ISSN (ONLINE):2456-5717
International Journal of Advanced Research in Basic Engineering Sciences and Technology (IJARBEST)
Vol.4, Issue.4, April 2018

Dielectric Resonator Antenna for *S* Band Applications

M.M. Prasada Reddy
Professor, Dept of ECE.
NCET, Hyderabad, 500070

Abstract – **This paper describes the design of a dual band Rectangular Dielectric Resonator Antenna (RDRA) for S band applications .In this deisgn a slot is introduced over ground palne and the antenna is fed by a microstrip line.The basic TE_{111} mode is excited with their resonance frequency .The resonance frequency canbe controlled by adjusting RDRA dimensions.This antenna is suitable for dual band operation such as space to earth applications (2.18 to 2.23 GHz) and Direct to home satellite (2.71 to 2.76 GHz) communication. Performance measures like return loss,VSWR,Gain and Directivity are showing reasonbilly good performance.**

Keywords: **Dielectric resonator, RDRA, permittivity, micro strip line, slot.**

I. INTRODUCTION

When a Dielectric Resonator (DR) is not completely enclosed by a conducting boundary, it can radiate .i.e. it acts as an antenna, termed as DRA. Its resonance frequency is a function of size, shape and permittivity. DRAs are much significance because of their small size, light weight and low cost. DRAs offer high radiation efficiency, flexible feed, compactness and geometry [1]-[4].Further, different feeding methods can be used to excite DRAs, such as, co-axial probe [5], micro strip feed line [6],an aperture coupled source [7] and a coplanar wave guide(CPW) [8].The inherent advantage of DRA is that they can achieve wide band width and high radiation efficiency. DRAs can be designed in different shapes like cylindrical, hemispherical, elliptical, pyramidal, rectangular and triangular. Rectangular shape DRAs have much significant over other shapes due to its design flexibility[9].In the last decade different DR structures [10]-[17],such as embedded DR, Tetra Hadrian, L shaped ,T shaped, Stair shaped, trapezoidal shaped are developed for band width enhancement.

II. LITERATURE SURVEY

Ravi Kumar Gangwar et al [18] have designed a RDRA in C band using co-axial probe and micro strip line feed with the aid of finite integration method (FIM) (CST micro wave studio) and Finite element method (FEM) (Ansoft HFSS). In probe feed method maximum coupling and wide band width is achieved on error and trial method varying probe length and probe position from the antenna. In micro strip line feed maximum coupling and wide band width is achieved when RDRA is placed at a $\frac{\lambda}{2}$ distance from the open end and strip length

$\Delta L = 4.1mm$.FEM is showing more accurate result over (FIM) interims of directivity, gain, radiation efficiency, total efficiency,3 dB beam width and cross polarization.

Mohsen Khalily et al [19] have designed a P shaped DRA for wide band wireless applications. This antenna covers wireless systems like WLAN and Wimax (C band 5.2, 5.5 and 5.8 GHz).In this work they are carried a parametric study(using CST micro wave studio) to improve return loss, which is useful to realize an antenna .In this work they have introduced a hole in different shapes in DR to reduce effective permittivity of the whole DR volume, which consequently reduce radiation Q factor of DR and thus increase impedance bandwidth. Highest band width (6.8 to 13 GHz .i.e. 62 %) is obtained when trapezoidal shaped hole is introduced.

Ravi Kumar Gangwar et al [20] have designed segment rectangular dielectric resonant antenna (DSRDRA) in free space and in presence of bio medium. The simulation results such as return loss, VSWR, band width of DSRDRA (free space) are compared with when DSRDRA is in direct contact with homogeneous bio medium(muscle layer).It is observed from simulation results that the SAR value increases with increase in frequency and when antenna is getting closed to bio medium .Penetration depth and transverse plane resolution in bio medium is increasing with reduction in frequency .

