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Miniaturization of Wearable Antennas Using Fractals in MICS Band

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Abstract:
A wearable antenna is designed to operate in MICS (Medical Implant Communication Service) band for telemedicine applications using the concept of fractals. A microstrip patch antenna consists of a substrate with a radiating patch and a ground plane on either side of the substrate. Fractal geometry is the procedure through which the reduction of size is achievable. In this proposed work, a self-similar fractal antennas using the technique of multicantor is implemented. The proposed models exhibit a good bandwidth and a return loss (S11) of more than -25 dB is approximately achieved in all the iterations. Miniaturization of the proposed antenna is achieved by cutting two rectangular segments in the edges after third iteration of the fractal. Approximately 24% of size reduction is achieved.

Keywords: *MICS, Wearable, Microstrip patch antenna, Self-similar fractal*

1. Introduction

In today's modern world with the increasing population there is demand for remote health care systems and patient monitoring system. There are numerous biomedical equipment's are already discovered for the medical purposes. But in today's modern world everyone needs the reliability, flexibility and mobility [4]. To observe patients from distant places and to support better healthcare facility by transmitting physiological and pathology parameters through wireless, fractal antenna on a microstrip platform is a solution for health monitoring system. The MICS (Medical implant communication services) band with range 400-405 MHz has been allotted for medical purposes [5]. Fractal antenna is a self-similar fragmented structure, subdividing the whole into parts and each of which shows a reduced size of the whole. Fractal structures may be of different types like Sierpinksi's Gasket, Cantor's Comb, Von Koch's Snowflakes, Minkowski Curve. Fractal have greater bandwidth and they are very compact in size compared to conventional antenna. Using fractal antenna, we can achieve resonant frequencies that are multiple band and those frequencies are not harmonics and also miniaturization of patch size and shape, better input impedance matching wideband, frequency independent. The main disadvantages of fractal antenna are gain loss, complexity and numerical limitations. The main advantages of these wearable antennas are flexible, nominal cost, resistance to shock and vibration. Wearable antenna is nothing but a rectangular microstrip patch antenna. The microstrip patch antenna fabricated by conducting material. The rectangular micostrip patch antenna consist of ground plane which is separated by substrate. The substrate of antenna is loaded with the dielectric material, the antenna length decreases as the relative dielectric constant of the substrate increases Microstrip.

Patch antenna are widely used in military purposes, satellite communication, GPS, telemedicine application due to its compact size and shape, light weight, less complexity and easy implement. The main disadvantages of these rectangular microstrip patch antenna are low gain, narrow bandwidth, and surface wave excitation. In this paper simulation has been done for the different iterations on the microstrip patch antenna using aperture feed.

2. Materials and Methods

The rectangular microstrip patch antenna with the aperture feed is shown in Fig 1. The antenna consists of a thin patch with width=174mm and length=223mm. The patch antenna is designed on a FR4 substrate(thickness= 3.2mm, ε_r=4.4) with ground plane at the bottom. The patch antenna is initially started with dimension 223mm × 174mm × 3.2mm of resonating frequency 405 MHz.
The dimension of antenna can be calculated from following formulas:

2.1. Calculation of the Width of Patch (W)

$$W = \frac{c}{2 f_o \sqrt{\frac{\varepsilon_r + 1}{2}}} \quad (1)$$

ε_r: Dielectric constant
f_o: Resonant frequency
W: Width of patch

2.2. Calculation of Effective Dielectric Constant

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

ε_{reff} = Effective dielectric constant
h= height of dielectric substrate

2.3. Calculation of Length of Patch (L)

$$\Delta L = 0.412\, h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \quad (3)$$

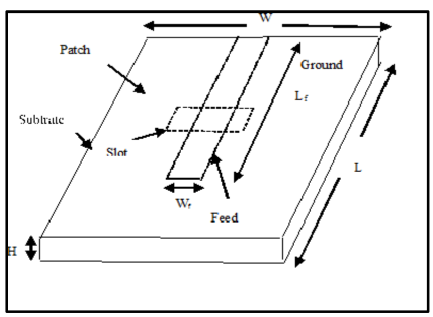

Figure 1: 3-D view of the proposed aperture fed rectangular antenna.

