

## Analysis of Unidirectional Archimedean Spiral Antenna Backed by Lossy Dielectric and Ground Plane

M. BHAGYA LAKSHMI<sup>1</sup>, A. VIJAYA SANKAR<sup>2</sup>

<sup>1</sup>Assistant Professor, Dept of ECE, V. R. Siddhartha Engineering College, Vijayawada, AP, India,  
E-mail: madhavi.munagoti@gmail.com.

<sup>2</sup>Associate Professor, Dept of ECE, V. R. Siddhartha Engineering College, Vijayawada, AP, India,  
E-mail: vijayasankar.anumala@gmail.com.

**Abstract:** This paper presents the design and analysis of a compact printed broad band circularly polarized Archimedean spiral antenna (ASA) for Ku band applications. The antenna has a simple configuration with size 30 mm\*30 mm\*1.6 mm and presumes Rogers RT/duroid 5880 (tm) substrate of dielectric constant ( $\epsilon_r$ ) 2.2, which operates in the band of 8-24 GHz. ASA radiates on both sides of the spiral plane but most of the applications require unidirectional patterns only. so a metal cavity is used to reflect the unwanted power in order to avoid back radiation and get unidirectional pattern. The impedance bandwidth of the designed antenna is enhanced by varying the turn thickness and strip width. The proposed antenna exhibits -10 dB impedance bandwidth in the range of 8-24 GHz and gain 11.25 dB at 21 GHz. The impedance bandwidth can be further improved by varying dielectric loss tangent values. The electromagnetic solver ANSYS High frequency structure simulator (HFSS) with the finite element method (FEM) is used in the design to perform the simulation analysis.

**Keywords:** ASA, Metal Cavity, Impedance Bandwidth, HFSS.

### I. INTRODUCTION

Spiral antenna is the popular frequency independent antenna, whose shape may be either planar, circular or rectangular. ASA is a bi-directional antenna originally introduced by V. H. Rumsey [1]. In order to make unidirectional cavity backed spiral have been earlier reported. These are limited in bandwidth because of the presence in the cavity with air-dielectric. The construction of these antennas can be made either on printed boards or as a wired connection in free space. Although they have bidirectional radiation patterns, it can be made unidirectional by backing with conduction plates ( $<$  quarter wave length distance) or cavities. To improve the pattern symmetry and direction finding capability of the antenna, in spite of two arm, four arm spiral antenna can be used. Several reports have been presented on design of broad band ASA antennas [2-4]. In these reports, it is seen that the size of the antenna is comparatively large and involves with complex design. In addition, most of the reports have not considered the effects of cavities in the antenna performance. Therefore, in this paper, a small and novel antenna for multi octave band circularly polarized ASA has been designed using An soft High Frequency Structure Simulator (HFSS) software and various parameters such as voltage standing wave ratio (VSWR), radiation pattern and total gain of the antenna are reported. The proposed antenna is design with following specifications: frequency range 8-24 GHz, VSWR less than 2, total gain of antenna 9.6dB and front to back ratio of -10 dB. Some other authors have reported dielectric loaded cavities [5]. Practical antennas have cavities loaded with

absorber operating over multi octave bandwidths typically covering 8-24GHz with satisfactory radiation patterns input VSWR and axial ratio. Lossy dielectrics instead of using carbon impregnated foam absorbers one can use lossy dielectric. In this paper analysis has been carried out on the effect of loss tangent of the dielectric backed by a ground plane rather than a cavity. This geometrical configuration has wide ranging applications in phased arrays. Specifically simulations have been carried out using HFSS software (Marketed by Ansys) loss tangents have been varied from 0.001-0.5. Variations of axial ratio and front to back ratio have been analyzed with respect to loss tangent. Results are reported.

### II. ARCHIMEDEAN SPIRAL ANTENNA

Archimedean spiral antennas are most popular spiral antenna structure, whose shape may be either planar, circular or rectangular [6]. The construction of these antennas can be made either on printed boards or as a wired connection in free space. The cavity used for backing the antenna may be a hollow metal cylinder with a depth of  $\lambda/4$ , where  $\lambda$  corresponds to central frequency of operating band. At broad side, to achieve the unidirectional pattern, spiral antennas are mounted above a reflector or absorbed- loaded cavity. A perfect conducting reflector should be at an optimum distance of  $\lambda/4$  from the antenna. To avoid this narrow band radiation and enjoy the wide bandwidth, absorbers can be used to back the cavity. The gain will be lowered by using the absorbers. But, the destruction of the radiation pattern producing

because of reflecting energy will be eliminated. The basic structure of 2-arm Archimedean spiral antenna is shown in below Fig.1.

