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DESIGN OF MICROSTRIP PATCH ANTENNA USING CROWN AND SIERPIENSKI FRACTALS FOR WIRELESS 1 GHz TO 6 GHz WIDEBAND APPLICATIONS USING MICROSTRIP LINE FEEDING TECHNIQUE

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Abstract: - This paper presents a design of fractal microstrip patch antenna using Crown and Sierpinski fractal slots by cutting different slots on rectangular microstrip antenna and practically studied on IE3D software. This design is achieved by reaping multi shapes in crown and sierpinski fractal pattern and placing a microstrip feed line. This design has been studied in only one iteration. The radiation patterns of the proposed microstrip fractal antennas retained because of the self similarity and centrosymmetry of the fractal shapes. The proposed antenna is designed on a FR4 substrate of relative permittivity of 4.4 and thickness 1.524 mm and mounted above the ground plane at a height of 6 mm. Details of the measured and simulated results of the iteration is presented and discussed.

Keywords: Patch antenna, Radiation pattern, Returns loss, fractal shapes, IE3D software

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INTRODUCTION

The hasty development of the wireless communication system has requested the multi-band or broadband antenna in order to maintain the different technologies and standards. Wireless local area network has several standards i.e., IEEE 802.11 b/g operative frequency range from 2.4 GHz - 2.48 GHz, IEEE 802.11a/g operative frequency range from 5.15 GHz - 5.35 GHz or 5.725 GHz - 5.825 GHz. These WLAN standards are proposed for short range (100 - 200 meters) from the transmitter (Wi-Fi standards). An additional standard like IEEE 802.16 d/e is proposed to obtain wider coverage working at some other frequencies, and is known as Wi-Max technology. Wi-Max has several frequency allotments and varies from country to country. In Indonesia 2.3 GHz and 3.3 GHz frequency bands have been assigned to allow Wi-Max technology. Therefore, there is a requirement to designed antennas that can operate at different frequency bands to bear several technologies and standards [1]. UWB have broad applications in short-range and high-speed wireless systems, such as ground penetrating radars, medical imaging system, high data rate WLAN, communication systems for military and short pulse radars for robotics and .

1. ANTENNA CONFIGURATION AND DESIGN

A microstrip patch antenna is one of the most vital antenna design used for practical applications [2]. Rectangular patch antenna can be delineated as an array of two radiating narrow slits, each of width (W) and heights (h) separated by a distance (L) ,illustrated in Figure (1) [3]. Because the size of the patch is finite along the width and length, the fields at the boundaries of the patch experience fringing. Radiation will take place from these fringing fields which extend the effective open circuit beyond the edge.

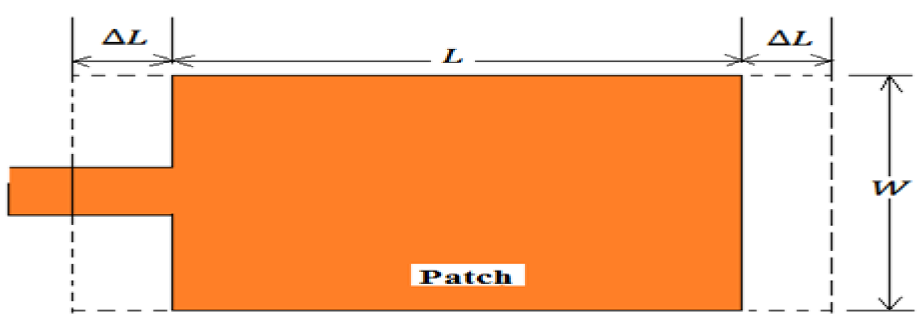

Figure 1: Effective length and actual length

Due to this fringing field, the patch is electrically slightly larger than its actual physical length. This difference between electrical and physical length is dependent on the height and dielectric constant of the PCB. This deviation is given by formula below.

