MINIATURIZED HEXAGONAL-SHAPED FRACTAL SLOT MICROSTRIP ANTENNA FOR WLAN APPLICATION USING DGS

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Abstract

A hexagonal-shaped fractal slot microstrip antenna has been designed and simulated for WLAN (Wireless Local Area Network) application. Two iterations of hexagonal fractal slot antenna have been examined. The proposed second iterated antenna covers band from 2.42 GHz to 2.48 GHz which can be utilized for WLAN application. It offers a return loss of -47.37 dB, VSWR of 1.01 and radiation efficiency of 65.3 % at 2.47 GHz center frequency. 25 % of size reduction has been achieved using the hexagonal fractal slot. Further this reduction changes to 43.67 % with the introduction of defected ground structure (DGS) in the proposed antenna.

Keywords: Fractal, Defected Ground Structures, WLAN, Microstrip Antenna

1. Introduction

Microstrip antennas are popular for their attractive features, such as a low cost, light weight, and compatibility with monolithic microwave integrated circuits (MMICs).[1-3] There are many approaches to reduce the size of the antenna without much affecting the antenna performance. The application of the fractal geometry is one of the techniques.

The term fractal has its roots in the Latin word fractus which is related to the verb fangere (meaning: to break).[4-5] Variety of applications of fractals has been found of in engineering and science. One of those is fractal electrodynamics, in which fractal geometry is combined with electromagnetic theory for the purpose of investigating a new class of radiation, propagation, and scattering problems.[6-7] Fractal is a rough or fragmented geometric shape that can be subdivided into parts each of which is a reduced copy of the whole. Fractals are usually composed of multiple copies of themselves at different scales and hence do not have a predefined size which makes their use in antenna design. Fractal antenna is an antenna that uses a fractal, self similar design to maximize the length or increase the parameter on inside sections or the outer structure of material that can receive or transmit electromagnetic radiation within a given total surface area or volume.[8] Fractal antennas have performance parameters that repeat periodically with an arbitrary fineness dependent on the iteration depth. Iteration depth refers to the number of iterations that should be carried out to get the higher order structure.[9] The self-similarity properties of certain fractals result in a multiband behaviour, and the

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space- filling capabilities of some fractal geometries involves a size reduction of the antenna at the fundamental mode.[10-14] The space-filling property of fractals tends to fill the area occupied by the antenna as the order of iteration is increased. Higher order fractal antennas exploit the space-filling property and enable miniaturization of antennas. Most of the allotted volume participated in the radiation.[15] Various fractal geometries have been found to be useful in developing new and innovative designs for antenna. These include Sierpinski gasket, Koch curves and Minskowski curves.[16]

Recently, defected ground structures (DGS) have been gaining interest for their planar form and ease of fabrication. In this method DGS pattern is etched out on the ground plane underneath the microstrip feed line. The former can be used to reduce the size of the antenna and to suppress harmonics.[17-19] Proximity coupled feeding technique is used in the antenna design such that there is no contact between the patch and the feed line. The feed line is placed between two substrates. The advantage of this feeding configuration is the increase in bandwidth due to increase in the overall substrate thickness.[20]

2. Design Geometry

The proposed design in this paper consists of proximity coupled hexagonal shaped fractal slot microstrip patch antenna. The DGS integrated with microstrip line is dumb-bell shaped DGS.

The primary hexagonal shaped patch is having side length S of 23.38 mm. From that patch, two hexagons of side length of S/2 mm has been taken out and this geometry is referred as the first iteration. The same procedure is repeated for the next iteration of hexagon side length of S/4 mm which results in 2nd iteration as shown in Fig. 1.

The structure consists of a two layer substrate. Hexagon patch is mounted on an upper layer substrate and the feed line is between two layers. The chosen substrate for both the dielectric layers are Arlon that has relative permittivity, ε_r, of 2.5, loss tangent, of 0.003 and thickness, *h*, of the substrate is 1.5748 mm. The antenna is fed by a microstrip line of length 15.5 mm and width of 4.5 mm which is electromagnetically coupled. The dumb-bell shaped pattern is etched out with two circular

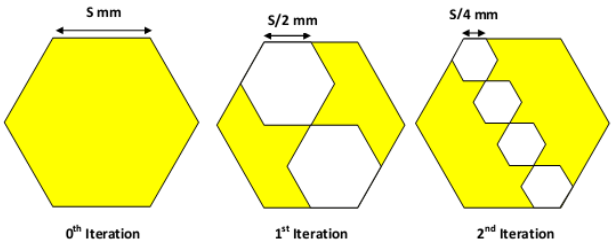

Fig. 1. Two iterations of hexagonal-shaped fractal slot

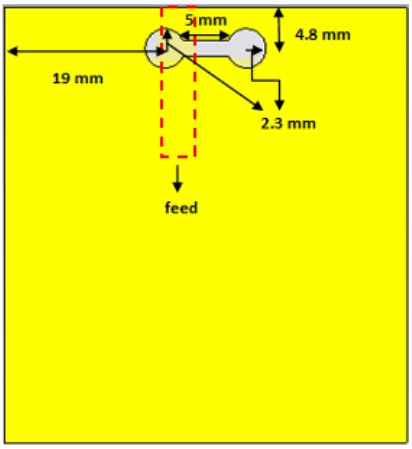

Fig. 2. Dumb-bell Shaped DGS

heads each of radius 2.3 mm on the backside metallic ground plane underneath the microstrip line as shown Fig. 2 with dimensions. This pattern is referred to as DGS.

