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CIRCULARLY POLARIZED CROSS-SHAPED DIELECTRIC RESONATOR ANTENNA FOR WIDE BAND OPERATION

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ABSTRACT

A multifunction and compact structured dielectric resonator antenna (cross-shaped) for large impedance bandwidth and wideband circular polarization is suggested in this section. A separately feeding technique by two strip line and slanted miniaturization technique are applied in this paper. The wideband circular polarization (CP) is achieved for this type of excitation geometry. A commercial software (CST microwave studio) simulated basic design configuration is proposed. Both experimental results and simulated results have better agreement which provides proper evidence for the proposed idea. The axial ratio value (minimum) of 0.3 dB is observed at $f = 10.8$ GHz. The proposed geometry provides 55% an impedance bandwidth and overlapping broadside Circular Polarization bandwidth (CP) of 11.5% have been achieved with impedance bandwidth 6.2 GHz and CP bandwidth 1.2 GHz.

KEYWORDS

cross-shaped dielectric resonator antenna, multifunction, wideband circular polarization, Excitation geometry.

1. INTRODUCTION

Nowadays, in microwave communication or in modern wireless broadband communication less weight, high gain with compact structure, high radiation efficiency and large bandwidth are the vital factor. The basic requirements for designing of an antenna are continuously updated according to the market demand. For the last ten years, there are two categories of brand of microwave antennas have been numerous researched and widely informed. One of them is micro strip patch antenna and another is dielectric resonator antenna (DRA). For the purpose of development in modern wireless broadband communications, both are widely efficient and suitable (Longfang, 2011). In many practical field of communication especially for portable communications dielectric resonator antenna has massive attraction due to their controlled bandwidth over the range from 1% to -20% by the proper selection of relative permittivity of the material and the geometrical structure of the resonator (Mongia et al., 1994). Through last twenty years, there is huge demand for dielectric antenna (DRA) because of the attraction of its various characteristics such as huge radiation efficiency, large bandwidth, miniaturized compact structure, and feeding mechanisms (Keyrouz and Caratelli, 2016). A lot of investigations have been done about dielectric resonator antennas (DRA) to highlight their interesting features. In This paper the wideband performance of DRAs for circular polarization is discussed which are applicable for satellite communications that eliminates the Faraday Effect due to the atmosphere (Asok et al., 2000).

The concept of this research work is focused on the standard size reduction technique for DRA, various shapes, materials selection and

feeding geometry for wideband operation. The crossed structures are used for getting high area per volume ratio (Long et al., 1983). This structure includes the basic as well as modified DRA shapes used widely for DRA miniaturization purpose. Choice of dielectric material is made based on the performance of DRA like – resonating frequency, bandwidth, gain, efficiency etc. (Laila et al., 2009). Different, improved feeding technique has also been analyzed, based on the performance of the DRA given in terms of resonating frequency (Zou and Fumeaux, 2010).

At first Ittipiboon et al. demonstrated a cross-structure dielectric resonator antenna by slot aperture feeding (Mongia et al., 1994). By controlling the dimension of two identical cross arms with resonating in phase quadrature the circular polarization operation is achieved. In their research work, by using low permittivity material ($\epsilon_r = 10.8$) the circular polarization (CP) bandwidth has been increased by 4%. Later, using a simple feeding technique, a cross-shaped high permittivity DRA is proposed by L. Zou & C. Fumeaux in a paper entitled, "High-permittivity Cross-Shaped Dielectric Resonator Antenna for Circular Polarization". Compared with this paper, the dimensions of those two identical arms are same as well as the circular polarization bandwidth (CP) which is obtained by exciting two quadrature micro strip lines (orthogonal phase-shift). For that antenna structure, 21% an impedance bandwidth and 13% CP bandwidth have been obtained. In this present paper, 55% an impedance bandwidth and overlapping circular polarization bandwidth (CP) of 11.5% have been obtained with impedance bandwidth 6.2 GHz and CP bandwidth 1.2 GHz.

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2. DESIGN CONFIGURATION

In this paper the resonator antenna is suggested a cross shaped structure of FR4 material. For the design purpose the thickness is 1 mm chosen for the dielectric material (FR4) of permittivity $\epsilon_r = 4.3$. Here, two same size rectangular slices are composed together to form a cross shape, which is cut from a dielectric sheet, Figure-1 shows that structure.

Figure 1: Perspective view

Figure 2: Overhead view

The proposed DRA consist cross shaped DR and backside copper metallized FR4 substrate, in which cross-shaped DR is mounted. The square substrate of 2mm thickness having dielectric constant of 4.3 and length of 70 mm. Composition of two rectangular slices the cross shaped DR is formed which is cut from a dielectric sheet of width 1 mm and dielectric constant of 4.3. By eliminating the mutual interactivity of them, the two slices are design first having height (h) =13 mm and length (L) =20 mm. The thickness of the slices is given d = 1 mm and the operating frequency is 12 GHz, the measurements of initial length and height (L&H) are evaluated by [2].

