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Design and Analysis of Cylindrical Stepped C-Shaped Dielectric Resonator Antenna for C-Band Applications

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Abstract: *As the Wireless communication grows very fastly the antenna design must have enhanced output parameters according to the new generation need. this paper presents the design of a stepped C-shaped Dielectric resonator antenna for C-band applications like weather detection, WiFi, long range tracking .The proposed DRA designed in this paper is used for satellite up-link communication operates at a frequency of 6GHz and is excited by microstrip line feeding. The dimensions of proposed DRA are optimized to obtain the desired functional frequency ranges using Ansys HFSS EM solver. The result shows peak gain around 7.2dB and an offered bandwidth of 1.77GHz. The parametric study, by varying different dimensions and parameters, is done and the simulated results of S11, VSWR, radiation pattern and gain are plotted.*
Keywords: *Dielectric resonator antenna (DRA), microstrip line feed, C-shaped DRA, stepped DRA*

I. Introduction

In recent years, DRA (Dielectric Resonator Antenna) have more significant use in wireless applications. Dielectric Resonator Antenna (DRA) is a radio antenna mostly used at microwave and millimeter frequencies that consists a block of ceramic material [1].The DRA have many advantages, as this has no metal inclusion the ohmic losses which are high at higher frequencies, which are completely avoided in DRA. Number of different structures was analyzed like cylindrical, hemispherical and triangular [1]-[2]. Every shape has its own characteristics and has its own advantages in terms of size and other dimensions. The use of high permittivity dielectric material as a radiation element provides advantages like very good radiation efficiency, low profile and temperature co-efficient, light weight etc [3]-[4].

The rise in demand for portable devices and wireless communication has led to increase in the compact and small size antenna designs. The attractive features of Dielectric Resonator Antenna (DRA) are small in size, less in weight, low loss, ease of excitation, high radiation efficiency, intrinsic mechanical simplicity, wide bandwidth, less conductor loss, and no surface-wave loss.[6]-[9]. Although there are various approaches to the improvement of bandwidth found in literature, many of them involve modifications of the DRA structure. The different bandwidth enhancement techniques includes the reduction of Q-factor by loading effect, employment of matching networks, the use of multiple resonators [10]. Thus, makes DRA effective in use of communication. The shapes of the DRA antenna can be spherical, circular, rectangular, hemispherical, and elliptical, and tetrahedron that are illustrated for the enhancement of various antenna design properties. The design parameters of the shapes of DRA are length, width, radius, height, aspect ratio. These design parameters can be optimized to make the antenna efficient in use. A number of excitation methods have been developed. The different coupling schemes used for the exciting the antenna are the coaxial probe, aperture coupling with a microstrip feed line, co-planar feed, direct microstrip feed line, slot line, strip line, conformal strip, waveguide probe, soldered through probe. The DRAs can be designed suitably so as to fit for applications in desired band of frequency.The C band refers to electromagnetic spectrum, including wavelengths of microwaves that are used for long distance radio telecommunications. The IEEE C-band (4 to 8 GHz) and its slight variations contain frequency ranges that are used for many satellite communications transmissions, some Wi-Fi devices, some cordless telephones, and some weather radar systems. Our proposed antenna aims at providing applications for this band.

II. Antenna Geometry And Design

The geometry of suggested antenna is shown in the figure below. Among the different shapes of DRA, the cylindrical-shaped DRA offers greater design flexibility. Thus the design of proposed antenna is initialized by a simple cylindrical shaped DR.

