# A Compact Dual Resonance Dielectric Resonator Antenna Array with Partial Ground Plane

Runa Kumari
Department of Electronics and Communication Engineering
National Institute of Technology, Rourkela
Rourkela, India
runakumari15@gmail.com

S K Behera
Department of Electronics and Communication Engineering
National Institute of Technology, Rourkela
Rourkela, India
prof.s.k.behera@gmail.com

***Abstract*: Design of Triangular shaped two element dielectric resonator antenna (DRA) array is presented for wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) applications. In this paper, the DRA array is excited by conformal patch connected to microstrip line which is an effective feed mechanism and more efficient in energy coupling than other type of feeding techniques. The result shows that the proposed antenna achieves an impedance bandwidth from 2.16 GHz to 2.94 GHz and 3.22 to 3.63 GHz covering 2.4 GHz WLAN band and 3.5 GHz WiMAX band. Parametric studies are carried out by varying the height of the triangular DRA array and conformal patches. The proposed antenna gives appreciable gain and better radiation patterns at dual resonant frequencies.**

***Keywords: Triangular DRA array, Conformal patch feed, dual resonance, wireless local area network (WLAN), worldwide interoperability for Microwave access (WiMAX).***

## I. INTRODUCTION

With rapid development in modern wireless and mobile communication, the dual-wideband technology has become one of the most fascinating technologies in in-door communication due to its great advantages including large capacity of data, high speed data rate and small size. However, WLAN (2.4 GHz to 2.4835 GHz) and WiMAX (3.3 to 3.7GHz), which are limited by IEEE 802.11, and IEEE 802.16, overlap each other. WiMAX refers to interoperable implementations of the IEEE 802.16 wireless-networks standard which can operate at higher bitrates or over extended distances. It is capable of operating in 3.4-3.6 GHz frequency range [1].

The dielectric resonator antenna has many attractive features like wide bandwidth, low dissipation loss at high frequencies, high radiation efficiency due to the absence of conductors and surface wave losses, high permittivity, light weight and ease of excitation [2-4]. In modern wireless communication systems dual or multi frequency operation is highly desirable. If a single dielectric resonator antenna (DRA) can support multi frequencies then the need for multi single frequency antennas are not necessary [5, 6]. Applications requiring different frequency bands can be operated simultaneously with one radiating element. This reduces the circuit size and leads to compact systems.

DRA's size and bandwidth can be easily controlled by the dielectric constant of materials in a wide range. In many cases with a single element DRA, desired specifications cannot be achieved. For example a high gain, high efficiency, directional radiation pattern cannot be synthesized with a single DRA of any shape. In these applications, a DRA array with appropriate element arrangement and modified feed configurations (like conformal patch connected to microstrip line feed) can be used to provide desired specifications [7-9]. The gain, bandwidth and radiation performance of DRA array can further be modified by using an air gap between dielectric resonator and ground [10-12].

In this paper, we presents a triangular dielectric resonator antenna array fed by microstrip line for WLAN and WiMAX applications. The proposed DRA array is fed by conformal patches connected to microstrip line to obtain the desired performance. The antenna is simulated to analyze the performance of the designed antenna array such as return loss, gain and radiation patterns. The design methodology of the triangular shaped DRA array is discussed and the detail results of the proposed antenna are presented in this paper.

## II. ANTENNA DESIGN

The geometry of the proposed DRA array has been shown in Fig. 1 (a), where triangular-shaped two element dielectric resonators having same dielectric constant 9.8, are placed above the substrate.

The advantage of the triangular DRA is that for a given height and resonant frequency, it offers a smaller area than either a cylindrical or rectangular DRA [13]. The resonance frequency of the $TM_{mnl}$ mode in an equilateral triangular DR on a ground plane is approximately given by [14, 15]

