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New fractal geometry for dual band and small size microstrip patch antenna

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Abstract

A new technique to reduce the size of microstrip patch antennas is proposed for dual band operation, by replacing each side of conventional square patch and drilling in center. It is found that, the resonant frequency of the antenna can be greatly lowered (from 1.44 GHz to 0.925 GHz), for the higher iteration order. And this property can be utilized to reduce the size of the microstrip antennas (5.5 times of patch size reduction is achieved). It is also found the variation in gain between the two resonances (f_0 =0.925 GHz and f_1=1.8 GHz) does not exceed 1 dB , which represents good variation for most applications. The patches derived from this technique can find applications in integrated low-profile wireless communication systems. Antenna performance has been evaluated using HFSSv11software package.

شكل هندسي كسوري جديد ثنائي الحزمة وصغير الحجم لهوائي شرائط دقيقة

الخلاصة:

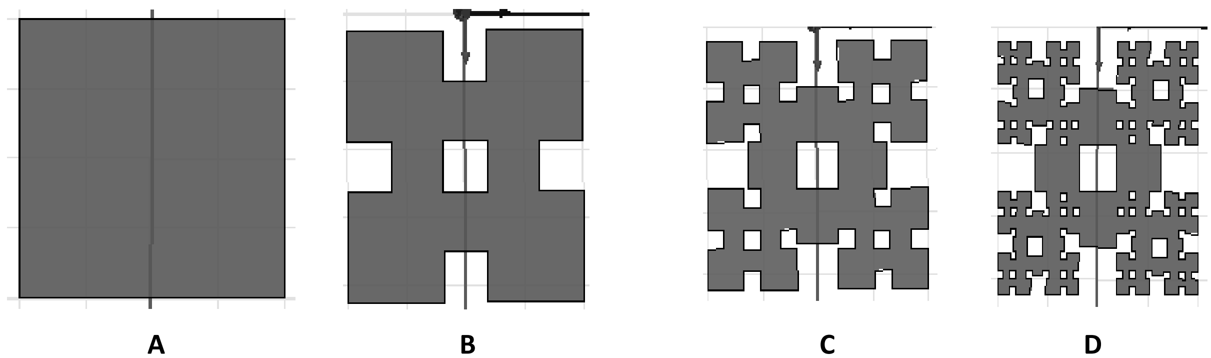
اقترح في هذا البحث تقنية جديدة لتقليل حجم الهوائي الشريطي الدقيق للتشغيل بحزمتي تردد وذلك باستبدال كل ضلع من إضلاع الرقعة المستطيلة و ثقب مركز الرقعة بفتحة مناسبة. وقد وجد إن التردد ألرنيني لهذا الهوائي ينخفض إلى حد كبير (من 1.44 GHz الى0.925 GHz) للمراتب العليا من التكرار لعملية الاستبدال و ألثقب للرقعة. ويمكن استخدام هذه الطريقة لتقليل حجم الهوائي الشريطي(حيث تم الحصول على 5.5 مرة انخفاض تقليص في حجم الهوائي). كذلك وجد إن التفاوت في الربح لا يتجاوز1dB بين الحزمتين (0.925 GHz و 1.8 GHz) , وهذا الفرق يمثل نتيجة جيدة بالنسبة لمعظم التطبيقات.حيث يمكن لرقع الهوائيات المستنبطة من هذه التقنية العمل في التطبيقات الدوائر المتكاملة في نظام الاتصالات اللاسلكية.وقد تم تقيم اداء الهوائي باستخدام برمجيات محاكاة حزمة الهياكل ذات الترددات العالية HFSSv11.

