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Design of DRA Using Different Dielectrics

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Abstract— This article presents a comprehensive study of the various structured Dielectric Resonator Antennas (DRAs) and also analyzes the effects generated due to change in material of substrate. Dielectric resonator antennas (DRAs) have received increased attention in various applications due to their attractive features in terms of high radiation efficiency, light weight, small size and low profile. Over last decades, various bandwidth enhancement techniques have been developed for DRAs. In this article, the attention is focused on a two type of DRAs that can almost same frequency 3.5 GHz frequencies and when replace the dielectric material of both antennas by FR4 having dielectric constant 4.4 there is a shift in frequency in antenna and another antenna having large bandwidth.

Keywords— "Backing cavity, Dielectric resonator antenna, Microstrip patch antenna, bandwidth, Resonant Frequency"

I. INTRODUCTION

Keeping with the market demand, the requirements for the antenna design are changing continuously. Today's consumer market demands electronic systems of high efficiency, wide bandwidth and reduced equipment size. Meeting these demands in the RF and wireless domain is a major challenge since it involves design of an antenna to be embedded into wireless products. Over the last two decades two classes of antennas, i.e., the microstrip antenna and the dielectric resonator antenna (DRA) have been under investigation for modem wireless applications. Being high Q antennas, the microstrip antennas, possess narrow bandwidth. To increase the bandwidth, one of the early proposals was to increase the electrical thickness of the substrate. It had two major disadvantages: increasing the surface waves & Ohmic losses and thereby reducing radiation efficiency. While research on microstrip antenna was picking up increasing attention around the globe, in early part of eighties, Stuart Long developed the dielectric resonator antenna (DRA) [1]. The DRA is a resonant antenna, fabricated from a high-permittivity (from about 6 to 100) dielectric material mounted on a ground plane and fed by a coaxial probe, slot

Coupling or a microstrip line in the ground plane, though some low values are being recently explored as antennas [2]. Theoretical and experimental investigations have been carried out with various shapes such as cylindrical, rectangular and hemispherical structure allowing for flexibility in design. The impedance bandwidth for a DRA is a function of material permittivity and aspect ratio (length-to-height ratio) [3]. Higher permittivity can result in size reduction, whereas lower permittivity can broaden the bandwidth. Most of the previous work focused on characterizing the basic properties of DRA for varieties of simple shapes and feed configurations. Also much effort has been put into investigations on linearly polarized wideband DRAs [4].

Since 1970's, dielectric resonators helped achieving the miniaturization of active and passive microwave components, such as oscillators and filters [5, 6]. In a shielded environment, the resonators build with DRs can reach the unloaded Q factor of 20,000 at frequencies between 2 and 20 GHz. The principle of operation of the dielectric resonator can best be understood by studying the propagation of electromagnetic waves on a dielectric rod waveguide. The mathematical description [7] and the experimental verification [8] of the existence of these waves has been known for a long time. When a dielectric resonator is not entirely enclosed by a conductive boundary, it can radiate, and so it becomes an antenna. DR antenna was successfully built and described in [9], while the rigorous numerical solution was published in [10]. Review treatments of DR antennas can be found in [11], [12] and [13].

II. PERFORMANCE OF DRA IN COMPARISON WITH MSA

At mm-wave, the DRA offers advantages like smaller size than conventional antennas by a factor of square root of the dielectric constant of the material (εr), high radiation efficiency (> 95%) due to absence of conductor or surface wave losses, increased bandwidth, low cost and compatibility to planar antenna feeding techniques. Compared to the microstrip antenna, the DRA has wider impedance bandwidth. For a simple rectangular DRA, a bandwidth of 10% can be achieved for a dielectric constant of 10 or less [1]. The microstrip antenna radiates through two narrow edges of the patch whereas the DRA radiates through its entire surface except the grounded portion. Surface waves are absent in the DRA in contrast to the microstrip antenna [4] improving the efficiency and reducing distortions in the radiation pattern.

