Evaluation Koch Fractal Textile Antenna using Different Iteration toward Human Body

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***Abstract*- A Koch Fractal textile antenna are designed using denim material operating at 0.915 GHz. From the zero through second iteration, all the antennas performance in terms of return loss, bandwidth, realized gain and efficiency have been compared and analyzed. Then, on-body simulations was conducted using Voxel Human Body model in using CST Microwave software. At the same time, maximum Specific Absorption Rate (SAR) toward the backside body are discussed using two different orientations of the antenna; vertical and horizontal.**

I. INTRODUCTION

Nowadays, the wearable system has been developed for monitoring, tracking and healthcare activity. The wearable system is capable of taking real-time information data including human body condition and user location .Therefore, textile antenna is introduced to give comfort to the user at the same time still perform well on the wearable activity [1]. Flannel, denim, felt and foam have been chosen as main element for producing textile antenna. Most fabrics are low profile with low permittivity, flexible and durable material. Although the fabric material has inconsistent surface layer and high loss tangent, the antennas have good performance similar to the rigid board such as FR4 and Duroid [2 and 3].

Small and compact size antennas are required for the wearable system. Implementation of the fractal geometry into the wearable antenna design can help to achieve a miniaturized design. However, producing small antenna with this technique, may limit the antenna performance. Then, incrementing Q factor will produce narrow bandwidth of antenna due to its addition iteration reduction in the size antenna [4]. Therefore, Koch curve geometry has property of approximately of filling a plane[5] which are introduced to overcome the limitations of the antenna performance unlike other Euclidean geometry . Besides, increasing iteration of fractal geometry likes Koch curve, triangular and rectangular meandered line will shift the resonant frequency to the lower frequency band. Hence the lower radiation resistance also decrease [6]. From previous research work, the patch-slotted, array log period antenna was presented . Then printed and wired monopole antenna have been designed using Koch curve geometry [7].

The effect of placing antenna on human body is another issue which is discussed. ICNRIP basic retraction stated that the maximum power of electric devices and component must have less than 2 W/kg in 10 g of tissue for Specific Absorption Rate (SAR) value toward the human body [8]. Furthermore, when the antennas are placed closed with the human body, the coupling affect antenna performance in terms of resonant frequency and efficiency.

In this paper, Koch fractal textile dipole antennas are designed for 0^{th}, 1^{st} and 2^{nd} iteration at 0.915 GHz using CST Microwave Studio as shown in Figure 1. Planar and simple types of dipole antenna will provide omni-directional radiation patterns which are suitable for the wearable application. Mostly, the wearable computing system will communicates with the other system using Bluetooth, ZigBee and LAN network operating at 0.915 GHz band. Then, comprehensive analysis has been conducted to compare antenna performance and SAR value on human body between antenna with different iteration.

II. ANTENNA DESIGN

Firstly, the textile antenna is produced using denim material as the substrate with thickness of 0.8 mm. For the conducting layer, the conventional copper tape has been used. The estimated conductivity of this copper tape is 5.88×10^7 S/m. The relative permittivity ε_r and loss tangent tan δ of denim material are discovered using the open ended coaxial probe that show the value of ε_r = 1.71 and tan δ=0.085 at 0.9 GHz. The Koch fractal textile antennas are designed at 0.915 GHz using CST Microwave Studio using the estimated and measured properties of the materials.

Simple and planar dipole antenna structure are introduced that will be integrated with Koch fractal structure to miniaturize the length of antenna. All antennas are designed with flare angle of 45 degree. The theoretical formula of total length of the antenna for dipole structure are shown in equation (1)

$$l_0 = \frac{3 \times 10^8}{2f\sqrt{\varepsilon_{eff}}} \qquad (1)$$

where; l_0 is theoretical length of antenna, f is the determined resonant frequency and ε_{eff} is the effective permittivity.