2.3.1. Design Process

By scaling the patch of dimension 223mm×174mm (I_0) [Fig 2(a)], the required self-similar structures are constructed. The scaling factor of three is chosen along both x and y axes to perform the further iterations of fractals. This leads to the development of six rectangles each of equal dimensions starting from 1 to 9 [Fig 2(b)].
Rectangle number 1,3,4 and 6 are eliminated from Fig 2(b) which gives the first iteration (I_1), shown in Fig 2(c).
Following this principle the further iterations are performed till the fourth iteration (I_3). Fig 2(d) and Fig 2(e) show the iterations performed on (I_0).

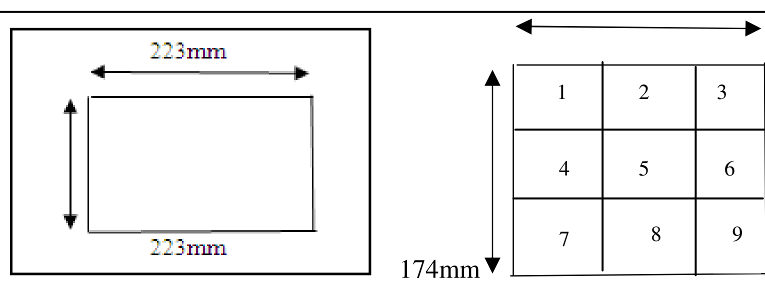

Figure 2 a. *Figure 2 b.*

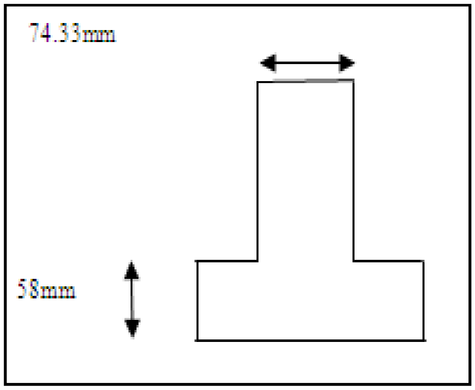

Figure 2 c.

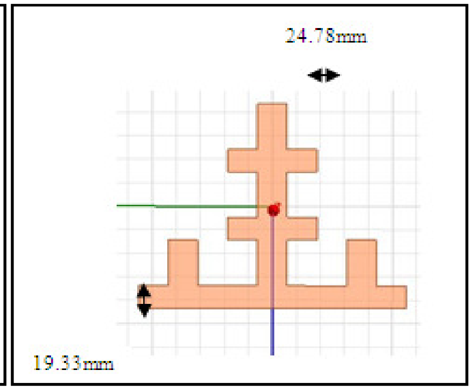

Figure 2 d.

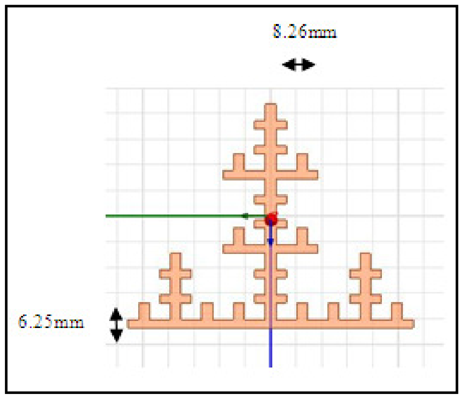

Figure 2 e.

Figure 2

The structures of the antenna is given in Fig (2) and the parameters of the antenna are given below in the Table 1.

Length of Patch(L)	223mm
Width of Patch(W)	174mm
Length of Substrate(L)	223mm
Width of Substrate(W)	174mm
Height of Substrate(h)	3.2mm
Width of Feed(W_f)	20mm
Length of Feed(L_f)	158mm

Table 1

3. Result and Discussion

3.1. Zero Iteration of Patch

The performance of antenna at zero iteration has been investigated by using HFSS software. After proper optimization of slot and feed, maximum gain of -9.76dB and return loss of 32.97dB have been obtained.

