DESIGN OF DIELECTRIC RESONATOR ANTENNA ARRAYS FOR WIRELESS APPLICATIONS

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

MASTER OF TECHNOLOGY

IN

COMMUNCATION AND SIGNAL PROCESSING

BY

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211EC4104

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY ROURKELA-769008

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UNDER THE GUIDANCE OF

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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY ROURKELA

Date: 21-05-1013

CERTIFICATE

This is to certify that the thesis entitled, "Design of Dielectric resonator antenna arrays for wireless applications" submitted by Mr. **IMRAN KHAN** in partial fulfillment of the requirements for the award of Master of Technology Degree in Electronics and Communication Engineering with specialization in "**Communication and Signal Processing**" during session 2012-2013 at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any degree or diploma**.**

S.K.BEHERA

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This project is by far the most significant accomplishment in my life and it would be impossible without people who supported me and believed in me.

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IMRAN KHAN

CONTENTS

ABSTRACT

This thesis presents design of dielectric resonator antenna array for wireless applications. Three antenna designed are presented in the following sections. The first design is a notched chamfered two element rectangular dielectric resonator antenna (DRA) array for wireless (WLAN and WIMAX) applications. Here 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 types of feeding techniques. The shape is notched and chamfered to improve the performance of the antenna. From the Simulation results it can be observed that the proposed antenna covers 2.4, 3.6 and 5 GHz WLAN bands and 3.4 to 3.7 GHz WIMAX bands, achieving an impedance bandwidth from 2.18 to 3.75 GHz and 4.84 to 5.14 GHz. Parametric study is done by varying the shapes of the rectangular DRA arrays (Simple Rectangle, chamfered and chamfered with notched). Another parametric study is carried out by varying the dimension of the ground plane of the final design. The proposed antenna design gives the appreciable gain and radiation pattern at the resonant frequencies.

The second design is a rectangular shaped two element Dielectric Resonator Antenna (DRA) array for 2.4 GHz WLAN application. Here microstrip feed line in corporate (parallel) arrangement is used for feeding. Simulation result shows that the antenna achieves a bandwidth from 2.1 to 3 GHz, covering the 2.4 GHz WLAN band. Here the parametric study is done by varying the feed line and the ground plane of the antenna. The simulation results as well as the parametric studies are incorporated in this thesis.

The third one is the Design of four element rectangular shaped dielectric resonator antenna (RDRA) array for wireless applications. The RDRA array is fed by rectangular conformal patch (RCP) connected to microstrip line. Simulation result shows that the proposed antenna achieves an impedance bandwidth from 4 GHz to 7.1 GHz covering various wireless bands. Parametric studies have been carried out by varying the RCP height and the ground plane of the final design. The proposed antenna design gives the appreciable gain and better radiation pattern at the resonant frequencies.

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CHAPTER-1: THESIS OVERVIEW

1.1 THESIS MOTIVATION:

Bandwidth enhancement is one of the major design considerations for most practical applications of Dielectric resonator antennas. Microstrip antennas have some limitations compared to dielectric resonator antennas as narrow bandwidth, lower gain, lower power handling capacity etc. For that reason, dielectric resonator antennas are preferred over microstrip and conventional antennas. In recent few decades, research scientists have developed several techniques to increase the bandwidth and obtain multi band response for an antenna. Making DRA arrays by using different types of feeding techniques is one of the most popular bandwidth enhancement approach. The recent advancements in wireless communication industry, especially in the area of mobile communication and wireless data communication, have led to the increased demand for multi band antennas, which promoted the study and design of DRA arrays.

1.2 LITERATURE REVIEW:

For many years, the dielectric resonator (DR) has primarily been used in microwave circuits, such as oscillators and filters [1]. Because of these traditional applications, the DR was usually treated as energy storage device. Dielectric resonator was first discussed as an antenna by S. A. Long in a paper entitled, "The resonant cylindrical dielectric cavity antenna," IEEE Transactions on Antenna and Propagations [2]. At that time, it was observed that the frequency range of interest for many systems has gradually progressed upward to the millimeter and near millimeter range (100–300 GHz). The conductor loss of metallic antennas becomes severe and the efficiency of the antenna is reduced significantly at these frequencies. But the only loss for a DRA is that due to the imperfect dielectric material, and its value is almost negligible. After the cylindrical DRA has been studied, Long and his colleagues subsequently investigated the rectangular and hemispherical DRAs [3], [4]. Analysis of their resonant modes, radiation patterns, and method of excitation made it clear that these dielectric resonators could be used as antennas and offered a new and attractive alternative to traditional low gain radiators. In the early 1990, emphasis was placed on realizing various analytical or numerical techniques for determining the input impedance and Q-factor. Focus was mainly on individual elements. A significant amount of this characterization was carried out by two research teams; one was led by Kishk, Glisson, and Junker and the other by Luk and Leung. Much of the early work to characterize the performance of the basic DRA elements was summarized in a 1994 review paper by Mongia and Bhartia [5]. They also proposed different modes for DRA, and provided a set of simple equations for predicting the resonant frequency and the Q-factors for several DRA shapes. By the mid-1990s more attention was being given to linear and planar DRA arrays, ranging from simple two element arrays, up to complex phased arrays of over 300 elements with beam-steering capability. The development of ferrite resonator antennas, DRAs operating at 40 GHz, and DRAs with nearly 40% impedance bandwidth also occurred in this period. Many of the recent advances were reported in a 1998 paper by Petosa et al. [6]. K. W. Leung proposed a new excitation scheme in year 2000 which employs a conducting conformal strip for dielectric resonator antenna excitation by using a hemispherical DRA [7]. M.S.M. Aras, M.K.A. Rahim, Z.Rasin, M.Z.A. Abdul Aziz proposed an array of Dielectric resonator Antenna for wireless application in 2008 [8]. Wael M. Abdel Wahab, Safieddin Safavi Naeini, and Dan Busuioc Modelled and Designed a Millimeter-Wave High Q-Factor Parallel Feeding Scheme for Dielectric Resonator Antenna Arrays in 2011 [9]. Yong Mei Pan, Kwok Wa Leung and Kai Lu Proposed Omnidirectional Linearly and Circularly Polarized Rectangular Dielectric Resonator Antennas in 2012 [10].

1.3 SCOPE OF THIS PROJECT:

The scope of this work is to design and fabricate dielectric resonator antenna arrays which can be used for wireless applications according to IEEE 802.11 and 802.16 standards. The operating frequency band must cover the 2.4, 3.6, 4.9 and 5 GHz WLAN bands covered by IEEE 802.11 standards and 2.3, 2.5, 3.5 and 5.8 GHz WIMAX bands covered by 802.16 standards. The antenna should be small in size and easy to manufacture with available laboratory equipments. The return loss must be less than -10 dB within the wireless range, which means only 10% of power will be reflected back while 90% of power is transmitted. Other aspects, such as beam width, side lobes and directivity, were not considered during the design stage; but, they were evaluated for the final designs.

Special attention had been paid to the feeding techniques used, as it is a very important parameter in the design of the dielectric resonator antenna array. Corporate feeding techniques with matched lines are used for the purpose.

1.4 INTRODUCTION TO WLAN AND WIMAX:

Wireless communications have grown at a very rapid pace across the world over the last few years, which provide a great flexibility in the communication infrastructure of environments such as hospitals, factories, and large office buildings. WLAN and WIMAX are the standard based technologies enabling the delivery of the wireless broadband access. A wireless local area network (WLAN) links two or more devices using wireless distribution method and provide a connection through an access point to the wider internet. By this a user has the mobility to move around a local coverage area and still be connected to the network. WLANs are based on IEEE 802.11 standards, marketed under the Wi-Fi brand name. The 802.11 covers mainly three different frequency range. Those are 2.4 GHz, 3.6 GHz and 4.9/5 GHz. The 2.4 GHz channel comes under 802.11b/g/n standards, 3.6 GHz comes under 802.11y standard, 4.9 GHz frequency comes under 802.11y and 5 GHz frequency is included in 802.11a/h/j/n standards. In WLAN a number of standards have been defined in the 5 to 6 GHz range that allow data rates greater than 20 Mb/s, which offers attractive solutions for real-time imaging, multimedia, and high speed video applications.

Worldwide Interoperability for Microwave Access (WIMAX) is a wireless communication standard to provide higher data rates. WIMAX refers to interoperable implementations of the IEEE 802.16 family of wireless network standards. WIMAX can provide at home or mobile Internet access across whole cities or countries. Now a days WIMAX is used to provide internet access in remote places at a low cost. It can operate over higher bit rates and longer distances. The bandwidth and range of WIMAX make it suitable for providing portable mobile broadband connectivity across cities and countries, to provide broad band internet access and for data and telecommunication services. The frequencies included in 802.16 standards are 2.3, 2.5, 3.5 and 5.8 GHz which have many practical applications [11].

1.5 THESIS OUTLINE:

In Chapter 1 the thesis overview is shown. The literature review for the project work is done in this chapter and the introduction to WLAN and WIMAX and its different standards are shown in this chapter. Chapter 2 presents the basic theory of DRAs, including the characteristics of the DRAs, its advantages and its applications, Comparison to microstrip antennas and different feeding methods (coaxial feed, slot aperture, microstrip line feed, proximity coupled microstrip line feed, co-planar feed & dielectric image guide). It also shows some of the equivalent circuits of the feed line and transmission line modeling for microstrip feed design. At last this chapter shows the study of rectangular DRA and some of its modified shapes for bandwidth enhancement. Chapter 3 focuses on the study of DRA array and shows the different feeding techniques for DRA arrays. It also shows the study of mutual coupling between the resonating elements and how to avoid its occurrence.

Chapter 4 describes the design of a notched chamfered rectangular dielectric resonator antenna for WLAN and WIMAX applications. In this design, 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 types of feeding techniques. In chapter 5 design of two elements rectangular shaped dielectric resonator antenna (RDRA) array is presented for 2.4 GHz wireless applications. The RDRA array is excited by microstrip line coupling arranged in a corporate feed technique. Simulation result shows that the proposed antenna achieves an impedance bandwidth from 2.1 GHz to 3 GHz covering 2.4 GHz wireless band. The fabricated antenna and its measured reflection coefficient vs. frequency curve is also shown in this chapter. Chapter 6 presents a four element rectangular shaped dielectric resonator antenna (RDRA) for wireless applications. The RDRA array is excited by rectangular conformal patch (RCP) connected to microstrip line. Simulation results have been shown for this design.

Conclusion of the thesis is given in chapter 7 and the future work of the DRA array is shown in this chapter.

CHAPTER-2: DIELECTRIC RESONATOR ANTENNA

2.1 INTRODUCTION:

Dielectric resonator antenna consists of dielectric materials in its radiating patch also called as dielectric resonators (DRs) on one side of the substrate and has a ground plane (metal) on the other side [12], [13]. The dielectric constant of the dielectric resonators on the DRAs can vary from 2 to 100. The dielectric resonators have three basic shapes i.e. circular, rectangular and triangular, but rectangular shape is generally used because the design and analysis of rectangular shape is comparatively easy [3], [4]. As compared to the microstrip antenna, the DRA has a much wider impedance bandwidth (~10% for dielectric constant $\varepsilon_r \sim 10$). This is because the microstrip antenna radiates only through two narrow radiation slots, whereas the DRA radiates through the whole DRA surface except the ground part [12]. Avoidance of surface waves is another attractive advantage of the DRA over the microstrip antenna. However, many characteristics of the DRA and microstrip antenna are common because both of them behave like resonant cavities. For example, since the dielectric wavelength is smaller than the free-space wavelength by a factor of $\frac{1}{\sqrt{\varepsilon_r}}$, both of them can be made smaller in size by increasing ε_r [12], [13]. Preferably, the relative permittivity ε_r of the substrate should be low ($\varepsilon_r < 2.5$), to enhance the fringing fields that account for the radiation. However, as per the performance requirements, the value of the dielectric constant of the substrate may vary and can be of some greater value (say 4.4). Various types of substrates having a large range of dielectric constant and loss tangent values have been developed. Sometimes if we increase the dielectric constant or relative permittivity of the substrate or the dielectric resonators (DRs) there is chance to increase the performance of the antenna, but materials with higher dielectric constant values may or may not be available for fabrication. Fig.1 shows the basic shapes of the DRAs. There are a number of effective excitation methods that can be used for DRAs. Some of the examples are the coaxial probe, aperture-coupling with a microstrip feed line, aperture-coupling with a coaxial feed line, direct microstrip feed line, co-planar feed, soldered-through probe, slot line, strip line, proximity coupled microstrip feed, conformal strip, and dielectric image guide feed[12], [22], [23]. Microstrip feeding technique is most general and simple method of feeding. Here the DRAs are fed with 50 Ω microstrip lines.

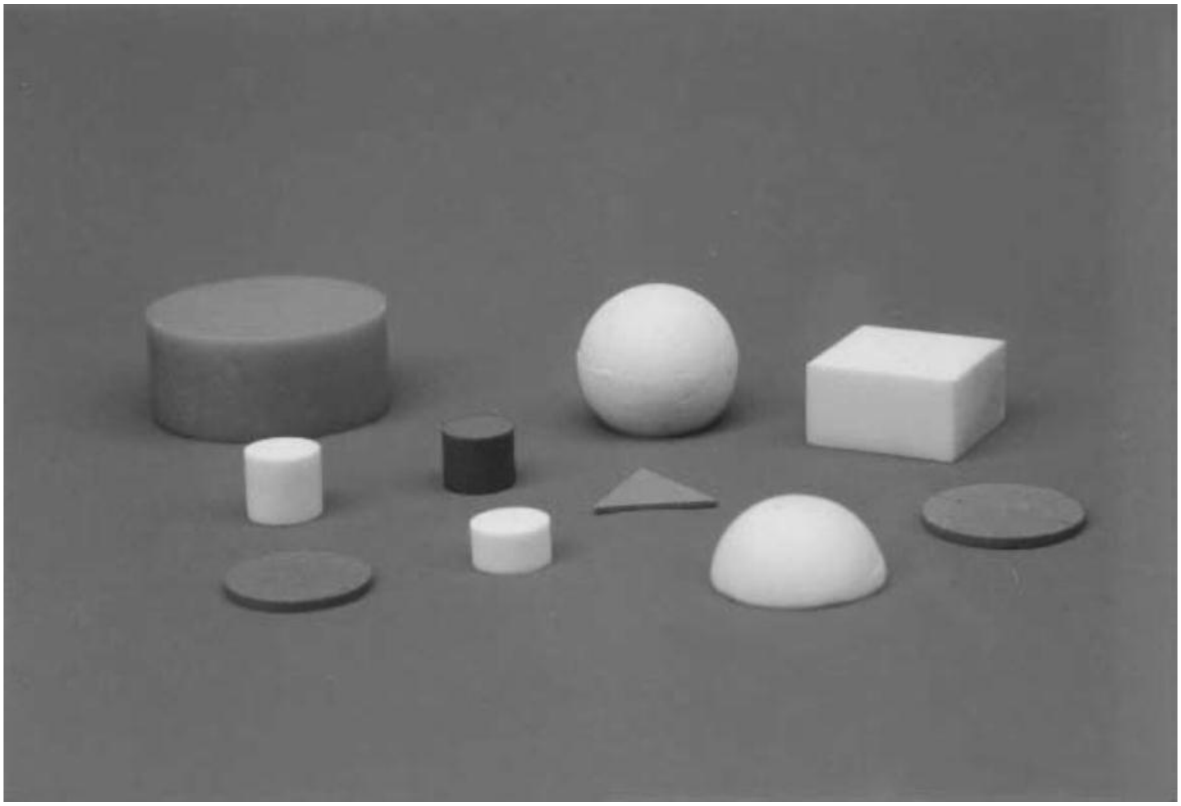

Fig.1 DRAs of various shapes

2.1.1 MAJOR CHARACTERESTICS:

Some of the main characteristics of the dielectric resonator antennas are summarized below;

1. The size of the DRA is proportional to $\lambda_0 / \sqrt{\varepsilon_r}$, where λ_0 is the free space wavelength at the resonant frequency, and ε_r is the dielectric constant of the material.

2. The resonant frequency and radiation Q-factor is also affected by the aspect ratio of the DRA for a fixed dielectric constant, permitting additional design flexibility to the designers.

3. A wide range of dielectric constants can be used allowing the designers to control the physical size and the bandwidth of the DRA.

4. By selecting a dielectric material with low loss characteristics, a high radiation efficiency can be maintained in DRAs.

5. DRAs can be designed to operate over a wide range of frequencies from 1 GHz to 44 GHz.

6. DRA has much wider impedance bandwidth compared to microstrip antennas.

7. Depending upon the resonator shape, various modes can be excited within the DRA producing either broad side or omnidirectional radiation patterns for different coverage requirements.

8. DRAs have high dielectric strength and hence higher power handling capacity.

9. It has high degree of flexibility and versatility, allowing for designers to suit a wide range of physical or electrical requirements of varied communication applications.

10. Several feeding methods can be used to efficiently excite the DRAs, such as probes, microstrip lines, slots & dielectric image guides & co-planar wave guide lines [12], [13].

2.1.2 LIMITATIONS:

1. The fabrication price is more as compared to microstrip antenna.

2. Ceramic materials are typically used, which must either be machined from large blocks or cast from molds. Drilling may be required and the DRA has to be bonded to a ground plane or substrate.

