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Analysis of Different Waveguide Modes of a Cylindrical Dielectric Resonator Antenna for Wireless Communications

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Abstract- **This paper presents effect of different waveguide modes on the design and construction of a dielectric resonator antenna (DRA). 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 in MATLAB program to effectively observe the Q-factor and bandwidth of CDRA. Radiator design parameters has been calculated for different waveguide modes such as TE, TM, HE, EH. DRA, a volumetric source improves the radiation power factor of the radiating slot.**

Keywords- Cylindrical Dielectric Resonator Antenna (CSDRA), TE, TM, HE, EH, Q-factor, Bandwidth, narrowband, wideband

I. INTRODUCTION

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 [1]-[7] with a resulting increase in bandwidth that is much wider than the bandwidth of the micro strip antennas.

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.

II. ANTENNA DESIGN

Antenna is an annular-slot coaxial fed cylindrical dielectric resonator. Relative permittivity of the dielectric substance used as resonator in CDRA 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.

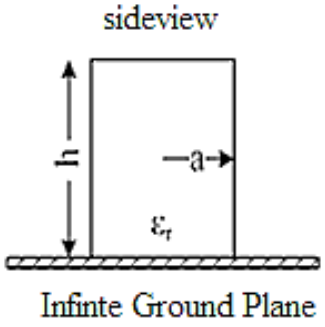


Figure 2 Specification Parameters of CDRA

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.

III. ANTENNA SYNTHESIS

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.

Figure 3.1 shows the plot of ratio of radius of dielectric resonator to its height Vs. dielectric resonator radius and height. From Figure 3.2, plot of ratio of radius of dielectric resonator to its height Vs. Q-factor of CDRA and Figure 3.3 shows plot of ratio of radius of dielectric resonator to its height

Vs. bandwidth of CDRA. These figure plots the antenna design parameter curves for different waveguide modes.

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

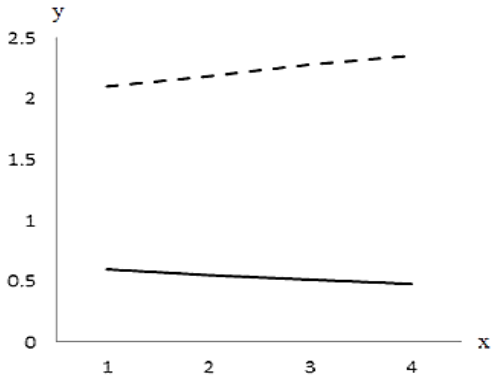
S. No.	a/h	a (cm)	h (cm)	Q-Factor	Bandwidth (%)
1.	3	3.226	1.075	5.721	7.136
2.	3.5	3.56	1.017	6.212	6.572
3.	4	3.91	0.9774	7.236	5.642

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

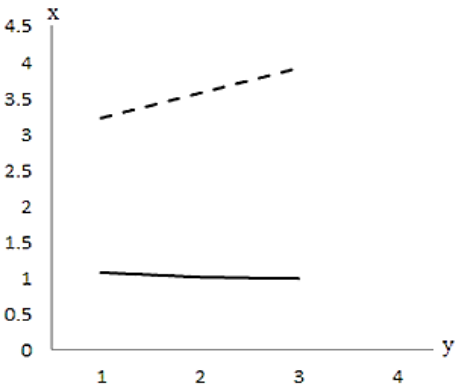
S. No.	a/h	a (cm)	h (cm)	Q-Factor	Bandwidth (%)
1.	3	2.873	0.9576	5.208	7.839
2.	3.5	3.23	0.9228	4.267	9.568
3.	4	3.595	0.8988	3.562	11.46
4.	4.5	3.969	0.8820	3.057	13.35
5.	5	4.351	0.8703	2.710	15.06

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

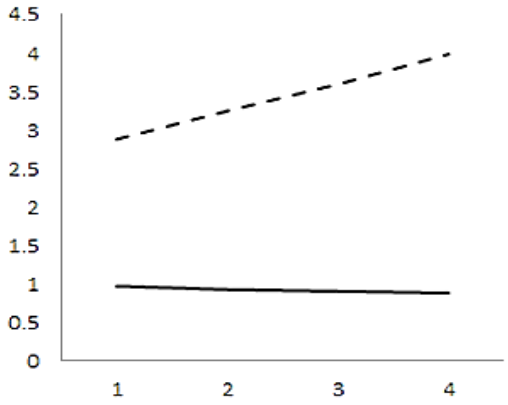
S. No.	a/h	a (cm)	h (cm)	Q-Factor	Bandwidth (%)
1.	3	2.908	0.9694	3.485	11.72
2.	3.5	3.136	0.8959	2.837	14.39
3.	4	3.399	0.8497	2.304	17.72
4.	4.5	3.700	0.8223	1.886	21.64
5.	5	4.043	0.8086	1.584	25.64



