Design and Analysis of Liquid Based Dielectric Resonator Antenna for Wireless Application

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Abstract- *A combine DRA structure of two liquids within two corresponding cylindrical shells is designed by using a probe feed and is also investigated its performance with the help of CST microwave studio. Different cylindrical DRAs are analysed and it's results are also observed. A proposed scheme is involved where different dielectric materials are combined in concentric cylinders to obtain higher bandwidth for better size miniaturization. The effect of liquid height and the effect of probe feed position within the DRA on the characteristics of the antenna performance are also studied. Combining materials having different dielectric constant values, the effective bandwidth of the overall antenna is increases. By altering the level of liquid in the DRA the proposed antenna might be used at multiple frequencies and hence the antenna is tuned to a particular frequency as well as resonant frequency. The proposed DRA is liquid based, the operating frequency is varied by changing the level of liquid, during tunability, if feeding is provided at one liquid column, the operating frequency is adjusted by changing the liquid level of the other liquid column. This structure provides reliability into impedance matching and can prove to be more useful.*

Index term- Liquid dielectric resonator, concentric cylinder, Probe feed, tuning the liquid level.

1. Introduction

As stated earlier, DRA offer a lot of attractive features over microstrip patch antennas in terms of structure simplicity, flexibility in feeding mechanism, low losses and high radiation efficiency. Not only that, antennas with wider bandwidth and multiband are in huge demand at this moment in the market [1][2]. In the recent past, a lot of research is done in developing several techniques to increase the bandwidth, obtain multiband and reduce the volume of the antenna and there has been an ever increasing demand for such antenna configuration in the market. This has been a key motivating factor into development of this project. Dielectric resonator antennas (DRA) can be easily employed to attain higher bandwidth and an array DRA structure can be employed to be used for multiband operations [3]. Added to that, high value of dielectric constant automatically results in miniaturization of the antenna size [4]. Being miniaturized size, lighter weight and low profile, which are considered to be good characteristics of an antenna, DRA are already a step ahead of the conventionally available metallic antennas [5].

Liquid dielectric materials offer higher values of dielectric constant than solid DRA materials. So design of an antenna made of such liquid would reduce the size of the antenna significantly [4]. Moreover, liquid have no fixed shape so tunability of the resonant frequency of the antenna might be easily achieved by adjusting the height of the liquid column [6]. Hence the objective of the project will be to Design a DRA of simplified geometrical structure, Study the dimensions of the DRA with different liquid, Combine two liquids to form a single DRA with wider bandwidth, Construct an array structure for multiband operation [7]. For this purpose, a simple discrete port feeding is employed in this structure. The only thing that has to be kept in mind is to place the height and width of the port such that it is matched with the reference 50 Ω impedance.

By analysis of the different cylindrical DRA, the bandwidth is not enhanced as it is desired. So, a new proposed scheme is involved in this paper where different dielectric materials are combined in concentric cylinders to obtain higher bandwidth keeping in mind the property of size miniaturization. From the proposed scheme results, it is clear that the given antenna has got a wide bandwidth of 1.5 GHz and hence it is applicable for simple WiFi applications like in router antennas. Moreover the antenna can tuned to different centre frequency that can enhance the system performance further.

2. Liquid Based Antenna Design

Initially, a comparison is done between the dimensions of cylindrical DRAs made of different materials. The materials that are being used are glass, glycerine, salt water and distilled water [8].

. It is known that the free space wavelength of the propagating wave can be calculated using the formula [9].

$$\lambda = \frac{c}{f} \quad \text{(i)}$$

Where c = speed of light in vacuum, f = propagating wave frequency and λ = free space wavelength of the propagating wave [9].

$$\lambda_0 = \frac{\lambda}{\sqrt{\varepsilon_r}} \quad \text{(ii)}$$

Where λ_0 = the device wavelength of the propagating wave, λ = free space wavelength of the propagating wave and ε_r = dielectric constant of the antenna.