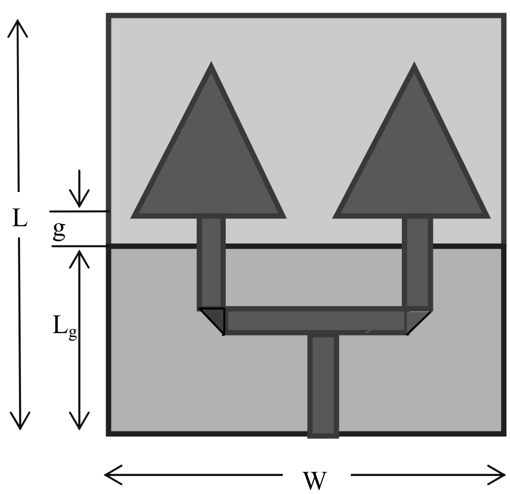
$$f_{mnl} = \frac{1}{2\sqrt{\varepsilon\mu}}\left[\left(\frac{4}{3L_r}\right)^2\left(m^2 + mn + n^2\right) + \left(\frac{1}{2h_r}\right)^2\right]^{\frac{1}{2}} \qquad \text{(i)}$$

where $L_r$ is the length of each side of the triangle and $h_r$ is the height of the resonator. The indices m, n and l should satisfy the condition l+ m+ n=0 but they all cannot be zero simultaneously. For low profile resonators where $L_r >> h_r$, this expression can be further simplified as

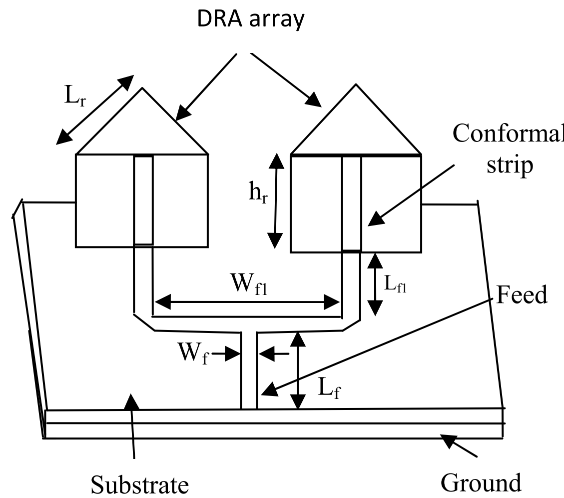
$$f_{lmn} \approx \frac{1}{4h\sqrt{\varepsilon\mu}} \quad \text{(ii)}$$

In this contribution we presented a triangular shaped dielectric resonator array. The proposed array consists of two equilateral triangular shaped dielectric resonator elements having same dielectric constant 9.8. The two triangular shaped resonators having same height $h_r$ = 13.75 mm and size $L_r$=20 mm. The DRA array fed by microstrip line designed on top of 28 mm by 56 mm ground plane. The 60 mm by 56 mm dimensions substrate is made up of 1.6 mm thick FR4 material with $\varepsilon_r$ = 4.4. The resonators are fed by conformal patches, attached on one side of the DR's and connected to a microstrip feed line. The conformal patch has width $b_c$=3 mm and height $h_c$=13.75 mm. The microstrip feed line is etched on FR4 substrate with width $W_f$ = 3mm, $W_{f1}$=28mm, length $L_f$=$L_{f1}$=14mm, and is connected to a SMA connector. There is an air gap g =3 mm between dielectric resonators and ground to enhance the performance of antenna. Fig. 1 (b) shows the schematic view of the triangular DRA array.

This dual-band design of the proposed triangular DRA array adopts different methods. Here by changing the size of the conformal patch, the coupling between the DR and the feed mechanism can be easily adjusted, thus a dual-band impedance matching is obtained.




(a)




(b)

Fig. 1 (a) Geometry and (b) Scematic view of the Triangular shaped Dielectric Resonator Array

## III. Results And Discussion

### *A. Parametric Results*

Here parametric studies of triangular shaped dielectric resonator antenna array are carried out. As discussed in previous section the gain, directivity and radiation pattern of DRA can be modified by using array method. From the simulated results, it was observed that the proposed antenna achieves an impedance bandwidth from 2.16 to 2.94 GHz and 3.22 to 3.63 GHz covering 2.4 GHz WLAN band and 3.5 GHz WiMAX band.

Furthermore, to achieve dual band operation, the DRA array is excited by using a conformal patch connected to microstrip feed line [16, 17]. In this type of feeding technique by altering the height of the DR's and conformal patches, we have observed a resonant frequency variation in simulated results. Parametric studies are carried out by varying the height of DR and conformal patch of the triangular DRA array to achieve good antenna performances. Fig. 2 shows the simulated S parameter for different heights of conformal patches such as 9.75 mm, 10.75 mm, 11.75 mm, 12.75 mm and 13.75 mm. For the case $h_c$= 13.75 mm, dual band with good return loss is observed. Fig 4 shows the simulated return loss for different heights of triangular DR. For triangular DR height $h_r$ =13.75 mm, dual resonant frequencies with good return loss is achieved. Simulated results shows that the proposed DRA array has better resonant frequencies for Dielectric Resonator and conformal patch height, $h_r$ = $h_c$ = 13.75 mm.