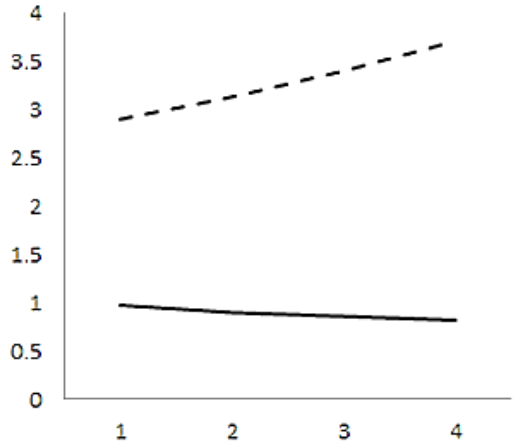
(a) TE_{01} Mode



(b) TM_{01} Mode

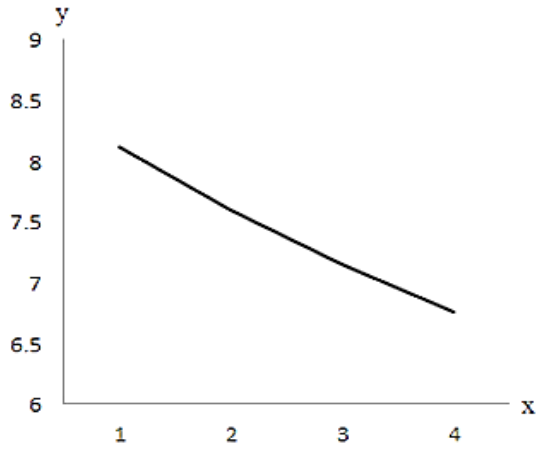


(c) HE_{11} Mode

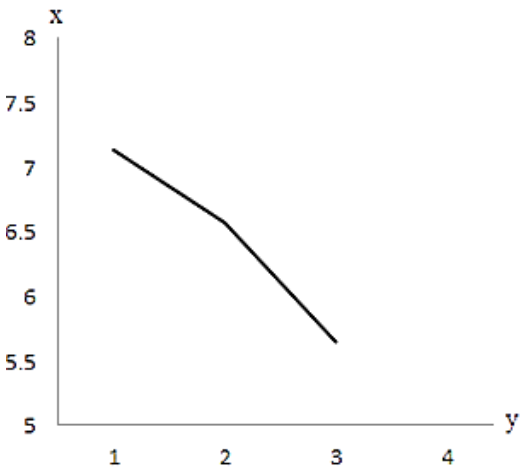


(d) EH_{11} Mode

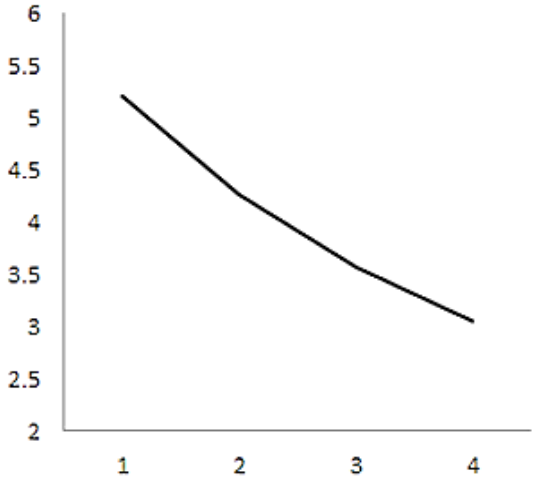
Figure 3.1 Plot between ratio of Radius of Dielectric Resonator to its height Vs. Dielectric Resonator's Radius and Height for different Waveguide Modes.



