Design and Simulation of Rectangular Dielectric Resonator Antenna for UWB Application

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Abstract— An objective of the paper is to optimize the parameters, and simulation analysis of rectangular dielectric resonator antenna (RDRA). In this paper, a rectangular dielectric resonator antenna is presented using relatively low dielectric constant material and single microstrip patch. The rectangular DRA is fed with a modified stepped microstrip feed to ensure efficient coupling between the RDRA and the feeder. The performance of the proposed antenna has been significantly improved by loading the RDRA with two narrow conducting metallic strips of suitable widths, which results in dual-resonance excitation and leads to a wider operating bandwidth (3.569-9.236 GHZ). The frequency characteristics and radiation performance of the proposed antenna are successfully optimized. Design and simulation results are in excellent agreement.

Key words: Rectangular dielectric resonator antenna, Metallic strip, Ultra-Wide band.

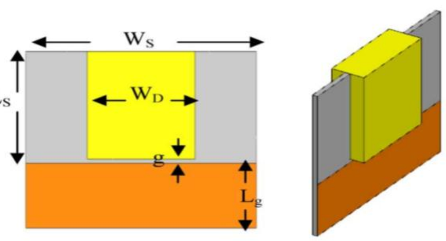
I. INTRODUCTION

The present day technology demands continuing growth in electronic systems operating in the RF and microwave spectrum. These systems are designed to provide high efficiency, wide bandwidth and reduced equipment size. Recent advances in wireless communications has resulted in development of antennas that can be embedded into wireless products. Since the last two decades two classes of antennas i.e., the microstrip patch antenna and the dielectric resonator antenna have been under investigation for modem wireless applications.

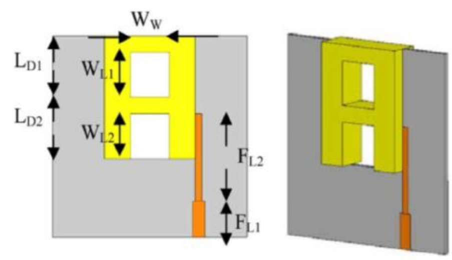
In the early 1980's, Prof. Stuart Long developed the dielectric resonator antenna(DRA). The DRA is a resonant antenna, fabricated from a high-permittivity dielectric ceramic material mounted on a ground plane and fed by a coaxial probe, slot coupling or a microstrip line in the ground plane. Different geometries of the DRA such as rectangular, cylindrical, hemispherical, circular, triangular etc. are possible. Microstrip line offers the advantage of easy and cost-effective fabrication of DRA. It is a disadvantage that polarization of the array is dictated by the orientation of the microstrip line. Moreover, this excitation scheme may also generate surface waves in the dielectric substrate which is highly undesirable. Dielectric resonator antenna is an excellent radiator as it has negligible metallic loss. It offers advantages such as small size, wide bandwidth, low cost and compatibility with the existing feeding techniques when operated at millimeter wave frequencies.

II. DESIGN AND GEOMETRY OF RDRA USING METALLIC STRIP

A lot of research has been reported on bandwidth enhancement in DRAs. It's always good to have wideband response instead or narrow band because a wideband antenna covers more frequency range in a spectrum. Many bands like cellular, GPS, etc. can be covered in just one band and that is called wideband. It is also important to have wideband antennas for high data transfer rate communication applications. Due to losses or mismatch present between the transmitter and receiver antennas, if some percent band of the total bandwidth is lost, then also we can extract the information at the receiver end due to wideband antenna. It is noticed that stacking and embedding of different dielectric materials gives more bandwidth but it makes the DRA more complicated to fabricate. In they investigated stacked and embedded DRAs and they came out with a conclusion that the stacked and embedded DRA has up to 68.1% of matching bandwidth compared to 21.0% for a homogenous DRA. The resonant frequency and size is same for the comparison the largest bandwidth was achieved with the embedded stacked geometry. While the homogeneous DRA yielded only a single resonance within the frequency range of interest, both stacked and core-plug embedded DRA geometries yielded two, and the embedded stacked DRA geometry yielded three which were reasonably well matched. In recent years, the demand for wideband antennas for wireless mobile communications has led to the development of antennas that are low profile and small in size. In the last two decades, microstrip patch antennas and DRAs have been extensively investigated as suitable antennas for wireless applications. The DRA offers attractive features such as low ohmic loss, low profile, small size, and wide impedance bandwidth as compared to the microstrip antenna. Figure 1 shows the geometry of a stepped microstrip feed rectangular DRA. The optimizations of the designed antenna are achieved through simulations using a commercial 3D full-wave analysis software package CST Microwave Studio Suit 2014.



