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Design and Simulation of Compact Multiband Microstrip Fractal Patch Antenna for C Band Applications

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ABSTRACT: In recent years multiband fractal patch antennas have their own capability because of their multiband operation. This paper presents a rectangular shaped fractal antenna, which resonates at 4.18GHz, 5.02GHz, 6.45GHz,7.08GHz.Three iterations has been applied to basic rectangular patch in terms of rectangular slots to obtain multiband. This antenna finds the application in the area of military and defense applications. The proposed multiband antenna operates in C (4 to 8GHz) band, where it can be used for Radar and secure communication. The antenna is designed in IE3D simulation software. The results are analyzed in terms of return loss, VSWR and gain of the antenna with radiation pattern.

KEYWORDS: Fractal shape, IE3D, Multiband, rectangular slot.

I. INTRODUCTION

The increase in demand for wireless communication system has attracted significant interest in antenna design. Many novel designs are being proposed for multiband antenna. Microstrip patch antennas are gaining popularity for use in modern wireless communications systems due to their low-profile, low weight, low cost structure. Therefore they are extremely compatible for defence antennas in wireless communication such as Radars, satellites etc.

The various fields of applications such as in the radar applications, satellites and even in the military systems like in the aircrafts, missiles, rockets, etc. The microstrip antennas are having more usage in all the fields and areas and now they are gaining popularity in the commercial aspects due to the low cost of the substrate material and fabrication. The patch antennas are also used as wide range over the conventional antennas because of their good advantages over conventional antennas and maximum application in the various areas such as military, defense, radar, satellites, etc.

Radar Application: Radar is used for detecting moving targets example people and vehicles. It requires a low profile, light weight antenna subsystem, the microstrip antennas are the ideal choice. The fabrication technology is based on photolithography and enables the bulk production of microstrip antenna with reconfigurable characteristics and performance at a cheaper cost in a lesser time as compared to the conventional antennas.

Related work

The fractal word meaning is broken or irregular fragments were first defined by Benoit Mandelbrot in 1975 to represent a family of complex shapes that possess an inherent self-affinity and self-similarity in their geometrical structure. A self-affine set is a well-defined contraction which reduces an image by different factors horizontally and vertically [7] whereas a self-similar is one that consists of iterateddown into copies of itself i.e. a contraction which reduces an image by same factors horizontally and vertically [7]. Due to these properties, fractals have infinite complexity and detail. As long as you are zooming in on the right location, their complexity and detail remain the same no matter how far you zoom-in.The patch antennas are having advantages over conventional light weight and low volume, low profile, low fabrication cost, supports multiband frequency operations, and it is mechanically robust when mounted on rigid surfaces [1]in making such low-profile systems in communication domain, the size of the antenna is critical. Therefore, many kinds of miniaturization techniques, such as the substrates of high dielectric constants, applying resistive or

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reactive loading and optimizing the shape by increasing the electrical length of the antenna, have been proposed and applied to microstrip patch antennas. By applying iterations of fractals into antenna elements:

• We can create smaller antenna size.
• The multiband characteristics can be achieved with different resonant frequencies.
•The optimization can be done in terms of gain and shape of the antennas in order to increase their electrical length.

There are two main features in fractal geometries i.e., self-similar and space filling properties, the advantages of fractal shape antenna elements are: wide bandwidth, multi band, and reducedantenna size, among others [2]. The size of antenna can be reduced without affecting the performance of the antenna for the same resonant frequency, such as the return loss,VSWR and radiation pattern by etching the rectangular microstrip patch antenna as fractal based with limited iteration orders. The same method is proposed in this paper for reducing the size of multiband antenna at C band frequencies [3].In [4], the hexagonal fractal antenna has been found to possess multiband behaviour similar to the Sierpinski gasket antenna. Also, it has been stated that larger frequency separation is required to match the antenna which allows flexibility in multiband operations. Unlike the Sierpinski gasket antenna resonant frequencies which repeat with a factor of two, the hexagonal fractal antenna repeats with a factor of three for resonant frequencies.A novel and compact printed monopole antenna [5] was presented with simple but radiating patch for multiple wireless mobile communication and mobile devices. The circular polarizationwith multiband operation[6] and radiation was obtained by combining square and Giuseppe Peano fractal geometries, which were realized on two layer microstrip antenna.