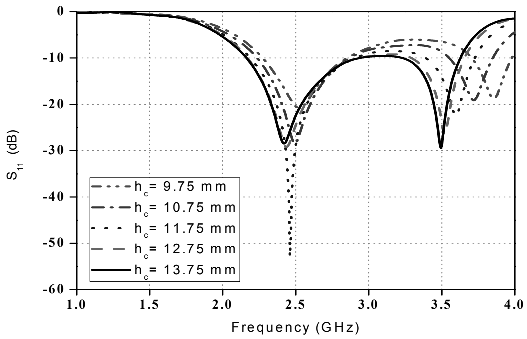



Fig. 2 Comparison of S parameters at various height of the conformal patch

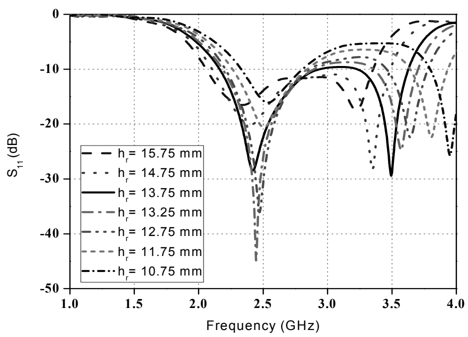



Fig. 3 Comparison of S parameters at various height of the triangular DR

### B. Bandwidth Response and VSWR

A triangular shaped DRA array for 2.4 GHz and 3.5 GHz band has been designed and analyzed. Fig 2, 3, 4 shows the simulated S parameters. In Fig 2, 3 we observed that the resonant frequencies of the DRA array directly influenced by varying the size of the conformal patch and dielectric resonator height. From Fig 2, it has been noticed that with conformal patch height $h_c$=13.75 mm, the DRA achieves bandwidth from 2.16 to 2.94 GHz and 3.22 to 3.63 GHz which is showing a good performance as compare to different values of heights.

Thus, the final simulated $S_{11}$ parameter of triangular DRA array with $h_c$=13.75 mm height of conformal patch, and $h_r$ = 13.75 mm height of triangular DR plotted against frequency is shown in Fig.4. The simulation results of proposed triangular DRA array is also showing very good radiation patterns and return loss over the entire operating bandwidth.

The simulation result of proposed triangular shaped DRA array is also showing a very good voltage standing wave ratio (VSWR) over the entire frequency range. Fig. 5 shows the simulated VSWR against frequency. It has been remarkable that VSWR values are less than 2 over the entire bandwidth.