(b)



(d)

Fig. 1 Geometry of the rectangular DR on a vertical ground plane edge: (a) back, (b) isometric, (c) front view of A-shaped and (d) isometric view of A-shaped. [1]

Fig. 1 shows the evolution of the proposed DRA. Fig. 1(a) shows the rectangular DRA excited by a strip feed. DRAs excited by a strip-fed were reported in[16].Some deformations in the E-plane patterns were observed at the upper frequency range of the antenna band because of the asymmetric structure and the higher order modes [16]. Fig. 1(b) shows the rectangular DRA mounted on a vertical ground plane edge. Mounting the DR in this way reduces the total volume of the antenna as compared to the structure in Fig.1(a).The proposed structure provides much wider impedance matching bandwidth. However, this structure shows similar asymmetry with respect to the broadside direction in the E-plane patterns at the upper end of the frequency band as those observed from the structure in Fig. 1(a). The size of the DRA is 14 mm width, 18.3 mm length, and 5.08 mm thickness with a dielectric constant of 10.2, and it is supported by a 30x30mm RT6002 substrate with a dielectric constant of 2.94 and a substrate thickness of 0.762 mm. The ground plane is partially printed on the substrate under the DRA. The size of ground plane is 11x30 mm on one side and a printed probe extends from the micro-strip line of the same width that ends with the 50 line after certain length that is used as a matching transformer of length (Lg-Lf1) . The rest of the antenna parameters are shown in Fig. 2 with Ws=30mm, Wd=14 mm, Ls=19 mm, Ld=18.3 mm, Lg=11 mm, FL1=4 mm,FL2=14.2 mm,Fw1=1.9 Fw2=1mm,g=0.7 mm. The modified geometry has DR with two open tunnels mounted on a vertical ground plane edge. Using the same parameters stated with rectangularDRwithWw=6mm,WL1=WL2=6.7mm,LD1=LD2=9.15mm,FL1=5.12mm,and FL2=13mm .The resonance frequency of TE111 mode of antenna can be determined using the following equations.

$$k_x^2 + k_y^2 + k_z^2 = \varepsilon_r k_0^2$$

$$k_z \tan\left(\frac{k_z H}{2}\right) = \sqrt{(\epsilon_r - 1)k_0^2 - k_z^2}$$

Where$k_x = \frac{\pi}{W}$ and $k_y = \frac{\pi}{L}$

By solving the equations Kz and Ko, The resonance frequency can be obtained from:

$$f_0 = \frac{c}{2\pi} k_0$$

III. SCHEMATIC DESIGN OF RECTANGULAR DRA USING DOUBLE METALLIC STRIP

The schematic design of the proposed low profile RDRA fed with double stepped microstrip line and loaded two metallic strips along with width is shown in Figure 2. With intensive EM simulations, the antenna is designed and optimized using a commercial 3D full-wave analysis software package using CSTMWS 2014. Excitation of RDRA can be done through proximity coupling using microstrip lines. The coupling between a microstrip line and RDRA is capacitive since the DRA is located near the maximum electric field in the microstrip line. In the microstrip scheme of excitation, the level of coupling can be controlled by varying the lateral distance between the RDRA and the microstrip line and the dielectric constant of the DRA material. It has also been found that the coupling decreases with a decrease in the height of the substrate. The metallic strip over the RDRA affects significantly its gain and bandwidth. A metal strip on the RDRA disturbs the shield current and it can change the effective inductance and capacitance of the DRA. A narrow stepped microstrip width resulted in high input impedance, much higher than 50Ω, whereas a wide strip lowered the input impedance of the DRA.

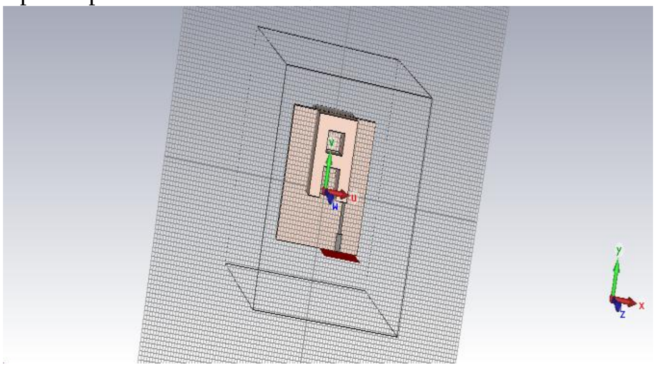


Fig. 2: Schematic design of RDRA using single metallic strip

RESULT OF RDRA

IV. RESULT ANALYSIS AND PERFORMANCE PARAMETER

Simulation result of return loss using stepped microstrip RDRA shown in fig.3. We get the result of stepped microstrip on DRA.

