Design An Novel Three Dimension Spiral Antenna for a High Directive CP Radiation

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1. Introduction

Spiral antennas[1~4] have good characteristics of broad bandwidth and circular polarization in operations. Regular spiral antenna structures radiate in both directions of upward and downward to the spiral plane with relatively broad patterns[2]. Thus in practical applications, the spiral antenna is placed on the top of a cavity filled with absorber materials and tends to loss a half of the power. To improve the efficiency and also make the radiation more directive, a broadband antenna design that extends the concepts of designing spiral antenna arms, is proposed in this paper for the potential applications of antenna measurements. It may achieve a broad frequency bandwidth of operation and radiates fields with a circular polarization as usually seen in the regular spiral structure. To enhance the directivity, the antenna structure is axially elevated on its spiral arms such that the fields tend to be radiated in the upward direction with a beamwidth narrower than that radiated from an analogous spiral antenna, which is found to be suitable for the applications of antenna measurement inside an anechoic chamber.

2. Antenna Structure

The proposed antenna is configured in Figure 1 (a), where the antenna's projection on a x-y plane exhibits spiral curves as governed by an ordinary two arm spiral antenna. As usual, the polar coordinates, (r,θ), of the first spiral arm are described by [1,2]

$$r = a^{\theta} \tag{1}$$

where a is the exponential rate, and θ is a rotating angle measured with respect to x-axis. Note that θ in (1) increases from 0 to $\theta_{\max}$ which can be as large as one desires. The coordinates of 2nd arm are determined by rotating the first arm with an angle of π. Thus the first arm's coordinates in a rectangular coordinate system can be expressed as

$$\begin{cases} x = r\cos\theta \\ y = r\sin\theta \end{cases} . \tag{2}$$

To enhance the directivity, Figure 1 (a) introduces a z-coordinate by

$$z = \frac{\theta \cdot h}{\theta_{\max}} \tag{3}$$

where h is the maximum vertical height at termination, which allows the height gradually increase from 0 at feeding terminals to h.

This antenna is excited by a pair of differential feeds which are placed at the bottom of the two arms, respectively, as shown in Figure 1 (a) and (b). These differential feeds provide excitations with equal powers and a phase difference of π on the two arms, and allow the antenna radiating in a sum mode which gives a maximum field strength in the boresite of the antenna.

3. Numerical Examination

Numerical examination is based on the simulation using CST MICROWAVE STUDIO [5], which has been shown reliable in the simulation of various antenna designs. To reduce the diffractions from the finite arm termination, the edges of the arm termination are rounded[6], which may reduce the sidelobes at middle frequency ranges. First Figure 2 shows s11 of above antenna design with various $\theta_{\max}$. In this case, $h = 160\text{mm}$ and $a = 1.5$. As one expects that larger $\theta_{\max}$ will increase arm's length and in turn extends the operation to a lower frequency. It also improves the impedance match as well. Figure 3 shows the gains and efficiencies with respect to frequency variations. It shows that the antenna has good efficiencies beyond 90% in the frequency range shown in Figure 2, and beyond the range the efficiency starts to drop due to a poor s11. On the other hand, gain tends to increases and indicates highly directive at higher frequencies.

Figures 4 (a)~(c) show the radiation patterns at different frequencies. It shows that at a higher frequency, a higher directivity is achieved. Also the CP characteristics appear performing better at higher frequencies. At a low frequency, the radiating position is further away from the center, and shows apparent back-lobes due to longer path differences in this structure.

4. Discussions

This paper presents a numerical study over a proposed antenna structure which tends to improve an analogous spiral antenna and still exhibit broad bandwidth and good CP characteristics. It further increases the directivity with narrower radiation beamwidths. Numerical results validate the design concepts. Experimental validation is undergoing and will be shown in the presentation in conference.

References

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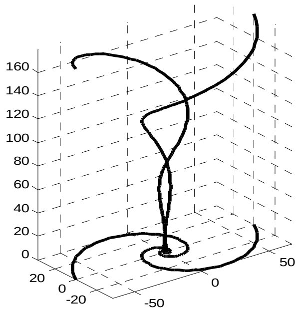
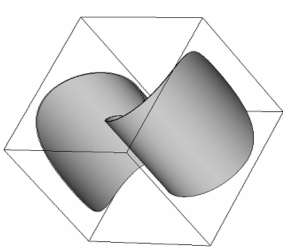


(a) Curves of the antenna



(b) CST model

Figure 1: The antenna structure.

