A New Compact Dual Band GPS Patch Antenna Design Based on Minkowski-Like Pre-Fractal Geometry

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Received on: 7/10/2008
Accepted on: 5/3/2009

Abstract

A low profile compact microstrip antenna for GPS (L1/L2) application has been presented in this paper. The proposed antenna design is based on the 3rd iteration Minkowski-like pre-fractal geometry. The resulting antenna design offers a compact size, low profile and light weight making it suitable for use in handheld applications. Antenna performance has been evaluated using the EMSightTM from the Applied Wave Research. The proposed antenna has shown to possess two resonance bands (for return loss ≤-10 dB) covering the two GPS bands. Reasonable radiation characteristics have been achieved at the GPS frequencies (L1:1575.42 ± 10.23 MHz, L2:1227.60 ± 10.23 MHz) with good circular polarization characteristics. Realized circular polarization Bandwidths (for axial ratio ≤ 3 dB) are found to cover adequately those required for these GPS bands.

Keywords: GPS (L1/L2), Fractal Antenna, Dual Band Antenna, Circular Polarization, Axial Ratio.

تصميم جديد لهوائي شرائط دقيقة مدمج ثنائي الحزمة بالاعتماد على شكل منكوفسكي ما قبل الجزئي لمحدد الموقع العالمي

الخلاصة

هوائي الشرائط الدقيقة صغير الواجهة للـــ GPS في تطبيقات (L1/L2) قدم في هذا البحث. التصميم المقترح للهوائي يعتمد على التكرار الثالث لشكل منكوفسكي الجزئي. التصميم الناتج يعطي حجم صغير, واجهة صغيرة ووزن قليل مما يجعله ملائماً للتطبيقات اليدوية. الهوائي المقترح أظهر أن لديه حزمتي رنين (لخسائر رجوع ≤-10dB) تغطي حزمتي الـــ GPS. تم انجاز ميزات إشعاع معقولة في ترددي الـــ GPS (L1:1575.42 ± 10.23 MHz, L2:1227.60 ± 10.23 MHz) مع ميزات استقطاب دائري جيدة. وجد أن حزمتي الاستقطاب الدائري المتحققة (لنسبة محورية ≤ 3dB) تغطي بشكل مناسب الحزم المطلوبة للـــ GPS.

Introduction

Microstrip antennas offer many advantages such as low profile, the ease of fabrication, and the low cost. These make them very popular and attractive for the designers since the early days they appear. In many cases, where the antenna size is considered an important limitation, their large physical size, make them improper to be used in many applications. Several methods have been considered to reduce the microstrip antenna size [1-5]. These methods include the use of shorting posts [1], material loading and geometry optimization [2]. Use of slots with different shapes in microstrip patch antennas had proved to be satisfactory in producing miniaturized elements [3, 4, 5].

As a result, microstrip antennas are extensively used in the global positioning system (GPS). GPS antennas operating at L1 and L2 bands have been realized using two stacked patches and a small air-gap between the substrates with aperture-coupled multiple patch antennas fed through feed divider network [6,7]. Due to their promising application in microwave circuit and antenna design, much of

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https://doi.org/10.30684/etj.27.7.12
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research work had been devoted to the use of periodic structures [8-10]. These periodic structures include the photonic crystals, electromagnetic bandgap (EBG) structures or metamaterials. The EBG structures have been applied to antennas with various polarizations to improve antenna gain

II. The 3rd Minkowski-Like Pre-Fractal Antenna

and radiation patterns. Recently more research works have been devoted to make use of the space-filling and self similarity properties of some fractal objects to produce miniaturized multiband antenna elements [11, 12].

Dual band GPS antennas had been also achieved using two elliptical annular patches that are concentrically printed on two stacked substrates separated by an airgap. A central conducting wall shorts the two patches to the ground plane. The sizes of the patches have been chosen to make the upper and bottom patches resonating on the L1 and L2 frequencies [13,14].

In this paper, a compact multiband microstrip antenna based on 3rd iteration Minkowski-like pre-fractal structure has been designed and the antenna performance of many structures has been computed using a full-wave numerical method of moment (MoM). The proposed structures have been applied in dual-frequency GPS antennas at L2:1.2276 GHz and L1:1.57542 GHz.

Fractal geometry defines a structure with long lengths that fit in a compact area. Due to the iterative generating process, the multiple scales of the recurring geometry resonate at different frequency bands. The iterative generation procedure of a Minkowski-like pre-fractal up to the 3rd iteration is demonstrated in Fig.1.