III. DRA DESIGN

In this work firstly we designed a DR antenna suggested by K.K. So and K.W. Leung [14]. They designed an annular-slot excited hemispherical Dielectric Resonator Antenna whose substrate was made up of (εr= 9.5) with a backing cavity, excited in the fundamental broadside TE." mode. The antenna feed is achieved by coaxial excitation across one side of an annular slot between the cavity and the DRA dielectric. In this DRA the focus is on the behavior of the antenna itself, not its feed. Therefore, the model will feed with a lumped port across an annular slot. The design's operating frequency is 3.5 GHz. The S11 parameter, VSWR and corresponding gain is show in figure 2, figure 3 and figure 4 respectively. In the second stage we replace the dielectric material with FR4 and analyze the effect of change in dielectric on parameters of antenna. The S11 parameter, VSWR and gain is show in figure 5, figure 6 and figure 7 respectively. Another antenna is designed at 3.6 GHz having a shape of hemispherical. The antenna configuration is shown in Fig 1.

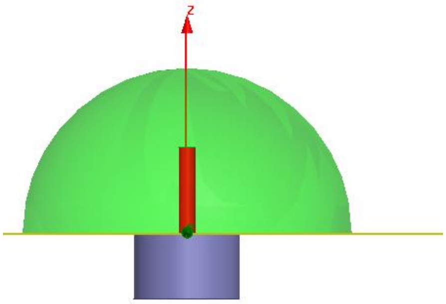


Fig. 1 Design of hemispherical DRA

The DR of radius a is fed a probe of length L and radius r1 located at a displacement b from the center. The outer radius of the coaxial aperture is r2. To measure the displaced probe case b > 0, a dielectric hemisphere of effective radius 12.5 mm (height 12.3 mm and base radius 12.8 mm) and dielectric constant εr = 9.8 was used. A coaxial probe of diameter 1.25 mm and length 6.5 mm penetrated the DR with displacement b = 6.4 mm. For the case of a center fed probe, a dielectric hemisphere of effective radius 11.5 mm (height 11.2 mm and base radius 11.9 mm) and dielectric constant εr = 9.8 was measured. A coaxial probe of diameter 1.25 mm and length 4.5 mm penetrated the center of the dielectric hemisphere (b = 0). In both cases, the ground plane was a 60 cm square copper plate. Similarly again we replace the dielectric by FR4 and analyze the effect of change in dielectric on parameters of antenna. And finally compare all the results and made conclusion. The S11 parameter, VSWR and corresponding gain of design 2 is show in figure 8, figure 9 and figure 10 respectively. Results of modified antenna design like S11 parameter, VSWR and gain is show in figure 11, figure 12 and figure 13 respectively.

IV. RESULTS

By seeing the above graphs we can analyze the results of our work. Here in table 1 we summarize all the results.

By above table we find that in type-1 design if we are reducing the value of dielectric constant from 9.8 to 4.4 the resonant frequency has been shifted at 9 GHz from 3.5 GHz and there are one more notch at 5.25 GHz frequency so it become multiband antenna. Gain of the system is increased from 5.3 to 6.4 dB.

Similarly in type-2 design if we are reducing the value of dielectric constant from 9.8 to 4.4 the resonant frequency has been shifted at 5.6 GHz from 3.6 GHz and if we see Fig 5.10 carefully the curve goes down -10 db return loss at frequency 5.18 GHz and goes up at frequency 6.15 GHz. So here we are getting 1.07 GHz band. Hence this antenna can be work as wide band antenna. There is a drastic increment in the gain of the system gain was increased from 1.2 dB to 4 dB.

