SAUSAGE MINKOWSKI SQUARE PATCH ANTENNA FOR GPS APPLICATION

Riyadh Khlf Ahmed[1], Assistant Lecturer. Israa H. Ali[2]
University of Diyala, College of engineering,
Dep. of communication. Diyala. Iraq.

ABSTRACT

Square Patch Antennas find wide range in practical modern communication system. The novel idea employed in this paper is to use Sausage Minkowski of square patch antenna as a candidate for using in Global Positioning System (GPS) applications. The antenna has been designed to operate at frequency resonance of 1.575 GHz which is the upper GPS band (L1). The proposed antenna is designed and simulated using CST Studio suite version-2014. The proposed antenna has been simulated on substrate TMM4 of relative permittivity equals to 4.5 and thickness of 1.6 mm. The results are reported in terms of reflection coefficient, VSWR, directivity and gain. According to our results, the antenna at 2nd iteration has gain 4.61dB, VSWR is 1.2 and reduce in area of patch about 42.8% less than 0 iteration. The antenna is more efficient by applying fractal geometry.

KEYWORDS: *Global Positioning System (GPS), GPS Antennas, Sausage Minkowski, Patch antenna, Reflection Coefficient, VSWR.*

I. INTRODUCTION

In recent years, large efforts have been made to develop the characteristics of the microstrip patch antenna for use in modern communication system. Square patch antennas are one of microstrip antennas categories which have many advantages as compared to conventional antennas kinds such as light weight, tiny size, low profile and cost, easy to manufacture and installation [1]. Furthermore, microstrip patch antenna has the ability to operate in dual frequency, circular polarization and wide band width. Several advantages enable microstrip patch antenna to operate in various practical microwave systems [2].

GPS is the navigation system which is used for applications of civil and military when we want to update time, position, tracking, direction finder and travelling from one position to another. Most of GPS antenna is achieved by microstrip antenna fabrication [3], [4].Different techniques are used to enhance the performance of microstrip patch antenna such as fractal geometry [5], defected ground structure [6]and cutting slots on patch [7], [8].

Fractal geometry can be introduced as broken or irregular fragments and widely used. Many models of fractal geometry are designed and implemented to improve the characteristics of antenna such as Minkowski fractal geometry, Hilbert curve, Koch curve, array fractal, Sierpinski, Sierpinski sieve.

In a previous study, (Amandeep & Surinder, 2015) present a design experimental and measured a wideband antenna at x- band region using Sierpinski fractal. The wideband frequencies were 12.2–13.4 GHz and 21–30 GHz with good gain achieved for using fractal.While in [9], offered a monopole antenna design for 2.1 and 3.6 GHz. Then used a circular iterative tree fractal on it. The new design operates at three resonance frequencies 5.6 GHz, 6.47 GHz and 7.89 GHz with a good gain.Also in this paper used monopole antenna but anew design of fractal. Crinkle fractal applying on top side of antenna [10].Another two papers in same year [11], [12], present a design of microstrip antenna using afractal geometry. 1stpaper used Koch curve fractal to the triangular patch to get circular polarization and gain about 4 dB. The 2nd paper operated at triple frequencies region(s, c and x) band. The Fractal elements add to the nine corners of the nonagon patch.[13], offered design a triple microstrip antenna

with CPW feed. Then employed fractal Koch based on the patch of antenna. The gain of triple frequencies is (−4.5, 3.75 and 5.3) dB for (1.5, 3.5 and 5.4) GHz respectively.
According to above, in this work, we present a design of square patch antenna operating at 1.575 GHz for GPS civil applications. Then, a new Sausage Minkoski fractal with 1st and 2nd iteration was implemented on square patch antenna. Finally, the proposed antenna parameters such as gain, VSWR, reflection coefficient and the area of three models are compared to each other to support the advantages of fractal method for improving the antenna parameters.
The organization of our research is divided in six sections. The 1st section deals with introduction and literature survey for the previous researches in this field. The 2nd section deals with methodology and materials which are used in design and simulation. The 3rd section explains the implementation of Sausage Minkowski Fractal steps. While the 4th section depicts the results and discussion for the three models. The 5th section deals with the conclusion. Our suggestion is presented in section six.