The dimension of a fractal provides a description of how much a space it fills. A dimension contains much information about the geometrical properties of a fractal. The generator used to develop the proposed Minkowski-like pre-fractal structure (Fig.1a) involves similarity transformations of more than one ratio; a_1 and a_2, and thus its dimension can be obtained from the solution of the following equation [13]:

$$2\left(\frac{1}{2}(1-a_1)\right)^D + 2a_2{}^D + a_1{}^D = 1 \qquad (1)$$

where D, represents the fractal dimension, a_1 is the ratio W_1/L_0, and a_2 is the ratio W_2/L_0. The perimeter, P_n, of the nth iteration MLPF antenna is then calculated using [15]:

$$P_n = (1+2a_2)P_{n-1} \qquad (2)$$

In this paper, many 3rd iteration MLPF antenna structures, corresponding to different values of a_1, had been designed and modeled at the design frequency of the GPS (L2:1.2276 GHz).

III. The Antenna Design and simulation

The geometry of the 3rd iteration MLPF microstrip antenna is shown in Fig.1*e* .It has been depicted with enlarged scale to show the smallest details. The proposed antenna design has been computed using an FR4 substrate with relative dielectric constant of 4.4 and a substrate height of 1.6 mm. The design frequency is the GPS L2:1227.60 MHz, since the multiresonance behavior of the MLPF antenna implies that the lowest resonance frequency takes place at the design frequency [15, 16].

The dimensions of the traditional half-wavelength patch antenna, (Fig.1*b*), have been calculated at the design frequency using the prescribed substrate parameters. The perimeter, P_o, of this patch is found to be of about 228 mm. The corresponding perimeter, P_3, of the 3rd iteration MLPF antenna is then calculated using Equ.2. This results in an MLPF patch length of 26.3 mm.

The resulting dimension of the 3rd iteration MLPF microstrip antenna corresponds to a reduction in size of about 78% compared with the conventional microstrip antenna operating at the same frequency and using the same substrate.

The middle segment width ratio of the generator structure, (Fig.1*a*), has been adjusted to many different values. Best results had been obtained for a value of $a_1 = 0.2$. The resulting antenna element has been excited with a two-port configuration having the same amplitude but in phase quadrature to enhance producing of circular polarization required for the GPS operation.

IV. Simulation Results

Theoretical performance of each of the proposed antenna structure has been predicted using a full-wave numerical method of moment (MoM). EMSight™, of the Applied Wave Research, includes a full-wave electromagnetic solver that uses a modified spectral-domain method of moments to accurately determine the multi-port scattering parameters for planar structures [17].

Fig.2 shows the computed return loss for the modeled antennas. It is clear that the simulated results show that two resonance bands exist: the first band is from 1.16 GHz to 1.26 GHz, and the second band is from 1.28 GHz to 1.71 GHz. The two bands include the GPS L1 band and L2 band frequencies.

Figs.3 and 4 show the E field radiation patterns for RHCP and LHCP at the GPS frequencies L2:1.2276 GHz and L1:1.57542 GHz. Respectively.

V. Conclusion

A new 3rd iteration Minkowski-like pre-fractal dual band GPS patch antenna structure is presented, which possesses a compact size and low profile. The proposed low-profile dual-frequency GPS antenna has good radiation patterns GPS L1 and L2 bands. The presented antenna offers a reduction percentage in size of 78% as compared with conventional rectangular Microstrip patch antenna designed at the same frequency and using substrate with similar parameters. Additional work has to be performed applying the same design idea for other dual-band communication systems.

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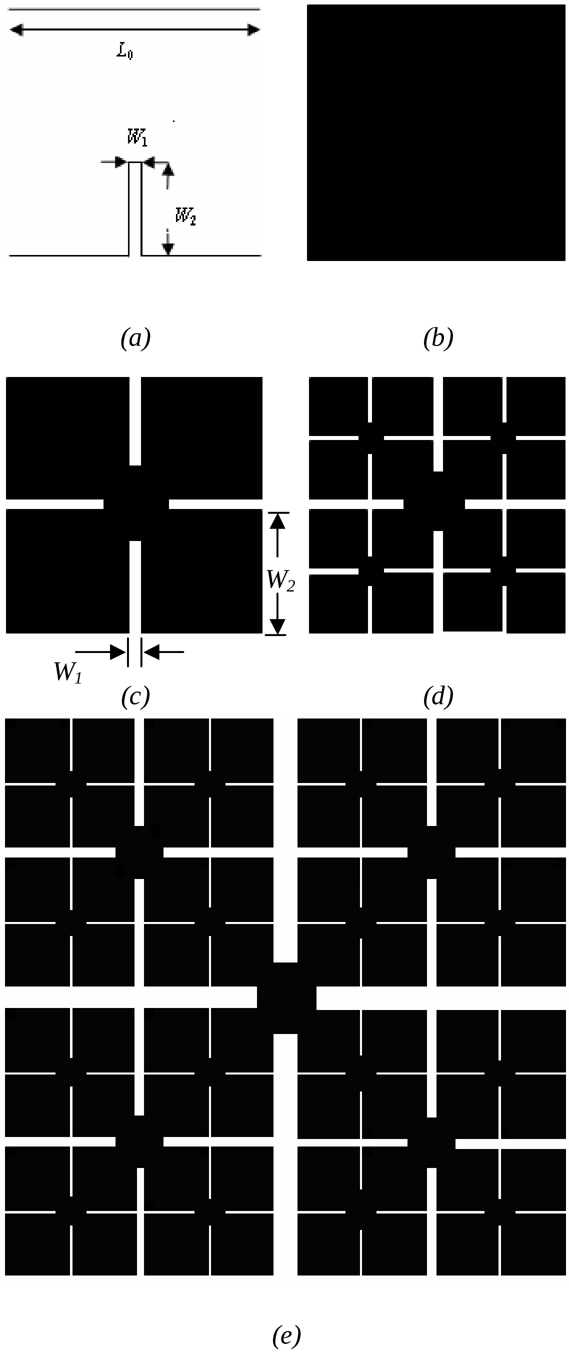

