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Modified Rectangular Dielectric Resonator Antenna for Circular Polarization

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1. Introduction

DRs are widely used in microwave circuits including oscillators, filters and cavity resonators. In recent years, application of these components as a radiator at microwave and millimetre band has been extensively studied [1-7]. These types of antennas provide efficient radiation due to low loss in dielectric materials. DRAs provide different modes of operation leading to different radiation patterns. Moreover, they are small in size, low cost and simple coupling structures such as feed probe, microstrip and microstrip–slot methods could be used in antenna structure. DR Antennas in cylindrical [1], hemispherical, rectangular [6] and other geometries located on top of a ground plane could operate as antennas by proper excitation of the resonator. Rectangular resonators are more suitable compared with other geometries, for their ease of fabrication, and the existence of two independent aspect ratios which lead to a better design flexibility to meet impedance and radiation requirements.

Early development of mobile and wireless communication systems such as Bluetooth and Wireless Local Area Network (WLAN) working at 2.4 GHz needs a broadband antenna. Moreover better connectivity could be obtained using circular polarization (CP) especially for indoor communication systems.

However, DR antennas suffer from some disadvantages including narrow bandwidth and based on their exciting method they normally radiate linear polarized waves. For CP mode of operation especial techniques have to be used. The method of corner chopped and diagonal rectangular microstrip antenna is reported by Gupta in [8].

In this paper two new and simple, one point feed structure of probe-fed RDRAs including corner chopped RDRA and diagonal fed RDRA are presented to provide CP waves at 2.4 GHz. Antennas are simulated using High Frequency Structure Simulator (HFSS). The results show that AR of nearly 0 dB and impedance bandwidth of 5.6% for VSWR<2 are obtained which could be useful in broadband communication systems application.

2. Antenna Structures

Figure 1a shows a top view of the antenna under investigation. The resonator has a relative dielectric constant of ε_r and its dimensions are a, b and h along x-, y- and z-direction respectively. The DR is placed on the top of a circular ground plane with a diameter d and feed by a single probe.

Two structures are investigated in this paper. The top view of the first structure is shown in Fig. 1a in which the resonator is corner chopped and is excited by a vertically oriented coaxial probe of height h located at x=a/2 and φ=0°.

In Fig. 1b the top view of the second structure, called diagonal probe-fed RDRA, is shown while the feeding probe is placed at the corner of the resonator in which the resonator width, b , is larger than its length a. Tables 1 and 2 summarize the detailed dimensions of the antenna structures.

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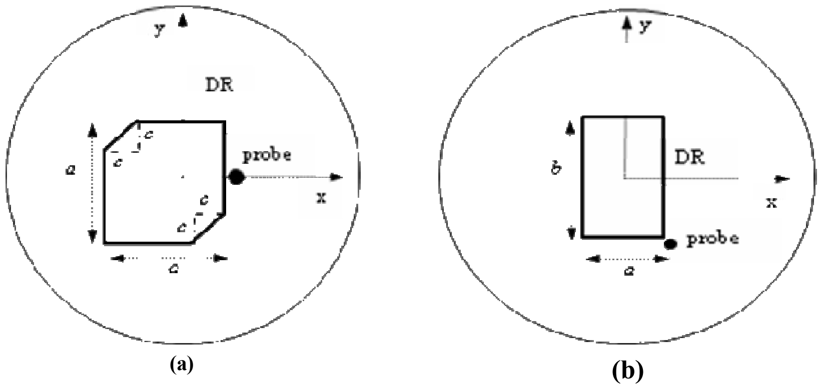


Figure 1: Antenna structure a) Structure 1, b) Structure 2

3. Antenna Simulation

The antennas are numerically investigated using High Frequency Structure Simulator (HFSS). HFSS is a software package based on the FEM. In general, in HFSS, the geometric model is divided into a large number of elements, which are tetrahedral. The value of a vector field quantity such as E- or H-field inside each element is obtained by interpolation from the vertices of the tetrahedron. The antenna structure modelled is surrounded by an absorbing sphere with the second order radiation boundary condition given by [9]:

$$(\nabla \times \overline{E})_{\tan} = jk_0 \overline{E}_{\tan} - (j/k_0)\nabla_{\tan} \times (\nabla_{\tan} \times \overline{E}_{\tan})$$
$$+ (j/k_0)\nabla_{\tan}(\nabla_{\tan} \cdot \overline{E}_{\tan})$$

where $\overline{E}_{\tan}$ is the tangential component of the E-field on the surface. The absorbing sphere is placed at least a quarter of wavelength away from the source of the signal. The HFSS then maps the E-field computed in [4] on the absorbing surface and calculates the far-field, antenna characteristics and radiation patterns of the antenna.

