

DESIGN OF ARCHIMEDEAN SPIRAL ANTENNA FOR RADAR APPLICATIONS

S.RAJESH KUMAR¹, E.JEEVITHA², V.KEERTHI³, S.KIRUTHIKA⁴, V.MANIMEKALAI⁵

¹Assistant Professor, Department of Electronics and Communication Engineering,
V.S.B Engineering College
Karur, India

rajesh26july@gmail.com

^{2,3,4,5}Department of Electronics and Communication Engineering,
V.S.B Engineering College
Karur, India

ejeevitha04@gmail.com, keervivek03@gmail.com, skiruthikaece97@gmail.com,
vjmanimekalai66@gmail.com

ABSTRACT

A circularly polarized Archimedean spiral antenna has been designed with return loss is less than -20dB and VSWR is nearer to one. In this antenna, polarization, radiation pattern and impedance matching remain unchanged over a large bandwidth. The two arm spiral antenna is proposed to have circular polarization for wide band applications. It operates over the frequency range about 1GHz to 36GHz. It has been designed using a CST (Computer Simulation Technology) microwave studio to analyse the performance of the characteristics of an antenna. The gain, directivity, radiation pattern, return loss, power, VSWR and Axial ratio of the coaxial Archimedean spiral antenna is analysed.

KEY WORDS

Archimedean spiral antenna, circular polarization, large bandwidth, impedance matching

1. INTRODUCTION

In today's world, currently the progress of antenna is rapidly increasing in the communication field. It is used in the wide band applications and satellite communication. Antenna is used to communicate between the transmitter and receiver through free space or medium. In that, spiral antennas are used for wideband communications and used for monitoring the frequency spectrum [3], [6]. Archimedean is one of the common planar types of spiral antenna. It is a frequency independent, circularly polarized antenna and it has very large bandwidth as high as 30:1[5]. It means the lower frequency is 1GHz and antenna would be efficient up to 30GHz. Spiral antennas have high input impedance approximately $Z_{in} \leq 200\Omega$ and the characteristics impedance is 50Ω [2]. To increase the efficiency of the spiral antenna,

the transmitter and receiver should be in same polarization. The one arm spiral is started from 90° to 180° and the other arm is started from 270° to 180° . The coaxial feed is given to the two arms at the centre of the spiral. The material which is used for this design is Teflon with the dielectric constant is 2.1. In this letter, we built two arms Archimedean spiral antenna between the 1GHz to 36GHz and tested by the antenna parameters using CST tool.

2. RESEARCH BACKGROUND

Different kinds of antenna structures such as coaxial rectangular spiral antenna, single arm, two arm and three arm Archimedean spiral antenna, wide band and low profile unidirectional spiral antenna with meta material absorber and Archimedean spiral antenna with finite ground plane and back cavity are used to analyse the characteristics of an antenna. N.H.AbdulHadi et al. [12] proposed the Rectangular spiral antenna with the centre frequency of 2.45 GHz and bandwidth of 22MHz. The simulation of RSMA is carried by using a commercial 3D Electromagnetic simulator. It is fabricated on FR4 substrate with 4.9 dielectric constant and 1.54mm of thickness. Vector network analyser ZVA40 is used to measure all the parameters. Omni directional pattern with VSWR less than 2, return loss of less than -10dB, the line impedance 50 ohm and gain of 5dBi has been achieved.

Baixiao et al. [9] designed an Archimedean spiral antenna and calculated its directivity performance. The axial ratio of this antenna is obtained below 3db and it has good polarization.

KarimLouertani[11] proposed an antenna backed by circular patches on the magnetic substrate by a Meta Material Absorber. The parameters such as reflection coefficient, polarization and gain have been analysed with Meta Material absorber.

3. PROPOSED SYSTEM DESIGN

In proposed antenna design, the Archimedean spiral antenna with two-arm structure is proposed. Teflon with dielectric constant $\epsilon_r = 2.1$ was chosen as substrate. The antenna operation covers the frequency range from 1GHz to 36 GHz. In this antenna, the polarization, radiation pattern and impedance remain unchanged over large bandwidth.