Introduction:

In recent years, as the demands of portable systems have increased, low-profile systems have drawn much interest from researchers. In making such low-profile communication systems, the size of the antenna is critical. Therefore, many kinds of miniaturization techniques, such as using of high dielectric substrates [1], applying resistive or reactive loading [2], and increasing the electrical length of the antenna by optimizing its shape [3], have been proposed and applied to microstrip patch antennas. The application of fractal geometry to conventional antenna structures optimizes the shape of the antennas in order to increase their electrical length, which thus reduces their overall size. Because fractal geometries have two main features in common, space-filling and self-similar properties, fractal shape antenna elements present various advantages: wide bandwidth [4], multiband [5], and reduced antenna size, among others. Koch fractal geometry exhibits well-known features that have been used to construct miniaturized monopole and loop antennas [6&7]. Other literature concerning the techniques of reducing the size of patch antenna by etching the edges of the patch as Koch curves and inner patch as the sierpinski carpet[8]. A compact microstrip antenna practical for both the GPS/DCS dual-band mobile communication had been presented[9]. In this work, Koch fractal geometry has been applied to microstrip patch antennas to reduce their overall size, and the effectiveness of this technique is then verified through numerically analyzed using HFSSv.11 software package. [It is found that as the iteration number increase, the resonance frequencies become lower than those of the zero iteration, which represents a conventional square patch. In other words, microstrip patch antennas employing Koch fractal island geometry can operate at a much lower frequency range while maintaining an identical.]

Antenna Design:

The fractal geometry can be obtained by replacing each side and dropping in center of the main square patch by a modified square slot whose iteration factor is 0.1875*side length of main patch. Fig(1) shows the proposed fractal shapes with different iteration orders. Because the shape of achieved fractal is similar to butter flay, we call them Fractal Butter Fly(FBF).



Fig(1). Geometries of the proposed novel fractal shapes combined by(0.1875*side length of main patch). A_Zero iteration, B_ First iteration, C_ Second iteration, D_ Third iteration

Fig.(2) shows the simulated configuration of proposed small_size patch antenna with third iteration order using HFSSv.11, and the configuration of order antennas with different iteration orders are same to fig.(2). All of these antennas are fabricated on 3.2 mm thickness substrate with relative permittivity 4.5. The length of the square patch is 40 mm, also it can be seen as the iteration number increases, the average electrical length of the patch also increases, just like the inductive loading and slot loading,techniques reported in [10] and [11], thus to lowering the resonant frequency of the proposed patch antennas. The proposed antenna is candidate for use in application as global system for mobile (925 MHz and/or 1800 MHz) communication GSM.

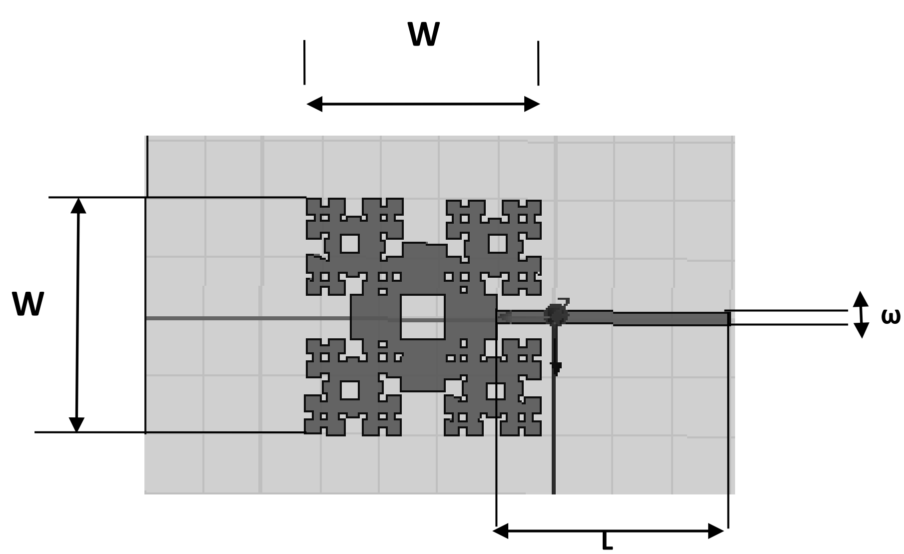


Fig.(2) Simulated configuration for the proposed small_size fractal antenna with third iteration order

Results:

Four FBF antenna structures, had been modeled at the design frequencies (0.925 and 1.8)GHz. The computed input return losses of these antenna patches are shown in Fig.(3). This does not prevent the possibility of other resonant bands out of this range.

