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Nature Inspired Golden Spiral Super-Ultra Wideband Microstrip Antenna

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***Abstract*—This paper presents the design and simulation of a nature inspired fibonacci sequence based golden spiral super-ultra wideband microstrip antenna. The antenna has a compact size of 40 mm x 40 mm x 1.6 mm. Various parameters like return loss (S_{11}), radiation pattern, gain and radiation efficiency are analyzed. The impedance bandwidth ranges from 1-35 GHz and bandwidth ratio is 34:1. The proposed antenna is designed, simulated and optimized in HFSS commercial software. Because of the high impedance bandwidth, the antenna can be used in many applications like satellite navigation, GPS navigation, WiFi and high speed technologies like 5G mobile communication.**

***Index Terms*—Fibonacci Sequence; Golden Spiral; Microstrip Antennas; Super-UWB Antennas; Tapered Feed**

I. Introduction

Microstrip patch antennas are becoming popular because of their ease of use as compared to traditional antennas. Patch antennas are low cost, have a low profile and can be easily printed directly onto a circuit board [1]. The S-UWB microstrip antenna provides a high data transfer rate, larger bandwidth, simple hardware configuration, low power consumption and excellent immunity to the multipath interference [2]. The proposed S-UWB antenna uses fibonacci sequence as its basic design parameter for the construction of a golden spiral antenna [3], [4]. Fibonacci sequence is a mathematical sequence in which any number is the sum of the previous two numbers in the sequence. Fibonacci sequence and golden ratio can be seen in biological systems, natural phenomena like shell formation, flower petal formation, tree branch formation etc. The similarity of the proposed antenna with the snail's shell which follow golden spiral can be seen in Fig. 1.

The proposed antenna is compact and works in the entire range of the 10 dB impedance bandwidth from 1 GHz to 35 GHz. The ground is made partial for impedance matching purpose and for the inclusion of lower frequency in the 10 dB bandwidth [5]. A trapezoidal feedline is used it's the upper part tapered to improve the return loss and gain performance [5]. The antenna gives the best results at l_i=1.5mm [6], [7]. Two semicircular slots of the same dimensions are cut from the ground plane symmetrically as shown in Fig. 3. This is done for the inclusion of the lower frequency ranging from 1.3 GHz to 2.5 GHz in the impedance bandwidth [7]. As the frequency is increased, the radiation pattern changes as shown in Fig. 5. and Fig. 6.

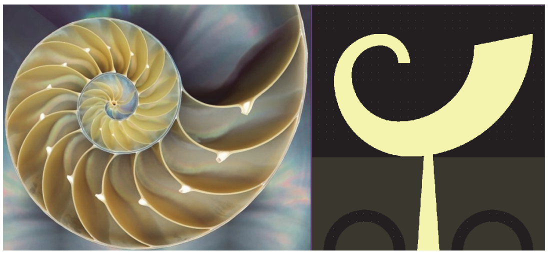

Fig. 1. Nature Inspired (Snail's Shell) and the proposed antenna

In the remaining paper, section II describes the unique design and dimensions of the proposed antenna based upon the golden ratio. In section III various performance parameters like return loss (S_{11}), radiation pattern, gain and radiation efficiency are analyzed. Section IV concludes the paper.

II. Antenna Design

The antenna design is unique and is inspired from the snail's shell which follows the golden spiral as shown in Fig. 1. The substrate used is a Flame Retardant (FR) type 4 epoxy material which has a permittivity of 4.4 and loss tangent equal to 0.02. The antenna dimensions are 40 mm x 40 mm x 1.6 mm where L(length of antenna) = W(width of antenna)= 40 mm and H_S(height of antenna) = 1.6 mm. The antenna is divided into two views for better understanding and easy analysis. The front view and the back view of the antenna are shown in Fig. 3. Each of these views are described below.

A. *FRONT VIEW*

The proposed antenna consists of two spiraling patterns of different dimensions which are joined together to give a complete two dimensional geometry to the patch. Each spiraling pattern is made up of four quarter circular arcs which are combined together to form a complete spiral. The circumferences of the quarter circular arcs are shown in Fig.