For patch antenna the length and width are used as calculated from the equations (1). The expression for ε_{reff} is given by Balanis as [3]:

$$\varepsilon_{\mathrm{reff}} = \frac{\varepsilon_{\mathrm{r}}+1}{2} + \frac{\varepsilon_{\mathrm{r}}-1}{2}\left[1 + 12\frac{\mathrm{h}}{\mathrm{W}}\right]^{1/2} \quad (1)$$

The dimensions of the patch along its length have now been extended on each end by a distance ΔL, which is given empirically by Hammerstad as [4]:

$$\Delta \mathrm{L} = 0.412h \; \frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \quad (2)$$

The effective length of the patch $\mathrm{L}_{\mathrm{eff}}$ now becomes:

$$\mathrm{L}_{\mathrm{eff}} = \mathrm{L} + 2\,\Delta\mathrm{L} \quad (3)$$

For a given resonance frequency (f_0), the effective length is given by

$$\mathrm{L}_{\mathrm{eff}} = \frac{c}{2\, f_o \sqrt{\varepsilon_{reff}}} \quad (4)$$

For a rectangular microstrip patch antenna, the resonance frequency for TM_{mn} mode is given by James and Hall as:

$$f_o = \frac{c}{2\sqrt{\varepsilon_{reff}}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{1/2} \quad (5)$$

For efficient radiation, the width W is given by:

$$\mathrm{W} = \frac{\mathrm{c}}{2\mathrm{f_o}\sqrt{\frac{\varepsilon_{\mathrm{r}}+1}{2}}} \quad (6)$$

2. FRACTAL SLOTS

Fractals stand for irregular fragments. Fractals explain a composite set of geometries ranging from self similar/ self-affine to other irregular configurations. Fractals are usually self-possessed of several copies of themselves at different scales and hence don't have a predestined shape or size, which makes their use in antenna design very promising. Fractal antenna engineering is an engrossing field that employs fractal concepts for developing new types of antennas with notable characteristics. Fractal shaped antennas demonstrate some smart features which results from their geometrical properties [5]. The inimitable features of fractals such as self-similarity and space-filling qualities facilitate the realization of antennas with interesting feature such as multi-band operation and miniaturization. A self sowed set is one that consists of scaled down copies of itself. This property of self-similarity of the asymmetrical fragment geometry [6] aids in the design of fractal antennas with multiband feature. The self-sown current circulation on these antennas is expected to cause its multiband characteristics. The space-filling characteristics of fractals have a tendency to fill up the area occupied by the antenna as the order of iteration is increased. Higher order fractal antennas accomplishment the space filling property and enable miniaturization of antennas. Fractal antennas and arrays also display minor side lobe levels. Fractals have been applied effectively for miniaturization and multi-band operations of simple antennas generally loop, dipole, and patch antennas. It has been experiential that such as approach result in decrease of the input impedance bandwidth [7].

3. MICROSTRIP LINE FEED

In microstrip line feed technique, a conducting strip is connected directly to the edge of the microstrip patch [3] as shown in the Figure 2:

