Circularly Polarized Wideband EQSP Antenna Backed by a Cavity with Arc-Shaped Strip Absorbers

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Introduction

Self-complementary antennas have the desirable characteristics of frequency-independent input impendence, radiation pattern and gain. An equiangular spiral (EQSP) located in free space [1][2] is a self-complementary antenna [3] when the length of the spiral arms is infinite. The EQSP radiates a circularly polarized (CP) wave in the two directions normal to the spiral plane (bi-directional beam).

In practice, the EQSP has finite-length arms and hence it is no longer self-complementary. It therefore loses the frequency independence of the input impedance, radiation pattern, and gain. The finite arms determine the lower edge of the operating frequency band.

The finite-arm EQSP in free space has a limited, but wide operating frequency band. This bandwidth is affected when the EQSP is backed by a conducting plane or cavity, which is used to transform the bi-directional beam to a unidirectional beam. The authors have already performed a theoretical analysis of a finite-arm EQSP backed by a cavity (abbreviated as the EQSP-C) in [2], and revealed the frequency response of the antenna characteristics.

This paper presents an EQSP-C where two arc-shaped strip absorbers are placed inside the cavity. The analysis in this paper reveals the effects of the cavity on the antenna characteristics when the cavity height H_{cav} is varied.

Analysis and Discussion

Fig. 1 shows an EQSP-C, where two arc-shaped strip absorbers are placed under the antenna arms. The spiral arms, located at height H_{sp}, are specified by an equiangular spiral constant a_{sp} and by radius r_{max}. The cavity has a height H_{cav} (= H_{sp}) and diameter D_{cav}. The arc-shaped strip absorbers have thickness H_{ABS} (= H_{cav} = H_{sp}), width T, and arc-angle ϕ_{ARC}. The following parameters are used for the antenna under analysis: a_{sp} = 0.35/rad, r_{max} = 56.5 mm, and D_{cav} = 120 mm, T = 18 mm, and $\phi_{ARC} = 90^o$. Note that TDK EM Absorber material is used for making the strip absorbers.

The electric field **E** and magnetic field **H** within an analysis space including the spiral are obtained using the FDTD method [4][5]. The magnetic field **H** is used for calculating the current on the spiral arms, from which the input impedance is calculated. Fig. 2 shows the input resistance R_{in} as a function of frequency, with cavity height H_{cav} as a parameter. It is found that, as height H_{cav} is increased, the variation in the input resistance at low frequencies (2 GHz – 4 GHz) decreases, as desired. This tendency is also seen for the input reactance X_{in} (not shown in Fig. 3).

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The radiation field is calculated using the electric current $\mathbf{J}_e$ and magnetic current $\mathbf{J}_m$ on a surface that encloses the EQSP-C. This radiation field is decomposed into two components: a right-hand CP wave component E_R and a left-hand CP wave component E_L. As the cavity height H_{cav} is increased, the cross-polarization component (E_L) decreases. Fig. 3 shows representative radiation patterns when the antenna height H_{cav} is 3.5 mm = $0.058\lambda_5$ and 10.5 mm = $0.175\lambda_5$, where λ_5 is the wavelength at a frequency of 5 GHz.

The axial ratio AR presented in Fig. 4 is calculated using the radiation field components E_R and E_L in the z-axis direction. As the cavity height H_{cav} is increased, the axial ratio improves. The axial ratio for H_{cav} = 10.5 mm is within 3 dB over a wide frequency range, from 2.5 GHz to 10 GHz (1: 4).

Further analysis reveals that, as the cavity height H_{cav} is increased, the gain at low frequencies (2 GHz – 4 GHz) increases; as a result, the radiation efficiency increases. The radiation efficiency at 3 GHz is 22.9% for H_{cav} = 3.5 mm and 67.2% for H_{cav} = 10.5 mm.

Conclusions

An equiangular spiral antenna backed by a cavity is investigated using the electric and magnetic fields obtained using Yee's FDTD method. Strip absorbers are placed inside the cavity. Antenna configuration parameters other than the cavity height H_{cav} are fixed throughout this paper, where the cavity diameter D_{cav} is chosen to be 120 mm (slightly larger than the antenna diameter of 113 mm). The investigation is performed for frequencies from 2 GHz to 10 GHz. The cavity height H_{cav} is chosen to be small and varied from 3.5 mm = $0.035\lambda_3$ to 10.5 mm = $0.105\lambda_3$, where λ_3 is the wavelength at 3 GHz. It is found that, as the cavity height H_{cav} is increased, (1) variation in the input impedance becomes smaller over a wide frequency range, i.e., the input impedance characteristic becomes relatively constant, (2) the axial ratio at low frequencies improves, and (3) the gain at low frequencies increases.

