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Fabrication of Hybrid Fractal Microstrip Antenna for Mobile and Wi-Max Applications

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Abstract: This paper presents the fabrication of an octagonal fractal hybrid micro strip radiator patch antenna that operates over a frequency range of 1.5 GHz to 2GHz suitable for low frequency wireless and mobile applications. The radiator has a dimension of 85x85mm^{2}on the radiating side and 100x86mm^2 ground plane. The model is fabricated on Fire Redundant4 substrate with thickness of 1.6mm over a 10x10mm^{2}dimension and uses coaxial feeding technique. The model is tested for its performance in the range of 1.5 to 2 GHz on the radiator test bench consists of MIC10 antenna trainer kit with an allowable frequency of up to 2GHz. The radiation characteristics shown are having good return loss and average gain of 39dB with omni directional radiation pattern. The size is to be optimized as the dimensions are very large compared to the usual requirements.

Keywords: Parasitic patch, Low Frequency, Octagonal Shape, Micro Strip Antenna, Dielectric Constant, VSWR Resonant frequency.

I. Introduction

GA. Desschamps in 1953[1] was the first to propose patch radiator in its most basic form, and described it as a radiating element on one side of a substrate and a planar surface on the other side. The bottom ground plane is customarily larger to the active patch. On a radiator, the flow of current is sideways, the direction of the electric field $\vec{E}$ & feed wire, follows the current. A simple patch antenna radiates a linearly polarized wave. The key demerit of this type of radiator is its thin bandwidth. To obtain wider bandwidth, thicker substrates are to be used, but thicker substrates often suffer from surface wave. Microstrip antennas also suffer limitations like less efficiency, lower gain and power handling capacities. The use of thick substrates (height), cutting slots in metallic patch, scrounging patches can help in rise in the performance of the antenna. The common microstrip patch antennas, the geometrical shapes or any other continuous shape. The use of dielectric spacers and metal patch that is mounted above a ground plane, is used as a replacement to the dielectric substrate some patch antennas, is less rugged but has more bandwidth.

Practically the dimensions of a microstrip antenna is contrarywise to the operational frequency. The radiation patch is generally made of quick conducting material [2] like copper (CU) or gold(AU). This paper elevates the fabrication and testing of a new geometrical antenna with fractal hybrid octagonal shape and is suitable for network or cellular applications. The radiator profile is chosen to be octagonal as it has the benefit of occupy small metalized area on substrate than other configurations.

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II. DESIGN OF OCTAGONAL FRACTAL PATCH

Fractal antennas are also referred to as multilevel and space filling curves, but the key aspect lies in their repetition of a motif over two or more scale sizes, or "iterations". For this reason, fractal antennas are very compressed, multiband or wideband, and have useful applications in cellular & microwave communications.

A paper published by Mandelbrot describes geometric fractals as "a irregular or fragmented geometric shape that can be split into parts, each of which is a reduced-size copy of the whole" but limited.

The proposed Octagonal shaped patch antenna is iterated for creating a fractal structure having self-similarity. An octagonal structure is chosen as it can be regular [4] or irregular, and regular octagons have sides that are congruent which means that all of the sides of the octagon are the same measurement. They have congruent angles. The exterior angles of a regular octagon are 135°and the interior 45°.

It is important to note that regular octagons are always classified as convex while irregular octagons can be either concave or convex.

The area of an octagon is given by the formula

$$A = 2\left(1+\sqrt{2}\right) * a^2 \qquad (1)$$

where a is side of an octagon, and the resonant centre frequency of 1.8GHz by the equation given below

$$F_r = \frac{Xmn * C}{2\pi A\sqrt{\epsilon_r}} \qquad (2)$$

Equation 2 is given in [3], where "F_r"is the center frequency, "X_{mn}" is 1.8411, "C" is velocity of electron in free space (3x10^8 meter/sec) "ϵ_r" is relative permittivity of dielectric medium and "A" is the actual radius of the shape.

The width and length of the antenna is given by the relation

$$W = L = \frac{c}{2\pi\sqrt{\epsilon_r}} \qquad (3)$$

Fig 1. Octagonal patch antenna –Top view

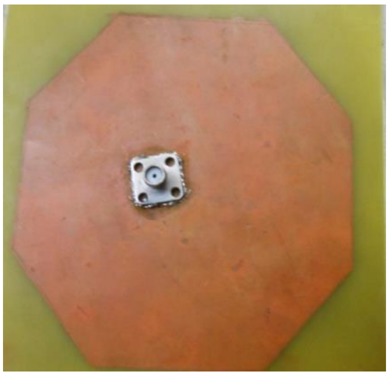

Fig 2. Octagonal patch antenna –Bottom view

Table -1 Antenna Details

Description	Details
Patch antenna shape	Octagonal
Frequency Fr	1.5 to 2 GHz
Length	85mm^2
Width	85mm^2
Ground	100x86mm^2
Substrate material	FR4
Dielectric constant	4.4
Height of substrate	1.6mm
Feed	Coaxial feed

The inner octagonal geometry side is 1cm. the area of each octagon is 1cm^2. There are 14 octagons and the complete area of the full patch is 85mm^2. The profile of the radiating patch is premeditated in the form of an octagon with effective side equal to 85mm, the S_0 (effective area) of the patch. But since the space between the cascaded interior octagons are removed in the design course thus making via slots to form 3 corner angles and parallelogram. The side of each triangle is 5mm.