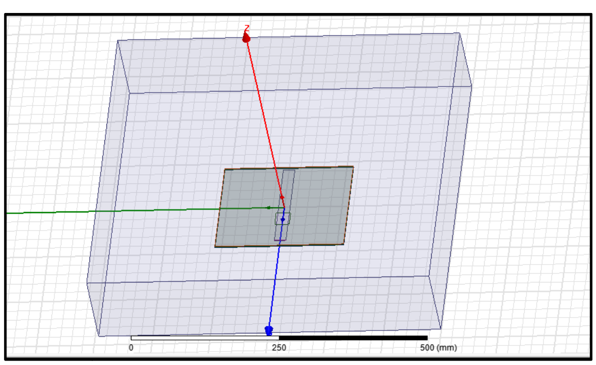

Figure 3: 3-D view of the zero iteration model in HFSS

3.2. First Iteration of Patch

The resonant behavior of fractal antenna is shown in fig. Initially the patch antenna resonates nearby the 404 MHz frequency. The feed and slot position is again optimized to resonate nearby the solution frequency to achieve the maximum return loss of31.9dB

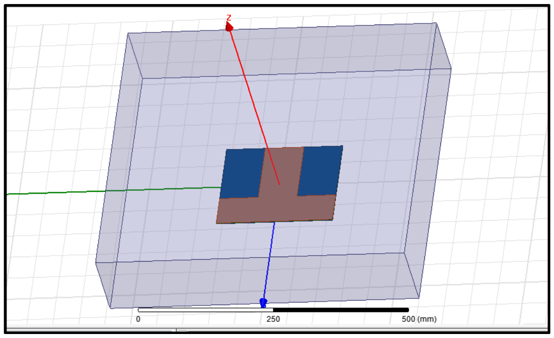

Figure 4: 3-D view of the first iteration model in HFSS

3.3. Second Iteration of Patch

The resonating behavior of fractal antenna is shown in Fig (5)

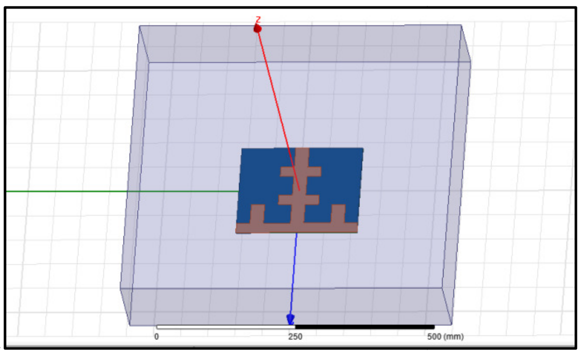

Figure 5: 3-D view of the second iteration model in HFSS

Iteration	Return loss	Gain	VSWR	Bandwidth
Zero	-32.97dB	-9.78dB	1.045	17MHz
First	-31.9dB	-16.2dB	1.07	13MHz
Second	-29.5dB	-17.6dB	1.06	14MHz
Third	-26.62dB	-17.43dB	1.09	15MHz

Table 2

3.4. Third Iteration of Patch

The final iteration has been proposed toreduce the size of patch antenna. After the experimental investigation of all the iterations of the self-similar fractal cantor antenna, the resonant frequency has not been deviated and an average return loss of 25dB is maintained.

