International Journal on Emerging Technologies **11**(3): 293-297(2020)

ISSN No. (Print): 0975-8364
ISSN No. (Online): 2249-3255

Simulation of Different Modes of Excitation and Field Patterns of CDRA Antenna for Integrated Applications

Saranga Mohan, Dioline Sara and Santhosh
Department of Electronics and Communication,
GITAM (Deemed to be University), Bangalore Campus (Karnataka), India.

(Corresponding author: Saranga Mohan)
(Received 20 February 2020, Revised 08 April 2020, Accepted 11 April 2020)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: C band is the desired resonant frequency for designing Cylindrical Dielectric Resonator Antenna (CDRA) because of its best radiation efficiency. This paper discusses the different modes of excitation and field patterns of CDRA antenna. CDRA can excites in both resonating and non-resonating modes like TE01δ, TM01δ, HEM11δ, HEM12δ and HEM21δ modes. HEM11δ mode is the best among them because of best radiation efficiency. CDRA radiates almost uniformly in all the directions which uses surface coaxial probe feed technique for excitation. Cylindrical shaped dielectric resonators have higher Q factor and their smaller size make them perfect to use in micro strip technology. The radiation properties of CDR is utilized to look at the radiation characteristics of a probe- fed cylindrical structured DRA. The main motivation of this research is to design an antenna with a wide impedance bandwidth and high gain properties. CDRA antennas are designed by using a glass epoxy dielectric material with dielectric constant of 4.4. The FR4 material is widely available and is less expensive as compared to higher dielectric constant materials. The main challenge is to achieve a wide bandwidth and good radiation characteristics with this lower material. The designed antenna meets all the common features of the DRAs, but the main advantage is its ability to resonate with a considerably low- permittivity dielectric material.

Keywords: CDRA, Directivity, DRA, HEM11δ, field pattern, surface coaxial probe feed technique

Abbreviations: CDRA, cylindrical dielectric resonator antenna; RF, radio-frequency; DRA, Dielectric Resonator Antenna; FDTD, finite-difference time-domain.

I. INTRODUCTION

DRA is a radio receiving structure utilized at microwave frequencies and above and it constitutes a block of materials of ceramic made and a dielectric resonator on a ground plane. The improvement of less loss materials of ceramic made paved a path for utilization of above mentioned dielectric resonators because of their high Q segments for circuits. The dielectric resonators are normally protected to forestall radiation and in case the protecting is evacuated and a legitimate excitation to dispatch the proper mode is given, a similar dielectric resonators can radiate proficiently. In addition, by bringing down their dielectric constant, the radiation can be kept up over a generally wide range of frequencies. Cylindrical shaped resonators have higher Quality factor and their minimal size make them perfect for utilizing in filters and oscillators, especially micro strip innovation. The radiation properties of CDR is used to take a look at the radiation attributes of a probe- fed cylindrical shaped DRA.

Dielectric resonator reception apparatuses share a significant number of the benefits of micro strip reception structures which has minimal dimension, delicate, simplicity to couple numerous transmission lines, etc. The principle inspiration to plan a cylindrical dielectric resonator antenna is its particular capacity to use for reception apparatus applications by prudence of their higher radiation productivity, adaptable feed techniques, basic geometry, and ability to create distinctive radiation design utilizing different methods. Taking care of procedures like test feed, aperture slot, miniaturized scale strip line and coplanar line enables them to get together with microwave fabrication process.

Cylindrical structured antennas assume significant jobs in present day correspondence frame works, for example, spatial area numerous entrance (SDMA), radar systems, aerospace applications and beam-steering array antennas. Thus DRAs exhibit the ability to make use of existing technology to provide more sophisticated results. Also DRA's maintain a strategic distance from certain constraints which contains higher conductor losses at very small frequency range, affectability to tolerances and limited bandwidth. The aforementioned characteristics of DRA make them very much suitable for the millimeter wave applications.

The main objective is to design an antenna that is suitable for both commercial and military utilities with a wide impedance bandwidth and high gain properties. Every one of the parameters, for example, field patterns and radiation patterns are researched for this setup using EM simulator.

The organization of the paper was as follows. Related literature was discussed in section II. The problem statement of the current research was discussed in section III. The analysis of the problem was explained in section IV. System Design is discussed in V. The results obtained were presented in section VI. Finally, the conclusion is discussed in section VII.

