DESIGN AND ANALYSIS OF DIELECTRIC RESONATOR ANTENNA

A THESIS
SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF TECHNOLOGY

IN

COMMUNICATIONS AND SIGNAL PROCESSING

BY

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National Institute of Technology

Rourkela-769008

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UNDER THE GUIDANCE OF

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Date: 20-05-2013

CERTIFICATE

This is to certify that this thesis entitled **“DESIGN AND ANALYSIS OF DIELECTRIC RESONATOR ANTENNA”** submitted by Mr. **MUDAVATH SREENU**, in partial fulfilment of the requirements for the award of Master of Technology Degree in Electronics and Communication Engineering with specialization in **“Communications and Signal Processing”** during session 2012-13 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.

Dr. S K Behera

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Acknowledgment

This project work 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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Sreenu Mudavath
May 2013
National Institute of Technology, Rourkela

Dedicated to

My

PARENTS AND TEACHERS

ABSTRACT

Present scenario of communication, all wired ones becoming as wireless. So, to achieve efficient and affordable communication in wireless technology, compact and efficient radiators required. One of the efficient radiators is dielectric resonator antenna (DRA). Almost all the applied power will be lost in the radiated fields only, with this attractive feature DRAs become much popular in wireless communication field at microwave frequencies. In this project, new type of DRAs designed for popular wireless applications like Wireless Interoperability Microwave Access (WIMAX), Wireless Local Area Network (WLAN) and Wireless Fidelity (Wi-Fi). This project covers the design of DRA which including all parametric studies of the return loss, radiation patterns, gain and directivity for specific wireless application. DRAs became very popular in the core sectors of a country like defense, military, radar and especially for millimeter wave applications. Due to this flexibility in DRAs, they can be designed with different shapes as per coverage requirements depending upon the applications in the wireless communication industries. Here, all the designed DRAs are excited by using Co-planar waveguide (CPW) feeding technique, having advantageous features (less radiation leakage, operating at extremely high frequencies). Among four designed DRAs, first two DRAs having single Dielectric Resonator (DR) element and radiating at 2.4 GHz and 5.8 GHz and rest of two designs having stacked method. Here, the concept of stacking is used to get the multiple resonant frequencies and wide bandwidths. The first stacked DRA is covering the resonant frequencies at 5.20GHz, 5.84GHz which covers WLAN bands and second stacked DRA resonating at 3.5GHz and 5.5GHz, which covers Wi-MAX and WLAN bands respectively. This project work concludes that, the designed DRAs efficiently radiates at IEEE -802.11a/b/g and IEEE-802.16 bands.

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Chapter 1

Thesis Overview

1.1 Introduction

Wireless Communications are becoming as a part of day-to-day life of human beings. So, to achieve efficient and affordable wireless communications, compact and efficient radiators required. Indeed, one of the efficient radiators is dielectric resonator antenna (DRA). The dielectric resonator antenna efficiently radiates at microwave frequencies. DRA is economically affordable and it is having desirable features like - easy design, simple fabrication methods and gives flexibility in design and to analyse the results in order to achieve required resonant frequencies depending upon our coverage requirements. In general DRA having high-radiation efficiency, bandwidth and polarization flexibility make them by far superior and better replacement to conventional microstrip patch antennas (MPA). DRAs are intrinsically immune to those surface wave power leakage and conductor loss problems, which plagues the MPA and reduces their efficiency. DRA consists of high dielectric constant materials, high quality factors and mounted on a grounded dielectric substrate of lower permittivity [1]. DRA is fabricated from low-loss and high relative dielectric constant material of various shapes whose resonant frequencies are functions of the shape, dimensions of the shape and permittivity of the material. DRA can be in a few geometries including cylindrical, rectangular, spherical, half-split cylindrical, disk, and hemispherical shaped [1]. The DRAs have properties such as very less phase noise, small size, stability in frequency and temperature, ease of integration with existing technologies and other hybrid MIC circuitries, flexible construction and the ability to withstand harsh environments. The DRA has some interesting characteristics, like small size, ease of fabrication, high radiation efficiency, increased bandwidth and low production cost. DRAs are very promising for applications in wireless communications like Wireless Local Area Networks.