H Roggad et al [21] have designed a dual band DRA fed by a micro strip line. In this design both fundamental TE_{111} and higher order TE_{113} propagation modes are excited. The resonant frequency of TE_{111} and TE_{113} modes are adjusted by varying the dimensions of the DRA. This antenna is suitable for digital communication system (1710 - 1880 MHz) and WLAN (2400- 2484 MHz) applications. This antenna has shown good directional radiation pattern for both the resonating frequencies. This design is a good choice for new communication system requirements.

III. DRA DESIGN

The basic dimensions of DRA can be obtained in two different modes like Dielectric Wave guide Model (DWM)[18] and Magnetic Wall Wave guide mode (MWM)[19].Assuming MWM at the surface of the resonator, the following equations are obtained for wave numbers and for resonance frequency for dominant mode (TE to Z mode)

$$f_r = \frac{1}{2\sqrt{\epsilon\mu}}\sqrt{\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2 + \left(\frac{p}{h}\right)^2} \qquad (1)$$

where $m = n = p = 1$ and
$\epsilon =$ permittivity of the material in transverse plane (X-Z)
$\mu =$ permeability of the material
$L, W, h =$ Length, Width and Height of the resonator .
Dimensions of Dielectric resonator can be obtained from the following equations

$$k_0 = \frac{2\pi f_r}{c} \tag{2}$$

k_0 = Wave number in free space

$c = 3 \times 10^8 m/s$ = Velocity of light

$$k_x^2 + k_y^2 + k_z^2 = \varepsilon_r k_0^2 \tag{3}$$

$$k_x = \frac{m\pi}{L}, k_y = \frac{n\pi}{W} \ and \ k_z = \frac{p\pi}{2h}$$

k_x, k_y, k_z = Wave numbers along x, y and z directions of resonator.

dielectric resonator must satisfy the condition

$$k_z \tan\left(\frac{k_z h}{2}\right) = \sqrt{(\varepsilon_r - 1)k_0^2 - k_z^2} \tag{4}$$

when $\frac{W}{h} < 1$

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\left(1 + 12\left(\frac{h}{W}\right)\right)^{-1/2} + 0.04\left[1 - \left(\frac{W}{h}\right)^2\right]\right] \tag{5}$$

when $\frac{W}{h} \geq 1$

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\left(1 + 12\left(\frac{h}{W}\right)\right)^{-1/2}\right] \tag{6}$$

slot dimensions

$$L_s = \frac{0.4\lambda_r}{\sqrt{\varepsilon_e}} \tag{7}$$

$$\varepsilon_e = \frac{\varepsilon_r + \varepsilon_s}{2} \tag{8}$$

$\varepsilon_r, \varepsilon_s$ = Dielectric constant of RDR and substrate

$$W_s = 0.2\, L_s \tag{9}$$

stub length $L = \frac{\lambda_g}{4}$ (10)

λ_g = Guided wave length in substrate
Micro strip line length and width is given by

$$X_f = \frac{L}{2\sqrt{\varepsilon_e}} \ \ and \ \ Y_f = \frac{W_s}{2} \tag{11}$$

ISSN (ONLINE):2456-5717
International Journal of Advanced Research in Basic Engineering Sciences and Technology (IJARBEST)
Vol.4, Issue.4, April 2018

IV. ANTENNA CONFIGURATION

Figure 1 shows the structure of slot coupled RDRA fed by a micro strip line. The thickness and permittivity of FR4 substrate is 0.8mm(0 to -0.8 mm) and 4.4.The micro strip line with a thickness 0.4 mm (-0.8 to -0.4mm) is placed at the bottom of substrate .The ground plane with a thickness 0.4mm (0 to 0.4mm) is placed on the top surface of substrate. A slot is introduced on the ground with a thickness of 0.4 mm. The micro strip line is extended beyond the slot center to maximize the coupling and to serve as a matching circuit. The Dielectric resonator with a permittivity of 30 is placed on slot as shown in figure 1(A).Various parameters such as resonator permittivity, slot dimensions and micro strip length show their impact on DRA characteristics. After conducting a series of simulation experiments on error and run basis it is observed that the resonance frequency decrease as permittivity increases and as slot length decreases the return loss is gradually increasing in second resonant frequency. Further we have studied the effect of strip length on input matching of the resonant modes. The optimized length chosen for this design is 5 mm(beyond slot)