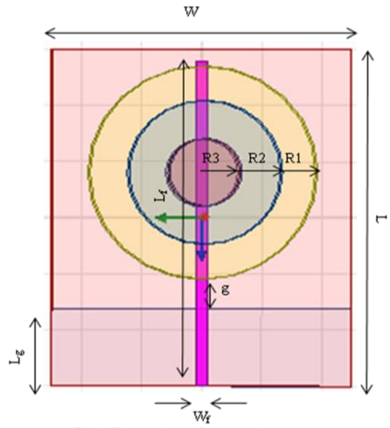

Fig1: Dimensions of proposed antenna

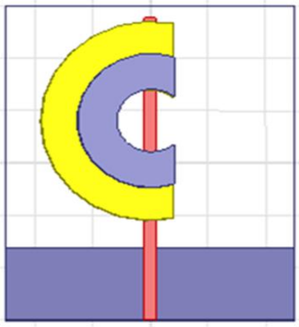
Fig2: The top view of proposed DRA

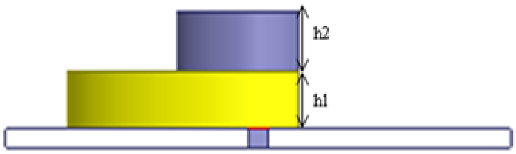

Fig.3: The side view of proposedDRA

The proposed DRA design starts with a cylindrical shaped DR having radius R_1=19mm , R_2=12.806mm , R_3=6mm and height h_1=5mm, h_2=5mm ,h_3=10mm. Microstrip line feeding offers the advantages of easy, simplest , and cost- effective fabrication of DRA. so, the DRA is excited by the microstrip line feeding , which has dimensions of L_f=57.75mm and W_f=2mm. the DR along with the feed line is mounted on the top side of FR4 substrate measuring 60-mm long by 50-mm wide with a thickness h_s of 1.6mm. A partially printed ground plane with dimensions 50 x 13.5 mm^2 (L_g x W) was present on the bottom side of the substrate.

III. Parametric Study

In this section, the changes in the resultant response are studied by varying its various parameters. The antenna design is analyzed and optimized using High Frequency Structural Simulator which is based on Finite Element Method (FEM) which is more accurate for designing antennas as compared to other antenna software.

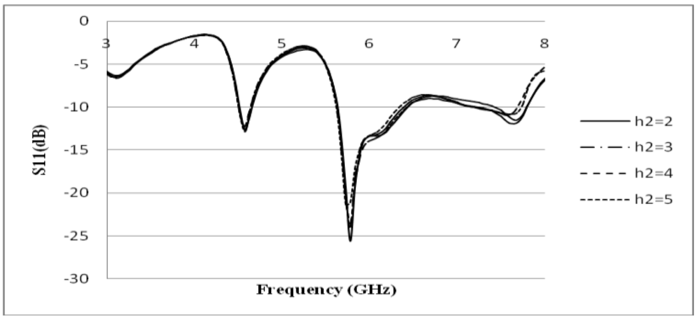

Fig.4: S-parameter plot with respect to variations in height

The Fig.4 above shows the simulated graphs of impedance bandwidth of the DRA by varying the height(h2) of antenna.

The Fig.5 below shows the simulated graphs of impedance of the DRA by varying the permittivity values of DRA. It is observed that the bandwidth changes as the permittivity values of DRA is varied. Thus relative permittivity (ε_r) is a function of antenna bandwidth.

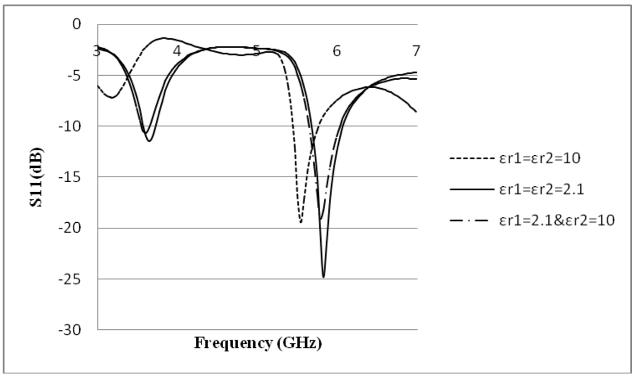

Fig.5: S-parameter plot with respect to variations in $\varepsilon_{r\ \text{values}}$

Fig.6 below shows the simulated return loss by varying the air gap (g) between the ground plane and DR.

