A Novel Offset Feed Annular Ring Dielectric Resonator Antenna for Bandwidth Enhancement

K. Tulasi, K.Jyothi, B .L.V.Kumari, K. Charitha Sri, M. Mani Kavya, M. Mounika G. Divya

Abstract: ***This article presents a design and analysis of novel offset feed annular ring dielectric resonator antenna for bandwidth increment technique. The proposed antenna design consists of a square-shaped question mark feed with an annular ring. The proposed design generates triple-band characteristics by changing the feed width. The proposed design operates in the following frequency bands 2.2-2.7 GHz, 3.13-3.94 GHz & 5.7-7.15 GHz with corresponding bandwidth of 22%, 23%, 21%. The applications of the proposed antenna are like Wi-Fi (2.4 GHz), mobile broadband, broadband radio service (3.5 GHz), Radars, commercial WLAN (6.8 GHz).***

Keywords: Triple band, annular ring, Wi-Fi.

I. INTRODUCTION

Dielectric resonator antenna is an antenna was proposed by Professor S. A. Long in the early 1980s.Now a days DRAs are more popular among all antennas. Dielectric resonator antennas are winning antenna elements as they offer several advantages over different types of antennas[1]-[6].Microstrip antennas offer more conduction losses, less bandwidth, and low radiation efficiency. To overcome the above problems, DRA is another approach for the researches in present growing technology. The bandwidth of DRA depends on different parameters such as the excitation method, shape, dimensional parameters, and dielectric constant of DRA material. By introducing the air gap in the middle of the ground plane and dielectric resonator can increase the bandwidth, making a cavity-backed dielectric resonator antenna to increase gain and bandwidth [7].

For many years, several bandwidth improvement techniques have been developed for DRAs. DRAs are mainly used at microwave frequencies and higher. One of the best methods for improving the bandwidth of cylindrical DRA is to detach a segment of the central chunk of the DRA to form halo or annular i.e. annular ring DRA.

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An annular ring-shaped DRA is another type of DRA. This antenna offers more bandwidth, low Q factor, fabrication is easy. The Annular ring DRA offers a firm configuration which does not use the parasitic elements to enhance the bandwidth [8-9].

In this design, the bandwidth is very less by taking the cylindrical DRA or rectangular DRA about (15%). So this annular ring DRA with the height of (8mm) is used for bandwidth enhancement. The material used for the substrate of the proposed antenna is FR4 . By introducing a circular patch along with the feed and adjusting the height of the annular ring, the bandwidth is increased. The article is orderd in the following manner :Antenna geometry, Antenna explanation, Results, Conclusion.

II. ANTENNA GEOMETRY

The feeding structure and proposed antenna are shown in Figs.1a and 1.b respectively. The proposed antenna is designed on an FR4 substrate (εr=4.4). The annular ring DRA, alumina (ε_r=9.9).By optimizing the dimensions of the feed (2.5mm) for best impedance matching (53.1Ω). The vertical strip is used to improve the gain. The dimensions of the proposed antenna are given in Table1.

III. ANTENNA EXPLANATION

By using CST microwave studio the evaluation of the proposed antenna is carried out.

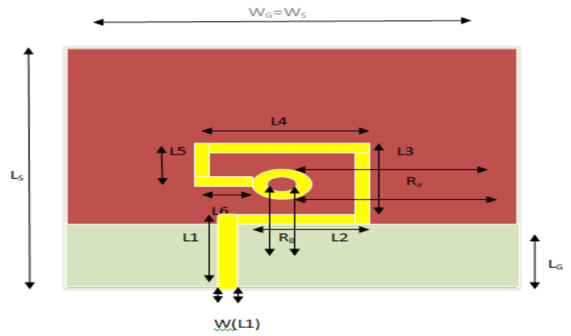

Fig.1.a . Feeding structure (stage4)

