FOUR-ELEMENT CYLINDRICAL DIELECTRIC RESONATOR ARRAY : BROADBAND LOW PROFILE ANTENNA FOR MOBILE COMMUNICATIONS

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ABSTRACT

A new design of a dielectric resonator array is presented as a wideband radiator having uniform monopole-like radiation patterns. Four cylindrical DRAs are symmetrically packed together around a coaxial probe which itself is surrounded by another small dielectric cylinder. The fundamental $HE_{11\delta}$ mode in each element is employed to generate the desired radiation patterns. The simulation and measured data are presented. As much as 2.7 dBi peak gain with nearly 30% impedance bandwidth (VSWR<2) has been achieved from an optimum design occupying $0.12\lambda_0$ by $0.58\lambda_0$ surface area.

INTRODUCTION

Dielectric Resonator Antennas (DRA's) have become popular in recent years because of many advantages they offer [1]. The dominant mode radiation patterns in most of the probe-fed or slot fed structures [1], [2] are in the broadside direction of the elements. Many wireless applications demand for monopole or monopole-like radiation patterns. Only a few handful investigations with DRAs having monopole-like radiation are available in open literature [3], [4]. There, the DRA elements are annular dielectric rings axially excited by the central conductor of a coaxial probe and the resonating mode is TM 01. Normally the bandwidth of those designs is very small and the excitation of the DRA is sensitive to the ring dimensions.

In this paper, we propose a different approach to achieve a uniform monopole-like radiation pattern from a cylindrical DRA array. The antenna geometry is intuitively conceived by employing the fundamental $HE_{11\delta}$ mode which is very easy to excite and can provide oblique radiation pattern over the entire azimuth. The design, which is based on simulation results, is presented. Nearly 30 % return loss bandwidth(S_{11}<10 dB) and 2.7 dBi peak gain over the entire operating frequency range have been achieved . The simulation and measured results are presented.

THE ANTENNA GEOMETRY

In the proposed design, four cylindrical DRAs each of same height h_1 and radius a are arranged in a planar configuration over a metallic ground plane (GP) and are symmetrically packed together in the most compact fashion as shown in Fig. 1. The array is excited centrally by a coaxial probe having its height l above the GP. The central conductor of the probe is surrounded by another dielectric cylinder so that its boundary just touches each DRA element and helps in exciting them. The dielectric constant of the DRA is chosen as 10.2 and that of the central dielectric as 13.2. This mode of feeding excites the fundamental $HE_{11\delta}$ mode in each cylindrical DRA (CDRA) element and it is clear that the composite radiation fields will nullify the radiation in broadside and cause a uniform oblique radiation pattern surrounding the antenna structure.

RESULTS AND CONCLUSIONS

The proposed antenna has been characterized with the help of the simulation and measured results. Use is made of Ansoft's HFSS V9 to generate the data. The input impedance and radiation characteristics of the antenna have been studied for various antenna parameters. The experimental results with a prototype measured on HP 8510B Network Analyzer are also presented. The investigations are executed in several steps : (i) by optimizing the probe length and radius, (ii) by optimizing the height and radius of the central dielectric ring and (iii) by optimizing the height and radius of the DRA elements. For brevity, few representative results are presented.

Figure 2 shows the S11 values for different probe lengths with the optimum value of the probe diameter where *l*= 9mm appears to be the best choice for the given set of parameters. The choice of the dielectric constant value and the height of the central dielectric ring are critical as revealed from Figs. 3 and 4. The quantities ε_{r2} =13.2 and h_2= 10 mm appear to be the optimum values to achieve an optimum input impedance response. Nearly 30% impedance bandwidth (VSWR<2) has been recorded for a set of optimum antenna parameters. Figure 5 shows the measured return loss values for a prototype built from a Eccostock 10 and 13 dielectric constant rods. The antenna dimensions are given in the figure caption. The return loss curve shows 26% impedance bandwidth (S11<-10dB). This is in close agreement with the simulation data. Other parameters remaining same, the CDRA dimension severely affects the bandwidth parameter and this is examined in Fig. 6 for two different CDRA radii.