II. METHODOLOGY AND MATERIALS

2.1 Square Patch Antenna

Square patch antennas are the amongst famous antenna types use in wireless communication, especially in the application which needs frequency from 1 to 6 GHz [2]. As a result of great development in the science of communication and the urgent need for devices running certain frequencies and be of particular specifications in weight and size design. To this came the need to increase research at the 1970's about these antennas because of their light weight and proper size compared to other types of antennas options, made it attractive for airborne and spacecraft applications [3]. Latterly, patch antennas with different types are used high dielectric constant materials to decrease the size and thus become more widespread in a cellular phone, GPS receivers and enormous-produced wireless manufactures to have these properties. For a square patch, the length L of the element is as a rule the L< λg / 2 (where λg is the guide wavelength on the substrate). To provide better efficiency and larger bandwidth must thick substrates with low dielectric constant however at the expense of larger element size and vice versa [6].
Suppose a square patch antenna of width *Wp* at y direction, length *Lp* at x direction lean on the height of a substrate *hs* along z direction as shown in Figure(1) [14]. In order to operate in the essential mode, the patch's length must be less than λd/2.
Where $\lambda d = \lambda_0 / \sqrt{\varepsilon_{reff}}$, λd is the wavelength in dielectric medium, λ_0 is free space wavelength and ε_{reff} is the effective dielectric constant.

The dimensions of the antenna width (*Wp*) and length (*Lp*) are calculated from classical equations (1) and (3), the width *Wp* is given as [15]:

$$wp = \frac{v}{2f_r\sqrt{\frac{\varepsilon_{r+1}}{2}}} \quad (1)$$

The equation (2) is to determine the height of the dielectric substrate [15]:

$$hs = \frac{0.3v}{2\pi f_r\sqrt{\varepsilon_r}} \qquad hs \leq 0.06\,\frac{\lambda d}{\sqrt{\varepsilon_r}} \quad (2)$$

The actual length is obtained using equation (3):

$$Lp = L_{eff} - 2\Delta Lp \quad (3)$$

Equation (4) gives the length extension (ΔLp) as:

$$\Delta\, Lp = 0.412hs\,\frac{(\varepsilon_{reff}+0.3)\left[\frac{wp}{hs}+0.264\right]}{(\varepsilon_{reff}-0.258)\left[\frac{wp}{hs}+0.8\right]} \quad (4)$$

Effective dielectric constant (ε_{reff}) is given in equation (5) [14]:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left[1+12\frac{hs}{wp}\right]^{\frac{-1}{2}} \quad (5)$$

$$Lp_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} \quad (6)$$

Where Lp_{eff} is the effective length of the patch.

Equation (7) and (8) give the width (WG) and the length (LG) of the ground plane [16]:

$$WG=6hs+Wp \quad (7)$$

$$LG=6hs+Lp \quad (8)$$

2.2 Sausage Minkowski Fractal Geometry

There are two criteria to make the antenna work well at all frequencies [12]:

1. The antenna dimension must be symmetric about a point.
2. The antenna must subdivide in parts each of which is a reduced-size copy of the whole that makes it has to be fractal.

The fractal is self-similar design to maximize the length. the fractal geometry is used to miniaturize the dimensions of antenna that used in modern communication which work in large resonant frequencies [13]. Principle of operation of fractal depend on iterative mathematical process, which is described by an iterative function system (IFS) algorithm. The sausage Minkowski fractal is calculated as shown in Figure (2).
The resulted fractal by replacing each side of the square with the broken line is shown and applying this procedure repeatedly on the resulting polygons [17]. The length of each segment is calculated as in equation (9):

$$ls = \left(\frac{1}{\sqrt{5}}\right)^n \quad (9)$$

Where ls is the length of segment and n is the number of iteration
Figure (3) depicts the steps for fractal generation of a Sausage Minkowski patch antenna. It is a collection of the 3 first such polygons [17]. Their side-number S(n) is equal to $4*3^n$. The last polygon having S(4) = 324 sides.

