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Design of Cylindrical Dielectric Resonator Antenna Array for Applications at 9 GHz

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Abstract**:** ***This paper brings out a requirement to study a coaxial probe fed cylindrical dielectric resonator antenna array (CDRAA) suggested for applications at 9 GHz with a return loss of -32.5 dB. The proposed CDRAA comprises of eight cylindrical dielectric resonators arranged in four groups. The dimension of the antenna array is 70 mm × 60 mm. The suggested CDRAA is having a power divider circuit with circular patches and keeping the cylindrical shaped dielectric resonators on those circular patches on one side of FR4 substrate. On the rear side we have conducting ground plane with coaxial connector. Material used for cylindrical dielectric resonator is Teflon of relative permittivity 2.1. The software generated results show that CDRAA has a resonant frequency of 9 GHz. Design simulation of CDRAA is done using high frequency structure simulator (HFSS), based on finite element methods (FEM). Simulated and measured S11 parameters are in good agreement. The suggested antenna shows a maximum gain of 8.77dB.***

Index Terms-CDRAA, FR4, Coaxial Feed, Return Loss.

I. INTRODUCTION

The dielectric resonator antenna (DRA) is becoming popular because of its compactness, flexible excitation methods, impedance bandwidth and withstanding to high temperatures. Though different shapes of DRAs are available, cylindrical DRA is initially introduced [1]. The electric fields in a CDRAA are horizontally polarized due to different modes like HEM$_{11\delta}$, HEM$_{12\delta}$, and TM$_{01\delta}$ for efficient radiation. A new method to excite HEM$_{12\delta}$ mode in a CDRAA was suggested [2]. A cylindrical dielectric resonator antenna (CDRA) fed by non-resonant microstrip patch excites for efficient radiation. An array of 2×2 antenna with HEM$_{12\delta}$ mode is recommended for high gain at centre frequency of 9.04 GHz [3]. The imperfections on surface cause reduced mechanical contact between a dielectric resonator and the conducting surfaces [4]. Input impedance of radiating mode TE$_{111}$ of probe-fed hemispherical dielectric resonator antenna is calculated and investigated using a Green's function [5]. Embedded DR antenna is proposed in [6]. Reconfigurable DR antenna with band stop properties is suggested in [7]. The physical dimensions of the dielectric resonator antenna decide the mode of operation. The criterion to support HEM$_{12\delta}$, a/H should be from1.05 to 1.4 [8].

In this paper, cylindrical dielectric resonator antenna array (CDRAA) at the centre frequency of 9 GHz with a return loss of -30 dB, comprises of eight cylindrical dielectric resonators arranged in four groups with coaxial fed power divider circuit, operates in HEM$_{12\delta}$ is proposed for efficient radiation and higher directive gain.

II. ANTENNA ARRAY GEOMETRY

The CDRAA is designed at 9 GHz frequency on FR4 substrate of thickness 1.6 mm, is shown in Fig. 1. Antenna geometry is shown in Fig. 2. FR4 is low cost and easily available material. The properties of FR4 material are given in Table I. The dimensions of CDRAA is 70 x 60 mm^2 consists of eight cylindrical shaped dielectric resonators each of radius 4.76 mm with a thickness of 4.76 mm arranged in four groups are concentrically placed on circular shaped conductors of radius 2.2 mm.

(a)

(b)

Fig. 1. Fabricated antenna array (a) front view and (b) rear view

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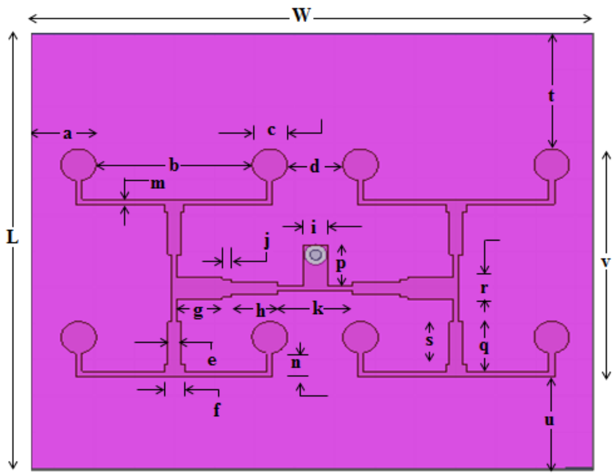