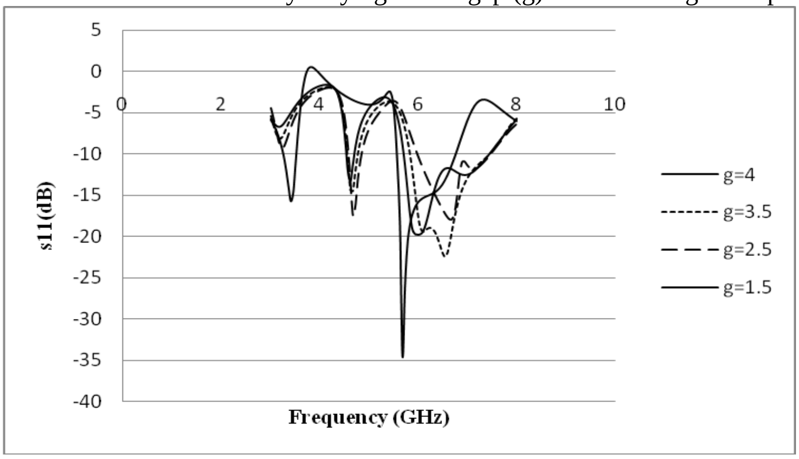

Fig.6: S-parameter plot with respect to variations in g values

Fig.7 below shows the simulated return loss by varying the radius R1 and R2 of the cylindrical DRAs.

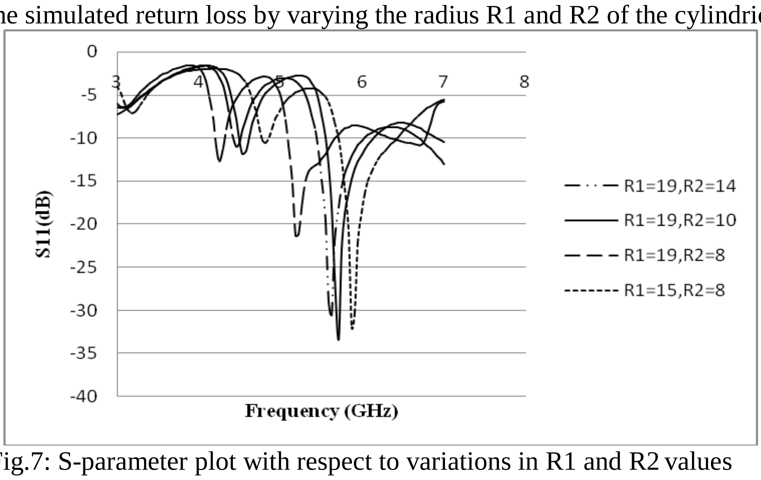

Fig.7: S-parameter plot with respect to variations in R1 and R2 values

The Fig.8 below shows the plot of VSWR of DRA when height h2 is varied from 2 to 5mm with the air gap (g) between DR and ground is 4.5

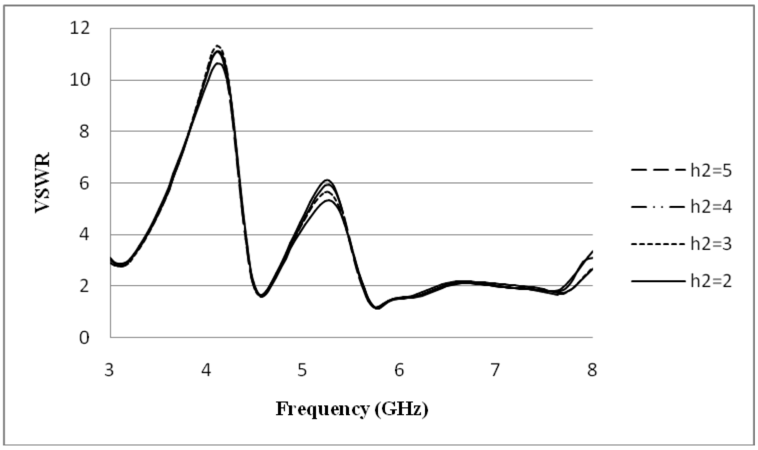

Fig.8: Plot of VSWR with respect to variations in height with g=4.5

IV. Optimized Design

On the basis of the detailed study of the plots and other results obtained in the parametric study, the optimized dimensions for the antenna design is decided and experimentally validated and verified. The design parameters are optimized such that they provide maximum bandwidth and gain.