III. IMPLEMENTATION OF MINKOWSKI SAUSAGE FRACTAL GEOMETRY ON SQUARE PATCH ANTENNA

A. Basic Square patch with 0 iteration

Square Patch Antenna (SPA) design is shown in Figure (4). It used the Coaxial cable technique, which is the most important types of feeding that used to feed or transmit electromagnetic energy to a patch antenna. It consists of the dimensions of SPA according to Equations (1-8) at the resonant frequency 1.575GHz. The antenna has utilized a crossbred structure and using Rogers TMM4 as a substrate with dielectric constant ϵ_r= 4.5 and the thickness is h = 1.6 mm. The thickness of the ground plane and square patch (PCE) material is t = 0.6 mm. The size of the feed line is calculated according to make the impedance of the antenna is 50 Ω.

B. First iteration of Sausage Minkowski Fractal antenna

With enforcement of Minkowski Sausage on the square shaped, the length of each segment is $\frac{1}{\sqrt{5}}$, so the number of segments after the 1st iteration is 12. The resulted structure is first iteration of sausage Minkowski fractal patch antenna (F1) as shown in Figure 5. Table 1 depicts the dimensions of F1.

C. 2nd iteration of sausage Minkowski fractal antenna

Same procedure is implemented on F1 as it was implemented on square shaped. The length of each segment is $\frac{1}{\sqrt{5}}$, so the number of segments after the 2nd iteration is 36. And resulted structure is first iteration of Sausage Minkowski fractal patch antenna (F2) as shown in Figure 6. The dimensions of F2 are depicted also in Table (1).

IV. RESULTS AND DISCUSSION

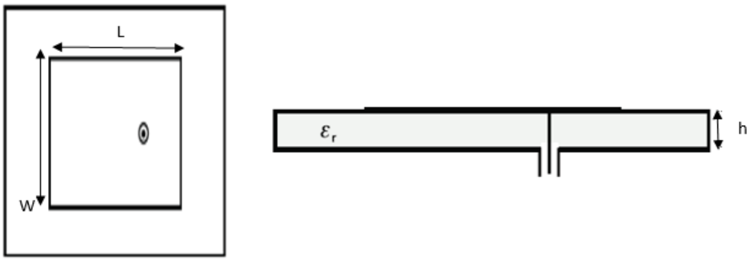
The antenna parameters gain, directivity which is directly proportional to the gain of the antenna by the value of the efficiency, reflection coefficient, SWVR and radiation pattern are obtained for the proposed antenna. It has been found that the values of reflection coefficient will be decreased from (-17 to – 25)dB with respect to the increasing of the number of iteration. These values of reflection coefficient are plotted as function to the frequency as shown in Figures (7, 9 and 11) for all modes of iteration and listed as shown in Table (2). Moreover, the Table (2) includes full details about the main parameters for the three modes of fractal iteration such as gain, VSWR and the area of square patch. The value of SWVR will decreased with respect to the increasing of the number of iteration. These VSWR values were recorded 1.6, 1.4 and 1.2 for the 0th iteration, 1st iteration and 2nd iteration respectively. The gain of all modes of iteration has good agreement which was 4.5 dB, 4.54 dB and 4.61 dB for the 0th iteration, 1st iteration and 2nd iteration respectively as shown in Figures 8, 10 and 12 for 3D plot and polar plot. The reducible area from 1849 mm^2 to 1242.5625 mm^2 in first step of fractal iteration and then to the 1056.25 mm^2 in the second step of fractal iteration is good indicator to reduce the physical size in fractal iteration technique for GPS application Sausage Minkowski patch antenna in parallel form with the enhancement the antenna parameters.

