Design of conjugate DRA with power divider for WLAN applications

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***Abstract*—In this paper, a new conjugate dielectric resonator antenna (DRA) with aperture coupled feeding is presented for wireless local area network (WLAN) applications. Here two different DRAs of permittivity 15 and 10 respectively are fed using aperture coupling method. A power divider is designed to provide same power to both the DRAs. The power divider is designed by inserting quarter wavelength lines in the feed line connecting both the DRAs. The width of the quarter wavelength line is calculated using appropriate mathematical equations. Both the DRAs are excited at the same time and in the result a narrow band with center frequency at 2.9 GHz is obtained. This can be used for IEEE 802.11b WLAN applications. The parametric studies are done by varying the horizontal slot length and the feed line lengths using CST software.**

Keywords-Dielectric resonator antenna (DRA), Power divider, Aperture coupled feed, WLAN

I. INTRODUCTION

The field of wireless communication has been undergoing a revolutionary growth in the last decade such as 2G-cellular communication (portable mobile phones), 3G, Bluetooth, WLAN, etc. The crucial component of any wireless communication is antenna. In the last two decades mainly two types of antenna are used i.e. microstrip patch antenna and dielectric resonator antenna. DRA has much more advantages compared to microstrip antennas [1]-[3]. A dielectric resonator antenna is a radio antenna mostly used at microwave frequencies and higher. It consists of a block of ceramic material i.e. dielectric resonator mounted on a ground plane. Since the requirement of frequency range has been increased and now a day's millimeter wave frequencies and microwave frequencies are required, the conduction losses in metallic antennas also increase with frequency [2].

DRA has an advantage that they do not have any metal parts which become lossy at high frequencies, dissipating energy [7]-[8].By selecting a dielectric material with low loss characteristics, a high radiation efficiency can be maintained even at millimeter wave frequencies, due to absence of surface waves and minimal conductor losses associated with the DRA [1]-[4]. In DRA, several feeding methods can be used to excite it. Such as coaxial probes, microstrip lines [4], slots, coplanar waveguide (CPW), etc. Also several modes can be excited within the DRA, many of which radiation patterns similar to short electric or magnetic dipoles, producing either broadside or omnidirectional radiation patterns for different coverage requirements [5]. In this design, aperture coupling feeding method is used which is easier to model and has a moderate spurious radiation [9]. The ground plane between the dielectric resonators and substrate isolates the feed from the radiating element and so the interference of spurious radiation can be minimized for pattern formation and polarization purity. In this design the substrate electrical parameters, width of the feed line, slot size and position are optimized through parametric study [6].

In this paper, a rectangular dielectric resonator antenna with aperture coupling feed is proposed. The rectangular DRA offers greater design flexibility compared to other basic DRA shapes, having 2 degrees of freedom (length/width and depth/width) [10]-[11].

II. ANTENNA DESIGN

Figure 1 shows the geometry of the proposed antenna. This antenna consists of two dielectric resonators i.e. DRA 1 and 2 with dielectric constants ε_r=15 and 10 respectively. These two DRAs are placed above a ground plane with dimension $70\times70mm^2$. The substrate has same dimension with dielectric constant 4.4. Here dimensions of the DRA are calculated by the following equation

$$k_x tan\,(k_x d/2) = \sqrt{(\varepsilon_r - 1)k_0{}^2 - k_x{}^2}$$

Where

$$k_0=\frac{2\pi}{\lambda_0}=\frac{2\pi f_0}{c},\ k_y=\frac{\pi}{w},\ k_z=\frac{\pi}{b} \text{ and } k_x{}^2+k_y{}^2+k_z{}^2=\varepsilon_r k_0{}^2$$