Acknowledgement

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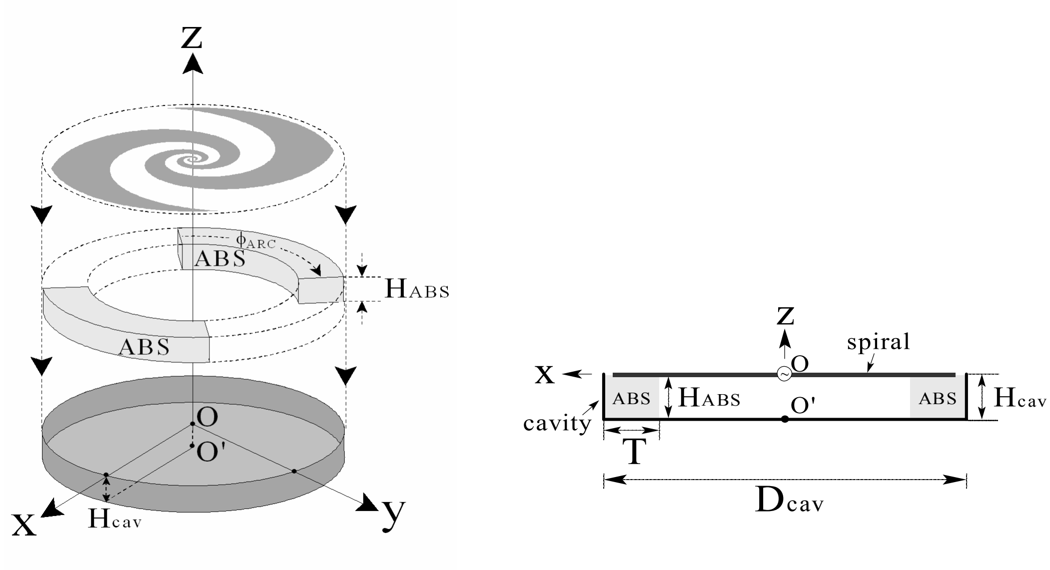
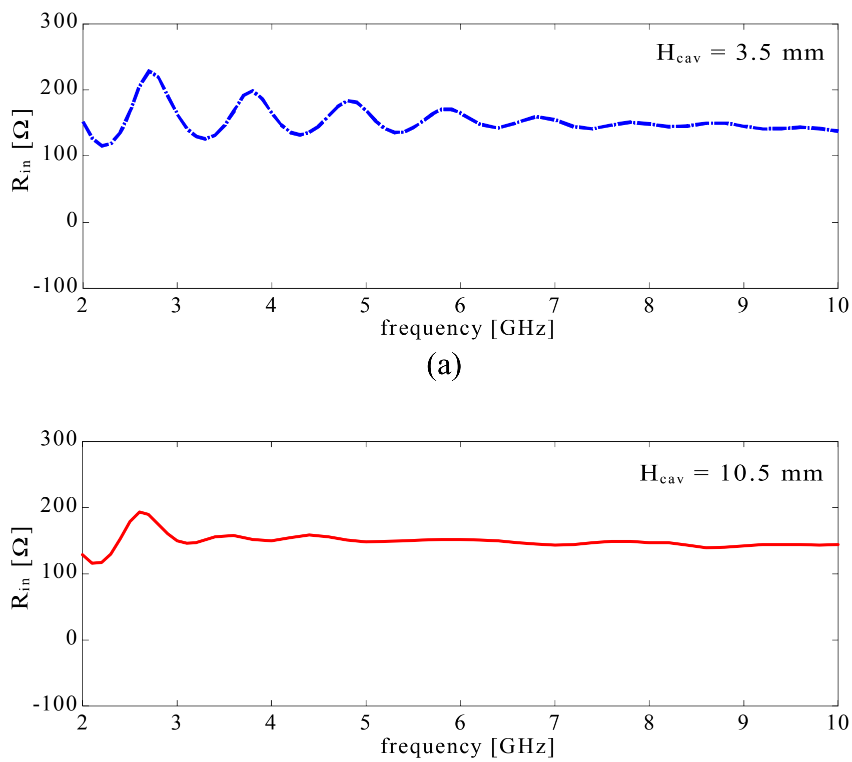


(a) (b)

Fig. 1. Equiangular spiral backed by a cavity.
(a) Exploded view. (b) Side view.