TABLE I
DIMENSIONS OF THE PROPOSED ANTENNA

Front view (Patch)

Parameters	Values(mm)
R_{a_j}	3, 5, 8, 13
R_{b_j}	5, 8, 13, 21
H	16.5
W_B	3.8
l_i	1.5

Back view (Ground)

H_G	16
$\frac{R_2}{R_1}$	1.4
W	40
L	40

2. The radii of these arcs follows the fibonacci sequence as given in the following equations.

$$R_{a_j} = R_{a_{j-1}} + R_{a_{j-2}} \tag{1}$$

$$R_{b_j} = R_{b_{j-1}} + R_{b_{j-2}} \tag{2}$$

where $j = \{3,4\}$, R_{a_j} is the radius of the a_j quarter circular arc and R_{b_j} is the radius of the b_j quarter circular arc.

The values of the radii are as follows: R_{a_1} = 3 mm, R_{a_2} = 5 mm, R_{a_3} = 8 mm and R_{a_4} = 13 mm; R_{b_1} = 5 mm, R_{b_2} = 8 mm, R_{b_3} = 13 mm and R_{b_4} = 21 mm. In Fig. 2. (a_1, a_2, a_3, a_4) and (b_1, b_2, b_3, b_4) are the two spiraling patterns. The corresponding length of the quarter circular arc can be calculated from the following formulae:

$$a_n = \frac{\pi}{2} R_{a_n} \tag{3}$$

$$b_n = \frac{\pi}{2} R_{b_n} \tag{4}$$

where $n = \{1,2,3,4\}$, R_{a_n} is the radius of the a_n quarter circular arc and R_{b_n} is the radius of the b_n quarter circular arc.

The golden ratio ($\phi \approx 1.618$) can be seen from the equations below.

$$\phi \approx \frac{R_{a_j}}{R_{a_{j-1}}} \approx \frac{R_{a_{j-1}}}{R_{a_j} - R_{a_{j-1}}} \tag{5}$$

$$\phi \approx \frac{R_{b_j}}{R_{b_{j-1}}} \approx \frac{R_{b_{j-1}}}{R_{b_j} - R_{b_{j-1}}} \tag{6}$$

where $j = \{3,4\}$.

A trapezoidal feedline with the parallel widths W_B = 3.8 mm and l_i = 1.5 mm is attached to the golden spiral patch to form the complete copper patch design of the antenna as shown in Fig. 3.

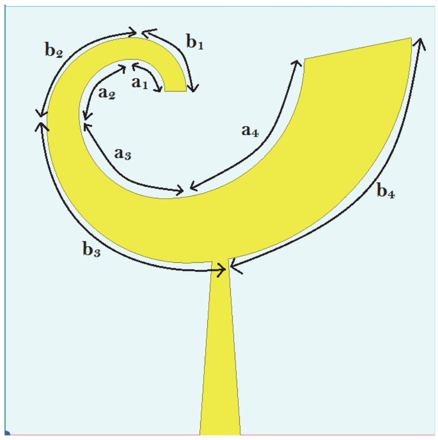

Fig. 2. Description of fibonacci sequence in the proposed antenna

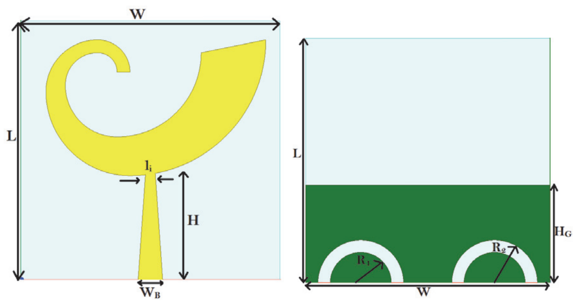

Fig. 3. Front and Back view of the proposed antenna

B. BACK VIEW

Fig. 3. shows back view with the partial ground having width W = 40 mm and height H_G = 16 mm. The ground is made partial for impedance matching and bandwidth extension. Two semicircular slots of equal dimensions are cut from the ground for the inclusion of lower frequency values in the 10 dB bandwidth. The radii of the semicircles are in the ratio [7]

$$\frac{R_2}{R_1} = 1.4 \tag{7}$$

III. SIMULATIONS AND RESULTS

The S_{11} comparison of the antenna with and without the semicircular slots is shown in Fig. 4. From the figure the better performance of the slotted antenna can be seen. There is inclusion of the lower frequency range from 1.3 GHz to 2.5 GHz in the slotted antenna thus increasing the bandwidth and working range of the antenna.