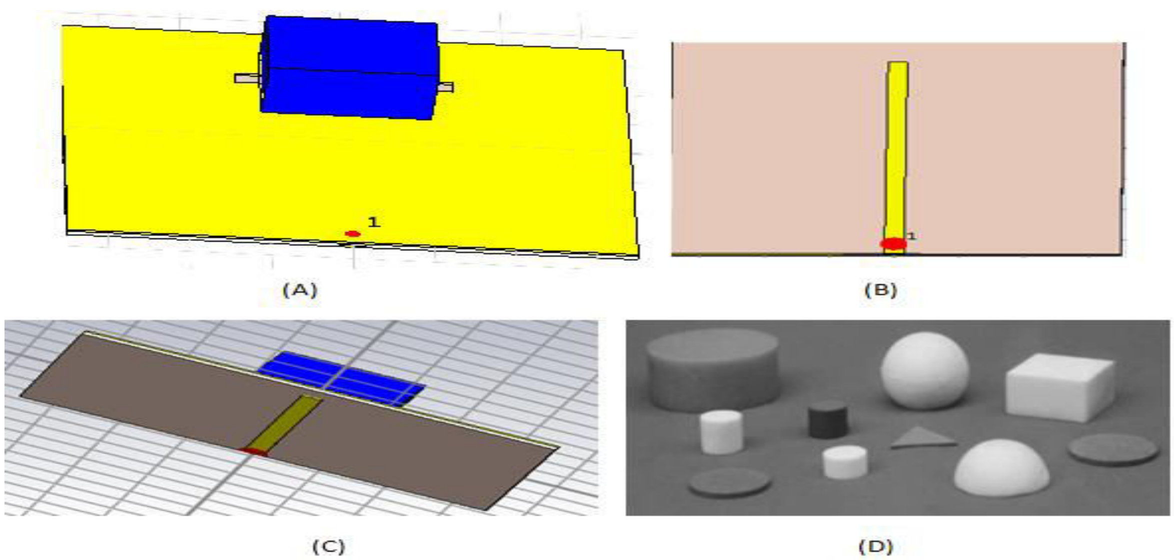

Fig. 1 Geometry of DRA (A) top view of RDRA (B) bottom view of RDRA (C) Side view of RDRA (D) DRAs in different shapes

TABLE 1: DESIGN PARAMETERS OF RDRA

Parameter	Dimension
substrate	70×70×0.8 (0 to -0.8) (FR4 permittivity 4.4)
Ground	70×70×0.4 (0 to 0.4)(copper)
slot	2.6×26×0.4 (0 to 0.4)
Micro strip line	2.6×28×0.4 (-0.8 to -0.4) copper
DRA	22×16×11 (0.4 to 11mm) permittivity 30

V. SIMULATION RESULTS

The designed antenna is designed and simulated in CST micro wave studio .The antenna is simulated at an input impedance of 50Ω.Figure 2 shows that the return loss for both the resonating frequecies is less than -10 and VSWR is less than 2(figure 3)

