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HIDDEN KULDO, ROTATED SQUARE AND KULDO FRACTAL ANTENNAS OF 2.4 TO 5.4 GHZ

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Abstract: This paper is introducing three antennas using different fractal structures with desired performance properties such as multi-band behaviour and small size. The proposed fractal patterns are taken of a Square and Koch Snowflake of the third iteration. The antenna is fed with a microstrip (50Ω) transmission line, and the slot structure is to be etched on the reverse side of the substrate. The proposed antennas have been simulated using FR4. The COMSOL software has been applied to analyze the performances of the designed antennas such as return loss, radiation patterns and electrical field. The resulting antennas exhibit an interesting behaviour of multi-band resonant frequency making it suitable for multi-band communication systems including the dual band WLAN and WMAN applications. The effects of antenna parameters on its performance were carried out by parametric study.

Keywords: *Fractal Antenna, COMSOL, WLAN, WMAN, Multi-band.*

تصميم هوائيات ذات النمط الهندسي التكراري: الكلداني المخفي والمربع المداروالكلداني بمدى ترددي (من 2,4 الى 5,4 كيكاهرتز)

الخلاصة: قدم هذا البحث ثلاث أنواع من الهوائيات باستخدام النمط الهندسي التكراري (الكسوري) اخذين بنظرالاعتبارخصائص الأداء مثل حزم النطاق المتعددة والحجم الصغير . الأنماط الهندسية المقترحة مشتقة من المربع وكوخندفة الثلج ثلاثي التكرار تغذية الهوائي الشريطي تمت من خلال خط نقل ذومقاومة50 اوم وبنية الاخدود محفورة على الجانب العكسي من الركيزة تم محاكاة الهوائيات المقترحة باستخدام ركيزة من نوعFR4. استخدم برنامج COMSOLلغرض تحليل الأداء لهذه الهوائيات لاختبار خسائر الارجاع ونماذج الاشعاع وكثافة الفيض الكهربائي. حققت الهوائيات المصممة سلوكا مقبولا لتعدد حزم التردد الرنيني وكانت هذه الترددات مناسبة للعمل مع أنظمة الاتصال ذا تتطبيقات النطاق المزدوجة WLANوWMAN. تاثيرات معاملات الهوائي على الأداء قد نفذت بدراسة حدودية .

1. Introduction

Unique fractals geometry existing in the nature was the basis of the concept of fractal antenna [1,2]. Fractals are designed by repetition of complex geometric shapes or the repetition of the statistical properties by numerous scales and are thus, "self-similar"

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Fractals, which are designed by self-similarity property and are based on natural systems where the properties of sought-after antenna are provided through complexity of geometries. Fractal geometries which were used to design fractal antennas offer characteristic properties like space filling, self-similarity, and complexity in their structure. Description of the complex geometrical family shapes which attained an inherent self-similarity in their geometrical structure is presented by B. B. Mandelbrot [1]. Fractal antennas implemented on different structures, which are commonly used in many antenna designs for various applications [3,4] .

Antenna characteristics such as small size and wide bandwidth are the most suitable for modern communication systems; therefore it was necessary to search for antennas which afford these specifications. Fractal antennas can provide the answer. Antenna applications were introduced using many of the fractal geometries and successful modifications for improving antenna performance [5,6]. Many of these geometries are especially useful in reducing antenna size [7], [8], while other designs incorporate multi-band characteristics [9], [10] and [11].

In this paper fractal antenna is designed using Square and Koch Snowflake fractal geometries. Three shapes we called Hidden Kuldo, Rotated square and Kuldo fractal antennas have been studied. These designs are simulated using COMSOL software. The Koch fractal technique that has been applied to the antenna structure after two iterations achieves the aims of reducing the length of the elements making it suitable for small wireless devices as well as getting on multiband response.

In the present paper compact fractal microstrip antennas with fed patch for Wifi, Wimax and WLAN applications are proposed. Return loss of -10 dB has been adopted for each antenna bandwidth, which satisfies the applications of system demands. The main structure of this paper as follows, Section II presents basic theory of a fractal antenna. The geometries of the proposed antennas were introduced in Section III. Results of the simulation are described in Section IV. Lastly, Section V contains the summarized conclusions.

2. Basic Theory of Fractal Antenna

Fractal idea had been applied to many divisions of engineering, including fractal electrodynamics for radiation, scattering and propagation. Benefits of fractals are more than those of conventional antennas. The main advantage of the former is its multiband frequency at compact size. On execution iterations on the basic form, one can obtain the value-added to bandwidth and multi-band nature, contributing to improved insertion loss radio and SWR.

Fractal includes a recursive creating methodology where fractal geometry is constructed each iteration. The results are shapes with infinitely complex fine geometries. These are based on shapes being self-similar usually based on a constructing procedure that grows repeatedly and reiterated Fractal loading was the first use of fractals as antennas that uses holes or bends with different sizes and scales to mimic the effects of discrete capacitors and inductors. The fractal holes or bends attend as continuous loading elements or lumped through arrangement of these holes or bends.

