International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-2 Issue-4, April 2013

Radiation Pattern Analysis of a Fractal Micro-Strip Patch Antenna

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Abstract- ***There are number of methods that can be used to reduce the size of the antenna especially when it is too be used at lower operating frequencies. Fractal is one of the ways which can be used to miniaturize antennas due to their space filling ability. It helps in fitting large electrical lengths into small volume. In this paper the the radiation pattern of 1X4 array of micro-strip patch antenna over fractal geometry can be observed.***

Key words: Fractal antenna, micro-strip patch antenna, ADS software, returns loss

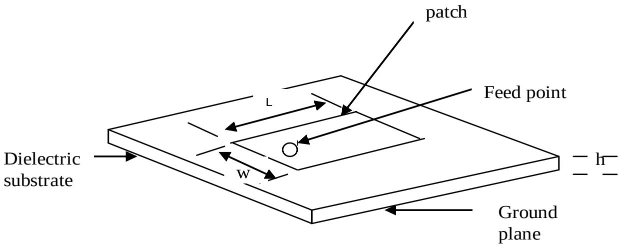
The micro strip patch antenna has following advantages.

i. They are low profile antennas.
ii. They are easily comfortable to non planar surfaces.
iii. They are very easy and inexpensive to manufacture in large quantities using modern printed circuit techniques.
iv. When mounted to a rigid surface, they are mechanically robust.
v. They are versatile elements in the sense that they can be designed to produce a wide variety of patterns and polarizations depending on the mode excitation and the particular shape of the patch used.

Micro-strip Patch Antennas:

A Micro-strip patch antenna is a thin square patch on one side of a dielectric substrate and the other side having a plane to the ground. The patch in the antenna is made of a conducting material Cu (Copper) or Au (Gold) and this can be in any shape, rectangular, circular, triangular, and elliptical or some other common shape. The basic antenna element is a strip conductor of length L and width W on a dielectric substrate with constant εr; thickness or height of the patch being *h* with a height and thickness *t* is supported by a ground plane. The rectangular patch antenna is designed so as it can operate at the resonance frequency. The length that is for the patch does depend on the height, width of the patch and the dielectric substrate.

Geometrical configuration of Rectangular Micro strip Antenna



The rectangular micro strip antenna is the rectangular patch mounted on a dielectric substrate of thickness h, shown in above fig.

Manuscript published on 30 April 2013.
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Micro strip patch antenna consists four parts.

A very thin flat metallic region called the patch dielectric substrate

Ground plane

A feed, which supplies RF power to the radiating element

Feed may be coaxial feed and inset feed.

Dimensions of the Rectangular Patch

The dimensions, bandwidth and gain of the micro-strip patch antenna are determined by the operating frequency of the antenna, the relative dielectric constant, and thickness of the substrate material.

The following formulas are based on the transmission line model:

The width and length of a rectangular micro strip patch are given by,

$$W = \frac{C}{2 f_r} \left[\frac{\varepsilon_r + 1}{2} \right]^{-1/2}$$

$$L = \frac{C}{2 f_r \sqrt{\varepsilon_e}} - 2\Delta l$$

Where

C is the speed of light (m/s)

f_r is the operating frequency, MHz

ε_r is the relative dielectric constant and

ε_e is the effective dielectric constant

$$\varepsilon_e = \left[\frac{\varepsilon_r + 1}{2} \right] + \left[\frac{\varepsilon_r - 1}{2} \right] \left(1 + \frac{12h}{W} \right)^{-1/2}$$

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

Where h is the Dielectric thickness in cm.

Antenna Design

First of all, a conventional square microstrip patch antenna with patch dimension *WL*× as 28.2 mm x 28.2 mm, printed on a dielectric substrate FR-4 (*r*ε = 4.4) of thickness 1.6 mm, with resonating frequency 2.46 GHz is designed as shown in Fig.1. This conventional antenna is treated as the basis for the comparison in terms of size reduction.