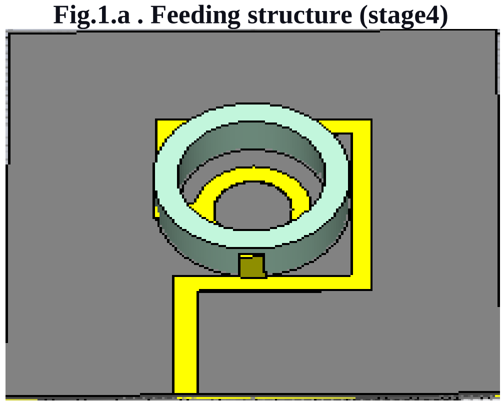

Fig.1.b. Top view of the proposed antenna

To view this article , we have separated the design of the proposed antenna into 4 different antennas. Each of the individual design is shown in Fig.2

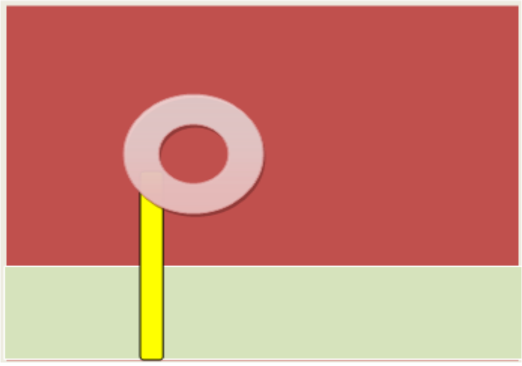

Fig.2. Stage1

Table: Dimensions

Symbol	Value,mm
L_G(ground plane length)	16
W_G(ground plane width)	25
L_S (substrate length)	25
W_S(width of substrate)	25
R1(outer radius)	10
R2(inner radius)	7.5
D(height of DRA)	8
H_G(ground plane height)	-0.2
H_S(height of substrate)	1.6
R_a(outer radius)	6
R_b(inner radius)	4
L1	16
L2	14.5
L3	21.5
L4	20
L5	12.5
L6	4.5
L_S(strip length)	6.4
W_S(width of strip)	2.5
$W_{(L1)}$(width of L1)	2.5
WIDTH(L2=L3=L4=L5=L6=L_S)	2

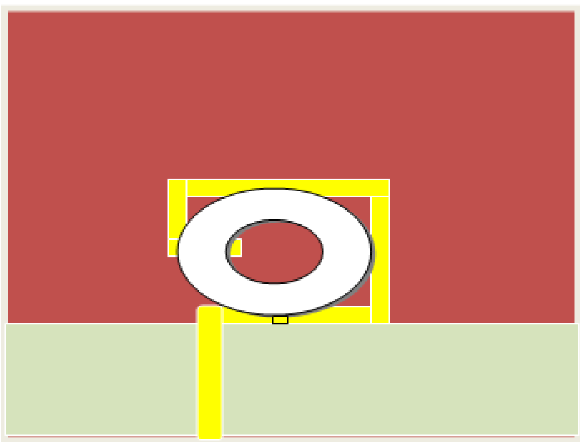

Fig.2.bStage2

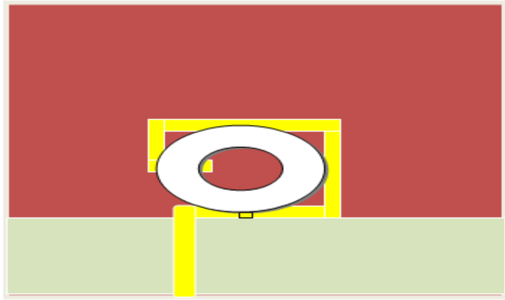

Fig.2.bStage2

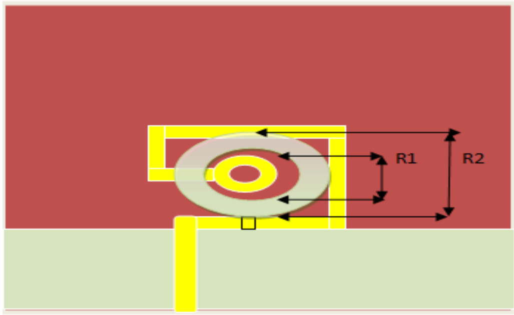

Fig.2.c. Proposed Antenna (stage3)

A. Assessment of the proposed antenna structure:

The dissimilarity of S11 characteristics for different antenna configurations is shown in Fig.3.a,3.b.