3. Compared to the printed circuit antennas, the fabrication is generally more complex and more costly, especially for array applications.

4. Difficult to get dielectric materials of desired dielectric constants, so have to work with limited available sources.

5. Excitation of surface waves [12], [13].

2.1.3 APPLICATIONS:

1. Satellite communication, direct broadcast services.

2. Doppler and other radars.

3. Missiles and telemetry.

4. Mobile radio (pagers, telephones, man pack systems).

5. Biomedical radiators and intruder alarms.

2.2 FEEDING METHODS:

Feeding techniques are required to energize the antenna i.e. to transfer the power into the antenna. Early microstrip antennas were fed either by a microstrip line or a coaxial probe through the ground plane. Dielectric resonator antennas have radiating elements on one side of dielectric substrate and for these designs a number of new feeding techniques have been developed [12], [13]. Some feeding techniques are easy to fabricate where as other are difficult, and some feeding techniques can enhance the bandwidth. For example, aperture and proximity feeds are used to increase the bandwidth but fabrication is the major problem because these two feeding techniques useful when two substrate are present.

2.2.1 MICROSTRIP FEED:

Excitation of the dielectric resonator antenna by a microstrip line on the same substrate is the easiest method of feeding. In this type of feed technique, a conducting strip is connected directly to the edge of the dielectric resonator (DR) or inserted under the DR. A common method of excitation with microstrip line is to use it by proximity coupling. The amount of coupling from the microstrip line to the DRA can be controlled to a certain degree by adjusting the spacing between the DRA and the line for the side-coupled case or the length of the line underneath the DRA for the direct-coupled case [12]. The dielectric constant of the DRA also affects the coupling. Higher the value of dielectric constant, higher will be the value of the coupling. This is an easy feeding scheme and it provides ease of fabrication and simplicity in modeling as well as impedance matching. As the thickness of the dielectric substrate of the DRA increases, surface waves and spurious feed radiation also increase, so the thickness of the substrate should be kept less [12]-[15]. Fig.2 shows the microstrip feed technique to DRA.

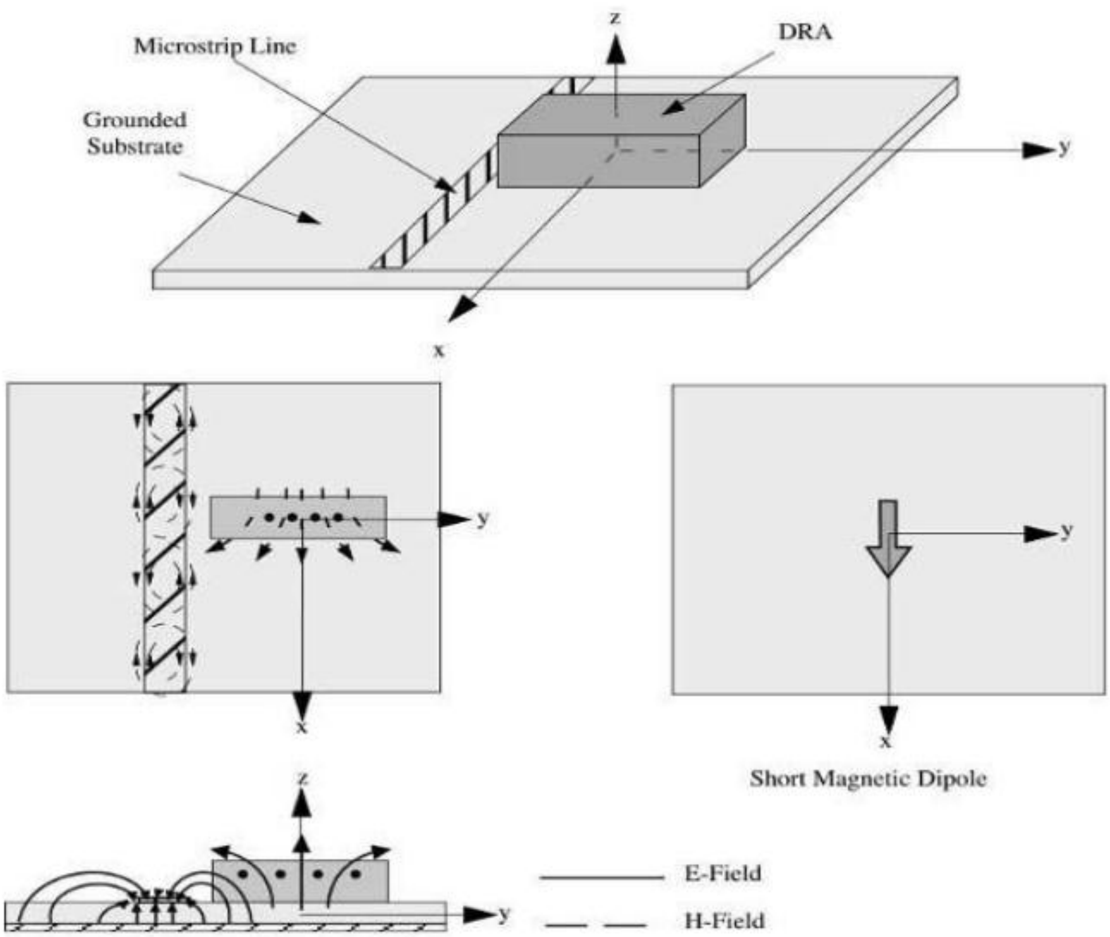

Fig.2 Microstrip feed

2.2.2 COAXIAL/PROBE FEED:

Another common method of coupling to DRA is with a probe. The probe usually consists of the center pin of a coaxial transmission line that extends through the ground plane. The center pin can also be soldered to a flat metal strip that is placed adjacent to the DRA, whose length and width can be adjusted to improve the impedance match [12], [13]. The coaxial connector is attached to the back side of the DRA and the coaxial center conductor after passing through the substrate is drilled into the dielectric resonators. The amount of coupling can be controlled by adjusting the probe height and the DRA location. The probe length is generally chosen to be less than the height of the DRA, to avoid probe radiation. Feeding the probe adjacent to the DRA is preferred since it does not require drilling into the DRA. The advantage of the coaxial probe excitation is the direct coupling into a 50-Ω system without the need for a matching network [16], [17]. Fig.3 shows the probe coupling to the DRA.

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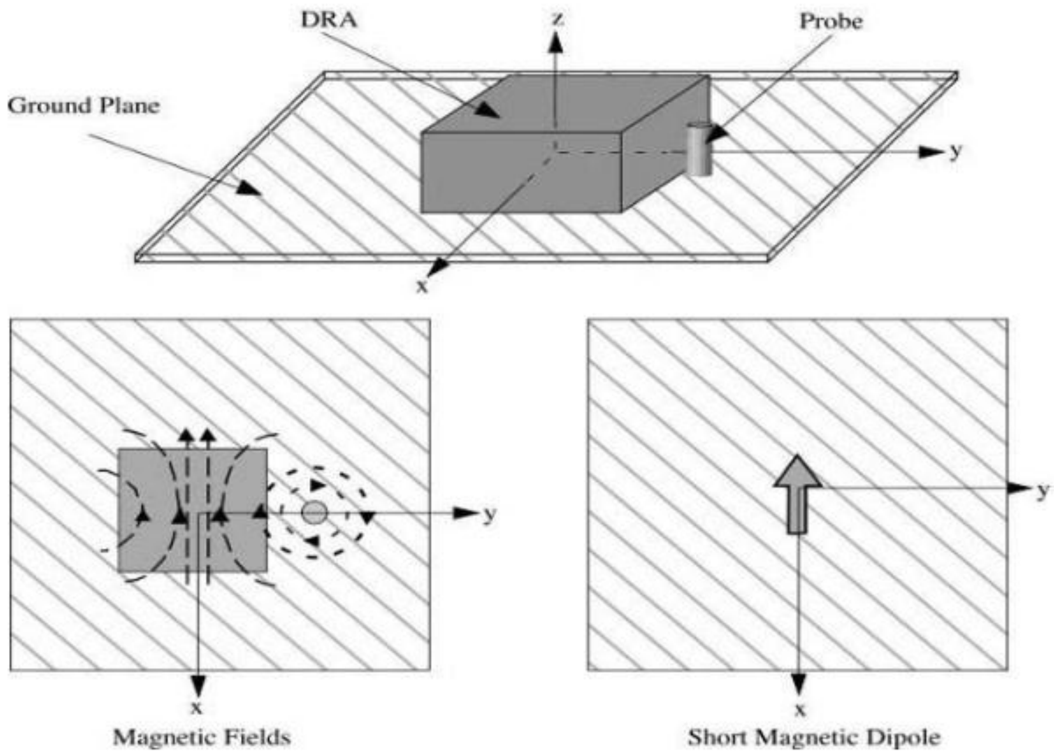


Fig.3 Probe feed

2.2.3 APERTURE FEED:

One common method of exciting a DRA is through an aperture in the ground plane upon which the DRA is placed. Small rectangular slot is the most widely used aperture [12], [13], [18]. By keeping the slot dimensions electrically small, the amount of radiation beneath the ground plane can be minimized. Annular slots are generally used for exciting cylindrical DRAs, while cross-shaped and C-shaped slots are used to excite circular polarization. The aperture can be fed by a transmission line (either microstrip or coaxial) or a waveguide. Aperture coupling offers the advantage of having the feed network located below the ground plane, isolating the radiating aperture from any unwanted coupling or spurious radiation from the feed [12]. Feeding the aperture with a microstrip transmission line is the most common approach, since printed technology is easy to fabricate. Microstrip line also offers a degree of impedance matching not available with coaxial lines or waveguides [19]-[21]. Fig.4 shows the aperture coupling to the DRA.

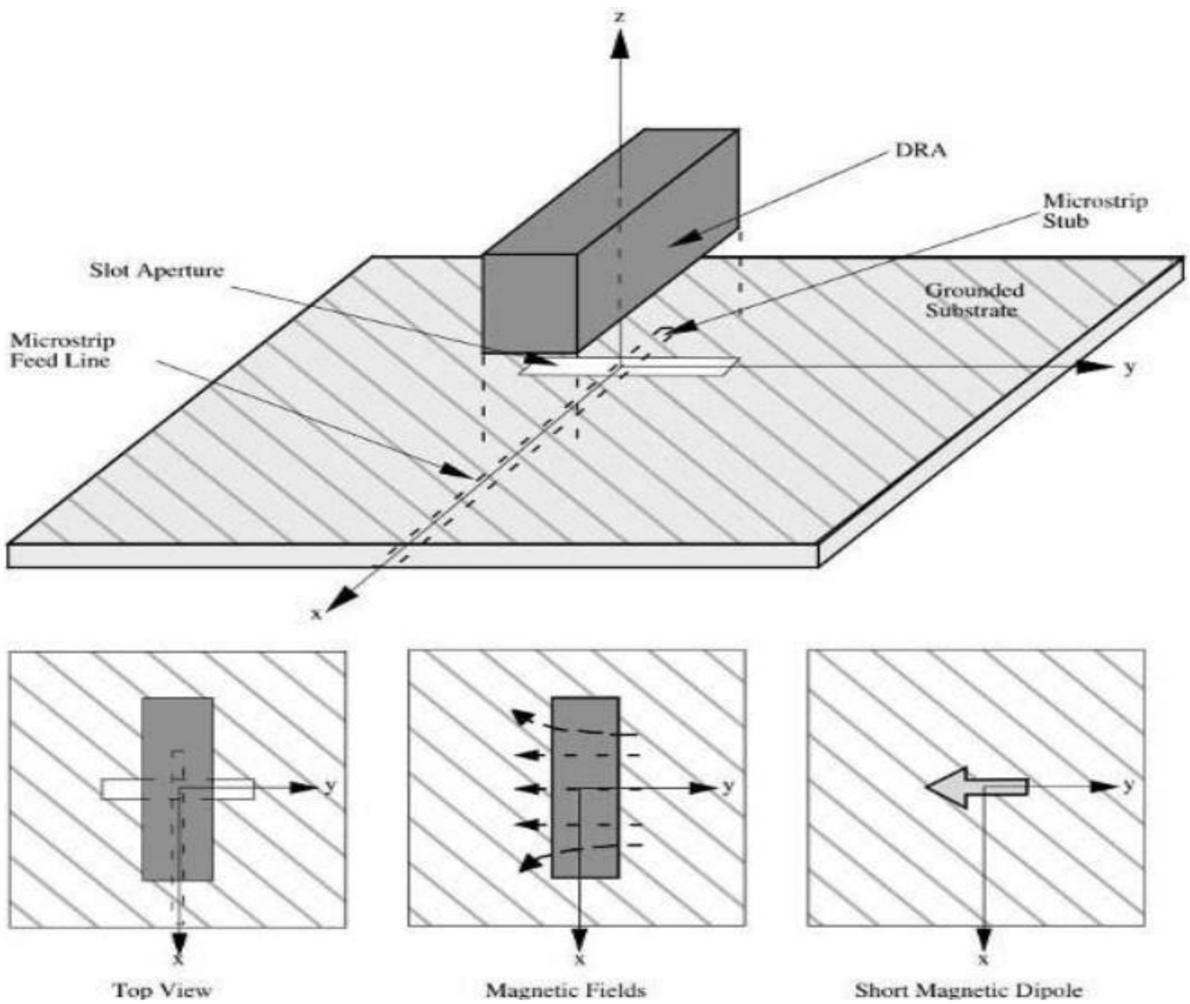


Fig.4 Aperture feed

2.2.4 PROXIMITY COUPLED MICROSTRIP FEED:

In this type of feeding we use a two layer substrate and the DRA is placed on the upper layer. This feed is also known as an electromagnetically coupled feed. To design this feed Two substrates are required, and the feed line shoud be in between the two substrates. The fabrication of the antenna is difficult and the thickness of the antenna is increased due to the presence of two substrates. By using this feeding technique The bandwidth of the antenna can be improved. The substrate parameters of the two layers can be selected to increase the bandwidth and to reduce spurious radiation, for this the lower substrate should be kept thin [22], [23]. The equlent circuit diagram for this type of feeding is shown in fig.7 which consists of inductor, capcitor & resistors. Proximity-coupled microstrip antenna is also known as non-contacting feeds.

Some advantages are:

- No physical contact between feed line and radiating element
- No drilling required.
- Less spurious radiation.
- Better for array configurations.
- Good suppression of higher order modes
- Better high frequency performance

2.2.5 COPLANAR FEED:

Coupling to DRAs can also be achieved by using coplanar feeds. Open-circuited waveguides can be used to directly feed the DRAs. Additional control for impedance matching can be achieved by adding stubs or loops by the end of the line. Fig.5 shows a cylindrical DRA coupled to a co-planar loop. The coupling level can be increase or decrease by positioning the DRA over the loop and by moving the loop from the edge of the DRA to the center. The dimensions of the coplanar feed should be chosen large enough to ensure proper coupling, but small enough to avoid excessive radiation in the back lobe [12], [13]. The coupling behavior of the co-planar loop is similar to coaxial probe, but the loop offers the advantage of being non-obtrusive. [18], [24].

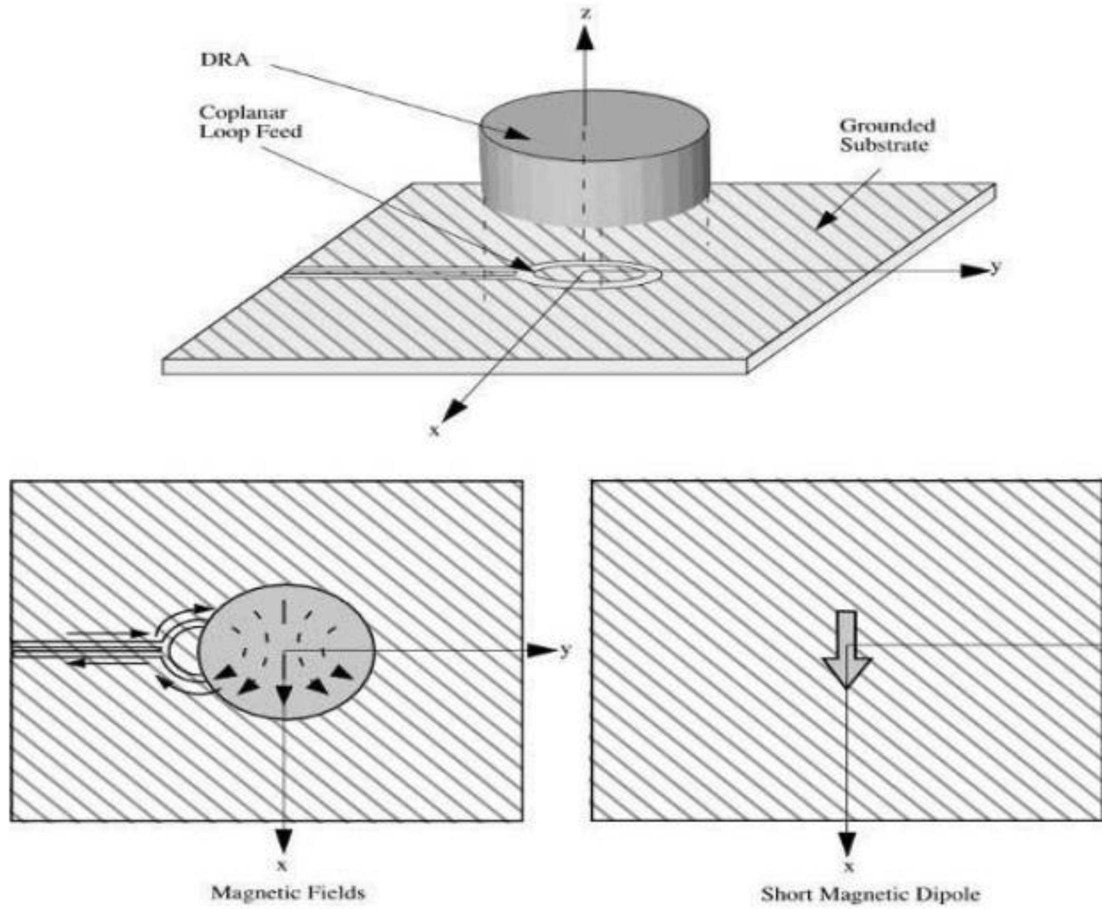


Fig.5 Coplanar feed

2.2.6 DIELECTRIC IMAGE GUIDE FEED:

This coupling technique is similar to microstrip line coupling, but instead of perfect electric conductor we use dielectric material as feed line. Dielectric image guides offer advantages over microstrips at millimeter-wave frequencies, since they do not suffer from conductor losses. The coupling can be controlled by adjusting the spacing between the guide and the DRs [12], [13], [18], [25]. Fig.6 shows the dielectric image guide coupling of the DRA.