Table 1: Dimensions of square patch antenna

Variables	**0th iteration**	**1st iteration**	**2nd iteration**
Lp (mm)	43	35.25	32.25
Wp (mm)	43	35.25	32.25
LG (mm)	86	86	86
WG (mm)	86	86	86
hs (mm)	1.6	1.6	1.6
tp (mm)	0.6	0.6	0.6

Table 2. The parameters of square patch antennas

Parameters	**0th iteration**	**1st iteration**	**2nd iteration**
Reflection coefficient (dB)	-17	-24	-25
Gain (dB)	4.5	4.54	4.61
VSWR	1.6	1.4	1.2
Area of patch (mm2)	1849	1242.5625	1056.25



(a) (b)

Figure 1. Square patch antenna (a) top view, (b) side view

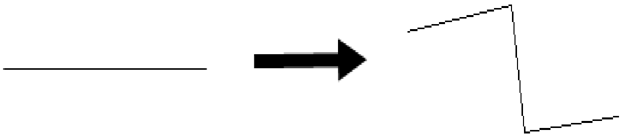


Figure 2. Minkowski Sausage fractal curve illustrate

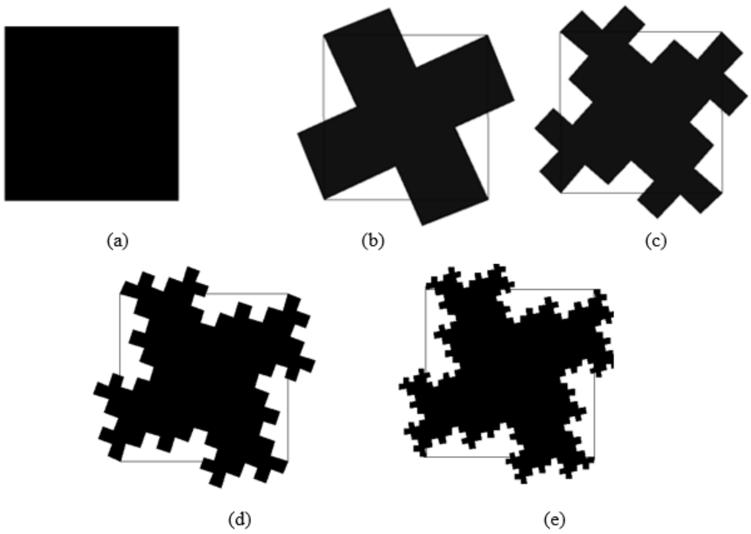


Figure 3: Minkowski sausage fractal (a) 0 iteration, (b) 1st iteration, (c) 2nd iteration, (d) 3rd iteration, (e) 4th iteration

