Journal of The Gujarat Research Society
ISSN: 0374-8588
Volume 21 Issue 10, October 2019

DESIGN AND ANALYSIS OF DIELECTRIC RESONATOR ANTENNAS (DRA) USING NUMERICAL METHODS: A COMPREHENSIVE SURVEY

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Abstract

This paper provides an in-depth analysis of noteworthy research performed over more than two decades on dielectric resonator (DR) antenna modelling by utilizing the numerical methods. Due to its captivating features namely small size, low loss, high performance, large bandwidth, three-dimensional design versatility compared to traditional antennas, etc., the dielectric resonator antenna (DRA) has produced its individual life in antenna engineering. Nowadays, DR antennas are generally designed by applying the numerical techniques. The primary goal of this review article is to give an overview of DRA designing with the help of single as well as the hybrid numerical methods. Another objective is to provide a compressive review of noteworthy numerical designing studies conducted on DRAs and last but not the least aim is to provide some favourable future concentration for antenna scientists in order to apply numerical techniques to some ground breaking DRA geometries.

Keywords: *Antenna Survey, Antennas, Dielectric Resonator (DR), Different Applications, Dielectric Resonator Antenna (DRA).*

I. INTRODUCTION

The dielectric resonator antenna, commonly known as the DRA or sometimes the DR antenna, has gained remarkable attention across the globe in recent years. Richtmyer1 invented the dielectric resonator design in 1939 as a high Q-factor material, but it was used in 1983 as an effective electromagnetic radiator [1]. Since then, it has evolved rapidly over the conventional antenna because of many important advantages, such as broad bandwidth, low loss, and three-dimensional design versatility, high performance, and large power handling capability [2]. The 3-dimensional architecture's flexibility depends on the respective basic shapes controlling parameters such as hemispherical shape radius, cylindrical shape height to radius ratio, and the depth/width ratio of rectangular shapes as well as the length/width ratio [3].

Several other shapes shown in Figure 1 are now also used to satisfy different electrical and physical specifications on a regular basis. Therefore, different ways of reviewing the DRAs have been suggested over the last two decades, but no one has conducted an application-oriented survey/review and this form of survey/review article is equally relevant to antenna researchers and antenna designers before, in the opinion of authors, designing any DRA for any particular application [4]. The word dielectric resonator (DR)-antenna or dielectric resonator antenna (DRA) is derived simultaneously from the dielectric, resonator and antenna. It is essentially an antenna that resonates with a dielectric material at a certain frequency.

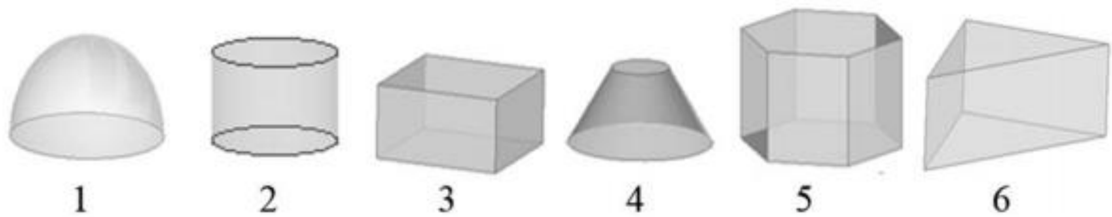

Fig. 1 depicts multiple geometrical forms of dielectric resonator antennas.

Therefore, in the last two decades, different ways of reviewing the DRAs have been suggested, but nobody has conducted an application-oriented survey/review and this type of survey/review article is equally important to antenna researchers as well as antenna designers before designing any DRA for any specific application [5]. Innovation is very significant from a research point of view, but it is cognitively incomplete without real field application [6]. To this end, in order to be well viewed, researchers often strive to materialise their definition, which is well represented in the history of DRAs [7]. Although the development of DRAs took place in the early 1980s, rapid growth and adoption started in the 2000s [8].

The width W of the DRA antenna can be determined by utilizing the following equation.

$$w = \frac{c}{2\,f_r\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

Where
f_r denotes the resonant frequency, and
r represents substrate dielectric constant

The effective dielectric constant (ε_{reff}) of DRA antenna is derived by using the following equations.

$$\varepsilon_{reff} = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{2}\sqrt{\left(1 + 12\frac{h}{W}\right)}$$

Where h denotes the height of the antenna and W denotes the width.

The length of the antenna may be measured by applying the following equation.

$$L = \frac{c}{2\, f_r \sqrt{\varepsilon_{reff}}}$$

The antenna length extension is calculated by applying the equation below.

$$\Delta L = 0.412\, h\, \frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{W}{h} + 0.246\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)}$$

Here W represents the width and h denotes the height.

The real length (L_{eff}) of the antenna can be calculated by using the following formula.

$$L_{eff} = L + 2\Delta L$$

II. LITERATURE REVIEW

Kumar et al. have carried out an analysis on the circularly polarised microstrip patch antenna. For mobile communication and GPS applications, a triple-frequency single-feed S-shaped circularly polarised microstrip antenna with a minimal frequency ratio has been proposed. In the centre of a square patch of 84.5 to 84.5 mm2 for multi-band service, an S-shaped slot is eliminated. The suggested antenna geometry consists of a single microstrip line with an aperture-coupled feeding structure. The results of the simulation show that the proposed antenna can be used with an efficient return loss of -34.34 dB, -18.23 dB and -24.75 dB at 1.193 GHz, 1.454 GHz and 1.615 GHz respectively for multiband service [9].

A review article on the pentagon slot resonator frequency reconfigurable antenna for wideband reconfiguration was carried out by Borakhade et al. With advances in the field of communication and the current state of affairs in the production of antennas, the need for small, multiband, multifunctional and cost-effective antennas is rising. The study of reconfigurable antennas has made considerable progress in recent years. They are lighter in weight, smaller in size and lower in price. Again, the reconfigurable antennas may provide a range of features, such as operational resonant frequency shift, polarisation, and radiation pattern [10].

III. DISCUSSION AND CONCLUSION

In a computational modelling approach, this review article highlighted the chronicled description and a synopsis of the current state of DRA, which form of review is rarely accessible in open literature. The basic steps of DRA modelling using various numerical methods (mainly FDTD, MOM and FEM) are analysed in this study work, and some of the notable research carried out on the basis of individual as well as hybrid techniques is also summarised. A technically interesting distinction is made between FEM, MOM and FEM as well as commercially available CAD tools.

Although the DRA research has been done so far using numerical techniques, from a broad point of view, it is clear that there is a need for memory requirement minimization for almost all cases as well as some modifications are also required, such as (1) reduction of grid requirement in FDTD, (2) need for simplified Green's function for complex geometries and (3) alternative of sparse matrixes.

From a prospective point of view, this paper may be helpful for antenna researchers in (1) analysing/modelling DRA using numerical methods according to the steps given in the respective sections, (2) getting an idea of new research done in recent decades based on various numerical techniques, (3) introducing some new techniques/modifications to avoid the unresolved disadvantages such as memory.

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