



Comparative study of Fractal Antenna and Conventional Microstrip Patch Antenna for the Antenna Array of Wind profiler Radar

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Abstract- UHF Spaced Antenna Wind profiler Radar needs to have large antenna array in order to have a narrow beam for finding accurate wind speed and direction. To reduce size and weight of the antenna array, fractal based microstrip patch antenna element is designed to operate in UHF band. The goal of this paper is to evaluate performance of Sierpinski Carpet fractal antenna element over Conventional Rectangular microstrip Patch antenna element using High Frequency Structure Simulator (HFSS). For cost effective design, aluminium metal and air are used as a patch and substrate respectively with coaxial probe feeding.

Keywords: Wind profiler Radar, Antenna array, Sierpinski Carpet, Fractal antenna, Microstrip Antenna

I. INTRODUCTION

Observations of Wind velocity profiles are more useful for weather forecasting and understanding meteorological phenomena. Wind profiler Radar is one of the remote sensing instruments for observing height profiles of wind velocity vector with time and height resolutions[1]. Propagation of radar signals through atmosphere is dependent on meteorological conditions [2][3]. The UHF Spaced antenna wind profiler Radar uses (considered) naturally occurring fluctuations in refractive index and precipitation as targets. UHF profilers operating around 400- 1300 MHz[4] are suitable for measuring winds in lower troposphere region[5].

Modern UHF Spaced Antenna Wind profiler Radar Systems require low profile, light weight, high gain and simple structure antennas to assure reliability, mobility and high efficiency. Microstrip patch antenna has been used as antenna array element of Wind profiler Radar which operates at frequency 445MHz in UHF-band. In order to miniaturization the antenna array, Fractal is a concept which is being implemented in microstrip antenna to reduce size and weight than conventional microstrip antenna.

The term fractal was introduced by the French mathematician B.B Mandelbrot during 1970's after his research on several naturally occurring irregular and fragmented geometries. The main objective of fractal antenna engineering is to develop new varieties of antenna designs and synthesis concepts beyond Euclidean geometry [6]-[7]. Obtaining special antenna characteristics by using a fractal distribution of elements is the main aim of the study on fractal antenna arrays. Properties of antenna arrays are decided by their distribution rather than properties of individual elements. Some common examples of fractals are Cantor set, Koch curve, Sierpinski gasket, Sierpinski Carpet.

Cantor set



Sierpinski gasket



Koch curve



Sierpinski carpet

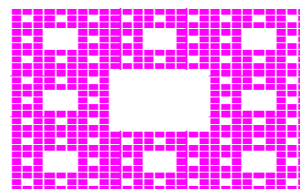


Fig1: Some common examples of fractals.

Several fractal geometries have been introduced to improve antenna characteristics. Some of these geometries have been useful in reducing the size of antenna array, while other designs are to get multi-band characteristics.[8]-[12]

II. MICROSTRIP ANTENNA DESIGN

The Rectangular Microstrip Antenna was designed with help of Finite Element Method (FEM) based High Frequency Structure Simulator (HFSS) to operate at 445 MHz by following steps below.[13][14]

Design Specifications:

Essential parameters for the design are:

- Operating frequency $f_0 = 445$ MHz
- Dielectric Substrate is air $\epsilon_r = 1$
- Height of substrate = 2.5 cm.

Step 1: calculation of width (W):

The Width of Rectangular microstrip antenna is

$$W = \frac{C}{2f_0 \sqrt{\frac{\epsilon_r + 1}{2}}}$$

Substituting $C = 3 \times 10^8$ m/s (speed of light in free Space), $\epsilon_r = 1$ (for air dielectric) and $f_0 = 445$ MHz (operating frequency of microstrip patch antenna) then $W = 0.3371$ m = 33.71 cm

Step 2: Calculation of Effective dielectric constant (ϵ_{eff}):

The effective dielectric constant is

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-1/2}$$

Substituting $\epsilon_r = 1$ for air dielectric, $W = 33.71$ cm and $h = 2.5$ cm

Then $\epsilon_{eff} = 1$

Step3: Calculation of Effective length (L_{eff}):