The radius is kept fixed by using equation (i) and (ii). The height of the liquid column is then adjusted to maintain a fix resonating frequency that is desired. The feeding is provided at the centre with a probe thickness of 1 mm x 1 mm. this feed is chosen to maintain simplicity of the design. The different views of the antenna structure along with its dimensions are shown in the diagram below.

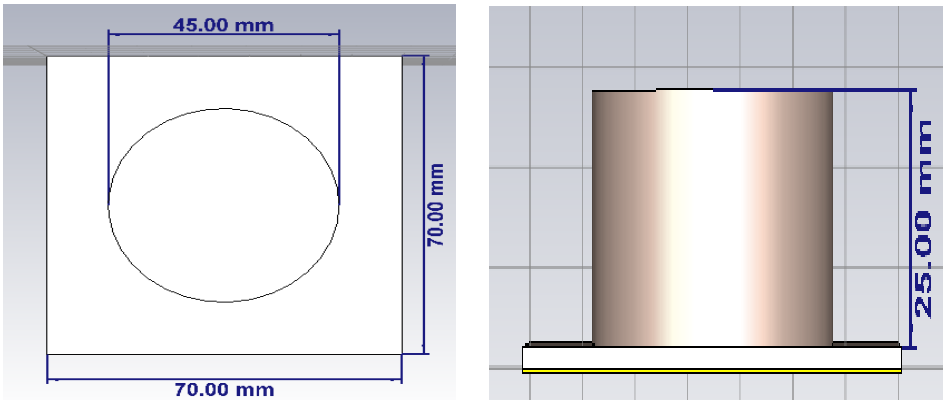

Figure 1: Top View and Side View of the Cylindrical DRA Made of Glass

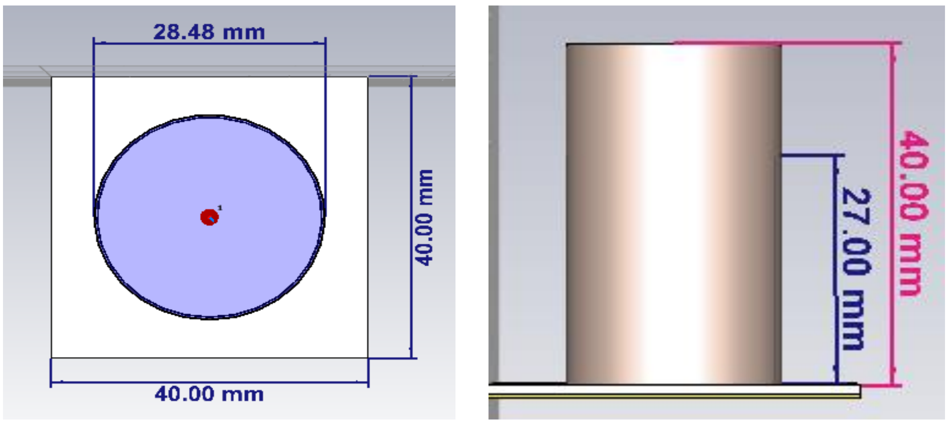

Figure 2: Top View and Side View of the Cylindrical DRA Made of Glycerine

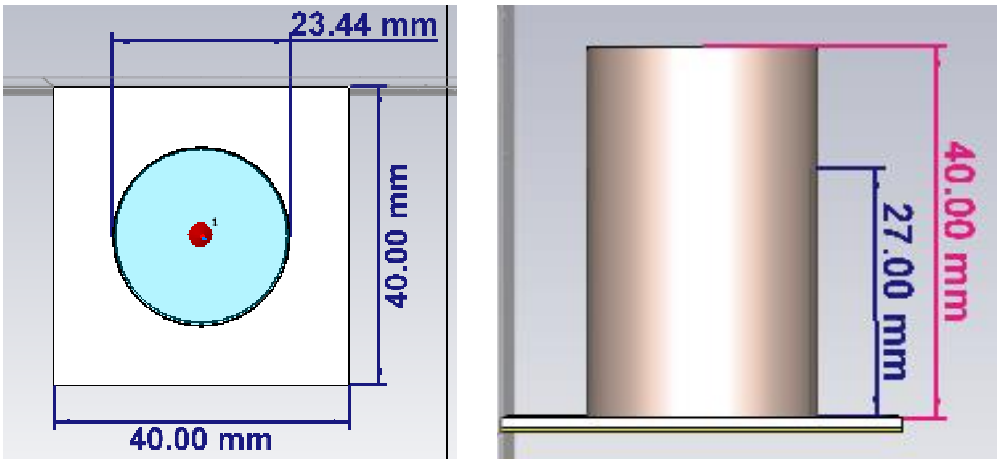

Figure 3: Top View and Side View of the Cylindrical DRA Made of Salt Water

The table given below compares the dimensions of cylindrical DRA made out of different materials along with their central frequency, dielectric constant value and bandwidth obtained.

Table 1: Comparison of Performance of Cylindrical DRA Made of Different Materials

Material used	Operating frequency (in GHz)	Dielectric constant	DRA dimensions (in mm)	Bandwidth (in GHZ)
Glass	5.8	4.8	Diameter = 45, height = 25	0.7
Glycerine	2.2	50	Diameter = 28.28, height = 40	0.1
Salt water	2.7	74	Diameter = 23.24, height = 27	1

3. Proposed Structure