1. In stage1, only offset feed with annular ring DRA is designed. The design generates one frequency band i.e. from 5.12-7.13GHz with a fractional bandwidth of 34% and gain is 4.9 dB.
2. In stage2, square-shaped question mark feed with annular ring DRA is designed. It generates two frequency bands ranging from 4.02-4.39GHz and 6.48-7.05GHz with a fractional bandwidth of 8% in both cases. The gain of these resonant frequencies is 3.4dB, 4.7 dB.
3. In stage3, the design is completely different from the above two stages. Here the proposed design is observed with triple-band characteristics. In this case the antenna acts as a Hybrid Antenna (combining of annular ring DRA and a novel offset microstrip feed). The frequency bands ranging from 2.2-2.74GHz, 3.13-3.94 GHz, 5.72-7.15GHz with a fractional bandwidth of 22%, 23%, 21%. The gain of these frequencies is 2dB, 4.80dB, 6.74dB.

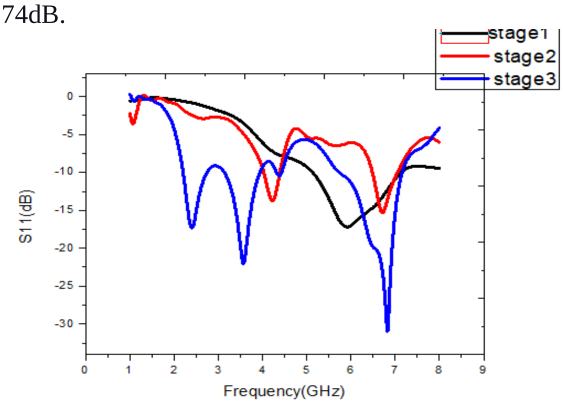

Fig. 3.a. S11 characteristics for different antenna configurations.

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B. Excitation of TM11, HEM11δ modes in proposed antenna and mathematical calculations:

Fig.4.a, 4.b. shows the near field distributions of antenna at 3.5GHz and 6.8GHz respectively. From Fig.4.a,4.b it is clear that TM_{11}, $HEM_{11\delta}$ modes are generated at 3.5GHz and 6.8GHz .To find out the resonance frequency due to TM_{11} mode theoretically ,by using following formula

$$f_r = \frac{c}{2\pi R_{avg}\sqrt{\varepsilon re}} \;\ldots\ldots\; (1)$$

Where,

$$R_{avg} = \frac{\left(\frac{R1}{2}\right)}{2} \;\ldots\ldots\ldots\ldots\ldots\ldots\; (2)$$

$$\varepsilon_r = \left[\frac{1}{2}(\varepsilon_{r\,sub}+1)+\frac{1}{2}(\varepsilon_{r\,sub}-1)\right]\left[1+\frac{10h}{w}\right]^{\left(\frac{-1}{2}\right)} \;\ldots\ldots\ldots\ldots\ldots\ldots\; (3)$$

h=substrate height

w=width of ring.

From equations (1), (2) and (3) resonant frequency of TM_{11} mode is found to be 3.5GHz .Theoretically calculated resonant frequency of TM_{11} mode is 4.0GHz.