The radiation patterns of the antenna are shown in Figs. 7 and 8. The pattern is very similar to that of an electric monopole and is uniform too over the entire frequency band. The peak gain is found to vary between 2.4 to 2.7 dBi depending on the radiation frequency. However, the bandwidth of the proposed DRA array is approximately double the normal bandwidth of an electrical monopole having its height more than two times compared to the proposed DRA. The optimum antenna dimension appears to be 0.58λ_0 by 0.12λ_0. Thus this low profile DRA antenna should be commercially viable and also technically suitable for WLAN and other wireless communications systems.

REFERENCES

[1] M. S. Al Salameh,Y. M. M. Antar and G. Seguin, "Coplanar-waveguide-fed slot-coupled rectangular dielectric resonator antenna", *IEEE Trans. Antennas Propagat.* vol. 50, no. 10, pp.1415-1419,Oct. 2002.

[2] Y. M. M. Antar and Z. Fan,"Characteristics of aperture coupled rectangular dielectric resonator antenna" *Elect. Lett.* vol. 31, no.15, pp. 1209-1210, 20th July 1995.

[3] G. P. Junker, A. A. Kisha, A. W. Glisson and D. Kajfez, "Effect of air gap on cylindrical dielectric resonator antenna operating in TM_{01} mode" *Elect. Lett.* Vol.30, no.2, pp. 97-98, 20th Jan. 1994.

[4] R. K. Mongia, A. Ittipiboon, P. Bhartia and M. Cuhaci "Electric monopole antenna using a dielectric ring resonator" *Elect. Lett.* Vol.29, no.17, pp. 1530-1531, 19th Aug. 1993.

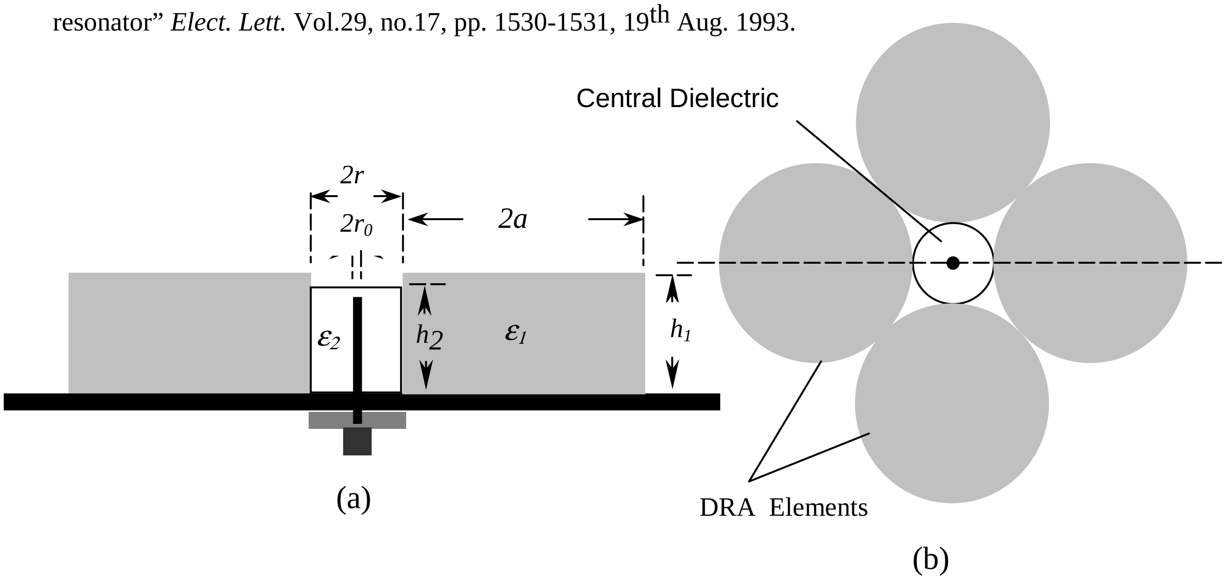
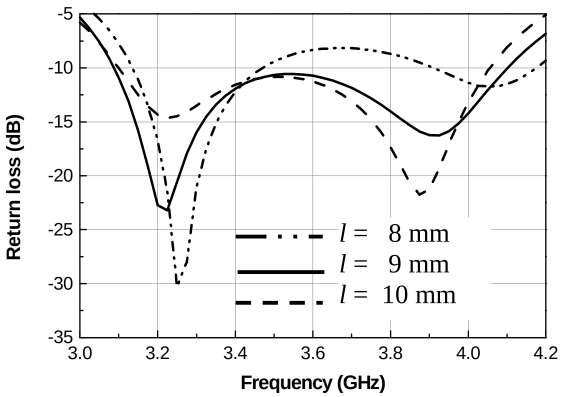