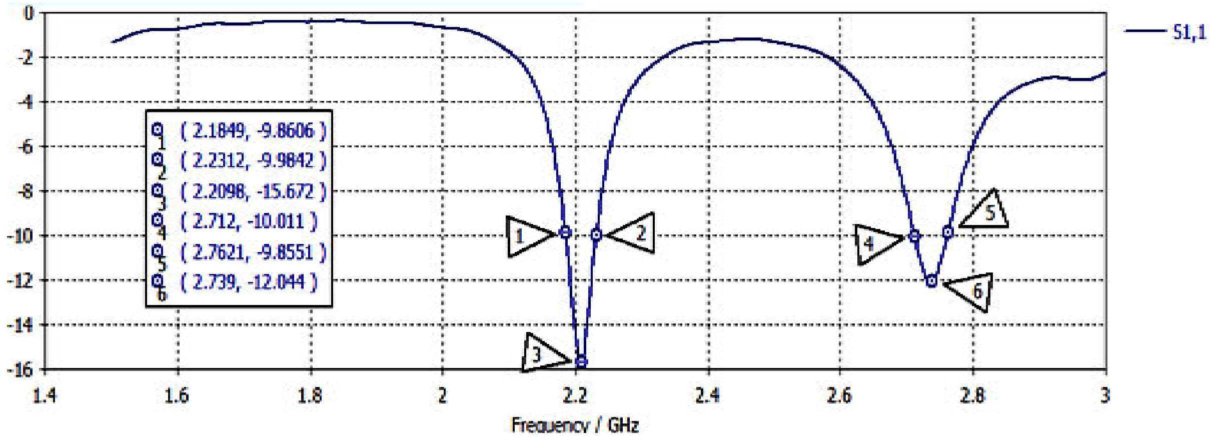

Fig. 2 Return loss Vs Frequency

From figure 2 it is observed that the antenna is resonating at 2.2GHz and 2.73 GHz .In S band the frequency ranges 2.17 to 2.2 GHz and 2.5 to 2.7 GHz is used for space to Earth communications and for Direct-to-Home satellite television. Then It is obvious that the frequency ranges 2.1849 to 2.2312 and 2.712 to 2.7621(figure 2) are showing good agreement to S band frequency ranges .Hence the same antenna can be used for two different applications in S band .