It is seen that by combining materials of different dielectric constant values, the effective bandwidth of the overall antenna increases. Since the DRA is liquid based, the operating frequency is varied by changing the level of liquid. Moreover, during tunability, if feeding is provided at one liquid column, the operating frequency is adjusted by changing the liquid level of the other liquid column [6]. This provides reliability into impedance matching and can prove to be more useful. The feeding is provided at the centre to provide design simplicity.

The proposed structure is shown in the diagram along with its dimensions in different view.

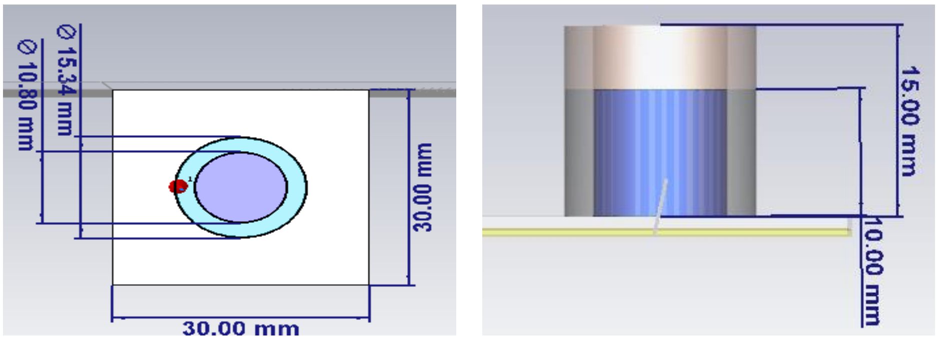

Figure 4: Top View of the Proposed Structure

4. Result and Discussion

In CST microwave studio, the proposed dielectric resonator antenna is simulated and its corresponding results are mentioned below. the s – parameter and the radiation pattern of the all single cylindrical structure designs using the materials glass, glycerine and salt water are now compared shown in the figure 5,6,7.

The S – parameter for glass, glycerine and salt water is obtained. The resonating frequencies are 5.8 GHz, 2.2 GHz and 2.7 GHz respectively. The dimension are to be compared and it is seen that the size is miniaturized according to the increasing dielectric constant values. The radiation pattern of glass, glycerine and salt water are obtained. It is seen that the antenna attain towards a perfect dipole characteristics as the value of dielectric constant increases.