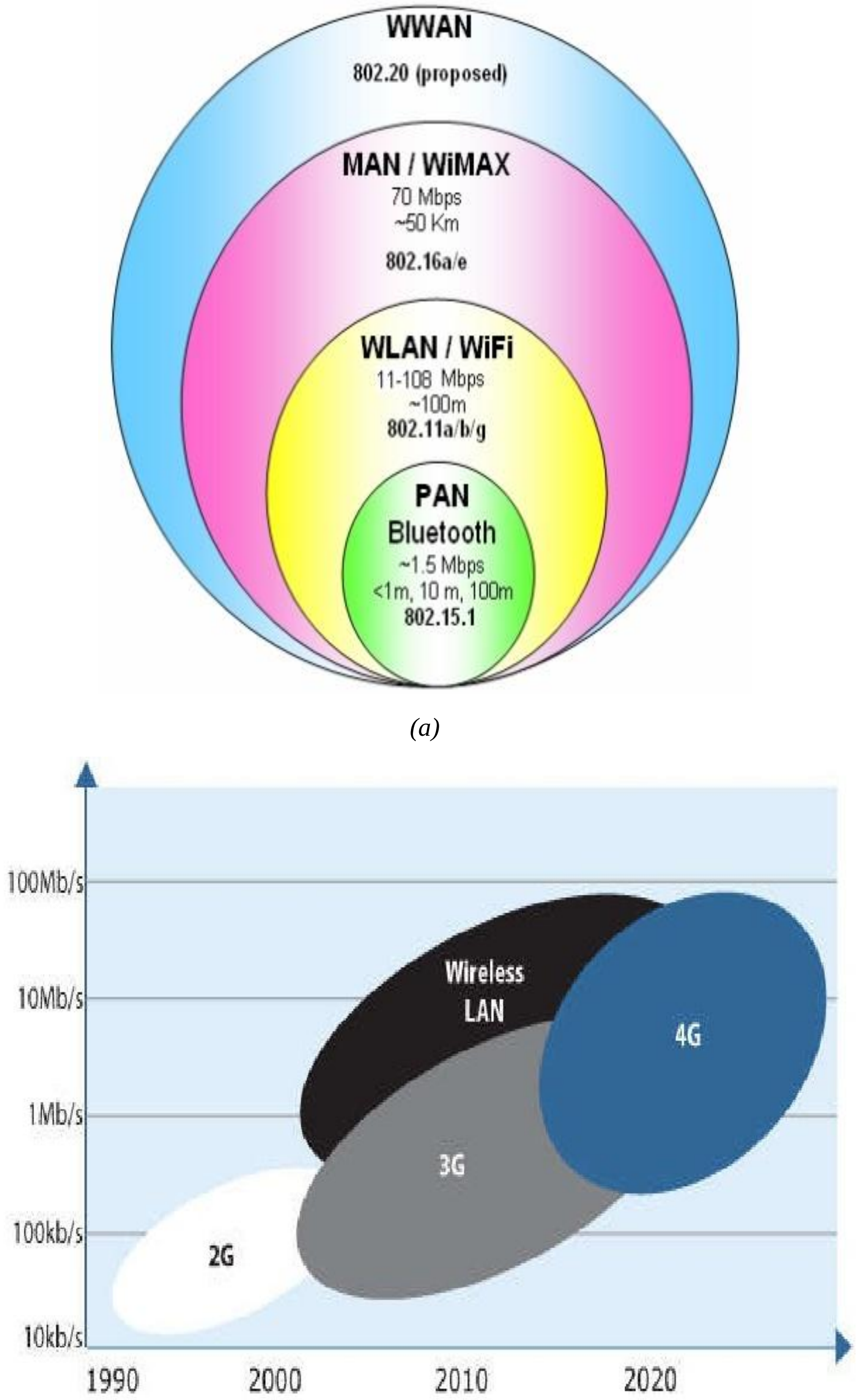
1.2 Literature Review

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 [2]. Dielectric Resonator Antennas (DRA)’s became very popular in the core sectors of a country like defence, military, radar and especially for satellite and millimetre wave applications. The resonating frequencies of a DRA are nothing but the function of size, shape and dielectric constants only. Due to this flexibility in DRAs, they can be designed with different shapes as per coverage requirements depending upon the applications in the wireless communication industries. For many years, the dielectric resonator (DR) has primarily been used in microwave circuits, such as oscillators and filters, where the DR is normally made of high-permittivity material, with dielectric constant εr > 20. The unloaded Q-factor is usually between 50 and 500, but can be as high as 10,000. Because of these traditional applications, the DR was usually treated as an energy storage device rather than as a radiator [2]. DRAs can also be excited with different feeding methods, such as microstrip lines, dielectric image waveguide feeding, aperture coupling, probes, slots, and co-planar lines. The DRAs are good replacement for the Microstrip antenna, because the DRA has a much wider impedance bandwidth and higher power handling capability due to their many advantageous and attractive features. As such, these include their flexibility in design, light weight, compact size, the versatility in their shape and feeding mechanism, simple structures, easy fabrication and wide impedance bandwidth.

Wireless communications is, by any measure, the promptest growing segment of the communications industry in wireless field. As such, it has captured the attention of the media and the imagination of the public, end users and consumers. Cellular systems have experienced exponential growth over the last decade and there are currently around two billion users worldwide. Indeed, the cellular phones have become a critical business tool and part of everyday life in most developed countries, and are rapidly supplanting antiquated wire line systems in many developing countries. In addition, wireless local area networks (WLAN) currently supplement or replace wired networks in many homes, businesses, and campuses. Many new applications, including wireless sensor networks, automated highways and factories, smart homes and appliances, and remote telemedicine, are emerging from research ideas to concrete systems. The explosive growth of wireless systems coupled with the proliferation of laptop and palmtop computers indicate a bright future for wireless networks, both as stand-alone systems and as part of the larger networking infrastructure. However, many technical challenges remain in designing robust wireless networks that deliver the performance necessary to support emerging applications [3].

