Archimedean Spiral Antenna with Finite Ground Plane and Backed Cavity

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Abstract

Wide band circularly polarized spiral antenna with high gain antenna literature survey is presented here for the frequency ranges from 1 GHz to 10 GHz with different configuration. Single and dual arm spiral antenna with back cavity, spiral antenna with conical wall, different ground plane radius, unidirectional and bidirectional Archimedean spiral are presented and comparison between different paper are presented.

Keywords: RHCP, Spiral Antenna, Finite Ground plane, Single and Dual arm spiral

I. INTRODUCTION

Spiral antenna is frequency independent wide band antenna. In its normal operation it generates circular polarization. Orientation of polarization is dependent on direction of rotation of the turn according to finger turns. Spiral antenna shape is defined by angles only and not on the wavelength or frequency. Different papers of Different types of spiral antenna with different mechanism for different frequencies are presented.

II. THEORY

Archimedean spiral antenna is shown in Fig. 1. The input impedance of a self-complementary is

\[ Z_{\text{metal}} Z_{\text{air}} = \eta^2 / 4 \]

where \( \eta \) is the characteristic impedance of the antenna in medium. For a self-complementary Archimedean spiral antenna the input impedance in free space should be

\[ Z_{\text{input}} = \eta_0 / 2 = 188.5 \, \Omega \]

The proportionality constant of spiral antenna is determined by the width of each arm, \( w \), and the spacing between each turn, \( s \), which is given by

\[ r_0 = \frac{s + w}{\pi} \]

The spacing between the strip width of each arm can be found from the following equation

\[ s = \frac{2N}{N - 1} - w \]

where \( r_2 \) is the outer radius of the spiral, \( r_1 \) is the inner radius of the spiral and \( N \) is the number of turns.

![Fig. 1: Archimedean spiral antenna](image-url)
The Archimedean spiral antenna radiates from where the circumference \(2\pi r\) of the spiral equals one wavelength \(\lambda\). This is the active region of the spiral. If self-complementary spiral is there then each arm of the spiral is fed 180° out of phase, when the circumference of the antenna is one wavelength long the current at both the end will add in phase in a far field.

The low frequency operating point of the spiral is determined theoretically by the outer radius and is given by

\[ f_l = \frac{c}{2\pi r_2} \]

where \(c\) is the speed of light. Similarly the high frequency operating point is based on the inner radius giving

\[ f_h = \frac{c}{2\pi r_1} \]

In practice the low frequency point will be greater than \(f_l\) due to reflections from the end of the spiral. The reflections can be minimized by using resistance loaded at the end of the arm or by adding conductive loss at part of the outer turn arm. Also, the high frequency limit may be less than \(f_h\) due to feed region effects.

When the inner radius \(r_1\) is less than the arm width \(w\) the real part of the input impedance is less than the desired 188 ohms, and when the inner radius is greater than the arm width \(r_1 > w\) the real part of the input impedance is greater than expected. Also, when the inner radius is not equal to the arm width, both the real and imaginary parts of the input impedance vary greatly with frequency. For a frequency-independent spiral, self-complementary spiral the input impedance should be 188 ohms and equal over a wide frequency range. This achieved when the inner radius is equal to the arm width, \(r = w\).

Spiral antenna is radiating circular polarization in broadside. Polarization of the antenna is in the direction of rotation of finger and the radiation will be in the direction of thumb. If the antenna is RHCP, the LHCP in that hemisphere creates a cross polarization. Now if the spiral antennas is backed by a cavity, it will restrict the radiation into one hemisphere (back side) and improves impedance bandwidth at cost of a 2-3 dB gain decrease due to the reduction in antenna efficiency. Recently the use of spiral antennas with conducting ground planes has become more popular. These types of spirals have more gain but the axial ratio and pattern bandwidths are drastically decreased compared to spirals backed by cavities. Most of the spiral element and array simulations in this thesis will be simulated in free space, but for some cases it may be desirable to use a ground plane.