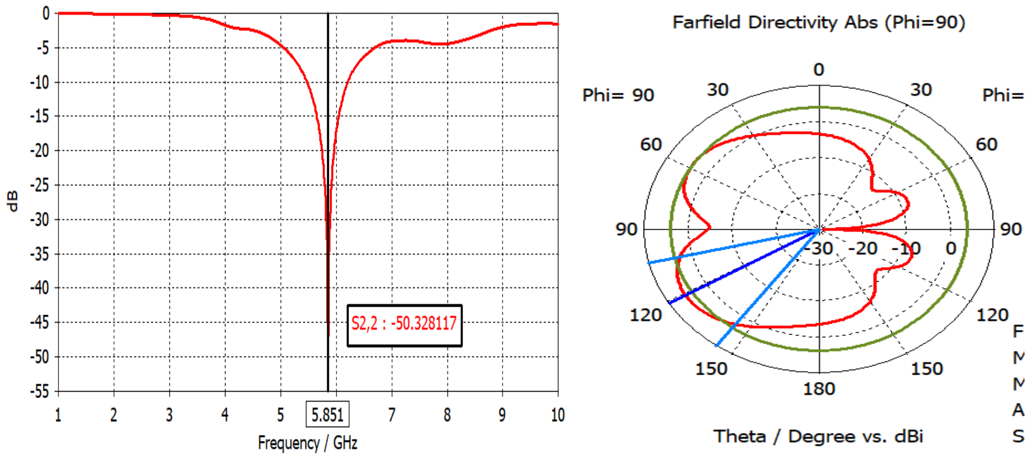

Figure 5: Return Loss and Radiation Pattern Plot for Cylindrical DRA Made of Glass

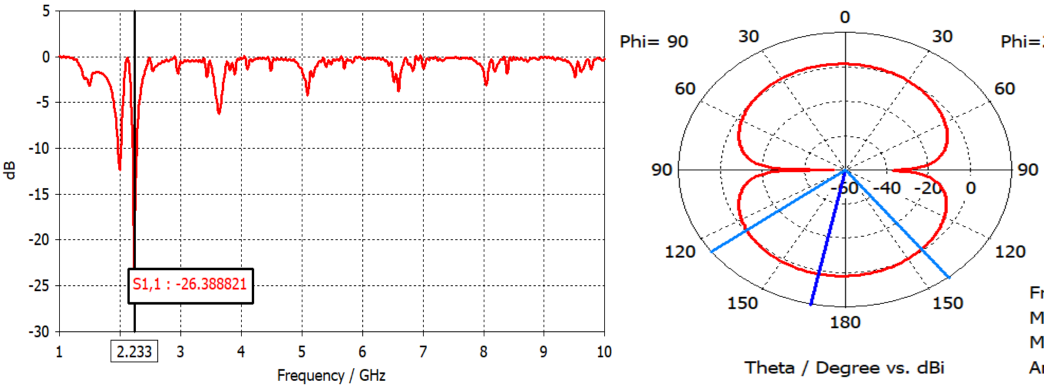

Figure 6: Return Loss and Radiation Pattern Plot for Cylindrical DRA Made of Glycerine

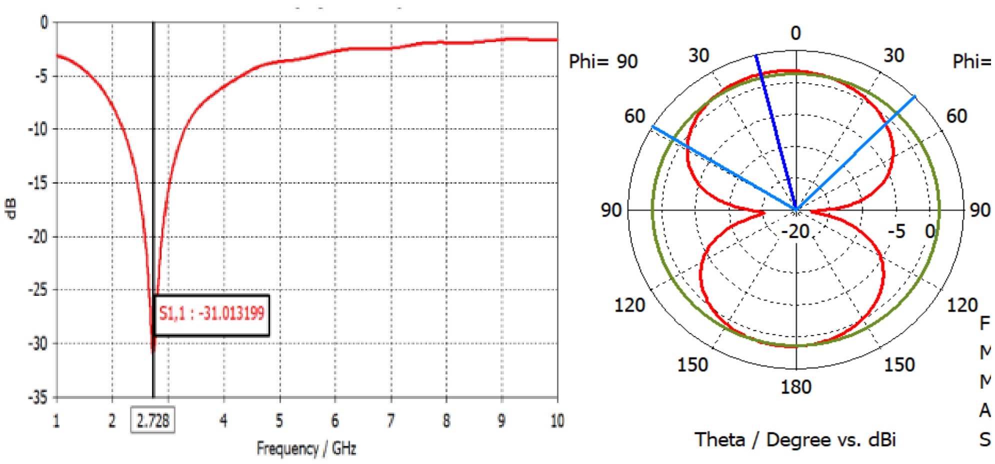

Figure 7: Return Loss and Radiation Pattern Plot for Cylindrical DRA Made of Salt Water