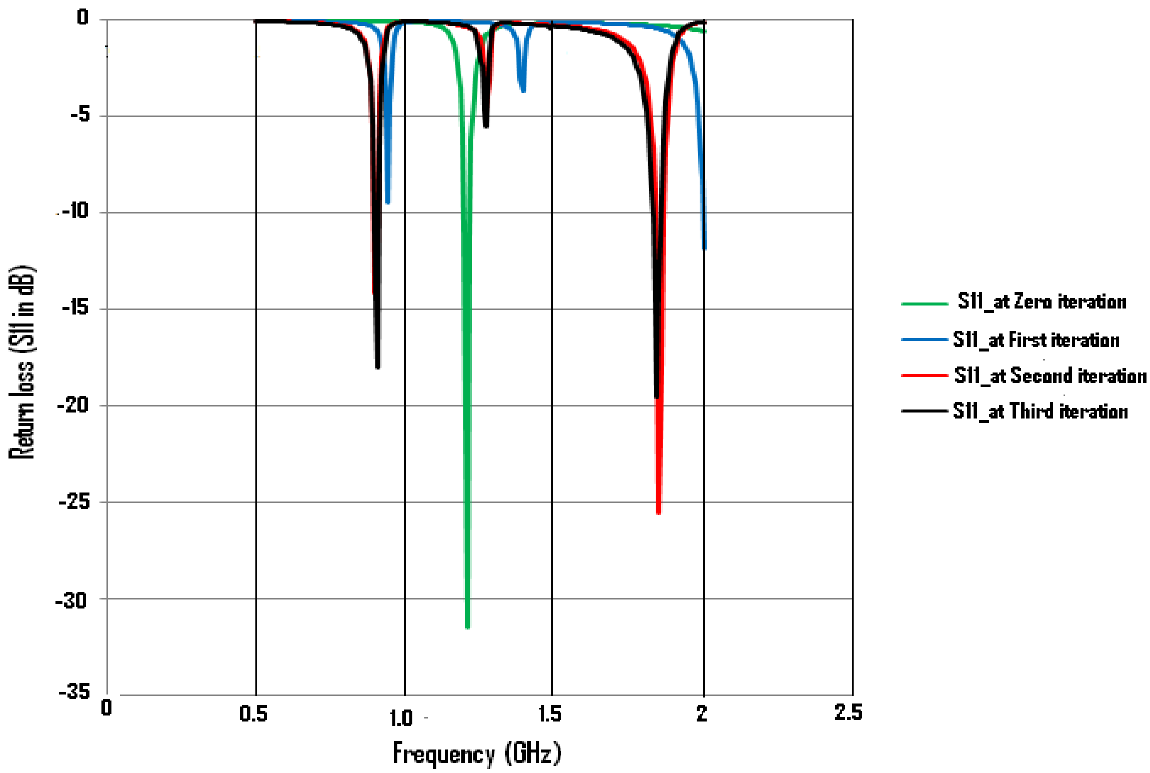


Fig.(3) the calculated input return loss for the 4 modeled fractal patch elements.

Table 1: summary of the simulation Result.