Fig. 2. Antenna array geometry

Breakdown voltage	55KV
Density	1850 Kg/m^3
Dielectric constant	4.4
Dielectric strength	20Mv/m
Dissipation factor	0.017
Loss tangent	0.02
Mass density	1900
Relative permeability	1
Surface resistivity	2 x 10^5 Mohm
Temperature index	140^{0}C
Tensile strength	Less than 310 MPa
Volume resistivity	8 x 10^{7}Mohm cm
Water absorption	Less than 0.25%

Table 1: Properties of FR4 substrate

Thickness of substrate FR4	1.6
Substrate length (L)	60
Substrate width (W)	70
Number of circular dielectric resonator elements	8
Radius and height of each circular dielectric resonator element	4.76
a	11.5
b	20
c	4.4
d	7
e	1.60
f	2.5
g	5.65
h	6.35
i	3.28
j	0.7
k	9.84
m	0.7
n	3.1
p	5.65
q	6.37
r	1.6
s	5.3
t	16
u	12.5
v	31.5

Table 2: Dimensions of the proposed antenna (mm)

III. DESIGN EQUATIONS

General design equations for resonant frequency of different modes are as follows.

Let free space wave number $k_0 = \frac{2\pi f_0}{c}$

c = speed of light (3 x 10^8 m/s)

f_0= resonant frequency

a = radius

H = thickness or height = 1.6 mm

c is the velocity of light =3 × 10^8 m/s,

$\epsilon_r = 4.4$

fr the resonant frequency= 9 GHz

Resonant frequency for Mode HEM_{11} (valid for 0.4≤ a/H ≤6)

$$k_0 a = \frac{6.324}{\sqrt{\epsilon_r + 2}}\left[0.27 + 0.36\left(\frac{a}{2H}\right) + 0.02\left(\frac{a}{2H}\right)^2\right]$$

Resonant frequency for Mode $TE_{01\delta}$ (valid for 0.33≤ a/H ≤5)

$$k_0 a = \frac{2.327}{\sqrt{\epsilon_r + 1}}\left[1.0 + 0.2123\left(\frac{a}{H}\right) + 0.00898\left(\frac{a}{H}\right)^2\right]$$

Resonant frequency for Mode $TM_{01\delta}$ (valid for 0.33≤ a/H ≤5)

$$k_0 a = \frac{\sqrt{3.83^2 + \left(\frac{\pi a}{2H}\right)^2}}{2}$$

Resonant frequency for Mode $TE_{011\delta}$ (valid for 0.33≤ a/H ≤5)

$$k_0 a = \frac{2.208}{\sqrt{\epsilon_r + 1}}\left[1.0 + 0.7013\left(\frac{a}{H}\right) + 0.002713\left(\frac{a}{H}\right)^2\right]$$

IV. RESULTS AND DISCUSSION

9 GHz resonant frequency response with a return loss of -32.5dB is achieved by the proposed 8 element cylindrical dielectric resonant antenna array (CDRAA). The proposed antenna array is printed on FR4 substrate and cylindrical dielectric resonators are placed over circular shaped conductors and is simulated by finite element method (FEM) based high frequency structure simulator (HFSS). Experimental setup is shown in Fig.3 and simulated return loss parameters are shown in Fig. 4. Measured results are taken from E 5071 vector network analyzer (VNA) as shown in Fig. 5 and they are in good agreement with simulated one. A little discrepancy of simulated and measured results is attributed to soldering and fabrication defects. The bandwidth of an antenna array shows 300 MHz at 8.8–9.1 GHz. The impedance bandwidth of propose antenna array shows 3.3% at resonant frequency.

Antenna Gain describes transmitted power in the direction of peak radiation to that of an isotropic source. The proposed antenna has a peak gain of 8.77 dB as given in Fig. 6. Radiation patterns of E and H plane are given in Fig. 7. E plane radiation pattern is simulated by taking elevation angle θ at all points keeping azimuth angle φ as 0 and 90 degrees at 9 GHz frequency. H plane radiation pattern is simulated by taking azimuth angle φ at all points keeping elevation angle θ as 0 and 90 degrees at 9 GHz frequency. Current distributions of the proposed CDRAA which resonates at 9GHz is shown in Fig. 8.

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The red colour field shows the maximum current distribution of the suggested antenna array. Parameters of suggested eight element CDRAA is shown in Table 3.