By using the above equations, the dimension of the DRA 1 is calculated as 20mm × 20.3mm × 6.7mm and the dimension of the second DRA is 14mm × 8mm × 8mm. Below to the DRA the ground plane with thickness 0.05mm is placed. Here FR4 substrate with thickness of 1.6 mm is used. Two slots of dimensions $11\times 2\ mm^2$ and $9.6\times 1.7\ mm^2$ are made on the ground plane for aperture coupling. The slot length l_s and width w_s are calculated using the formula

$$l_s=\frac{0.4\lambda_0}{\sqrt{\varepsilon_e}},\ \text{where } \varepsilon_e=\frac{\varepsilon_r+\varepsilon_s}{2}$$

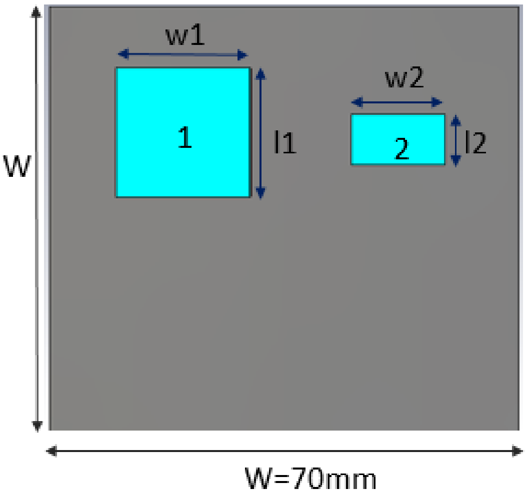
And ε_r and ε_s are the dielectric constants of the DRA and the substrate.

$$w_s=0.2l_s$$

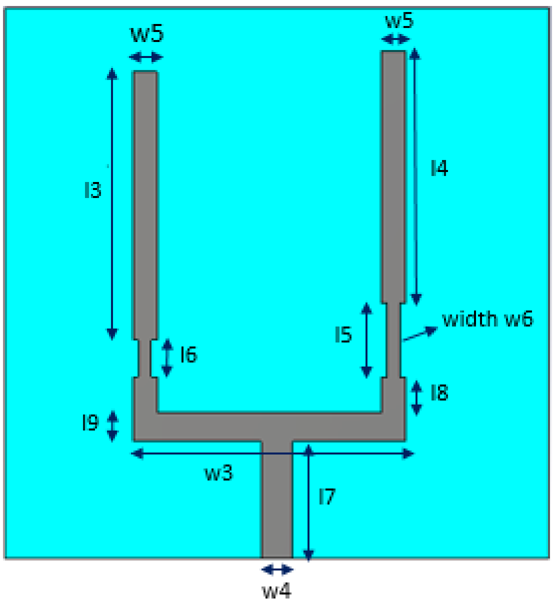
The stub extension s is calculated by

$$S=\frac{\lambda_g}{4}$$

Both the DRAs are separated by appropriate distance as shown in the figure.



(a)

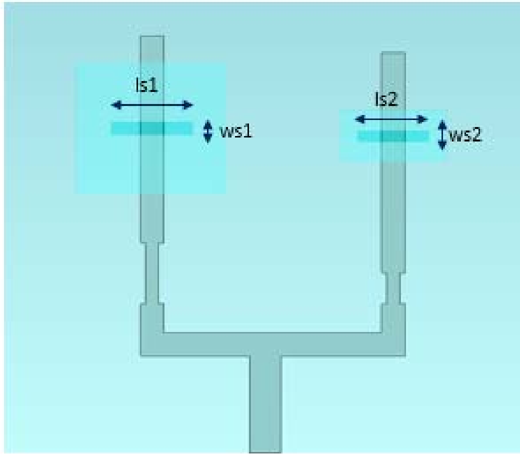


(b)

Fig 1: schematic diagram of the proposed DRA
(a) Front view (b) rear view

TABLE 1
Antenna dimensions

Parameters	Values(mm)	Parameters	Values(mm)
w	70	l2	8
w1	20	l3	34
w2	14	l4	32
w3	35.1	l5	9.43
w4	4.1	l6	4.78
w5	3.1	l7	15
w6	1.633	l8	5
l1	20.3	l9	3.6
ls1	11	ls2	9.6
ws1	2	ws2	1.7



The feed network of the antenna is shown in fig 1 (b).Two quarter wavelength transformers are used on two sides of the feed network. The length and width of the quarter wavelength transformer are calculated by using the following formula.