Next, the structure is modified by the addition of multiple V-groove along the length and width in three steps, which corresponds to the three iterations of the fractal generation. The addition of the groove is based upon the “Koch curve”. The starting structure is a square patch. Each straight segment of the square is divided into three equal parts. The middle part is replaced by two straight lines meeting at 600 angle (a bent) and they fit into the original gap in an equilateral triangular fashion as shown in the Fig. 2. Thus the dimension of each newly generated straight line is now one third of the original straight line and each side of the square when stretched out, increases by one third of the original length.

The iterative process of dividing a straight line into three equal segments and replacing the middle by a bent curve is continued. In the true fractal, this process is repeated for infinite number of times. In the present work, three iterations are considered and the fractal patch obtained is shown in the Fig. 3. This figure shows the proportionate reduction in patch area by keeping the total perimeter of the square constant after each fractal iteration. Thus with each iteration, the total perimeter of the square increases by 4/3 times the original perimeter of the square. It is observed that although the length of the radiating patch with proportionate reduction is kept constant at 28.2 mm but the resonant frequency does not remain constant at 2.46 GHz..

Ferrite and YIG are the main ferromagnetic materials. The magnetic permeability (μr) of these substrates can be changed by varying the biasing magnetic field, which is utilized to tune the resonance frequency of the MSA. Besides having high εr, these materials have high μr, leading to further size reduction in MSAs.The most commonly used ceramic substrate is alumina, which has very low loss brittle. The semiconductor materials are silicon and galliumArsenide (GaAs), which have a high εr. The substrates of synthetic and composite materials are suitable for designing MSAs, but the cost of these substrates is high. New varieties of substrates are available with reasonably low tan δ with prices as low as one fourth of the prices of the synthetic and composite substrates, allowing for reductions in the cost of the MSA.To sum up, the choice of the substrate are the first step in the successful design of an MSA. Besides electrical and mechanical parameters, there are many other physical and chemical properties of the substrates, including flexibility, power handling capability, chemical resistance, ruggedness, strain relief, bond ability, and nonporous ness. These factors also influence the decision of the selection of the substrate.

For micro strip antennas the dielectric constants are usually in the range of 1.03 to 12. Dielectric constants in the lower end of the range can give as better efficiency, large bandwidth; loosely bound electric field for radiation into space, but at the expance of large element space.

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GaAs	13	0.0006	--
Silicon	11.9	0.0004	--

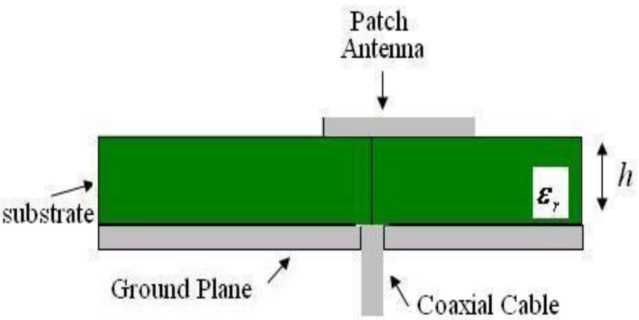


Fig: Micro strip Rectangular patch with coaxial feed Patch parameters are calculated as follows.

Frequency (in GHz) = 1.35

Dielectric constant of the substrate = 2.2

$$W = \frac{C}{2f_r}\left[\frac{\varepsilon_r + 1}{2}\right]^{-1/2}$$

$$L = \frac{C}{2f_r\sqrt{\varepsilon_e}} - 2\Delta l$$

W=88mm

L=87mm

Beam width of an array

No of Elements of the Array and array size can be calculated based on the AZ and EL beam width requirements.

$$\theta = \frac{51\lambda}{D} \text{ deg}$$

Where θ is the beam width and D is the diameter of the array.

