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Dual Band Fractal Antenna for Wireless Sensor Network Application

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Abstract**—**A wireless sensor network (WSN) is a collection of sensor nodes organized into a cooperative network. These nodes communicate through a wireless antenna. Reduction in physical size and multiband operation is an important requirement of WSN antenna. Fractal antenna is used for miniaturization and multiband operation. The self-similar or self-affine and space filling property of fractal geometry increases the effective electrical length of the antenna, reduces the size and make them frequency independent. This paper elaborates on Dual band fractal antenna with Coplanar Waveguide (CPW) feed for WSN. The proposed antenna is designed on a FR4 substrate with the dimension of 27mm x 28.5mm x 1.6mm, resonates at 2.4GHz and 5.2GHz with a return loss less than -10dB. The design and simulation process is carried out using IE3D simulation software. The simulated and measured results are found in good agreement.

Keywords**—**CPW, Fractal, Iterations, Miniaturization, Space filling, Self Similar, WSN, WLAN.

I. INTRODUCTION

WSN is used for several applications of smart environments. It consists of spatially distributed autonomous sensor nodes [1]. Each node is equipped with a sensor, an ADC, a MCU, a storage unit, a power management unit and a RF transceiver which can sense, store, process and communicate with other sensors [2]. As the application of WSN is spreading, it is appreciable to have a small node size. Microstrip patch antenna is an attractive candidate to reduce the node size due to its low profile, low cost and ease of fabrication [3]-[7].

This paper aims to reduce the size of node by designing an antenna with miniature size [8]-[10]. As the size of the antenna is reduced, the node size gets reduced and the power consumed for radiation is also reduced [11], [12]. Hence antenna for lower frequency application with reduced size is a main challenge. Several techniques have been used to reduce the size of antenna, such as using dielectric substrates with high permittivity, using negative refractive index material, (Metamaterials), by applying resistive or reactive loading, by increasing the electrical length of antenna, by optimizing its shape, utilization of strategically positioned notches on the patch antenna, various shapes of slots and slits have been introduced, increasing the geometry of the antenna by using space filling and self symmetry characteristic of fractal Geometry [13], [14]. But for lower frequency design, the size reduction is not fully satisfied as frequency and wavelength are inversely proportional [15]. To overcome the above challenges, this paper use fractal method to reduce the antenna size as well as to resonate at lower frequencies.

A fractal structure is a rough or fragmented geometric shape [16] that can be subdivided into parts, each of which is approximately a reduced-size copy of the whole [17]. The two main properties of fractal structure are self-similarity and space filling. These two properties overcome the following limitations [18]:

- Fractal structure is produced with the self-similarity of fractal dimensions through iteration. This gives miniaturized antenna, and the directional antenna.
- The electrical length of the antenna is increased by effectively utilizing the antenna area using the space filling property.

Hence this paper is to design a miniature antenna by using fractal method .Fractal is achieved by several iterations and the size is still reduced by using CPW feeding technique. The advantage of using this type of feed is that there are no double side printings, no alignment problem and low losses at higher frequencies. A CPW-feed is also advantageous for wide bandwidth and good radiation patterns. The proposed antenna is characterized and simulated in terms of impedance bandwidth, radiation pattern and gain using IE3D simulation software.

II. ANTENNA DESIGN

A fractal antenna which resonates at 2.4GHz and 5.2GHz is proposed on an FR4 substrate. The reduced antenna size is a great challenge for WSN environment. So miniaturization of the antenna is made by increasing the electrical length. Fractal geometry is another miniaturization technique by which the electrical length is increased. The design starts with a simple rectangular patch (initiator) shown in Fig. 1 of 27mm x 28.7mm in the first stage.

For the initiator structure, the iteration order is zero. The shape chosen for fragmentation is a hexagon. The rectangular patch is converted into hexagonal patch in the first iteration. Then the hexagonal indentation is applied along the perimeter of the hexagonal patch which results in the second iteration. The patch is assumed to be divided into six equal hexagons and the central part is removed to form the star shaped hexagonal antenna. Then this shape is repeated three times to obtain the final structure shown in Fig. 2 and its corresponding lengths are tabulated in Table I. It can be noticed that the

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perimeter gets increased when the outer contour assumes the shape of fractal. However the metalized area occupied by the fractal shape is less compared to the original rectangular patch.

