TWO-ARM MICROSTRIP SPIRAL ANTENNA WITH A CIRCULAR APERTURE ON THE GROUND PLANE

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I. Introduction

Remarkable progress in wireless and mobile communication technologies in recent years has prompted the research and development of antennas for these applications. Spiral antennas have a wide bandwidth and radiate circularly polarized waves. These features make them a good candidate for mobile and satellite communication antennas [1, 2]. Typical spiral antenna radiates circularly polarized waves in a direction that is normal to the spiral plane [3]. On the other hand, an eccentric spiral antenna radiates circularly polarized waves in a direction that is off-normal to the spiral plane [4]. These spiral antennas require a vertical feed network with a balun circuit resulting in complicated design and fabrication processes. While planar spiral antennas have been investigated [5-7], antenna designs for making both conventional and eccentric spiral antenna characteristics have yet to be reported. This paper presents a two-arm microstrip spiral antenna with a circular aperture on the ground plane that exhibits the characteristics of both the conventional and eccentric spiral antennas.

II. Antenna design and characteristics

Figure 1 shows the proposed spiral antenna. A circular aperture with radius r_o is located on the ground plane, with two spiral arms on the other side of the substrate. An electromagnetic wave absorber supports the antenna in order to attain a unidirectional beam. Two spiral arms are of Archimedean spiral type and represented as:

$$r_1(\varphi)=(d+w)\frac{\varphi}{360^{\circ}}+r_{\mathrm{a}}, \qquad \varphi_{\mathrm{i}} \le \varphi \le \varphi_{\mathrm{e}}$$

$$r_2(\varphi)=(d+w)\frac{(\varphi-180^{\circ})}{360^{\circ}}+r_{\mathrm{a}}, \qquad \varphi_{\mathrm{i}}+180^{\circ} \le \varphi \le \varphi_{\mathrm{e}}+180^{\circ}$$

$r(\varphi)$ is the radial distance from the origin to the arbitrary point on the centerline of the spiral, φ the winding angle, and d the radial distance between initial point and ending points after one turn. r_a is the radial distance from the origin to the initial point of the spiral line, with w_f and w the line widths designed as 50 Ω and 100 Ω, respectively. $r_2(\varphi)$ is the symmetric structure of $r_1(\varphi)$ relative to the origin. A 50 Ω feed line is divided into two 100 Ω lines that feed the spiral antenna from the outer end of the spiral arms (see Figure 1). The line length difference between two 100 Ω lines is represented as $\lambda_g/2$, where λ_g is the guided wavelength at frequency f_o to achieve a 180° phase difference at the two outer end of the spiral arms. The circumference of a circular aperture on the ground plane is approximately 1.5 λ_g at f_o.

The antenna was fabricated on a 0.7874 mm thick RT/Duroid substrate with ε_r=2.2, backed by an electromagnetic wave absorber with 19 mm thick AN-74 by EMERSON & CUMING. The design parameters of this antenna are: r_o=23 mm, r_a=0.5 mm, w_f=2.4 mm, w=0.7 mm, d=5.6 mm, φ_i=0°, and

φ_e=1265°. The frequency f_o was set at 3.0 GHz. The polarization sense of the spiral is the same as that of the spiral winding direction from outer to inner arm, as seen from the circular aperture. Right-hand circularly polarized (RHCP) waves radiate to the upper half plane for this antenna structure.

Figure 2 shows the computed main beam direction of the antenna as a function of frequency. Both θ and ϕ angles are maintained as approximately 0° from 2.5 GHz to 3.3 GHz. They move linearly in θ and ϕ directions with increasing frequency. As such, the main beam direction of the antenna is normal to the spiral plane at a frequency of around f_o and off-normal to the spiral plane at a higher frequency. This is due to the phase progression of the traveling current wave appearing asymmetrically in the vicinity of two spiral arms as the frequency increases. Therefore, this structure has the radiation characteristics of both conventional and eccentric spiral antennas.