The expected beam width for the array is ^{0}

Antenna Array Gain

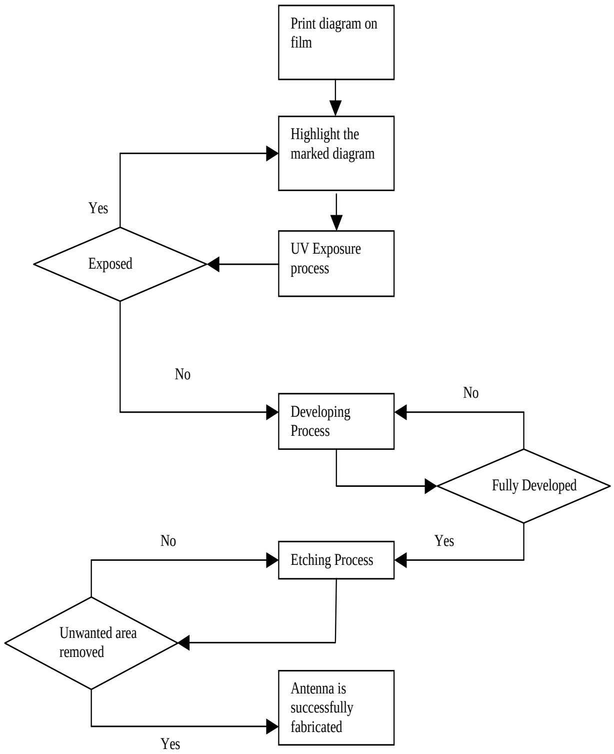
Gain of the antenna can be given by

$G = 4\pi\eta A_e/\lambda^2$

The expected and simulated gain of the patch is 10.43Db

Element Spacing

To have a wide covering angle in AZ & EL without grating lobe the elements has to be placed denser.



Fabrication flow chart- Micro-strip Patch Antenna

3D Radiation pattern of 1X4 array antenna

The radiation pattern of a generic dimensional antenna can be seen below, which consist of side lobe, black lobes, and are undesirable as they represent the energy that is wasted for transmitting antennas and noise sources at the receiving end the pattern is below,

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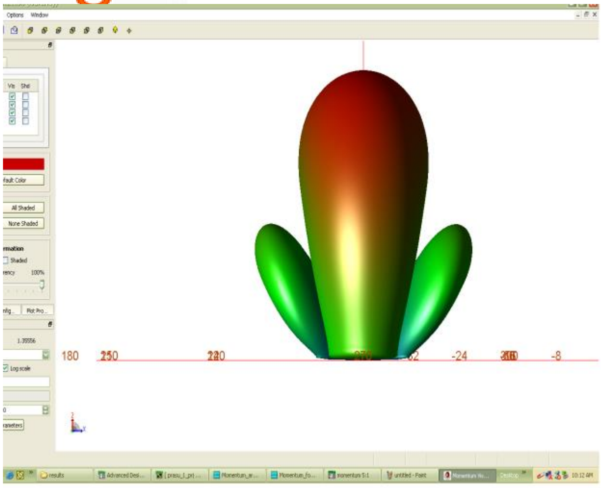
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)



The Method of Moments (MoM) simulators like Momentum, thus requiring the use of full 3D simulation methods, such as Finite elements (FEM) or time domain (FDTD) approaches.

3D Current Distribution

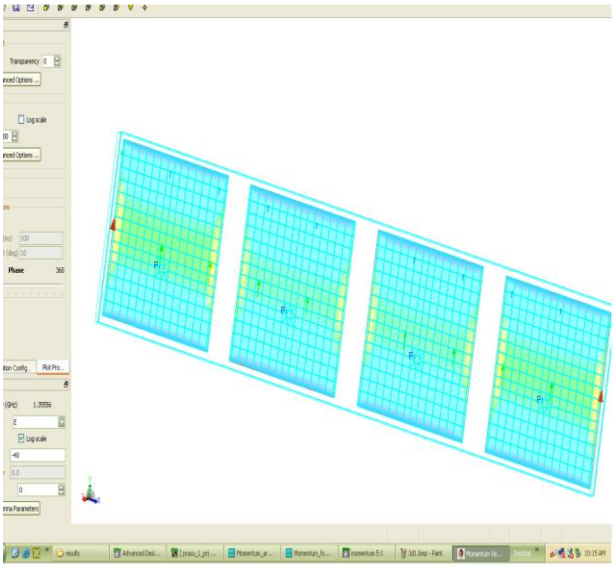


Fig: 3D Current Distribution

CONCLUSION

Fractal patch antennas are good candidates for size reduction as large electrical length can be fitted into the small physical volume. The radiation pattern of 1X4 elements of micro-strip patch antenna can be observed. Further iteration methods are applied for reducing the geometry.

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