II. PATCH ANTENNA DESIGN EQUATIONS

First a rectangular patch antenna is designed using the following design equations,

$$W = \frac{c}{2f0\frac{\sqrt{\varepsilon r+1}}{2}} \quad (1)$$

$$\varepsilon e = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}[1 + \frac{10h}{W}]\hat{}(-0.5) \quad (2)$$

$$f0 = \frac{c}{2\sqrt{\varepsilon r}}[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2]\hat{}0.5 \quad (3)$$

$$Le = L + 2\Delta L = \frac{\lambda}{2\sqrt{\varepsilon e}} \quad (4)$$

$$We = W + 2\Delta W \quad (5)$$

$$\Delta L = \frac{h}{\sqrt{\varepsilon e}} \quad (6)$$

Where,
W=width of the patch
εe= effective dielectric constant
fo= resonant frequency
Le= effective length
We= effective width

III. ANTENNA DESIGN AND IMPLEMENTATION

The above designed basic rectangular patch dimensions are given in Table I. The fractal iterations are applied upto 3 steps to obtain multiband characteristics. The rectangular slots are introducedin theiterations with reduced size. The figure 1(a),1(b),1(c) below shows all the iterated patches. The substrate material FR4 with dielectric constant 4.4 has been used with loss tangent of 0.025. A co-axial feed is used match the impedance and to feed input power to the antenna.

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Table-I: Antenna design parameters

Sl.No	Parameters	Antenna
1.	Lengthof patch((L)	48mm
2.	Width of patch(W)	57mm
3.	Substrate height	1.5mm
4.	Dielectric constant(ϵr)	4.4
5.	Loss tangent	0.025

IV. Simulation Results

The basic rectangular patch is iterated up to 3 steps to obtain the multiband characteristics with substrate of FR4 and height of 1.6mm. The figure 1 shows the basic rectangular patch which resonates at 3.1GHz. The figure-2 shows first iterated patch which resonates at 4.18GHz and 5.02GHz with return loss of -10.56dB and -12.13dB, VSWR of 1.84 and 1.69.

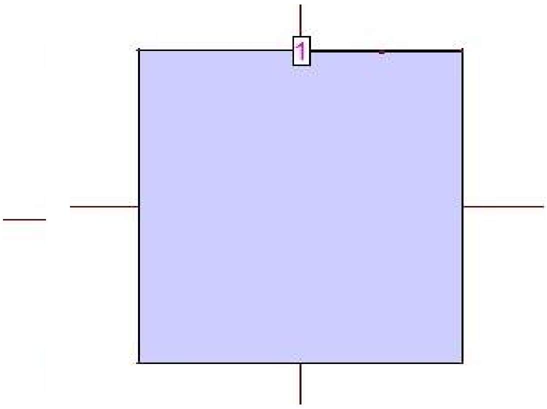

Figure-1

Figure-2

The second iterated patch is shown in the figure-3; the third iterated patch is shown in figure-4. The third iterated patch will give a good performance in terms of return loss, VSWR, Bandwidth and gain of the antenna.

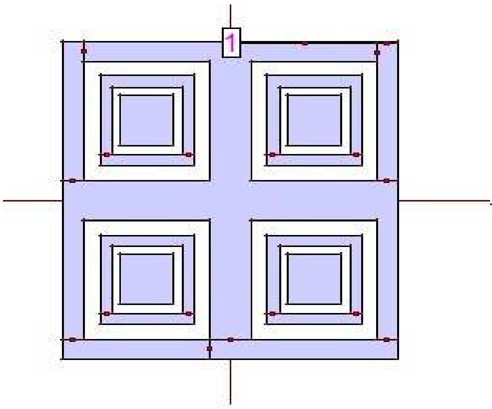

Figure-3

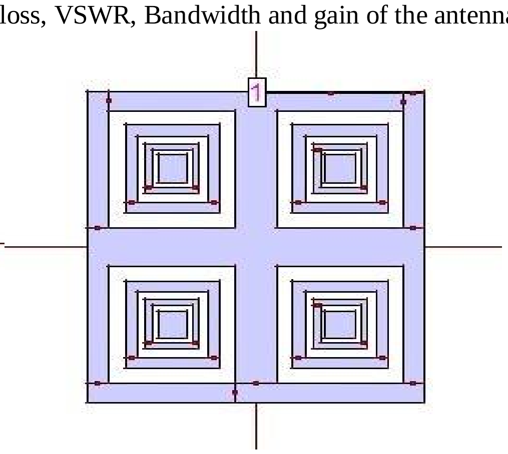

Figure-4

Figure 5 and 6 shows the return loss and VSWR of 3rd iterated patch. The bandwidth are analyzed at -10dB return loss cut with respect to resonant frequency.