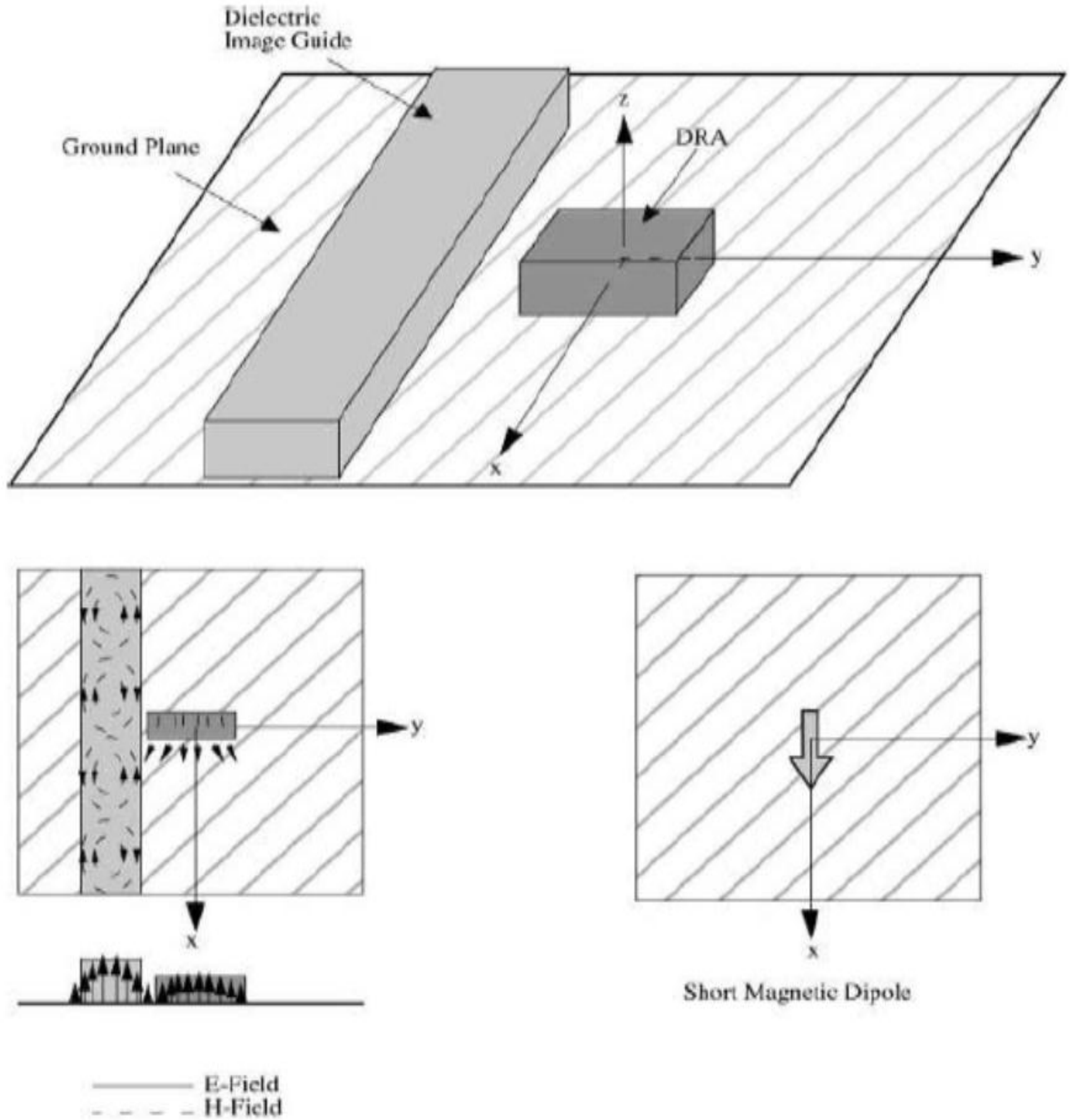


Fig.6 Dielectric image guide feed

Fig.7 shows the equivalent circuits of some of the feeding techniques used for DRAs.

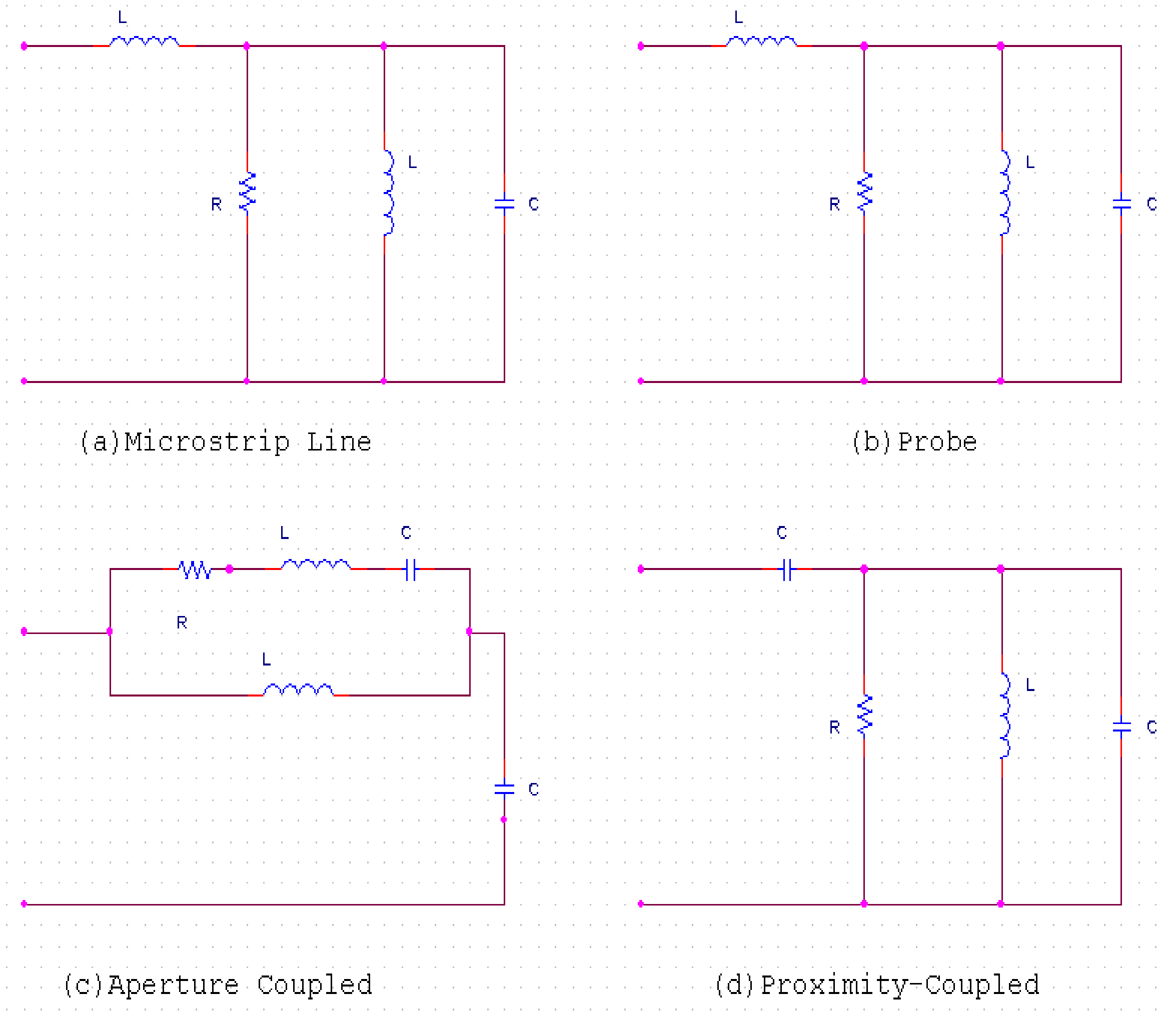


Fig.7 Equivalent circuits for some typical feeding techniques

2.3 TRANSMISSION LINE MODELING:

Transmission line model is the easiest modelling technique for microstrip antennas, but it yields the least accurate results and it lacks the versatility. However, it does gives a good understanding on microstrip line. Here in case of DRA this model is generally used to design and analyse the microstrip line feeding. A rectangular microstrip antenna can be represented as an array of two radiating narrow apertures (slots), each of width W and height h, seperated by a distance L. A typical microstrip line is shown in Fig.8(a) while the electric field lines associated with it are shown in Fig.8(b).

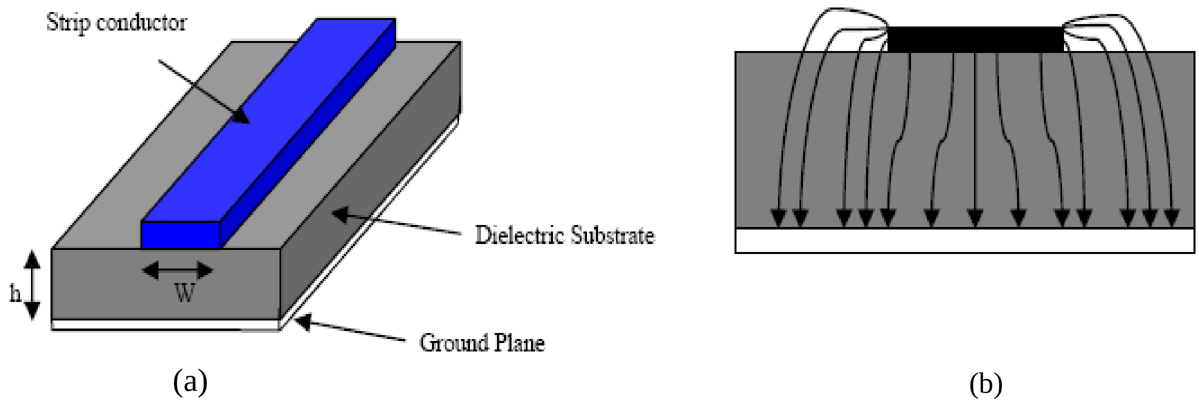


Fig.8 (a) Microstrip line and (b) Electric field lines

As L/h >>1 and ε_r>>1,the elctric field lines concentrate mostly in the substrate. The Fringing effect in this case makes the microstrip look wider elctrically comapred to its actual physical size. Since some of the waves travel in the substrate and some in air, an effective dielectric constant ε_{reff} is introduced to account for fringing and the wave propogation in the line.

For a design with air gap above the substrate, the effective dielectric constant has values in the range of $1< \varepsilon_{reff}< \varepsilon_r$. For most applications where the dielectric constant of the substrate is much greater than unity (ε_r>>1), the value of ε_{reff} will be closer to the value of the actual dielctric constant ε_r of the substrate

When $\left(\frac{W}{H}\right) < 1$

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\left(1 + 12\left(\frac{H}{W}\right)\right)^{-\frac{1}{2}} + 0.04\left(1 - \left(\frac{W}{H}\right)\right)^2\right] \rightarrow \qquad 2.1$$

When $\left(\frac{W}{H}\right) \geq 1$

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\left(\frac{H}{W}\right)\right)^{-\frac{1}{2}} \quad \rightarrow \quad 2.2$$

2.4 RECTANGULAR DIELECTRIC RESONATOR ANTENNA DESIGN:

The DRA with a rectangular crossection is known as the rectangular DRA. It is characterized by a height h, width w, depth d, and a dielectric constant ε_r. The rectangular DRA is considered to be a truncated section of an infinite dielectric waveguide of width w and height b = 2h due to the image effect of the ground plane. Fig.9 shows the geometry of a rectangular DRA. The rectangular shape offers a second degree of freedom because the w/h and w/d ratios can be choosen independently, making it the most versatile of the basic shapes [12], [13]. By using this design flexibility, we can achieve the desired profile and bandwidth characteristics for a given resonant frequency and dielectric constant. In a rectangular DRA perfect magnetic walls are assumed along the four surfaces parallel to the direction of propagation in the dielectric guide, while the tangential components of the electric and magnetic fields are assumed to be contineous across the two surfaces, perpendicular to the direction of propagation [12]. The basic modes in a dielectric waveguide is TE or TM, but the TE mode is usually excited while the DRA is mounted on the ground plane. By properly choosing the DRA dimensions, it can be ensured that unwanted modes do not appear over the frequency band of operation. The rectangular DRA supports TE^x, TE^y and TE^z modes, which are dependent on the dimensions of the DRA and the relationship between w, d and b. If w > d > b, then $f_x < f_y < f_z$, where f_x is the resonant frequency of TE^x mode. Therefore a rectangular DRA will have a resonant frequency f_{mn} on the $TE^x_{\delta mn}$ mode, which can be solved by using the following transcedental equation [5], [10], [12], [13].

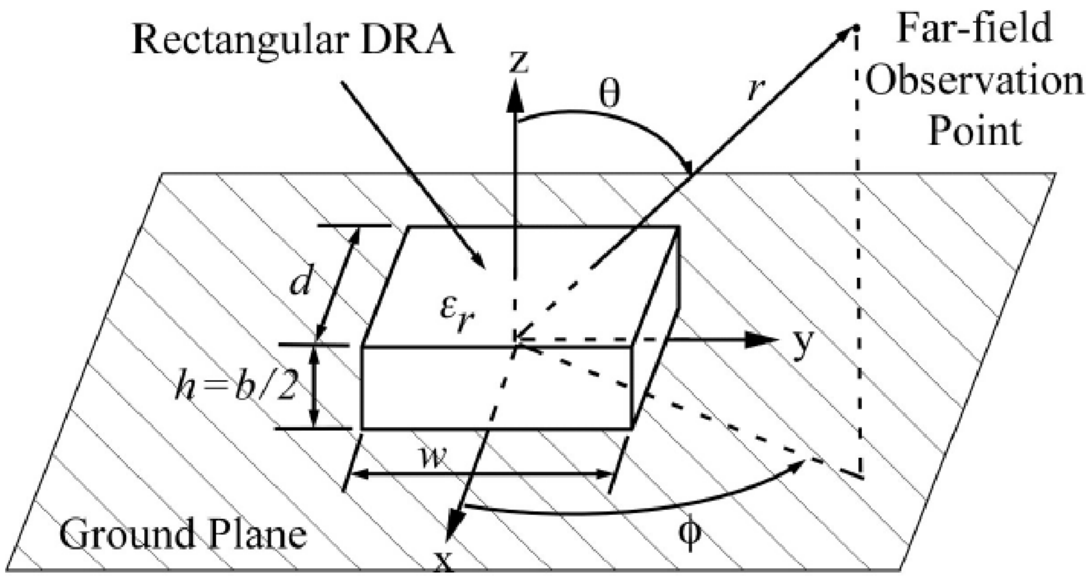


Fig.9 Geometry of rectangular DRA

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

Where,

$$k_{mn} = \frac{2\pi f_{mn}}{c} \qquad k_y = m\frac{\pi}{w} \qquad k_z = n\frac{\pi}{b} \quad and \;\; k_x^2 + k_y^2 + k_z^2 = \varepsilon_r k_{mn}^2$$

And m and n are positive integers corresponding to the field variation within the y and z direction respectively. The E and H fields within the DRA for the various modes can be approximated by

$$E_x = 0 \qquad \rightarrow \qquad 2.3$$

$$E_y = k_z \cos(k_x x) \begin{Bmatrix} \cos(k_y y) \\ \sin(k_y y) \end{Bmatrix} \begin{Bmatrix} \sin(k_z z) \\ \cos(k_z z) \end{Bmatrix} \qquad \rightarrow \qquad 2.4$$

$$E_z = -k_y \cos(k_x x) \begin{Bmatrix} \sin(k_y y) \\ \cos(k_y y) \end{Bmatrix} \begin{Bmatrix} \cos(k_z z) \\ \sin(k_z z) \end{Bmatrix} \rightarrow \quad 2.5$$

$$H_x = \frac{k_y^2 + k_z^2}{j2\pi\mu f_{mn}} \cos(k_x x) \begin{Bmatrix} \cos(k_y y) \\ \sin(k_y y) \end{Bmatrix} \begin{Bmatrix} \cos(k_z z) \\ \sin(k_z z) \end{Bmatrix} \rightarrow \quad 2.6$$

$$H_y = \frac{k_x k_y}{j2\pi\mu f_{mn}} \sin(k_x x) \begin{Bmatrix} \sin(k_y y) \\ \cos(k_y y) \end{Bmatrix} \begin{Bmatrix} \cos(k_z z) \\ \sin(k_z z) \end{Bmatrix} \rightarrow \quad 2.7$$

$$H_z = \frac{k_x k_z}{j2\pi\mu f_{mn}} \sin(k_x x) \begin{Bmatrix} \cos(k_y y) \\ \sin(k_y y) \end{Bmatrix} \begin{Bmatrix} \sin(k_z z) \\ \cos(k_z z) \end{Bmatrix} \rightarrow \quad 2.8$$

Where the upper functions are chosen when the values of m and n are odd and the lower functions when m or n are even [12], [13].