1.3 Thesis Motivation

Dielectric resonator antennas (DRA) possess some attractive characteristics which are making them as very promising and affordable at microwave frequencies for wireless applications especially for WLAN applications. Wireless Communications are becoming part in day-to-day life of public. So, to achieve efficient wireless communications, efficient radiators required. Definitely, one of the promising radiators is nothing but dielectric resonator antenna (DRA). The dielectric resonator antenna efficiently radiates at millimetre-wave frequencies. DRA is economically affordable. DRA has desirable features like - easy design, simple fabrication methods and gives flexibility in design and to analyse the results in order to achieve required resonant frequencies depending upon our coverage requirements. In this thesis we will find the design of dielectric resonator antenna and analysing for optimizing the antenna parameters through parametrical studies.



(a)

(b)

Figure 1.1 Wireless Technologies

1.4 Scope of this Project

The scope of this project work is to design and fabrication of a Dielectric Resonator Antenna which can be used for narrow band specific wireless applications according to the Federal communication commission specifications. That is used the operating frequencies like WiMAX, WLAN, Wi-Fi etc. and the antenna should be small in size and easy-to-manufacture with available laboratory equipment. The return loss must be less than -10 dBi at wireless frequencies, which means only 10% of power will be reflected back while 90% of power is transmitted. Other aspects, such as beam width, side lobes, VSWR, Polarization, Impedance measurements were not considered during the design stage.

Special attention had paid in design stage to get the double bands at a time by optimizing the feeding techniques and structures of the dielectric resonators.

1.5 Thesis Outline

The following topics are the outline of this thesis,

Chapter 2: In this chapter the basics of antenna parameters which were used in antenna measurements such as return loss, directivity, radiation pattern, bandwidth, VSWR, Gain etc. are presented.

Chapter 3: This chapter gives the basic theory behind DRA and basic shapes used in DRAs are discussed. Some of the Bandwidth Enhancement techniques in DRAs are also discussed. The advantage of stacked Dielectric method in Bandwidth Enhancement, when compared to other methods is also presented.