Similarly we have to calculate the resonant frequency due to $HEM_{11\delta}$ mode theoretically, by using the following formula:

$$f_r = \frac{6.321c}{2\pi d\sqrt{\varepsilon_{r,eff}+2}}\left[0.27+0.36\left(\frac{d}{2H_{eff}}\right)+0.02\left(\frac{d}{2H_{eff}}\right)^2\right] \;\ldots\ldots\ldots\; (a)$$

Where, $\varepsilon_{r,eff}$ is the dielectric constant of proposed antenna, H_{eff} is the total height of the proposed antenna, c and d(=R1/2) denote the speed of light and outer radius of annular ring DRA respectively. The value of $\varepsilon_{r,eff}$ and H_{eff} can be calculated as

$$\varepsilon_{r,eff} = \frac{H_{eff}}{\frac{H}{\varepsilon_{r,DRA}}+\frac{H_S}{\varepsilon_{r,sub}}} \;\ldots\ldots\ldots\; (b)$$

And

$$H_{eff}=H+H_s \ldots\ldots\ldots\ldots (c)$$

From equations (a), (b) and (c) resonant frequency of $HEM_{11\delta}$ mode is 6.8GHz. Theoretically calculated resonant frequency of $HEM_{11\delta}$ mode is 7.0GHz.

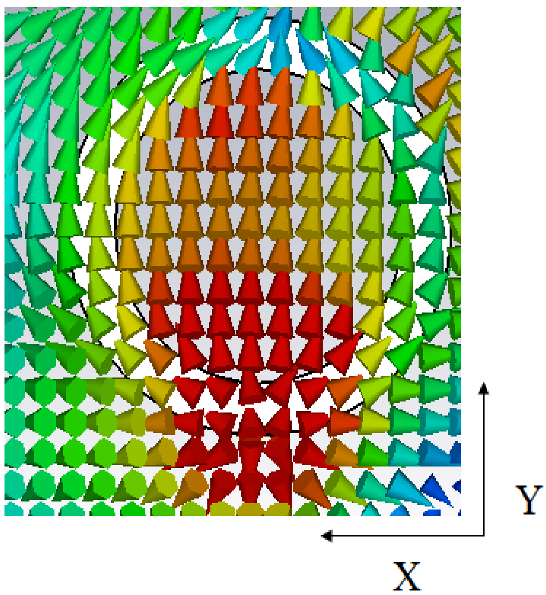

Fig.4.a E-field at 3.5GHz

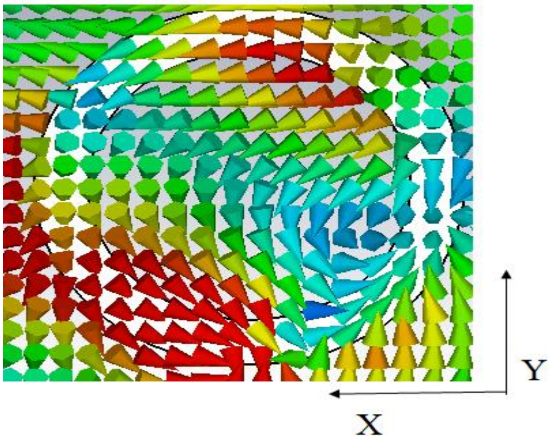

Fig.4.b E-field at 6.8GHz.

4. In this case, the overall design is Observed without DRA (only with microstrip feed), it is operated at a lower frequency range of 2.51-3.01GHz with a fractional bandwidth of 18%. The surface current distribution at the microstrip feed is observed at 2.73GHz.

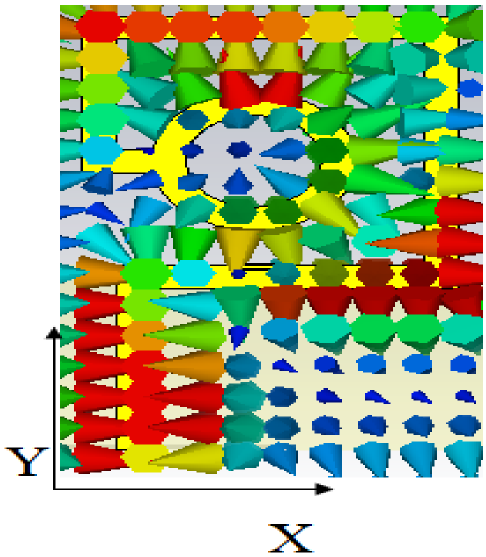

Fig.4.c. Surface current distribution at 2.73 GHz.

