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Optimization of Design Parameters of Dielectric Resonator Antenna (DRA)

Puneet Kaur, Sonia Goyal

***Abstract*— Dielectric Resonator Antenna (DRA) is one of the most imperative antennas used extensively in wireless communication. The spherical dielectric resonator antenna (DRA) is investigated first time. With an optimum combination of radius and permittivity, a maximum bandwidth is attained. The proposed spherical DRA is resonated at frequency of 3.75 GHz. In this paper, proposed spherical DRA with annular feed ring loading resonates at multiple frequencies with gain and bandwidth enhancement. The dielectric resonator antenna (DRA) is shape independent. The spherical DRA is also characterized by simple manufacturing and compact size.**

***Index Terms*— annular feed ring, Dielectric Resonator Antenna (DRA), impedance bandwidth, infinite ground plane, isotropic antenna, radiation pattern.**

I. Introduction

The antenna is defined as "a mean for radiating or receiving radio waves" efficiently with least amount of loss of signals. DRA is extensively used in wireless communication. Dielectric Resonator Antenna (DRA) is a radio antenna mostly used at microwave and millimeter frequencies that consists a block of ceramic material [1]. The dielectric resonator is mounted on a metal surface or also known as ground plane. Radio waves are introduced inside the resonator material from the transmitter circuit and bounce back and forth between the resonator walls, forming standing waves. The walls of the resonator are partially transparent to radio waves, allowing the radio power to radiate into space.
An advantage of dielectric resonator antennas is they lack metal parts, which become lossy at high frequencies, dissipating energy. So these antennas can have lower losses and be more efficient than metal antennas at high microwave and millimeter wave frequencies.

The rise in demand for portable devices and wireless communication has led to increase in the compact and small size antenna designs. The attractive features of Dielectric Resonator Antenna (DRA) are small in size, less in weight, low loss, ease of excitation, high radiation efficiency, intrinsic mechanical simplicity, wide bandwidth, less conductor loss, and no surface-wave loss.[2]-[5]. Although there are various approaches to the improvement of bandwidth found in literature, many of them involve modifications of the DRA structure. The different bandwidth enhancement techniques includes the reduction of Q-factor by loading effect, employment of matching networks, the use of multiple resonators [6]. Thus, makes DRA effective in use of communication.

The shapes of the DRA antenna can be spherical, circular, rectangular, hemispherical, and elliptical, and tetrahedron that are illustrated for the enhancement of various antenna design properties. The design parameters of the shapes of DRA are length, width, radius, height, aspect ratio. These design parameters can be optimized to make the antenna efficient in use.

A number of excitation methods have been developed. The different coupling schemes used for the exciting the antenna are the coaxial probe, aperture coupling with a microstrip feedline, co-planar feed, direct microstrip feedline, slot line, strip line, conformal strip, waveguide probe, soldered through probe.

This paper presents the designing of spherical dielectric resonator antenna using Ansoft's High Frequency Simulated Structure (HFSS) software. The paper is organized as follows: The recent work is presented in section II. Section III describes problem formulation. The proposed design of the antenna is presented in Section IV. Simulations results and discussions are described in section V. Finally, the conclusion is given in section VI.

II. Related Works

This section is a literature review of published studies about designing and optimization of dielectric resonator antenna (DRA). The Dielectric Resonator Antenna (DRA) was first proposed by R.D. Richtmyer [1]. In 1975, Stuart A. Long, [3] proposed the Quasi-Isotropic coverage. In this the combination of linear and slot antenna was fabricated to obtain the isotropic radiation pattern. In 2010, Ivana Radnovic[4] developed a new type of turnstile antenna by feeding two orthogonal dipoles in phase quadrature. A balun was accomplished with lumped parameters to make the structure symmetrical. In this type of antenna high gain and omnidirectional radiation pattern was obtained. In 2011, Adam P. Huynh [6] investigated probe-fed cylindrical DRA. By varying permittivity and aspect ratio, maximum impedance bandwidth and radiation pattern was attained and infinite ground plane was used. A study on the effects of dielectric loss on the bandwidth was attained. Various

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Puneet Kaur
Department of Electronics and Communication Engineering, Punjabi University, Patiala, India.
Sonia Goyal
Department of Electronics and Communication Engineering, Punjabi University, Patiala, India.