Chapter 4: This Chapter presents the basic theory behind the various feeding or excitation techniques for DRA including the basic geometries and their characteristics. The advantages and disadvantages of different feeding methods also discussed in brief.

Chapter 5: This chapter shows the design of a Compact CPW Fed Cylindrical DRA for Wi-Fi Applications. This chapter covers the designed DRA including all parametric studies of the return loss, radiation patterns of proposed DRA, gain and directivity graphical views for specific wireless applications.

Chapter 6: In this chapter we will discuss the design of a Compact CPW Fed DRA for WLAN Applications. This chapter covers the designed DRA including all parametric studies of the return loss, radiation patterns and gain and directivity graphical views for specific wireless application will be presented.

Chapter 7: This chapter gives a brief view regarding a Compact CPW Fed Stacked Cylindrical for WLAN Applications. This chapter covers the designed DRA including all parametric studies of the return loss, radiation patterns and gain and directivity graphical views for specific wireless application will be presented.

Chapter 8: In this chapter we will find analytical view of the design regarding CPW Fed Stacked Dielectric Resonator Antenna for WIMAX and WLAN Applications. This chapter covers the designed DRA including all parametric studies of the return loss, radiation patterns and gain and directivity graphical views for specific wireless application will be presented.

Chapter 9: This chapter presents a conclusions and the scope of future work about DRAs for specific wireless applications.

After the chapter-9, list of Publications and references presented.

Chapter 2

Antenna Parameters

2.1 Radiation pattern

The basic term “radiation” means that, the distribution of power through respective fields of antenna. An antenna radiation pattern or antenna pattern is defined as “A mathematical function or a graphical representation of radiation properties of the antenna as a function of space coordinates”. However, in most cases the radiation pattern is determined in the far field region and is represented as function of directional coordinates. The properties of Radiation are power flux density, radiation intensity, field strength, directivity phase or polarization. The radiation properties of most concern are the two or three dimensional spatial distribution of radiated energy as function of the observer’s position along a path or surface of constant radius. A trace of received power at constant radius is called power pattern. On the other hand, a graph of spatial variation of the electric (or magnetic) field along constant radius is called amplitude field pattern. In practice the dimensional pattern is measured and recorded in series of two dimensional patterns [4].

2.2 Radiation Intensity

Radiation intensity in given direction is defined as “the power radiated from an antenna per unit solid angle”. The radiation intensity is far field parameter and it can be obtained by simply multiplying the radiation density by the square of the distance [4]. In the mathematical from it can be expressed as

$$U=r^2W_{rad} \tag{2.1}$$

U = Radiation intensity (W/Unit solid angle)

W_{rad} = Radiation intensity (W/m^2)

The radiation intensity is also related to far-zone electric field of an antenna by

$$\frac{r^2}{2\eta}[E(r,\theta,\phi)]^2=\frac{r^2}{2\eta}[E_\theta(r,\theta,\phi)]^2+E_\phi[(r,\theta,\phi)]^2 \tag{2.2}$$

E = Far zone electric field intensity of the antenna

E_θ ,E_ϕ =Far zone electric field component of antenna

η = Intrinsic impedance of the medium.

2.3 Directivity

In the 1983, version of the IEEE standard Definition of terms for antennas, there has been a substantive change in definition of directivity, compared to definition of 1973 version. Basically the term directivity in the new 1983 version has been used to replace the term directive gain of the old 1973 version. In the 1983 version the term directive gain has been deprecated. According to authors of the new standard this change brings this standard in line with common usage among antenna engineers and with other international standard notably those of the international electrochemical commission (IEC) therefore directivity of an antenna defined as the ratio of radiation intensity in given direction from the antenna to the radiation intensity averaged over all directions. The average radiation intensity is equal to the total power radiated by the antenna divided by 4π . if direction is not specified the direction of maximum radiation intensity is implied. Stated more simply the directivity of non-isotropic source is equal to the ratio of it radiation intensity in given direction over that of isotropic source [3]. In mathematical form it can be written as

$$D = \frac{U}{U_O} = \frac{4\pi U}{P_{rad}} \tag{2.3}$$

$$D_{max} = D_O = \frac{U_{max}}{U_O} = \frac{4\pi U_{max}}{P_{rad}} \tag{2.4}$$

D = Directivity

D_O = Maximum directivity

$U =$ Radiation intensity (W/unit solid angle)