Antenna type	**f_0 (GHz)**	**f_1 (GHz)**	**S11(dB) at f_0**	**S11(dB) at f_1**	**Bandwidth at f_0**	**Bandwidth at f_1**	**Size Reduction**	**Gain(dB) at f_0**	**Gain(dB) at f_1**
Zero iteration	1.44	—	-31.4726	—	3.1%	—	—	3	—
First iteration	0.9425	2	-9.44	-12.06	—	—	63.44%	—	—
Second iteration	0.9249	1.793	-14.15	-25.52	1.2%	6.8%	72%	1.315	0.87
Third iteration	0.925	1.8	-18.13	-15.06	1.2%	7.2%	76%	1.078	0.466

Based on the simulated results given above, the size reduction property of the proposed fractal patch antenna can be discuss through the summarized results listed in table1. Column1 shows the fractal antenna with different iteration orders, columns(2, 3),(4,5) ,(6,7), and (9,10)show the simulated resonant frequencies, return loss, bandwidth, and antenna gain respectively. Column 8 shows size reduction in percentage of the proposed patch antenna (using novel technique) compared to their conventional counterpart.Also it can be seen from table1, the antenna in first, second, and third iteration order achieved 17.625%100, 30.125%100, and 33.875%100 size reduction respectively. And this means that the proposed fractal antenna (third order iteration) is more than (no) times smaller than the conventional patch antenna resonated at the same frequency. From results in column2 (no2 and no3), it is observed that dual resonant band are achieved in frequency range specified by this study. As can be seen from fig.(3) and table1, the square patch antenna (antenna fractal with zero iteration), is resonated at 1.44 GHz has one resonant band in the frequency range specified by this study. While it also observed that, when the antenna fracted with first iteration, two bands noticed at 0.9425 GHz and 2 GHz, that's mean the lower resonant frequency 1.44 GHz (antenna with zero iteration fractal) shifted to 0.9425 GHz (antenna with first iteration fractal)and new resonant band is occur (2GHz). And also the proposed fractal patch antennas in second and third iteration orders, are resonated at (0.9245,1.793)GHz and (0.925,1.8)GHz respectively. These results show the frequency lowering phenomenon. Also it is observed that is the resonant frequency lowering in return loss ($S11 \leq -10$ dB) effect will be insignificant when the iteration order becomes higher.

Antennas gain results are also carried out at their resonant frequencies, and it is observed that the peak gain of conventional square patch antenna (zero order iteration) resonated at 1.44 GHz is 3dB, and the peak gain of the proposed fractal patch antennas with second and third iteration order, are (1.315, 0.87) dB and (1.078, 0.466) dB, respectively. The antenna peak gains is inevitable when effective radiation area of the proposed fractal patch antennas decreased.

Fig.(4_a), shows the normalized radiation patterns, for FBF zero iteration (conventional square patch)at resonance frequency 1.44 GHz.Fig.(4_b), shows the normalized radiation patterns, for FBF second iteration at resonance frequencies 0.9249 GHz, and 1.793 GHzit can be shown that, the variation in gain does not exceed 1 dB whichconsidered good variation for most applications. Fig.(4_c), shows the normalized radiation patterns, for FBF third iteration at resonance frequencies 0.925 GHz, and 1.80 GHz. Also it can be shown that, the variation in gain does not exceed 1 dB