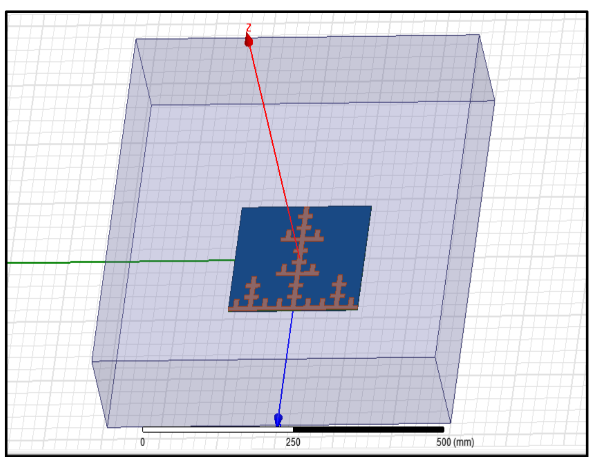

Figure 6: 3-D view of the third iteration model in HFSS

The final experimental investigation of antenna parameters are given in Table 2.

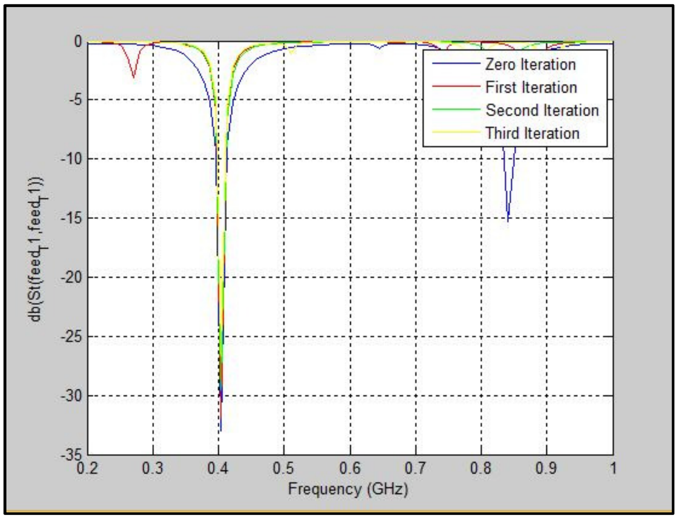

Figure 7: Return Loss for all iteration of the proposed antenna

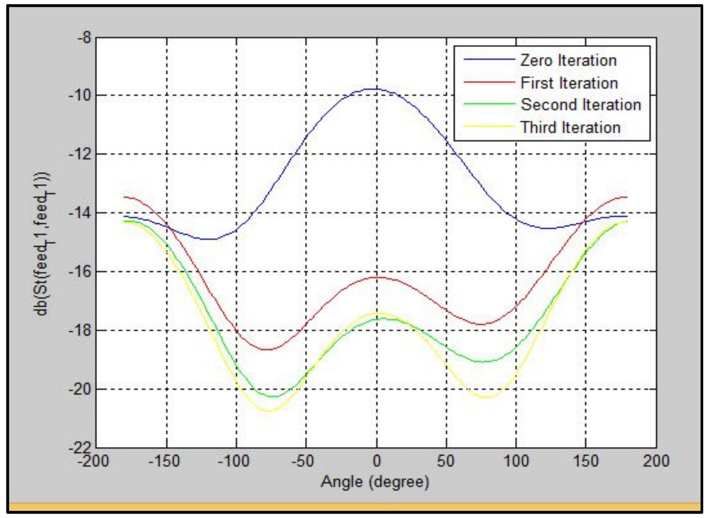

Figure 8: Gain for all iteration of the proposed antenna

3.5. Miniaturization of Rectangular Patch Antenna

The main purpose of this paper was to propose a miniaturized version of the patch without much altering of the properties of wearable fractal antenna as shown in Fig (8). The proposed model showed an enhancement of return loss of 33.05 dB with bandwidth remaining the same [Fig (9)]. There also has been an improvement in the gain of the antenna shown in Fig (10)

