Cylindrical Dielectric Resonator Antenna for Communications

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Abstract-

The proposed design is combination of cylindrical antenna cavity and a Cylindrical Dielectric Resonator substance; hence this radiating structure is called as cylindrical dielectric resonator antenna (CDRA). Synthesis and analysis of CDRA at 2.4 GHz operating frequency has been done to effectively observe the Q-factor and bandwidth of CDRA. Simulated results promise for remarkably satisfactory performance of the CDRA showing high gain broadside radiations caused by both $HEM_{12\delta}$ and $HEM_{11\delta}$ modes.

Keywords- CDRA, Q-factor, Bandwidth, narrowband, wideband

I. INTRODUCTION

In this paper, yet another technique has been proposed. This is absolutely new as well as simple in configuration.No additional engineering is needed to realize special feed as was in [3] and [4]. Unusually long vertical probe has beenemployed as the feed. No additional structure has been invited. A study based on simulated data is presented indicatingnew possibilities of realizing this challenging mode for antenna purpose.

Over last three decades, DRA researchers had investigated different aspects of shape, composition, materials, butnot that much about its resonant modes, particularly for antenna or applications. First five modes were studied in isolatedcylindrical shaped DRA (CDRA) long ago [1], [2]. Only two of them ─ $HEM_{12\delta}$ and $HEM_{11\delta}$modes are commonly usedfor radiation purposes. Higher order $HEM_{12\delta}$ mode was theoretically studied in [1], [2], but it remained unexplored till2012 [3]. Present authors first realized this mode in a practical CDRA resulting in high gain broadside radiation. Someinherent limitations caused by the orientation of $HEM_{12\delta}$ modal fields kept DRA people away from using this mode forantenna applications, which are thoroughly discussed in [3]. It does not allow any electric boundary in the place of theground plane, which is the primary challenge in using $HEM_{12\delta}$ mode. A floating feed in the form of an equivalent currentribbon was conceived and successfully used in [3]. A different approach has been reported very recently by these authorsin which the feed technique is quite novel [4]. A rectangular shallow trough or

defected has been used in a solid metalground plane. Required boundary condition was achieved in [4] using improvised ground plane.

Since 1920, guided electromagnetic propagation by dielectric media has been subject of investigation. Dielectric materials of different relative permittivity have been widely used as resonators, antennas and waveguides. Core of these dielectric waveguide are made up of high permittivity dielectric substance, which is surrounded by a dielectric cladding. These structures support an infinite number of modes but there are only some which are not attenuated, with their fields localized in the central dielectric core.

Dielectric resonator antennas (DRA) have been the interest of research and investigation due to its highly desirable characteristics such as small size, light weight, highly efficient in microwave and mm wave spectrum. The most popular shape studied for practical antennas applications have been the cylindrical dielectric resonator antennas, rectangular dielectric resonator antennas, spherical dielectric resonator antennas and many more different structure are reported. The stacked DRA has also been tested [5]-[12] with a resulting increase in bandwidth that is much wider than the bandwidth of the micro strip antennas.

II. ANTENNA DESIGN

Antenna is an annular-slot coaxial fed cylindrical dielectric resonator. Relative permittivity of the dielectric substance used as resonator in CDRA (Shown in Fig.-1) is 12 and radiator design specification has been calculated for 2.4 GHz frequency of operation. Antenna simulation and observations has been performed for four different waveguide modes, namely TE, TM, HE and EH. Synthesis of CDRA has been achieved by maintaining the value of VSWR to 1.5 and minimum fractional impedance bandwidth to 5 %. During the calculation minimum and maximum radius to height ratio is assumed to be 3 and 5 respectively. Antenna design has been shown in figure 2.

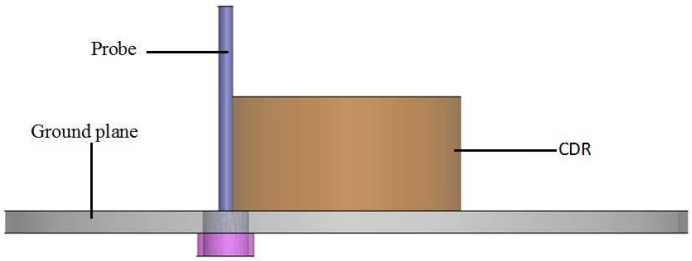

Fig. 1. Schematic diagram of a CDRA symmetrically placed on a ground plane, fed by a long probe.