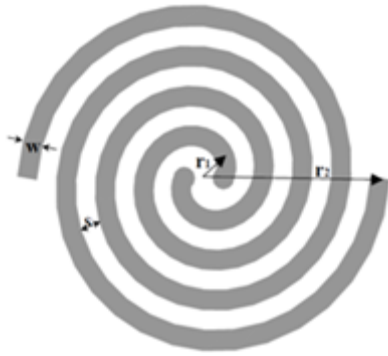


Fig 1. Basic ASA structure.

Each arm of ASA is defined by the equation

$$r=r_0+a\phi \tag{1}$$

The two arms of the spiral antenna are to be fed at the center. One arm should be fed with center conductor of coaxial cable and ground or shield of cable to the second arm. The two arms of spiral antenna should have balanced currents. The cavity used for backing the antenna may be a hollow metal cylinder with a depth of  $\lambda/4$ , where  $\lambda$  corresponds to central frequency of operating band. At broad side, to achieve the unidirectional pattern, spiral antennas are mounted above a reflector or absorbed- loaded cavity.

III. ANTENNA CONFIGURATION

The geometrical parameters are defined in such a way that the ratio of the equivalent strip width ( $w$ ) = 0.6 mm to the spacing width between the neighboring wires is unity. The parameters are as follows: spiral constant  $a = 0.381$  mm; inner radius ( $r_1$ ) = 1.2 mm, outer radius ( $r_2$ )= 30 mm, offset angle 90. The spiral antenna is backed by a perfectly conducting plane reflector of infinite extent, and handled by the FEM method in the present analysis. The simulated antenna is shown in Fig 2.

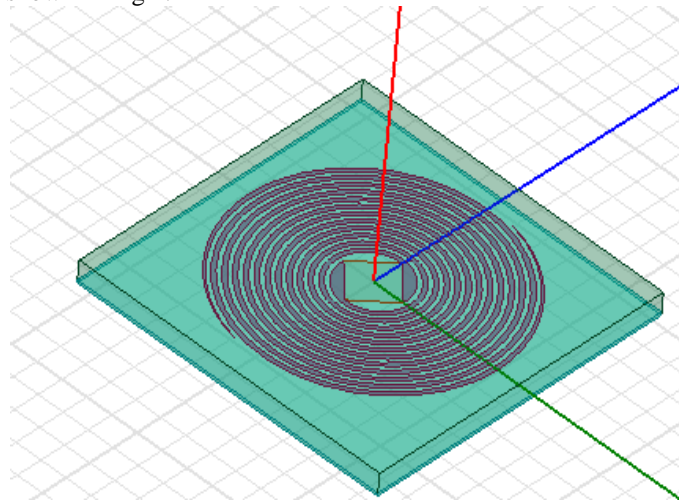


Fig 2. Designed antenna structure.

In this design Rogers RT/duriod 5880 (tm) material with dielectric constant ( $\epsilon_r = 2.2$ ) is used for substrate. Here cavity place a main role to reduce back radiation and then automatically gain will be improved, power loss should be minimized.

IV. SIMULATION RESULTS

The antenna has been simulated using ANSYS HFSS software. Various parameters like return loss, VSWR, radiation pattern, gain and Current field distribution are estimated using simulations.

A. Return loss

The loss of power occurring due to the discontinuities in the optical fiber is termed as Return loss. It is inversely proportional to SWR. Return loss measures the matching between the lines or devices. If the match is perfect, return loss is high and insertion loss is low. The return loss and VSWR plots are shown in below Figs 3 & 4.

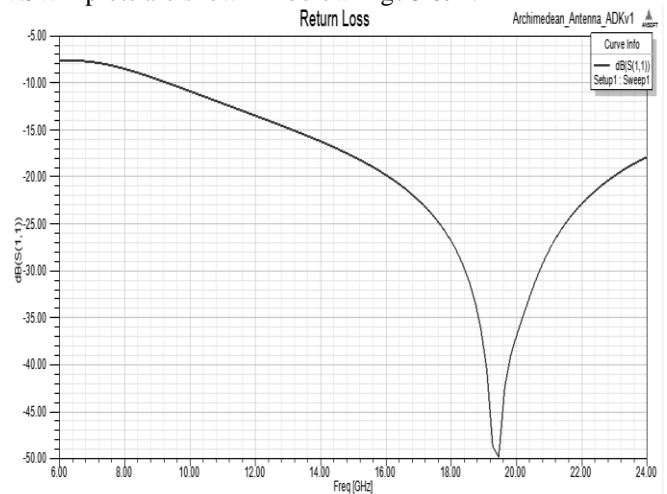


Fig 3. Return loss Plot.