III. Simulation Results

The proposed star shaped hexagonal antenna has been simulated using IE3D electromagnetic simulator. The antenna iterations are shown in Fig. 3 and its response is represented in the comparison table shown in Table II.

The simulation results in all the three cases have been swept over a frequency range from 1 to 6 GHz, VSWR between 1 & 2 with return loss less than -10dB

Fig. 1 Rectangular Patch (Initiator)

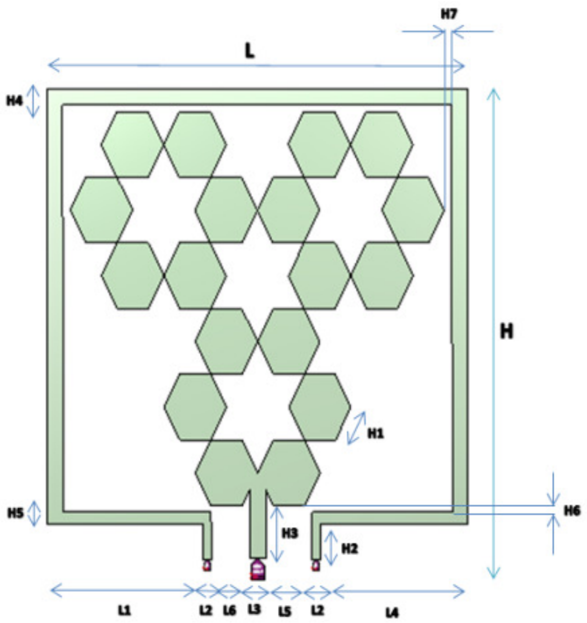

Fig. 2 Final Iteration

A. Return Loss (dB) and VSWR

Return loss of an antenna is an important parameter in any antenna design analysis. It gives the measure of how much amount of power will be reflected back from the antenna. It is represented in decibel. It should be kept as minimum as possible. The simulated result has good return loss of below -10 dB. The return loss of the antenna can be calculated theoretically as follows,

$$\text{Return loss (dB)} = -20 \log (\text{IrI}) \qquad (1)$$

The comparison of S – parameter for all the three iterations is shown in Fig. 4 (a) and the measured result of final iteration is shown in Fig. 4 (b). The next important parameter is Voltage Standing Wave Ratio (VSWR) .It is VSWR which determines whether the calculated bandwidth is useful or not. It also gives the ratio of the peak maximum to peak minimum of the standing wave.

$$\text{VSWR=V max/V min} \qquad (2)$$

TABLE I
Physical Dimensions of Final Iteration

Physical Dimensions	***All in mm***
L	27
L1	10
L2	0.5
L3	1
L4	9.5
L5	2.9862
L6	2.5
H	28.7
H1	2
H2	2.2
H3	3.2
H4	1
H5	0.7
H6	0.4
H7	0.5

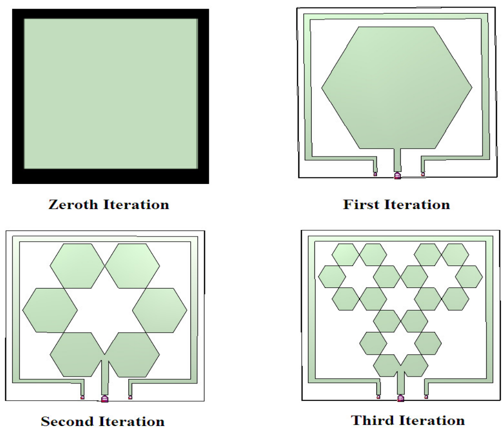

Fig. 3 Antenna Iterations

TABLE II
Comparison of Parameters

Parameters	***Iteration1***	***Iteration2***	***Iteration3***
Frequency	**3GHz**	**2.8GHz**	**2.4GHz** **5.2GHz**
Bandwidth	**200MHz**	**200MHz**	**100MHz** **400MHz**
VSWR	**1.6**	**1.7**	**1.25**
S Parameter	**-13dB**	**-12dB**	**-19dB** **-13dB**

The comparison of VSWR for all the three iterations is represented in Fig. 5 (a) and the measured result of final iteration is shown in Fig. 5 (b).