The effective length is

$$L_{eff} = \frac{C}{2f_0 \sqrt{\epsilon_{eff}}}$$

Substituting $\epsilon_{eff} = 1$, $C = 3 \times 10^8$ m/s (speed of light in free Space), and $f_0 = 445$ MHz (operating frequency of microstrip patch antenna). Then

$$L_{eff} = 33.70 \text{ cm}$$

Step 4: Calculation of length extension (ΔL):

$$\Delta L = 0.412h \frac{(\epsilon_{eff} + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\epsilon_{eff} - 0.258) \left(\frac{W}{h} + 0.8 \right)}$$

Substituting $\epsilon_{eff} = 1$, $W = 33.71$ cm and $h = 2.5$ cm

Then $\Delta L = 1.736$ cm

Step 5: calculation of actual length of Rectangular microstrip patch (L):

Actual length (physical) of Rectangular patch is given by

$$L = L_{eff} - 2\Delta L$$

Substituting $L_{eff} = 33.70$ cm and $\Delta L = 1.736$ cm Then $L = 30.228$ cm.

Step 6: calculation of ground plane dimensions (L_g and W_g):

Design the Ground plane is finite instead of infinite ground plane due to practical considerations. dimensions of ground plane are greater than the patch dimensions by approximately six times the substrate thickness along length and width.

$$L_g = L + 6h = 45.23 \text{ cm}$$

$$W_g = W + 6h = 48.71 \text{ cm}$$

TABLE 1. Antenna parameters

Length	30.228 cm
Width	33.71 cm
(X _f , Y _f)	(0, 6.3 cm)
L _g	45.23 cm
W _g	48.71 cm

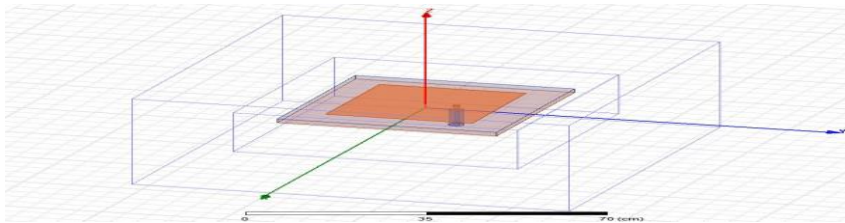


Fig.2:Conventional Rectangular Microstrip Patch antenna simulated model



Fig.3:Fabricated Conventional Rectangular Microstrip Patch Antenna

III. SIMULATED RESULTS FOR CONVENTIONAL RECTANGULAR MICROSTRIP ANTENNA

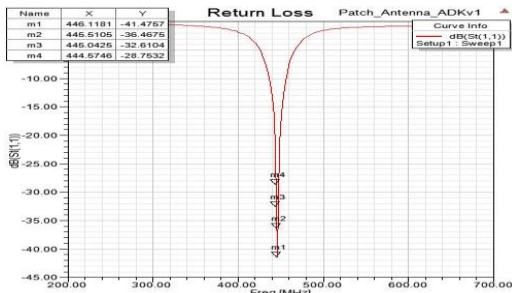


Fig.4:Return Loss vs frequency plot

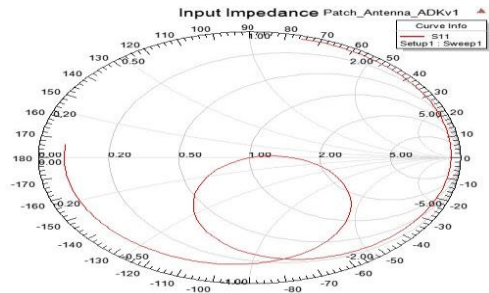


Fig.5: Input impedance of patch element plot

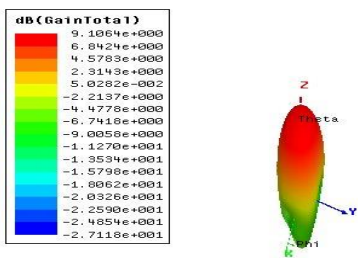


Fig.6: 3D Radiation pattern of patch antenna

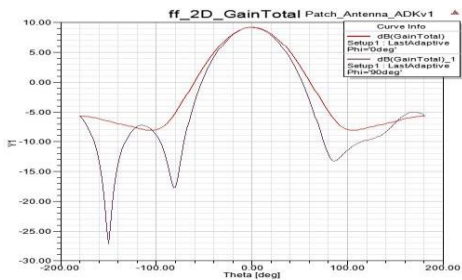


Fig.7: 2D Radiation pattern of patch antenna.