Fractals can be categorized into two main kinds as shown in Figure (1) [3], the first random fractals where they are quite familiar and many look like tree roots or discharge lightning. The second is a deterministic such as Tree fractal, Cesàro fractal, Barnsley's Fern, Dragon Curve, H-fractal, Square and Triangle, all of them are generated of several scaled-down and rotated copies of themselves as shown in Figure(1). Clearly, those patterns show that many fractals exist in nature and can be used to accurately model certain phenomena .

The benefit of fractal is to reduce the size of antenna, such as Koch monopole, dipole, loop and Minkowski loop. A triangle shape is the base element of generation the Sierpinski Gasket, where a start with a triangle and repeatedly cut out the centre of every segment. Notice how, after a while, exactly each smaller triangle looks the same as the complete pattern. In other enterprises, a single very wideband response can be attained by fractals. Figure (2) illustrated several elements of fractal antenna.

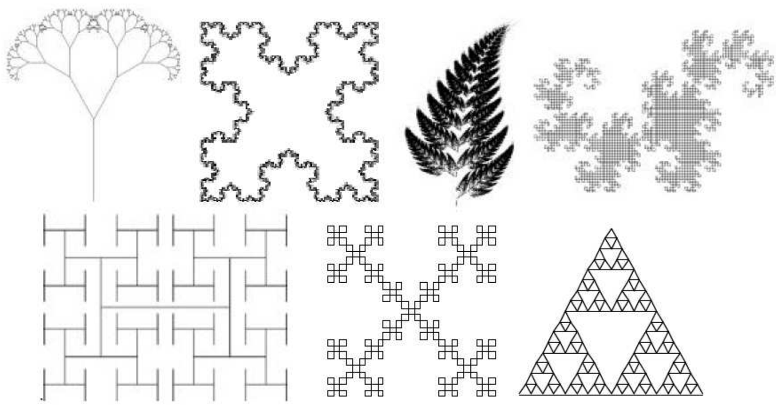


Figure (1): Tree fractal, Cesàro fractal, Barnsley's Fern, Dragon Curve, H-fractal, square and triangle.

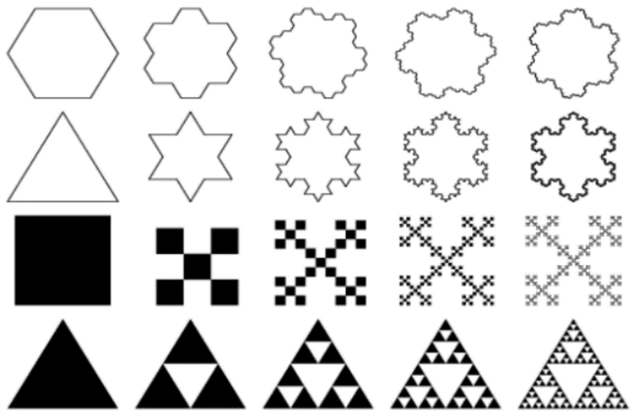


Figure (2): Different shapes of fractal structures with Hexagonal, triangle, sold square and sold triangle.

3. Proposed Antennas Geometries

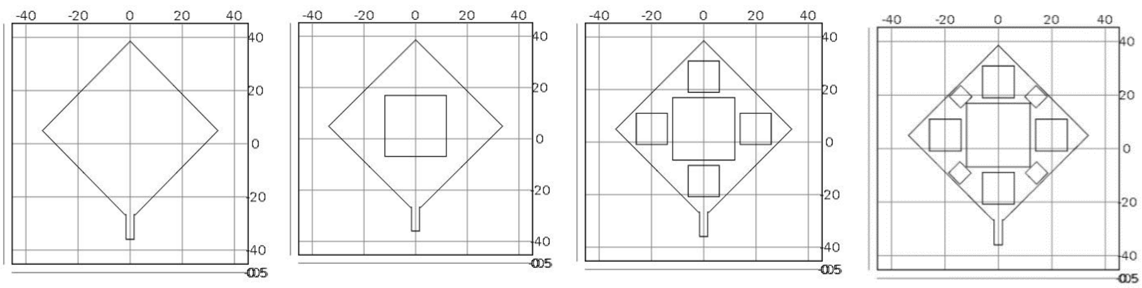
In this work, three geometries of the fractal antennas are discussed. The first one is: by taking the base of a rotated square with 45^o as an initiator for the fractal antenna. Microstrip line feeding technique has been used for the basic square microstrip patch antenna. The design is obtained by subtracting the initiator part with rotated fractional squares, the fraction size to the initiator is 1:2 from the middle of the each side. The detail of the dimensions of the initiator, first, second and third iteration is shown in Table (1). Substrate used glass epoxy (FR4) which has permittivity constant (ε_r) equals to 3.5. Structure of the first proposed fractal Microstrip antenna with different iteration stages is shown in Figure (3).Figure (4) shows the second proposed antenna. The design is obtained by subtracting the central part of the main square (rotated by 45^o) with rotated squares (also rotated by 45^o). Substrate was also used glass epoxy (FR4) which has permittivity constant (ε_r) =3.5. Descriptions of detail dimensions are shown in Table(1).