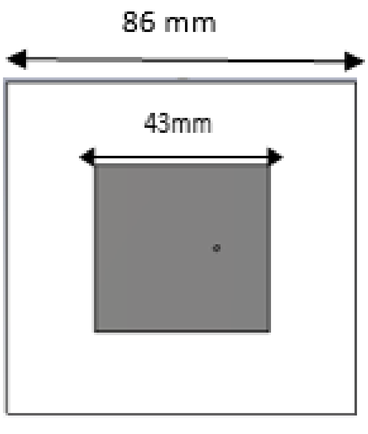


Figure 4: 0th iteration sausage Minkowski Square Patch Antenna

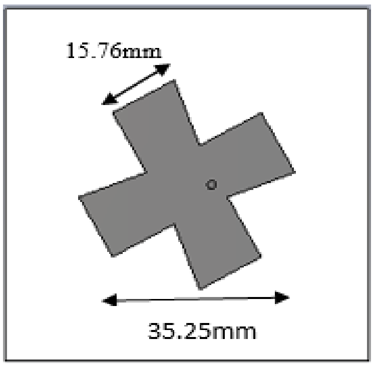


Figure 5: 1st iteration sausage Minkowski square patch antenna

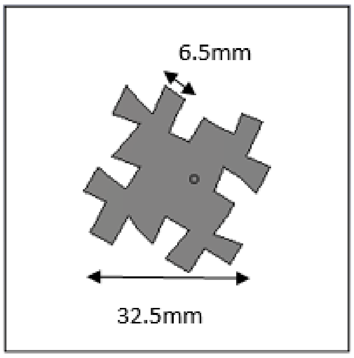


Figure 6: 2nditeration sausage Minkowski square patch antenna

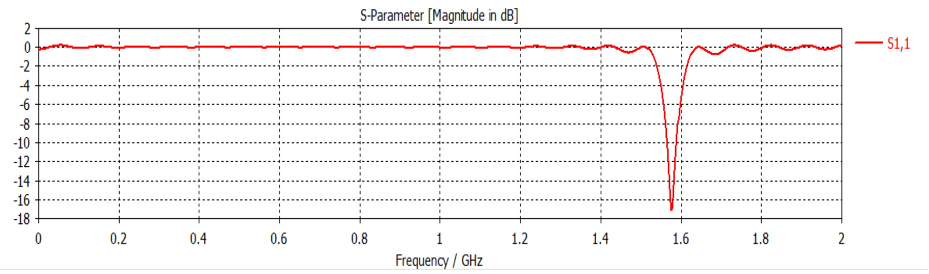
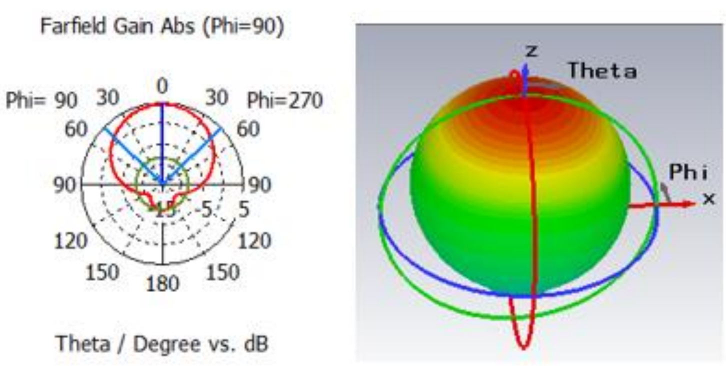


Figure 7: 0th iteration Reflection coefficient at 1.575 GHz



(a) (b)

Figure 8: 0th iteration Radiation pattern (gain) (a) polar, (b) 3D

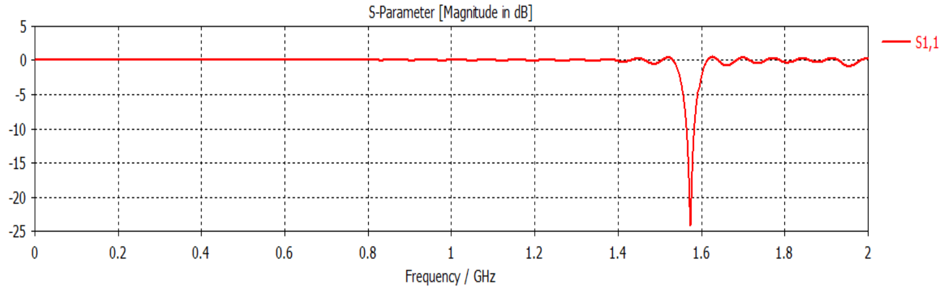
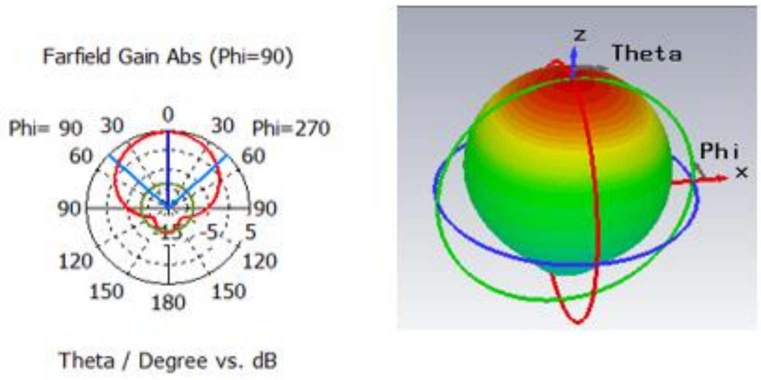