II. LITERATURE REVIEW

The literature shows a few related work in the Cylindrical dielectric resonator antennas (DRAs) using TE01δ, TM01δ and HEM11δ mode to see the radiation pattern, field distribution, and resonant frequency.
The electric and magnetic field design for most of the lowest resonant modes TE01δ, TM01δ, HEM11δ, HEM12δ and HEM21δ in cylindrical dielectric resonators are shown in different planes of convergence and its numerical stability through the normalization of the network is examined and a calculation for the assessment of the modular field parts is depicted [1]. The modes in CDRA's such as TE01δ, TM01δ and HEM11δ mode are inspected to see the radiation design and the simulation techniques are discussed [2]. Higher-order mode HEM12δ has been experimentally realized in a CDRA revealing broadside radiation like the HEM11δ dominant mode [3].
A DRA is positioned over a feeding pad in a conducting ground plane in a way that it excites the HEM mode. This design presents an examination of CDRA operated at C-band frequencies. A parametric study is performed to optimize the antenna performance and a prototype for microwave and WLAN application has been designed and measured [4]. The excitation of the different radiating modes using composite feeding structure method is explained [7].CDRA excitation using the combination of both super strate and reflector plane with respect to the bandwidth and gain parameters are explained [8].A four port multi input and multi output DRAs excited by aperture coupled orthogonal T feed micro-strip transmission line to perform the triband operation at targeted bands was analyzed in [9]. Das *et al*., (2019) proposed the design of diversity CDRA antenna which consists of four antenna elements and eight polarized ports, finding good results for the frequency ranges between 5.6 and 5.9 GHz for wireless local area network (WLAN) applications [10].
The characteristics of CDRA fabricated using $BaZrO_3$ material are investigated with micro strip line feeding mechanism and co-axial feeding technique and the experiment is performed by coaxial and micro strip line feed and fabricated from $BaZrO_3$ material of dielectric constant 27 [5]. The other alternative proposed is a finite-difference time-domain (FDTD) so as to acquire reasonable measures for the formulation of a four element DRA cluster and the patterns of radiation are controlled by exploiting the geometrical symmetry of the structure, investigating just a single half or one fourth of the whole area through two or four different FDTD runs [6].

III. PROBLEM STATEMENT

Cylindrical dielectric resonator when used as radiator can be excited with any one of the following five lowest modes; TE01δ, TM01δ, HEM11δ, HEM12δ and HEM21δ. This consists of both resonating and non-resonating modes. From the literature survey it can be confirmed that the HEM11δ mode is the most suitable mode for antenna applications because of its radiation characteristics. Here HEM11δ mode is excited using surface coaxial probe feed technique and estimated the design parameters of the CDRA for a desired C-band resonating frequency which provides the best radiation efficiency.

IV. PROBLEM ANALYSIS

Standard commercial Electromagnetic (EM) simulation tool, an soft HFSS (High- Frequency Simulation Software) is used to simulate the designed CDRA configuration.
The antenna is constructed by first forming a ground plane of finite dimensions on which the cylinder is placed. A hole is etched in the ground plane for probe connections and the feed mechanism. A wave-port is assigned to the coaxial probe and suitable adjustments are made to achieve the surface feed setup. Suitable materials are selected for each of the components. Perfect- E boundary is maintained for the entire design. Then a radiation boundary is created to resemble an anechoic chamber which is called the radiation box. The radiation boundary is selected to be vacuum whereas the ground plane is generally selected to of copper. Suitable solution setups are defined and the simulation parameters of the antenna which includes return loss (S- Parameters), input impedance, gain, VSWR, radiation pattern, electric- and magnetic- field patterns are obtained.

A. Radiation Mechanism of an Antenna

Observing the radiation from a conductor helps to understand the radiation mechanism of an antenna by calculating the following parameters
Radiation Pattern. The radiation pattern from an antenna is represented as a set of equations or as a pictorial form in terms of radiation properties with respect to spatial coordinates. Antennas can be classified using the radiation pattern as
– Isotropic Antenna: An isotropic antenna has uniform radiation in the entire 360 degree. The radiation characteristics of an isotropic antenna enables to use it as a reference antenna.
– Directional Antenna: A directional antenna transmits (or receives) radiations to (or from) a particular direction.
– Omnidirectional Antenna: The radiation pattern of an omnidirectional antenna shows more power in the direction perpendicular to the axis and zero power in other direction.
Directivity. The directivity of an antenna is given by "the ratio between the radiation intensity in a given direction from the antenna and the radiation intensity average over all directions". It is the amount of the volume of the radiated power in one direction. It could be seen as the extent it can arrange the transmitted power in a given direction.

$$D(\theta, \emptyset) = \frac{U(\theta,\emptyset)}{U_0} = \frac{4\pi U(\theta,\emptyset)}{Prad} \quad (1)$$

Radiation intensity, $U=r^2S_{rad}$ where; 'S_{rad}' is radiation density, 'r' is distance.
Polarization. The direction in which the electromagnetic waves line up away from the source is called polarization.
The different kinds include:
– Linear polarization: An electromagnetic wave is said to be linearly polarized if the electric field (or magnetic field) vector lines up in one direction along a straight line.