Third proposed antenna presented in this work is shown in Figure (5). These fractals are designed on the basis of simple Kaldu Koch. In this type of fractal, the generator and the initiator have specific meanings. They are mostly based on simple eight vertex star "Kaldu star" which enables us to generate the desired arrangement. Repeating the process of reforming for the third iteration will lead to the structure of Figure (5). The Kaldu Koch fractal grows by a factor of 4 times. Dimensions and properties of the third antenna are presented in Table (1).

Table (1): Parameters of the proposed antennas

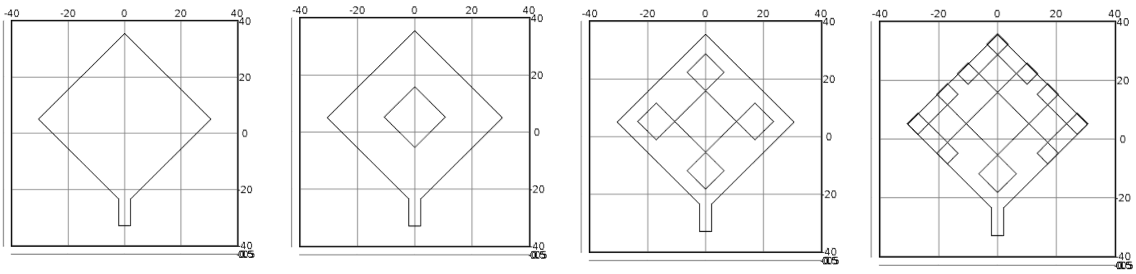
Basic configuration		Symbol	Dimensions (mm) First Antenna	Second Antenna	Third Antenna
Substrate		W	90	80	63
		L	90	80	63
Patch Antenna	Initiate	L1=W1	47.3	36	42
	1st iteration	L2=W2	23.65	12	10* U 9.25
	2nd iteration	L2=W2	11.825	7.5	5.7* U 5.29
	3rd iteration	L3=W3	5.9125	4.6	3.26* U 3.02
Permittivity		Er	3.5	3.5	3.5
Sub. Thickness		H	1.5	1.5	1.5

Where (*) square rotated by 45^o and (U) union

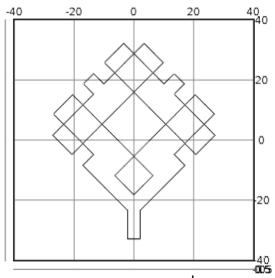


(a) Initial (b) 1st iteration (c) 2nd iteration (d) 3rd iteration

Figure (3): The photograph of the first proposed antenna.

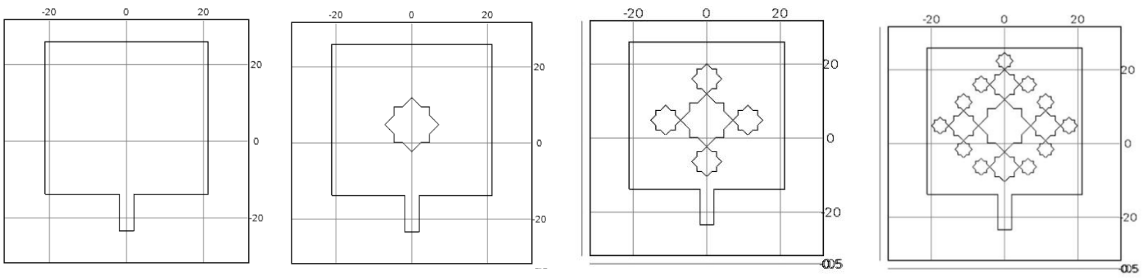


(a) Initial (b) 1st iteration (c) 2nd iteration (d) 3rd iteration



(e) Final shape of 3rd iteration

Figure (4): The photograph of the second proposed antenna.



(c) Initial (d) 1st iteration (c) 2nd iteration (d) 3rd iteration

Figure (5): The photograph of the third proposed antenna.

4. Results and Discussions

Through Figures of 6 to 8, the simulated insertion return losses for the three proposed antennas for the third iteration are shown. COMSOL has been used here as a simulation tool. Figure (6) shows that the antennas have a good return loss for 2.5GHz and 5 GHz with respect to -9.5 dB. The required specifications for Wifi, Wimax and WLAN applications were attained by this antenna.

Figure (7) shows the return losses of the second proposal antenna. It can be observed that for the resonant frequency of 4.2, 4.6 and 4.8GHz the return losses parameter S_{11} is less than (-10 dB). Also these frequencies are standard frequencies for Wifi, Wimax and computer network applications. The resonant frequencies are in the range of 5.4 to 5.8GHz for the third proposed antenna. Obviously, the S_{11} for this range is less than (-

10 dB). This antenna achieves the required specifications for Wimax and computer network applications.

The far-field radiation patterns in two dimensions (2D) and three dimensions (3D) of the proposed antennas, which denote to the directivity of the antennas, have been schemed through Figures (9-18). The electric field intensities were drawn for different resonant frequencies of proposed antennas as in Figures (19-22) to estimate the total energy density per cubic meter over the average time interval.