U_{max} = Maximum radiation intensity (W/unit solid angle)

U_O = Radiation intensity of isotropic (W/ unit solid angle)

$P_{rad} =$ Total radiated power (W)

$$D_O = D_\theta + D_\emptyset \tag{2.5}$$

$$\mathrm{D_\theta} = \frac{4\pi \mathrm{U_\theta}}{(\mathrm{P_{rad}})_\theta + (\mathrm{P_{rad}})_\emptyset} \tag{2.6}$$

$$D_\emptyset = \frac{4\pi U_\theta}{(P_{rad})_\theta + (P_{rad})_\emptyset} \tag{2.7}$$

U_θ = Radiation intensity in given direction contained in θ field component

$U_\emptyset$ = Radiation intensity in given direction contained in $\emptyset$ field component

$(P_{rad})_\theta$ = Radiation power in all direction contained in θ field component

$(P_{rad})_\emptyset$ = Radiation power in all direction contained in $\emptyset$ field component

2.4 Gain

Another useful measure describing the performance of antenna is the gain. Although the gain of antenna is closely related to the directivity, remember that directivity is measure that describes only the directional properties of the antenna, and it is therefore controlled only by pattern. Absolute gain of an antenna is defined as the ratio of intensity, in a given direction to the radiation intensity that would be obtained if power accepted by antenna were radiated isotropically. The radiation intensity corresponding to isotropically radiated power is equal to the power accepted by the antenna divided by 4π .In equation form this can be expressed as

$$\text{Gain} = 4\pi \frac{Radiation\ intensity}{total\ input\ accepted\ poer} = 4\pi \frac{U(\theta,\emptyset)}{P_{in}} \tag{2.8}$$

In most cases we deal with relative gain, which defined as the ratio of power gain in a given direction to the power gain of reference antenna in its reference direction. The power input must be same for both antennas the reference antenna usually a dipole horn or any other antenna whose gain can be calculated or it is known. In most cases however the reference antenna is lossless isotropic source. Thus

$$G = \frac{4\pi U(\theta,\emptyset)}{P_{in}(losless\ isotropic\ source)} \tag{2.9}$$

When the direction is not stated the power gain is usually taken in direction of maximum radiation [4].

2.5 Antenna efficiency

The total antenna efficiency e_o is used to take into account losses at the input terminals and within the structure of the antenna [3]. Such losses may be due, to two factors given below

1. Reflection because of the mismatch between the transmission line and the antenna

2. I^2R losses (conduction and dielectric)

In general the overall efficiency can be written as

$$e_o = e_r e_c e_d \tag{2.10}$$

Where, e_o = total efficiency

e_r = reflection efficiency

e_c= conduction efficiency

e_d= dielectric efficiency

2.6 Half power beam width

The half power beam width is defined as in a plane containing the direction of maximum of a beam the angle between two direction in which the radiation intensity is one half the maximum value of the beam often the term beam width is used to describe the angle between any two point on the pattern such as the angle between 10-dB points. In this case the specific point on the pattern must be described the 3- dB beam width.

The beam width of the antenna is very important figure of merit and is often used to as trade-off between it and side lobe level; that is as the beam width decreases the side lobe increases and vice versa. In addition the beam width of antenna is also used to describe the resolution capabilities of the antenna to distinguish between two adjacent radiating sources or radar targets. The most common resolution criterion states that the resolution capabilities of antenna to distinguish between two sources is equal to half the first null beam width (FNBW/2) which is usually used to approximate the half power beam width (HPBW). That is two sources separated by angular distance equal or greater than FNBW/2 = HPBW of an antenna with uniform distribution can be resolved. If the separation is smaller ten antennas will be tend to smooth the angular separation distance [4].