TABLE I
ANALYSIS OF RESULTS

Parameters of Antenna	Design Type-1 (ε_r=9.8)	Design Type-1 (ε_r=4.4)	Design Type-2 (ε_r=9.8)	Design Type-2 (ε_r=4.4)
Resonant Frequency	3.5 GHz	5.25 GHz / 9 GHz	3.6 GHz	5.6 GHz
VSWR	1.09	1.09	0.10	1.02
Gain (dB)	5.307	6.446	1.247	4 dB

Results of Antenna 1

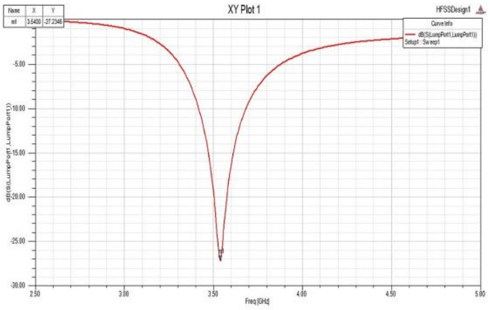


Fig. 2 S11 parameter of antenna design 1

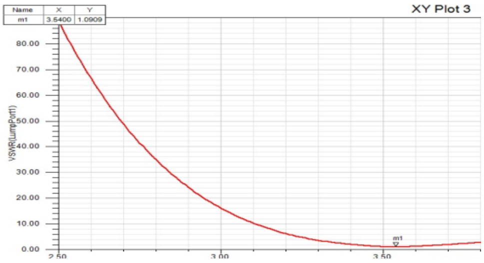


Fig. 3 VSWR of antenna design 1

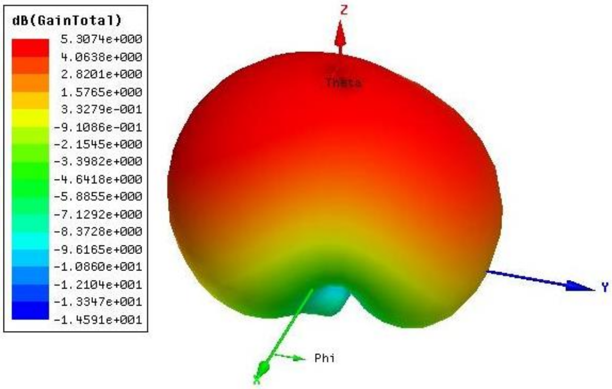


Fig. 4 Gain of antenna design 1

Results of antenna 1 when it is replaced by FR4 substrate

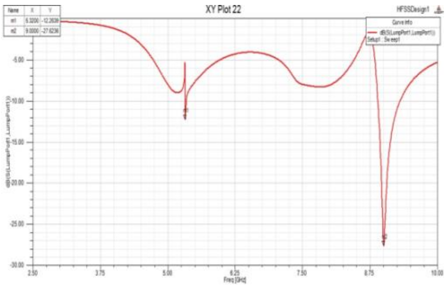


Fig. 5 S11 parameter of antenna design 1with FR4

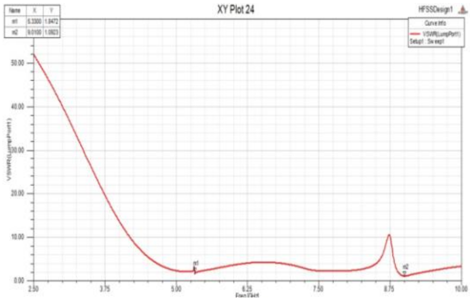


Fig. 6 VSWR of antenna design 1with FR4

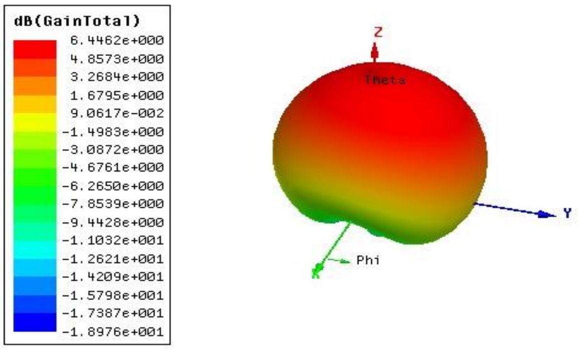


Fig. 7 Gain of antenna design 1 with FR4

Results of antenna 2

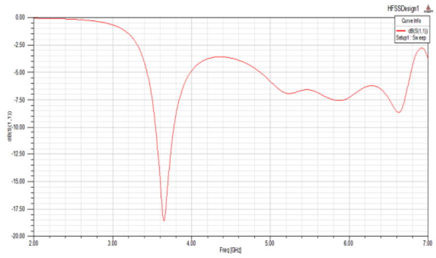


Fig. 8 S11 parameter of antenna design 2

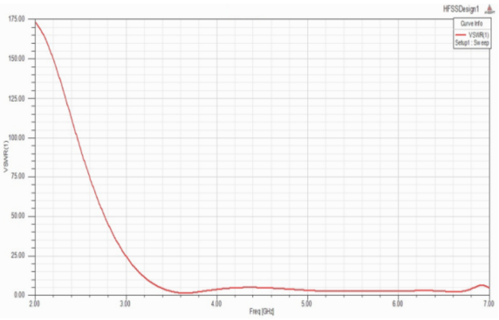


Fig. 9 VSWR of antenna design 2

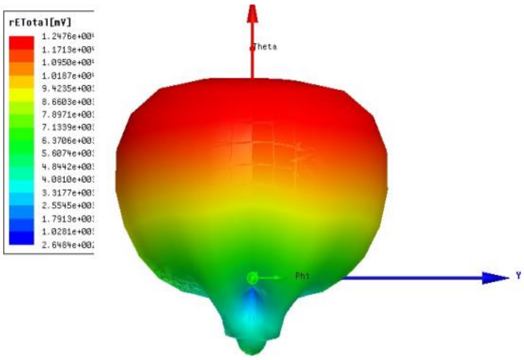