2.5 NOTCHED RECTANGULAR DRA:

A rectangular DRA with a central air gap is called notched rectangular DRA. By introducing a central notch inside the DRA the bandwidth of the antenna can be increased. The increse in bandwidth is based on by lowering the Q-factor**.** By introducing the central notch in DRA the radiation Q-factor of the DRA can be reduced. By applying image theory, the notched DRA appears similar to a square ring. By adjusting the dimension of the notch, a dual band or wide band response can be achived. If the gap height is more, the coupling may be less, so to increase the coupling, a high dielectric insert can be introduced. It acts as an impedance transformer between the microstrip line and the DRA [12]. Fig.10 shows the design of a notched rectangular DRA with a dielectric insert.

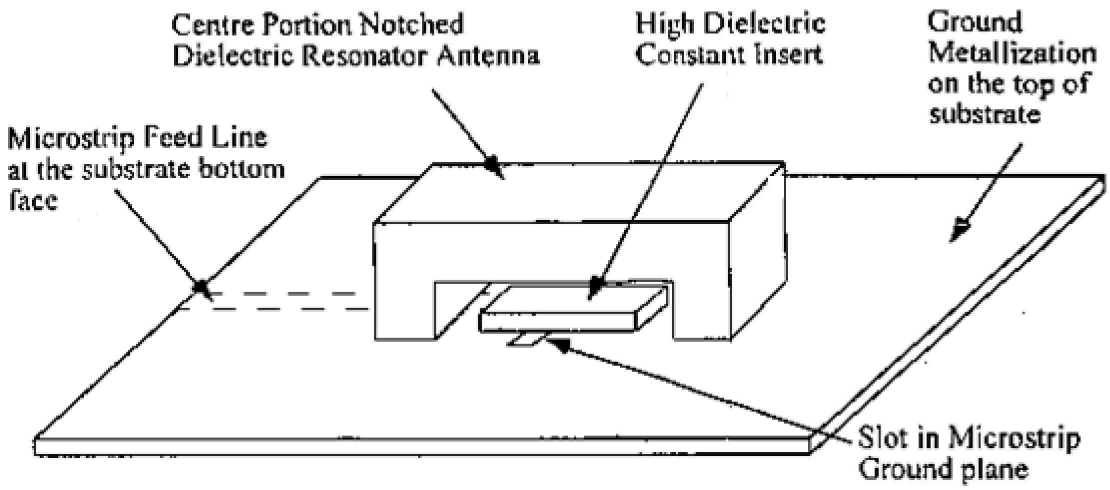


Fig.10 Notched rectangular DRA

2.6 CHAMFERED RECTANGULAR DRA:

A square DRA with four corners chamfered is used for generating circular polarization. It can also be used to increase the band width of the antenna compared to the simple rectangular DRA. Probe feeding is the best feeding technique for chamfered DRA. It decreases the radiation Q-factor and increses the bandwidth of the antenna [12]. Fig.11 shows a rectangular DRA with one chamfered face.

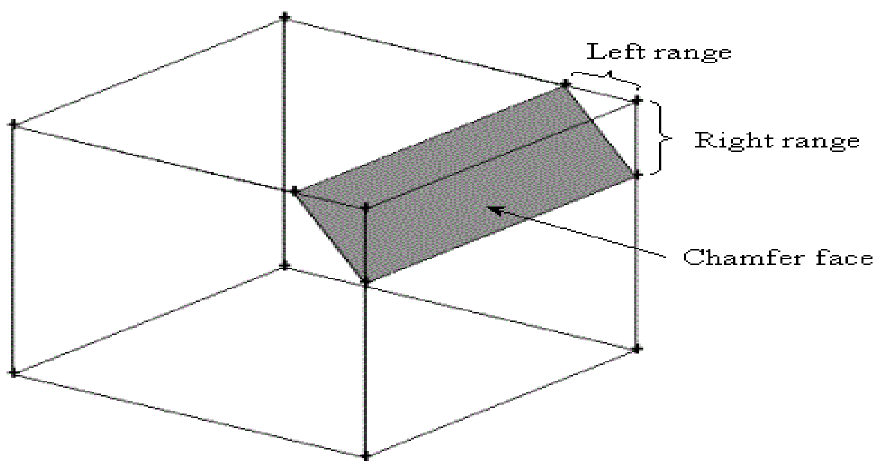


Fig.11 Chamfered rectangular DRA

CHAPTER-3: DRA ARRAY

3.1 DRA ARRAY THEORY:

Common antenna array elements include monopole, dipole, helixes, micro strip patches, printed tapered slots and waveguide slot apertures. Each has their own strengths and weaknesses and are generally selected to meet specific needs. Adding DRAs to the list of potential array elements, we can get certain advantages for specific applications not available with other conventional elements. DRAs are typically low gain antennas with broad radiation patterns, so they can be arrayed to achieve higher gain or shaped radiation patterns like other conventional antennas [12], [13], [27].

3.2 ARRAY THEORY:

The radiation pattern of an antenna of N-identical elements evaluated at a location $(\theta,\ \emptyset)$ in the far field can be approximated by the product of the radiation intensity of the element and the array factor using:

$$\text{Radiation pattern} = 20\log(Radiation\ intensity\ of\ the\ element\ \times Array\ factor)$$

Where,

$$\text{Array factor} = \sum_{n=1}^{N} A_n e^{j\psi_n}$$

And,

$$\psi_n = k_0 x_n \sin\theta \cos\phi + k_0 y_n \sin\theta \sin\phi$$

Where;

k_0 = free space wave number $\frac{2\pi}{\lambda_0}$

(x_n, y_n) = location of the nth element

A_n = complex voltage excitation

The above equation for array factor is the general equation and applicable to arrays where the elements are arbitrarily located and excited. For a linear array of N-elements where the elements are uniformly spaced a distance d apart, the array factor simplifies to:

$$Array\ factor = \sum_{n=1}^{N} A_n e^{jnk_0 d \sin\theta}$$

In this case a uniform amplitude excitation ($A_1 = A_2 = \ldots = A_0$) is chosen in order to obtain maximum directivity, and a linear phase progression ($\beta_1 = \beta,\ \beta_2 = 2\beta, \ldots \beta_N = N\beta$) is selected to scan the beam to a desired angle. The array factor is further simplified to:

$$Array\ factor = \frac{A_0 \sin\left(\frac{N\psi}{2}\right)}{\sin\left(\frac{\psi}{2}\right)}$$

Where;

$$\psi = k_0 \mathrm{d} \sin\theta + \beta$$

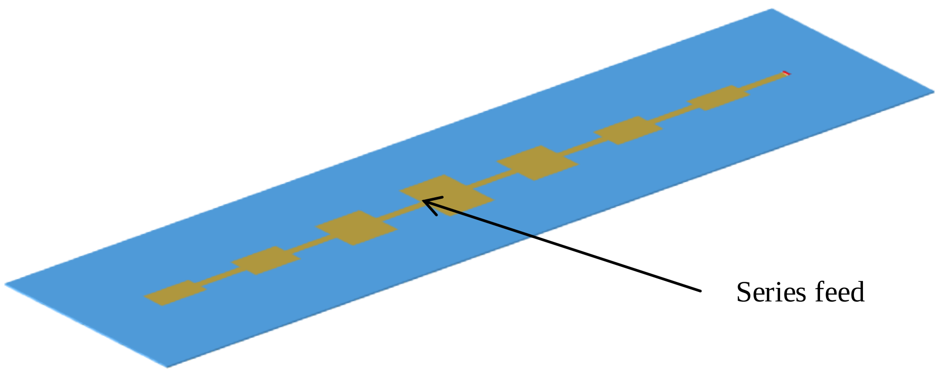
And,

$$\theta_0 = \sin^{-1}\left(\frac{-\beta}{k_0 d}\right)$$

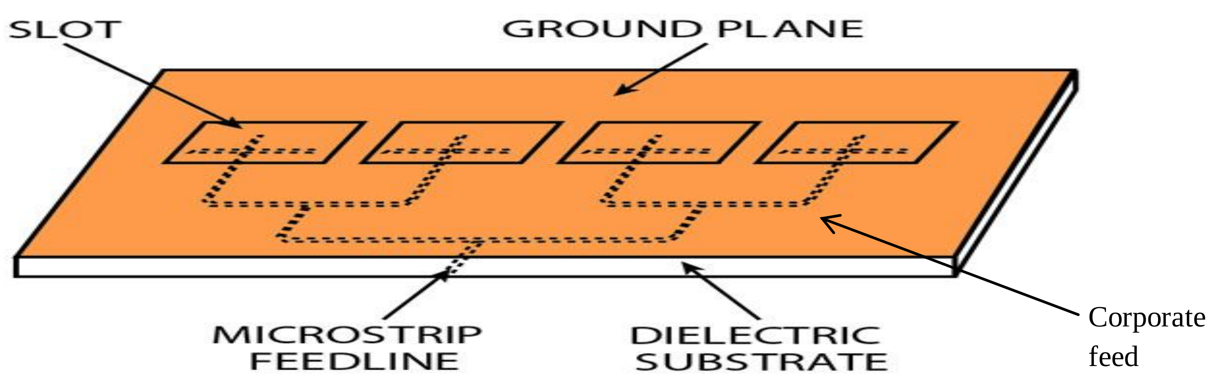
3.3 FEED NETWORK FOR DRA ARRAY:

A feed distribution network is required to achieve the required amplitude and phase excitation for each radiating element. Feed network design and its implementation is the most important part of the array design. By properly designing the feed network junctions we can achieve the desired amplitude excitation for each element. To get the desired power split at the junctions the impedances of the transmission line must be designed properly. The phase excitation for the array elements can be obtained by using passive phase delays within the feed network [12].

There are two types of feeding network used in DRA array. One is **series feed** and the other one is **parallel feed** or corporate feed. These are the part of the constrained feed. The series feed is a more compact network requiring less transmission line lengths and fewer junctions and resulting in a lower insertion loss than parallel feed. However the series feed has less bandwidth than parallel feed. The bandwidth of the end-fed series network is limited by the gain degradation. Another factor limiting the bandwidth of this feed is the mismatch loss that occurs due to the in-phase addition of the reflections from the various branches. For the parallel feed the path length to each element is identical. The parallel or corporate feed has a relatively wide bandwidth since it does not suffer from high mismatch losses. The corporate feed is much less compact than the series feed. More losses are associated with corporate feed than series feed due to the radiation from the discontinuities and longer line lengths [9], [12], [13], [27], [28]. Fig.12 shows the series and corporate feeds respectively.



(a)



(b)

Fig.12 (a) Series and (b) Corporate feed

The most common method to provide the desired excitation to the DRA elements is to use a microstrip feed network. If the elements are to be excited with equal amplitude and phase, a corporate feed network is usually selected. Microstrip lines suffer from increased conductor and surface wave losses at high frequencies. The parallel feed network although offering the broader bandwidth, suffer from higher losses due to the longer path lengths. The parallel feeding technique cannot be used in antennas where the physical spacing between the dielectric elements is very small. In microstrip series feeding method, power is transferred from the lines to the DRAs by electromagnetic coupling, which can be controlled by adjusting the spacing between the DRA and the line. In case of series feed network the spacing between the dielectric resonators is kept equal to the guided wavelength of the unloaded microstrip line in order to avoid coupling [12], [27], [28], [29].

Another method to feed the DRA array is by using low loss dielectric image guide in series feed technique. One disadvantage in microstrip feed is the losses due to conductor and surface waves at high frequencies. This will not occur in dielectric image guide feed. The dielectric material of dielectric constant ε_d is used as dielectric image guide line. The height and width of the image guide line is taken as H and W respectively. The spacing between the DRAs will be related to the guided wavelength of the dielectric image guide as similar to microstrip feed line, and the separation between the DRAs and the dielectric image guide will control the amount of coupling [12], [18], [29].

3.4 MUTUAL COUPLING:

In a transmitting array, power transmitted from each element will imping on the other elements in the array or in a receiving array, some of the scattered power from each element will imping upon nearby elements. The interaction between the elements of the array is referred to as mutual coupling. It causes distortions in the radiation pattern of the array and can also affect the input impedance of each element, resulting in mismatch losses. The type of antenna element used in the array, its feed network and its design parameters like gain, radiation pattern etc. affect the mutual coupling. The closer the dielectric elements placed in the antenna, the higher is the mutual coupling. To get the amount of mutual coupling in an array, the mutual interaction between two elements is often examined. The dielectric element spacing is kept normally from

0.5λ to 1.0λ to avoid mutual coupling in the antenna. The mutual coupling is mostly dependent upon the shape of the DRA and the feed mechanism. The E plane coupling is stronger than H plane coupling and it decreases less quickly with increasing element separation [12], [13], [29].

CHAPTER-4: NOTCHED CHAMFERED RECTANGULAR DRA

4.1 INTRODUCTION:

In this section a notched chamfered rectangular dielectric resonator antenna array design is presented for wireless applications. Here the DRA array is excited by conformal patch connected to microstrip line which is an effective feed mechanism and more efficient in energy coupling [30], [31]. The central portion of the dielectric resonators of the DRA array is removed (notched) and the four corners are chamfered to increase the bandwidth by lowering the Q-factor, and to get the desired resonant frequencies. The antenna is simulated to analyze the performance of the antenna array such as S-parameters, radiation patterns and realized gain. This proposed design covers 2.4, 3.6 and 5 GHz WLAN bands and 3.4 to 3.7 GHz WIMAX bands limited by IEEE 802.11 and IEEE 802.16 standards, which overlap with each other. The design methodology of this DRA array is discussed and the detail results of the proposed antenna are reported [32].

4.2 ANTENNA DESIGN:

The geometry of the rectangular DRA array has been shown in Fig.13, where rectangular shaped two element dielectric resonators having dielectric constant 9.8, are placed over the substrate having dielectric constant 4.4. The thickness of the substrate is 1.6 mm.

The dimension of the substrate is 58×56 mm^2 (W×L). The dimension of the ground plane is 58×27 mm^2 (W×L_g). Partial ground plane is used to further enhance the bandwidth of the DRA. The DRA array consists of two rectangular shaped dielectric resonators, where the resonators having height h_r = 13.5 mm and sides L_r = 17 mm. Fig.14 shows the geometry of the proposed notched chamfered DRA array. The four corners of the rectangular resonator is chamfered with L_c = 4 mm. The central portion of the resonators are removed i.e. rectangular notches are introduced in the centers with side L_n = 7 mm. The chamfered and notched techniques are used to enhance the performance of the antenna. Proper spacing between the two resonators is maintained to avoid mutual coupling. The conformal strips are adopted as an excitation mechanism which are attached on one side of the dielectric resonators and connected to a microstrip feed line. The conformal strips has height h_c = 13.45 mm and width W_c = 3 mm. The microstrip feed line is etched on FR4 substrate with width W_f = 3 mm, W_{f1} = 28 mm, and length L_f = L_{f1} = 14 mm which is connected by a SMA connector.

This design of the proposed DRA array is useful for multi-frequency operations [32], [33]. The multi-frequency technique is another alternative way to overcome narrow band limitations [34].