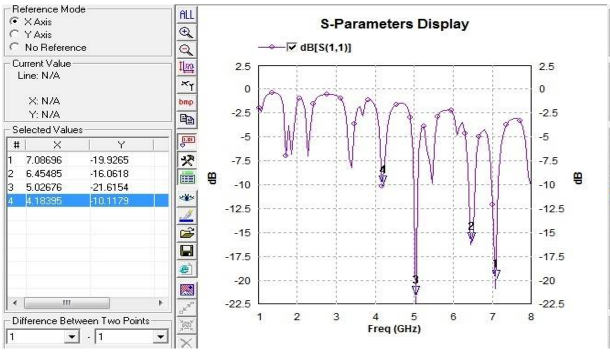

Figure-5

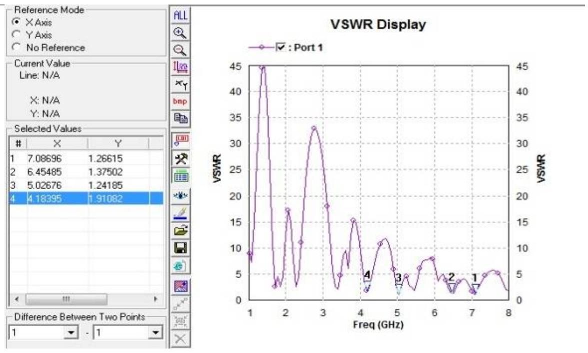

Figure-6

The Table-II shows the comparision of the itearted patches in terms of resonant frequency, return loss,VSWR and -10dB simulated bandwidth. The basic rectangular patch is resonated at 3.1GHz with return loss of -16.98dB,VSWR of 1.32 and bandwidth of 100MHz. The first iterated patch resonates at 4.18GHz and 5.02GHz with return loss of -10.18dB and -12.13dB respectively. The third itearted patch will give best performance in the C band. The third iterated patch has resonant frequencies of 4.18GHz, 5.02GHz, 6.45GHz and 7.08GHz with return loss of -10.11dB,-21.61dB,-16.06dB and -19.92dB respectively. The VSWR values are 1.91, 1.24, 1.37, 1.27 at repective resonant frequencies. The -10db simulated bandwidths are 10MHz, 100MHz, 120MHz and 160MHz ate repective reonant frequencies.

Table-II: Comparision Table of three iterated fractal patches

Iteartion No	Resonant frequency(GHz)	Return Loss(dB)	VSWR	-10dB bandwidth(MHz)
0	3.1	-16.98	1.32	100
1	4.18	-10.56	1.84	10
	5.02	-12.13	1.69	40
2	4.18	-10.11	1.91	10
	5.02	-21.63	1.24	50
	6.45	-15.85	1.38	100
	7.08	-15.79	1.38	100
3	4.18	-10.11	1.91	10
	5.02	-21.61	1.24	100
	6.45	-16.06	1.37	120
	7.08	-19.92	1.26	160

The radiation pattern of the antenna decides how much power is radiated by the antenna efficiently with respect to isotropic antenna.Figure 7 and 8 shows the radiation characteristics of the antenna at 7.08GHz and 6.45GHz with gain of 6.19dBi and 1.48dBi respectively, it is clear that the energy radiated in the main lobe only.

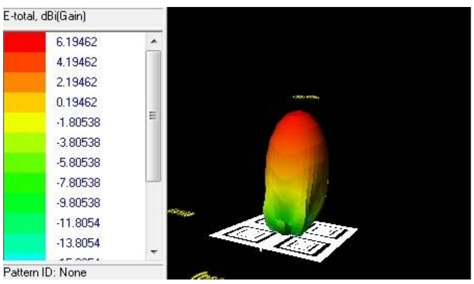

Figure-7

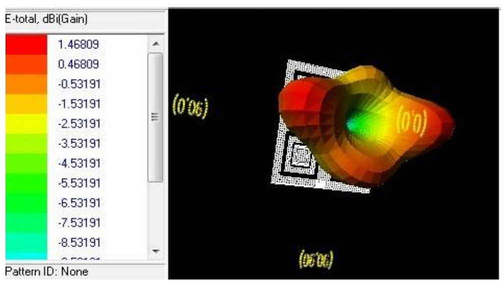

Figure-8

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V. CONCLUSION AND FUTURE WORK

By analyzing the simulation results, it has been concluded that by applying three iterations of fractal geometry,characteristics of antenna improve a lot. Initially a rectangularpatch is taken and antenna resonates at single band. Bythree iterations of fractal geometry, number ofbands increase from one to four. The effective area has been decreased and gain, bandwidths are increased by applying fractal geometry. Proposed antenna findsapplication for defense and secure communication, S bandand C band applications. These bands of operations used in secure and radar applications. The antenna resonates at 4.18GHz, 5.02GHz, 6.45GHz, and 7.08GHz with return loss of -10.11dB, -21.61dB, -16.06dB, -19.92dB, VSWR of 1.91, 1.24, 1.37, 1.26. The antenna has gain of 6.1dBi at 7.08GHz and 1.48dBi at 6.45GHz.

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BIOGRAPHY

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