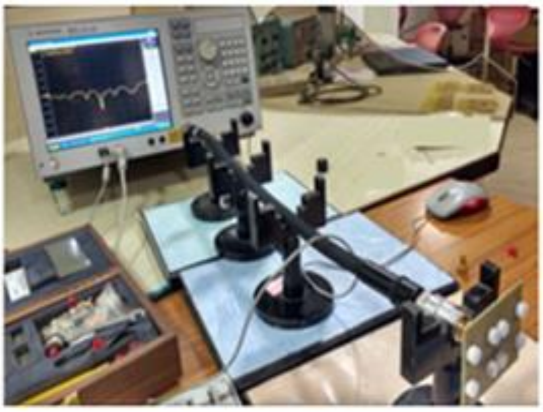

Fig. 3. Experimental setup to measure S11 parameters

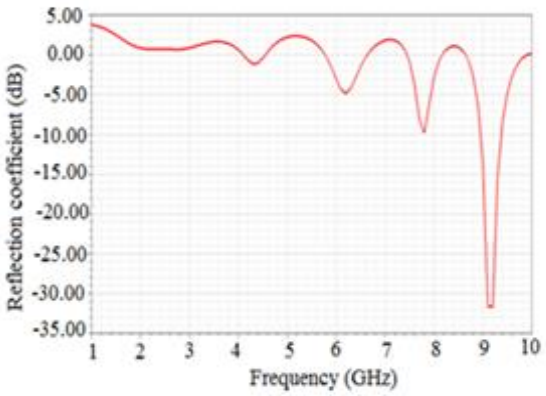

Fig. 4. Simulated return loss (S11) parameters

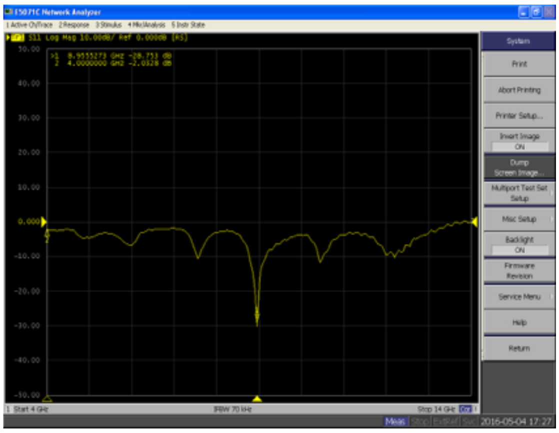

Fig. 5. Measured return loss (S11) parameters

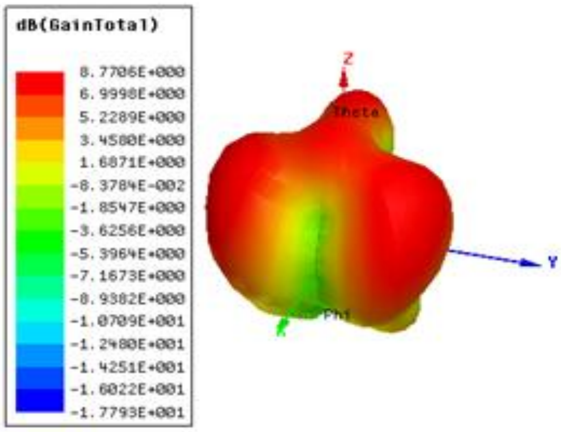

Fig. 6. Gain of antenna at 9.1 GHz

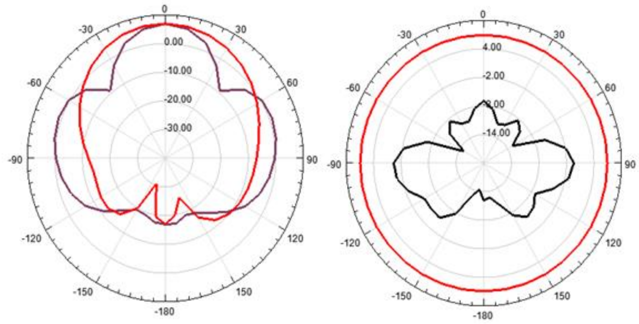

Fig. 7. E and H plane patterns at 9 GHz

Peak gain	8.77 dB
Peak directivity	9.35 dB
U Max	0.00423 Watts/steradian
Incident power	0.012 Watts
Power radiated	0.00625 Watts
Radiation efficiency	58%
Max rE (Total)	1.80 V
Max rE (Phi)	1.80 V
Max rE (Theta)	1.80 V
Max rE (x)	1.80 V
Max rE (y)	687.45 mV
Max rE (z)	719.38 mV

