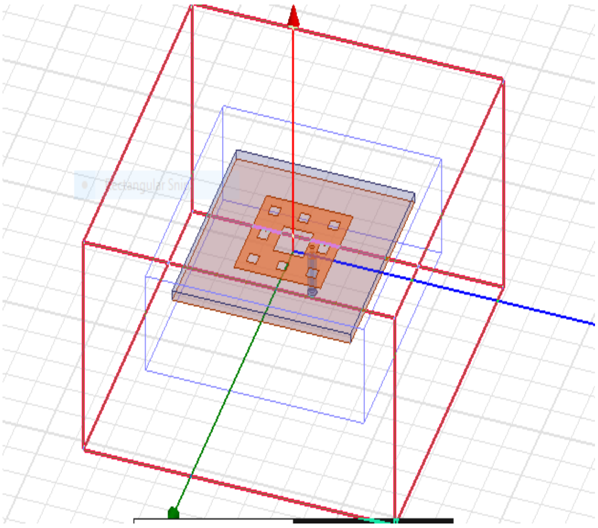

Fig. 6: Sierpinski Carpet fractal antenna Simulated model

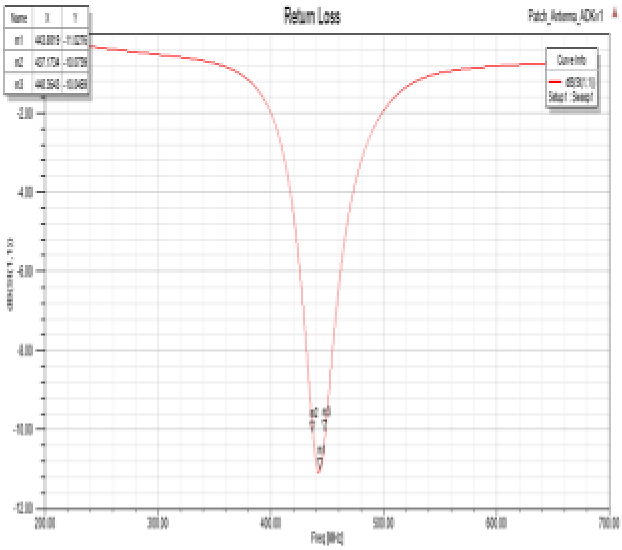

Fig. 7: Return Loss (S11) parameter plot for fractal antenna

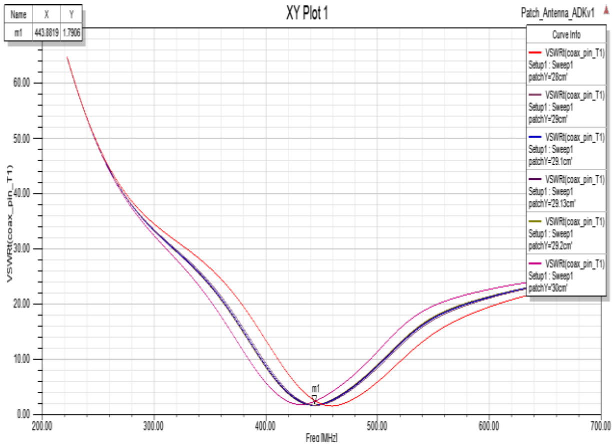

Fig 8: VSWR Plot for fractal antenna

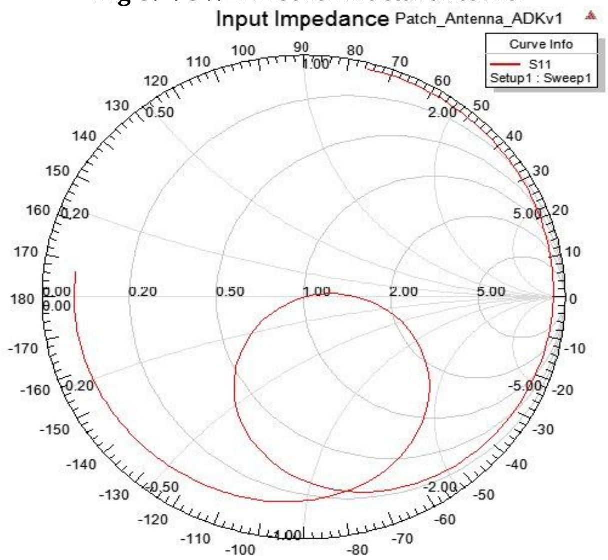

Fig.9: Input impedance plot for fractal antenna

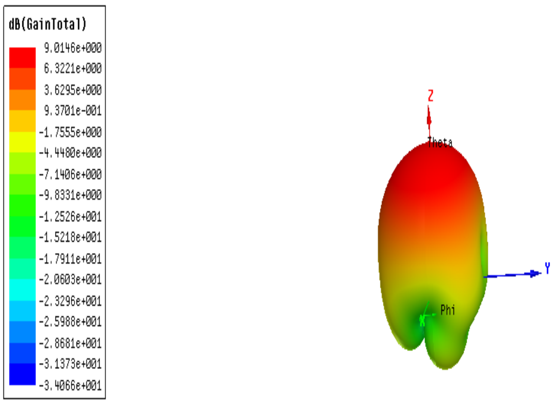

Fig.10: 3-D Radiation pattern for fractal antenna

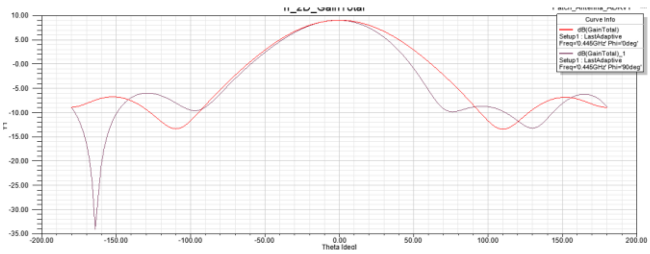

Fig.11: 2-D Radiation pattern for fractal antenna

V. RESULTS AND DISCUSSIONS

In Fig.7, curve shows that return loss is achieved as -11.05 dB at 445MHz and maintains bandwidth of 20MHz. Gain of the antenna is improved by using air as a dielectric substrate and coaxial probe feed, which is shown in Fig. 10 and Fig. 11. It is observed that the VSWR is 1.79 and antenna impedance approximately matched with 50 ohm coaxial probe feed as shown in Fig. 8 and Fig. 9 respectively.