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approaches to the improvement of bandwidth and modification of DRA structure are found in the literature. There were two techniques to be investigated. One technique was to use external matching network such as matching stub, quarter-wave transformers or impedance matching networks. Another technique was to lower the inherent Q-factor of the resonator since the Q-factor is inversely proportional to the impendence bandwidth. Due to this maximum impedance bandwidth was attainable by varying these parameters. In 2011, Zhijun Zhang [7] proposed a conformal switchable antenna system mounted on a cylindrical surface. In this a number of discrete antennas arrayed along the circumference of the cylinder were used to obtain omnidirectional radiation pattern. The low tri-polarization antenna was fabricated to achieve quasi-isotropic pattern. In 2012, Yong Mei Pan [8] investigated the rectangular DRA centrally fed by a probe. In this SMA connector had a square flange acting as the small ground plane of the antenna. In this we observed that if large ground plane is used it destroyed the antenna so by using small flange of a SMA connector and design became very compact. In 2014, Yong-Mei Pan [9] investigated the quasi-isotropic dielectric resonator antenna (DRA). A small ground plane was used in this paper which acts as an electric dipole. In this paper the common approaches to obtain the quasi-isotropic antenna was reviewed. One approach was to array a number of discrete elements like tri-polarization antenna and another approach was by using turnstile antenna. The choke was connected to suppress the stray radiation.
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III. Problem Formulation

Single band antenna supports only one frequency band of wireless standards and these days multiple frequency bands of wireless standards are supported by the devices. So they employ several antennas for each frequency. This leads to large area requirement in handheld devices. So, an antenna which supports almost all wireless standards is the need of today. The specifications which an antenna must have are multiband support for handheld devices, compact sized antenna, high gain and bandwidth, easy to design, and fabricate.

IV. Design Consideration of Antenna

A. *Geometry Design Details*

Fig.1 (a) shows the configuration of the spherical DRA with a radius of spherical cavity r1 and spherical DRA r2. The DRA is centrally fed by an annular feed ring of outer radius 6.8mm, inner radius 4.8mm and is mounted on an infinite ground plane. An annular feed ring spherical DRA is designed at 3.75 GHz using Ansoft HFSS. The DRA has a dielectric constant of $\varepsilon_r = 9.5$ and dimensions are given in table 1. Fig.1 (b) shows the top most view of the designed spherical DRA

Table I Proposed design considerations

Parameters		Dimension
DRA size	Spherical cavity	25mm
	Spherical DRA	13mm
Annular Feed ring	Outer radius	6.8mm
	Inner radius	4.8mm
Feed gap	Thickness	2mm
Air volume	Radius	30mm
	Height	35mm
Permittivity	ε_r	9.5

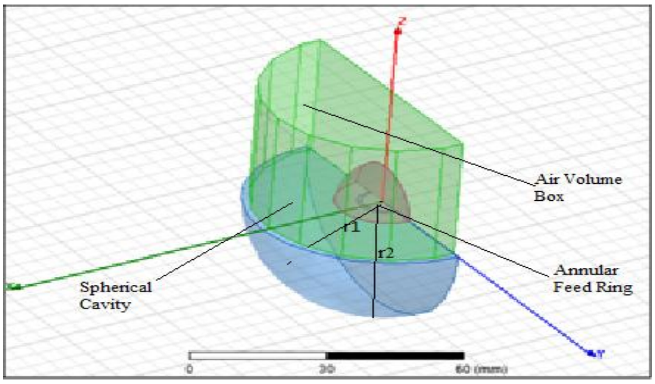

Fig 1 (a) Side view of the geometry

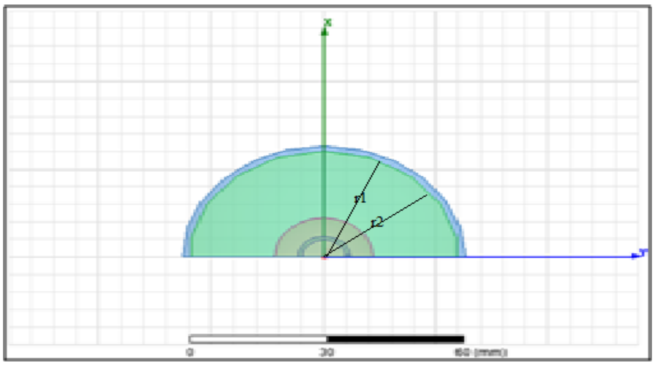

Fig.1 (b) Top view of the geometry

V. Simulations Results and Discussions

The value of relative permittivity is chosen on the basis of conditions of dielectric constant material. The design parameters are optimized for spherical DRA to attain the good results. Fig. 2 shows the return loss (S_{11}) characteristics of proposed DRA.

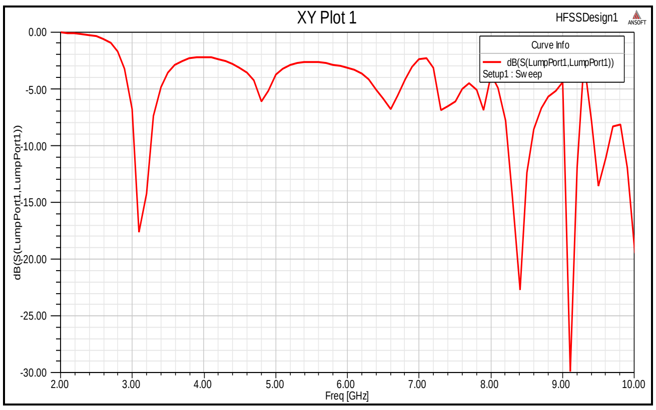

Fig. 2 Return loss (S11) characteristics of proposed spherical DRA radius r1=28mm and r2=12mm.