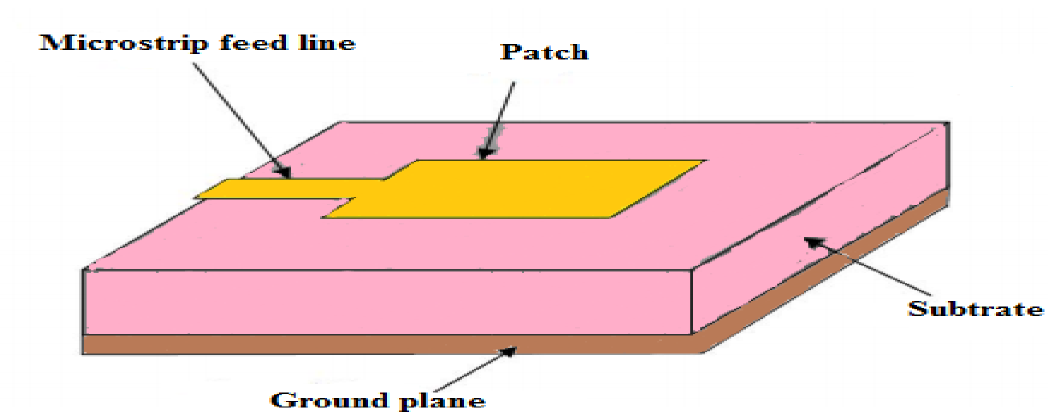

Figure 2: Microstrip line feed

The conducting strip is lesser in width as compared to the patch and this kind of feed arrangement has the benefit that the feed can be made on the same substrate to provide a planar structure. The reason of the microstrip line feed in the patch is to match the impedance of the feed line to the patch without the requirement for any additional matching element. This is achieved by properly controlling the feed position. Hence this is a trouble-free feeding scheme, since it provides ease of fabrication and simplicity in modeling plus impedance matching. However as the thickness of the dielectric substrate being used, increases surface waves and false feed radiation also increases, which hampers the bandwidth of the antenna. The feed radiation also leads to unwanted cross polarized radiation [3].

4. ANTENNA DESIGN

Designing an antenna in the wideband meant that the antenna dimension could be complex which is not desired. Bearing in mind this intention is to design a reduced size wide band microstrip antenna [8]. The design idea was taken from multi-band antennas to construct the antenna to operate in a different band of frequencies of the many broadband antennas a square patch antenna was chosen [9]. Hence the chosen shape of the patch was cutting of different Square and sierpinski fractal slots in iteration I. In this work, transmission line feed technique is used as its major advantage is that, the feed can be placed at any place in the patch to match with its input impedance (50 ohm). The software used to model and simulate the microstrip patch antenna using combining Square and sierpinski fractal slots by IE3D. This software is used to calculate and graph of radiation pattern, return loss, gain, smith chart, VSWR and other parameters. Wideband antennas that cover up all Wi-Fi and Wi-MAX frequency bands has been designed and simulated on FR4 substrate successfully. The wideband antenna characteristic covers the frequency of 2.3 - 6 GHz.

FINAL ITERATION I

The final geometry of iteration of projected microstrip patch antenna using Crown & Sierpienksi fractals shown in Figure 3. The design of iteration is achieved by cutting crown square fractal slots on a rectangular microstrip antenna. In the middle one crown square fractal slot is taken and four Sierpienski fractal slots are taken on each corner of the middle slot. The dimension of the central crown square fractal slot is 2 × 2 (length × width) and the dimensions of each of the four corner fractal slots are 1 × 1(length ×width).

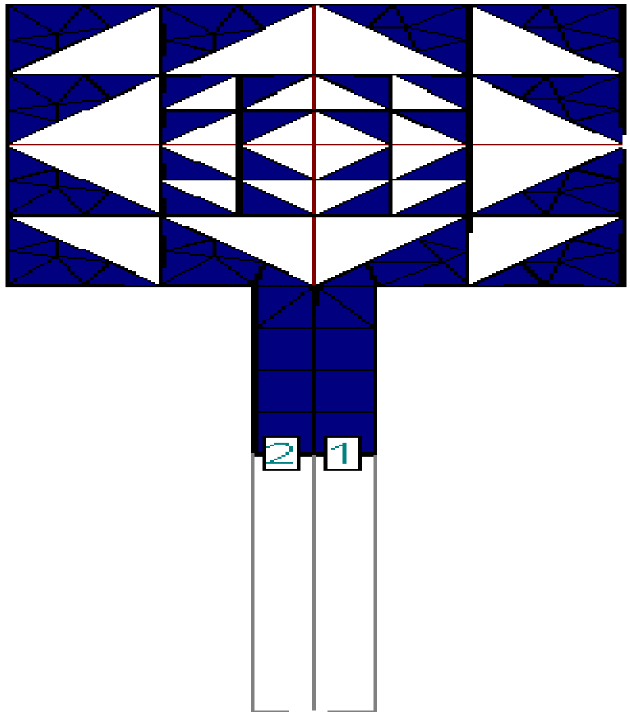

Figure 3: Geometry of iteration I (top view) with t = 1.524, Permittivity = 4.4 and grid size =0.025