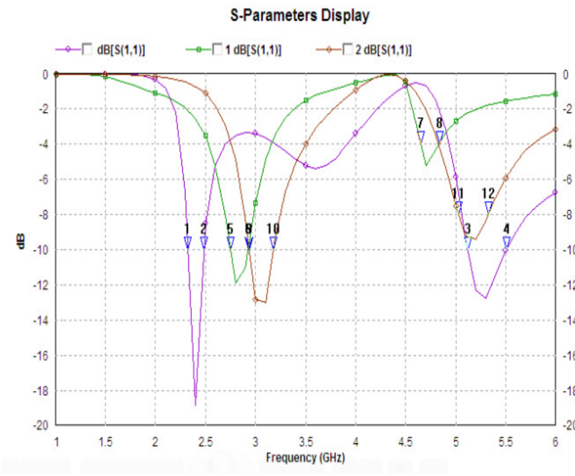

Fig. 4 (a) Comparison of S – Parameter

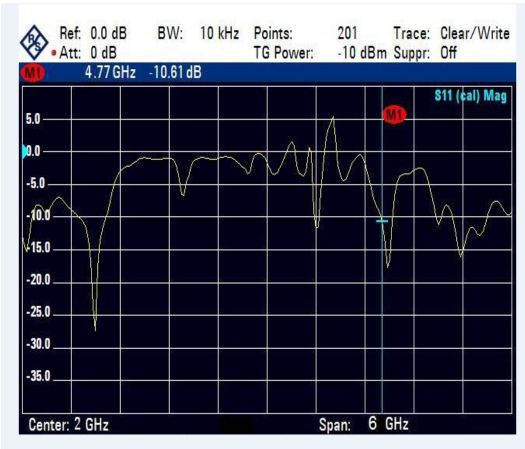

Fig. 4 (b) Measured return loss

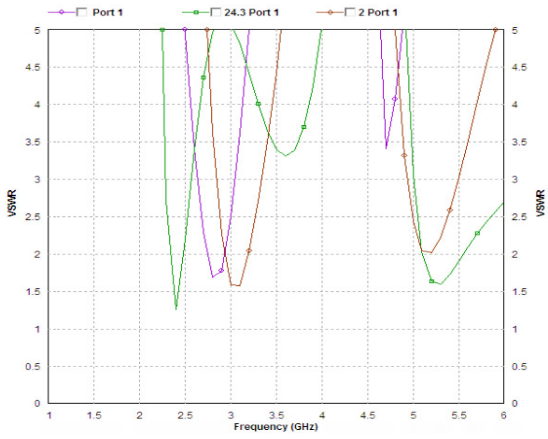

Fig. 5 (a) Comparison of VSWR

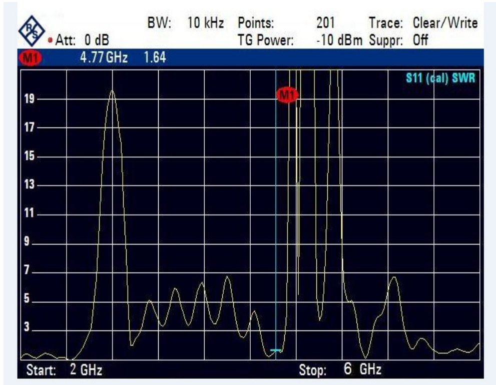

Fig. 5 (b) Measured VSWR

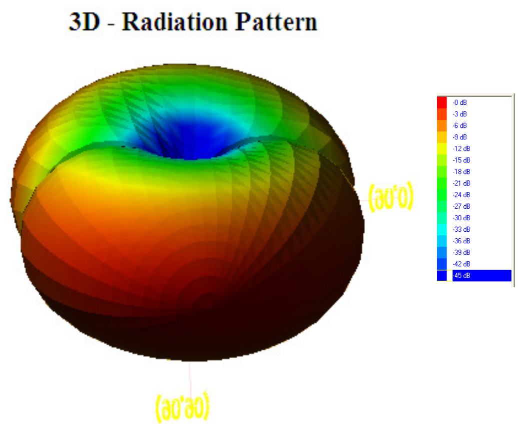

Fig. 6 (a) 3D Radiation Pattern

B. Radiation Pattern

The 3D radiation pattern of an antenna is used to describe the 3 dimensional radiation characteristics. It includes type of patterns, coverage, flux density, radiation intensity and polarization of the antenna. There are generally 3 types of patterns like, isotopic, directional and Omni directional patterns.

The Omni directional 3D radiation pattern corresponding to the final iteration of the proposed antenna is represented in Fig. 6 (a).

The 2D elevation pattern gain display of the proposed antenna with theta constant and phi variation is represented in Fig. 6 (b) and the 2D azimuth pattern gain