New Dielectric Resonator Antenna Design for Mobile Handsets

T.H. Lee, R.A. Abd-Alhameed and P.S. Excell
Mobile & Satellite Communications Research Centre, University of Bradford, Bradford BD7 1DP, UK
Email: thlee2@bradford.ac.uk, r.a.a.abd@bradford.ac.uk, p.s.excell@bradford.ac.uk

ABSTRACT

A new design of Dielectric Resonator Antenna (DRA) for mobile handsets is presented: the off-centre ring dielectric resonator antenna (OCRDRA). This achieved 15.9% impedance bandwidth (for S_{11} < -10 dB) by using high dielectric constant material (ε_r = 77) with coaxial probe feed. The geometry of the antenna is small, having key dimensions of the order of $\lambda_o/10$. Different inner diameters were tested and optimised for the best bandwidth. The numerical results of two different computational software approaches are investigated and compared. The results are in good agreement within the desired frequency band, 1.73 GHz ~ 2.03 GHz. The Specific Absorption Rate (SAR) for the antenna, as deployed near a sphere approximating the human head, is also presented.

INTRODUCTION

In recent years, Dielectric Resonator Antennas (DRAs) have become attractive due to their particular advantages for some applications, including zero conductor loss, low profile etc. It has been shown experimentally that this kind of element can be an efficient radiator [1]. Experimental and theoretical evaluations of DRAs have been reported by many investigators (e.g., [1] - [6]), although the results presented by these investigators mostly apply at high resonant frequencies (7 GHz to 12 GHz). In [6] it was shown that, in a DRA using high dielectric constant material, relatively low resonant frequencies may be obtained; in [5] it was reported that the resonant frequency can be reduced by covering it with a metallic patch on the top of the DRA.

In earlier work, Yee and Long [1-2] presented a mathematical analysis for the resonant frequency of the cylindrical dielectric resonator in different transverse modes. They also showed, theoretically and experimentally, that for different sizes of cylindrical dielectric resonator excited by different transverse modes, predictable resonant frequencies could be obtained. By the evolution of the antenna design methods, some investigators used different geometries of dielectric resonators, such as rectangular and hemisphere, as DRAs.

DRAs have a limited bandwidth of operation due to their resonant nature, but this can be improved by reducing the inherent Q-factor of the resonant antenna. One simple approach to reduce the Q-factor is to decrease the dielectric constant [7]. Although this is a simple solution, there are drawbacks: in particular, the size of the antenna will be increased, and this may not be desirable for many applications. Some other reported bandwidth enhancement techniques have included stacked twin dielectric resonators [3] and using multi-layer dielectric materials [7].

In this paper, a new cylinder dielectric resonator is designed as an antenna for a mobile handset. To let the antenna operate at the appropriate, relatively low radio frequencies (e.g. 1 GHz ~ 3 GHz), a high dielectric constant material is used as the main part of the antenna radiator. An 'off-centre' design is introduced in this DRA is to increase the bandwidth. For excitation, a coaxial probe is used and placed next to the antenna radiator. The DRA models are simulated using two different software packages: Ansoft High Frequency Structure Simulator (HFSS) [8] and CST Microwave Studio [9]. The SAR for different distances of the antenna from a biological sphere is presented and compared to some published data.

TECHNICAL DESIGN PRINCIPLES

Foundations of DRA design can be found in [10]. The cylindrical dielectric resonator was chosen as the basic geometry of the antenna radiator and the selected excitation method was by using a coaxial probe [10]. As mentioned earlier, the bandwidth of a DRA can be improved by reducing the Q-factor, hence, the cylindrical dielectric resonator used in this design was changed to a hollow design. Several attempts to modify the geometry for optimum performance were tried, such as the DR size and the location and size of the excitation probe. Unfortunately, the results were not encouraging since the computed return loss was between -4 to -5dB within the required bandwidth. The geometry of the initial design and its return loss are shown in Figures 1 and 2 respectively. To achieve the required practical return loss of better than -10 dB, a novel modification of the hollow cylindrical dielectric resonator was applied. This has been achieved by slightly moving the axis of the inner cylinder to make it 'off centre' relative to the outer cylindrical profile, as shown in Figures 3 and 4.