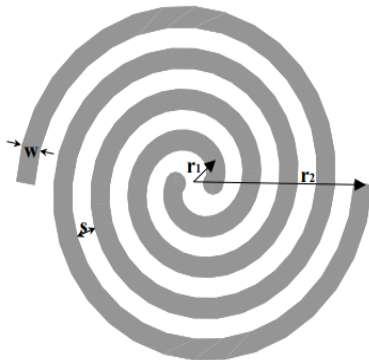


Figure (1): Geometry of Archimedean spiral antenna

[10] In Archimedean spiral antenna, each arm is linearly proportional to the angle, and is described by the following relationships

$$r = r_0\phi + r_1$$

$$r = r_0(\phi - \pi) + r_1$$

The proportionality constant of the Archimedean spiral is determined by,

$$r_0 = \frac{s + w}{\pi}$$

Where, r_1 is the inner radius of the spiral antenna, r_0 is Proportionality constant, w is width of each arm, s is spacing between each turn is mentioned in figure(1). The strip width of each arm is given by,

$$w = \frac{r_2 - r_1}{2N} - s$$

Where, r_2 is Outer radius of the spiral, N is number of turn. The above two equation represents the two arm Archimedean spiral antenna.

In Archimedean spiral antenna, the low frequency operating point of the spiral is determined by outer radius and is given by,

$$f_{low} = \frac{c}{2\pi r_2}$$

The high frequency operating point of the spiral is determined by inner radius and is given by,

$$f_{high} = \frac{c}{2\pi r_1}$$

The antenna has been designed by using these parameters such as $t = 0.35\text{mm}$, $n = 5$, $r_0 = w = 1.3\text{mm}$, $g = 1.2\text{mm}$, where t is height of the spiral, n is number of turns, g is inner gap of spiral and w is width of the spiral [6].

The first arm of the spiral is started from 90° to 180° and the other arm is started from 270° to 180° . The two arms are designed by using inner and outer radius of the spiral. The two arms are separated by using the above formula. Based on the inner and outer radius, the antenna structure is designed. The number of turns depends on the gap and width of the arm. The waveguide port is selected at the centre of the spiral for providing coaxial feed for two arms. The selection of waveguide port is based on width of the arm. The circular polarization is achieved with the two arm structure. It has high input impedance approximately $Z_{in} \leq 200\Omega$ and the characteristics impedance is 50Ω . In order to increase the efficiency of the antenna, the transmitting and receiving antenna should have same polarization. The side lobes are observed from the radiation pattern of E-plane and H-plane. By reducing the angular width, we can obtain the narrower radiation pattern. The axial ratio is an important parameter for spiral antenna which is used to analyse the circular polarization. It should have nearly 1 dB. The simulation results are discussed below.

4. RESULT AND DISCUSSION

It is observed that, the antenna is able to work well between 1 to 36GHz; particularly we have taken 2, 6.2, 12, 24 and 30 GHz. The voltage standing wave ratio (VSWR) with respect to the frequency (GHz) is 1 to 1.9 values between 1 GHz to 35 GHz, above 35 GHz, the VSWR value reaches above 2 is shown in fig(2a, 2b). The VSWR value should be nearer to one, which represents the antenna is perfectly matched. From VSWR results, the Archimedean spiral antenna has good VSWR. If the value of VSWR increases, the impedance mismatch is also increases. So, the obtained two values are acceptable for

wideband application. The VSWR of the antenna is improved by increasing the number of turns and optimization of the feed structure. It also indicates the impedance mismatch of the antenna. By using far field pattern in microwave studio, the radiation efficiency, total efficiency and the directivity values has been obtained. The total efficiency was calculated based on the stimulated power of the antenna which considers any occurring reflections at the feeding location, -6.755dB for 6.2GHz and -3.958dB for 30GHz in fig (3a, 3b). For other resonant frequencies, it leads gain inaccurate. The radiation efficiency is also depends on the radiated power and the accepted power of the antenna, it just mention the internal losses of the antenna, 17.31dB for 6.2GHZ, and 76.04dB for 30GHz in fig(3a,3b). The accepted power is obtained by subtracting the reflected power (power wasted out of the forward power) from the input power. The directivity of an antenna is calculated by radiation pattern of the antenna. It depends only on the shape of the radiation pattern and it is an important factor to determine the gain of the antenna,6.418dB for 6.2GHz and 5.241dB for 30GHz in fig(3a,3b). The simulations is done to improve the directivity in the far field direction and to avoid side lobes. The radiation pattern obtained at 6.2GHz does not contain any side lobes and the main lobe magnitude is 6.21dBi is shown in fig (5a). By reducing the angular width, we can obtain the narrower bandwidth. The main lobe magnitude should be greater than 3dBi. The higher frequency 30GHz has side lobe which has side lobe level is -0.9 dB is shown in fig (5b).The axial ratio is an important parameter for spiral antenna which is used to analyze the circular polarization. It should have nearly 1 dB. The Axial ratio for 6.2 and 30 GHz is shown in figure(4a, 4b). The return loss less than -20dB shows that back waves are reduced and the proposed antenna achieves good radiation efficiency. S11 will be always high when there is mismatch of antenna with feed line. The thickness and width are parameters which affects return loss. S11 is an important parameter which is mostly used to analyze the antenna performance. S11 represents how much power is reflected from the antenna and hence it is known as reflection coefficient. The s11 is tested for input matching. The simulation result shows that, the return loss

between 1 to 28 GHz has below 20 dB in fig (6a), above 28GHz in fig(6b)has return loss greater than 20 dB.

