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A Circularly Polarized Hula Hoop Antenna on a Rectangular Dielectric Body

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1. Introduction

Low-profile antennas for linear polarization such as inverted-L and F antennas are widely used in mobile communications [1]. It is also known that dielectric materials can be used to make those antennas much smaller. But the size reduction may depend on the antenna shape and radiation characteristics.

In this paper characteristics of a circularly polarized hula hoop antenna [2] on the surface of a rectangular dielectric body over an infinite ground plane are investigated to find out the effects of the rectangular dielectric body. The VSWR, current distribution and axial ratio are calculated by a FDTD method. The volume reduction ratio is obtained when the frequency of the minimum axial ratio is kept nearly constant for different dielectric constants.

2. Antenna Configuration

Fig. 1 shows the configuration of a rectangular hula hoop antenna on an infinite ground plane. The horizontal wire is on the surface of a rectangular dielectric body. The vertical wire is in the dielectric body and is fed at the bottom through the ground plane by a coaxial cable. Antenna parameters *h* (height of the horizontal wire), *a* (side length of the horizontal wire) and *s* (gap length) are selected to radiate circularly polarized waves in the *z*-direction. The size of the dielectric body is $c \times c \times h$. The antenna characteristics are calculated for two kinds of dielectric bodies ($c = a$ and 1.2 a) and are shown in the next section.

3. Results

In the calculation the cell sizes are $\Delta x = \Delta y = a/10, \Delta z = h/6$. It is assumed that the infinite ground plane is located on the *x*-*y* plane and $50 \times 50 \times 50$ cells above the ground plane are used for the analysis. Gap length *s* (= *a* /10) is fixed in the calculation.

Fig. 2 shows axial ratio characteristics in the *z*-direction with respect to frequencies for three different dielectric constants (ε_r). Here it is assumed that $c = a$, that is, the wire is along the sides of the dielectric body. For each ε_r, side lengths *a* and *h* are changed in a 1 mm step in order to keep the frequency of the minimum axial ratio around 1500 MHz. The axial ratio bandwidth (< 3dB) becomes narrower as ε_r increases. Table 1 shows the dielectric constant and the corresponding volume reduction for Fig. 2. The volume reduction of 56.3%

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is obtained when e_r is 4.

Figs. 3 and 4 shows the amplitudes and the phases of the current distributions on the wire at 1487 MHz, 1502 MHz and 1497 MHz where the axial ratios become minimum for the three dielectric constants in Fig. 2. The phase decreases from point A to F in Fig. 1 monotonously and the antenna radiates right-hand circularly polarized waves for the three cases. The feed voltage is assumed 1 V. Fig. 5 shows the VSWR characteristics corresponding to Fig. 2. Note that the VSWR is not optimized.

Fig. 6 shows axial ratio characteristics in the z-direction with respect to frequencies for the three different dielectric constants. For each e_r, side lengths *a* and *h* are changed in the same way as the results obtained in Fig. 2. Here it is assumed that c = 1.2 a and the vertical wire is in the dielectric body. Table 2 shows the dielectric constant and the corresponding volume reduction for Fig. 6. Compared to Table 1 the volume reduction becomes larger when the size of the dielectric body is larger than a horizontal part of the wire. The height reduction of the dielectric body is larger in Table 2, but the side lengths of the dielectric bodies are not changed much in Tables 1 and 2. It is known that height *h* for good circular polarization in the z-direction is about a quarter wavelength. Therefore the effect of the dielectric body is larger and the wavelength in the body is smaller for c = 1.2 a.

4. Conclusions

Characteristics of a circularly polarized hula hoop antenna on a rectangular dielectric body is investigated by using a FDTD method. When the horizontal surface of the dielectric body is larger than a hula hoop antenna, the volume reduction of the antenna including the dielectric body becomes larger.

References

[1] K. Hirasawa and M. Haneishi (ed.), "Analysis, Design and Measurement of Small and Low-Profile Antennas," Artech House, Inc., Boston, USA (1992).
[2] H. Morishita, K. Hirasawa and T. Nagao, "Circularly Polarised Rhombic Hula Hoop Antennas," Electronics Letters, Vol. 32, pp. 946-947, May 1996.