Area of triangle of side 5mm = $\frac{1}{2} * b * h$ =12.5mm

No of such triangles are 27.

Area of parallel gram = base X height = 5mm & 5mm=25mm^2.

No of such parallel grams are3.

Table- 2 Patch Measurements

Parameter Description	No.of shapes	Values (mm)	Area removed
Octagon shape	14	10	
Triangle (via slots)	27	5mm	12.5mm / each (S1)
Parallelogram	3	5mm	25mm/ each (S2)
Total area of the patch = S=S0-(S1+S2)		7225 - (337.5+75) = 6812.5mm^2	

III. FEEDING TECHNIQUE

A variety of approaches are existing for feeding the microstrip patch. In contacting technique, the Radio Freq. power is fed directly to the radiating patch using a connecting component such as a microstrip line with coaxial feed or probe feed [3], while the non-contacting feed mechanisms and are complex to design.

The probe feed or coaxial is a very common method used for radiating antennas. The benefit of this feeding scheme is that the feed can be placed at any chosen position inside the radiating patch area to match the input impedance of (50Ω). This feeding technique is easy to fabricate and has very low spurious radiation.

IV. FABRICATION PROCESS

This process involves the artwork preparation, fabrication, etching process and connecting the suitable connector.

Dielectric substrate: In this design, a double-sided copper clad FR4 PCB material was used to create the antenna. This FR4substrate is suitable for operation up to 10 GHz frequency with a dielectric thickness of 1.6 mil.

Connector: To connect the antenna to transmission lines for testing a BNC connector was first considered. But BNC connectors do not have good frequency response in the GHz range. Thus, 50Ω SMA connectors were chosen. The SMA connector's offer good impedance matching up to18GHz.

Radiating and ground plane: The octagonal shaped fractal antenna of 10x85mm^2 was printed on bottom side of substrate as ground plane and the proposed hybrid fractal octagonal structure was printed on top of the substrate as the radiating element with coaxial cable feed. Generally larger ground planes allow better radiation performance, but the trade-off must be made against the size of antenna.

Etching Process

Etching Process generally consists of following steps

- Micro strip laminates are cut into required size.
- Then print the layout on oilpaper and transfer it on to micro strip substrate by applying heat (using iron box).
- In etching process the printed micro strip laminate is kept in a chemical liquid (ferric chloride) to wipe off unwanted copper area.
- After etching process rinse the PCB with running water to remove traces of chemical liquid.
- After rinsing process allow the PCB for drying and thorough verification of the layout is to be observed for any leakages or hairline cracks.
- Cut the substrate material to the dimensions mentioned
- Drill a hole on the layout where the 50Ω impedance matching is identified as the feed point location.
- Then a 50Ω SMA connector is fused at the feeding point on the antenna.

The overall process for fabrication from the beginning to measurement is shown in the below chart:

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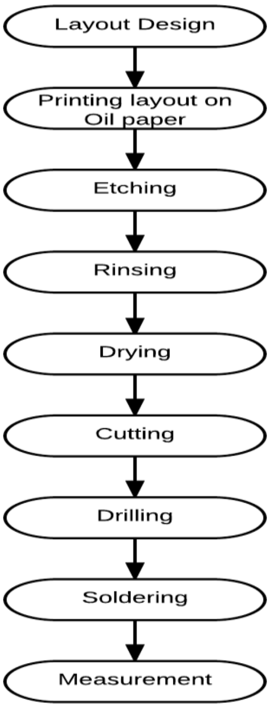

Fig. 2 Flow chart (fabrication process)

V. ANTENNA MEASUREMENTS

The antenna parameters are measured using MIC10 antenna trainer kit. From the fig 5. the transmitting and receiving antennas are positioned approximately 1meter apart. A typical dipole patch antenna is used as transmitter and test antenna as the receiver, the radiation pattern and gain values are measured. initially the dipole is to be placed in horizontal plane, and the receiver antenna to azimuthal direction to get E plane plot. In the experimental setup the dipole antenna is positioned on the transmitting trivet, and the proposed antenna is fixed to stand with stepper motor. The test antenna is allied in line to the transmitter by supervising the stepper motor.

The designed antenna is tested at 1500MHz, to obtain the radiation pattern, gain and bandwidth following set up.

Step1: Frequency is set as 1500MHz in both transmitter and receiver.

Step2: Fix the stepper motor step size 5 degrees, fast mode and clockwise direction.