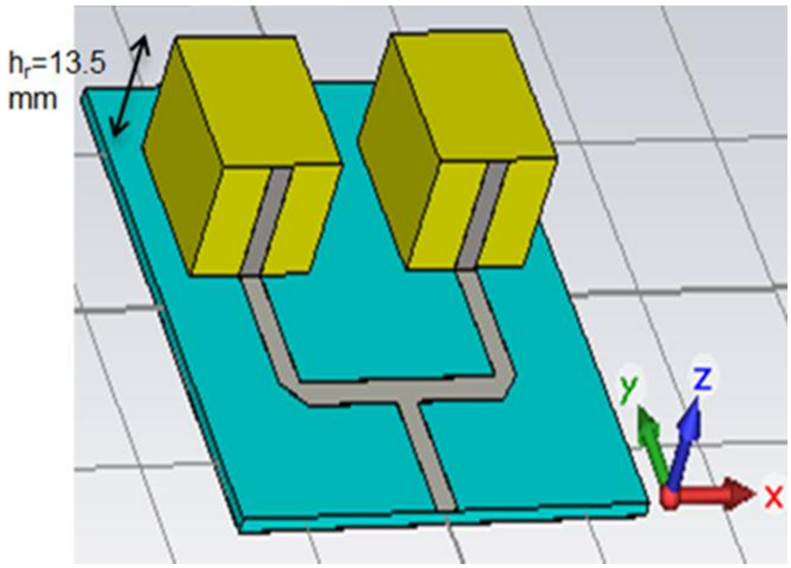
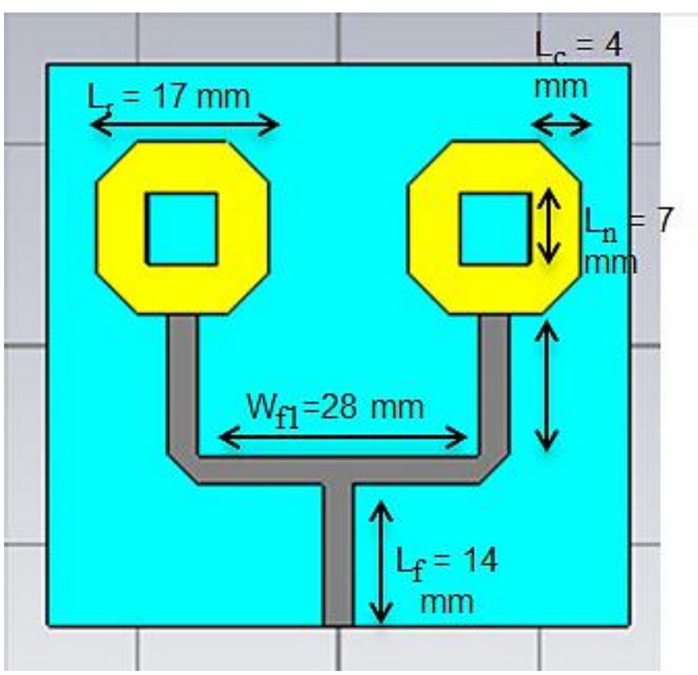
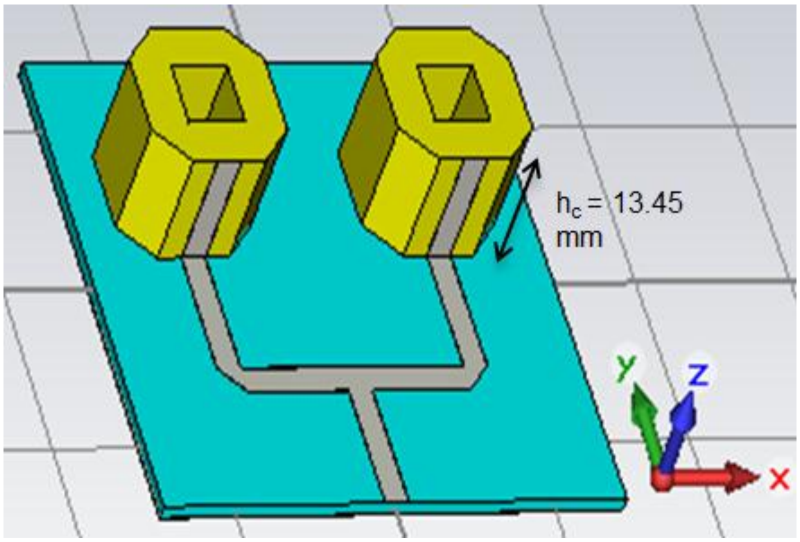


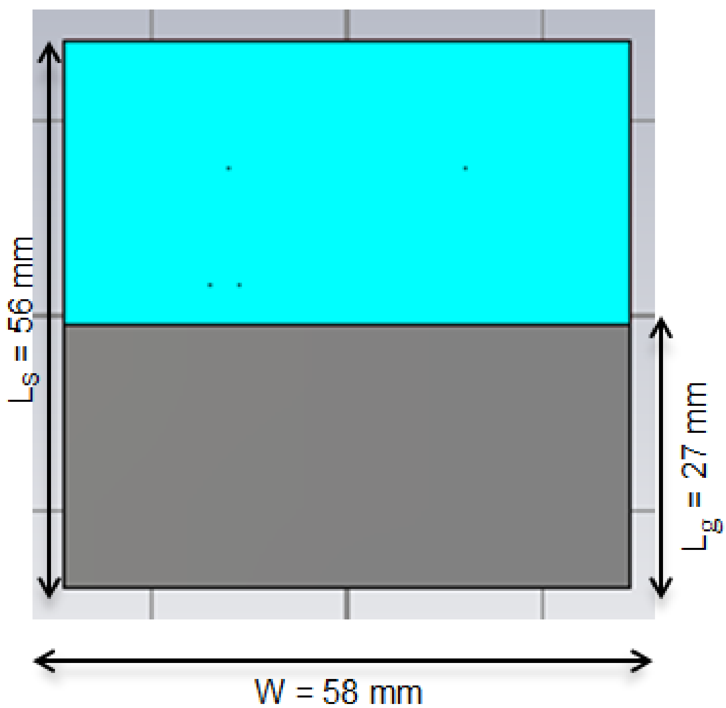
Fig.13 Perspective view of rectangular DRA



(a)



(b)



(c)

Fig.14 (a) Front view, (b) Perspective and (c) Rear view of the notched chamfered DRA array

4.3 RESULTS AND DISCUSSION:

The antenna is simulated using Microwave CST 2010 software and the simulation results are shown in the following sections. By comparing the three designs i.e. a simple rectangular DRA, a rectangular DRA with chamfered corners and a notched chamfered rectangular DRA, it can be observed that the DRA array with notched chamfered resonators give better results and desired resonant frequencies than the former two designs.

4.3.1 PARAMETRIC STUDY:

Parametric study is carried out by comparing different designs of the rectangular DRA array to achieve good antenna performances. Fig.15 shows the simulated S-parameter for different designs of rectangular DRAs. For the case of notched chamfered rectangular DRA array the widest bandwidth from 2.18 to 3.75 GHz with good return loss is obtained.

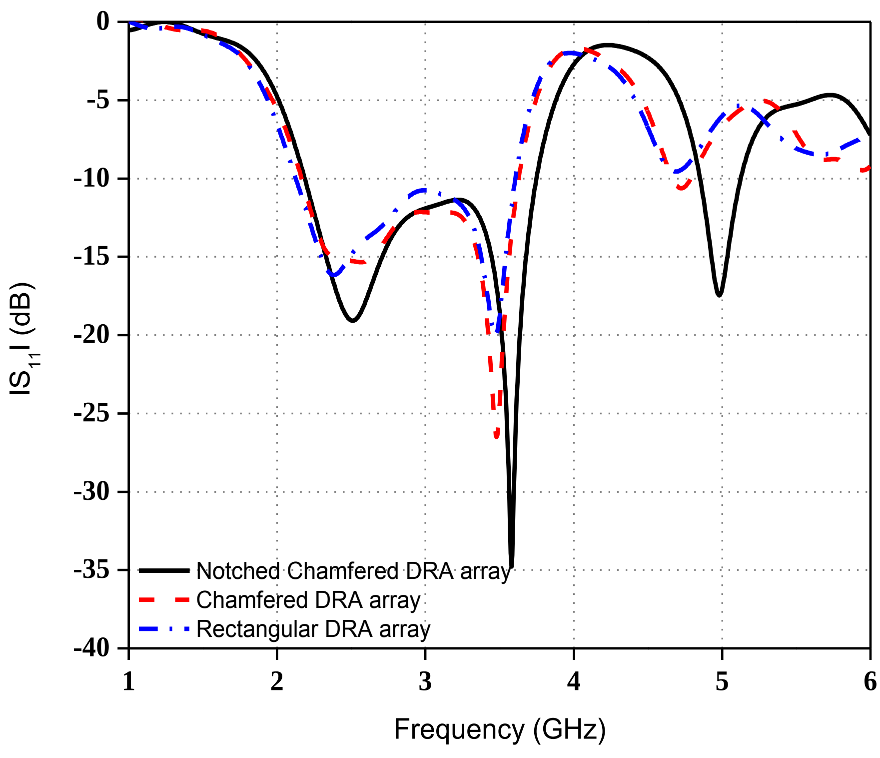


Fig.15 Comparison of S-parameter of different shapes of DRAs

A second frequency band from 4.84 to 5.14 GHz, covering the 5 GHz resonant frequency is also observed only in case of notched chamfered DRA. Simulated result shows the DRA array with the rectangular resonators having central notches and chamfered corners has a better resonant frequency, S-parameters and bandwidth for dielectric resonator's height h_r = 13.5 mm and conformal patch height h_c = 13.45 mm.

Another parametric study is carried out by varying the ground plane's dimension of the antenna which is shown in Fig.16. By taking different heights of the ground plane i.e. L_g = 25, 27 and 29 mm, it has been observed that L_g = 27 mm gives multi-band characteristics and covers the desired 2.4, 3.6 and 5 GHz resonant frequencies, while for other values of L_g the desired results are not obtained.

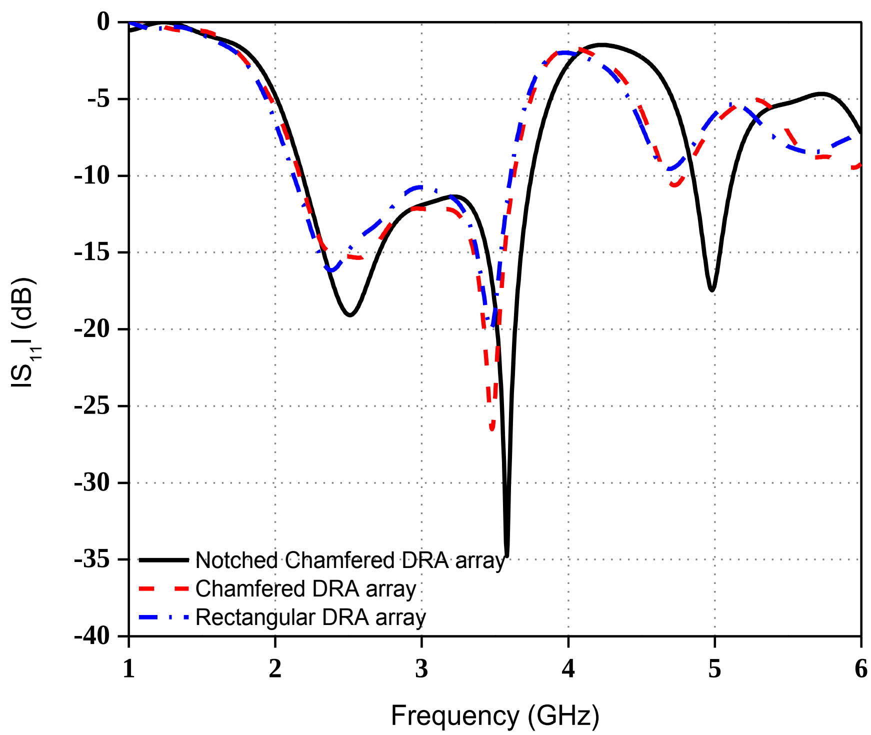


Fig.16 Comparison of S-parameter by taking different L_g values

4.3.2 GAIN CHARACTERESTICS:

Fig.17 plots the simulated gain versus frequency of the proposed DRA array, where the gain is 3.44 dB at 2.4 GHz, 5 dB at 3.6 GHz and 7.8 dB at 5 GHz. The gain of the DRA is improved by using array method. The DRA also gives a VSWR value less than 2 over the entire frequency range.

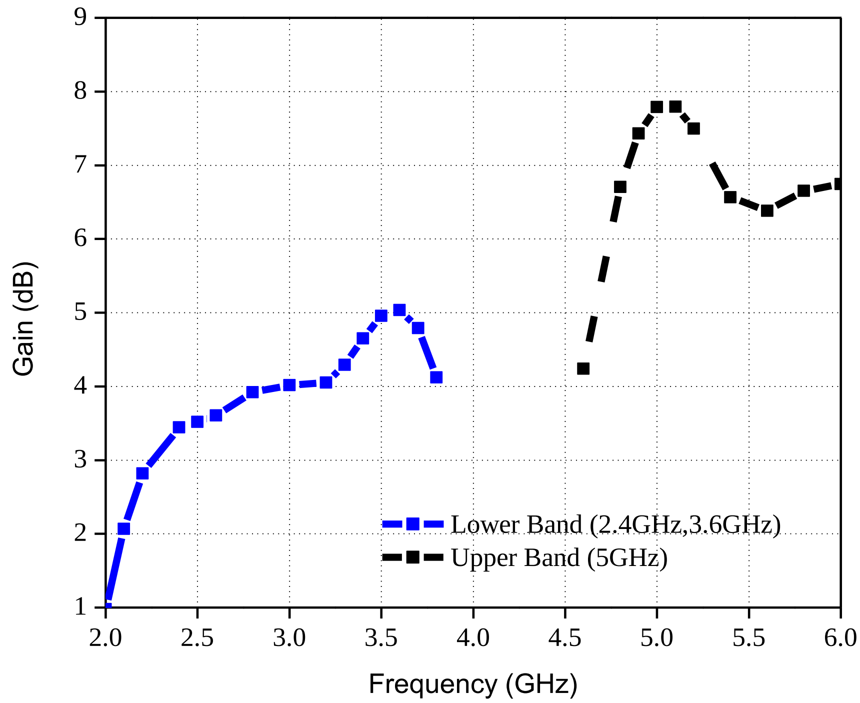
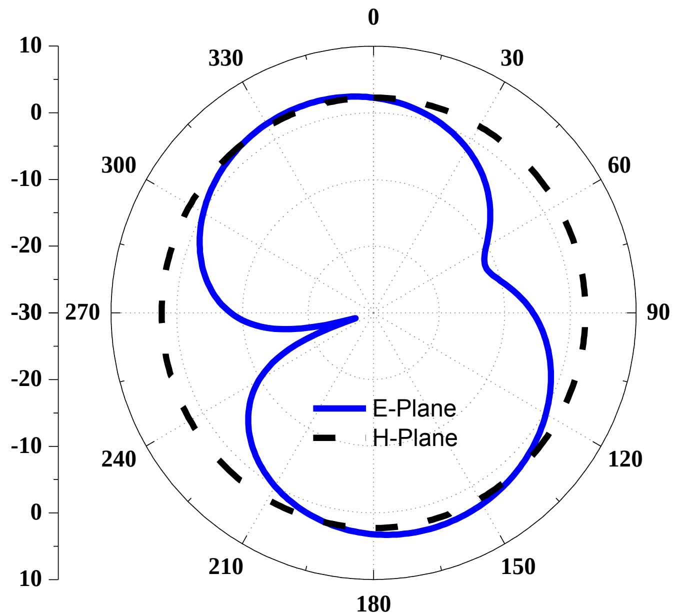


Fig.17 Simulated Gain vs. Frequency curve for 2.4, 3.6 and 5 GHz

4.3.3 RADIATION PATTERN CHARACTERISTICS:

The simulated far field radiation patterns of the proposed two elements rectangular shaped DRA array is shown in Fig.18. It shows the simulated radiation patterns at desired resonant frequencies (2.4 GHz, 3.6 GHz & 5 GHz). It has been observed that the E plane radiation patterns are in broadside direction and H plane are omnidirectional against frequency.



0
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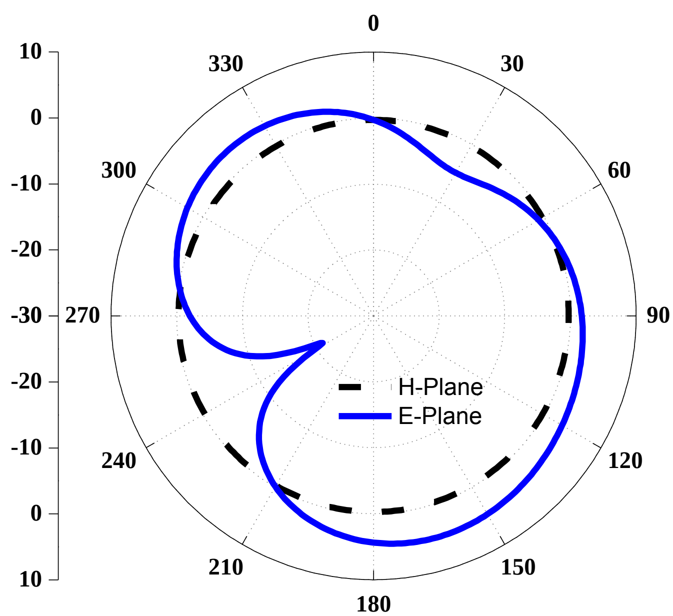
10
E-Plane
H-Plane

(a)



0
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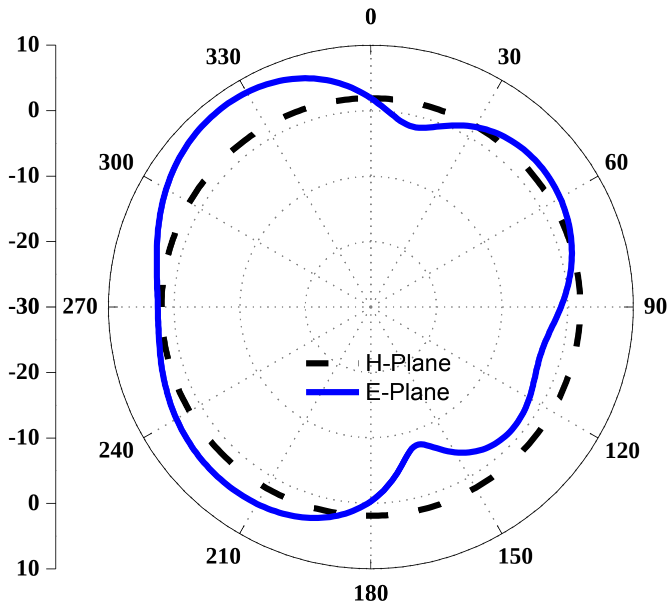
E-Plane

(b)



(c)

Fig.18 Simulated Radiation pattern of proposed DRA array at (a) 2.4 GHz (b) 3.6 GHz and (c) 5 GHz

4.4 CONCLUSION:

In this design, a chamfered rectangular shaped dielectric resonator antenna array with central notch is presented for wireless applications. The proposed DRA array consists of two rectangles of equal sides which are excited by conformal patch connected to microstrip line feed. The simulated results show that the designed antenna covers bandwidth from 2.18 to 3.75 GHz and 4.84 to 5.14 GHz. The frequency band covers the desired frequencies i.e. 2.4 GHz, 3.6 GHz and 5 GHz, which covers several important application bands in current wireless communication systems. The presented multi-band DRA array is suitable for WLAN and WIMAX applications.