Fig (2): VSWR

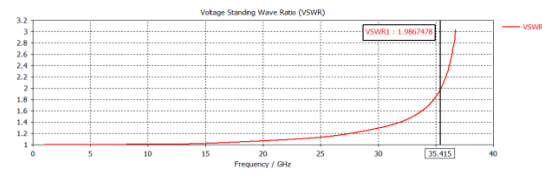
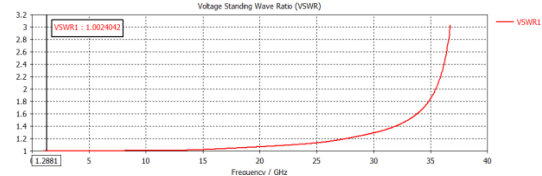


Fig 3: Far Field

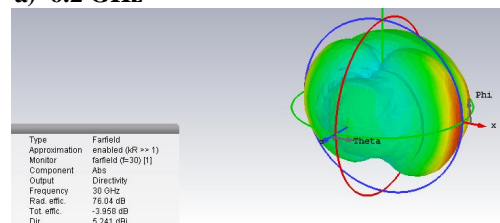
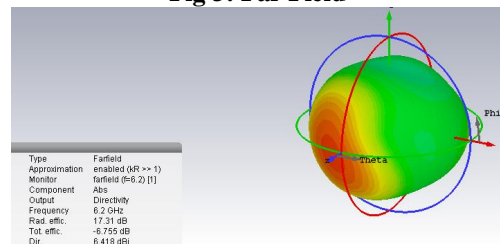
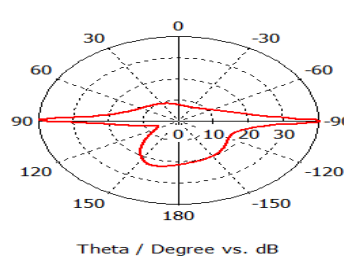
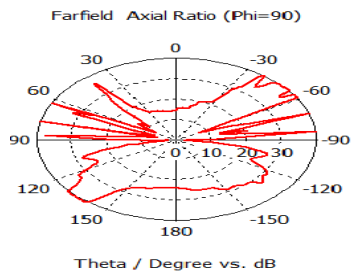


Fig 4: Axial Ratio

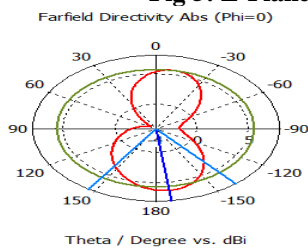
Farfield Axial Ratio (Phi=90)



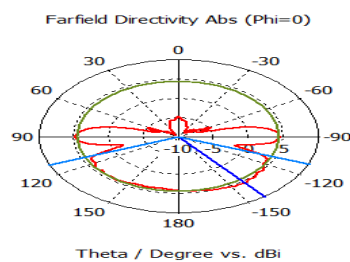


b) 30 GHz

Fig 5: E-Plane

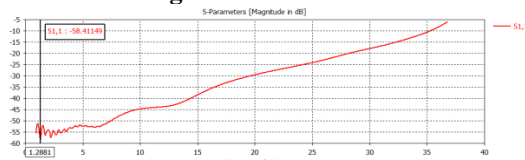


a) 6.2 GHz

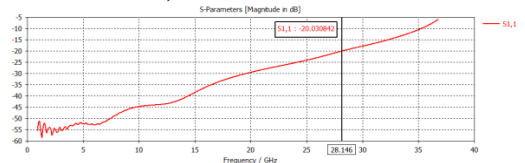


b) 30 GHz

Fig 6: Return Loss



a) Above 1 GHz



b) Between 1 to 29 GHz

5. CONCLUSION

In this paper, the Archimedean spiral antenna has been designed by coaxial feed by using CST Microwave studio. The antenna radiates to both sides of the spiral plane. By analysing all the parameters, we conclude that our proposed spiral antenna is efficient and exhibits circular polarization. Our simulation results show that, good VSWR which is nearer to one, return loss less than -20dB, without

side lobes, good directivity and axial ratio are achieved.

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