In Fig. 5. and Fig. 6. the radiation patterns of the E-plane and H-plane are shown at six different frequencies (2.9 GHz, 5.2 GHz, 7.6 GHz, 13.9 GHz, 18 GHz, 26.4 GHz). As the frequency is increased the antenna becomes more directional because of the increase in the number of lobes. Fig. 7. shows the gain v/s frequency curve of the antenna. As seen in Fig. 8. the radiation efficiency of the proposed antenna decreases with an increase in frequency.

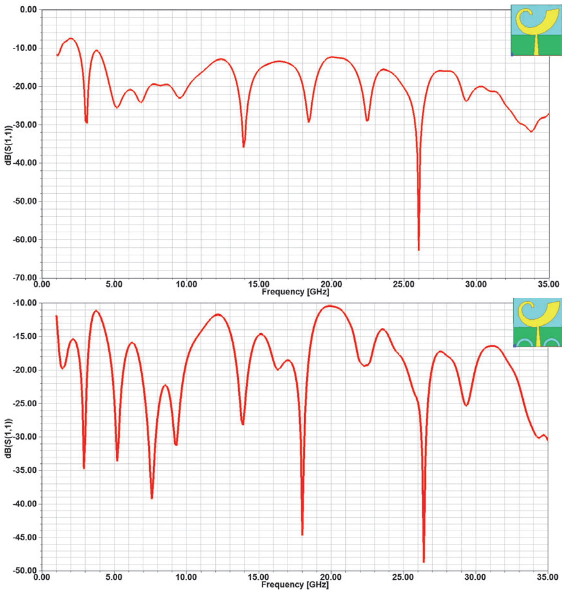

Fig. 4. Comparison of S_{11} Parameter between without semi-circular slots in the ground and with semi-circular slots in the ground

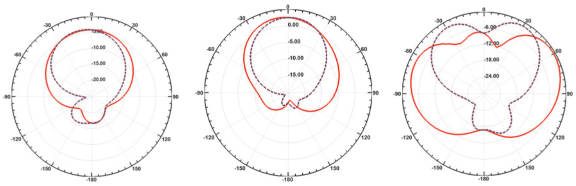

Fig. 5. Antenna radiation Pattern at 2.9GHz, 5.2GHz and 7.6GHz respectively. Solid Lines represent E-Plane and Dashed Lines represent H-Plane

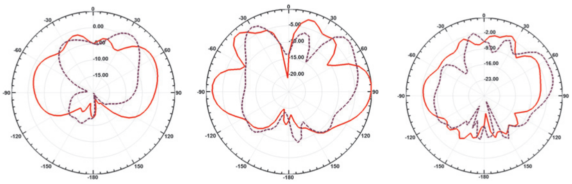

Fig. 6. Antenna radiation Pattern at 13.9GHz, 18GHz and 26.4GHz respectively. Solid Lines represent E-Plane and Dashed Lines represent H-Plane

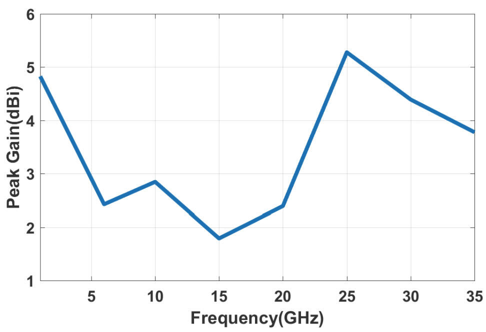

Fig. 7. Gain v/s Frequency curve of the proposed antenna

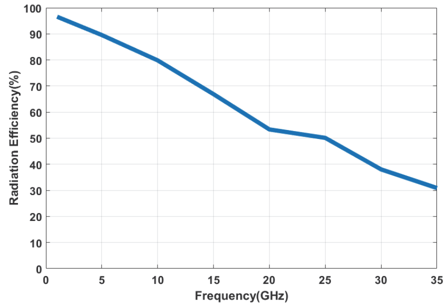

Fig. 8. Radiation Efficiency v/s Frequency curve of the proposed antenna

IV. Conclusion

In this paper a nature inspired golden spiral S-UWB microstrip antenna has been presented. The novelty of the antenna lies in it's inspiration taken from nature, it's working in 1-35 GHz frequency range and it's compact size. The results show that the proposed antenna has a wide 10 dB impedance bandwidth from 1GHz to 35GHz having positve gain and good radiation efficiency. The radiation efficiency of the proposed antenna is higher at lower frequencies and graduallly decreases with an increase in frequency. The antenna can be used in various applications such as GSM [8], RADAR, 5G Mobile Communication, maritime radio navigation and radio astronomy.

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