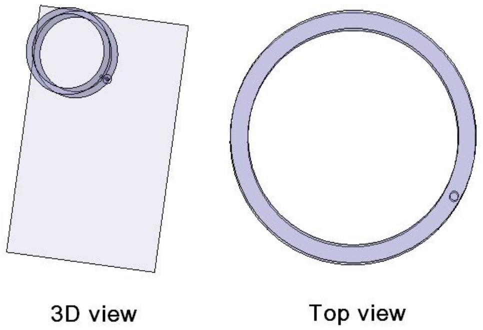

Fig. 1. The geometry of the initial design

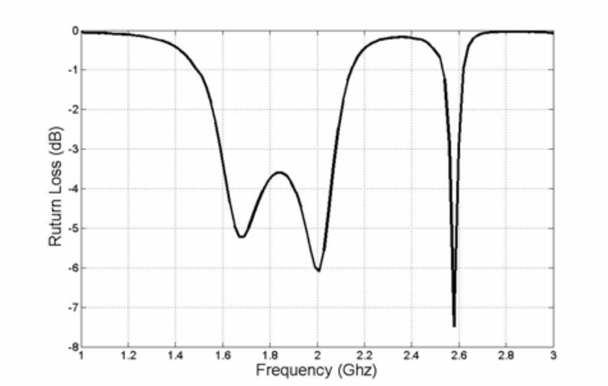

Fig. 2. Return loss of the antenna shown in Fig. 1.

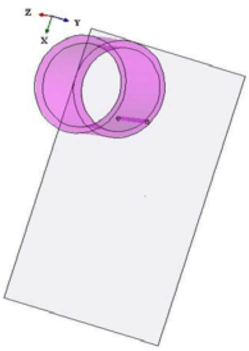

Figure 3. 3D view of OCRDRA and ground plane

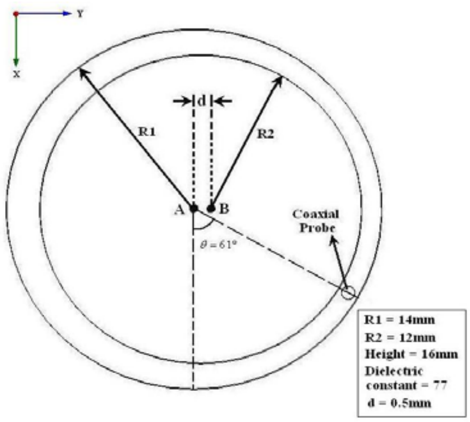

Figure 4. Top view of OCRDRA

The geometry of the off-centre ring dielectric resonator antenna is characterized by the outer radius (R1 = 14 mm), inner radius (R2), and the height (16 mm). It was placed offset, at the top of an 80mm x 50mm metallic plane simulating a mobile phone ground plane. The distance (d) between the two axes (A and B) is 0.5mm. A coaxial probe of length 12mm and diameter 1 mm is located at an angle of 61° from the axis through the centres (A-B).

SIMULATION RESULTS

Three different inner diameters (R2) of OCRDRA were simulated and the results are shown in Figure 5. When R2 was 10 mm, about 20% bandwidth was obtained at S_{11} < -4 dB, in the frequency band 1.3 GHz ~ 1.6 GHz. The frequency band shifted upward to 1.42 GHz ~ 1.78 GHz when R2 was changed to 11 mm; and about 22.5% bandwidth at S_{11} < -5 dB was obtained. The 2.5% bandwidth increase, resulting from changing the inner diameter suggested that a still larger value should be tried. The best case for three different inner diameters was found to be 12mm, giving 15.9% bandwidth for $S_{11} \leq$ -10dB. Although the bandwidth narrowed in this case, the matching was better than in the previous two cases. Fig. 6 shows the return loss of the OCRDRA: this result was obtained by using two different electromagnetic computation methods, the Finite Element Method (FEM) [8] and the Finite Integration Method (FIM) [9], which is closely related to the FDTD method. These results are in good agreement over the matching frequency band 1.73 GHz ~ 2.03 GHz, which corresponds to an impedance bandwidth, for $S_{11} \leq$ -10 dB, of 15.9%.