IV. SIERPINSKI CARPET FRACTAL ANTENNA

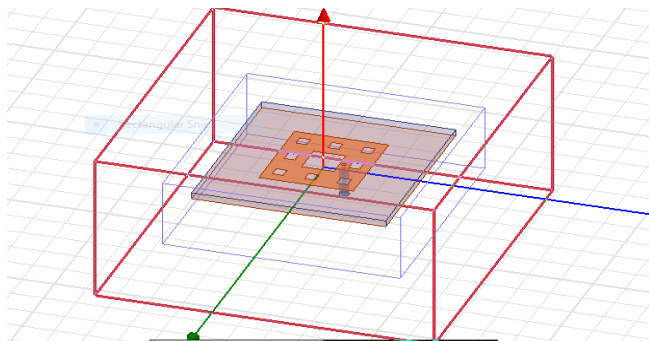


Fig. 8: Sierpinski Carpet fractal antenna Simulated model

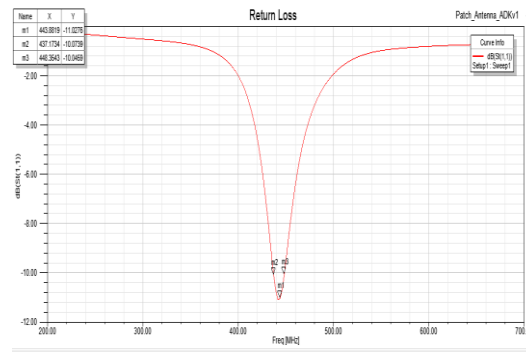


Fig 9: Return Loss (S11) parameter plot for fractal antenna

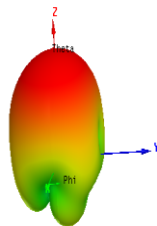
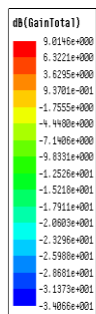


Fig10:3D Radiation Pattern for fractal antenna

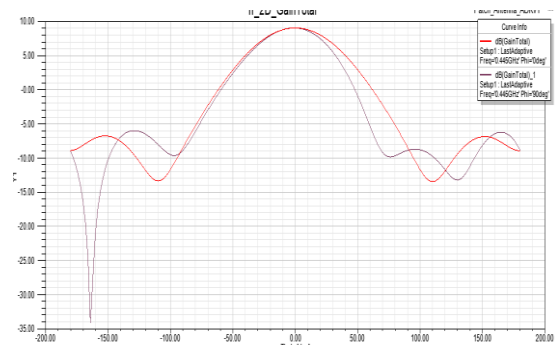


Fig11:2D Gain plot for fractal antenna

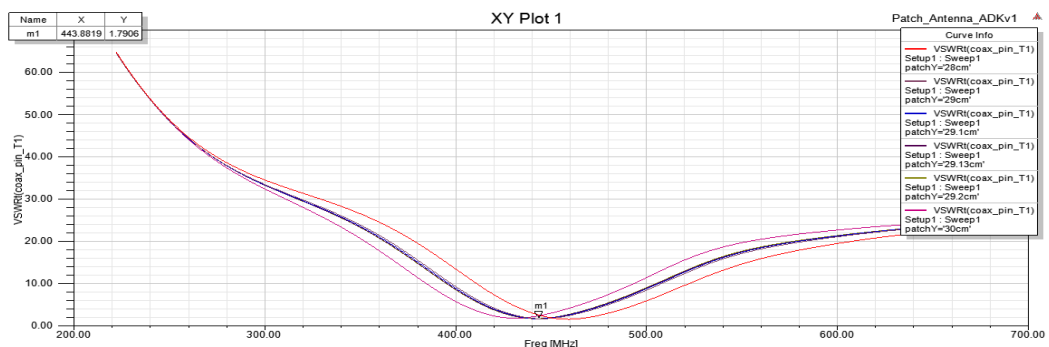


Fig 12 :VSWR Plot for fractal antenna

V. CONCLUSION

Here Sierpinski Carpet fractal Antenna is proposed with two iterations. When compared with Conventional Rectangular microstrip Patch antenna, a reduction of about 21 % is achieved in antenna weight and size. Return loss,VSWR, Directive gain, impedance bandwidth of Sierpinski Carpet fractal Antenna and Conventional Rectangular Microstrip Patch antenna are almost same values at 445MHz. Hence fractal antenna is more suitable than the conventional Rectangular Microstrip Patch antenna for wind profiler Radar in reducing antenna array size.

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