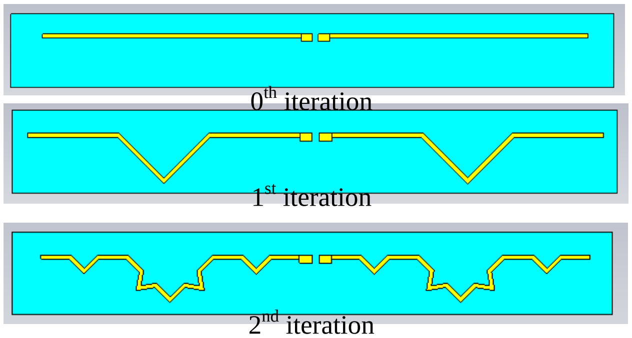

Figure 1 : Antenna design using the first, second and third iteration

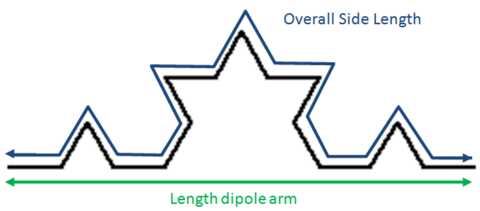

Figure 2: Overall Side Length and Length Dipole Arm

For the first case, three Koch fractal dipole antennas are designed with different iteration; zero, first and second with fixed length dipole arm = 132.5 mm. However, the overall side length increased related the value of iteration. Based on the formula, the overall side length of dipole antenna is calculated as shown in Equation 2.

$$l_{total} = l_0 \ (4/3)^n \tag{2}$$

where l_{total} is total overall side length, l_o is the length of antenna and n is the number of iteration . The optimization of the parameter is done using the simulation software. From the optimization, the width of 1 mm and the gap between antennas of 1.7 mm are obtained. The optimized overall side length and performance each antenna is summarized in Table 1. The results of the simulated return loss are shown in Figure 3. Figure 3 show the resonant frequency are shift to the low frequency due to the increasing iteration

TABLE 1: Comparison antenna performance based on different iteration antenna

Antenna Iteration	Overall Side Length (l_{total})	Resonant frequency (f_c)	Bandwidth (MHz)
0 th	132.5 mm	1.029 GHz	43.9
1 st	176.1 mm	0.959 GHz	69.9
2 nd	234.2 mm	0.915 GHz	72.5

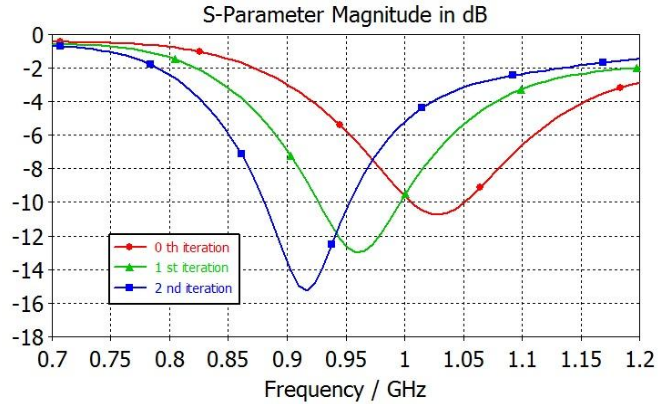

Figure 3: Simulated return loss with fixed length antenna parameter.

In the second case, all antennas are optimized at 0.915 GHz. The total length of dipole arm is 147.6mm for the zero iteration. Therefore, the length of the dipole arm will reduced to 139.08, and 132.48 mm for the first iteration and second iteration respectively as shown in table 2. The return loss for the second case is shown in Figure 4.

TABLE 2: Optimized Total length dipole arm at 0.915 GHz

Antenna Iteration	Length dipole arm (l_0)	Reduction Compared with 0th iteration (%)
0	149.28	-
1	139.08	6.8
2	132.48	11.3