Figure 3 shows the return loss and axial ratio in the direction of the main beam. The return loss is better than –10 dB for frequency higher than 2.5 GHz. Consistency was observed between the computed return loss obtained using IE3D and measured return loss. The frequency bandwidth for 3 dB axial ratio and VSWR<2 is evaluated as 2.5 GHz~9.4 GHz, which is approximately 1.9 octave bandwidth. The computed gain in the main beam direction has values of over 2.8 dBi in this frequency range, with the maximum gain of 4.98 dBi obtained at 5.2 GHz. Figure 4 shows the measured radiation patterns at three different frequencies, with an axial ratio lower than 3 dB satisfied for all measured radiation patterns.

III. Conclusions

This paper presented a two-arm microstrip spiral antenna with a circular aperture on the ground plane. The proposed antenna has the characteristics of both the conventional and eccentric spiral antennas. The main beam direction is normal to the spiral plane for frequency range of 2.5 GHz~3.3 GHz, with the direction of the main beam moving linearly in θ and ϕ directions with increasing frequency. Therefore, either an axial beam or a tilted beam is produced, depending on the operating frequency.

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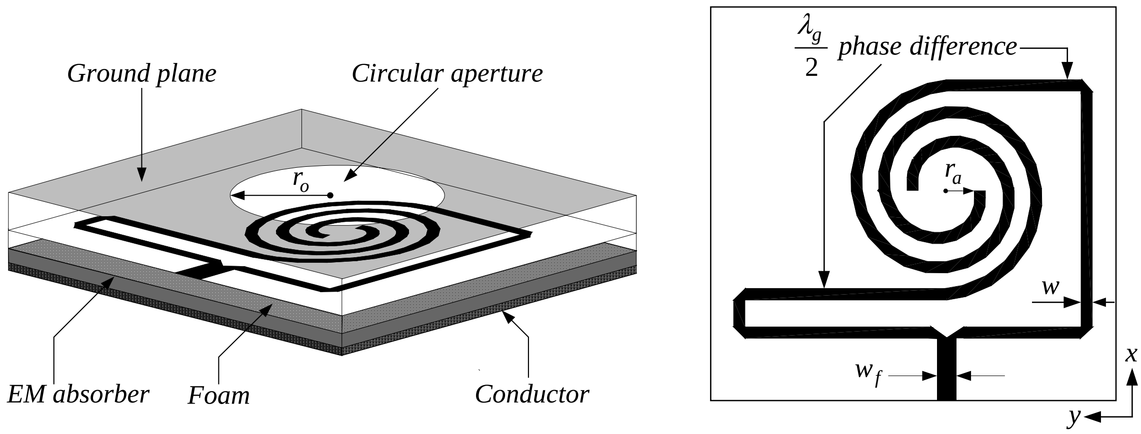


Figure 1. Proposed antenna structure.

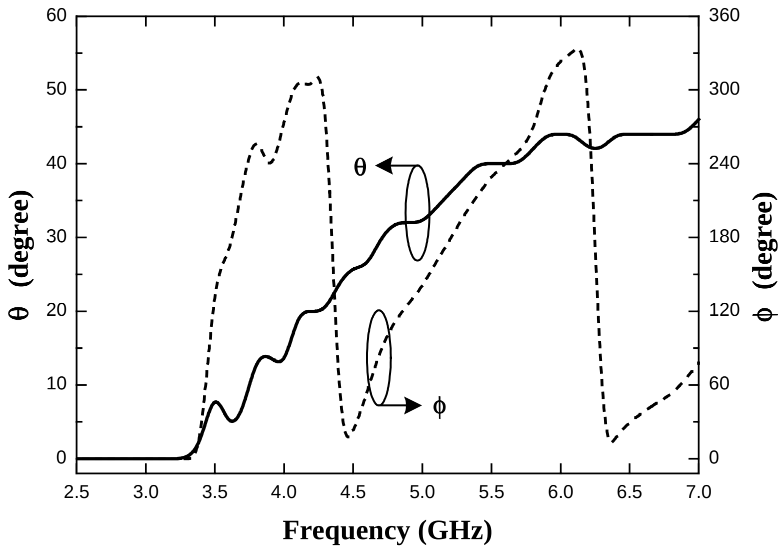


Figure 2. Computed main beam direction.