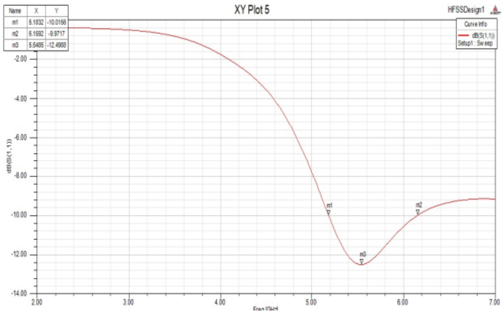


Fig. 10 Gain of antenna design 1

Result of antenna 2 when substrate replaced by FR4



Name	X	Y
m1	5.1832	-10.0156
m2	6.1592	-9.9717
m3	5.5486	-12.4988

Fig. 11 S11 parameter of antenna design 2 with FR4

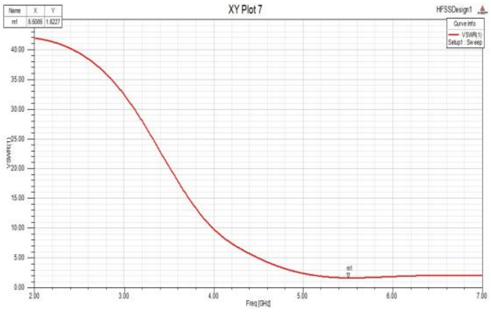


Fig. 12 VSWR of antenna design 2 with FR4

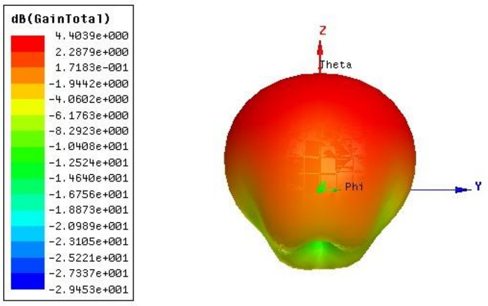


Fig. 13 Gain of antenna design 2 with FR4

V. CONCLUSION

In this research work we compare two DRA antennas with and without changing the dielectric substrate. Here we conclude that if we moves at the higher dielectric constant material the frequency band and bandwidth shift towards lower end. And if we move at lower frequency band we get high resonant frequency some times larger bandwidth and high gain. Here we made compare only in between two antennas and replace only one dielectric material but in future we can do the same experiment with a large number of dielectric materials so that we can put our results very strongly and understand the behaviour of DRA.

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