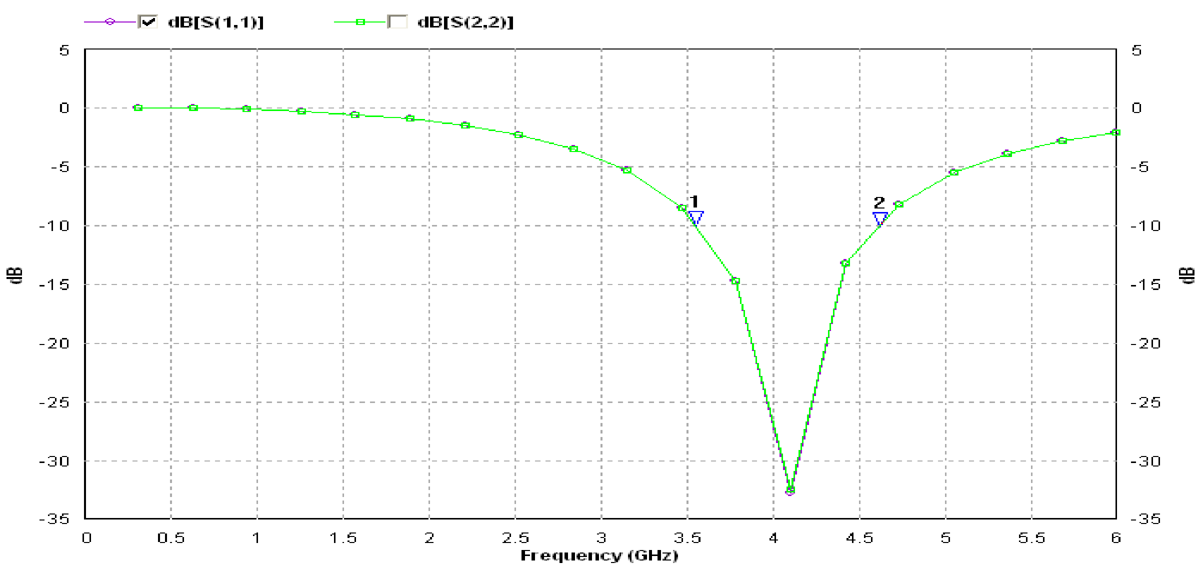

Figure 4: Return loss vs. Frequency curve of final iteration for proposed antenna