The s – parameter of the proposed DRA where different dielectric materials are combined in concentric cylinders is also evaluated with the CST microwave suite shown in figure 8. Here, it is seen that the bandwidth obtained is around 1.5 GHz which is higher than the previous case.

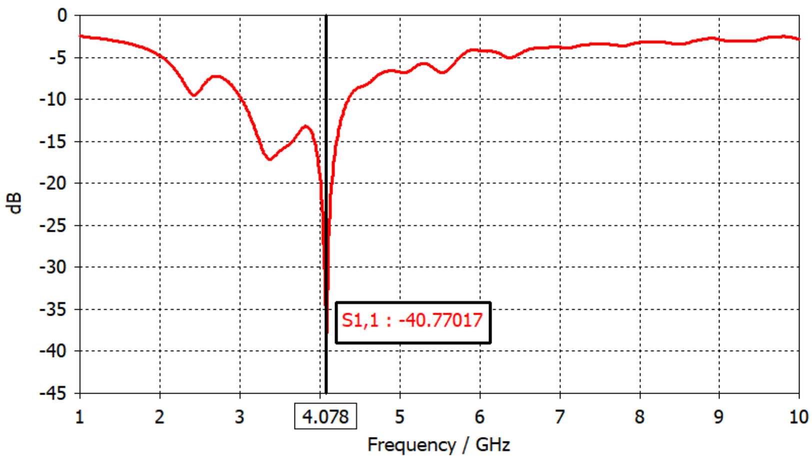

Figure 8: Plot of Return Loss Vs. Frequency of the Proposed Structure

As discussed earlier, the resonant frequency varies as the liquid level is altered. Theoretically, the frequency should increase as the liquid column height is decreased and vice versa [6]. This means that liquid height is in inverse proportion with the operating frequency. This is one major advantage of liquid over solid and compact DRA. However, it is known that the electric losses associated with liquid are high as compared to compact DRAs.

Keeping all this criteria in mind, the tuning property of the liquid based DRA is investigated. The dimensions associated with the design and its corresponding results are discussed in the table 2 below.

Table 2: Change in the Central Frequency by Altering the Height of Glycerine.

Height of glycerin (in mm)	Central frequency (in GHz)

8	4.4
9	4.2
10	4.0
11	3.8
12	3.6
13	3.4
14	3.2

From the S – parameter of the proposed DRA where different dielectric materials are combined in concentric cylinders in which the liquid level is altered is seen in the figure 9. The resonating frequency is altered as the liquid level changes. Here, only three heights are taken for evaluation so that the graph does not look messy.

