Effects of Arm Width On The Performance Of Two Arm Archimedean Spiral Antenna

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Abstract. This paper presents the parametric study effects on the performance of two arm Archimedean spiral antenna. The effects of arm width were investigated in order to obtain an improved return loss, high gain, good axial ratio, high radiation efficiency and good radiation pattern throughout the frequency band of 3.1-10.6 GHz. The investigation of the parametric effects was done through simulation in CST software. Unidirectional radiation pattern is achieved when the spiral antenna is placed over a conducting ground plane. The results revealed that antenna’s performance is directly proportional with the increment of the arm width. Also the study finds out that arm width mainly affects the gain and axial ratio compared to the other antenna characteristics while arm spacing affects the return loss and gain of the antenna, as the arm spacing is increased the return loss and the gain of the antenna improved.

1. Introduction
The ever increasing functionality for broadband satellite communication services, military communication and antenna arrays require enhanced performance from antennas. The Archimedean spiral antenna is a suitable candidate for the above mentioned applications because of its performance characteristics such as broadband width, high gain, wide beam width and circular polarization [1]. Therefore, in order to achieve an optimized performance of spiral antenna; a parametric study of spiral antenna’s parameters is needed. The spiral antenna parameters such as the effects of feed wire on radiation pattern and the effects of wire radius on spiral antennas have been analyzed before in [2] and [3] respectively. However, in this paper, a parametric study of two arm Archimedean spiral antenna parameters such as arm width is carried out. Section II reveals the antenna design, section III parametric study, section IV result and Section V conclusion.

2. Antenna design
The two arm Archimedean spiral antenna is shown in Figure 1. The outer radius of the antenna is calculated using equation found in [4]. For frequency independent behavior can be obtained by having equal inner radius, arm width and arm spacing. These parameters can be calculated by using the equation given in [5]. The antenna configurations were designed on a substrate of having permittivity of $\varepsilon_r=2.33$ and thickness of 1.6mm. In order to get high operating frequency band, the antenna is designed on a frequency range of 3.1-10.6 GHz.

For a fair comparison, the ground plane is placed behind the antenna at 0.25$\lambda$ in each case of the parametric study. While $\lambda$ is the operating wavelength at the lowest design frequency which is 3.1 GHz. The antenna is fed at the center and simulated via CST MWS. The calculated values of the
parameters are listed in Table I.

Table I. Antenna Parameters

| Parameters          | Values (mm) |
|---------------------|-------------|
| Outer radius ($r_2$) | 23          |
| Inner radius $r_1$  | 1.3         |
| Arm width ($w_o$)   | 1.3         |
| Arm spacing ($W_s$) | 1.3         |
| Number of turns ($N$)| 8           |

![Figure 1](image.png)

Figure 1: Two arm Archimedean spiral antenna

3. Parametric study
The antenna is designed in CST MWS. For parametric study; only one parameter is changed at a time while other parameters are kept in constant.

![Flowchart](image.png)

Figure 2: Parametric study of an Archimedean spiral antenna

A- Changing Arm Width

In this investigation, three different configurations are designed. Spiral 1 has the standard arm width of $W_A = W_o$. Spiral 2 has an arm width, which is calculated using equation 1, which was found in [5].
The spiral 3 has an arm width based on equation 2, also given in [5].

\[ W_{A3} = \frac{W_0}{1 + \sqrt{\varepsilon_r}} \]  

While \( W_0 \) is the standard arm width as shown in Table 1 and \( \varepsilon_r \) is the dielectric permittivity of the substrate which is 2.33. The calculated parametric study values are summarized in Table II.

**Table II. Parametric Study Values**

| Parameter | Values (mm) |
|-----------|-------------|
| Arm Width | \( W_1 \)   | 1.3mm       |
|          | \( W_{A2} \) | 1.029       |
|          | \( W_{A3} \) | 0.74        |

### 4. Results

The arm width is increased from 0.5 mm to 3.5 mm in each case; the arm spacing and inner radius are kept in 1.3 mm which is the calculated value as shown in Table I and \( \varepsilon_r \) is the dielectric permittivity of the substrate which is 2.33. Then all the cases of spiral antenna are simulated while changing arm width at a time.
5. Discussion

Figure 2 (a) presents the effects of width on the antenna gain. It can be seen from the Figure that when the width of the arm is increased from 0.5 mm to 3.5 mm; antenna’s gain also increases from 6 dB to 14 dB at 6.85 GHz. This is due to the increment of the radiating area of the arm [4]. However, it can be seen at higher frequency such as 10.6 GHz, the increment of the gain is lower than the gain increment of low and middle frequencies. This fluctuation is due to the ground plane because at higher frequency the height between the antenna and the ground plane is larger than quarter wavelength [4].