Length= $\frac{\lambda_g}{4}$, λ_g is guided wavelength and

$\lambda_g = \frac{\lambda_0}{\varepsilon_{reff}}$, λ_0 is free space wavelength

The impedance of the transformer is

$$Z_1 = \sqrt{R_{in} \times Z_0}$$

Width of the transformer can be calculated by using the formula below.

Width = $\frac{8e^A \times h}{e^{2A}-2}$, h is height of the substrate

Where A = $\frac{Z_1}{60}\sqrt{\frac{\varepsilon_r+1}{2}} + \frac{\varepsilon_r+1}{\varepsilon_r-1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right)$,

ε_r is relative permittivity of the substrate and its value is 4.4.

The quarter wavelength transformer is mainly used to match the antenna to the transmission line. Here initially the feed line is matched to 50Ω impedance, but as it is divided to two parts so the impedance of each side of the feed network changes. If we assume they are parallel then impedance of each side is changed to 100Ω. Therefore to make it again or to match it to 50Ω two quarter wavelength transformers are used on two sides of the feed network. So similar amount of power can be transmitted to both the sides at the same time and it can be used as a power divider.

III. RESULTS AND DISCUSSIONS

The proposed antenna as shown in fig 1 is simulated and analyzed using CST microwave studio 2012. The plot between return loss and frequency is shown in fig 2. To achieve optimal performance, a parametric study is performed to analyze the characteristics of the proposed antenna.

By varying the aperture slot length and width the resonant frequency and return loss value can be easily changed. Also by varying the extended length the resonant frequency changes. From the parametric study a suitable resonant frequency at 2.9 GHz is selected for WLAN application.

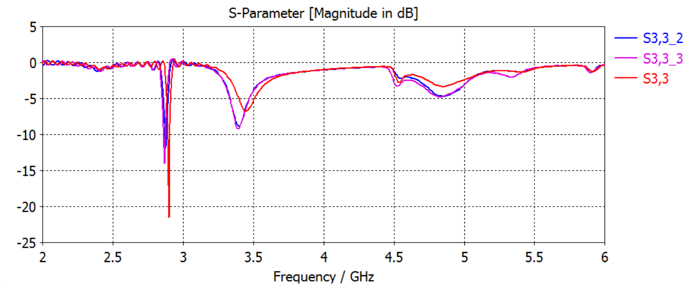


Figure 2 (a): Return loss vs frequency curve

From the above figure, it is shown that a narrow band is obtained at a center frequency of 2.9 GHz. This can be used for WLAN application. The simulation result of the proposed antenna also shows very good radiation pattern and input impedance plot over the entire region. From the figure it is found that the return loss value is also less than -20dB. The impedance bandwidth of the proposed antenna is found to be 4%. The realized gain of the antenna is positive and it is maximum at the resonant frequency. The plot between realized gain and frequency is shown in the figure below.

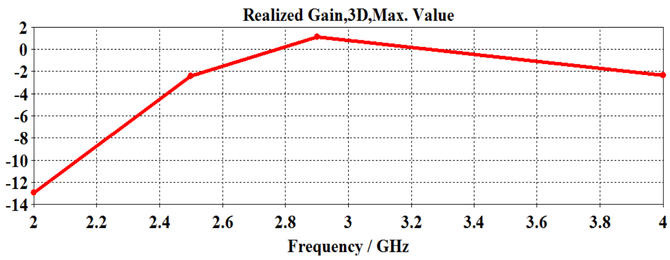


Figure 2 (b): Realized gain vs frequency plot

From the above plot, it is shown that realized gain is maximum at resonant frequency 2.9 GHz and its value is 1.6dBi. The realized gain determines how well the antenna converts input power into radio waves in a particular direction. It is calculated with respect to the isotropic radiator.