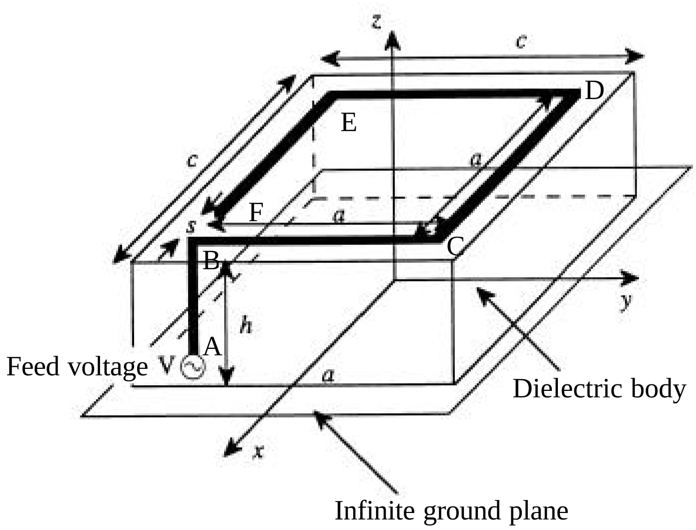

Fig. 1 A hula hoop antenna on a rectangular dielectric body

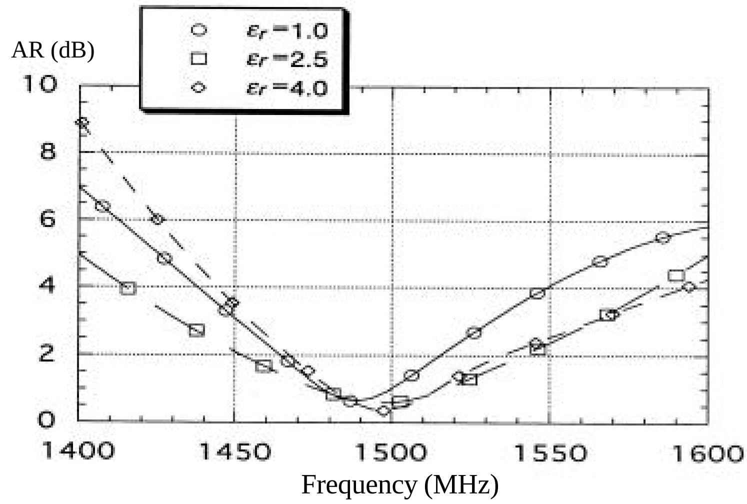

Fig. 2 Axial ratio (AR) ($c = a$)