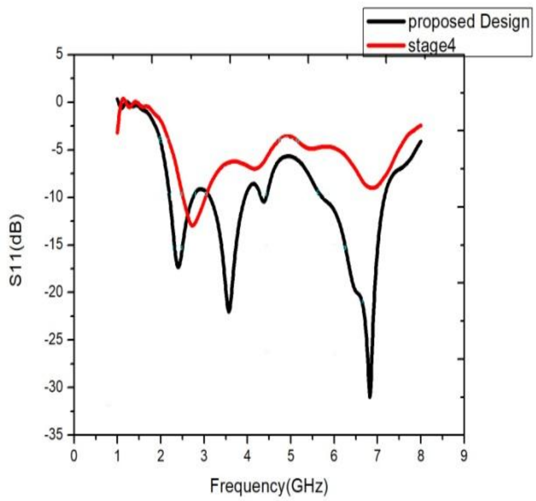

Fig.3.b .variation of S11 characteristics with and without DRA

C. Comparison between different stages:

Stage	Bandwidth	Resonant frequency	Gain	Directivity
Stage 1	34%	5.91GHz	4.9dB	5.07
Stage 2	8%,8%	4.22GHz 6.71GHz	3.4dB 6.71dB	3.6 4.9
Stage 3	22%,23%,21%	2.4GHz 3.5GHz 6.8GHz	2dB 4.8dB 6.74dB	2.4 5.1 6.9

IV. RESULTS

Radiation is the term used to represents the emission or reception of wavefront at the antenna, specifying its strengths. Radiation pattern refers to the directional dependence of the strength of the radio waves from the antenna or another source. The field patterns are plotted as a function of electric and magnetic fields they are plotted as a logarithmic scale. Fig 5 depicts a far-field radiation pattern along the antenna E-plane and H-plane at 2.4GHz. Fig 6 shows a far-field radiation pattern along the antenna E-plane and H-plane at 3.5GHz. Fig 7 shows the far field radiation pattern along the antenna E-plane and H-plane at 6.8GHz.