2.7 Bandwidth

The bandwidth of an antenna is defined as the range of frequency with in which the performance of antenna with respect to some charters tics conform to specified standard. The bandwidth can be considered to be a range of frequency on either side of centre frequency where the antenna characteristics are within acceptable value of those at centre frequency. For broad band antenna the bandwidth is usually expressed as the ratio of upper to lower frequency of acceptable operation. Because the characteristics of an antenna do not necessarily vary in the same manner or are even critically affected by the frequency there is no unique characterization of the bandwidth [4].

2.7.1 Frequency Bandwidth

- **Narrowband** - These antennas cover a small range of the order of few percent around the designed operating frequency.

$$\text{FBW} = \frac{F_h - F_L}{F_c} \times 100 \qquad (2.11)$$

Where, F_h= higher frequency

F_l =lower frequency

F_c = central frequency

- **Wide band or broad band**- these antennas cover an octave or two range of frequencies.

$$\text{FBW} = \frac{F_h}{F_L} \times 100 \qquad (2.12)$$

- **Impedance Bandwidth**- The impedance variation with frequency of the antenna element results in a limitation of the frequency range over which the element can be matched to its feed line.
  - ✓ Impedance Bandwidth is usually specified in terms of a return loss or maximum SWR (typically less than 2.0 or 1.5) over a frequency range conversion of bandwidth from one SWR level to another can be accomplished by using the relation between Bandwidth **B** and **Q**
  - ✓ $B = \frac{SWR-1}{Q\sqrt{SWR}}$ (2.13)
  - ✓ **%** Impedance Bandwidth = $\frac{F_h - F_L}{\sqrt{F_L F_h}} \times 100$ (2.14)

2.8 Voltage Standing Wave Ratio (VSWR)

The standing wave ratio (SWR), also known as the voltage standing wave ratio (VSWR), is not strictly an antenna characteristic, but is used to describe the performance of an antenna when attached to a transmission line. It is a measure of how well the antenna terminal impedance is matched to the characteristic impedance of the transmission line. Specifically, the VSWR is the ratio of the maximum to the minimum RF voltage along the transmission line. The maxima and minima along the lines are caused by partial reinforcement and cancellation of a forward moving RF signal on the transmission line and its reflection from the antenna terminals. If the antenna terminal impedance exhibits no reactive (imaginary) part and the resistive (real) part is equal to the characteristic impedance of the transmission line, then the antenna and transmission line perfectly obeys impedance matching condition [4]. In general,

$$VSWR = \frac{V_{Maximum}}{V_{Minimum}} \tag{2.15}$$

Where,

$V_{Maximum}$ = maximum amplitude of RF voltage

$V_{Minimum}$ = minimum amplitude of RF voltage

2.9 Polarization

In general polarization of an antenna is referred as, the orientation of radiation of that antenna. Polarization of an antenna in given direction is defined as the polarization of the wave transmitted by the antenna. When the direction is not stated the polarization is taken to be polarization in direction of maximum gain. In practice polarization of the radiated energy varies with direction from the centre of the antenna so that different part of the pattern may have different polarization. Polarization of radiated wave is defined as that properties of electromagnetic wave describing the time varying direction and relative magnitude of electric field vector specifically the figure traced as a function of time by the extremity of vector at fixed location at in space and sense in which it is traced as observed along the direction of propagation [4].

- Linear
- Circular
- Elliptical

2.10 Input impedance

Input impedance is defined as "the impedance presented by an antenna at it terminals or the ratio of voltage to current at pair of terminals or the ratio of the appropriate component of the electric to magnetic fields at a point". In this section we are primarily interested in the input impedance at pair of terminals which are input terminals of the antenna [5].

$$Z_A = R_A + JX_A \tag{2.16}$$

Z_A = Antenna impedance at terminals

R_A = Antenna resistance at terminals

X_A = Antenna resistance at terminals

Chapter 3

Dielectric Resonator Antenna

3.1 Introduction of Dielectric Resonator Antenna (DRA)

The structure of DRA mainly consists of three basic components; they are first one Substrate, secondly ground (Perfect Electric Conductor) material etched on substrate and some dielectric resonating material placed above the ground, generally referred as “Dielectric Resonator (DR)”. The designing of DRs and using them in structures of DRAs, discussed in chapters 5-8.