– Elliptical polarization: An electromagnetic wave is said to be elliptically polarized if the electric field (or magnetic field) vector lines up to form an elliptical path.
– Circular polarization: An electromagnetic wave is said to be circularly polarized if the electric field (or magnetic field) vector lines up to form a circular path
Gain. Gain of an antenna is given by “the ratio of the antenna output power for the input power given to the antenna”. The radiation output of an isotropic antenna has a spherical shape.

$$P_{gain} = Dir_{gain} \times \eta \quad (2)$$

where; ‘ η ’ is the antenna efficiency

V. SYSTEM DESIGN

Simulations of antenna characteristics were done using an electromagnetic simulator. For 3D passive device modelling and for testing an electromagnetic system, HFSS tool provides a platform with the help of Microsoft Windows graphical user interface. Vector network Analyzer, Anechoic Chamber, Automated turn table were used in the system design. The conditions required for simulating pattern measurements were provided by the anechoic chamber. A lossy medium (dielectric/ magnetic) prepared by top notch, low-thickness structure was used as the absorber in the chamber building process. The size of the chamber wall was adjusted to (24’ × 12’ × 10’) forming a tapered shape. It is then covered using carbon black impregnated polyurethane (PU) foam of suitable size and shapes such as pyramidal, wedge, or flat absorbers.

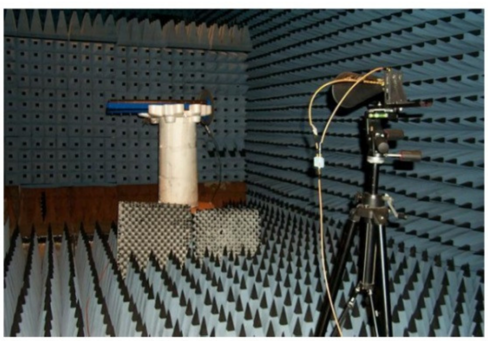

Fig. 1. Anechoic Chamber.

The geometrical impedance matching is provided by the PU foam structure and the scattered carbon provides a minimum gain for the frequency ranging between 500 MHz and 18GHz. The attenuation level was observed to about -40dB. Electromagnetic interference was cancelled out because of adding a thin aluminum sheet.

A. Fabrication Process

The fabrication procedure of CDRA is as follows.
– The optimized dimensions of CDR using FR4 substrate as the dielectric material, with a dielectric constant of 4.4 are considered.
– The thickness of the copper metal forming the ground plane is adjusted to 0.5mm with a cross section measuring 100mm × 100mm.
– The position where the probe is fed on the ground plane is marked using surface coaxial-probe excitation technique.
– A hole is drilled with a drill bit of 0.6375 mm radius, and then the coaxial probe is fixed.
– CDRA is fixed carefully ensuring that the probe in the ground plane touches surface of the CDRA.

VI. RESULTS

The fundamental goal of is to excite the CDRA in the HEM11δ mode and compare its characteristics with the more conventional TE01δ and TM01δ modes so as to highlight the advantages of HEM11δ mode. For this purpose radiation patterns are observed and analyzed with the standard field pattern of HEM11δ mode.

A. E-Field Pattern

Fig. 2 shows the E-field pattern of HEM11δ mode

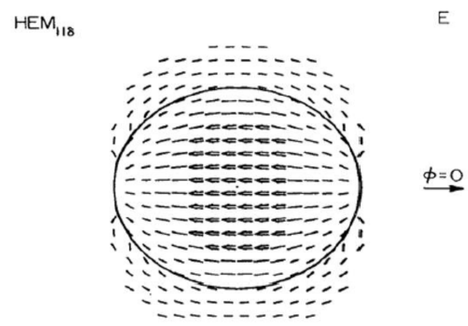

Fig. 2. Standard E-field pattern of HEM11δ mode.

The electric field pattern in various orientations is as shown. It is observed that throughout the frequency band of 2.1 GHz, HEM11δ mode exists, thus improving the utility of the mode.