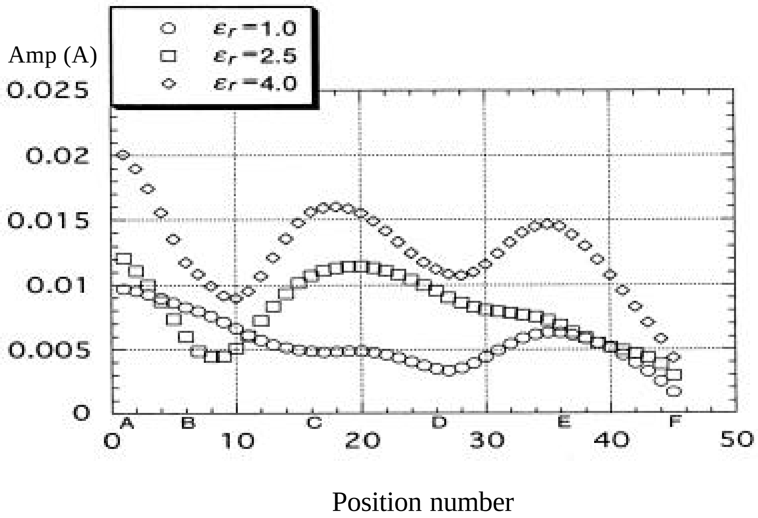

Fig. 3 Amplitude (Amp) of the current distribution

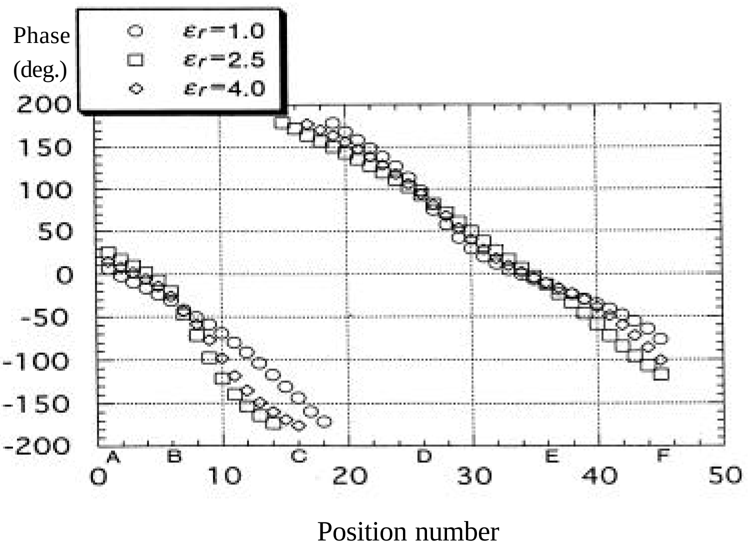

Fig. 4 Phase of the current distribution

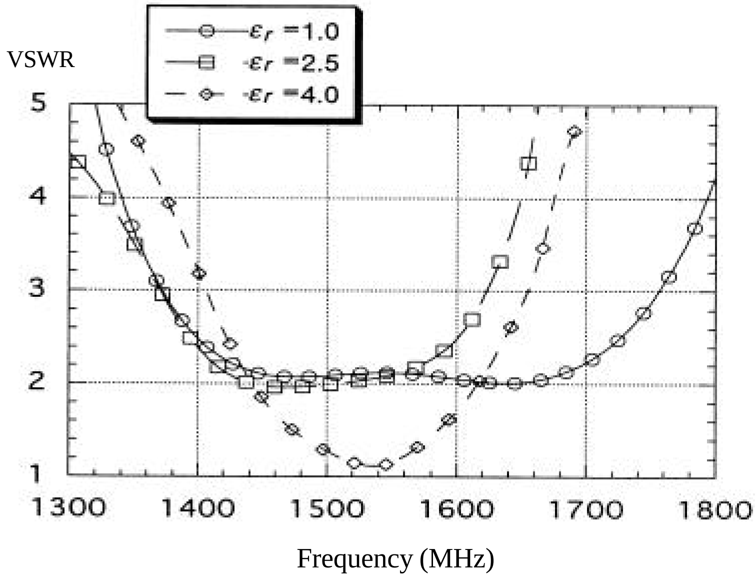

Fig. 5 VSWR

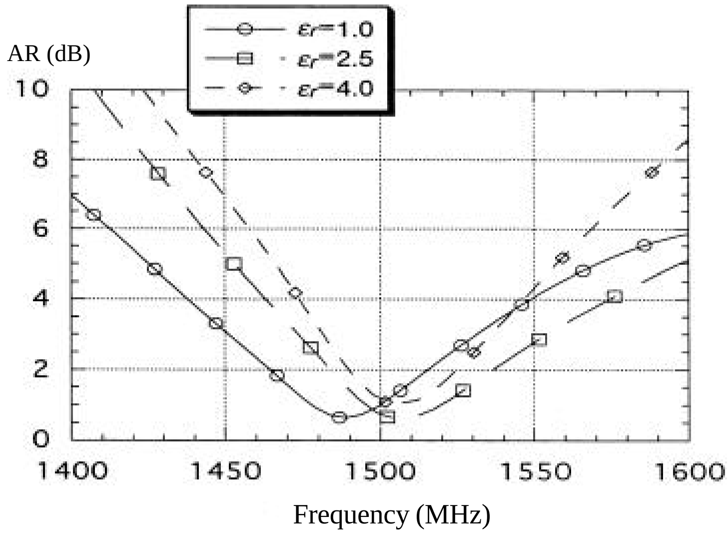

Fig. 6 Axial ratio (AR) (c = 1.2 a)

Table 1 Dielectric constant (e_r) and volume reduction (c = a)

e_r	c(mm)	h(mm)	Volume reduction (%)
1.0	64.0	38.4	100.
2.5	57.0	36.6	75.6
4.0	50.0	35.4	56.3

Table 2 Dielectric constant (e_r) and volume reduction (c = 1.2 a)

e_r	c(mm)	h(mm)	Volume reduction (%)
1.0	64.0	38.4	100.
2.5	60.0	33.0	75.5
4.0	51.2	27.6	46.0