4. Results

Structure 1, Corner Chopped RDRA: The resonator dimensions in this structure are $a=b=15$ mm, $h=11$ mm, $c=3.4$ mm and dielectric constant is $\varepsilon_r=38$. The cutting corner of the resonator is along the diameter of the rectangle DR. The return loss and axial ratio for this structure, corner chopped DR, versus frequency are shown in Fig. 2a and 2b. The resonant frequency (minimum S_{11}) is 2.43 GHz and impedance bandwidth of 130 MHz (5.4%) is obtained. The axial ratio is nearly 0.2 dB at the frequency of 2.38 GHz.

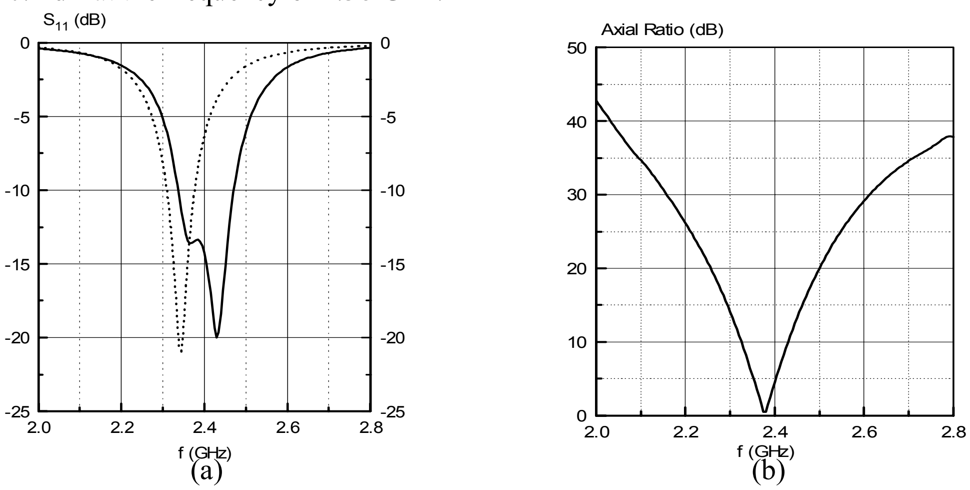


Figure 2: (a) Return loss of the structure 1 vs. frequency: corner chopped DR ▬▬ non-chopped ▪▪▪▪▪(b) *AR* of corner chopped RDRA vs. Frequency.

For comparison the results of the corner chopped RDRA with a conventional (ordinary RDRA) was numerically investigated while *c*=0. The return loss is shown as the dotted line in Fig. 2a versus frequency. It can be observed that the resonant frequency of the RDRA is 2.35 GHz with impedance bandwidth of 65 MHz (2.7%). The results also show that AR is at least 40 dB, which shows the non-cut RDRA is radiating a linearly polarized wave.

Structure 2, Diagonal fed RDRA: In this structure as is shown in Fig. 1-c, the resonator length, width and height are *a*=14 mm, *b*=15.5 mm, and *h*=11 mm respectively. The dielectric constant is also the same as the ε_r of the resonator of the structure 1. The return loss and AR for this structure are shown in Fig. 3a and 3b. It can be observed that the resonant frequency is 2.45 GHz and impedance bandwidth of 135 MHz (5.6%) is obtained. The axial ratio at the frequency of 2.39 GHz is nearly 0.25 dB.