Step3: After fixing properties of stepper motor, keep MIC10 source and receiver in auto mode.

Step4: After that, the receiver antenna starts rotating, to complete 0-359 degrees in steps of 5 degrees.

Step5: Next Rx will then start storing readings in its memory. After that readings will be uploaded to PC after selecting uploading option from receiver menu. The receiver will upload all locations to the computer.

Step6: Next open the antenna polar plot system software for plotting relevant readings selected locations from software control panel say 1 to 72 respectively.

Step7: To print a plot click on print button after right click on plot. A standard windows print dialog box is presented.

Step8: Next save the plot in any editing programs in any format.

Step9: Save the readings in a file by clicking save as button. A standard window save dialogue box is present.

The antenna trainer kit equipment which is used to test the antenna is shown below:

Fig. 4. MIC10 Kit analyzer Source

Fig. 5 MIC10 Receiver Kit

Fig.6 Stepper Motor Controller Unit

5.1. Polar plot

We can see from the above figure we had obtained a polar plot which is Omni-directional in nature and which has a maximum gain. From the above plot we had calculated and observed a half power beam width (HPBW) of 61.5^0 and average gain of 39db.

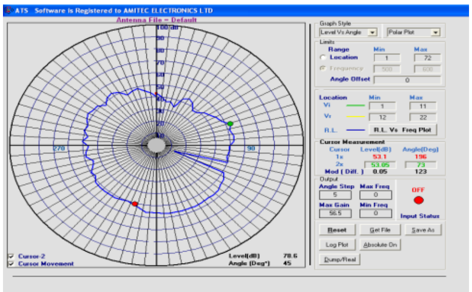

Fig. 7 Radiation Pattern (Level Vs Frequency)

5.2. Cartesian Plot

For Finding the Cartesian plot we had set source in auto mode for verifying the operation of antenna in (1500-2000) MHz and stepper motor is switched off while finding Cartesian plot

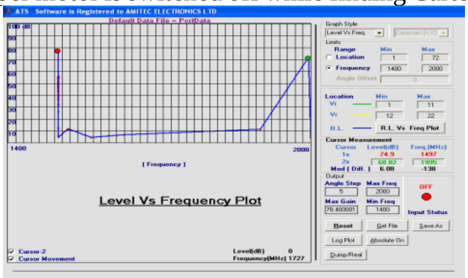

Fig. 8 Cartesian graph (Level vs Frequency)

By studying the Cartesian plot mentioned above it can be observed that maximum gain is obtained at frequencies 1500 and 1980 MHz.

5.3 Horizontal polarization:

Polar plot:

The result of the polar plot shows that Omni-directional in nature and a maximum gain of 50.2 db. From the above plot we had calculated and observed a half power beam width (HPBW) of 77.5^0[4] and average gain of 37db.

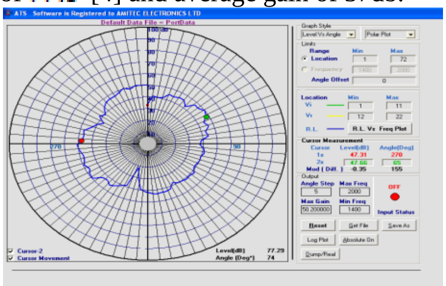

Fig.9 Radiation pattern (Level Vs Angle)

Cartesian Plot:

For Finding the Cartesian plot we had set source in auto mode for verifying the operation of antenna in (1500-2000) [5] MHz We observed that maximum gain is obtained at two frequencies 1500 and 1998 MHz same as vertical polarization.

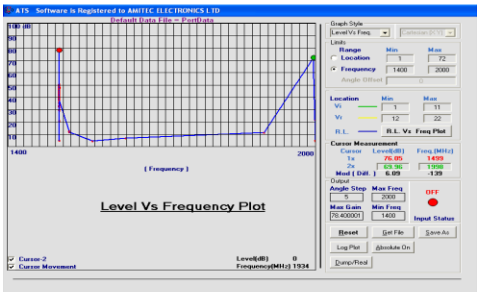

Fig.10 3Cartesian graph(Level vs Frequency)

VI. CONCLUSION

The proposed octagonal fractal hybrid antenna works in the frequency range of 1.5GHz – 2GHz. The octagonal radiator structures has fractal geometry, the via slots[6] formed are of squares and triangles shapes and decreases the electrical length by a few centimeters. In simulation the feed location is placed near the edge of the patch and observed that the current rotation on the surface of the radiator patch is less. The port is shifted to the middle to match with the 50Ω impedance [7] and measurements are verified, this resulted in radiation of current with almost equal distribution over the surface. Instead of change in feed port if a substrate material can also be used with large permittivity can be more apt. The proposed antenna has a return loss and average gain is 39dB which means that the antenna is having a considerable impedance matching and requires fine tuning the antenna so that it is suitable for wireless applications [8].

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