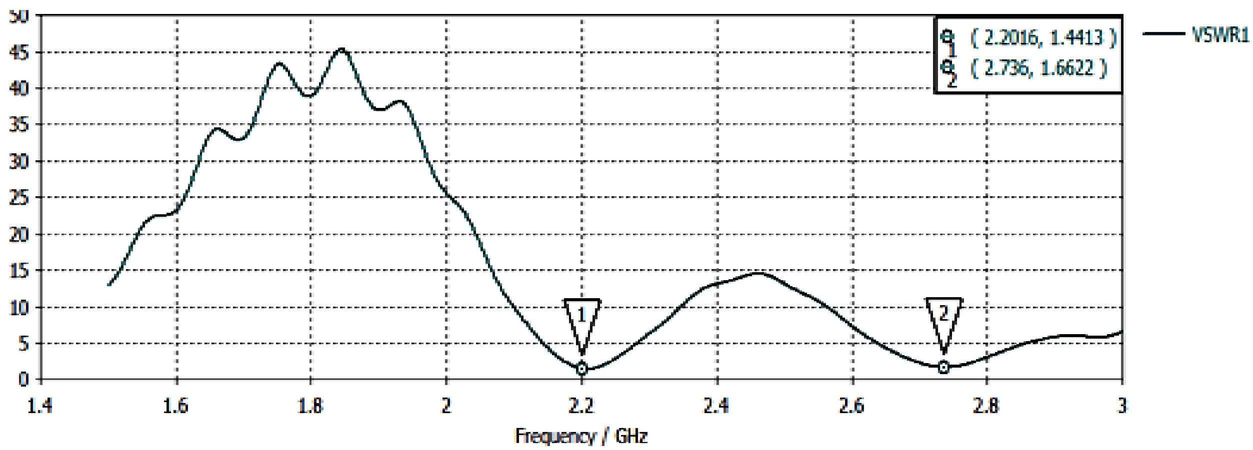

Fig. 3 VSWR Vs Frequency

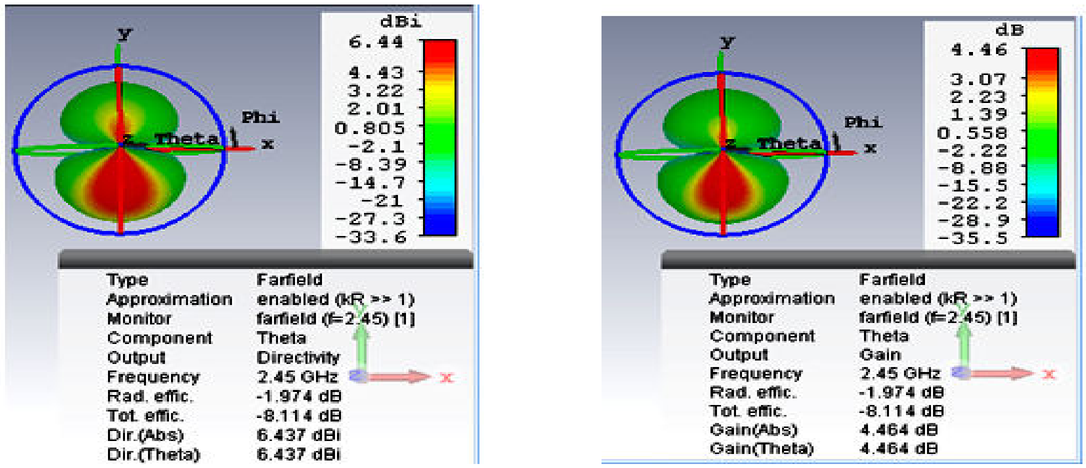

Fig. 4 Directivity and gain of RDRA

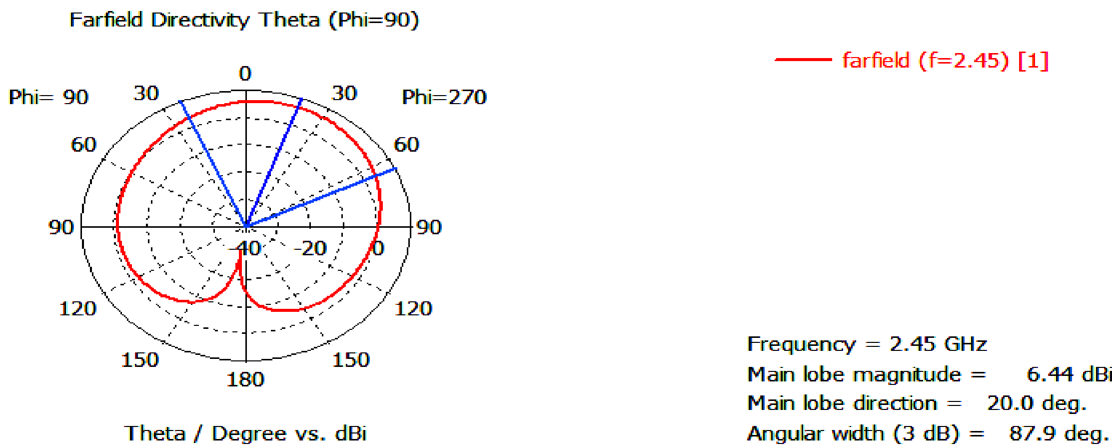

Fig. 5 Far field directivity of the antenna

VI. Conclusion

A compact dual band RDRA is designed and simulated .This antenna is showing good performance in S band .This antenna is suitable for space to earth communications (2.1849 to 2.2312)and Direct-to-Home satellite television(2.712 to 2.7621) applications. This antenna has achieved a desirable directional radiation pattern with a gain of 4.464 dB and directivity 6.437 dBi. This compact antenna is a good choice for new communication system design.

References

[1] Mongia, Rajesh K., and Prakash Bhartia. "Dielectric resonator antennas—A review and general design relations for resonant frequency and bandwidth." International Journal of RF and Microwave Computer-Aided Engineering 4.3 (1994): 230-247.