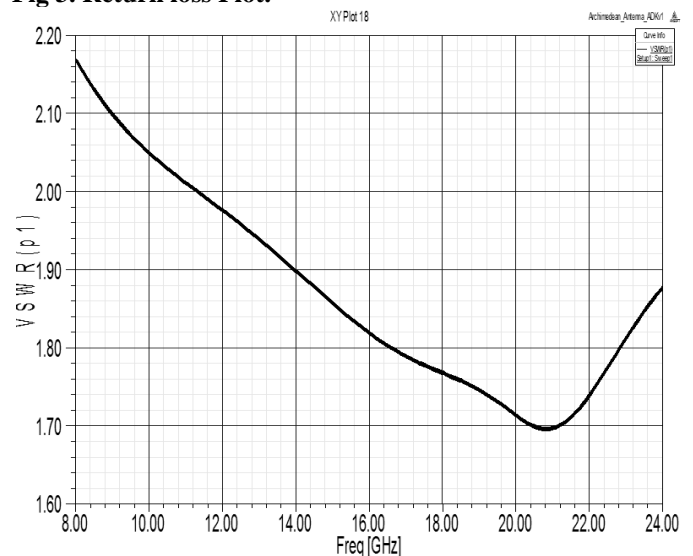


Fig 4. VSWR Plot.

At 10GHz:  $f_{high} = 20$  GHz,  $f_{low} = 18$  GHz

$$f_c = (f_{high}+f_{low})/2 = 19 \text{ GHz}$$

$$\text{Bandwidth} = (f_{high}-f_{low})/2 * 100 = 10.52\%$$

## Analysis of Unidirectional Archimedean Spiral Antenna Backed by Lossy Dielectric and Ground Plane

### B. Radiation Patterns

Simulated radiation patterns of both E & H planes at different frequencies are shown in the following Fig 5.

### C. Gain

The ratio taken between the power delivered by antenna in a specific direction to the power delivered to the antenna is considered as the Gain of antenna. The gain of the antenna shown in below Fig 6.

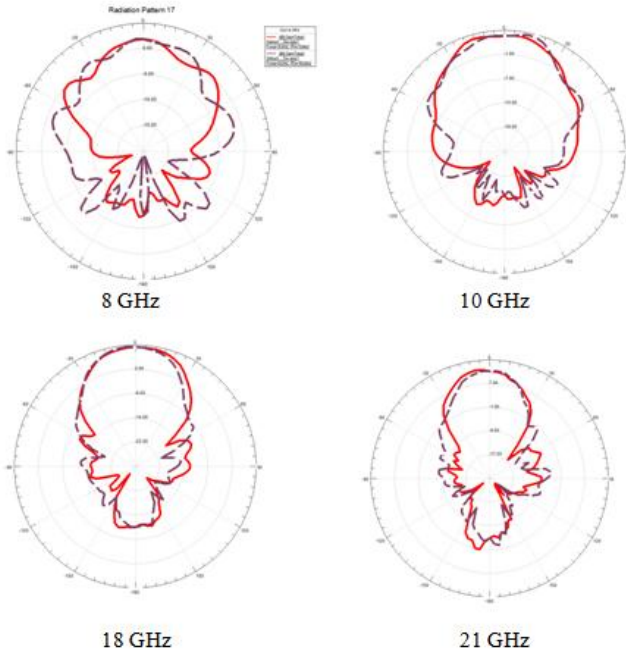


Fig 5. Radiation patterns (E & H planes).



Fig 6. 3D Gain (8 GHz).

Table I. Frequency V/S Gain

| Frequency (GHz) | Gain (dB) | Frequency (GHz) | Gain (dB) |
|-----------------|-----------|-----------------|-----------|
| 8               | 2.19      | 15              | 7.96      |
| 10              | 4.44      | 16              | 8.48      |
| 11              | 5.49      | 17              | 8.99      |
| 12              | 5.88      | 18              | 9.36      |
| 13              | 6.49      | 20              | 10.2      |
| 14              | 7.36      | 21              | 11.25     |

The gain of the unidirectional antenna is shown in Fig 7. Due to the placement of the cavity an antenna provides high gain. At 21 GHz the gain of 11.25 dB is obtained.