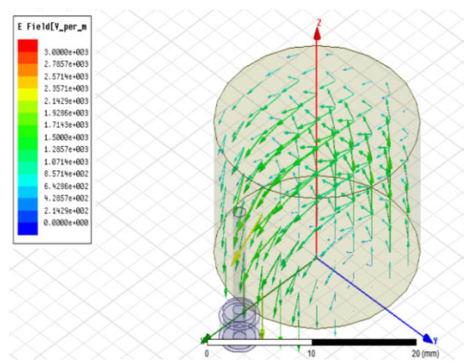

Fig. 3. E-field patterns of HEM11δ mode.

Thus, by comparing the standard and obtained field patterns, it can be confirmed that the antenna is actually excited in the HEM11δ mode.

B. H-Field Pattern

The standard H- field pattern is shown in Fig. 4. The correspondingly obtained H-field pattern in various orientations is shown in Fig. 5.
By comparing the standard and obtained plots it can be confirmed that the antenna is operating correctly in the desired HEM11 mode. The corresponding plots for other modes do not conform to the standard field patterns, thus making the antenna operate effectively in the HEM11δ mode.

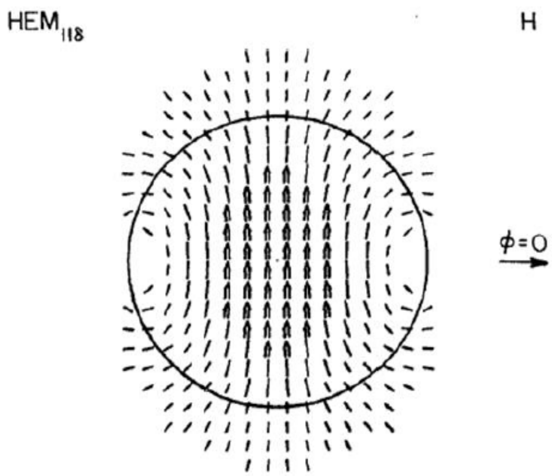

Fig. 4. Standard H-field pattern of HEM11δ mode.

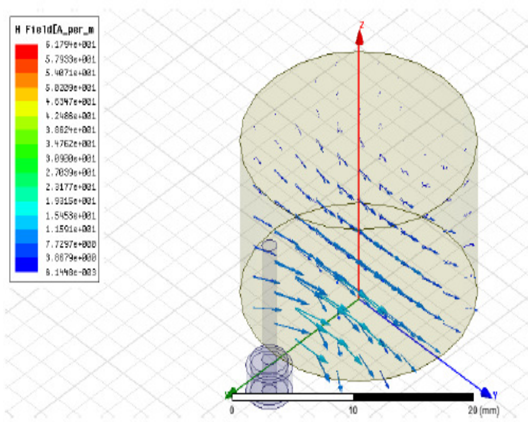

Fig. 5. H-field patterns of HEM11δ mode.

C. Radiation Pattern

The radiation pattern obtained for the designed CDRA gives some conclusions. The graphical plot shows that the antenna radiates almost uniformly in all the directions (Fig. 6). 3 D radiation pattern is shown in Fig. 7

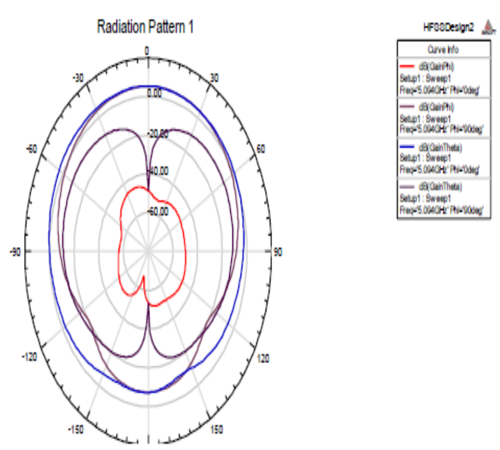

Fig. 6. CDRA Radiation pattern.

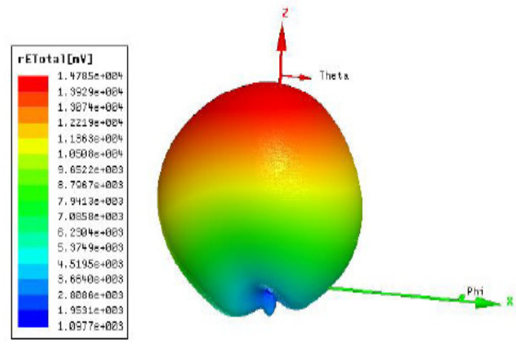

Fig. 7. Radiation pattern in 3D polar plot.

Below implications can be derived from this work.