[2] Mongia, R. Kumar, and Apisak Ittipiboon. "Theoretical and experimental investigations on rectangular dielectric resonator antennas." IEEE Transactions on Antennas and Propagation 45.9 (1997): 1348-1356.
[3] Rezaei, Pejman, Mohammad Hakkak, and Keyvan Forooraghi. "Design of wide-band dielectric resonator antenna with a two-segment structure." Progress In Electromagnetics Research 66 (2006): 111-124.
[4] Kajfez, Darko, and Ahmed A. Kishk. "Dielectric resonator antenna-possible candidate for adaptive antenna arrays." Proceedings VITEL 2002, International Symposium on Telecommunications, Next Generation Networks and Beyond. 2002.
[5] Almpanis, Georgios, Christophe Fumeaux, and Rdiger Vahldieck. "Dual-mode bridge-shaped dielectric resonator antennas." IEEE Antennas and Wireless Propagation Letters 9 (2010): 103-106.
[6] Ryu, Kenny Seungwoo, and Ahmed A. Kishk. "Ultrawideband dielectric resonator antenna with broadside patterns mounted on a vertical ground plane edge." IEEE Transactions on Antennas and Propagation 58.4 (2010): 1047-1053.
[7] Martin, JTH St, et al. "Dielectric resonator antenna using aperture coupling." Electronics Letters 26.24 (1990): 2015-2016.
[8] Kranenburg, Roger A., Stuart A. Long, and Jeffery T. Williams. "Coplanar waveguide excitation of dielectric resonator antennas." IEEE Transactions on Antennas and Propagation 39.1 (1991): 119-122.
[9] Gao, Yuan, Ban-Leong Ooi, and Alexandre P. Popov. "Dual-band hybrid dielectric resonator antenna with CPW-fed slot." Microwave and optical technology letters 48.1 (2006): 170-172.
[10] Shum, S. M., and K. M. Luk. "Stacked annular ring dielectric resonator antenna excited by axi-symmetric coaxial probe." IEEE Transactions on Antennas and Propagation 43.8 (1995): 889-892.
[11] Walsh, Andrew G., Christopher S. DeYoung, and Stuart A. Long. "An investigation of stacked and embedded cylindrical dielectric resonator antennas." IEEE Antennas and Wireless Propagation Letters 5.1 (2006): 130-133
[12] Kishk, Ahmed A. "Wide-band truncated tetrahedron dielectric resonator antenna excited by a coaxial probe." IEEE Transactions on Antennas and Propagation 51.10 (2003): 2913-2917.
[13] Denidni, Tayeb A., Qinjiang Rao, and Abdel R. Sebak. "Broadband L-shaped dielectric resonator antenna." IEEE Antennas and Wireless Propagation Letters 4.1 (2005): 453-454.
[14] Rao, Qinjiang, Tayeb A. Denidni, and Abdel R. Sebak. "Broadband compact stacked T-shaped DRA with equilateral-triangle cross sections." IEEE microwave and wireless components letters 16.1 (2006): 7-9.
[15] Kishk, A. A., and K. F. Lee. "Wideband stair-shaped dielectric resonator antennas." IET Microwaves, Antennas & Propagation 1.2 (2007): 299-305.
[16] Almpanis, Georgios, Christophe Fumeaux, and Ruediger Vahldieck. "The trapezoidal dielectric resonator antenna." IEEE Transactions on Antennas and Propagation 56.9 (2008): 2810-2816.
[17] Liang, Xian-Ling, and Tayeb A. Denidni. "H-shaped dielectric resonator antenna for wideband applications." IEEE Antennas and Wireless propagation letters 7 (2008): 163-166.
[18] Gangwar, Ravi Kumar, S. P. Singh, and D. Kumar. "Comparative studies of rectangular dielectric resonator antenna with probe and microstrip line feeds." Archives of applied science research 2.3 (2010): 1-10.
[19] Khalily, Mohsen, et al. "Wideband P-shaped dielectric resonator antenna." Radioengineering 22.1 (2013): 281-285.

AUTHOR BIOGRAPHY

Mr Reddy has submitted his doctoral thesis on wireless communications. His research interests include Image and signal processing ,wireless communications ,microwave engineering ,VLSI and Internet of things .He has authored more than 20 research papers in reputed journals and 3 books on communication Engineering .Currently he has focused on 5G antennas design and channel modeling.