$$f_0 = \frac{c}{2\pi\sqrt{\epsilon_r} \sqrt{K_x^2 + K_y^2 + K_z^2}}$$

Where,

$$K_x = \pi/L ; K_y = \pi/2h ; K_z = \pi/d$$

In this paper the two orthogonal micro strip lines (orthogonal phase-shift) get used to feed the proposed cross-shaped DRA. Two orthogonal Quasi TEM modes (orthogonal phase-shift) get used to feed the cross arms resulting, the circular polarization (CP) is achieved and also provides direct coupling. A T junction splitter is applied, to design the feeding geometry, where two 100 Ω feed-lines are attached to 50 ohm feed line. The network analyser is used and connected with 50 ohm transmission feed line. This connection is done by a SMA coaxial connector (waveguide port). 100 ohm impedance value is matched at ending terminals of every individual microstrip line; this is happen by optimizing the strip line length underneath the two resonator arms. Again, by fixing the location of angle of the T-junction the orthogonal phase difference is achieved. There is a quarter wavelength path difference at 12 GHz is found between the ending terminal of the two micro strip lines and T-junction.

To increase impedance bandwidth and to eliminate the reflection, two mini stubs are added. Table 1 manifests the dimensions of the antenna which is designed and fabricated.

Table 1: Antenna dimensions

Symbol	Value (mm)	Symbol	Value (mm)
L	20	d2	0.73
L1	2	Ls	70
h1	5.5	d1	3.75
h	13	d	1

3. MEASURED RESULTS AND PERFORMANCE DISCUSSIONS

The proposed dielectric resonator antenna (DRA) is software simulated with the help of CST microwave studio and its corresponding results are mentioned below. Based on these results, the proposed dielectric resonator antenna (DRA) structure is implemented in hardware. Two same prototype of the simulated design structure in CST microwave studio has been fabricated (one is for transmission and other is for reception) as seen in Fig. 3, with dimensions of the antenna are specified in Table 1.

Experiment is performed with this antenna in a laboratory. For experimental purpose the Gunn power supply setup is used for high frequency microwave generation. The results like Directivity, Polar Pattern of the radiation, loss parameter and Effective Gain etc. are evaluated. Main intention of this experiment is to compare the simulated result along with the experimental data.

Figure 3: Hardware implemented DRA

Figure 4 describes the measured and software simulated return-loss parameter. The software simulated impedance bandwidth covers a wide range of frequency up to 14.2 GHz from 8 GHz under S11 = -10 dB. The maximum loss is obtained at frequency 12.145 GHz by 100 Ω impedance matching. For cross-shaped DRA, the impedance bandwidth can possible to improve by combining different dielectric resonator materials (Sukla and Roy, 2017). Due to fabrication imperfections, between experimental and simulation results, there is a little difference arises.

Figure 4: Measured and software simulated return loss

Ludwig proposed a axial ratio concept of the antenna, according to that concept, the antenna axial ratio is evaluated (Ludwig, 1973). Fig. 5 shows a simulated axial ratio which is obtain over the wide side direction of $\theta = 0^\circ$. The antenna axial ratio value (minimum) is 0.3 dB which is obtained at frequency (f) = 10.8 GHz. Here, the axial ratio bandwidth of 3 dB covers a wide range of frequency up to 11.1 GHz from 9.9 GHz.

Figure 5: Simulated axial ratio

According to 'Balanis', gain-transfer approach is applied for measurement of the effective gain of this proposed cross-shaped dielectric resonator antenna (Balanis, 2005). Measured and software simulated gain comparison study between them is as detailed in figure 6. The proposed cross shaped dielectric resonator antenna gives the maximum gain around resonance frequency (12 GHz) as detailed in fig. 6. The simulated gain (maximum) is 7.34 dB found at frequency 12 GHz. The simulated gain remains above 5dB within a stable 3 dB circular polarization BW. Due to fabrication imperfections, between experimental and simulation result, the measured gain is little lower.

Figure 6: Measured and software simulated gain

Here, the experimentally measured and CST simulated radiation pattern is illustrated in figure 7. The microwave signal is generated through a Gunn power supply which is adjusted at a particular fixed frequency (11.2GHz) using the frequency meter. The experimentally measured radiation pattern is obtained at frequency 11.2 GHz. Due to influence of the T-junction splitter & micro strip line the radiation pattern become asymmetry.

Figure 7: Measured and CST simulated radiation pattern ($\phi=0$) at frequency 11.2 GHz

4. CONCLUSION

Miniaturized structure, large impedance bandwidth, wideband circular polarization and high gain with microstrip feed line in the two identical cross arm are researched in this study work. This antenna operates at resonance frequency of 12.145 GHz, covers the frequency range 8 GHz to 14.2 GHz in the X-band and Ku band. This antenna gives 55% an impedance bandwidth and overlapping broadside Circular Polarization (CP) bandwidth of 11.5% with impedance bandwidth 6.2 GHz and CP bandwidth 1.2 GHz. Because of its circular polarization, it eliminates the Faraday Effect and also gives the link reliability since there is a low risk of misalignment and interference, so this antenna is widely applicable for satellite communication & mobile communication. The maximum gain values are above 10.24 dBi. In addition with the geometrical structure of the antenna to the excitation technique can be merged to construct multi operation or wideband antenna.

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