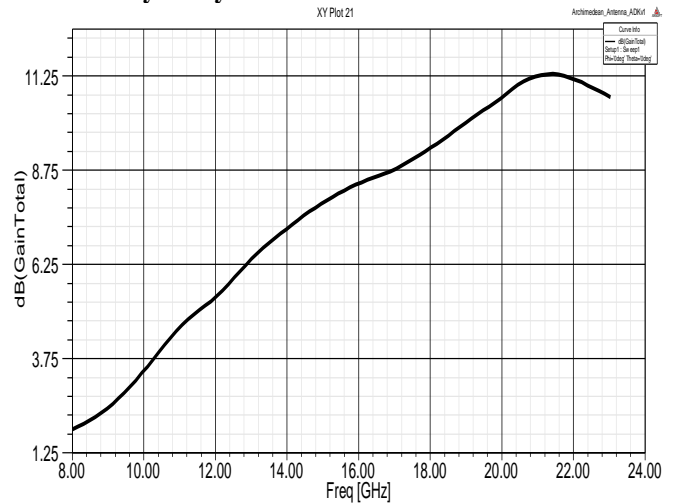


Fig 7. Frequency versus Gain plot.

### D. Current field distribution

In current distribution the under surface of the planar element and the ground plane of the spiral antenna have a large current flow. The influence of the objects affecting the antenna characteristics will have minimum affect on the spiral antenna because of its current distribution characteristics. The current field distribution of the antenna is shown in Fig 8.

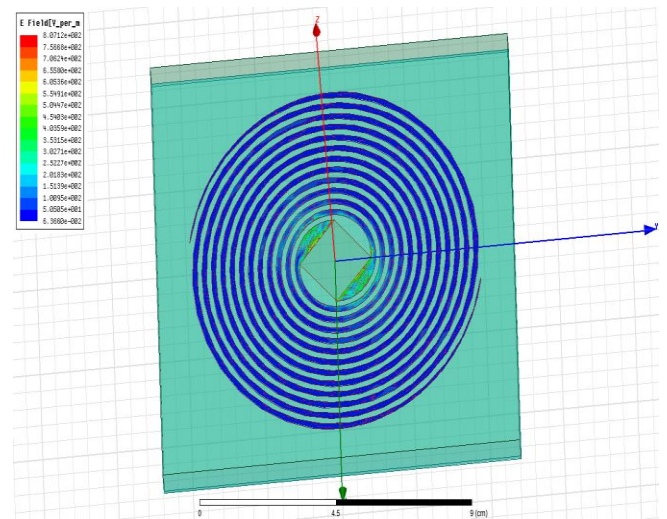


Fig 8. Current field distribution of antenna.

## V. CONCLUSION

The parameters of an Archimedean spiral antenna were analyzed and structure has been designed. The designed Archimedean spiral antenna radiates to both sides of the spiral plane. By using lossy dielectric impedance bandwidth enhanced. The antenna provides broad bandwidth over the frequency range and antenna has yielded a VSWR of less than 2.0 over the frequency range 8-24 GHz. The antenna exhibits unidirectional radiation pattern in E plane and omni directional in h plane, high gain performance is obtained by placing a hollow metal cavity at the back of the spiral. The designed antenna provides an operating bandwidth of 8-24GHz with circular polarization and gain of 11.25 dB at 21

GHz. This antenna can be used for satellite applications up to Ku band frequencies.

#### **VI. ACKNOWLEDGMENT**

The authors are thankful to Dr. K. Mohan Rao Former Director and Dr. A. V. Ratna Prasad, Principal, V. R. Siddhartha Engineering College, Andhra Pradesh, India for constant encouragement given throughout the tenure of the research work. We are also thankful to Dr. K. Sri Rama Krishna, Head, Department of Electronics and Communication Engineering for timely provision of the facilities in completing the work.

#### **VII. REFERENCE**

- [1] Rumsey, V.H., and Welch, W.J., "A solution to the frequency independent antenna problem," IRE Transactions on Antennas and Propagation, vol. AP-9, pp.527-534, November 1961.
- [2] B. Wang and A. Chen, "Design of an Archimedean spiral antenna", in proceedings. ISAPE, 2008, PP. 348-351
- [3] Paul C. Werntz Warren L. Stutzman, "Design, analysis and construction of an Archimedean spiral antenna and feed structure", the Bradley dept. Electrical Engineering and state university Blacksburg, Virginia.
- [4] John d. dyson, "The Equiangular spiral antenna", in IRE transactions on antennas and propagation.
- [5] christopher djoma, Michel Jousset, "Maximal bandwidth of an archimedean spiral antenna above a Reflector", IEEE antennas and wireless propagation letters, Vol.13, 2014.
- [6] Hossein Mosallaei, Kamal Sarabandi, "Antenna Miniaturization and Bandwidth Enhancement Using a Reactive Impedance Substrate", IEEE transactions on antennas and propagation, vol. 52, no. 9, September 2004.