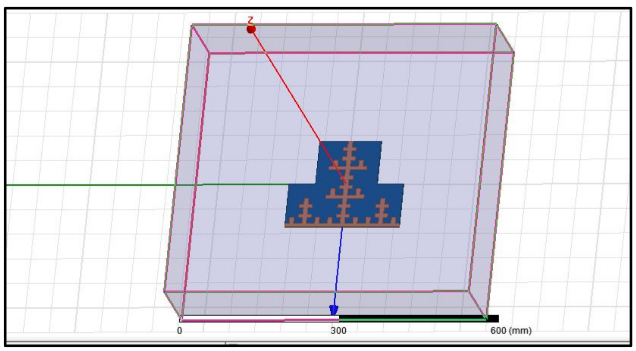

Figure 9: 3-D view of the miniaturization model in HFSS

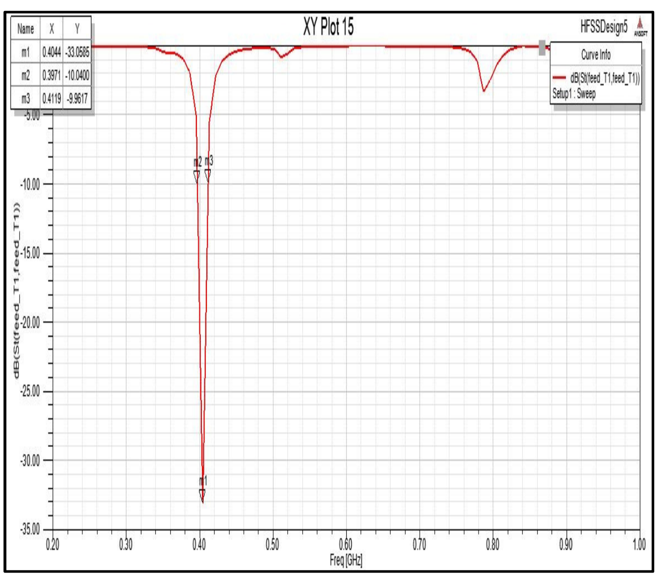

Figure 10: Return Loss of the proposed antenna

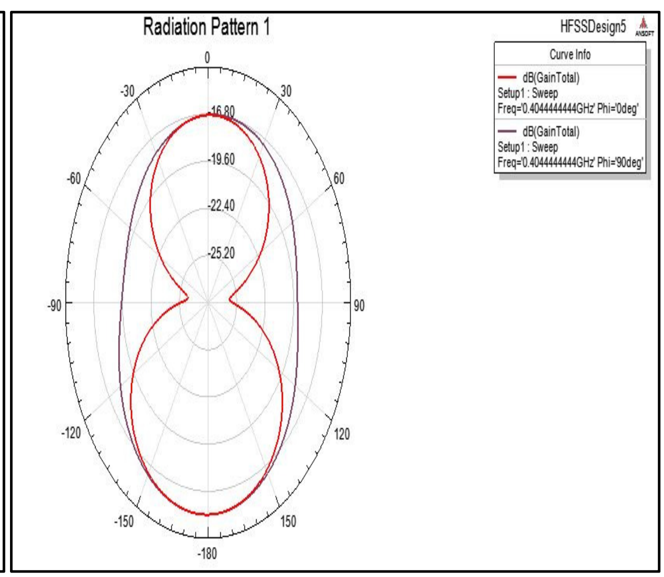

Figure 11: Gain of the proposed antenna

Comparison between original area and area obtained after miniaturization is shown in Table 3.

Reduced area (%)= $\frac{(Original)area-(Miniaturized)area}{(Original)area}\times 100$

Original area of antenna(mm^2)	Miniaturized area(mm^2)	Reduced area (%)
38802	29841	23.09

Table 3

4. Conclusion & Future Work

Based on the above investigation on different iterations, the following conclusions are drawn:

A low cost, light weight fractal antenna has been developed which operates in frequencies between the 402 MHz to 405 MHz (MICS band) with a wide bandwidth.

The return loss of propose antenna has been maintained for more than which can be used in any wireless telemedicine systems and can be monitored the physiological parameters and transmit the collected data.

The HFSS software has been used to simulate the antenna and observed that miniaturization of 23.09 % has been achieved without altering the resonating properties of the proposed antenna.

The future work includes the fabrication and comparison of measured and simulated results.

5. References

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