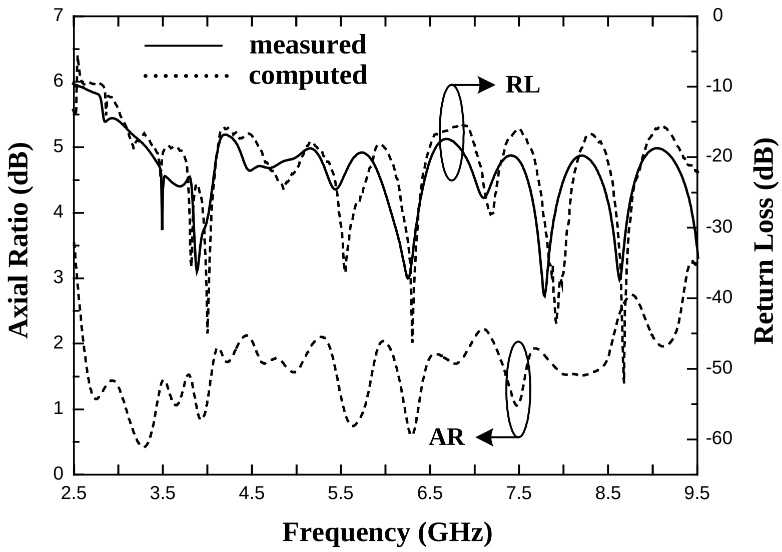
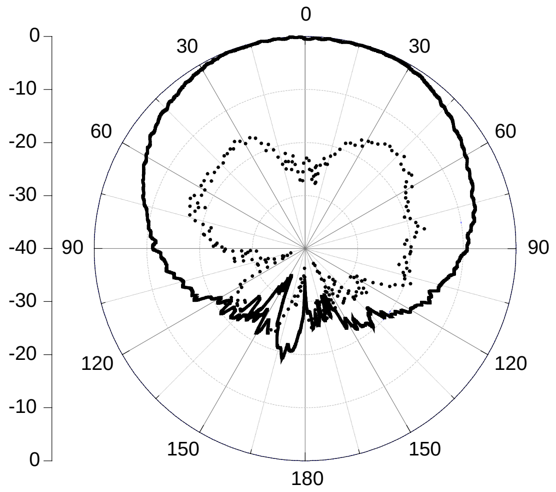
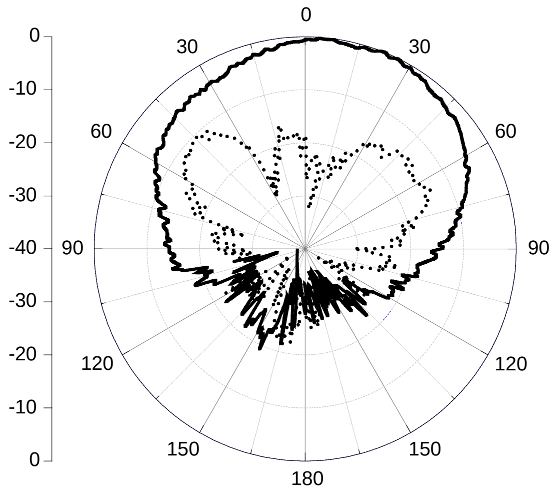


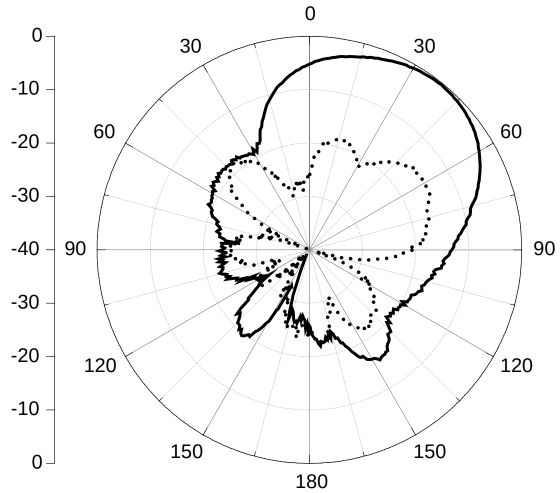
Figure 3. Axial ratio and return loss.



(a)



(b)



(c)

Figure 4. Measured radiation patterns. (a) 3.2 GHz; (b) 4.2 GHz; (b) 5.2 GHz.
——— RHCP - - - - - LHCP.