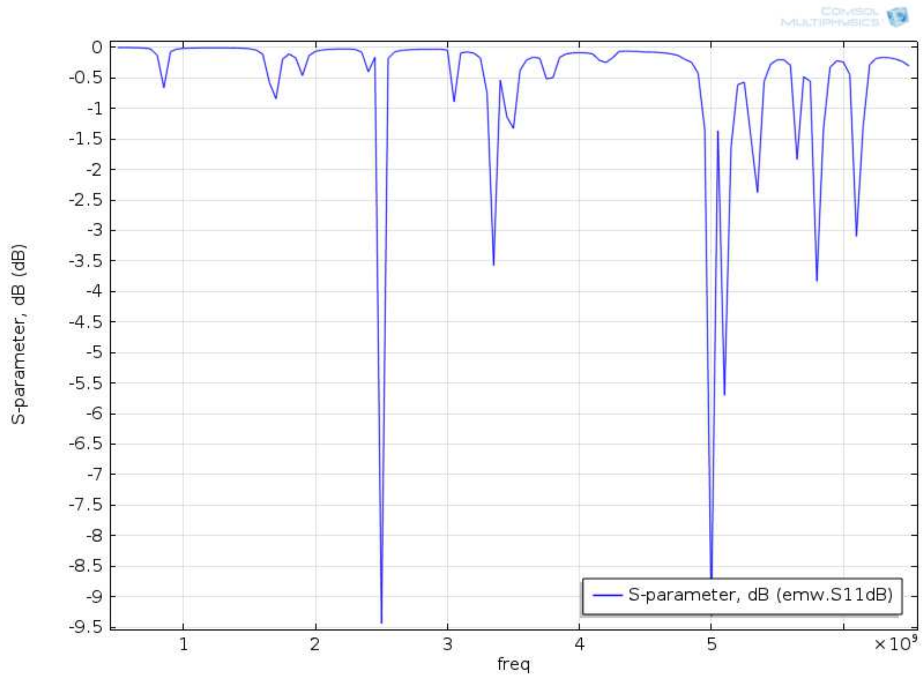


Figure (6): Return loss for the third iteration for first fractal antenna.

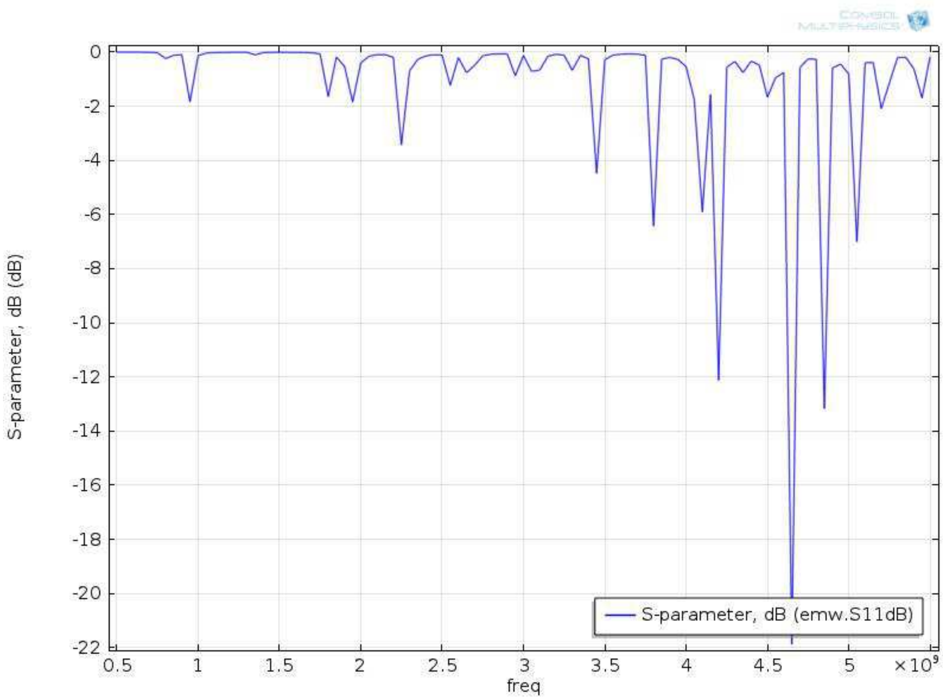


Figure (7): Return loss for the third iteration for second fractal antenna.