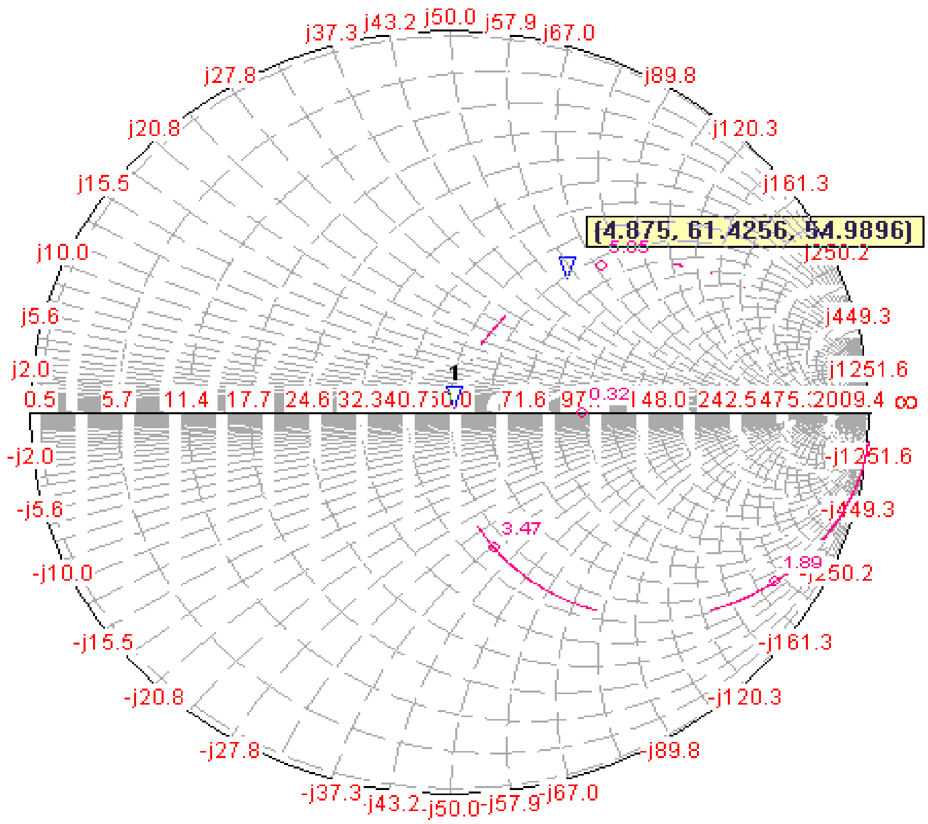

Figure 5: Input impedance loci using smith chart of final iteration

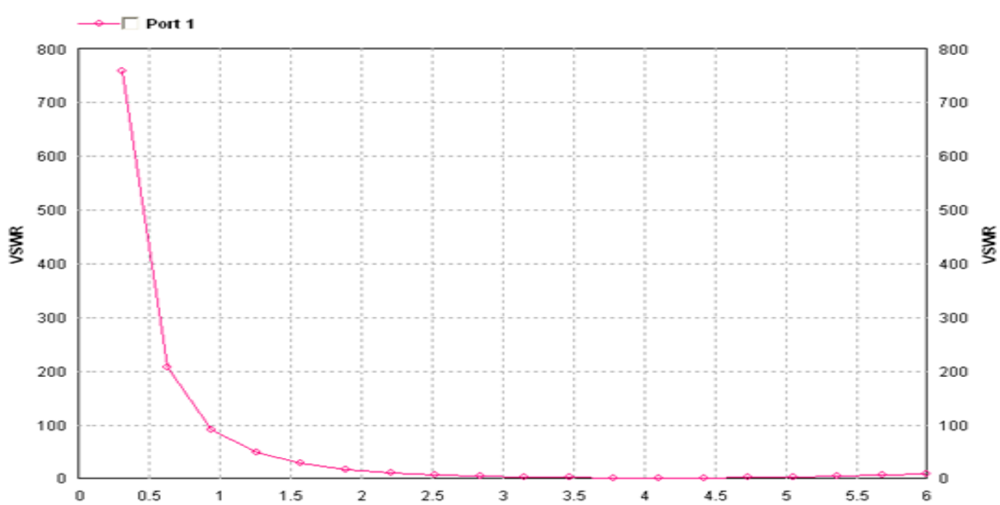

Figure 6: VSWR vs Frequency

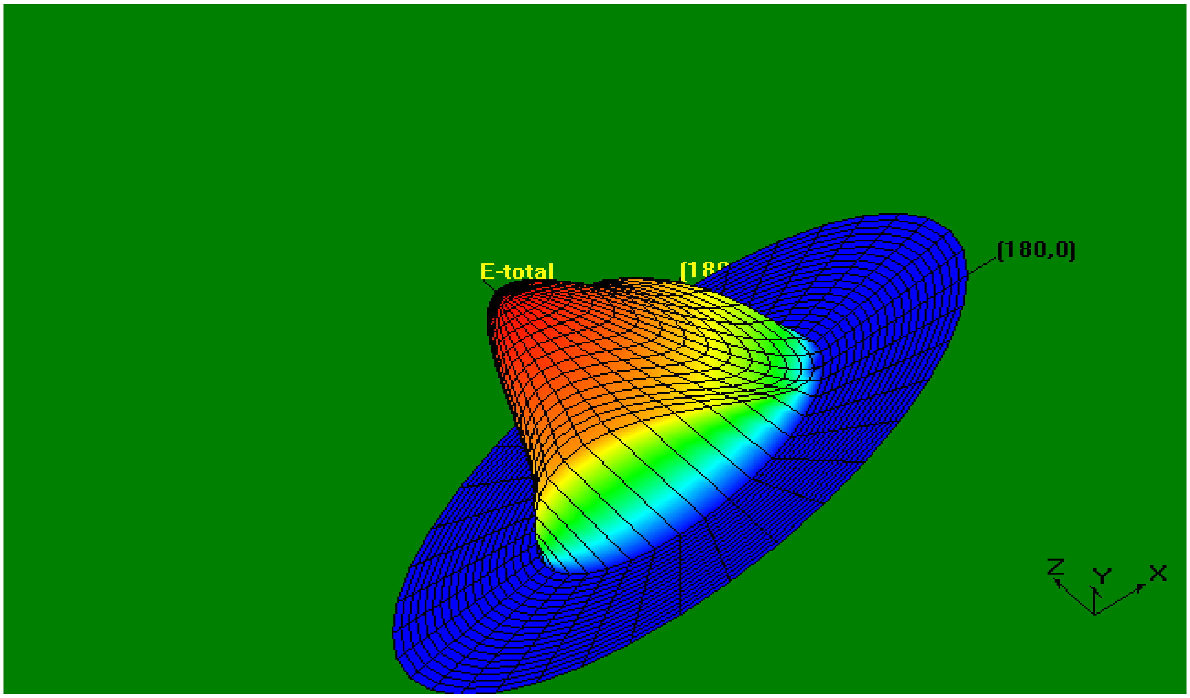

Figure 7: 3-D radiation pattern

Parameters	Calculated value
Resonant Frequency	4.15 GHz
VSWR	1.05
Return Loss	-33.4 dB
Bandwidth	30%

Table 1: Result of iteration I

5. RESULTS AND DISCUSSION

In this paper, microstrip patch antenna combining Crown and Sierpienski fractal slots slot are made-up on a FR4 substrate of thickness 1.524 mm and relative permittivity of 4.4. It is mounted over the ground surface at height of 6 mm. Table 1 shows the variation of Return Loss with frequency, VSWR and Bandwidth for iteration I. Figure 4 shows resonant frequency 4.15 GHz and minimum Return Loss for iteration I is -33.4 dB. Figure 5 shows the input impedance loci using smith chart for iteration I. In I iteration Input impedance curve passing near to the 1 unit impedance circle that shows the perfect matching of input and total available impedance bandwidth is 30% for iteration I. Figure 7 shows the 3-D radiation pattern which indicate that the antenna has a unidirectional radiation pattern.

The projected patch antenna has been simulated by using IE3D by Zealand Software Inc. It is well-considered as a benchmark for electromagnetic simulation packages. The primary formulation of the IE3D is an integral equation achieved through the utilize of Green's functions. In the IE3D software, it is probable to model both the electric current on a metallic structure & a magnetic current indicating the field allocation on a metallic aperture.

6. CONCLUSION

Designing of Multi-band or wide band antenna is the main challenge in wireless commutation system application due to bandwidth requirements. In this paper, a new model of microstrip wideband antenna using fractal geometries having better performance is designed. It is estimated that the antennas presented in this paper may have lot of applications in wireless communications. Simulation results show that the modeled fractal antennas have a multi-resonance behavior with fractional bandwidths sufficient for most of the wireless applications. Wideband antennas that cover up all Wi-Fi and Wi-MAX frequency bands have been designed and simulated on FR4 substrate successfully. The wideband antenna characteristic covers the frequency of 2.3 – 6 GHz. Traditional wideband antennas (log-periodic and spiral) and arrays can be analyzed with fractal geometry to shed new light on their working principle. More to the point, a number of new configurations can be used as antenna elements with better multiband characteristics. Due to the space filling properties of fractals, antennas designed from definite fractal shape can have far better electrical to physical size ratios than antennas designed from an understanding of shapes in Euclidean space.

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