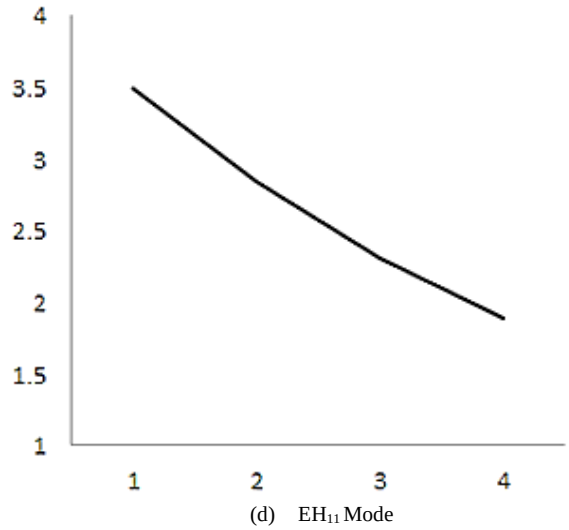
(a) TE_{01} Mode



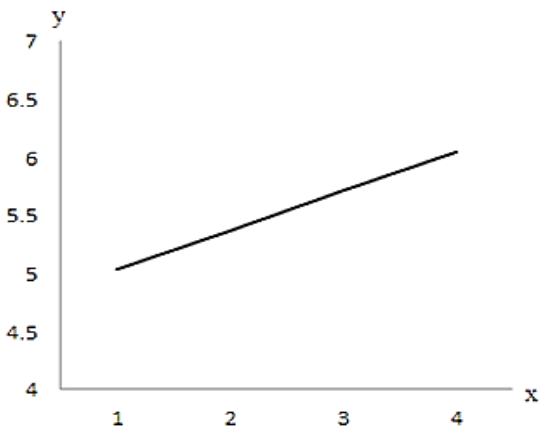
(b) TM_{01} Mode



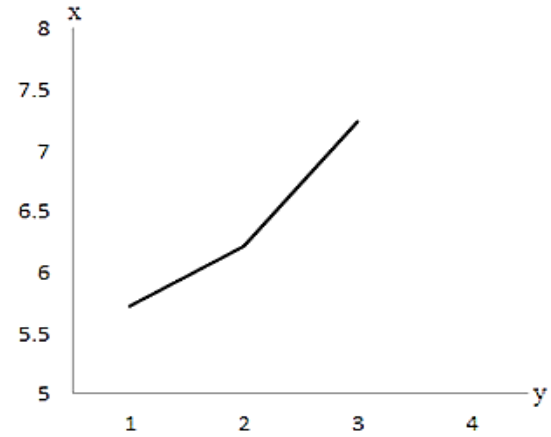
(c) HE_{11} Mode



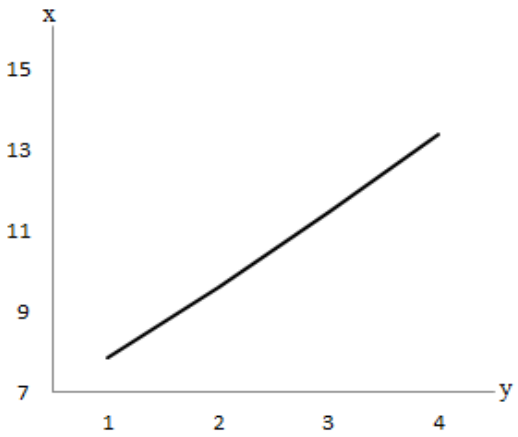
(d) EH_{11} Mode



(a) TE_{01} Mode



(b) TM_{01} Mode



(c) HE_{11} Mode

Figure 3.2 Plot between ratio of Radius of Dielectric Resonator to its height Vs. Q-Factor of CDRA for different Waveguide Modes.

(d) EH_{11} Mode

Figure 3.3 Plot between ratio of Radius of Dielectric Resonator to its height Vs. performance Bandwidth of CDRA for different Waveguide Modes.

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. DISCUSSIONS

i. It is observed from Figure 3.1 that as the radius of dielectric resonator is increased, its height requirement decreases for the specified design parameters of CDRA.
ii. Figure 3.2 shows that as the ratio of radius of dielectric resonator to its height increases, Q-factor of CDRA decreases.
iii. From Figure 3.3, it is found that as the ratio of radius of dielectric resonator to its height increases, performance bandwidth of CDRA increases.

V. 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.

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