display of the proposed antenna with phi constant and theta variation is represented in Fig. 6 (c) and the current distribution of the final iteration is shown in Fig. 7.

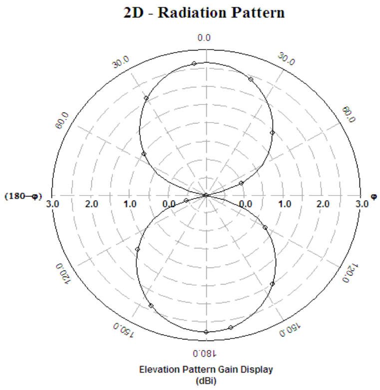

Fig. 6 (b) 2D Elevation Pattern Gain Display

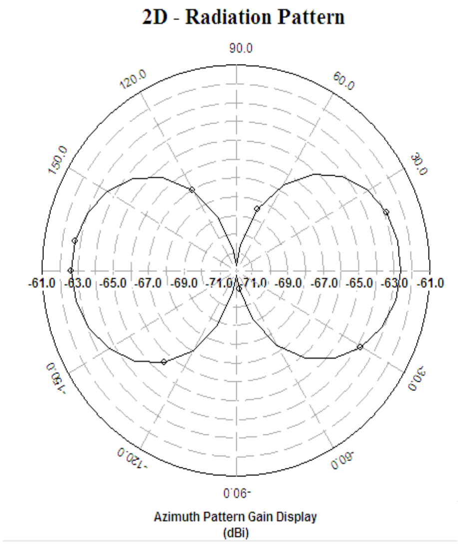

Fig. 6 (c) 2D Azimuth Pattern Gain Display

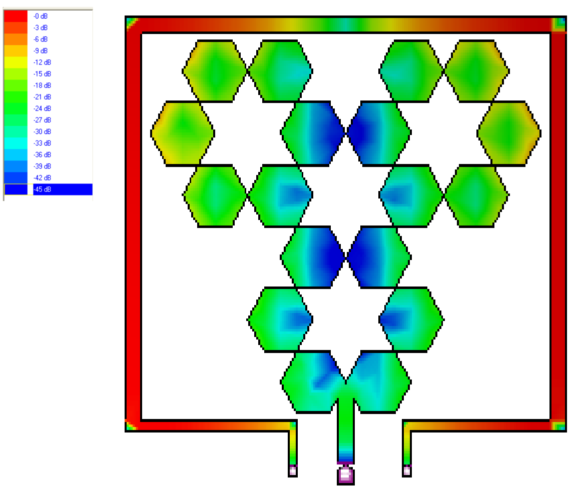

Fig. 7 Current Distribution of Final Iteration

IV. Conclusion

The design of antennas used in WSN is mainly intended to achieve miniaturization. Dual band fractal antennas which resonate at 2.4GHz and 5.2GHz has been designed, tested and fabricated. It is observed that incorporation of fractal geometry with proper indentation in the border length offers a considerable size reduction and frequency shift compared with the initiator. As the iteration order increases, the resonant frequency decreases, more towards the lower side and indicate more size reduction.

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