(a)

(b)

Fig. 2. Frequency response of the input resistance.

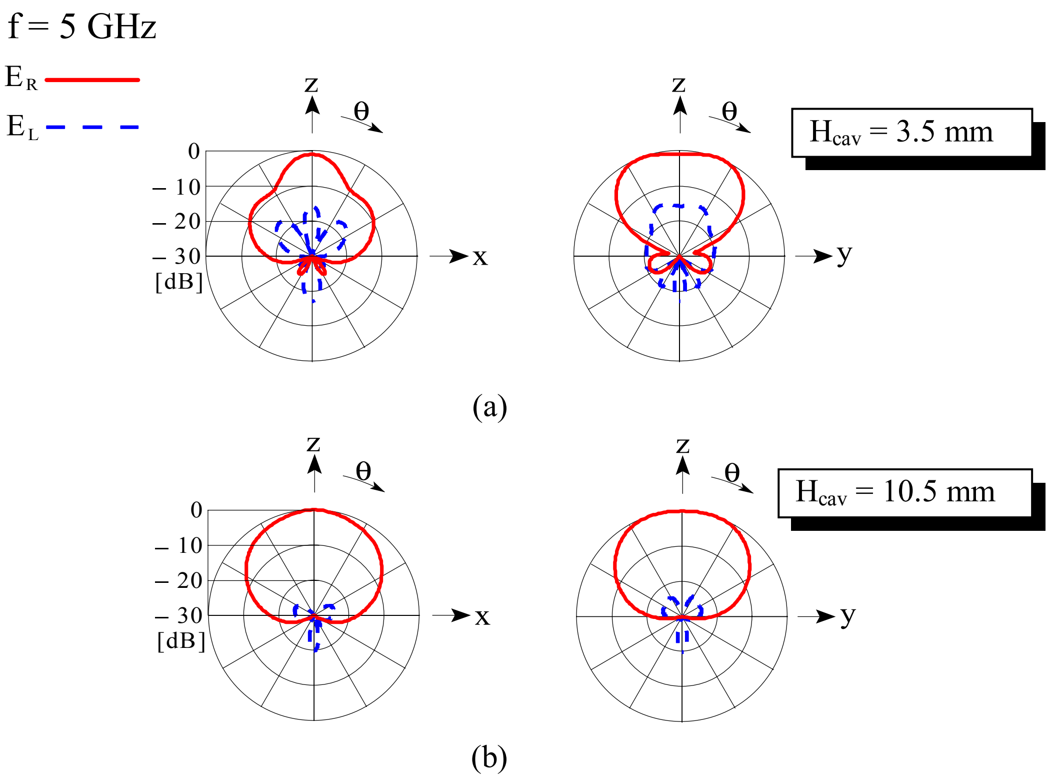


Fig. 3. Radiation patterns. (a) H_{cav} = 3.5 mm. (b) H_{cav} = 10.5 mm.

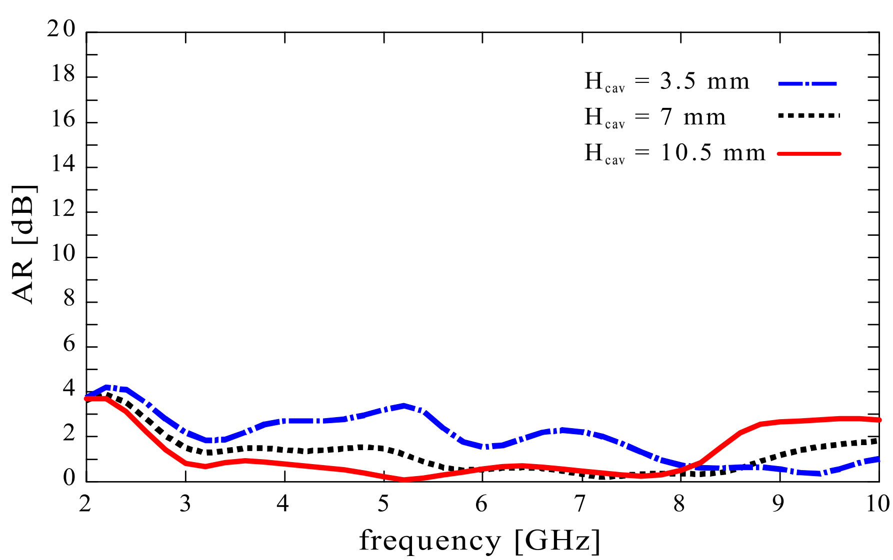


Fig. 4. Axial ratio as a function of frequency.