3. Results and Discussion

This antenna has been simulated using licensed version of CST Microwave Studio (V.10) for a resonating frequency of 2.4 GHz ISM (Industrial, Scientific and Medical) band for WLAN application. Results of proposed antenna have been discussed with and without using DGS.

3.1. *Hexagonal-Shaped Fractal Slot Microstrip Antenna without using DGS*

The simulated return losses of conventional (0th iteration), first and second iterated antenna are shown in Fig. 3. The length L and width W of conventional hexagonal-shaped patch antenna are 33 mm and 43 mm. The resonating frequencies are 2.4 GHz and 4.2 GHz.

It is clearly observed that a size reduction of 25 % has been achieved in 1st and 2nd iteration. It is due to the fact that as the order of iteration increases, electrical path length increases which leads to the lowering of the resonance frequency. Thus, this property can be utilized for size reduction. But introduction of more slots leads to the reduction of gain.

Table 1, summarizes the simulated results of conventional, first and second iterated antenna without using DGS. All antennas are resonating for 2.4 GHz

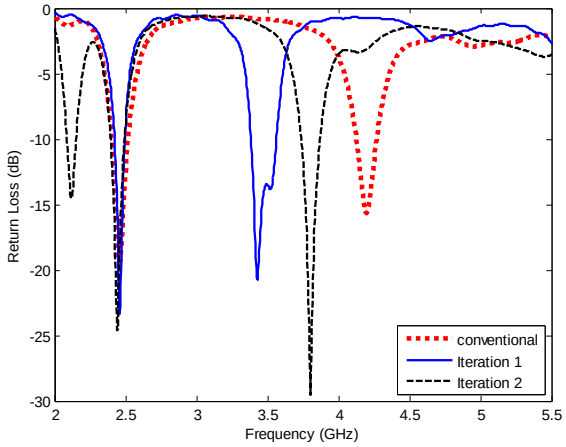

Fig. 3. Simulated return loss of all antennas (Without DGS)

ISM band. The second iterated antenna is proposed antenna, which shows quite a good return loss, VSWR and size reduction.

3.2. *Hexagonal-Shaped Fractal Slot Microstrip Antenna Using DGS*

Dumb-bell shaped pattern is etched out from the ground metal plane which is referred to as Defected Ground Structure (DGS). DGS improves the performance parameters of an antenna. DGS dimensions modify the effective inductance and capacitance of the microstrip line and thus achieves proper impedance matching.

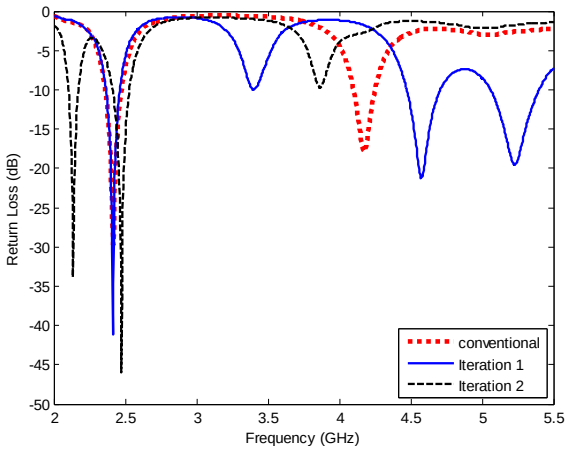

Fig. 4. Simulated return loss of all antennas (With DGS)

Simulated return losses of all the iterated antennas with DGS have been shown in Fig. 4. It can be observed that return losses are quite good of all the antennas by using DGS as compared to the antennas without using DGS. The values of VSWR are between 1 and 2, which is

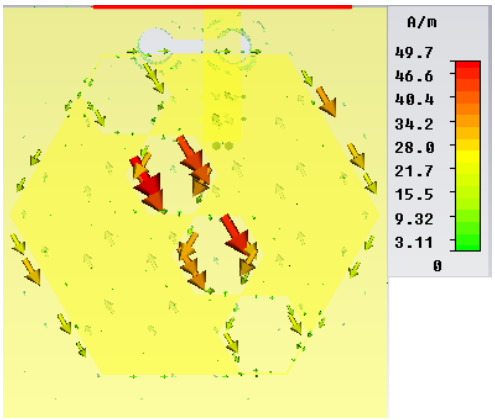

Fig. 5. Current distribution in proposed antenna (With DGS)

Table 1. Comparison Table of Results (Without DGS).