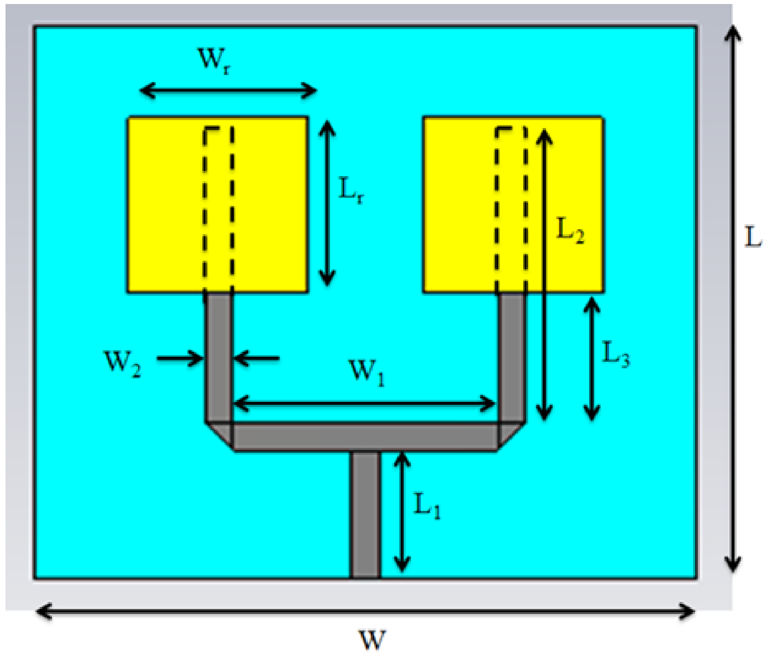
CHAPTER-5: TWO ELEMENT RDRA

5.1 INTRODUCTION:

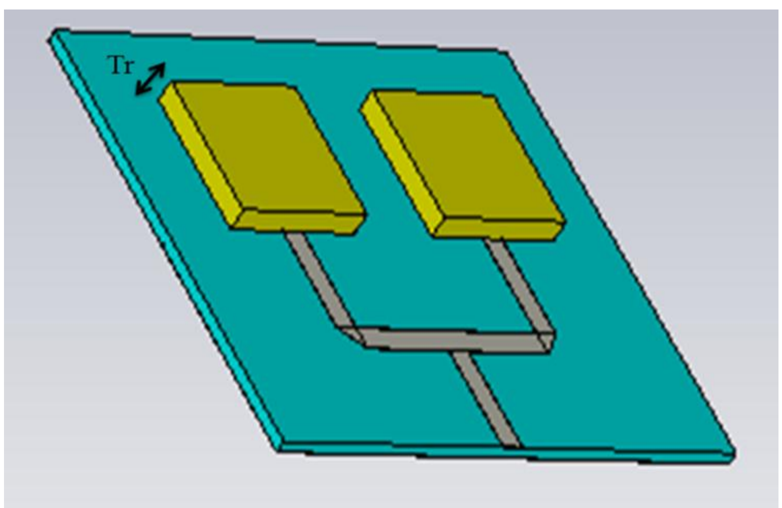
In this section, design of a two element rectangular shaped dielectric resonator antenna (RDRA) array is presented. The antenna covers the 2.4 GHz WLAN application limited by IEEE 802.11 standard. The RDRA array is excited by microstrip line coupling arranged in a corporate feed technique. Simulation results are shown to analyze the performance of the designed antenna array such as return loss, radiation patterns, gain and directivity. The design methodology is discussed and the detail results of the proposed antenna are presented in this design. The fabrication of the antenna is carried out and its measured reflection coefficient vs. frequency curve is shown.

5.2 ANTENNA DESIGN:

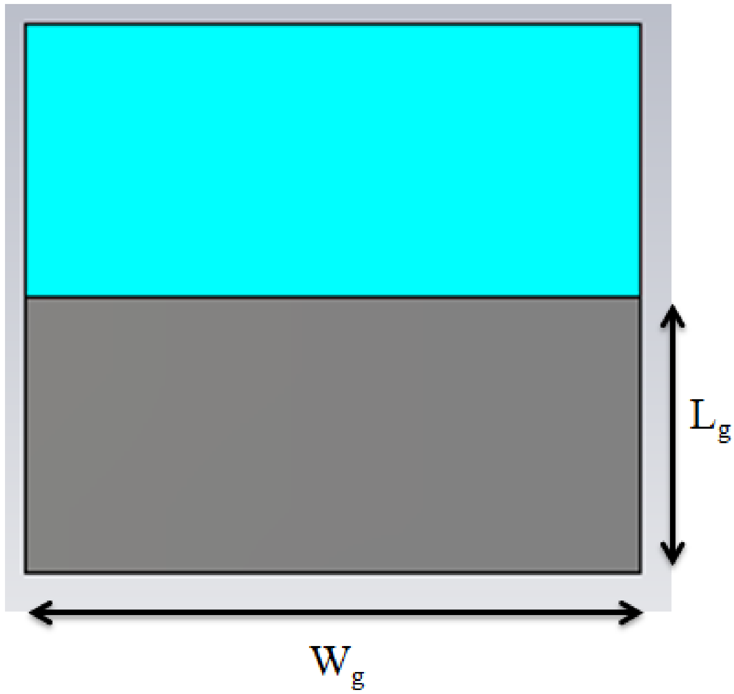
Fig.19 shows the geometry of the DRA array. Teflon of dielectric constant 2.1 is used as dielectric resonator (DR) for the DRA. The DR has been placed on the substrate having dielectric constant 4.4 with 1.6 mm of thickness. The dimension of the substrate is 70×60 mm^2 (W×L). The rear side of the substrate is covered with ground plane dimensioned as 70×30 mm^2 ($W_g \times L_g$). The RDRA is having resonators of square cross section of dimension 19×19 mm^2 ($W_r \times L_r$) with thickness T_r = 3 mm. The excitation mechanism adopts microstrip corporate feed arrangement. 50 Ω lines are used in the microstrip feed for impedance matching. The dimensions of the feed line are W_1 = 28 mm, W_2 = 3 mm, L_1 = 14 mm, L_2 = 32 mm, L_3 = 14 mm. Proper spacing is maintained between the dielectric resonators to avoid mutual coupling. Fig.20 shows the front and rear view of the fabricated antenna.



(a)

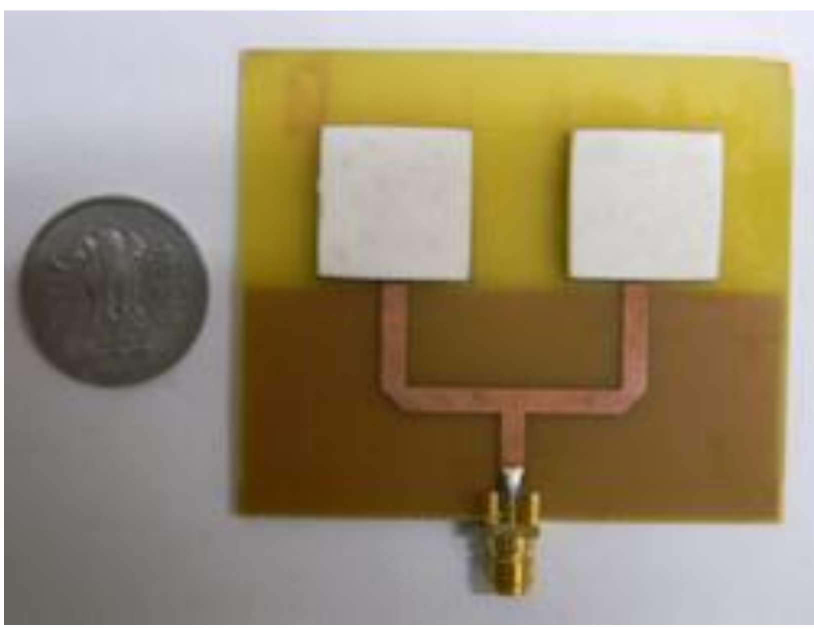


(b)

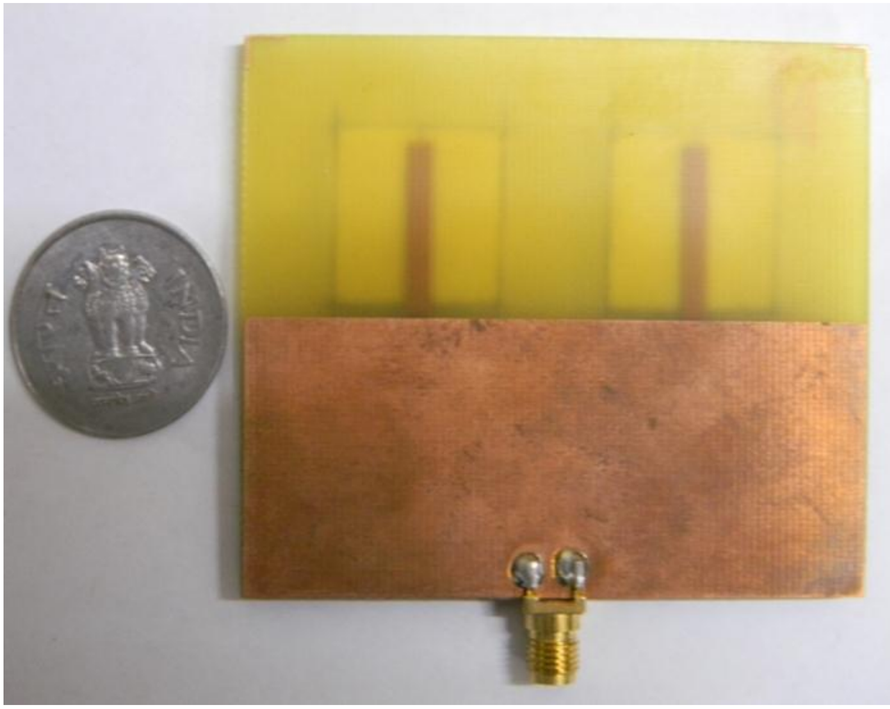


(c)

Fig.19 (a) Front (b) Perspective and (c) Rear view of the two element RDRA array



(a)



(b)

Fig.20 (a) Front view and (b) Rear view of the fabricated antenna

5.3 RESULTS AND DISCUSSIONS:

The given antenna is simulated using Microwave CST 2010 software and the simulation results are shown in the following sections.

5.3.1 PARAMETRIC STUDY:

Fig.21 shows the simulated S-parameter for different feed length (L_2) of the RDRA. By altering the L_2 value, the variation in resonant frequency can be observed. For the case of L_2 = 32 mm the desired resonant frequency at 2.4 GHz is achieved.

Another parametric study has been done by taking different height (L_g) of the ground plane shown in Fig.22. By setting ground plane L_g = 30 mm the desired resonant frequency at 2.4 GHz occurred which is not possible at other L_g values.

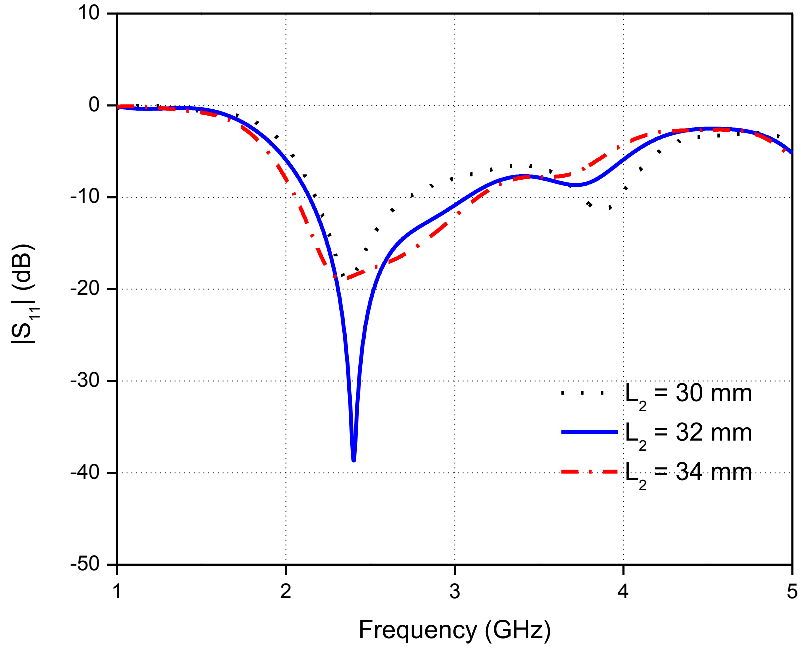


Fig.21 Comparison of S-parameters for different L_2 values

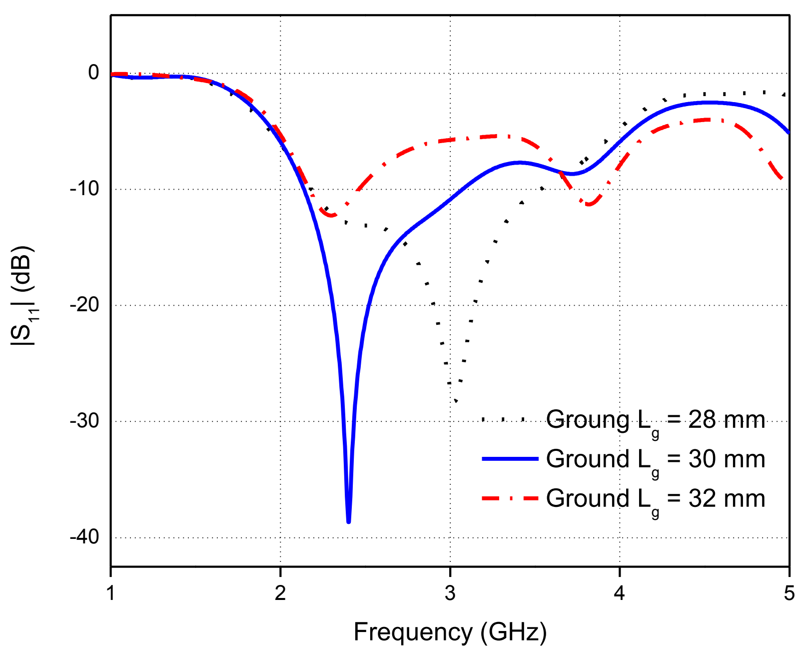


Fig.22 Comparison of S-parameters for different L_g values

Fig.23 shows the measured S-parameter result of the fabricated design taken by E5071C ENA Series Network Analyzer.

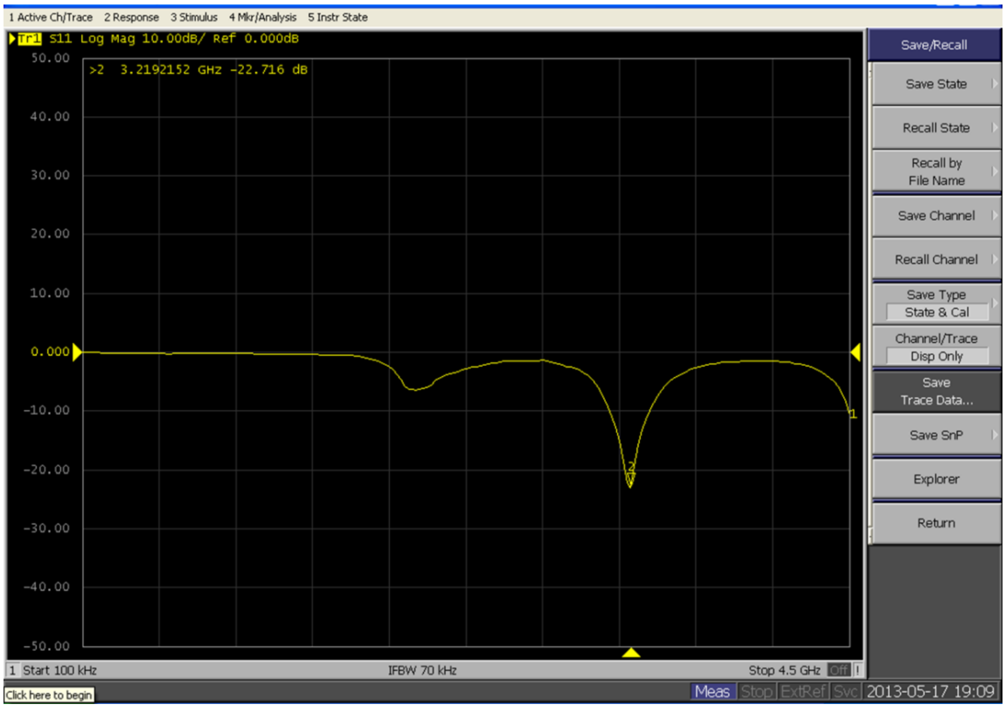


Fig.23 Measures S-parameter of the fabricated antenna

5.3.2 GAIN CHARACTERISTICS:

Fig.24 plots the simulated gain versus frequency of the proposed DRA array. From the gain characteristics it can be observe that the gain is 4.33 dB at 2.4 GHz.