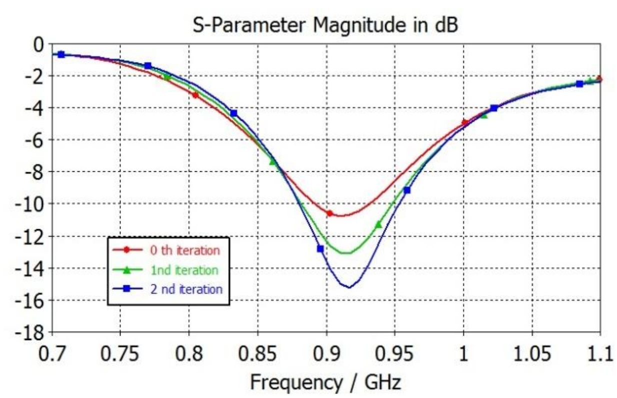

Figure 4: Simulated return loss of optimized at 0.915 GH

III RESULT AND DISCUSSION

A. *Simulation of Radiation Pattern*

Radiation patterns of the antenna (E-plane and H-plane) for the optimized results are shown in Figure 5. An omni-directional and dipole-like patterns are obtained for both H-and E-plane respectively. The size of radiation pattern increased when the number of iteration of Koch fractal antenna increases. At the same time, addition iteration value on the Koch fractal antenna will increase the efficiency and the realized gain as shown in Table 3.

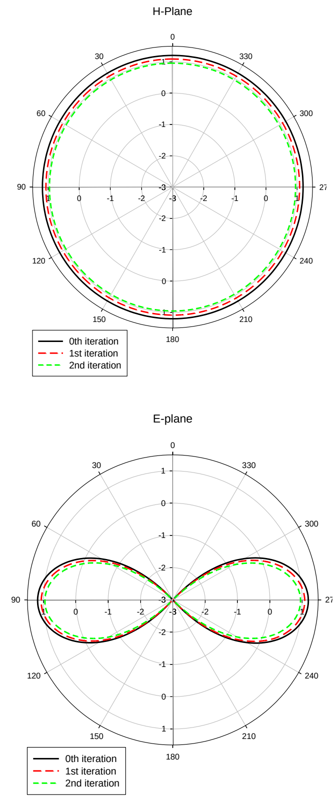

Figure 5: E-plane and H-Plane Radiation Pattern Antenna using Different Iteration

Table 3 : Realized Gain and Efficiency

Antenna Iteration	Realized Gain (dB)	Efficiency (%)
0	0.954	77.6
1	1.087	80.2
2	1.202	83.15

B. *On-body simulation*

From this research, the backside, chest and arm part of the body is chosen for the placement of the antenna compared to other locations. The antenna are placed 5 mm from the centre backside of Gustav man model which has the height of 163 cm and weight of 63 kg as shown in Figure 6. The backside body location is far away from the high permittivity organs such as the heart ($\varepsilon_r = 54.8$), the muscle ($\varepsilon_r = 50.8$) and the kidney ($\varepsilon_r = 52.7$) that will affect the antenna performance.

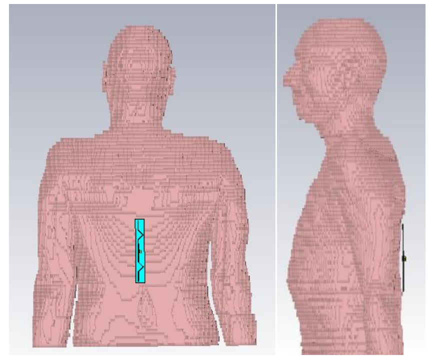

Figure 6: Placement Antenna at Backside Body

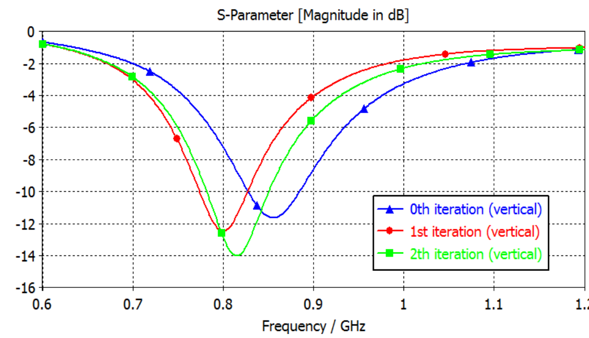

Figure 7: Return loss antenna performance using different iteration with vertical position.