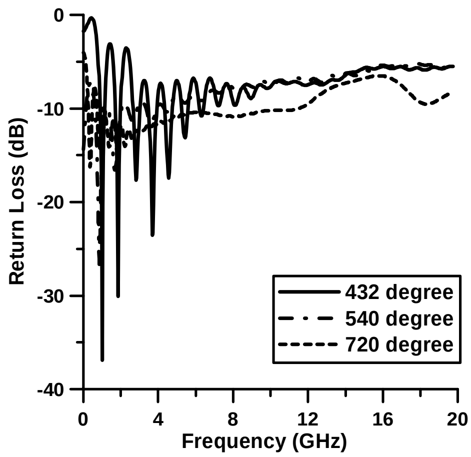
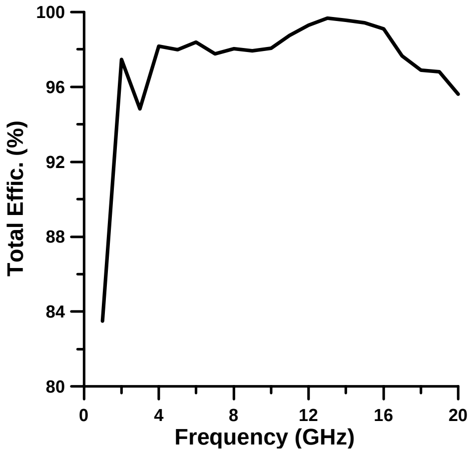
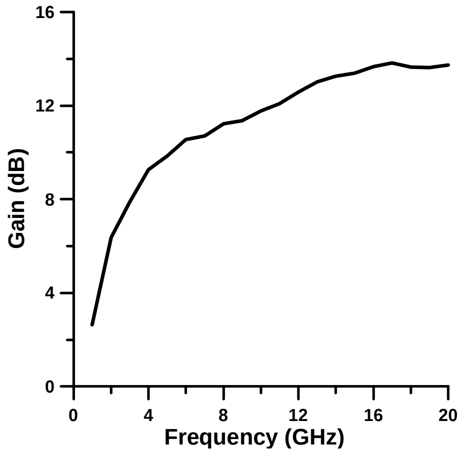


Figure 2: Return loss with various θ_{max} (432,540 and 720 degrees). Height is 160mm and a=1.5 in this case.

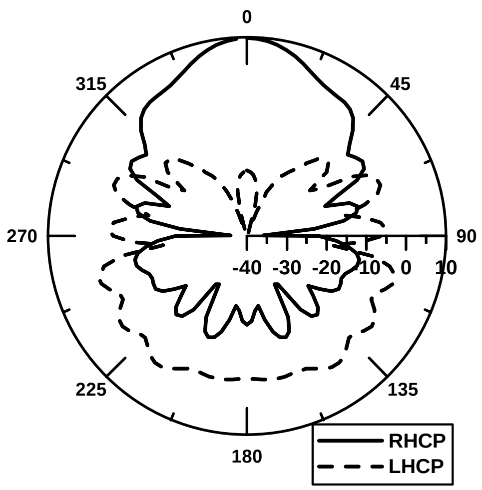


(a) Efficiency

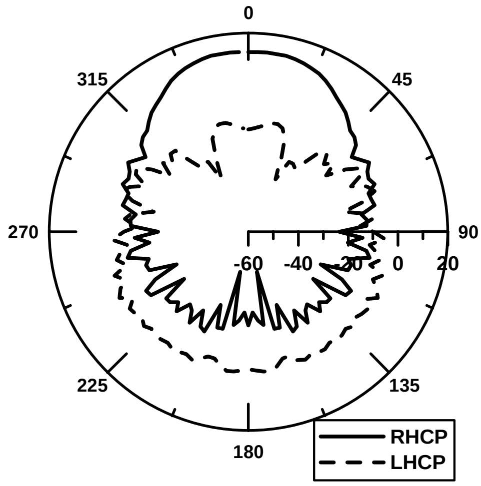


(b) Gain

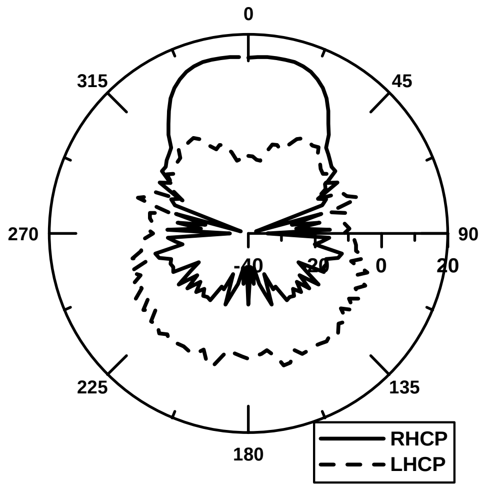
Figure 3: Efficiencies and gains



(a) 5GHz



(b) 12 GHz



(c) 18 Ghz

Figure 4: Radiation patterns of the antenna.