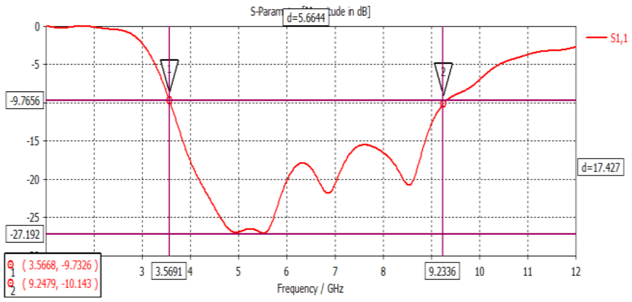


Fig. 3: S-parameter result of RDRA

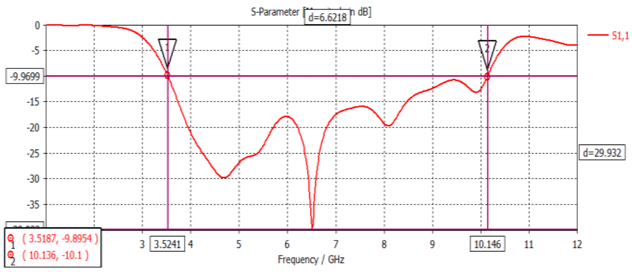


Fig. 4: S-parameter result of A-Shaped RDRA

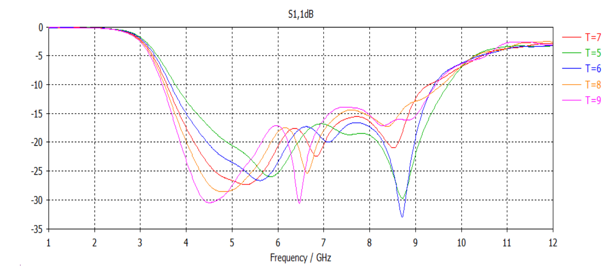


Fig. 5: Parameter Sweeping of S-parameter result of RDRA

Table:-1 S-Parameter Sweeping Result

T (mm)	FREQUENCY RANGE(GHZ)	RETURN LOSS(dB)	BANDWIDTH (GHZ)
5	3.74-9.721	-30.167	5.972
6	3.66-9.42	-33.234	5.763
7	3.59-9.29	-27.625	5.701
8	3.51-9.58	-28.817	6.071
9	3.47-9.46	-30.903	5.985

Simulated return loss characteristic for metallic strips placed along width is shown in fig.4. I. It has impedance bandwidth 6.621GHz (3.526-10.146 GHZ) by using the single strip on DRA along with width. Now creating two tunnels on the DRA (fig.5) and we get the frequency band of 3.5691-9.233 and bandwidth will carried out as 5.664 GHZ. By comparing both the result(fig.4 and fig.5) we get the result by using metallic strip along with length is excellent match. For matching them. Figure.4 illustrates the measured and simulated results, which are in good agreement within the frequency band of interest. A 10 dB return loss over a bandwidth of (3.5691-9.233 GHz) is obtained. We will use parameter x=6 and p=2.for good agreement within the frequency band of interest. It is clear that the height of the RDR affects directly to the resonant frequency which decreases as the RDR height increases. The optimized structure introduces a compact size with gain directly to 4.457db.

V. CONCLUSION

In this paper, a design of a RDRA has been presented. It is fabricated and measured for the validation purposes. In this design, a large bandwidth has been obtained by adding a metallic strip to the RDRA andstepped microstrip for enhancement of the matching, bandwidth, and gain of the proposed antenna. Gain and directivity of the antenna nearly remains unchanged; while the bandwidth significantly increased as strip width decreased. Parametric investigations for different geometrical variables have also been carried out. The obtained results show that the proposed antenna can produce a bandwidth of up to 2GHZ. The radiation patterns are stable over the whole operating frequency range. With this feature, the proposed antennas are suitable for wideband wireless systems at UWB frequency range.

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