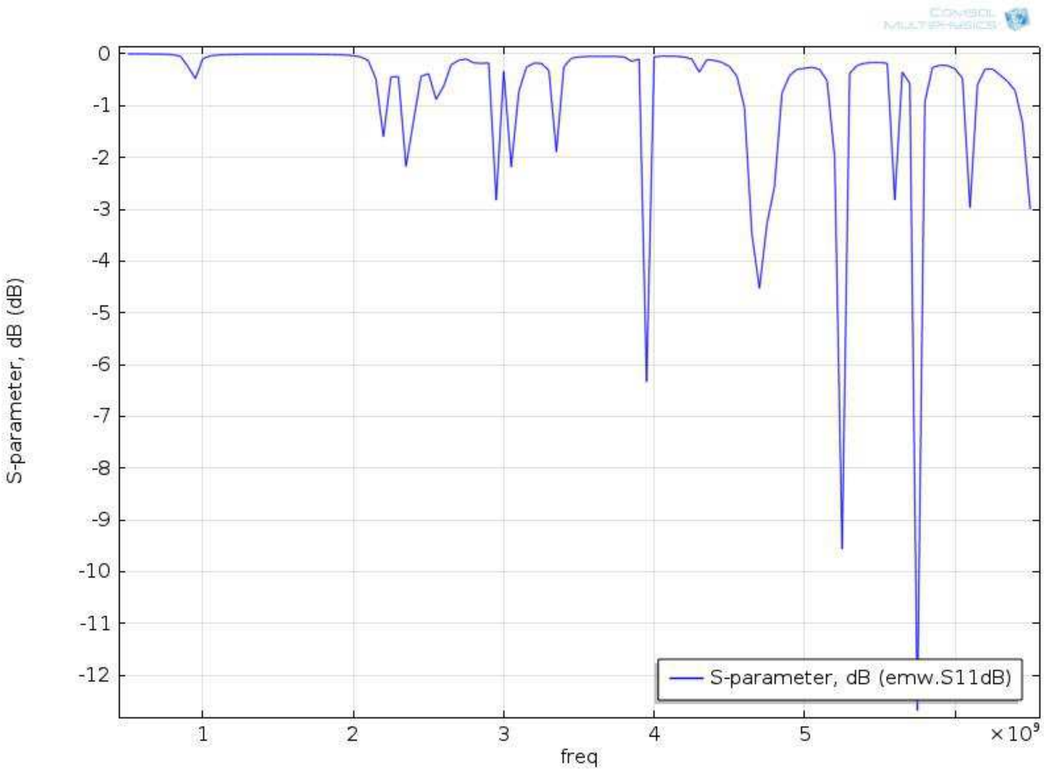


Figure (8): Return loss for the third iteration for third fractal antenna.

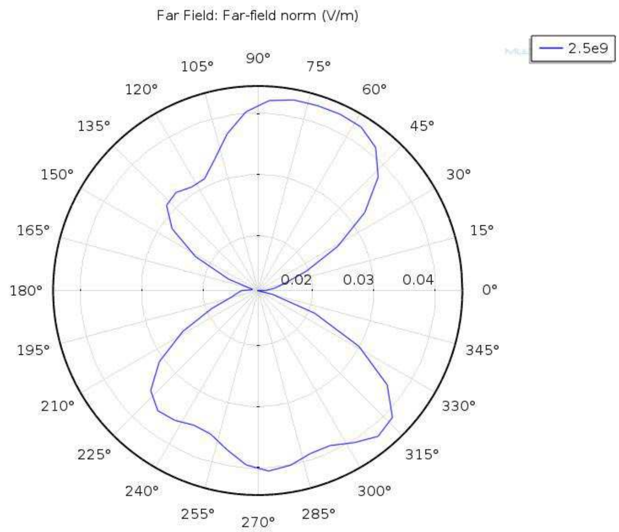


Figure (9): Radiation pattern (2D) for the first antenna at 2.5GHz.

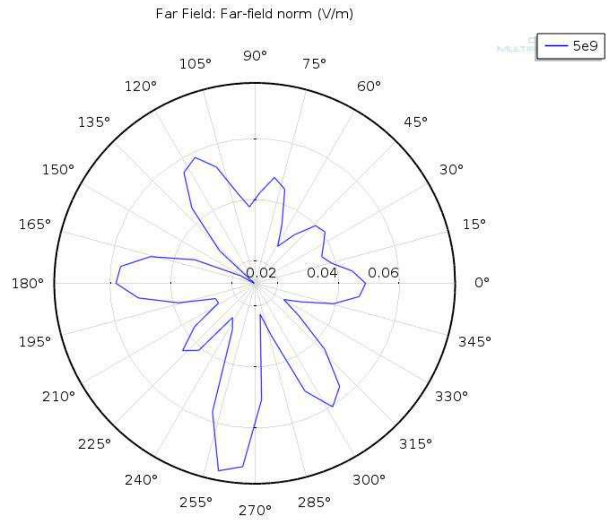


Figure (10): Radiation pattern (2D) for the first antenna at 5GHz.

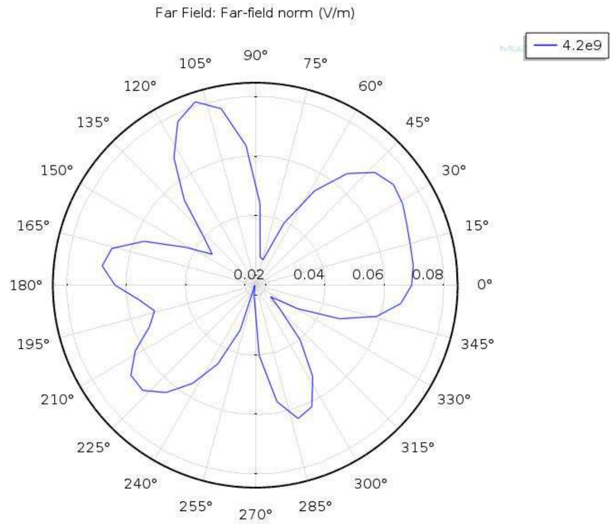


Figure (11): Radiation pattern (2D) for the second antenna at 4.2GHz.