The radiation patterns in the x-y, y-z, and x-z planes, for the centre frequency of 1.8 GHz, are presented in Fig. 7. The results show that the radiation patterns are nearly omnidirectional, with a distorted short-dipole character

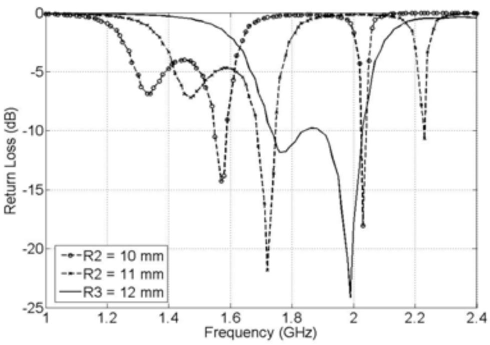

Figure 5. Return loss of OCRDRA with three different inner diameters (R2).

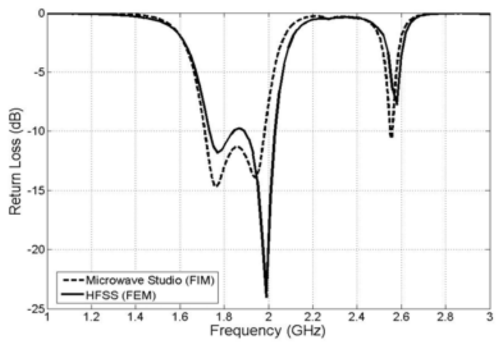

Figure 6. Comparison of return losses computed by FEM and FIM.

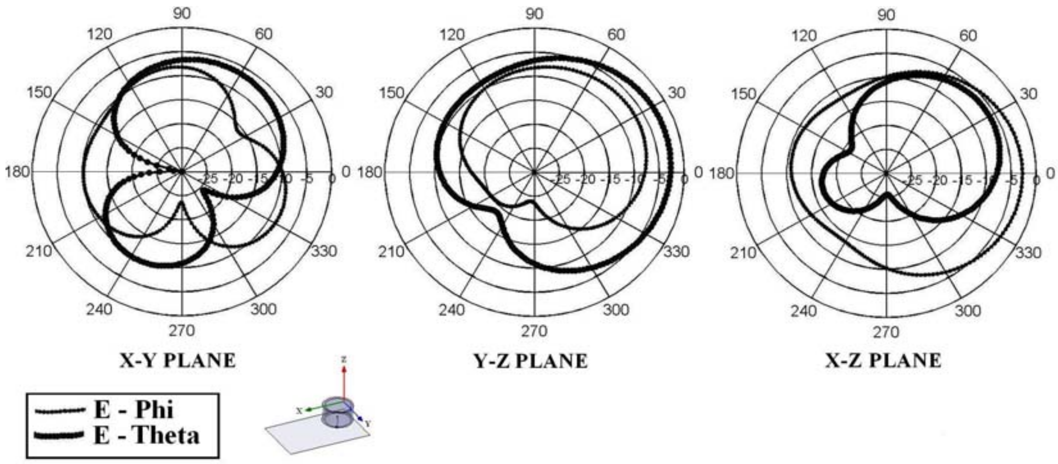

Figure 7. Computed radiation patterns at 1.8 GHz for the OCRDRA.

SPECIFIC ABSORPTION RATE FOR OCRDRA ADJACENT TO BIOLOGICAL SPHERE

The specific absorption rates (SAR) of this antenna have been simulated by using the Finite Element Method (HFSS [8]). A simple sphere structure was used in the simulation to represent the human head. The diameter of the sphere was 22.3 cm, with a homogeneous core and a containing shell 0.5 cm thick. The properties of the core were: permittivity: 42.9 and conductivity 0.9 S/m, whereas for the shell the permittivity was 4.6 and conductivity zero. The maximum averaged SAR over masses of 1g and 10g for different distances between the handset and the sphere are shown in Table 1. The input power for the antenna is 1 W.