Iteration	Frequency (GHz)	Return Loss (dB)	VSWR	Gain (dB)	Radiation Efficiency (%)	Bandwidth (%)	Size (mm^2)	Size Reduction (%)
0th	2.46	-20.04	1.22	5.777	65.1	4.06	33×43	- - - - -
	4.2	-15.56	1.4	3.732	54.6	3.33		
1st	2.44	-23.04	1.14	5.225	63.4	3.27	28×38	25
	3.43	-20.05	1.22	3.013	43	4.28		
2nd	2.125	-14.48	1.46	3.119	44.5	2.7	28×38	25
	2.44	-24.47	1.12	5.020	61	4.01		
	3.8	-29.5	1.06	3.289	47.64	3.42		

desired.

The proposed 2nd iterated antenna shows return loss of -47.37 dB at 2.4 GHz. The bandwidth of the 2nd iterated antenna have been improved to 4.81 % and VSWR to 1.01 by using DGS which can be referred in Table 2. The size of the antenna is reduced by 43.67 % as compared to the 2nd iterated antenna of without using DGS. Table 3, shows the comparison of 2nd iterated antenna with and without using DGS. The 2nd iterated antenna without using DGS shows higher harmonic at 3.8 GHz. This harmonic has been suppressed in the proposed antenna by using DGS. In the presence of DGS below feed line, the width of the stop band enhances in the transmission characteristics of feed.

Table 2. Comparison Table of Results (With DGS).

Iteration	Frequency (GHz)	Return Loss (dB)	VSWR	Gain (dB)	Radiation Efficiency (%)	Bandwidth (%)	Size (mm^2)	Size Reduction (%) (With DGS)
0th	2.43	-27	1.09	4.98	68.1	4.73	29×28.6	41.55
	4.173	-17.4	1.31	2.58	52.4	4.58		
1st	2.413	-41.09	1.017	4.54	64.5	4.14	26×26	36.46
	4.576	-21.26	1.18	1.98	49.5	5.02		
	5.23	-19.47	1.23	1.009	53.8	6.5		
2nd	2.141	-33.79	1.04	2.115	41	3.36	25.5×23.5	43.67
	2.47	-47.37	1.01	4.536	65.3	4.81		

Table 3. Parameters comparison of 2nd iterated antenna

Parameters	Without DGS	With DGS
Resonating Freq. (GHz)	2.125, 2.44, 3.8	2.141, 2.47
Return Loss (dB)	-14.48, -24.47, -29.5	-33.79, -47.37
VSWR	1.46, 1.12, 1.06	1.04, 1.01
Gain (dB)	3.119, 5.02, 3.289	2.115, 4.536
Bandwidth (%)	2.7, 4.01, 3.42	3.36, 4.81
Radiation Eff. (%)	44.5, 61, 47.64	41, 65.3
Size Reduction (%)	25	43.67
No. of Bands	3	2

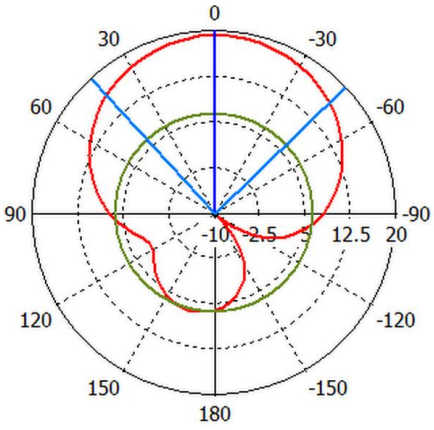

Fig. 6. E-plane radiation pattern of 2nd iterated antenna (With DGS)

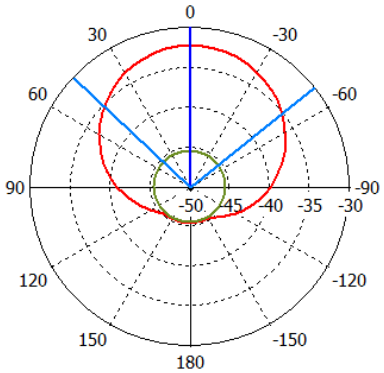

Fig. 7. H-plane radiation pattern of 2nd iterated antenna (With DGS)

This leads to the suppression of higher harmonics.

In Fig. 5, the current distribution on the hexagonal-shaped slot shows that most of the current density concentrates on the joints and edges. Increase in surface current path results in miniaturization. Fig. 6 and Fig. 7 represents E-plane and H-plane radiation patterns of the proposed antenna. It is observed that radiation patterns are unidirectional with a small back lobe due to DGS.

4. Conclusion

Microstrip patch antenna size reduction with hexagonal fractal slot and DGS has been achieved in this work. Hexagonal fractal slot leads to the size reduction of 25 % as compared to the conventional antenna. Further, size has been reduced by 43.67% in 2nd iterated antenna

with the introduction of DGS. DGS also leads to the suppression of higher harmonic in the proposed antenna. DGS marginally reduce the gain of an antenna without much affecting its performance. The proposed antenna is suitable for the Wireless Local Area Networks (WLAN) application.

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