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Radiation effect of fractal sierpinski square patch antenna

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ABSTRACT

Biological tissue interaction with Electromagnetic fields became one of the interesting studies in the last years. Wide variety wireless electronic devices are emerged in day to day life each providing a wireless connection for a certain service such as Global Positioning System, broadcasting systems, mobile communication systems, and networking. In this research article, fractal sierpinski square patch antenna is proposed and simulated to operate over L1 frequency range of 1.575 GHz for GPS applications using CST studio Suite where the proposed antenna has been investigated on Carpet shaped substrate made of Arlon 250 AD lossy. The dielectric constant equals to 2.5 and thickness of 1.6 mm. Thickness of patch is 0.6 mm. Also, the electromagnetic fields absorption on the human fingers is investigated where SAR levels are calculated for 0th, 1st, 2nd and 3rd iteration of the Fractal Sierpinski Square Patch Antenna. The results reported that the SAR limit of human finger tissue is enhanced with increasing the number of iteration: finger, human, tissue, GPS, SAR, absorption.

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1. INTRODUCTION

In the last three decades, small size, high efficiency and high performance antennas have been in wide demand in order to meet the integration for multiple telecommunication services. Square patch micro strip antenna is one of these kinds which has attracted by communication engineers. Microstrip antenna is constructed from three layers: Radiated patch component, dielectric substrate, and ground plane [1-5].

SAR limit is the ratio of the amount of power measured in watt to the average mass measured in gram. SAR is affected antenna kinds, the distance between antenna location and the human body, radiation patterns and radiated power [6, 7]. There are different approaches to SAR reduction, first approach is implemented by changing the angle of Electromagnetic source in relation to human body such as skin, brain and bone, second approach is investigated using fractal theory to reduce the size of antenna or changing the type of material covering the radiator [8]. SAR is determined mathematically by dividing the product of conductivity with square of the root mean square value of the electric field strength (E) to the volume density in certain tissue [9]:

$$\text{SAR} = \sigma * E2/2\rho \quad (1)$$

Where E denotes electric field strength in unit of v/m, σ is conductivity measured in (S/m) and ρ is the density (Kg/m3) of the interest tissue. Two standards introduce the SAR limit. First standard is IEEE C95.1: 1999 and the other standard is IEEE C95.1: 2005 which is comparable to the absorption limit expressed in ICNIRP. SAR limit of IEEE C95.1: 1999 can be expressed as1.6W/Kg in a SAR 1 gm averaging mass while SAR limit in the second kind is updated to 2W/Kg in a 10 gm averaging mass [10-12].

SAR limit was determined for Fractal Sausage Minkowski patch antenna for human head antenna [13]. The increasing the dielectric constant for substrate material will be increased the SAR limit for both IEEE and FCC standards [14]. Reducing the interface between human body and the radiator element was achieved using ferrite materials and Meta materials [15]. Four different human hand tissues are involved: skin, bone, muscle, and tendon in addition to three homogeneous sets of hands Using (SAM) hand phantom dielectric characteristics was presented [16]. The power is increased or decreased significantly in the experiment phase in some wavelengths when compared to the certain phases [17]. Study the mechanism of Electromagnetic waves absorption in both human hands and fingers was reported [18]. Study the impact of electromagnetic wave absorption on hand with respect to radiator element prosperities [19].

Enhancement of Body Flex application for allowing a suitable motion of the forearm and the wrist where the application is necessary for study the performance of electromagnetic effects from wireless phones [20]. Test of thirteen phones reported that various size dielectric slabs may increase the SAR measurements but cannot be representative of the high variations caused by a real hand [21]. SAR limit reduction was studied for four different iterations of Sausage Minkowski radiator element [22, 23]. In this research article, Fractal Sierpinski Square patch antenna for GPS applications was proposed and simulated. On other hand comprehensive study of radiation effect for this type of antenna on human finger is represented

2. METHODOLOGY AND MATERIALS

The suggested fractal antenna based on Carpet Sierpinski is simulated from square patch dimensions of Length (Lc) x Width (Wc) x Thickness (hc) equal to 115 mm x 115 mm x1.6 mm for substrate and ground layers. Substrate is selected according to dielectric constant (εr) of 2.5. Patch layer dimension is adjusted to operate in resonance frequency according to number of iteration. The simulation results are presented in triple iterations are designed using CST studio suite software 2014. First step is the determination of a square shape dimension [24-28]. The next step consists of division of it to nine tiny congruent squares. The open central square is dropped. The remaining eight squares are surrounded with eight smaller identical squares. Fractal dimension Dsi of a set A is expressed according to (2):

$$Dsi = \text{Log}(Ni) / \text{Log}(ri) \tag{2}$$

where Ni denotes the number of distinct copies identical to A, and A is reduced down by a ratio of 1/ri. Figure 1 shows the configuration details of Carpet Sierpinski fractal Square patch antenna for 0th iteration, 1st iteration, 2nd iteration and 3rd iteration respectively [29]. The third step involved the measurements of antenna radiation effect on human fingers tissue model based in two world standard ICNIRP and IEEE.