- Basically DR is an electronic component that exhibits ‘resonance’ for a wide range of frequencies, generally in the microwave band.
- If the DR placed in an open environment, Power will be lost in the radiated fields only. This fact makes dielectric resonators useful as antenna elements instead of elements in microwave circuits as energy storage devices [1].

Wi-MAX and WLAN are the standard-based technologies enabling the delivery of last mile wireless broadband access [2]. WiMAX refers to interoperable implementations of the IEEE 802.16 wireless-networks standard which can operate at higher bit rates or over longer distances. It is capable of operating in 3.4-3.6 GHz frequency range as well as at 5.5 GHz band [5]. While WLAN standards in the 2.4-GHz range have recently emerged in the market, the data rates supported by such systems are limited to a few megabits per second. By contrast, a number of standards have been defined in the 5-6 GHz range that allow data rates greater than 20 Mb/s, offering attractive solutions for real-time imaging, multimedia, and high-speed video applications. To achieve the necessary applications a high performance wide band antenna with high radiation efficiency are required [3]. Over the past few years, the dielectric resonator antenna (DRA) has received extensive attention due to its several advantages such as low profile, light weight, low dissipation loss, high dielectric strength and higher power handling capacity [5]. DRA can be in a few geometries including cylindrical, rectangular, spherical, half-split cylindrical, disk, hemispherical and triangular shaped.

The main purpose of design any antenna is to obtain a wide range of bandwidth. Several bandwidth enhancement techniques have been reported on modified feed geometries and changing the shape of the DRA. By using different bandwidth enhancement techniques in this thesis different shape of dielectric resonator antennas are designed and simulated. There is few soft wares available which allow the optimization of the antenna. Here, Simulation process was done by using Computer Simulation Technology (CST). In this thesis, have been design different shapes of single and multiple dielectric resonator antennas for wireless applications. Bandwidth enhancement techniques are used to obtain a large bandwidth for particular resonant frequencies.

3.2 Basic Characteristics of DRA

DRA offers several attractive features including the fallowing characteristics:

- In DRAs, we can use a wide range of dielectric constants (ϵ_r= 2.1 – 100), that allowing the designer to have control over the physical size of the DRA and its bandwidth.
- The Size of DRA is proportional to $\lambda 0/\sqrt{\epsilon_r}$, where λ0 is the free space wavelength at the resonant frequency, and ϵ_r is the dielectric constant of the material.
- DRAs can be designed to operate over a wide range of frequencies from 1.3 GHz to 40 GHz [2].
- High radiation efficiency (95%) due to the absence of conductor or surface wave losses.
- Several feeding mechanisms can be used (including slots, probes, microstrip lines, dielectric image guide, and coplanar waveguide lines) to efficiently excite DRAs.
- DRA can be excited by several modes, many of which radiate pattern similar to short electric or magnetic dipoles, producing either broadside or Omni-directional radiation patterns for different coverage requirements [4].
- By choosing a dielectric material with low-loss characteristics, high-radiation efficiency can be maintained, even at millimetre-wave frequencies, due to an absence of surface waves and minimal conductor losses associated with the DRA [1], [4].
- A Wide control over size and bandwidth
- A tight$\epsilon_r$tolerance: ± 1- 5%,
- A high quality factor Q: up to 10000 (f = 10GHz)
- A Wide range of temperature coefficient of resonance frequency: (-12…+30) ppm/^{o}C
- A Tolerance ± 0.5; ±1.0; ±2.0 ppm/ ^{o}C.