By using Sierpinski Carpet fractal geometry in the conventional Rectangular Microstrip Patch antenna, the electrical length of an antenna is increased more. Hence there is more reduction in antenna array size. Results show that Sierpinski Carpet fractal antenna is suitable to use as an element in the antenna array of UHF Spaced Antenna Wind profiler Radar in order to miniaturize.

VI. CONCLUSION

Microstrip Patch Antenna with Sierpinski Carpet fractal geometry is designed and analysed at 445MHz for UHF Spaced Antenna Wind Profiler Radar Using HFSS software. Sierpinski Carpet fractal antenna is implemented up to 2nd iteration in order to miniaturize the size of antenna up to 33%. The antenna properties like directivity, return loss (S11), VSWR and radiation pattern are accomplished with good performance. The weight and cost of an antenna is reduced with the use of air as dielectric.

REFERENCES

1. D. H. Werner and S. Ganguly, "An overview of fractal antenna engineering research," IEEE Ant. Propagat. Mag., vol. 45, no. 1, pp. 38-57, February 2003
2. L.K.Balaji Vignesh and .K.Kavitha, "A Survey on Fractal Antenna Design" International Journal of Pure and Applied Mathematics, Volume 120 No. 6 ,10941-10959, 2018
3. Vaisala, Inc. Wind Profiling, The History, Principles, and Applications, 2004.
4. B. Lindseth, William O.J. Brown, J. R. Jordan, D. Law, T. Hock, S. A. Cohn and Z. Popovic, "A New Portable 449 MHz Spaced Antenna Wind Profiler Radar." IEEE Trans. on Geoscience and Remote Sensing, vol. 50, no. 9, pp. 3544-3553, September 2012.
5. A. Chatterjee, T.Mondal, Deven G.Patanvariya, Ravi Prasad K. Jagannath ", Fractal-based design and fabrication of low-sidelobe antenna array" , International Journal of Electronics and Communications, vol. 83,pp. 549-557, January 2018.
6. B.T.P.Madhav, T.Anilkumar, S.K.Kotamraju "Transparent and Conformal Wheel-shaped Fractal Antenna forVehicular Communication Applications" International Journal of Electronics and Communications, 2018
   doi: https://doi.org/10.1016/j.aeue.2018.04.028
7. J. Anguera" Metallized foams for antenna design: application to fractal-shaped sierpinski-carpet monopole" Progress In Electromagnetics Research, PIER 104, 239-251, 2010
8. D.H. Werner, R.L. Haupt, and P.L. Werner, "Fractal antenna engineering: The theory and design of fractal antenna arrays," IEEE Ant. Propagat. Mag., vol. 41, no. 5, pp. 37-59, 1999.
9. S. Ullah, F.Faisal, A.Ahmad, U. Ali, F.A.Tahir and J. A. Flint "Design and Analysis of Novel Triband flower- shaped planer antenna for GPS and WiMAX applications" Journal of Electromagnetic waves and applications, vol. 31, no.9, pp. 927-940, April 2017.
10. Mohd G. Siddiqui, Abhishek K.Saroj, Devesh, and Jamshed A.Ansari "Multi-Band Fractaled Triangular Microstrip Antenna for Wireless Applications" Progress In Electromagnetics Research M, Vol.65, pp. 51-60, January 2018.
11. Arpan Desai, Trushit Upadhyaya, Riki Patel, Sagar Bhatt, and Parthesh Mankodi "Wideband High Gain Fractal Antenna for Wireless Applications" Progress In Electromagnetics Research Letters , Vol. 74, pp. 125-130, 2018.
12. Balanis C. A. Antenna Theory: Analysis and Design, John Wiley & Sons, (2005)
13. Ramesh G, Prakash B, Inder B, and Ittipiboon A. Microstrip antenna design handbook, Artech House, (2001).

AUTHORS PROFILE

Jayapal Elluru received the B.tech degree in electronics & communication engineering and M.tech degree in communication systems from NIT, Warangal, JNTU Hyderabad respectively. He is currently pursuing the Ph.D degree through a scheme of UGC-NET JRF at Sri Venkateswara University College of Engineering, Tirupati. He is involved in the Development, installation and commissioning the UHF Spaced Antenna Wind profiler Radar at SV University. His research interests include Antenna System designing, Electromagnetic and RF system designing, Processing Techniques of Atmospheric Radars.
e-mail: jaijrfscholar@gmail.com

Dr. S. Varadarajan received the M.tech degree from NIT, Warangal and Ph.D from Sri Venkateswara University, Tirupati. Currently he is a Professor at Sri Venkateswara University College of Engineering, Tirupati. He established the Centre of Excellence (CoE) laboratory for Atmospheric Remote Sensing and Advanced Signal processing. His research interests include atmospheric radar signal processing and communication networks.