The radiation pattern of the antenna is shown in the next figure. It shows how well power is radiated from the antenna in a particular direction.

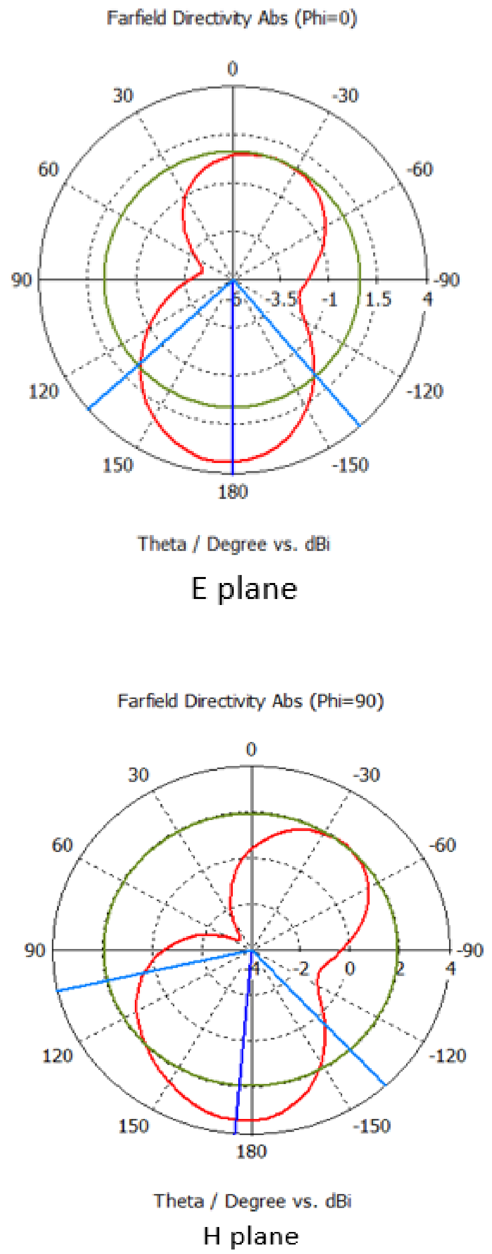


Figure 2 (c)

The simulated far field radiation pattern is shown in the figure 2(c). The E plane shows electric field vector in the direction of maximum radiation and the H plane is the plane consisting magnetic field vector in the direction of maximum radiation. The far field radiation pattern at 2.9 GHz is found to be omnidirectional with almost equal radiation in H plane. The 3D plot of the far field radiation pattern at 2.9 GHz is shown in the figure below.