Figure 9: 1st iteration Reflection coefficient at 1.575 GHz



(a) (b)

Figure 10: 1st iteration Radiation pattern (gain) (a) polar (b) 3D

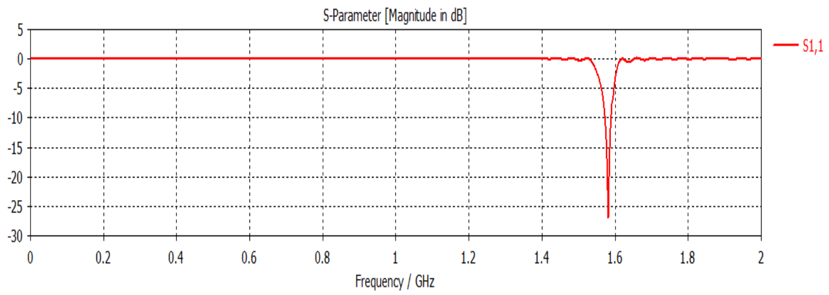
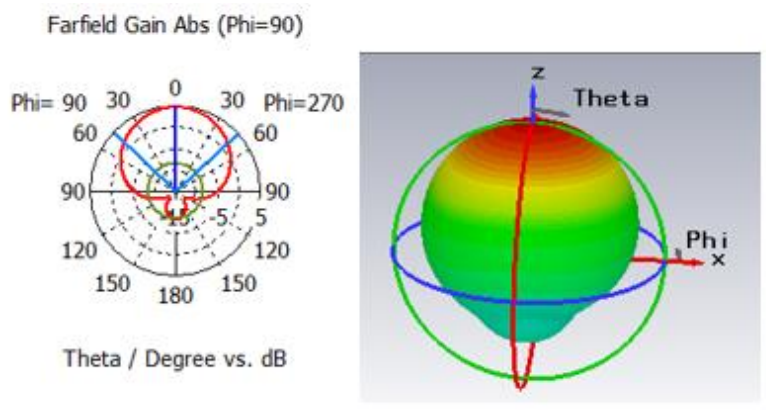


Figure 11:2nd iteration Reflection coefficient at 1.575 GHz



(a) (b)

Figure 12: 2nd iteration Radiation pattern (gain) (a) polar, (b) 3D

V. CONCLUSION

A novel and simple Sausage Minkowski based on patch antenna has been design and simulated. The designed antenna works in L1 band for GPS civil application. The results of the simulation reported that the proposed Sausage Minkowski patch antenna is efficient and good sufficient to satisfy the requirements of hardware model for GPS antenna. The requirements of modern communication systems need antenna have to be light weight, small profile, compact and stable performance. We conclude that the performance of antenna begins to improve with the increasing the number of iteration so, the gain and directivity increased with shrinking the size of antenna for 1^{st} iteration and 2^{nd}iteration for these fractal shapes. The low value of VSWR for 0^{th} iteration is 1.6 and the reducible values of 1^{st} iteration and 2^{nd} iteration 1.4and 1.2 respectively indicate that low back wave radiation towards the small satellite platform. Also the results show that when the number of iteration increased, other antenna characteristics will be better such as reflection coefficient and band width.

VI. FUTURE WORK

We suggest study and analysis the Specific Absorption Rate (SAR) effect of human head tissues for the three Square Patch antennas models.

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Riyadh Khlf Ahmed received the degree in Electronic and communication Engineering from college of Engineering/ University of Mosul in 1993. Master degree was received in 2005 from University of Technology. Ph.D was received in 2014from university of Baghdad. Currently, he is Lecturer at Communication Engineering/ college of Engineering/ University of Diyala.

Israa H. Ali. received the degree in Electronic Engineering from college of Engineering/ University of Diyala, in 2005.Master degree was received in 2013 from Almustansiriya University. Currently, she is an Assistant Lecturer at Communication Engineering/ collage of Engineering/ University of Diyala