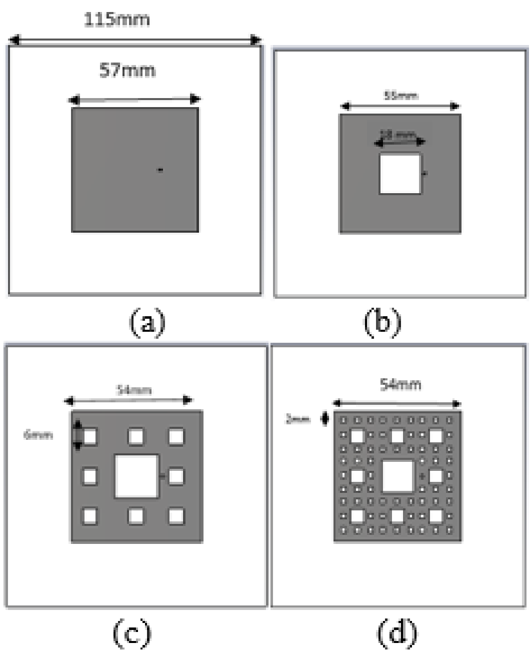

Figure 1. The geometry details of fractal carpet sierpinski SPA

3. RESULTS AND DISCUSSION

Firstly, Fractal Carpet Sierpinski based on Square patch antenna is designed and simulated. The simulation and results are carried out using CST software 2014. Four various iterations is designed to use in applications of GPS. The geometrical configuration of patch radiator is crossbred and utilizing dielectric material (Arlon 250 AD lossy) as substrate. The substrate is described with relative permittivity $\varepsilon_r = 2.5$, and thickness ($hc = 1.6\ mm$). The ground material is made of copper with thickness of $0.1\ mm$. The simulation results of reflection coefficient, gain, VSWR and the reduced area of the patch are shown in Table 1. From the observations from the Table 1, good indicator is recorded for the results. Reflection coefficient is decreased from (- 17 to - 25) dB with respect to the increasing of the number of iteration. The other parameters which are gain, directivity and voltage standing wave ratio are simulated. Maximum directivity values were recorded 7.52, 7.51, 7.50, 7.48 for number of iteration from 0th to 3rd respectively. Also, the gain of all modes of iteration has good agreement which was 5.48 dB, 5.74 dB, 6.15dB and 7.29 dB for the iteration number from 0th to 3rd respectively as shown in Table 1.

Table 1. The characteristics of fractal carpet sierpinski square patch antenna

Characteristics	Types of Fractal			
	0^{th} iteration	1^{st} iteration	2^{nd} iteration	3^{rd} iteration
Reflection coefficient (dB)	-16	-18	-25	-27
Bandwidth(MHz)	44	31.4	29	28
Gain (dB)	5.48	5.74	6.15	7.29
Directivity (dBi)	7.52	7.51	7.50	7.48
VSWR	1.65	1.65	1.7	1.6
Area of patch (mm^2)	3249	2701	2304	2052

The next step of our study is calculation of SAR limit for human fingers tissue model. Basically, the structure of human fingers tissue model contains three layers' bone, meat and skin. The proposed antenna is positioned at fixed distance about 5mm from the human fingers. Figures 2-5 show that the SAR simulation results for the proposed antennas.