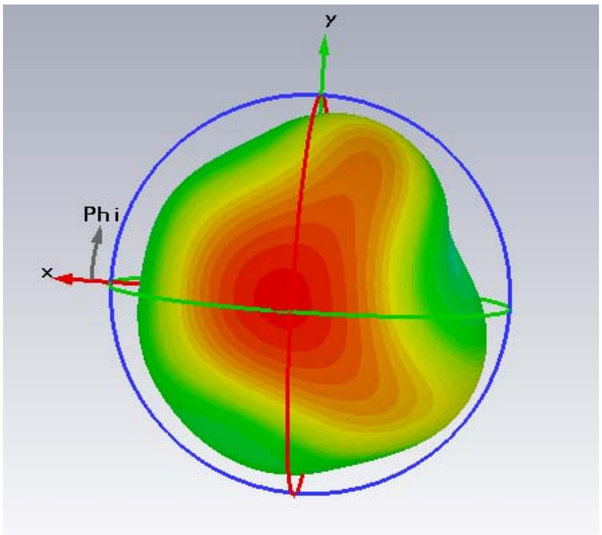


Figure 2 (d): 3D plot of radiation pattern at 2.9 GHz

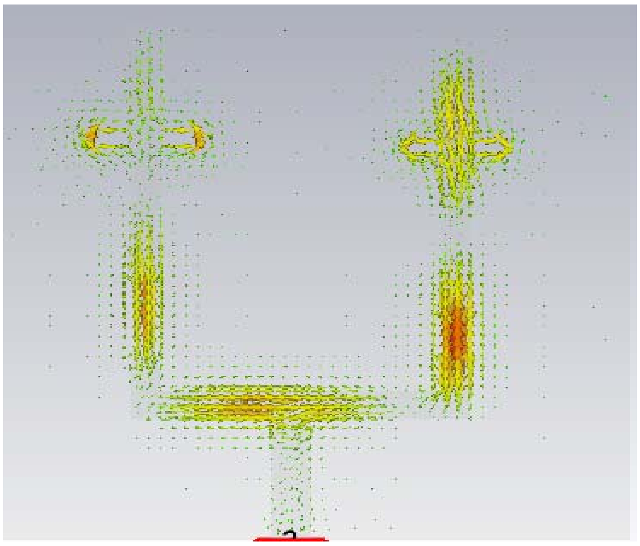


Figure 2 (e): Surface current distribution at frequency 2.9GHz

The above figure shows the surface current distribution of the proposed antenna at resonant frequency 2.9 GHz. The surface current shows that both the DRs are excited at the same time. The antenna operates in TEM mode.

IV.CONCLUSION

In this paper a conjugate dielectric resonator antenna with aperture coupled feeding is presented. The design consists of two dielectric resonators of dielectric constant 15 and 10 respectively. It gives one narrow band at a frequency of 2.9 GHz for WLAN applications. The impedance bandwidth is found to be 4% extending from 2.8 GHz to 2.92 GHz. A power divider is designed by using two quarter wavelength transformer at the feed network for efficient operation. The gain of the antenna is 1.6 dBi and the directivity is found to be 3.415 dBi.

REFERENCES

[1] A. Petosa, “Dielectric Resonator Antenna Handbook” , Artech House publishers, 2007.

[2] K.M. Luk and K.W. Leung, “Dielectric resonator antennas”,Heartfordshire,U.K. :Research studies press ltd.,2002.

[3] RK Mongia and A. Ittipiboon, “Theoratical and experimental investigations on rectangular dielectric resonator antennas,” IEEE Transactions on Antennas and propagation, vol.45, no.9,pp 1348-1356, September 1997.

[4] Chair,R.,Kishk,A.A., and Lee, K.F., “Wideband dielectric resonator antennas”, IET Microw,Antennas Propag.,2007,1,(2),pp. 299-305.

[5] R.K. Chaudhary, R. Kumar, and K.V. Srivastava, “Wideband ring dielectric resonator antenna with circular polarization,” Prog. Electromagn. Res. L,Vol. 34, pp. 91-100,2012.

[6] Y.M.M. Antar,and Z. Fan, “Theoretical investigation of aperture coupled rectangular dielectric resonator antenna,”IEEE proc.-Antenna propag.,Vol.143,No.2, April 1996,pp. 113-118.

[7] Runa Kumari, Kapil Parmar and S K Behera, “Conformal Patch Fed Stacked Triangular Dielectric Resonator Antenna for WLAN applications”, IEEE International Conference on Emerging Trends in Robotics and Communication Technology, 3-S December, 20 I 0.

[8] D. Guha and Y. M. M Antar, “Four-element cylindrical dielectric resonator array: broadband low profile antenna for mobile communications,” presented at the Proc. XXVIIIth General Assembly of the URSI,New Delhi, India, 2005.

[9] E. Lee and M. L. C. Ong, “Aperture coupled differentially fed DRAs,” in Proc. Asia-Pacific Microw. Conf.,2009, pp. 2781-2784.

[10] P. Rezaei, M. Hakkak and K. Forooraghi, “Dielectric resonator antennas for wireless lan applications”,IEEE antennas and propagation society symposium,Vol. 2, pp. 1005-1008,july 2006.

[11] Long S.A.,M.W. Mcallister, and L.C. Shen, “Rectangular dielectric resonator antenna,”IEEE Electronics letters, Vol. 24,No. 8, pp. 1156-1157, Sep. 1988.