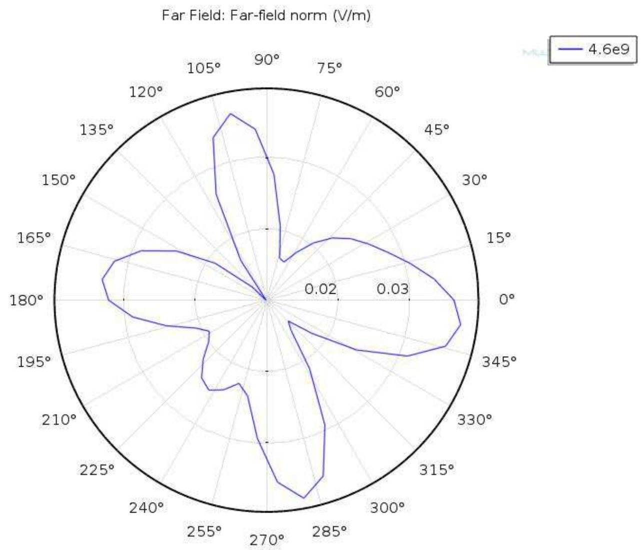


Figure (12): Radiation pattern (2D) for the second antenna at 4.6GHz

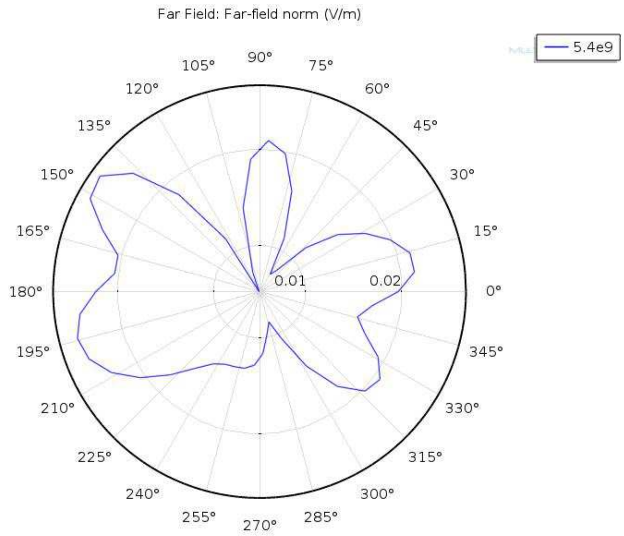


Figure (13): Radiation pattern (2D) for the third antenna at 5.4 GHz

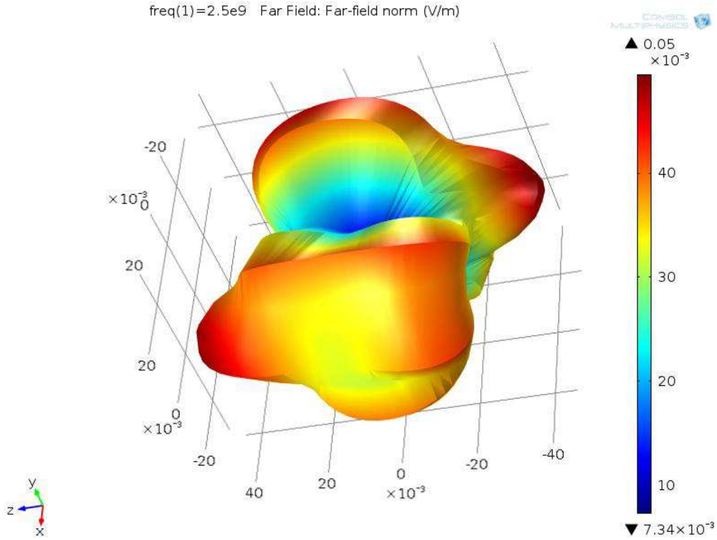


Figure (14): Radiation pattern (3D) for the first antenna at 2.5GHz.

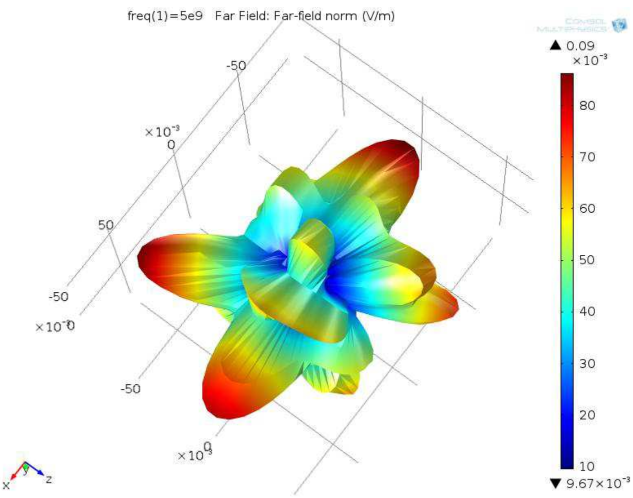


Figure (15): Radiation pattern (3D) for the first antenna at 5GHz.