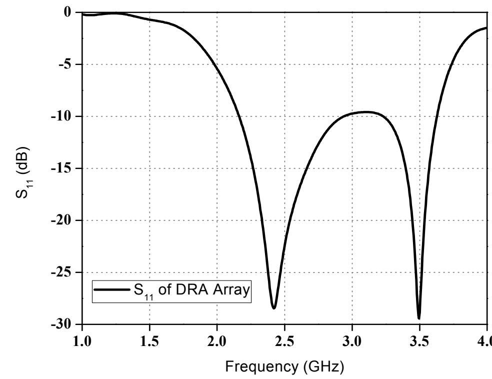



Fig. 4 S parameter of proposed triangular DRA array

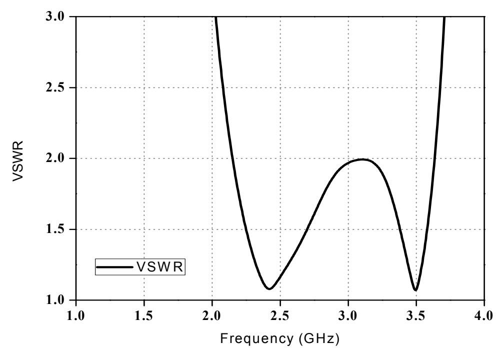



Fig. 5 VSWR of Triangular DRA array

### C. Input Impedance Characteristics

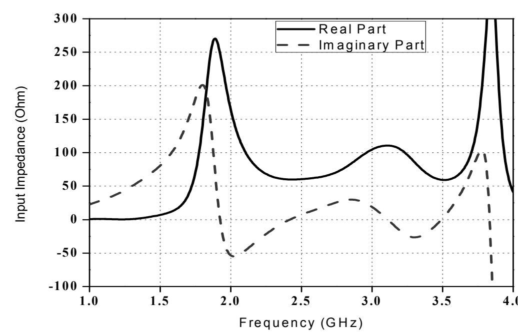
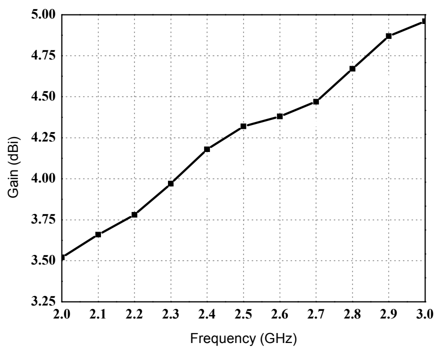



Fig. 6: Input Impedance for Triangular DRA array

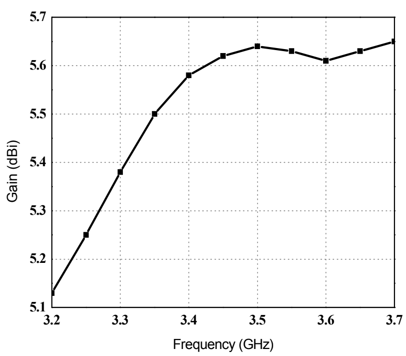
The real and imaginary part of simulated input impedance vs. frequency curves of the proposed antenna has been presented in Fig. 6. It is clear that the input resistance at resonant frequencies of the triangular array is found to be nearly 50 Ω where the imaginary part of the input impedance is zero, providing very good impedance match to 50 Ω microstrip line feeder.

## D. Gain and Radiation Pattern Characteistics

Fig. 7 plots the simulated gain versus frequency of the proposed DRA array, where the gain is 4.18 dBi at 2.4 GHz and 5.64 dBi at 3.5 GHz.

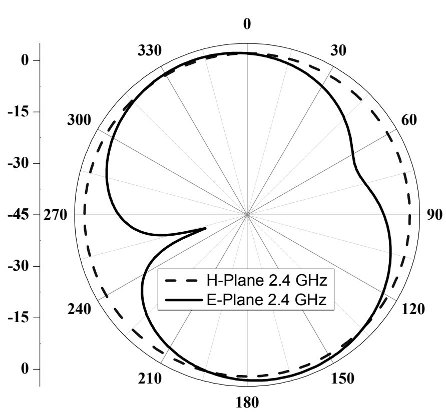



(a) For 2.4 GHz

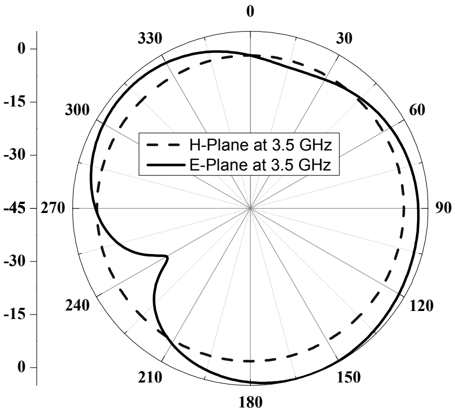



(b) For 3.5 GHz

Fig. 7 Simulated gain versus frequency




(a) At 2.4 GHz




(b) At 3.5 GHz

Fig. 8 Simulated radiation pattern of triangular DRA array at (a) 2.4 GHz and (b) 3.5 GHz

The simulated far field radiation patterns of the proposed two elements triangular shaped DRA array is shown in Fig. 8. It shows the simulated radiation patterns at desired resonant frequencies (2.4 GHz and 3.5 GHz). It has been observed that the E plane radiation patterns are in broadside direction against frequency and in H plane omnidirectional radiation patterns are found.

# IV. CONCLUSIONS

In this paper, a triangular shaped dielectric resonator antenna array is presented for dual band wireless applications. The proposed DRA array consists of two equilateral triangles which are excited by conformal patch connected to microstrip feedline. The simulated results show that the designed antenna offered desired dual resonant frequencies at 2.4 GHz and 3.5 GHz, which covers several important application bands in current wireless communication systems. This antenna design provides a maximum gain of 5.64 dBi. The presented dual-band DRA array is suitable for wireless local area networks WLAN (IEEE 802.11a) and WiMAX applications.