Figure 2 (b) shows the effects of width on the return loss of the spiral antenna. It can be observed that, at 0.5mm of width; the return loss of the antenna is -12.2 dB, -12 dB and -10 dB for frequencies of 3.1GHz, 6.85GHz and 10.6GHz respectively. As w is increased the return loss improves, for example, at 3.5 mm of the spiral width, the return loss is -16 dB, -14 dB and -12 dB for the frequencies of 3.1 GHz, 6.85 GHz and 10.6 GHz respectively. This states, for a better return loss performance, spiral antenna requires larger arm width.

Figure 2 (c) displays how the axial ratio is changed with the increment of width. At small width of 0.5 mm, the axial ratio is 5.1 dB for the higher frequency of 10.6 GHz. However, as width increases the axial ratio improves both at the lower frequency and at the higher frequency, for instance, at large arm width of 3.5 mm, 1.1 dB of axial ratio is achieved at higher frequency of 10.6 GHz. This improvement of the axial ratio (below 3dB) leads the antenna to have a circular polarization, which is important property for spiral antenna’s applications.

Figure 2 (d) puts on show the radiation efficiency of the spiral antenna against w. The Figure reveals that spiral antenna has radiation efficiency of 86% (0.86x100%=86%) at 3.1GHz, which is lower efficiency compared to the efficiency of the higher frequencies. But as w increases to 3.5 mm the radiation efficiency of the 3.1 GHZ increases to 100% same as the higher frequencies. This is because the area from which radiation occurs is increased [3].

6. Analysis

Generally, it can be seen that, as w is increased, the performance of the antenna improves. This is because at small w of 0.5 mm, the antenna is considered as electrically small antenna based on radian sphere theory [2-4]. This theory states that the antenna is small if its circumference less than 1 (r < X/2n). Electrically small antennas exhibit low gain, low efficiency and narrow bandwidth [2-4]. In order to improve spiral antenna’s performance, it requires, its circumference must be larger than 1 so that r >X/2n, and this needs to increase w of the spiral antenna. The increment of width leads to better performance and overcomes the limitations of electrically small antenna.

7. Conclusion

A parametric study of two arm Archimedean spiral antenna is presented. It is revealed that arm width mainly affects the gain and axial ratio compared to the other antenna characteristics while arm spacing affects the return loss and gain of the antenna, as the arm spacing is increased the return loss and the gain of the antenna improve. The improvement of the return loss is due to the reduction of the mutual
coupling between the neighboring arms. The inner radius highly affects for the most of the antenna characteristics so it is preferred to have small inner radius while the arm width and spacing, larger sizes are favored.

References

[1] D.J Muller, K. Sarabandi, “Design and analysis of a 3-Arm Spiral antenna,” IEEE Trans. on Antennas and Propagation, vol. 55, pp. 258–266, 2007.

[2] H. Nakano; Y. Minegishi; K. Hirose, “Effects of feed wire on radiation characteristics of a dual spiral antenna,” Electronics Letters Volume: 24, Page(s): 363 - 364, 1988.

[3] H. Nakano; Y. Minegishi; K. Hirose, “Effects of wire radius and arm bend on a rectangular spiral antenna,” Electronics Letters Volume: 19, Page(s): 957 - 958, 1983.

[4] J.M. Bell, M.F. Iskander, “Effects of an EBG ground plane,” Antennas and Wireless Propagation Letters, IEEE Volume: 3, Page(s): 223 - 226, 2004.

[5] http://www.docstoc.com/docs/47541623/Chapter-2 - Analysis of Archimedean-Spiral-Antenna, November 15 2012.

[6] REN, SI-WEI,” COMPACT QUASI-ELLIPTIC WIDEBAND BANDPASS FILTER USING CROSS-COUPLED MULTIPLE-MODE

[7] Neetu, Savina Bansal , R K Bansal ,”Design and Analysis of Fractal Antenna based on Koch and Sierpinski Fractal Geometries “IJAREEIE Vol. 2, Issue 6, pp. 2110-2116, June 2013.

[8] C. A Balanis, Antenna Theory and Design, 3rd edition, John Wiley & Sons Inc. 2005.

[9] A. Thomas Milligan, “ Modern Antenna Design “ 2nd edition, John Willey and Son Inc. 2005.