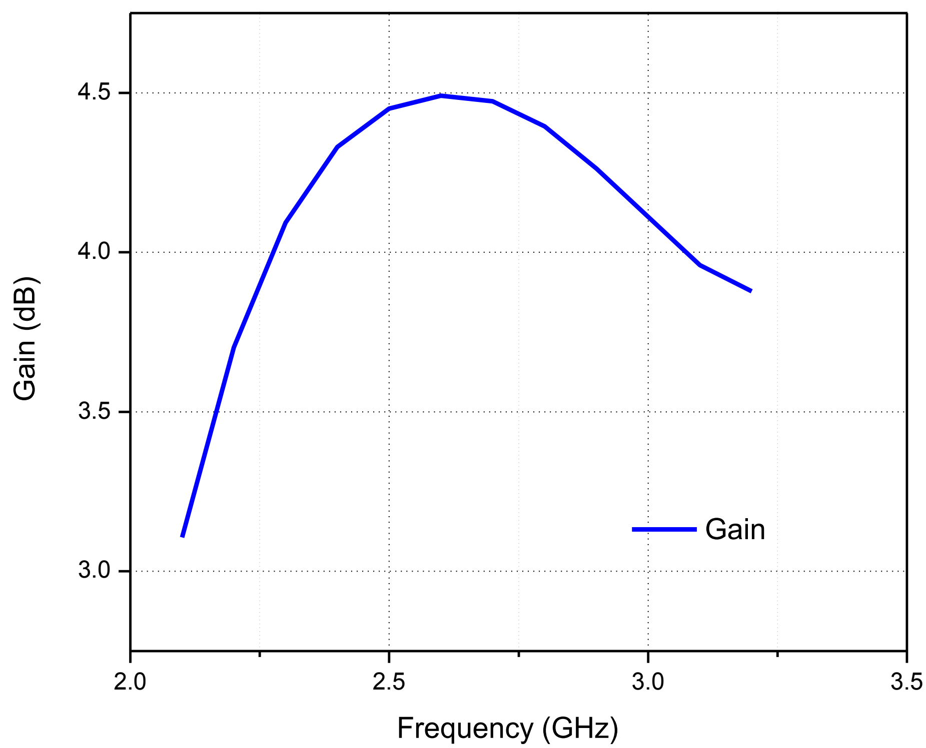


Fig.24 Simulated Gain vs. Frequency curve

5.3.3 RADIATION PATTERN CHARACTERISTICS:

The simulated far field radiation patterns of the proposed two elements RDRA array is shown in polar form. Fig.25 shows the simulated radiation pattern at 2.4 GHz. It has been observed that the E plane radiation pattern is in broadside direction against frequency and the H plane radiation pattern is omnidirectional.

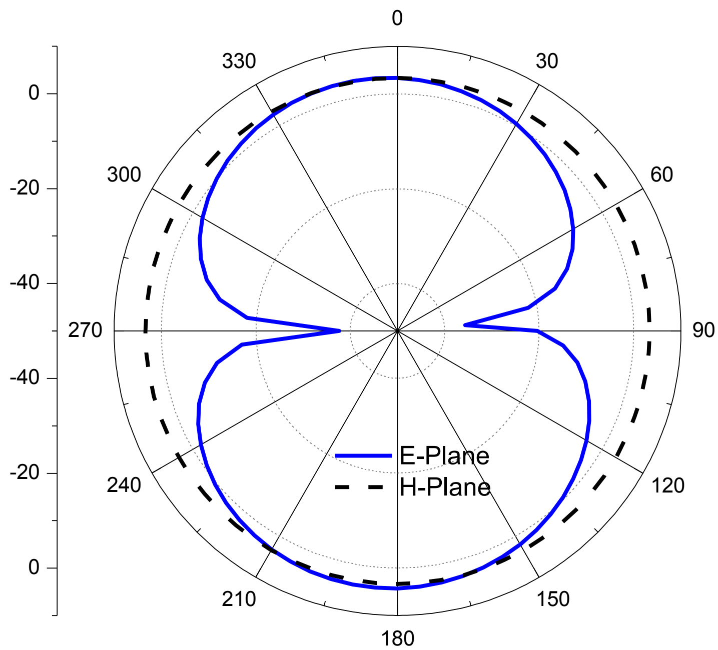


Fig.25 Simulated Radiation pattern for 2.4 GHz

5.4 CONCLUSION:

In this design, a two element RDRA array is presented for 2.4 GHz wireless applications. The proposed DRA array consists of two dielectric resonators of same sized rectangular cross section which are excited by microstrip lines in corporate feeding technique. The simulated result shows that the designed antenna covers the frequency range from 2.1 to 3 GHz which covers 2.4 GHz WLAN band in current wireless communication systems.

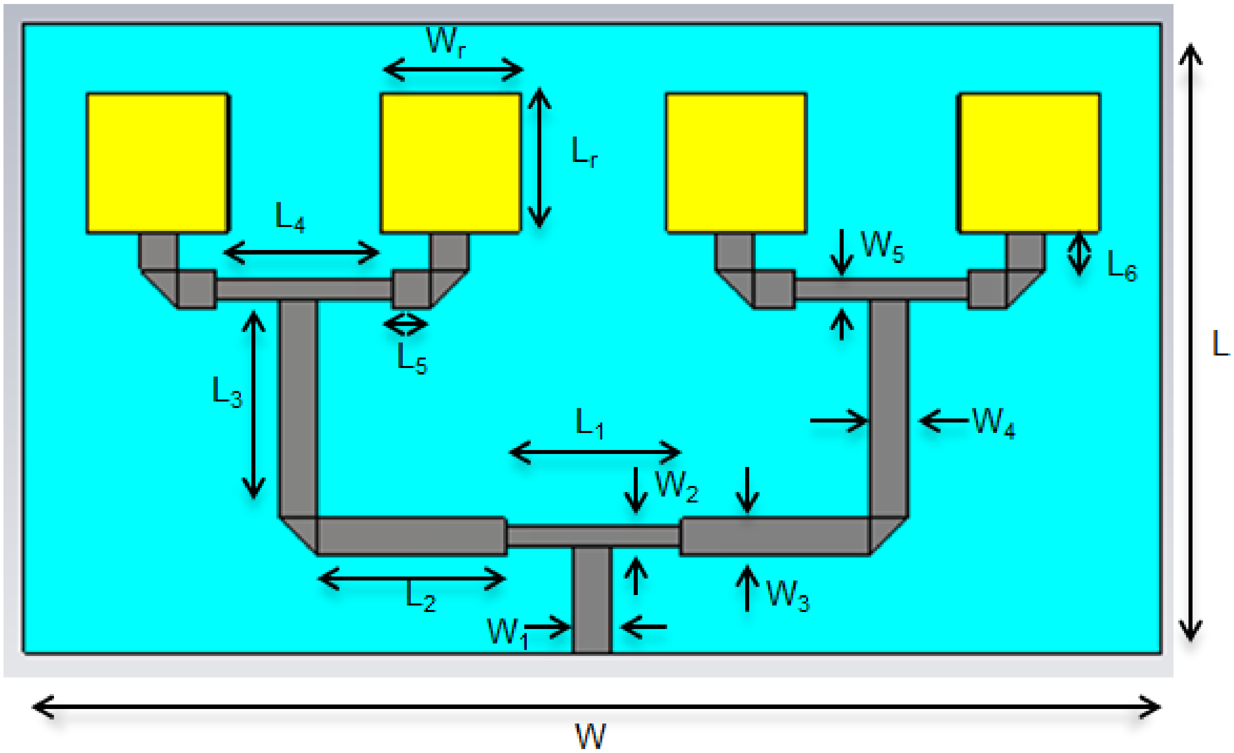
CHAPTER-6: FOUR ELEMENT RDRA ARRAY

6.1 INTRODUCTION:

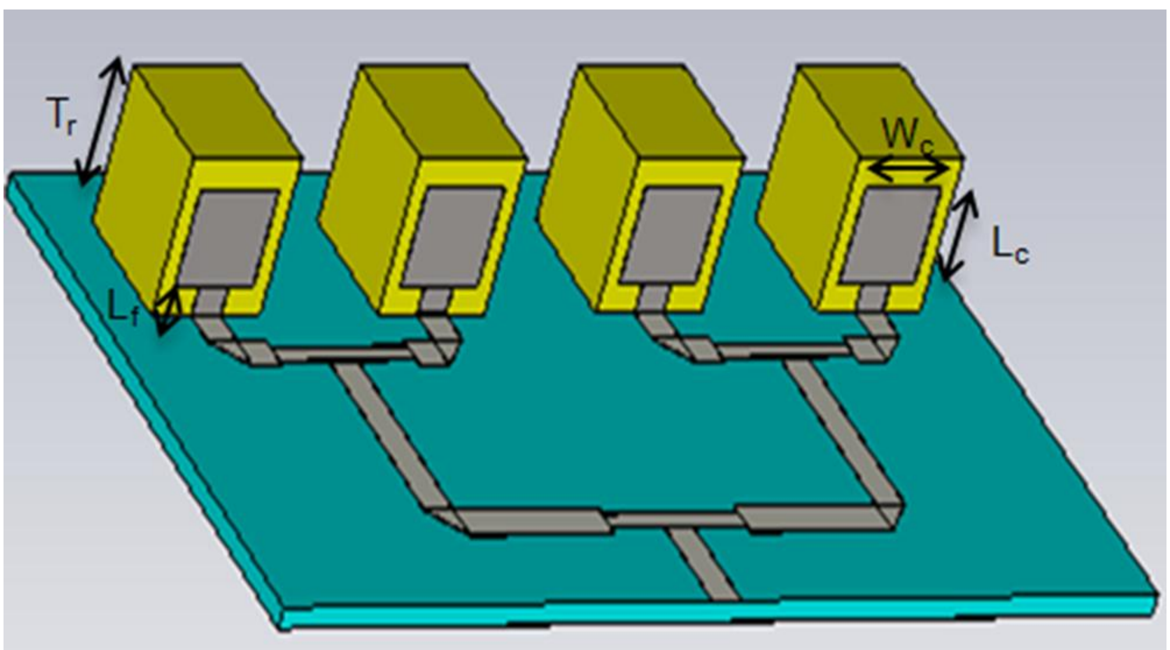
Here the design of a four element rectangular shaped dielectric resonator antenna (RDRA) array is presented for wireless applications. The RDRA array is fed by rectangular conformal patch (RCP) connected to microstrip line [30], [31]. The antenna is simulated to analyze the performance such as return loss, radiation patterns, gain and directivity. The RDRA array covers the WLAN 4.9 GHz and 5 GHz bands limited by IEEE 802.11y and 802.11a/h/j/n family. It also covers the WIMAX 5.8 GHz band of IEEE 802.16d family [11].The design methodology of this DRA array is discussed and the detail results of the proposed antenna are presented in this design. Parametric studies have been carried out by varying the RCP height and the ground plane of the final design. The proposed antenna gives significant gain and better radiation pattern at the resonant frequencies [36].

6.2 ANTENNA DESIGN:

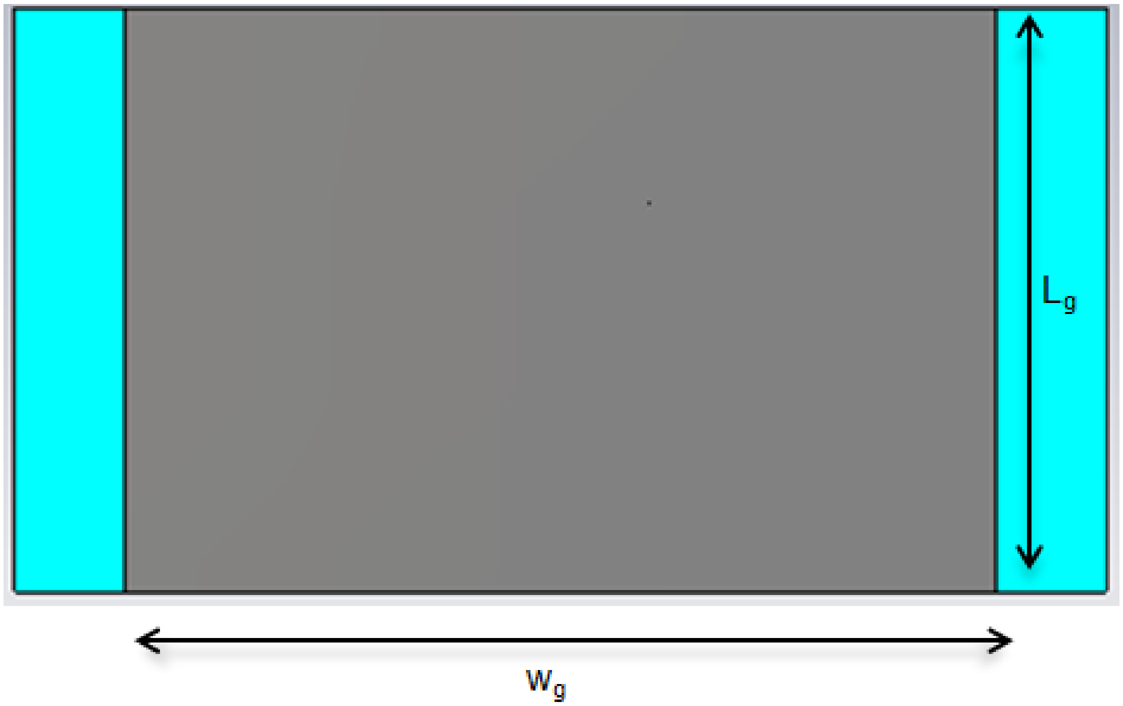
Fig.26 shows the geometry of the four element RDRA array. Teflon of dielectric constant (ε_r) 2.1 is used as Dielectric Resonator (DR). The DR has been placed on the substrate having dielectric constant (ε_{r1}) 4.4 with 1.6 mm of thickness. The dimension of the substrate is 90×50 mm^2 (W×L). The rear side of the substrate is covered with ground plane dimensioned as 72×50 mm^2 (W_g×L_g). The RDRA is having resonators of square cross section of dimension 11×11 mm^2 (W_r×L_r) with thickness T_r = 12 mm. The excitation mechanism adopts rectangular conformal patch of size 8×7.5 mm^2 (W_c×L_c) connected to microstrip corporate feed arrangement. 50 Ω lines and 70.5 Ω lines are used in the microstrip feed line for impedance matching. The dimensions of the feed line are W_1 = W_3 = W_4 = 3 mm, W_2 = W_5 = 1.6 mm, L_1 = 14 mm, L_2 = 14.8 mm, L_3 = 17.289 mm, L_4 = 14 mm, L_5 = 3.018, L_6 = 3 mm and L_f = 2.15 mm. Proper spacing is maintained between the dielectric resonators to avoid mutual coupling.



(a)



(b)



(c)

Fig.26 (a) Front view (b) Perspective view (c) Rear view of the four element RDRA array

6.3 RESULTS AND DISCUSSIONS:

The given four element DRA array is simulated using Microwave CST 2010 software and the simulation results are shown in the following sections.

6.3.1 PARAMETRIC STUDY:

Fig.27 shows the simulated S-parameter for different RCP heights of the RDRA. By altering the height of RCP, some variation in resonant frequency has been observed. For the case of L_c = 7.5 mm a total 3.1 GHz bandwidth (from 4 to 7.1 GHz) is obtained, whereas for the other values of L_c the entire bandwidth is not achieved.

Another parametric study has been done by taking different width of the ground plane shown in Fig.28. By setting different width of the ground plane the variation in the bandwidth curve can be monitored. By setting ground plane W_g = 76 mm the widest bandwidth occurred but with a notch in between the curve. With W_g = 68 mm a notch is coming in between the bandwidth curve, but with 72 mm a whole bandwidth from 4 to 7.1 GHz is achieved.