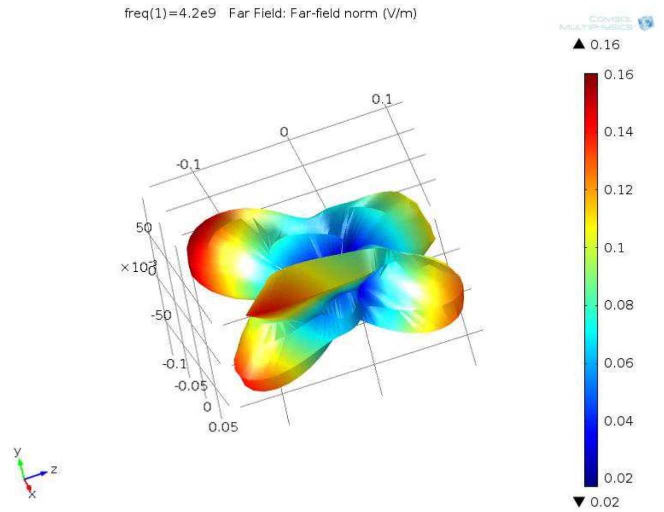


Figure (16): Radiation pattern (3D) for the second antenna at 4.2GHz.

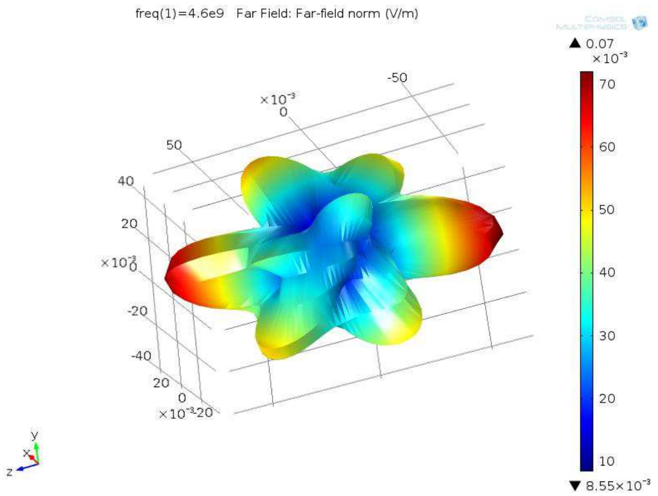


Figure (17): Radiation pattern (2D) for the second antenna at 4.6GHz

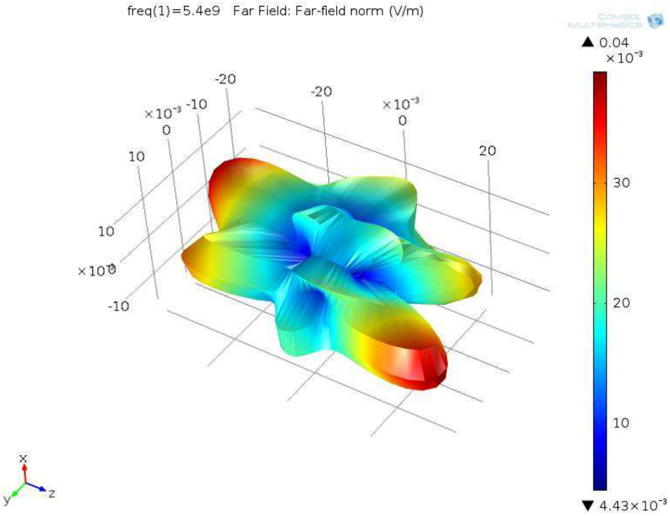


Figure (18): Radiation pattern (3D) for the third antenna at 5.4 GHz

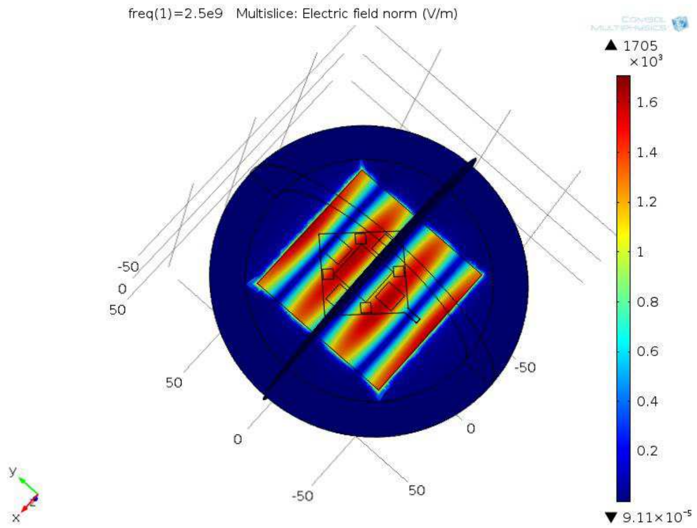


Figure (19): Electrical Field (emw) of the first antenna in (V/m) at 2.5GHz

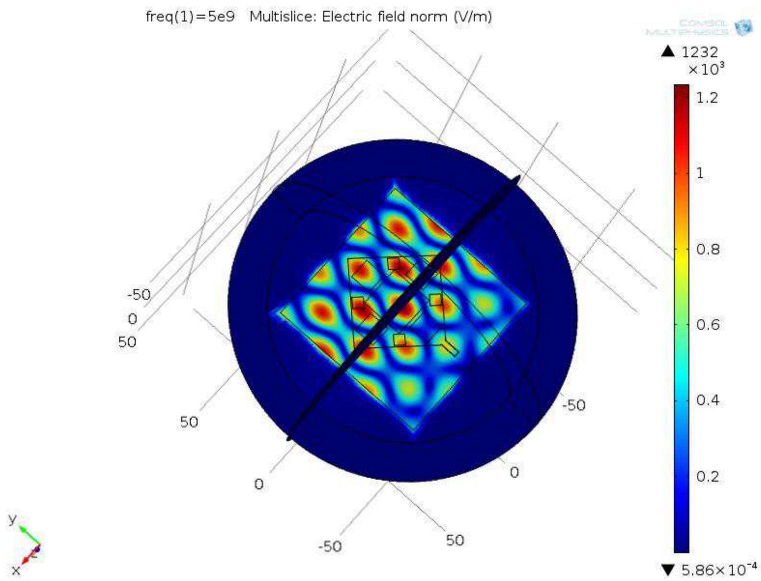


Figure (20): Electrical Field (emw) of the first antenna in (V/m) at 5GHz

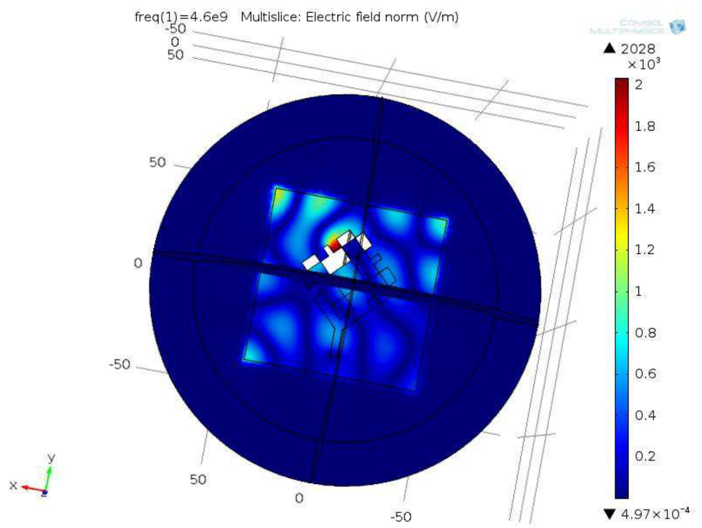


Figure (21): Electrical Field (emw) of the second antenna in (V/m) at 4.6GHz

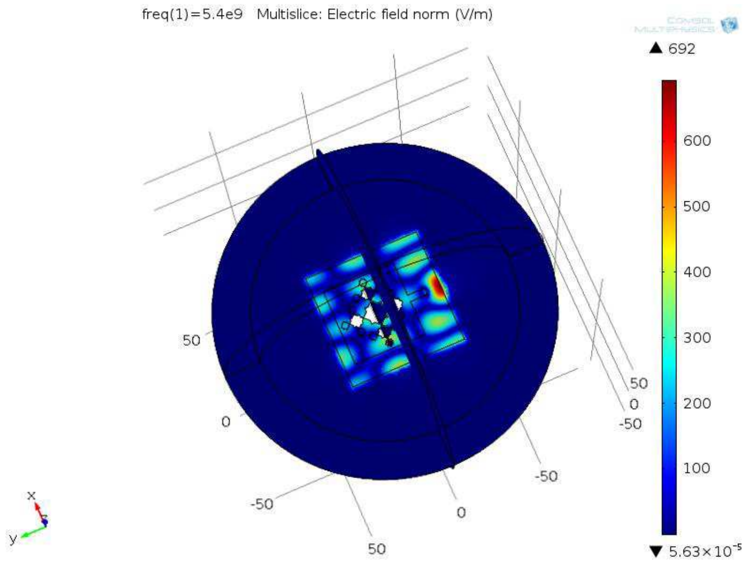


Figure (22): Electrical Field (emw) of the third antenna in (V/m) at 5. GHz

5. Conclusions

Fractal microstrip slot antennas, with structures based on different third iteration, have been described in this paper. A rotated square patch antenna achieved resonant frequencies used for specific required applications. Simulation results showed that the antenna possesses a multi-band resonant behaviour suitable for the requirements of the 2.4 to 5.4 GHz for Wifi, Wimax, WLAN and other modern communication systems. The antennas have been simulated and analyzed using COMSOL software. The performances of the most effective antenna parameters were studied. It was shown that the return loss was -9.5 dB at 2.4 and 5 GHz resonant frequencies for the first antenna, -12, -22, -13 dB return losses at 4.2, 4.6 and 4.7GHz respectively for the second proposed antenna. For the third antenna at resonant frequencies 5.4 and 5.8GHz, the return losses were-9.5 and -13dB.

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