The Performance Evaluation of SAR for a Sausage Minkowski Square Patch Antenna

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Abstract

Square patch antennas (SPA) are widely used today's in wireless communication systems, mainly with popular frequency of 1.575 GHz. Wireless devices are the main source of propagation and radiation for the Electromagnetic (EM) rays. The waves penetrate tissues of the human beings and cause health danger. A fractal Sausage Minkowski square patch antenna is proposed, designed and simulated. A Fractal antenna is designed and simulated at 1.575 GHz for GPS application using CST MW studio 2014. Specific Absorption Rate (SAR) is the term which measures the exposure of human to electromagnetic waves radiation for communication antenna. SAR values are calculated over tissues mass with respect to the IEEE and (ICNIRP) standards for head safety. The SPA antenna presents the smallest SAR levels in adult head tissues at 2nd iteration Sausage Minkowski fractal antenna. The results show that the SAR levels for the three different fractal iteration are the highest in (ICNIRP) standard as compared to (IEEE) standard.

Keywords: Square patch antenna (SPA), Specific Absorption Rate (SAR), head tissues, Sausage Minkowski and fractal.

1 Introduction

Microstrip Patch antennas have developed very fast in the last thirty years. Due to their advantages such as low profile, not heavy, simple to manufacture and cheap, many applications use it today [1-3]. Global Positioning System (GPS) applications mostly use Circularly polarized patch antennas since they require miniaturization and high performance [4]. It is not easy to achieve Miniaturization and high performance at the same time, particularly at lower frequencies. Reports show that some studies improved the performance of patch antennas via the use of periodic structures [5, 6]. It is a fact that because of surface wave losses, that a square patch antenna has a high relative permittivity (ε_r) substrate can never be a highly efficient radiator and that it has a very narrow bandwidth. People have used various techniques to compensate the performance of microstrip square patch antenna, like fractal geometry [7], defected ground structure [8] and cutting slots on patch [9].

Fractal geometry can be introduced as the broken or irregular fragments that are widely used. Minkowski fractal geometry, Hilbert curve, Koch curve, array fractal, Sierpinski and Sierpinski sieve are designed and implemented in many models of fractal geometry to improve the characteristics of antenna [10,11].

Because of nowadays advanced telecommunication technology, inventions such as cell phones are used by almost everybody around us. However, these devices are considered an essential source of the propagation and radiation that electromagnetic (EM) waves break through the body tissues and eventually cause critical health risk. The World Health Organization (WHO) reported that the microwave rays became main causes of defilement which is itself causes many diseases. Some brain tumours and cancer are proven to be caused by excess levels of radiated power of EM fields. Temperature rise and thermal effects can be a result of the heat that generates from the microwave radiated power. The resonant (absorbing matter) is occurred when the EM waves power interact with biological organism of human tissues. The resonant interaction between our bodies and EM fields radiation is explained by determination of SAR parameters that are directly proportional to the power of EM fields distribution in according to the special structure of our human body tissues [1].

SAR is the power absorbed by body tissues, typically averaged either over the whole body or over a small part volume (typically $1\ gram\ or\ 10\ grams$ of human beings body). (ICNIRP) and the (IEEE) have been developing recommendations for confining the electromagnetic field exposure to keep the protection for the users from the dangerous of electromagnetic field (EMF) exposure. The limit was set as $2\ Watt/kilogram$ by takingweight of $10\ gram$ of body tissues with respect to *IEEE C95.1:2005* by both mentioned organizations. On the other hand, SAR limit has been specified to $1.6\ Watt/kilogram$ by taking $1\ gram$ of human beings body tissues by (FCC) of American United State [1, 2]. IEEE describes the SAR as:

$$SAR = \frac{d}{dt}\left(\frac{dw}{dm}\right) \quad (1)$$

SAR is expression can be represented as a derivative of change in energy absorbed during certain time divided by to the change in mass involved in a volume of specific density [1, 3]. Normally, SAR is measured using two types of units. First type is the amount of watts per kilogram (W/kg). The second type of units is the amount of milliwatts per gram (mW/gm). Taking in account the electric field intensity, SAR can be defined SAR as [1,3]:

$$SAR = {}^{\sigma E^2}/_{\rho} \quad (2)$$

Where: - E is the RMS value (root mean square) of electric field strength which is measured in units of(V/m) , σ represents the conductivity of biological tissue which is measured in units of (S/m). and ρ expreses the density of biological tissue which is measured in units of Kg/m^3 .

2 Related Work

A former study presented a new compact in size, circularly polarized micorstrip fractal based slot antenna. Its structure is based on the inverted Sierpinski gasket fractal geometry of the third iteration. There is a single 50 Ω probe feeds the above mentioned antenna. This antenna is intended to be used for Global Positioning System L1 applications [7].

There is a comparative analysis that investigates different kinds of antennas which are widely used in multiuser applications such as mobile communication devices. Some of these devices are a circular patch, a helical, square patch and E-shaped antenna. Each one of these platform is designed, simulated and practically implemented. The testing is done via the use both of CST

Microwave Studio or HFFS. In addition, the test process was taking in account the distance change by getting close to the human beings body especially head or hand. Normally, the distance is changed from 0 to 20 mm then the performance of each radiator source is evaluated [4].