Fig.1 The iterative generation procedure of a Minkowski-like pre-fractal (MLPF); (a). The generator, (b). Square patch microstrip antenna, (the initiator), (c). The 1st iteration (d). The 2nd iteration and, (e).Enlarged scale of the proposed 3rd iteration MLPF structure.

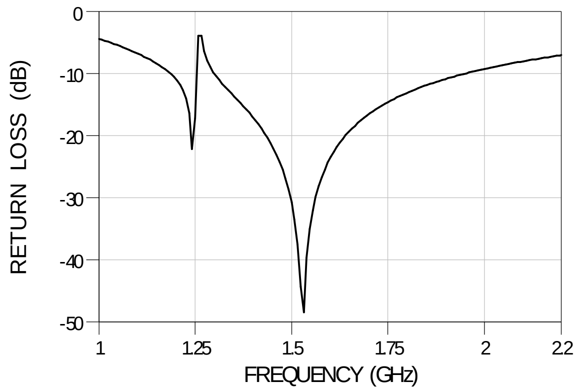

Fig.2 Simulated return loss of the proposed antenna

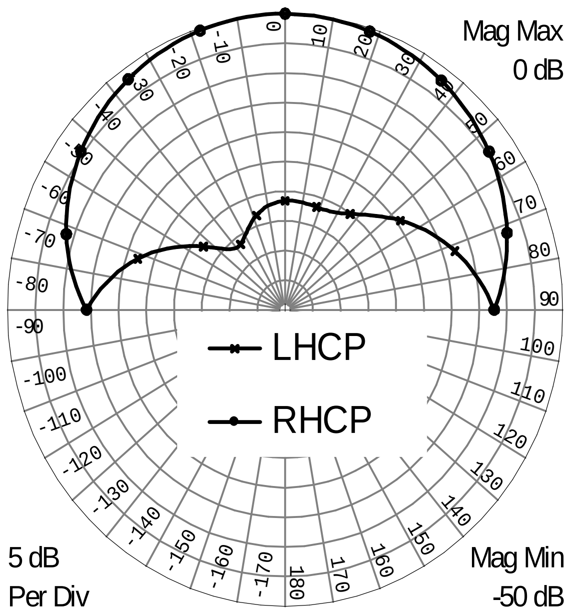

Fig.3 The RHCP and LHCP radiation patterns of the proposed antenna at 1.22760 GHz.

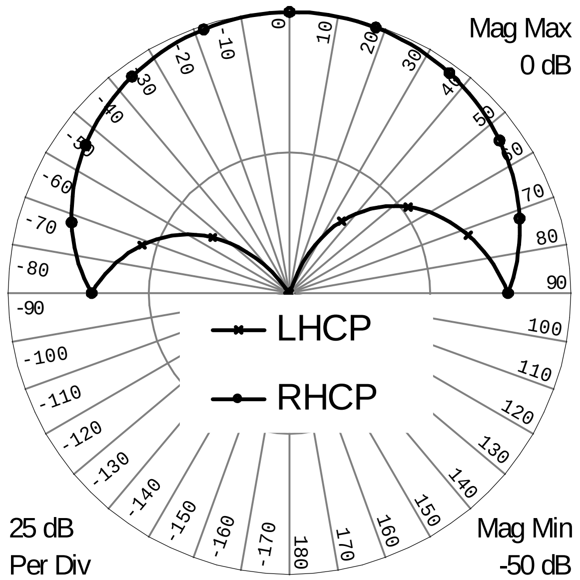

Fig.4 The RHCP and LHCP radiation patterns of the proposed antenna at 1.57542 GHz.