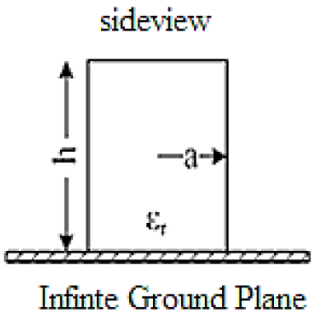

Figure-2 Specification Parameters of CDRA

In the Figure 2, h represents height of the dielectric resonator, radius of the dielectric resonator is represented by a; and relative permittivity of the dielectric resonator has been represented by ε_r.

During synthesis of CDRA, four different modes namely, TE, TM, EH and HE have been synthesized. Keeping the antenna design constraints fixed as discussed in antenna design section, radius and height of the dielectric resonator has been calculated; for different value of radius to height ratio's so as to design the required cylindrical dielectric resonator antenna.

Value of Q factor and bandwidth for TE, TM, HE and EH waveguide modes has been calculated and presented in Table 1, Table 2, Table 3 and Table 4 respectively.

Table 1 Parameter Value of CDRA for TE_{01} Mode

S. No.	a/h	a (cm)	h (cm)	Q-Factor	Bandwidth (%)
1.	3.5	2.095	0.5987	8.121	5.027
2.	4	2.188	0.5471	7.601	5.371
3.	4.5	2.276	0.5057	7.15	5.71
4.	5	2.357	0.4714	6.759	6.04

Table 2 Parameter Value of CDRA for TM_{01} Mode

S. No.	a/h	a (cm)	h (cm)	Q-Factor	Bandwidth (%)
1.	3	3.226	1.075	5.721	7.136
2.	3.5	3.56	1.017	6.212	6.572
3.	4	3.91	0.9774	7.236	5.642

Table 3 Parameter Value of CDRA for HE_{11} Mode

S. No.	a/h	a (cm)	h (cm)	Q-Factor	Bandwidth (%)
1.	3	2.873	0.9576	5.208	7.839

2.	3.5	3.23	0.9228	4.267	9.568
3.	4	3.595	0.8988	3.562	11.46
4.	4.5	3.969	0.8820	3.057	13.35
5.	5	4.351	0.8703	2.710	15.06

Table 4 Parameter Value of CDRA for EH_{11} Mode

S. No.	a/h	a (cm)	h (cm)	Q-Factor	Bandwidth (%)
1.	3	2.908	0.9694	3.485	11.72
2.	3.5	3.136	0.8959	2.837	14.39
3.	4	3.399	0.8497	2.304	17.72
4.	4.5	3.700	0.8223	1.886	21.64
5.	5	4.043	0.8086	1.584	25.64

III. ANALYTICAL RESULTS

Analysis of CDRA has been done by specifying the design parameters of dielectric resonator of CDRA for EH_{11} Mode, since in this mode CDRA performance in terms of bandwidth and Q-factor is good. For the calculation purpose, dielectric constant of the resonator is 12 and VSWR is assumed to be 1.5. Radius and height of dielectric resonator is found from Table 4, which is 4.043 cm and 0.086 cm respectively. These values are used because the CDRA exhibits highest bandwidth at these values. Analysis result of CDRA has been presented in Table 5.

Table 5 Analysis of CDRA for a = 4.043 cm and h = 0.8086 cm

S. No.	Waveguide Mode	Resonant Frequency (GHz)	Q-Factor	Bandwidth (%)
1.	TE_{01}	1.3992	6.7595	6.0396
2.	TM_{01}	2.7560	10.024	4.0725
3.	HE_{11}	2.5830	2.7101	15.0639
4.	EH_{11}	2.4001	1.5840	25.7733

IV. RESULT &DISCUSSIONS

RESULT

Synthesis and analysis of CDRA has been done for four different waveguide modes. Appropriate value of radius and height of dielectric resonator for different waveguide mode has been calculated and has

been presented in this paper. During the analysis, it is found that CDRA work well; when synthesized in EH_{11} mode, since CDRA provides highest performance bandwidth and low value of Q-factor. It is known that antennas with a high Q are narrowband and antennas with a low Q are wideband. It is also observed that higher the value of Q, the more sensitive the input impedance is to small changes in frequency. Thus, the designed CDRA is a suitable candidate for wireless communication at 2.4 GHz, which is sufficiently, supports wireless communication, e.g., wi-fi communication.

DISCUSSIONS

i. It is observed from Table-1 that as the radius of dielectric resonator is increased, its height requirement decreases for the specified design parameters of CDRA.

ii. Table-2 shows that as the ratio of radius of dielectric resonator to its height increases, Q-factor of CDRA decreases in Table-3.

iii. From Table-4, it is found that Q-factor decreases while performance bandwidth of CDRA increases.

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