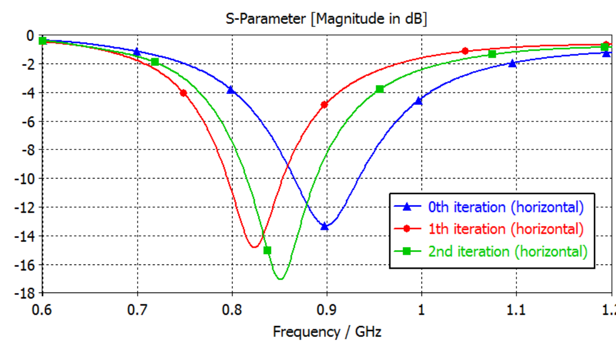

Figure 8: Return loss antenna performance using the different iteration with horizontal position.

Figure 7 and 8 show the simulated return loss for placement antenna with vertical and horizintal position at the backside body. The addition iteration for Koch fractal antenna will detune the resonant frequency to the low frequency. However, the Koch fractal antenna with first iteration more less affected on resonant frequency compared with the first iteration. Placement antenna at the backside body with vertical positon is more shifting resonant frequenc than the horizontal position

C. *Maximum SAR Value*

In the section, the simulation result of the SAR value is discussed toward the backside body when surrounding the textile antenna. The value SAR is highest when the high conductivity tissue organ such as heart, muscle and kidney surrounding the antenna. So, the backside body is a suitable placement for the antenna. From Figure 9, the highest SAR value is achieved when the antenna are placed with horizontal orientation for the second iteration with only 2.05 W/kg.

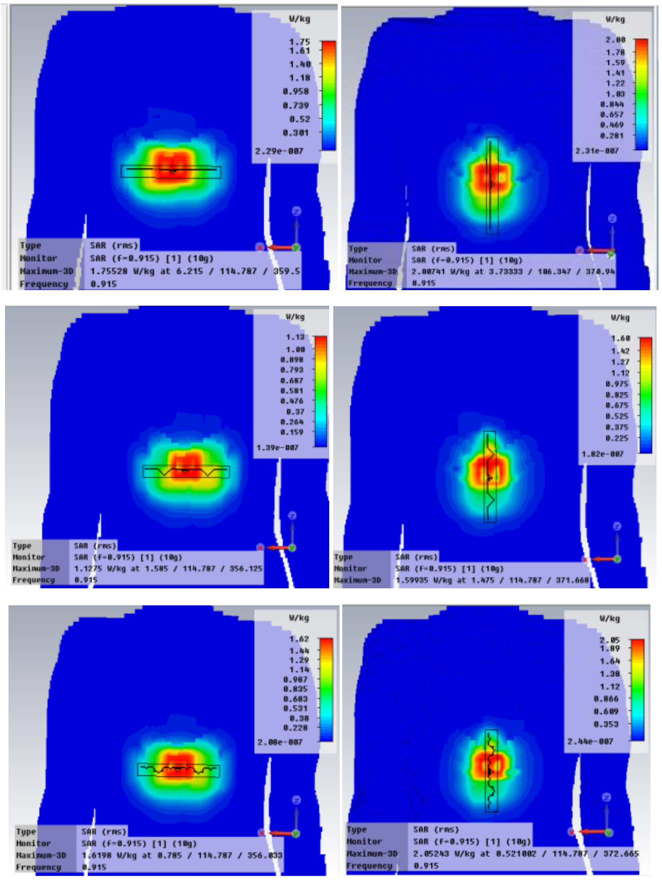

Figure 9: Maximum SAR Value on the human body

TABLE 4 : Comparison maximum SAR value based on different iteration antenna

Maximum SAR	Horizontal	Horizontal
0th iteration	1.75	2.00
1st iteration	1.13	1.60
2nd iteration	1.62	2.05

III. CONCLUSION

In this work, the Koch fractal textile antennas are designed and simulated using CST software. The antenna has been compared and analyzed with different iteration. Placement antenna at the backside body is under of basic restriction limit of SAR value.

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