The details of the optimized parameters are as described below. Based on the detailed parametric studies, the optimum dimensions obtained for the antenna are L_g=13.5mm, W_f=2mm, L_f=57.5mm, g=3.5mm, R1=19, R2=8, L=60mm W=50mm. The figures above show the plots of optimized antenna.

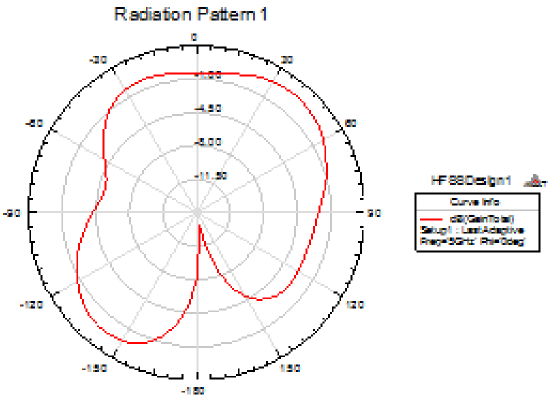

Fig.9: 2-D Radiation pattern of directivity of an optimized antenna in E-plane

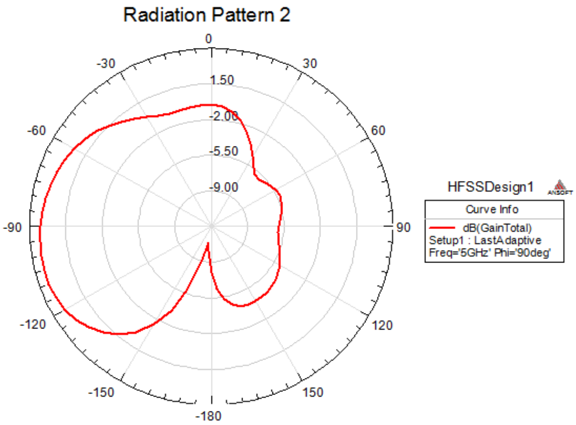

Fig.10: 2-D Radiation pattern of directivity of an optimized antenna in H-plane

Fig.9 shows the radiation pattern in E-plane of proposed optimized antenna. Fig. 10 shows the radiation pattern of the proposed optimized antenna design in the H-plane. It is observed that the antenna gives a bandwidth of 1.77GHz and resonates at a frequency of 6GHz and the gain obtained from the optimized design is 7.2dB. Fig.11 shows the 3-dimensional radiation pattern of the proposed antenna design in its optimum dimensions.

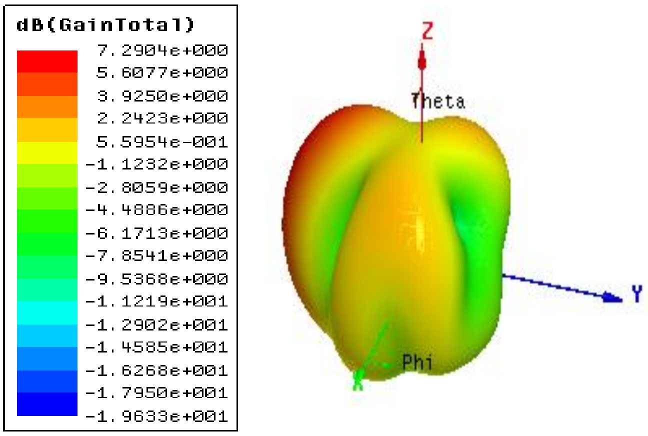

Fig.11: 3-D Polar plot of radiation pattern of optimized antenna

V. Conclusion

A compact dielectric resonator antenna for C-band applications has been demonstrated. The use of a stepped C-shaped dielectric resonators enhances the characteristics and performance of the antenna. From the antenna design, an impedance bandwidth of 1.77GHz is obtained in the c-band frequencies ranging from 5.69GHz to 7.44GHz and a gain of 7.2dB is obtained from the proposed design. The bandwidth is useful in the C-band range of frequencies. The centre frequency of the obtained bandwidth is situated at 6GHz is used for satellite Up-link communication. The compact DRA which is presented in the paper has better features when compared with other DRAs.

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