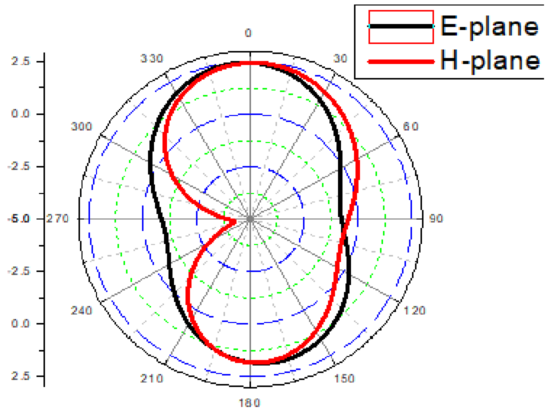

Fig .5. Radiation pattern at 2.4GHz

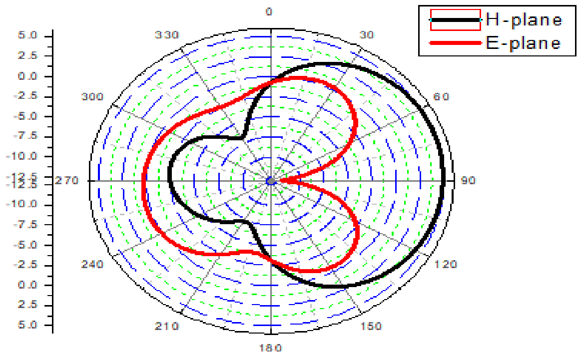

Fig. 6. Radiation pattern at 3.5GHz

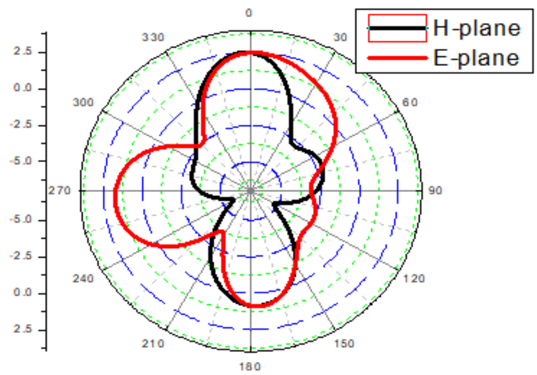

Fig. 7. Radiation pattern at 6.8GHz.

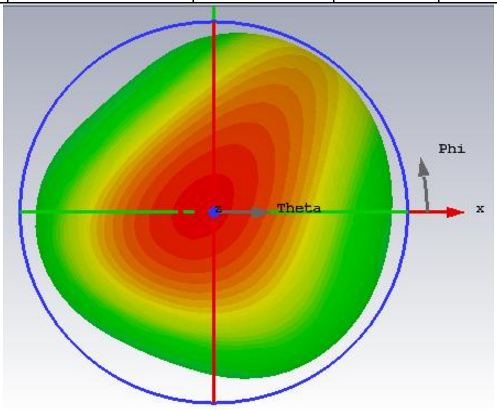

Fig .8. 3D Radiation pattern at 2.4GHz

The gain and directivity of above radiation pattern is 2 dB, 2.4 respectively.

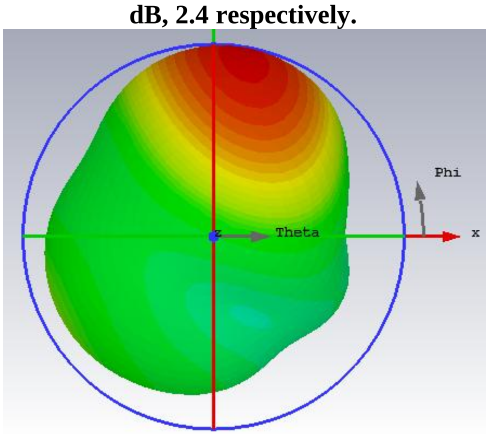

Fig. 9. 3D Radiation pattern at 3.5GHz

The gain and directivity of above radiation pattern is 4.80 dB, 5.1 respectively.

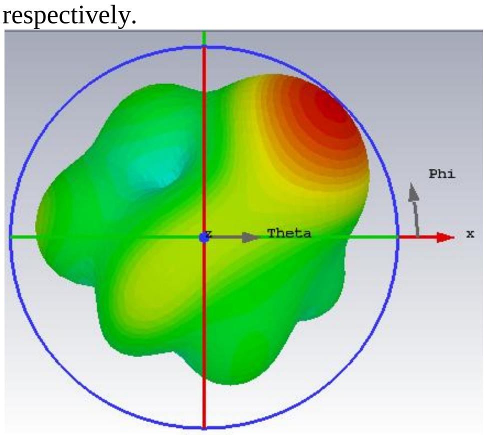

Fig. 10 . 3D Radiation pattern at 6.8GHz

The gain and directivity of above radiation pattern is 6.74dB, 6.9 respectively.

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V. CONCLUSION

The simple implementation of offset feed with annular ring DRA has been presented. Bandwidth improvement has been achieved by using an annular ring. Here triple bands are generated with the help of feed. The proposed design generates an effective radiation pattern at 2.4 and 6.8GHz.The highest gain for the proposed design is 6.74dB. The proposed antenna mainly used at Wi-Fi, Radar Applications.

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