Fig.1. A 4-Element Cylindrical DRA Array fed by a coaxial Probe : (a)Cross-sectional View (b)Top view



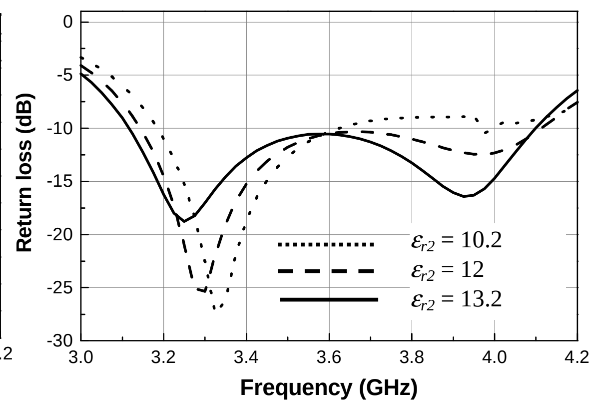
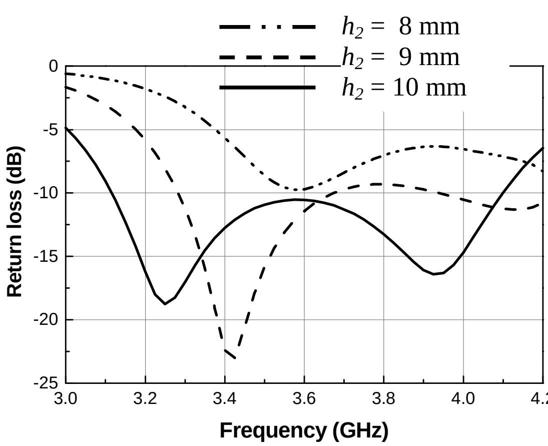


Fig 2. Return loss versus frequency of a probe-fed 4-element DRA array with different probe dimensions. a=10mm, r=4.15, h_1= 10mm, h_2=10 mm, ε_{r1}=10.2, ε_{r2}=13.2, r_0=0.55 mm

Fig 3 Return loss versus Frequency of a probe-fed 4-element DRA array with different ε_{r2} values. a=10 mm, r=4.15 mm, r_0= 0.55 mm, h_1= 10 mm, h_2=10 mm, l= 9 mm, ε_{r1}=10.2



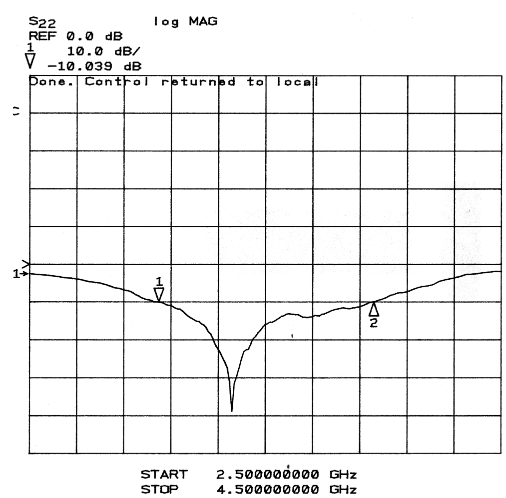


Fig. 4 Return loss characteristics of a 4-element DRA array with different heights of central dielectric. ε_{r2}=13.2 and other parameters as in Fig. 3.