### III. REVIEW OF PAPERS

**Extremely Low-Profile, Single-Arm, Wideband Spiral Antenna Radiating a Circularly Polarized Wave**[1]  
Hisamatsu Nakano, Fellow, IEEE, Ryohei Satake, Member, IEEE, and Junji Yamauchi, Senior Member, IEEE  
IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 58, NO. 5, MAY 2010

Here the spiral antenna with single arm is presented without using balun structures. As we know spiral antenna characteristic impedance is 188 ohm and idea SMA connector is having 50 ohm. So, as to adjust or match this loads balun or a transformer is needed. But the presented antenna doesn't need it as we can use a back cavity. Without using balun structure or a two arm spiral we can achieve gain & bandwidth requirement using finite ground plane in bottom.

This antenna is having three type of configuration, one is with finite ground/disk with single arm, backed cavity with single arm, two arm spiral antenna. all this three configuration are useful for high BW & gain requirement. In first case axial ratio can be decrease but with back cavity axial ratio will also be better.

This antenna was designed for 3 to 10 GHz wide band and cavity height is also small upto 0.07 \(\lambda\). Antenna dimensions are also small( \(r_{end}= 34\) mm ), Axial ratio of whole band is below 3 dB & VSWR is below 1.5. Gain of this kind of antenna is average 7 DB for all frequencies.

**Triple Band Spiral Antenna for Non-Linear Junction Detector**[2]  
Jeong-won Kim1, Kyeong-sik Min1, In-hwan Kim1, and Chan-jin Park1  
IEEE Proceedings of ISAP2012, Nagoya, Japan

In this paper author had made the Archimedean spiral on a top layer and in a slit in ground plane. This slit in a ground plane is designed for impedance matching. By decreasing the number of turns with keeping an elliptical shape patch on center position of radiating plane will create a wide band of spiral antenna. Return loss will be affected by the shape of matching element at a ground. The gain of spiral antenna proposed by reference had been decreased due to multiresonance characteristics. By optimizing the turns into spiral antenna antenna gain, return loss and axial ratio can be improve. Due to multi resonance of narrow bandwidth problem has been also solved by the optimized feeding position and the control of turn number. The measured main lobe directivity toward \(+z\) direction agreed well.

In NLJD system application power reduction by coupled wave from the hidden device will be reduce by using spiral antenna, because circular polarization (CP) antenna are mainly used for this application. Return loss at different frequencies are 2.5 GHz, 4.5 GHz and 7.5 GHz is -20 db, -20 db and -30 db.

**Miniaturization of A Circularly-Polarized, Uni-Directional, Ultra-Wideband Spiral Antenna**  
Ting-Yen Shih and Nader Behdad  

This paper contains a different approach to minimize the size of antenna in which loading structure, a feeding network and a ring shaped absorber are used. The loading structure possesses both capacitive and inductive characteristics, through which they increase the equivalent electrical length of the antenna with maintaining its maximum dimensions. The ground plane effect on this antenna is minimized by using an optimized ring-shape absorber.
Here in this antenna they printed two arms of the proposed antenna on the different sides of a dielectric substrate. A ground plane is placed behind the antenna to make the radiation patterns unidirectional. The feeding network is fabricated on roger layer below the ground plane. Coupling problem between the antenna and proposed ground plane is a problem because the radiation comes from horizontal waves, if are in close proximity of ground then causes a degradation in radiation performance. to resolve this issue absorber also can be placed there.

Multiband Spiral Antenna with High Gain by Conical Wall
Jae-Hwan Jeong , Kyeong-Sik Min, In-Hwan Kim, Sung-Min Kim

To improve the gain of spiral antenna, the conical wall was considered . The improved gain is 10.5 dBi, 15.36 dBi and 15.68 dBi at respectively 2.44 GHz, 4.88 GHz and 7.32 GHz and the axial ratio is below 2.4 DB. The cavity wall is having thickness of FR 4 glass epoxy is 2mm with metal cap thickness of 0.2 mm. The required antenna bandwidth including transmitting frequency and receiving frequency is from 2.4 GHz to 7.36 GHz.

IV. CONCLUSION

By analyzing all the paper and theory we can conclude that the spiral antenna is best source of the circular polarization. By using finite ground plane with single arm or by using a back cavity we can achieve the best axial ratio with fulfilling gain requirements. Ground plane or a back cavity reflects the cross polarized wave in backward direction, hence the gain increases in forward direction and increases the gain in forward direction.

REFERENCES