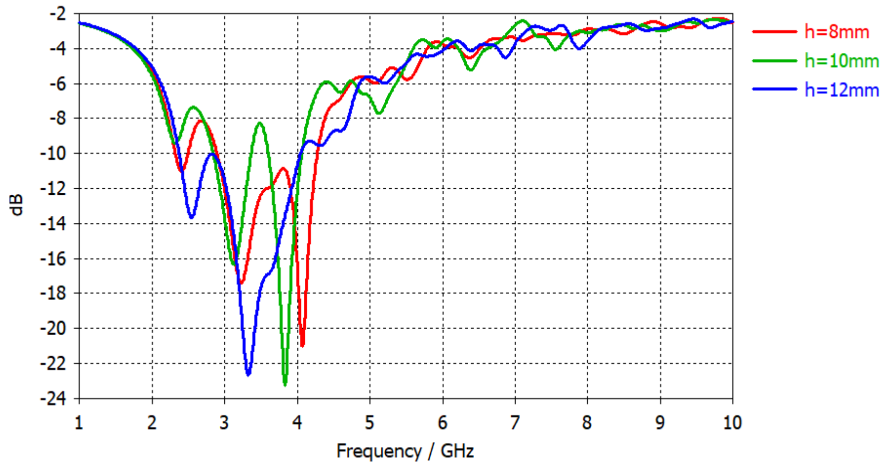

Figure 9: Plot of Return Loss Vs. Frequency for Different Height of Glycerine

The software simulated gain is as detailed in figure 10. The proposed DRA antenna where different dielectric materials are combined in concentric cylinders gives the maximum gain around the frequency 5.5 GHZ as detailed in figure 10.The maximum simulated gain is 5.7 dB found at frequency 5.5 GHz.

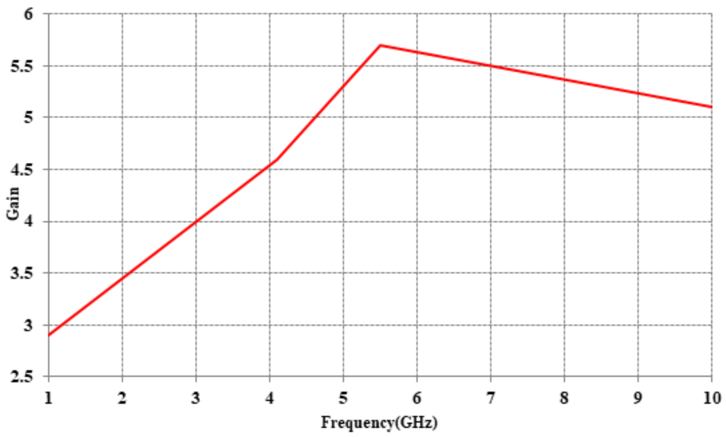

Figure 10: Plot of Directivity Vs Frequency of the Proposed Structure

The simulated radiation pattern is as detailed in figure 11. The radiation pattern obtained tells us that the antenna is structured very well for wiFi and WiMAX applications.

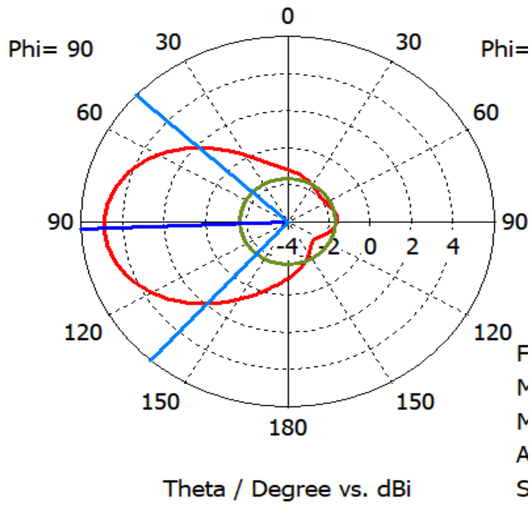

Figure 11: Polar Plot of the Proposed Structure

5. Conclusion

Different cylindrical DRAs are analysed and it's results are also observed. A combine DRA structure of two liquids is investigated where different dielectric materials are used in concentric cylinders to obtain higher bandwidth for better size miniaturization. The effect of liquid height and the effect of probe feed position within the DRA on the characteristics of the antenna performance are also studied. Combining materials of different dielectric constant values, the effective bandwidth of the overall antenna is increases. From the above simulated results, it is clear that the given antenna has got a wide bandwidth of 1.5 GHz. The results of the proposed work demonstrate that the antenna is readily tuned across a bandwidth of 40% in use of a single probe of fixed length. Varying the probe length over a greater range would clearly extend the results. This approach will of course only be suitable for the transmission or reception of narrow band signals and also can be used for simple WiFi applications like in router antennas. Moreover the antenna can tuned to different centre frequency that can enhance the system performance further.

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