Fig. 5 Measured Return loss versus Frequency of a probe-fed 4-element DRA. a=10 mm, r=4.15, $2r_0\approx$ 1.12 mm, h_2= 10mm, $l\approx$ 9 mm, ε_{r1}=10, ε_{r2} = 13

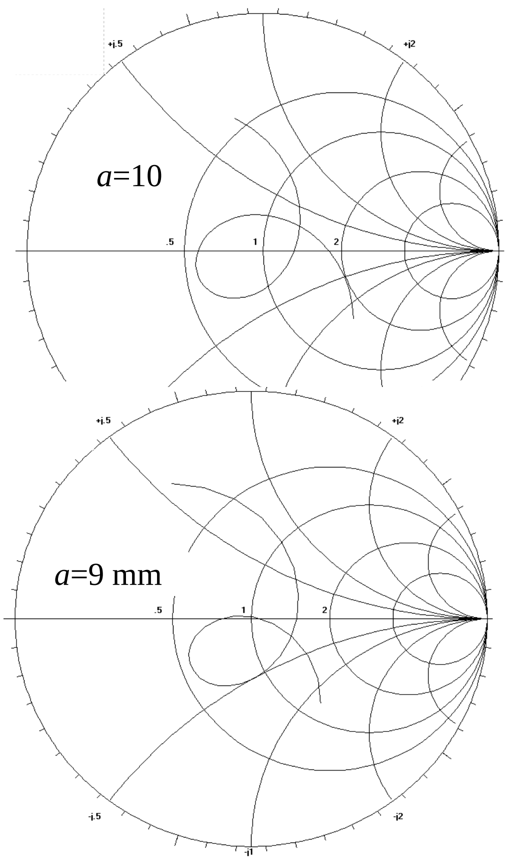


Fig. 6 Simulated Impedance loci for two different radii values.

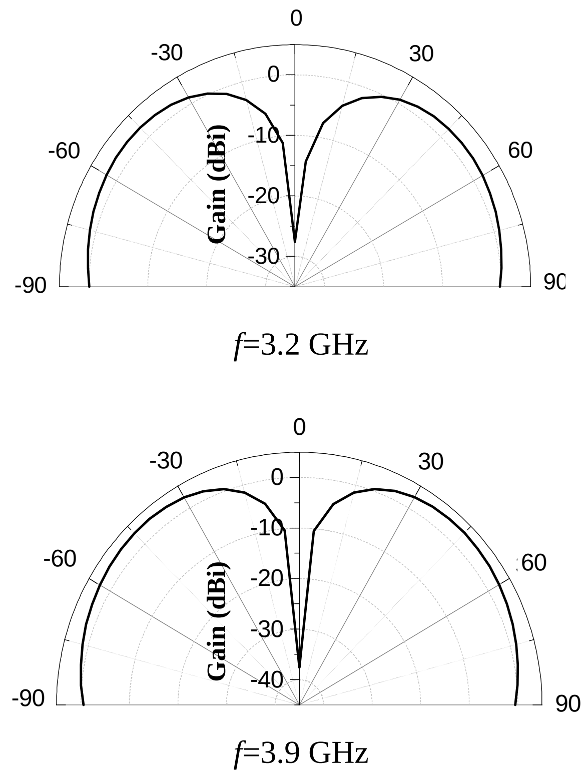


Fig. 7 Gain$_{\theta}$ versus angle θ for ϕ= 0 ^{o} at two different frequencies of the operating band. *a*=10mm, *r*=4.15 mm, r_0= 0.55 mm, h_1= 10mm, h_2=10 mm, *l*=9 mm, ε_{r1}=10.2, ε_{r2}=13.2

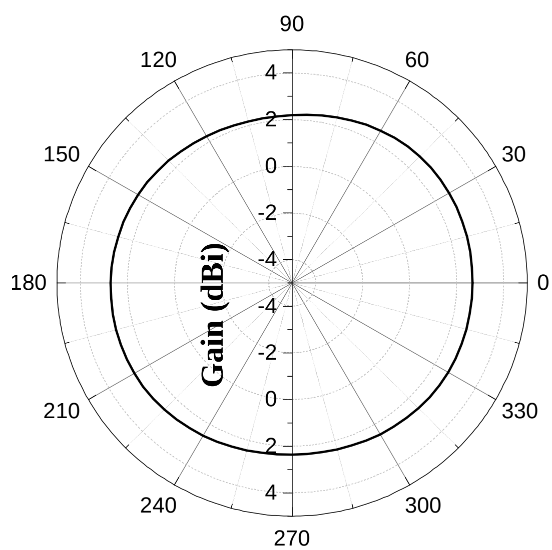


Fig. 8. Gain$_{\theta}$ versus angle ϕ for θ = 45 ^{o} at central frequency of the operating band of a 4-element DRA array studied in Fig. 7. *f*= 3.6 GH.