The proposed DRA structure resonates at f_r = 3.75 GHz with return loss of -30.98 dB and gain of 5.683 dBi. The simulation shows the impedance bandwidth (S_{11} < -10dB) around 3.33GHz and close resonance at 3.75GHz. The return loss (S_{11}) is as a function of frequency. The values of antenna parameters (such as gain, return loss and number of resonant frequencies) are achieved by varying the radius. The proposed antenna has a bandwidth ranging from 3GHz to 3.5 GHz.

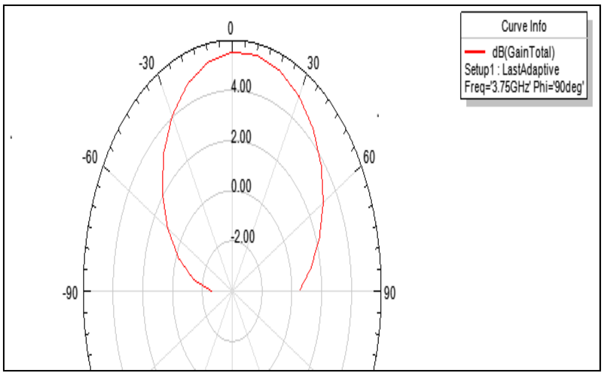

Fig. 3 Radiation pattern for theta = "90 degree"

The radiation pattern of proposed DRA for "90 degree" is shown in fig. 3 respectively. The gain plots of proposed DRA with varying radius are shown in fig. 4 and fig. 5. The achievable gain of proposed antenna is 5.68dBi.

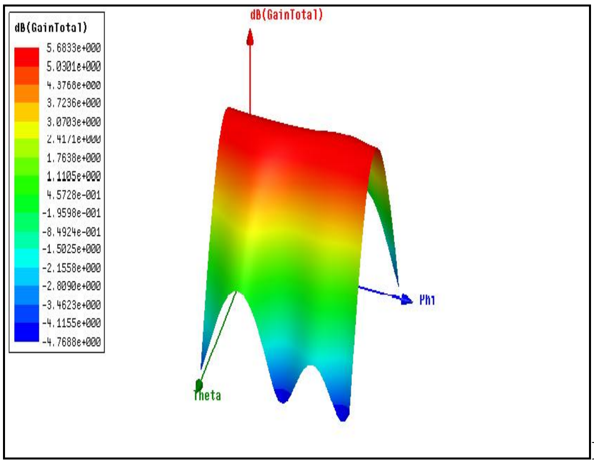

Fig. 4 Illustrative the 3-D view of radiation pattern for total gain (3-D rectangular plot)

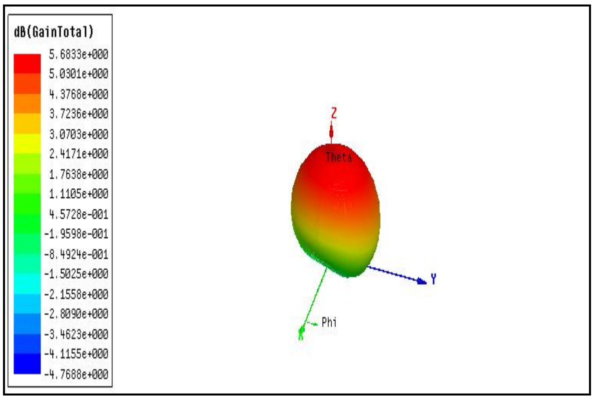

Fig. 5 Illustrative the 3-D view of radiation pattern for total gain (3-D polar plot)

In practical terms, to achieve the best coupling, the spherical DRA must be fabricated from materials having high permittivity but in contrary spherical DRA must have low dielectric constant for wider bandwidth. The application of the Spherical DRA will be greatly enhanced if the dielectric can generate isotropic radiation pattern.

VI. CONCLUSION

The spherical shaped DRA has been proposed and investigated. The proposed antenna is excited by an annular feed gap. The high gain and isotropic radiation pattern is achieved at the resonant frequency of 3.75 GHz. The antenna has good radiation characteristics over the operating bandwidth. Since an infinite ground plane is used, so spherical DRA is very compact in size. The study of the spherical DRA is done to examine the effects of the various design parameters.

It is observed that the other feeding schemes can also be used for the DRA like co-axial, strip-fed etc. Due to these, there can be an increase in the flexibility of the design. As a result, the proposed Spherical DRA is attractive and can be practically used for different wireless applications.

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Puneet Kaur is pursuing M.Tech final year in department of Electronics and Communications Engineering at Punjabi University Patiala. She has done her B.Tech in trade Electronics and Communication Engineering from Department of Electronics and Communication ,Punjabi University Patiala . Her topic of research is Optimization of Design Parameters of Dielectric Resonator Antenna (DRA) using HFSS

Mrs. Sonia Goyal is Assistant Professor at Department of Electronics and Communications Engineering, Punjabi University Patiala. She is pursuing PhD from Punjabi University Patiala. She has to her credit many papers in international journals.