Analysis the influence of inclination angles variation between the human being head and mobile device antenna on SAR levels was presented in [1]. Also the effects of the metal-glass cases of mobile phone devices on the SAR levels were recorded to watch the proximity of the human body to the electromagnetic wave radiator. Also, the return losses were simulated for the different cases to observe performance evaluation. This comparative study was achieved by implementation (FDTD) method in CST [1].

According to related works as shown above, simulation of square patch antenna and Sausage Minkowski fractal antenna are presented using CST Microwave studio 2014. SPA and its fractal equips a return loss along a wide angle of beam and equips a good gain, are designed and simulated for GPS civil application. SAR levels are determined over mass of head tissues for human with respect to the IEEE and ICNIRP standards for head safety. The inclination angle is taken to be 0 degree. The evaluation of the presented antenna is carried out when the distance is adjusted to 5 cm between body of human and microwave device at frequency of the evolution of SAR values is carried out for adult human, and the head tissues is consisted of three layer (skin, skull and brain).

The objective of this article is reduction the SAR levels using fractal Sausage Minkowski square patch antenna where antenna is designed for GPS application. The simulation is done by exposure the brain to Electromagnetic (EM) fields represented as microwave frequencies utilizing the method of Finite Difference Time-Domain (FDTD). SAR levels are recorded by changing the location of human being head to the fractal sausage minkowaski square patch antennas. Finally, SAR values have been calculating and comparing to each other over tissues mass of the proposed antenna for the two iterations to support the benefits of fractal method according to the IEEE and (ICNIRP) standards for head safety. The results of this work are used as measures for this comparative study involving the values of Specific Absorption Rate (SAR). It found that the determined SAR levels within each of the tested tissues are different for the three iterations of Sausage Minkowaski antennas that are being investigated with respect to the standard numbers that it issued from health safety. For GPS civil applications, square patch antenna operating at L1 (1.575 GHz) was designed and simulated, and then, a novel Sausage Minkoski fractal with first and second iteration was simulated [14].

3 Methodology and Materials

Square microstrip patch antennas are the most used ones out of all the types of microstrip antennas that exist. The highest performance evaluation needs to select suitable following factors such as substrate material, reduced antenna volume (length, width and thickness) and the method of feeding. All the factors help in determining the performance of microstrip antenna. Hence, among various feeding methods, inset fed techniques are used for the implementation of squaremicro strip patch antenna at 1.575GHz [12,13].

The proposed antenna consists of Rogers TMM4 as a substrate with relative permittivity ϵr= 4.5 and the height is h = 1.6 mm. The ground plane and square patch (PEC) material with thickness of t = 0.6 mm [14]. The dimensions of the feed line are adjusted according to make the impedance of the antenna to be 50 Ω.

Good conductor materials (PEC) are used for feeding, square patch and ground plane. The geometrical configuration of square patch antenna is depicted in Figure 1. The length, width and height of the proposed microstrip antenna are 43 mm, 43 mm and 0.6 mm in series are there. A circuit board of Teflon (PTFE) with substrate of dimensions 86 mm × 86 mm × 1.6 mm was used to apply the simulation of fractal sausage minkowski antenna [14].

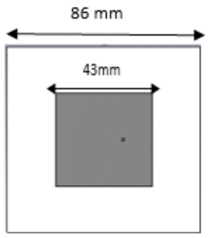
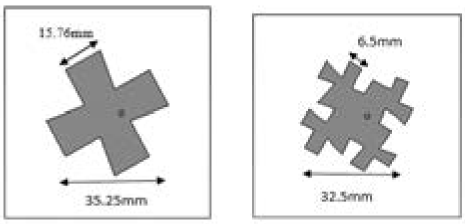


Figure (1): Square Patch Antenna

Fractal geometry is used to miniaturize the dimensions of antennas used in modern communication which work in large resonant frequencies. The principle of operation of fractal depends on iterative mathematical process, which is elaborated by an iterative function system (IFS) algorithm. The Minkowski sausage fractal resulting by changing each side of the square with the broken line shown and applying this process repeatedly on the resulting polygons as shown in Figure 2.

Figure (2): Fractal Sausage Minkowski polygons

Enforcement Sausage Minkowski on the square shaped structures will result first iteration and second iteration of fractal Sausage minkowski patch antenna as shown in Figure 3.



(a) (b)

Figure (3): Sausage Minkowski SPA
(a): 1st iteration (b): 2nd iteration

4 Result and Discussion

The square patch with 0th, 1st and 2nd iteration fractal antenna has been simulated using CST MW Studio 2014 software. The calculation of SAR values for the human beings head tissues became one of the most priorities in the world. The calculations are taken for two world standards: ICNIRP and IEEE. The human head tissues consist of three layers: brain, bone and skin.

The Figures 4, 5 and 6 show the results of the peak value of SAR level in (1gram) and (10gram) at 1.575 GHz for the square patch antenna and its fractal.