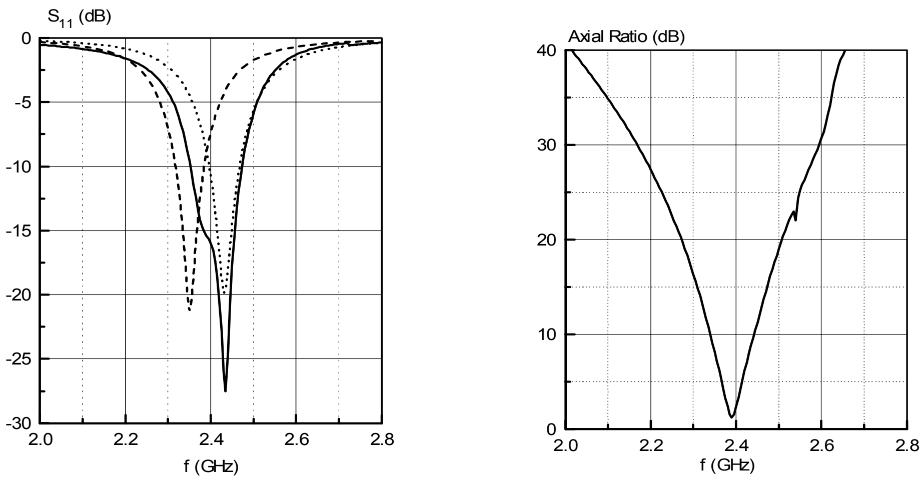
To compare the results of this structure with the results of the same resonator in which the feed probe is placed at the middle of the length and width two more simulations were carried out. In the first one, the feed probe is placed at x = a/2 and y = 0, which normally is used for linear polarization. The input impedance in this case is shown in Fig. 3a as the dotted line and the resonant frequency is 2.43 GHz with input impedance of 60 MHz (2.47%). In the second simulation the feed probe is placed at x = 0 and y = -b/2. The results in this case show a resonant frequency of 2.35 GHz and an impedance bandwidth of 65 MHz (2.8%). The results of both structures in detail are summarized in tables 1 and 2.

5. Discussion and Conclusion

Radiation characteristics including impedance bandwidth and polarization of the radiated wave of two RDRA structures fed by a single probe was investigated numerically by the FEM.

Results show that the corner chopped DR lead to CP waves to radiate. Moreover, in this case the impedance bandwidth of the antenna is improved by a factor of 2 compare with the non-corner chopped resonator. Another structure using a diagonal fed resonator in which its width is longer than its length was analysed. It was shown in this case also CP wave is radiated by an AR of 0.2 dB while the impedance bandwidth is 5.6%.

Both structures use single point feed using a probe located at the edge of the resonator provide CP radiation with reasonable bandwidth which is two times more than the bandwidth of an ordinary RDRA which normally radiates a linear polarized wave. However, more investigation and an optimization procedure are needed to provide wider bandwidth CP radiated waves and also consider radiation patterns and directivity of antenna structures.



(a) (b)

Figure 3: (a) Return loss of the structure 2 vs. frequency (b) *AR* of diagonal fed RDRA vs. Frequency.

Table 1: The simulated results of RDRA structure 1 in Fig. 1-b.
Resonator Parameters: a=b=15 mm, d=100 mm, h=11 mm, ε_r =38

	Corner Chopped DR *c*=3.4 mm	**Ordinary DR with *c*=0 mm**
Resonant frequency (GHz)	2.43	2.35
Bandwidth (*VSWR*<2) (MHz)	130 (5.2%)	65 (2.7%)
Axial Ratio (*AR*) (dB)	0.25	> 40 dB
Bandwidth (*AR*<3 dB) (MHz)	45 (1.9%)	-

Table 2: The simulated results of RDRA structure 1 in Fig. 1-b.
Resonator Parameters: a=14 mm, b=15.5 mm, d=100 mm, h=11 mm, ε_r =38

	Diagonal fed RDRA	**Probe at $x = a/2$, $y = 0$**	**Probe at $x = 0$, $y = -b/2$**
Resonant frequency (GHz)	2.45	2.43	2.35
Bandwidth (*VSWR*<2) (MHz)	135 (5.5%)	60 (2.47%)	65 (2.8%)
Axial Ratio (*AR*) (dB)	0.25	> 40 dB	> 40 dB
Bandwidth (*AR*<3 dB) (MHz)	40 (1.9%)	-	-

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