Table 1. Average SAR (W/kg) for various distances between sphere and handset

Distances / Mass	0 mm	10 mm	20 mm
1g Average SAR	6.23	5.44	2.83
10g Average SAR	5.25	3.52	2.05

Compared to a simple monopole handset antenna, the above results are small. For example, when the antenna is adjacent to a spherical head the peak averaged SARs for the monopole handset are around four times higher than the values computed with the novel DRA. A simple explanation might come from the position of the DR on the handset itself (on the back of the handset ground plane), since the plane is a good reflecting surface. However, for the distance setting 20mm; the average SARs in 1g and 10g for the DRA are very similar, suggesting good 'spreading' of the SAR, avoiding concentration regions. The SAR distribution over two different planes for 0mm distance between the sphere and the DRA is shown in Figure 8, and the far field for this case is shown in Figure 9.

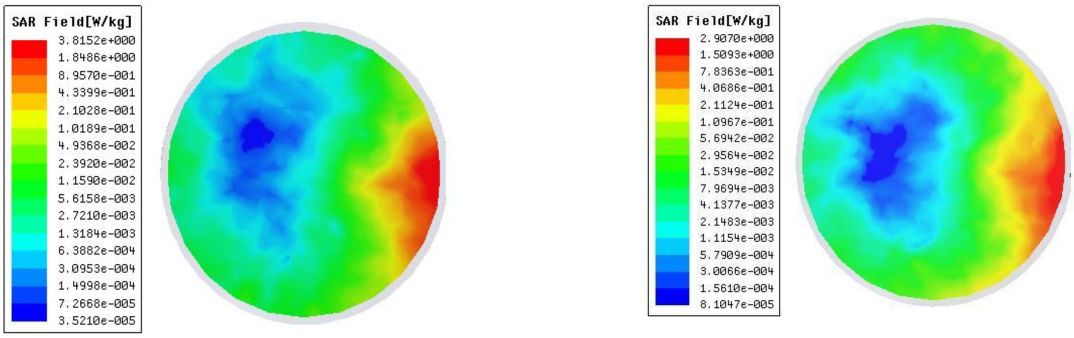

Figure 8. SAR distribution in W/kg for 1W input power in (left) yz- plane and (right) xz- plane (handset touching sphere).

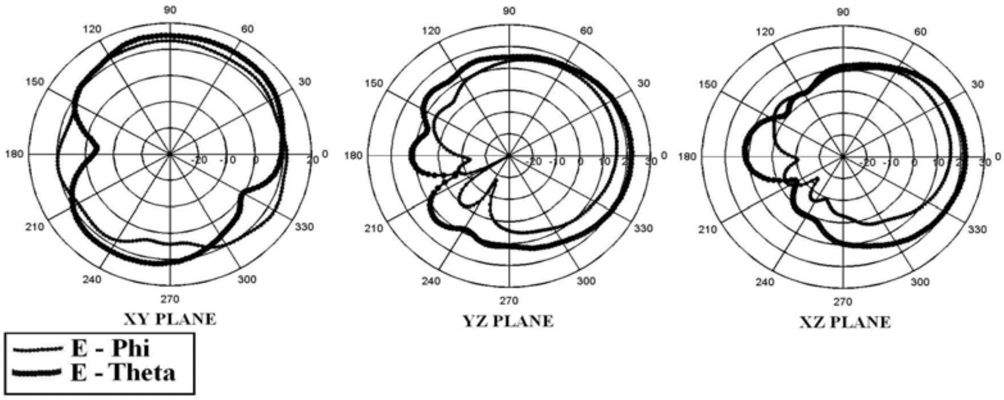

Figure 9. Computed radiation patterns at 1.8 GHz for the OCRDRA on a handset touching the sphere.

CONCLUSIONS

A new geometry of dielectric resonator antenna has been designed and presented. The simulated results were verified by modelling the geometry with two different well-known software packages. The SAR of the antenna, mounted on a simulated handset adjacent to a sphere of biological tissue material, has been computed using the Finite Element Method. The impedance bandwidth was observed and optimized by changing the inner diameter of the off-centre resonator. A maximum of 15.9% relative bandwidth was observed, for the constraint $S_{11} \leq -10$dB, which is sufficient to cover the new generation mobile bands. The SAR was relatively widely distributed in the sphere, showing that the antenna will easily satisfy current SAR safety guidelines.

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