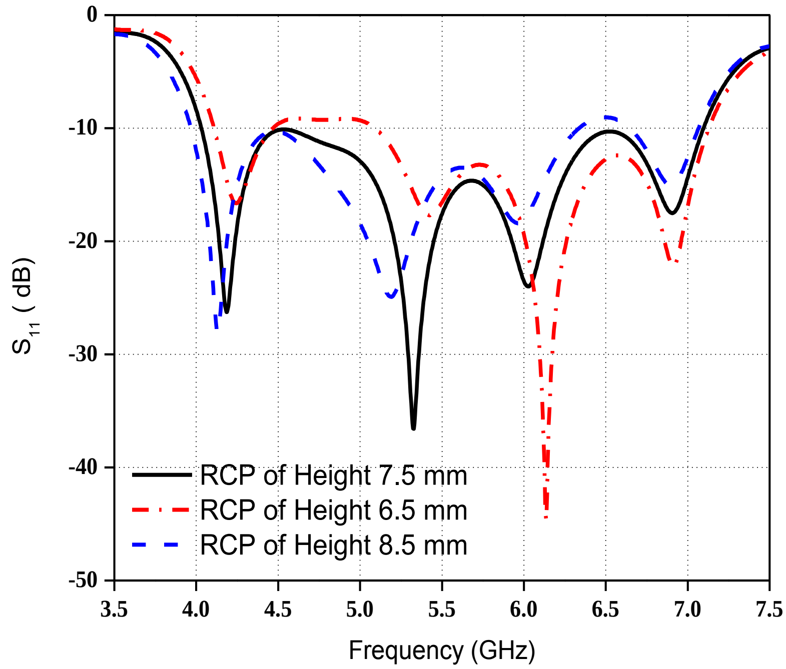


Fig.27 Comparison of S-parameter for different RCP values

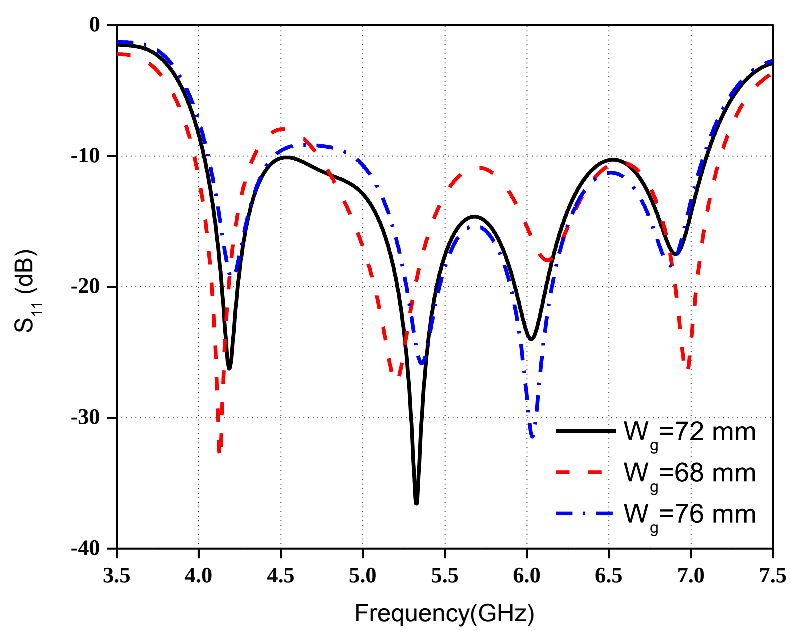


Fig.28 Comparison of S-parameter for different W_g values

6.3.2 GAIN AND DIRECTIVITY CHARACTERISTICS:

Fig.29 plots the simulated gain and directivity versus frequency of the proposed DRA array, where the gain is 7.852 dB at 4.2 GHz, 9.083 dB at 5.2 GHz, 10.55 dB at 6.2 GHz and 9.568 dB at 7 GHz. It also shows directivity of 7.898 dB at 4.2 GHZ, 9.109 dB at 5.2 GHz, 10.57 dB at 6.2 GHz and 9.783 dB at 7 GHz. From the plot it can be concluded that the given antenna shows very good gain and directivity values.

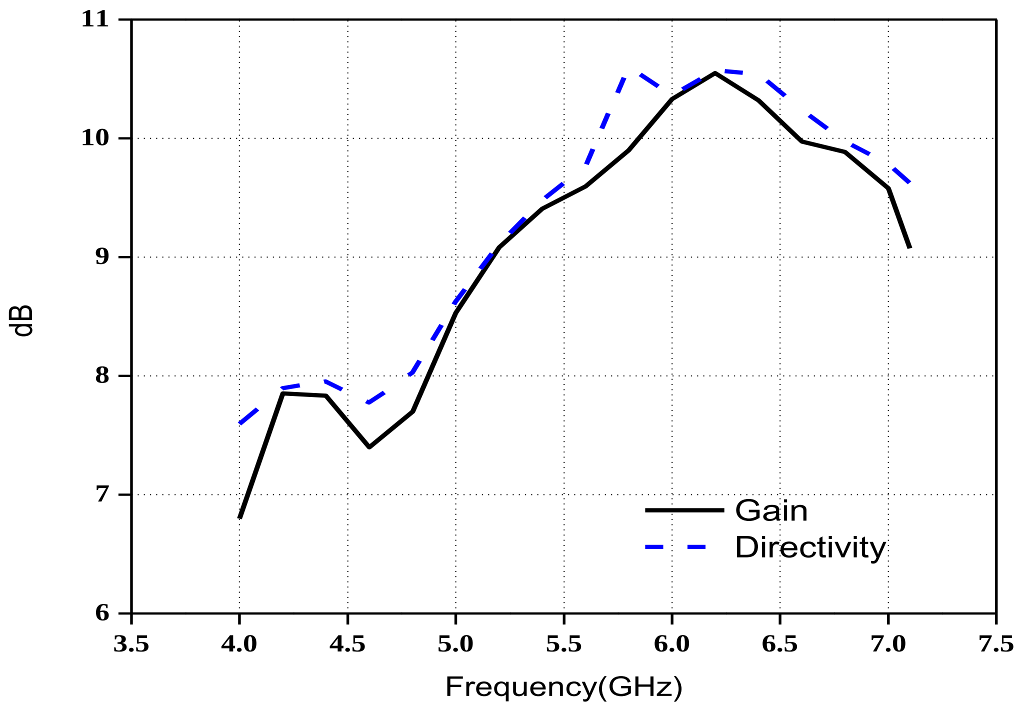


Fig.29 Gain and Directivity curves for the RDRA array

6.3.3 VSWR CHARACTERISTICS:

The simulated result of the proposed RDRA array is also showing a very good voltage standing wave ratio (VSWR) over the entire frequency range. Fig.30 shows the simulated VSWR against frequency. It has been remarkable that VSWR values are less than 2 over the entire bandwidth.

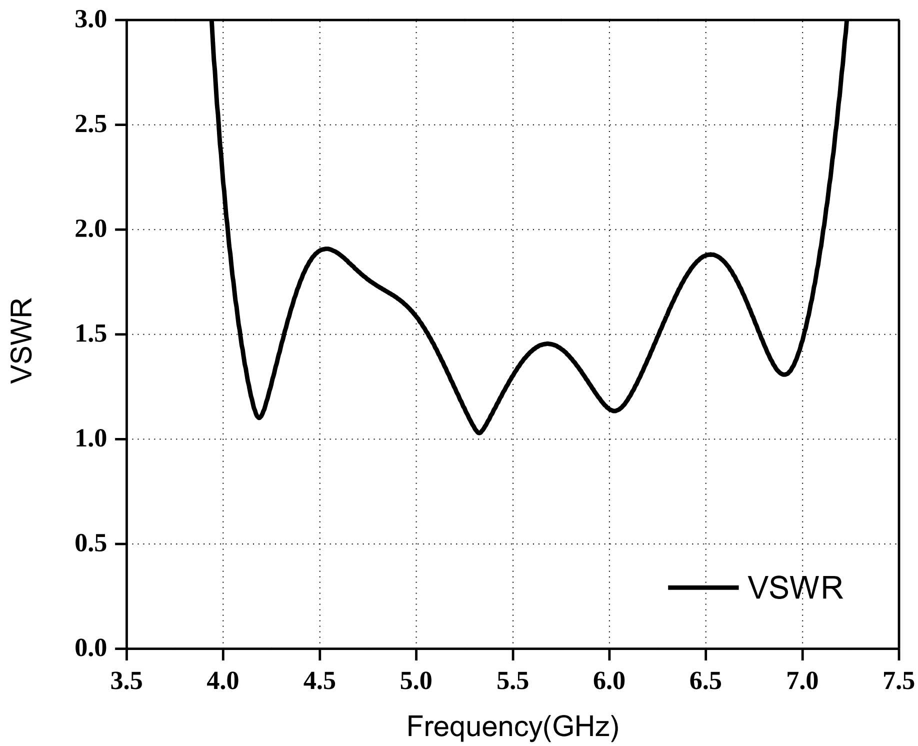
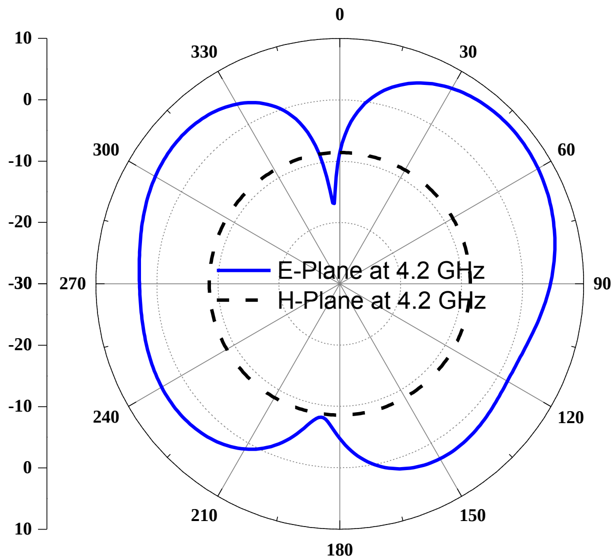


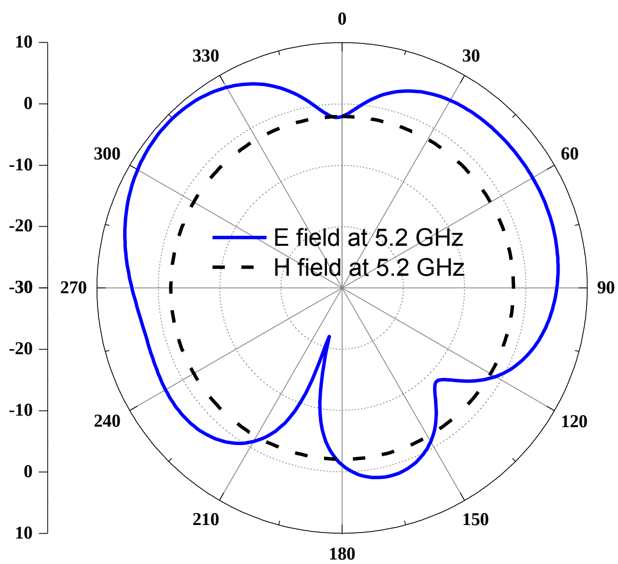
Fig.30 VSWR vs Frequency curve

6.3.4 RADIATION PATTERN CHARACTERISTICS:

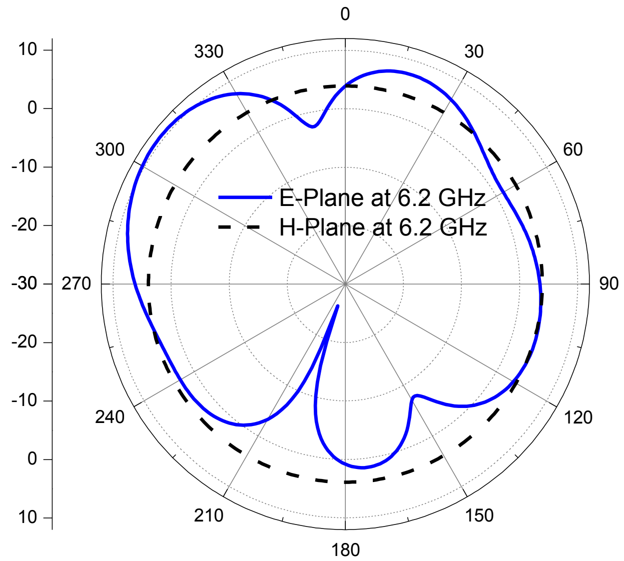
The simulated far field radiation patterns of the proposed four elements RDRA array is shown in Fig.31 in polar form. It shows the simulated radiation patterns at 4.2, 5.2, 6.2 and 7 GHz. It has been observed that the E plane radiation patterns are in broadside direction against frequency and the H plane radiation patterns are omnidirectional.


E-Plane at 4.2 GHz
H-Plane at 4.2 GHz

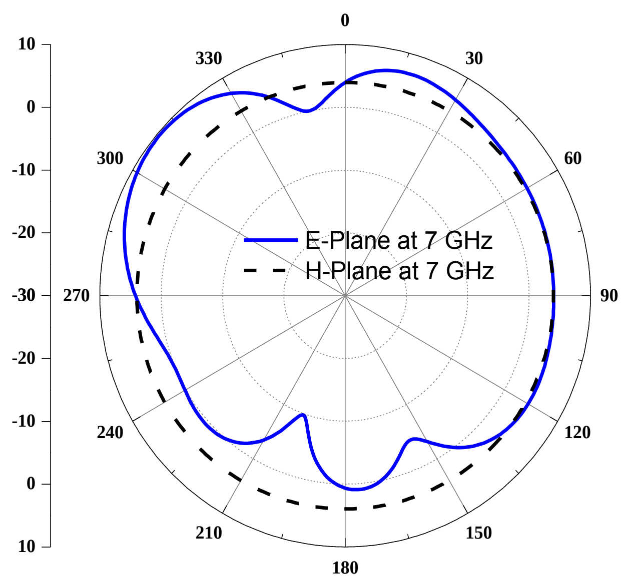
(a)


E field at 5.2 GHz
H field at 5.2 GHz

(b)



(c)



(d)

Fig.31 Radiation pattern of the RDRA Array at (a) 4.2 (b) 5.2 (c) 6.2 and (d) 7 GHz

6.4 CONCLUSION:

In this section a four element RDRA array is presented for wireless applications. The proposed DRA array consists of four dielectric resonators of same sized rectangular cross section which are excited by RCP fed connected to microstrip line in corporate feeding technique. The simulated results show the designed antenna covers the frequency range from 4 to 7.1 GHz which covers several important application bands in current wireless communication systems.

CHAPTER-7: CONCLUSION & FUTURE WORK

7.1 CONCLUSION:

In the first section the WLAN and WIMAX bands and its applications are discussed. Different shapes of Dielectric resonator antennas have been studied in this thesis. In the first part of the thesis an introduction of DRA is given, and its characteristics, advantages, disadvantages and applications are studied briefly. In this chapter the feeding methods used for DRAs are also discussed. As in this thesis all the antenna designs are based on rectangular shape, a brief study is done on the rectangular shapes of the DRA. In the next chapter the study of the DRA array is given. The two types of feeding i.e. the parallel or corporate feed and the series feed is discussed. The mutual coupling between the elements in a DRA array is also studied in this chapter.

In the fourth chapter a chamfered rectangular shaped dielectric resonator antenna array with central notch is presented for wireless applications. The proposed DRA array consists of two rectangles of equal sides which are excited by conformal patch connected to microstrip line feed. The rectangular dielectric resonators further notched and chamfered to get better results. The simulated results show the designed antenna covers the desired frequencies at 2.4 GHz, 3.6 GHz and 5 GHz, which covers several important application bands in current wireless communication systems. It also shows gain values of 3.44 dB at 2.4 GHz, 5 dB at 3.6 GHz and 7.8 dB at 5 GHz. The presented multi-band DRA array is suitable for WLAN and WIMAX applications.

In the second antenna design, a two element RDRA array for 2.4 GHz wireless applications is presented in fifth chapter of this thesis. The proposed DRA array consists of two dielectric resonators of same sized rectangular cross section which are excited by microstrip line in corporate feeding technique. Here Teflon of dielectric constant 2.1 is used as dielectric resonators. The simulated results show the designed antenna covers the frequency range from 2.1 to 3 GHz covering the 2.4 GHz WLAN band.

In the last design, a four element RDRA array for wireless applications is presented in sixth chapter. The proposed DRA array consists of four dielectric resonators of same sized rectangular cross-section which are excited by RCP fed connected to microstrip line in corporate feeding technique. The simulated results show the designed antenna covers the frequency range from 4 to 7.1 GHz which covers several important application bands in current wireless communication systems. It also shows the gain values of 7.852 dB at 4.2 GHz, 9.083 dB at 5.2 GHz, 10.55 dB at 6.2 GHz and 9.568 dB at 7 GHz. The antenna covers the WLAN 4.9 GHz and 5 GHz bands limited by IEEE 802.11y and 802.11a/h/j/n family. It also covers the WIMAX 5.8 GHz band of IEEE 802.16d family.

7.2 FUTURE WORK:

Based on antenna designs, the following points were identified which would be helpful for further investigation.

- Fabrication and measurements of four element rectangular dielectric resonator antenna array and the notched chamfered DRA array will be carried out in future.

- Since the impedance bandwidth of Dielectric resonator antenna can be enhanced by using multiple DRAs (stacked, embedded and DRA array), design of dielectric resonator antenna arrays using embedded technique, will be carried out in future.

- Besides, the experience of designing DRAs with microstrip line feeding with conformal patch, Dielectric resonator antenna array with dielectric image guide feeding can further be designed to minimize the metallic losses.

Publication

- Imran Khan, Runa Kumari & S K Behera, "A Notched Chamfered Rectangular Dielectric Resonator Antenna Array for Wireless Applications" IEEE International Multi Conference on Automation, Computing, Control, Communication and Compressed Sensing (iMac4s-2013), ISBN 978-1-4673-5088-4 Feb 2013, Kerala.

- Imran Khan, Runa Kumari & S K Behera, "A Four Element Rectangular Dielectric Resonator Antenna Array For Wireless Applications" IEEE International conference on Emerging Trends in Computing, Communication and Nanotechnology (ICECCN-2013), ISBN 971-1-4673-5036-5, Feb 2013, Tamilnadu.

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