It seems the value of SAR is decreased with increase the iteration of fractal for both standards. It observed the values of maximum SAR (0. 4 W/Kg) in 0 iteration of sausage Minkowski fractal antenna according to ICNIRP standard. While in IEEE standard limit, the value of SAR (0.165 W/Kg) at same human head tissues.

Table 1 shows the results of SAR level at (1g) which are (0.4, 0.122 and 0.0351) W/Kg for (0th, 1stand 2nd) iteration of sausage Minkowski fractal antenna respectively. While in (10g) the SAR values are(0.165, 0.0943and 0.0124) W/Kg for same iteration above.

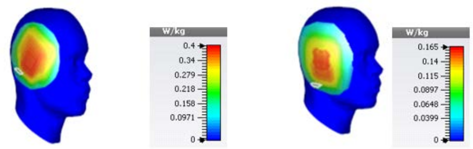


Figure (4): Specific absorbing rate (SAR) for SPA with 0 iteration, (a)1g, (b) 10g

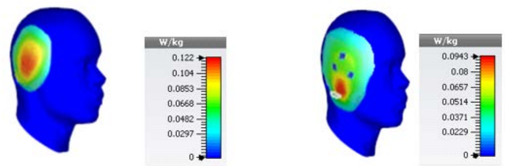


Figure (5): Specific absorbing rate (SAR) for SPA with 1stiteration, (a) 1g, (b) 10g

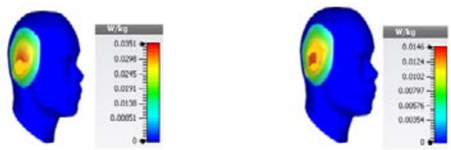


Figure (6): Specific absorbing rate (SAR) for SPA with 2nd iteration, (a) 1g, (b) 10g

Table (1): values of peak SAR for Fractal Sausage Minkowski antenna

Iteration of Fractal	SAR (W/Kg)	
	1g	10g
0	0.4	0.165
1st	0.122	0.0943
2nd	0.0351	0.0124

5 Conclusion and Future work

The issues of health awareness become the main criterion for many countries when standards are approved. Comparative study of Specific Absorption Rate (SAR) levels for three different fractal Sausage Minkowskil iteration antenna exposed to RF frequency is carried out in this paper. Square patch antenna (SPA) is simulated at 1.575 GHz of wireless communication applications, with distance of 5 cm from the wireless device the antenna away. The SPA antenna produces the smallest SAR levels in adult head tissues at 2nd iteration fractal Sausage Minkowski antenna. The SAR levels in the three different fractal iteration are the highest in standard (ICNIRP) as compared to (IEEE). The next proposal for our work is study the effect of proximity between the fractal Sausage Minkowski antennas and the human head on SAR levels. Also study the effect inclination angle on SAR levels for the different fractal Sausage Mnkowski. This study provides some investigations and promising valuable indications for perfect fractal Sausage Minkowski design operating at low SAR for GPS applications.

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تقييم الاداء لمعدل الامتصاص المحدد لهوائي الرقعة المربعة السوسج منكوسكي

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الخلاصة

هوائي الرقعة المربعة يستخدم اليوم بكثرة في انظمة الاتصالات اللاسلكية وخصوصا ضمن التردد الشائع 1,575 غيغاهيرتز. تعتبر الاجهزة اللاسلكية المصدر الرئيسي للاشعاع الموجات الكهرومغناطيسية .الموجات الكهرومغناطيسية تخترق انسجة الانسان وتسبب الخطورة على صحته. نحن نقترح, تصميم ومحاكاة هوائي الرقعة المربعة بتقنية التجزئة صوصج منكاوسكي. هوائي الهندسة الجزيئية تم تصميمه ومحاكاته ليعمل بتردد 1,575 غيغاهيرتز المستخدم في تطبيقات انظمة تحديد المواقع العالمي باستخدام برنامج تقنية محاكاة الحاسوب مايكرويف ستوديو-2014. ان معدل الامتصاص المحدد هو مصطلح لقياس تعرض الانسان لاشعاع الموجة الكهرومغناطيسية من هوائي الاتصالات. قيم معدل الامتصاص المحدد ستحسب لكتلة من انسجة الانسان حسب النظامين العالمين الهيئة الدولية للحماية من الاشعاع غير المؤين و مؤسسة مهندسي الكهرباء والالكترونيك. قيم معدل الامتصاص المحدد الماخوذة لراس الانسان البالغ اقل ما يمكن في حالة التكرار الثاني للهندسة الجزيئية ساوساجمنكاوسكي لهوائي الرقعة المربعة. كذلك اثبتت النتائج ان قيم معدل الامتصاص المحدد المحسوبة حسب النظام العالمي الهيئة الدولية للحماية من الاشعاع غير المؤين اكبر ما يمكن من القيم الحسوبة حسب النظام العالمي مؤسسة مهندسي الكهرباء والالكترونيك في حالات التكرار الثلاثة للهندسة الجزيئية .