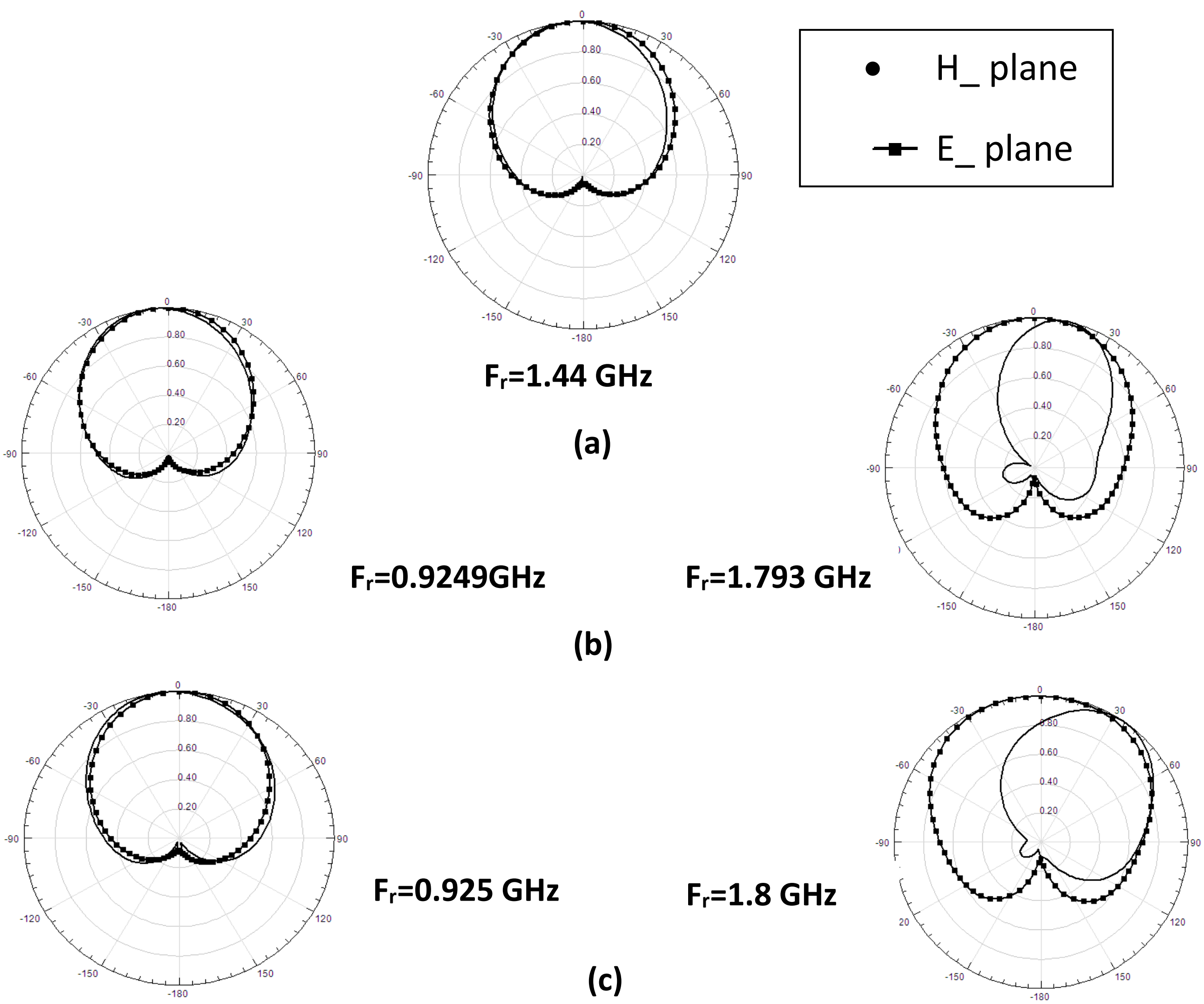


Fig.(4) normalized radiation patterns of the proposed fractal patch antennas (a), (b),and (c).

Conclusion:

From simulated results the following points are conclude:

1- The resonant frequency of the fractal antenna is lowered (from 1.44 GHz to 0.925 GHz), that means this property can be used to reduce the size of the patch antenna.
2- The simulated results show a maximum 5.5 times of patch size reduction is achieved by the proposed fractal antennas.
3- Small size and dual band (0.925 and 1.8 GHz) operation patch antenna is proposed in this work as candidate for global system GSM.
4- For the dual resonant frequency achieved in second and third iteration the variation in gain between f_0 (0.925 GHz) and f_1(1.8 GHz) does not exceed 1dB, (Gain=1.078 dB at f_0)&(Gain=0.466 dB at f_1) which consider good variation for most applications.
5- Wider operating frequency bandwidth achieved at resonant frequency 1.8 GHz (antenna at third iteration) than that achieved at resonant frequency 1.44 GHz (antenna at zero iteration).

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