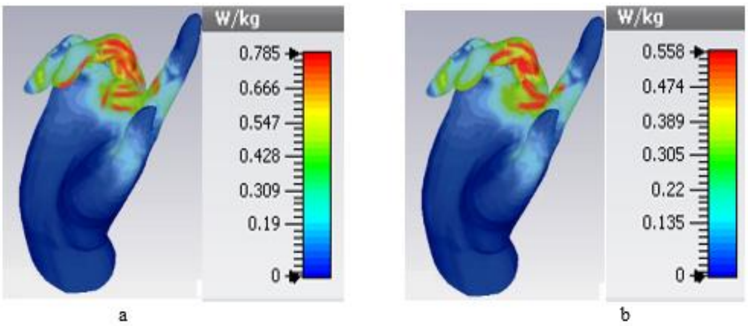

Figure 2. Specific absorbing rate (SAR) for SPA with 0 iteration, (a)1g, (b) 10g

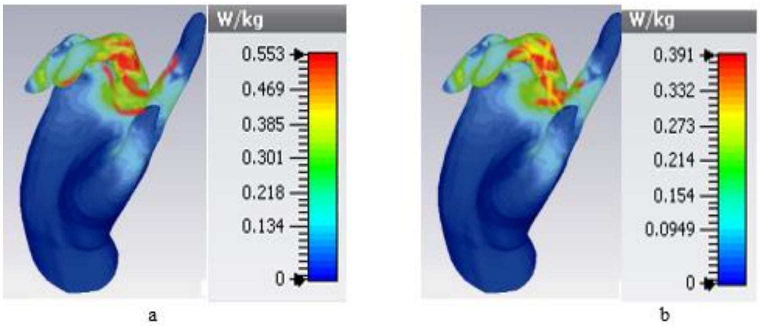

Figure 3. Specific absorbing rate (SAR) for SPA with 1^{st} iteration, (a)1g, (b) 10g

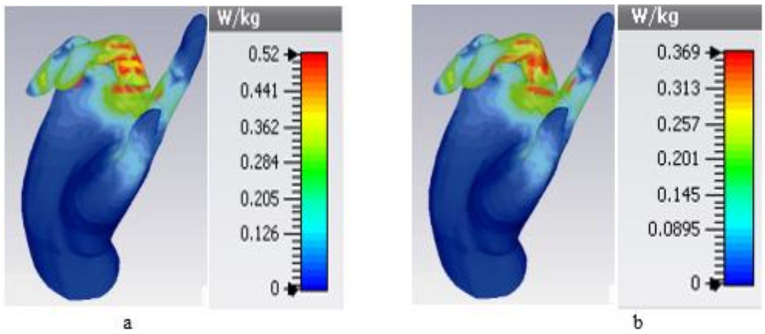

Figure 4. Specific absorbing rate (SAR) for SPA with 2nd iteration, (a)1g, (b) 10g

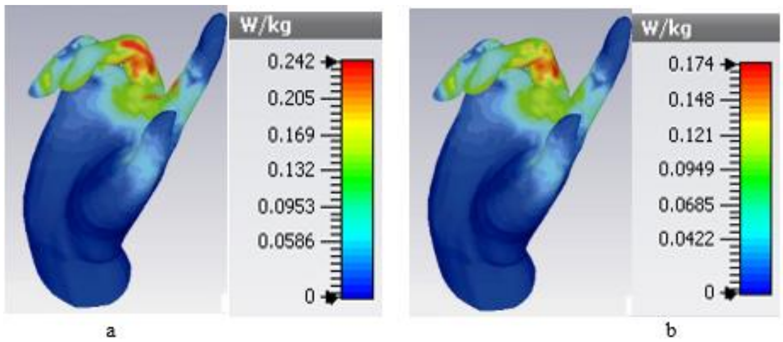

Figure 5. Specific absorbing rate (SAR) for SPA with 3rd iteration, (a)1g, (b) 10g

As shown in Table 2 where the SAR value is improved gradually with increasing the number of iteration. The red color indicates the region of fingers tissue which absorbed the maximum energy of radiated E.M fields from the proposed antenna. From Table 2, the low SAR value at all the resonance frequencies is noticed to satisfy the international safety standards (FCC & ICNIPR) at (1 g & 10 g). The proposed 3rd iteration of the fractal antenna has a very low SAR value.

Table 2. Values of peak SAR for fractal carpet sierpinski antenna

Iteration of Fractal	SAR (W/Kg)	
	1g	10g
0th	0.785	0.558
1st	0.553	0.391
2nd	0.52	0. 369
3rd	0.242	0. 174

4. CONCLUSION AND FUTURE WORK

A novel and compact Fractal carpet sierpinski patch antenna has been designed and investigated. The proposed tiny antenna operates in L- band of 1.575 GHz for navigation system. High demand for new kinds of antenna for modern communication applications motivates the researchers to study the radiation effect on human health. SAR is considered as a crucial factor and must be taken on account for many industrial applications. Therefore, new design is introduced and fabricated to enhance the SAR limit. A design and simulation show that the characteristics of the antenna will be enhanced in parallel with the increasing the number of fractal iteration like gain, directivity, radiation pattern, SWVR and return loss. In addition, the values of SAR for 1st, 2nd and 3rd iteration indicate that SAR levels will be decreased with increasing the number of iteration. The results are compatible with the yearly reports limits of the two standards (ICNIRP&IEEE). As a conclusion, the investigation of high efficiency, low size and not expensive antenna using simple technique, SAR is reduced as parallel with fractal process and the proposed antenna can be used for navigation purpose. Finally, we concluded that reducible values for low SAR level of radiator device (antenna) for human fingers will never degrade the RF performance of antenna. The suggestion is study the radiation effect of this type of antenna on human head or other part of human body.

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