Table 3: Parameters of proposed eight element CDRAA

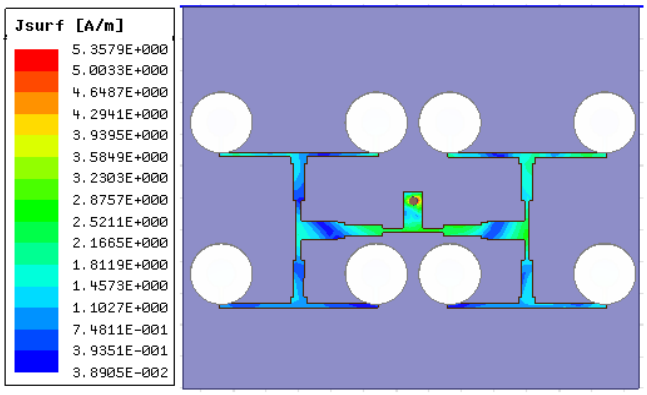

Fig. 8. Current distribution of proposed CDRAA at 9.1 GHz

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V. CONCLUSION

In this paper, an eight element cylindrical dielectric resonant antenna array with coaxial probe fed is designed for applications at 9 GHz with a return loss of -32.5 dB. The ratio of radius to height of CDR (Cylindrical Dielectric Resonant) element is taken as one to ensure $HEM_{12\delta}$ mode of operation. Placing CDR elements on circular patches increase the return loss and gain. The suggested antenna array design fulfils the needs of X band applications. In order to enhance the directivity and gain more number of elements can be added.

REFERENCES

1. S. Long, M. McAllister and L. Shen, "The resonant cylindrical dielectric cavity antenna," *IEEE Trans. Antennas Propag*., vol. 31, no. 3, pp. 406-412, May. 1983.
2. D. Guha, A. Banerjee, C. Kumar and Y.M.M. Antar, "Higher order mode excitation for high-gain broadside radiation from cylindrical dielectric resonator antennas," *IEEE Trans. Antennas Propag.*, vol. 60, no. 1, pp. 71-77, Jan. 2012.
3. B. Rana and S.K. Parui, "Non-resonant microstrip patch fed dielectric resonator antenna array," *IEEE Antennas Wirel. Propag. Lett*., vol. 14, pp. 747-750. Dec. 2014.
4. G.P. Junker, A.A. Kishk, A.W. Glisson and D. Kajfez, "Effect of fabrication imperfections for ground-plane-backed dielectric-resonator antennas," *IEEE Antennas Propag. Magazine*, vol. 37, no. 1, pp. 40-46, Feb. 1995.
5. K.L. Wong, N.C. Chen and H.T Chen, "Analysis of a hemispherical dielectric resonator antenna with an air gap," *IEEE Microw. Guided Wave Lett*., vol. 3, no. 10, pp. 355-357, Oct. 1993.
6. S. Ballav and S.K. Pauri, "Aperture coupled dielectric resonator antenna embedded in a secondary substrate for mechanical firmness," *Radio Engineering*, vol. 27, no. 3, pp. 679- 685, Sep. 2018.
7. A.S. Elkorany, S.A. Saad and D.A. Saleeb, "Compact reconfigurable band notched UWB cylindrical dielectric resonator antenna using single varactor diode," *Advanced Electromagnetics*, vol. 7, no. 3, pp. 35-39, Aug. 2018.
8. D. Guha, A. Banerjee, C. Kumar, Y.M.M. Antar and M.T. Sebastian, "Design guidelines for the cylindrical dielectric resonator antenna using the recently proposed HEM12δ mode," *IEEE Antennas Propag. Magazine*, vol. 56, no. 4, pp. 148-158, Oct. 2014.
9. K.M. Luk and K.W. Leung, "Dielectric Resonator Antennas", Research Studies Press Ltd. 2003.
10. K. Singh, N. Suryavanshi and P. Jain "Design of DRA Using Different Dielectrics", *International Journal of Computer Science and Mobile Computing*, vol. 5, no.9, pp. 126-132, Sep. 2016.

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