# REFERENCES


[1] Z. Abate, "*WiMAX RF Systems Engineering"*, Artech House Publishers, 2009.

[2] A. Petosa, 'Dielectric Resonator Antenna Handbook'', Artech House Publishers, 2007.

[3] A. Petosa, A. Ittipiboon, Y.M.M. Antar, D. Roscoe, and M. Cuhaci, ''Recent advances in dielectric resonator antenna technology'', *IEEE Antennas Propag. Mag.,* vol. 40, No. 3, pp. 35-48, Jun 1998.

[4] R. K. Mongia and P. Bhartia, "Dielectric resonator antennas-a review and general design relation for resonant frequency and bandwidth, " *Int. J. Microw. Millimeter-Wave Computer-Aided Eng.*, vol. 4, no. 3, Jul. 1994, pp. 230-247.

[5] A. Buerkle, K. Sarabandi, and H. Mosallaei, "Compact slot and dielectric resonator antenna with dual-resonance, broadband

characteristics," *IEEE Trans. Antennas Propag.*, vol. 53, no. 3, pp. 1020–1027, Mar. 2005.

[6] T. W. Li and J. S. Sun, "Dual-frequency dielectric resonator antenna with inverse T-shape parasitic strip," in *IEEE Appl.v Comput. Electromagn. Soc. Int. Conf.*, Apr. 2005, pp. 384–387.

[7] M.S.M. Aras, M.K.A. Rahim, Z.Rasin and M.Z.A. Abdul Aziz, "An Array of Dielectric Resonator Antenna for wireless application," *IEEE International RF and Microwave Conference Proceedings*, pp. 459.463, Dec 2008.

[8] Runa Kumari, Kapil Parmar & S K Behera "Conformal Patch Fed Stacked Triangular Dielectric Resonator Antenna for WLAN Applications", *Proceedings of the IEEE International conference on Emerging Trends in Robotics and Communication Technologies*, Chennei, India, INTERACT-2010, pp 104-107, Dec 2010.

[9] G. Drossos, Z. Wu, and L. E. Davis, "Four-element planar arrays employing probe-fed cylindrical dielectric resonator antennas," *Microw.Opt. Technol. Lett.*, vol. 18, no. 5, pp. 315–319, 1998.

[10] Runa Kumari and S K Behera, "Ring Dielectric Resonator Antenna For Broadband Applications," *Proceedings of the IEEE International Conference on Computational Intelligence and Communication Systems*, Bhopal, India, CICN, pp 7-10, Nov. 2010.

[11] A. K. Bhattacharyya, "Effects of finite ground plane on the radiation characteristics of a circular patch antenna," *IEEE Trans. Antennas Propag.*, vol. 38, pp. 152–159, Feb. 1990.

[12] K. S. Ryu and A. A. Kishk, "Ultra wideband Dielectric resonator antenna wth broadside patterns mounted on a vertical ground plane edge," *IEEE Transactions on Antennas and Propagation*, vol. 58, no. 4, pp. 1047-1053, Apr. 2010.

[13] Lo H.Y., Leung K.W., Luk K.M. and Young E.K.N., "Low-profile equilateral-triangular dielectric resonator antenna of very high permittivity," Electronics Letters, Vol 35, No. 25, pp. 2164-65, December 9, 1999.

[14] K. M. Luk and K. W. Leung, "*Dielectric Resonator Antennas*." Hertfordshire, U.K.: Research Studies Press Ltd., 2002.

[15] Yoshihiko A., "Operation modes of a waveguide Y circultor," IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-23, PP. 954-960, 1974.

[16] Liang X.-L., Denidni T.A and Zhang L. N, "Wideband L-Shaped dielectric resonator antenna with a Conformal inverted-trapezoidal patch feed", *IEEE Trans. Antennas Propag.,* vol. 57, no. 1, Jan 2009,pp. 271-274.

[17] Lucia C. Y. Chu, Guha D. and Antar Y. M. M, "Conformal Strip-Fed Shaped Cylindrical Dielectric Resonator: Improved Design of a Wideband Wireless Antenna", *IEEE Antennas Wirel. Propag. Lett.*, vol. 8, 2009, pp 482-484.