– Depending on the resonator shape, disparate modes can be excited within the DRA element. These modes can emit different radiation patterns for various coverage requirements. Also, the Q-factor of some of these modes will depend on the aspect ratio of the DRA, thus enabling one more degree of flexibility in the design.

– Many of the current feeding schemes can be used (slots, probes, micro strip, coplanar waveguides, dielectric image guide, etc.). This makes integration easier with existing technologies.

– Compared with the micro strip antenna, DRA has a much wider impedance bandwidth. This is because the micro strip antenna radiates only through two narrow radiation slots, whereas the DRA radiates through the whole antenna surface except the grounded part. Moreover the operating bandwidth of a DRA can be varied by suitably choosing the dielectric constant of the resonator material and its dimensions.

– DRAs have been formulated to operate over an extended frequency range (1 GHz to 44GHz) compared with other antennas existing in the literature.

– DRAs high dielectric strength enables higher power handling capacity. Also the temperature-stable ceramics enable the antenna to operate in a wide temperature range.

VII. CONCLUSION

The simulation of cylindrical dielectric resonator antenna (CDRA), which is excited with HEM11δ as dominant mode using surface coaxial probe feed technique is analyzed. The designed antenna radiates in the entire C-band with a resonant frequency and has the best radiation efficiency. The dominant HEM11δ mode prevails throughout the band improving the utility of the antenna in this mode for various applications. The novelty of the method is to obtain the radiating characteristics of the CDRA using a low dielectric constant material FR4_glass epoxy, with a permittivity as low as 4.4.

VIII. FUTURE SCOPE

Reducing mode degeneracy caused by high cross-polarization from the H-field to obtain better response of the antenna. The ground plane of the antenna must be reduced to save space where space is a constraint.

Conflict of Interest. No conflict of Interest.

REFERENCES

[1]. Kajfez, D., Glisson, A. W., & James, J. (1984). Computed modal field distributions for isolated dielectric resonators. *IEEE transactions on Microwave Theory and Techniques*, *32*(12), 1609-1616.

[2]. O'Keefe, S. G., Kingsley, S. P., & Saario, S. (2002). FDTD simulation of radiation characteristics of half-volume HEM-and TE-mode dielectric resonator antennas. *IEEE Transactions on Antennas and Propagation*, *50*(2), 175-179.

[3]. Guha, D., Banerjee, A., Kumar, C., & Antar, Y. M. (2013). New technique to excite higher-order radiating mode in a cylindrical dielectric resonator antenna. *IEEE Antennas and Wireless Propagation Letters*, *13*, 15-18.

[4]. Lin, C. H., Chen, G. Y., Sun, J. S., Tiong, K. K., Peng, T. H., Chen, Y. H., & Chen, Y. D. (2009). Cylindrical DR antenna design. In *PIERS Proceedings*, 329-330.

[5]. Gupta, N., Rout, S. K., and Shivaji, K. (2009). Characteristics of Cylindrical Dielectric Resonator Antenna, *Microwave Review, 15*, 29-32.

[6]. Gentili, G. B., Morini, M., & Selleri, S. (2003). Relevance of coupling effects on DRA array design. *IEEE Transactions on Antennas and Propagation*, *51*(3), 399-404.

[7]. Sharma, A., Das, G., Ranjan, P., Sahu, N. K., & Gangwar, R. K. (2016). Novel feeding mechanism to stimulate triple radiating modes in cylindrical dielectric resonator antenna. *IEEE Access*, *4*, 9987-9992.

[8]. Dash, S. K. K., Khan, T., Kanaujia, B. K., & Nasimuddin, N. (2017). Wideband cylindrical dielectric resonator antenna operating in HEM11δ mode with improved gain: a study of superstrate and reflector plane. *International Journal of Antennas and Propagation*, 1-17.

[9]. Pahadsingh, S., & Sahu, S. (2018). Four port MIMO integrated antenna system with DRA for cognitive radio platforms. *AEU-International Journal of Electronics and Communications*, *92*, 98-110.

[10]. Das, G., Sahu, N. K., Sharma, A., Gangwar, R. K., & Sharawi, M. S. (2019). Dielectric resonator-based four-element eight-port MIMO antenna with multi-directional pattern diversity. *IET Microwaves, Antennas & Propagation*, *13*(1), 16-22.

How to cite this article: Mohan, S., Sara, D. and Santhosh (2020). Simulation of Different Modes of Excitation and Field Patterns of CDRA Antenna for Integrated Applications. *International Journal on Emerging Technologies*, *11*(3): 293–297.