Design and Simulation of Compact Wideband Rectangular Dielectric Resonator Antenna for Satellite Applications

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Abstract— An objective of the paper is to optimize the parameters, and simulation analysis of compact wideband rectangular dielectric resonator antenna (RDRA). In this paper, a compact wideband, rectangular dielectric resonator antenna is presented using relatively low dielectric constant material and using double 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 (16.274-18.200 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, Double Metallic strips, Ku-band, CSTMWS 2013

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 DOUBLE 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 2013.

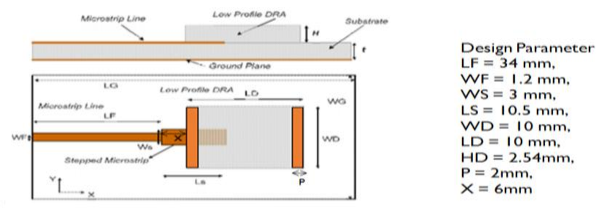

Fig. 1: Double metallic microstrip DRA (Side and Top view) [1]

The geometry of the low profile RDRA (fig.1) is fed with a stepped microstrip line whereas the feeding microstrip has length LF = 34 mm and width WF = 1.2 mm. The feed microstrip line has a 50 Ω characteristic impedance whereas the width and length of the stepped section are WS = 3 mm and LS = 10.5 mm, respectively as shown in Fig. 1. The wide strip in essence provides the necessary impedance matching. The dielectric constants of RDRA and the substrate are chosen to be the same. Figure 1 shows the schematic diagram of the designed antenna with dimensions WD = 10 mm, LD = 10 mm, and HD = 2*1.27 mm. The substrate used for this simulation was Rogers RT 3010 with height of subtract = 1.27 mm and a dielectric constant of = 10.2 which is commonly used. The TE_{111} mode of the resonator is excited.

III. 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 2013. 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.

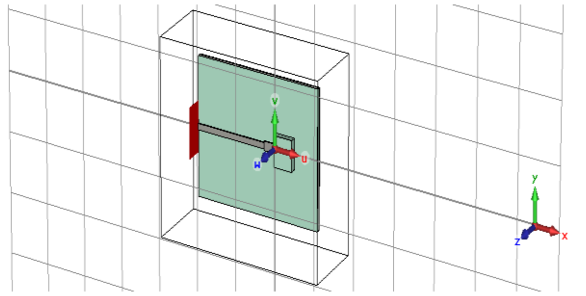

Fig. 2: Design of RDRA using double metallic strip

IV. RESULT ANALYSIS AND PERFORMANCE PARAMETER

EM simulation results are shown in Fig. 3. A 10 dB return loss bandwidth of (8.8 - 9.6 GHz) with a centre frequency of 9.2 GHz is obtained. The difference between the computed and simulated central frequencies is only 0.80% (80 MHz). The optimized structure introduces a compact size with gain up to 6.4 dB, efficiency up to 92 %, and directivity of about 6.6 dB. The resonance frequency of TE_{111} mode of antenna can be determined using the following equations.

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

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

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

By solving the equations K_z and K_o, The resonance frequency can be obtained from:

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

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

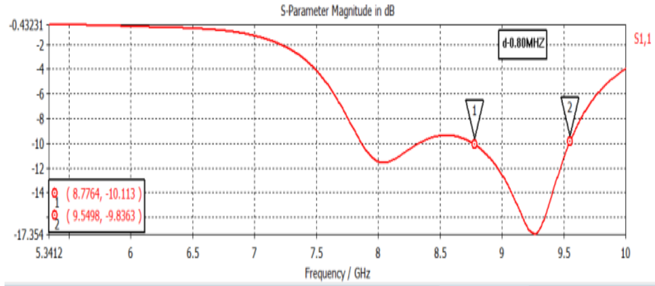

Fig.3: S-parameter result of RDRA using stepped micro strip

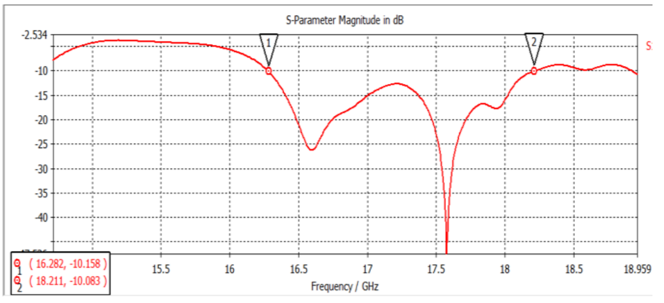

Fig.4: S-parameter result of RDRA using double metallic strip on DRA along with width

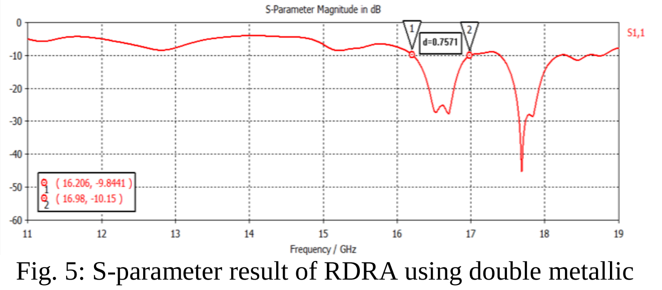

Fig. 5: S-parameter result of RDRA using double metallic strip on DRA along with length

Simulated return loss characteristic for metallic strips placed along width is shown in table 1. It is observed that two modes are excited at 16.666 and 17.660 GHz. It has impedance bandwidth 1.96GHz (16.274-18.201 GHz) by using the double strip on DRA along with width. Now using the double metallic strip along with length (fig.5) and we get the frequency band of 16.224-16.981 and bandwidth will carried out as 0.7572 GHz. By comparing both the results (table.1)

We get the result by using double metallic strip along with length is excellent match. 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 (16.274-18.20 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 6.66dB.

Name Of Antenna Design	Resonant Frequency	Frequency Range	Bandwidth	Efficiency	Gain
RDRA Without Metallic Strips	9.2 GHz	8.8-9.6 GHz	0.80GHz	92%	6.45dB
RDRA With Two Metallic Strips Along With Width	17.5 GHz	16.274-18.200 GHz	1.96 GHz	85%	6.66dB
RDRA With Two Metallic Strips Along with Length	16.5GHz	16.274-16.980 GHz	0.75 GHz	93%	6.97dB

Table 1: Comparision of Different Simulated Rdra Results

V. CONCLUSION

By designing the compact wideband rectangular Dielectric resonator antenna works at frequency band of 16.274-18.201 GHz. A bandwidth enhancement has been obtained by adding a double metallic strips above the RDR and by using stepped microstrip feed. The obtained results show that the proposed antenna can produce a bandwidth of 1.96GHz efficiency of 85%. With this feature, the proposed antennas are suitable for wideband wireless systems at Ku-band frequency range.

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