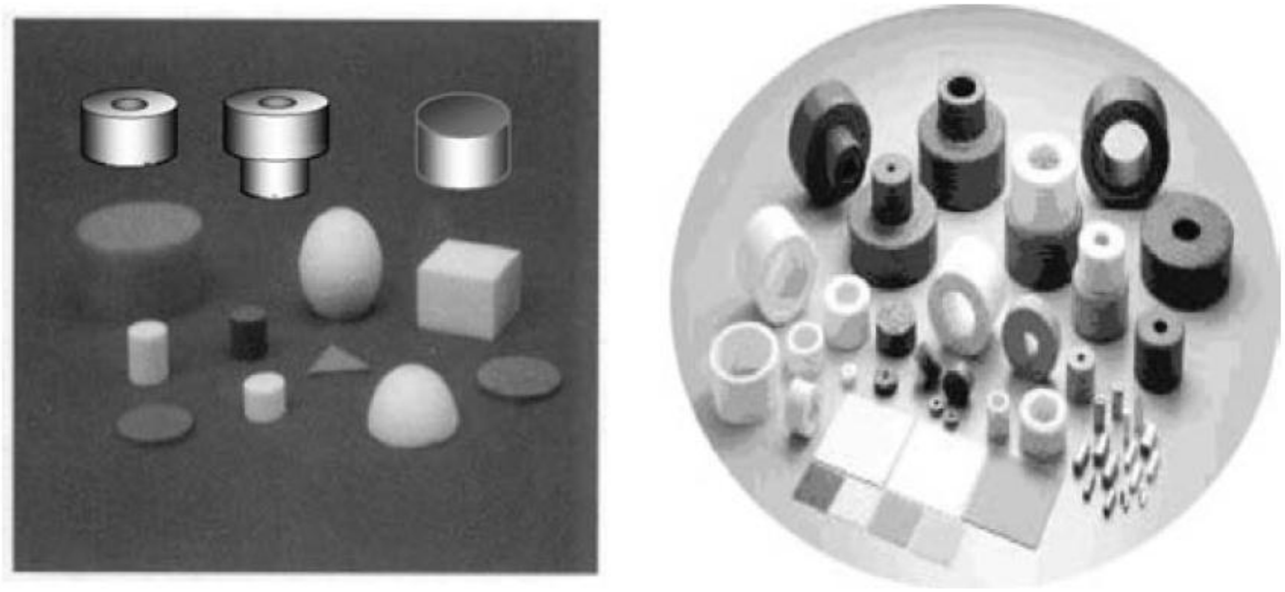


Figure 3.1 DRAs of various shapes (cylindrical, rectangular, hemispherical, low-profile circular-disk, low-profile triangular)

3.3 Advantages

In the past few years, extensive studies on the DRA have been focused on resonators of various shapes, the feeding techniques, and bandwidth enhancement methods. Specific features of DRAs has made them suitable for a variety of applications specially millimetre wave (MMW) applications. DRAs can be easily coupled to almost all types of transmission lines. They can be integrated easily with MMIC circuits. In MMW applications conductor loss of metallic antennas become severe and the antenna efficiency decreases considerably, conversely the only loss for a DRA is that due to the imperfect material of the DRA which can be very small in practice. Therefore DRAs have high radiation efficiency. In comparison to microstrip patch antennas, Dielectric resonator antennas have wider impedance bandwidths. For a typical DRA with dielectric constant of 10 the impedance bandwidth of 10% can be achieved. Avoidance of surface waves is another attractive advantage of DRAs over microstrip antennas. Single DRAs of different shapes has been possible, including rectangular, cylindrical, triangular, conical, hemispherical, etc. However, among these different shapes cylindrical and rectangular are the most common and the rectangular has the advantage of having one more degree of freedom for design purposes. Here, a variety of feed structures, which electromagnetic fields can be coupled to DRAs [6]. Usually common feed arrangements are coplanar waveguide feeding, microstrip aperture coupling, direct microstrip coupling, probe coupling and conformal strip coupling. Among these feed configurations, aperture coupling is more suitable for MMW applications. In aperture coupling configuration, since the DRA is placed on the ground plane of the microstrip feed, Figure 3.1 DRAs of various shapes (cylindrical, rectangular, hemispherical, low-profile circular-disk, low-profile triangular) parasitic radiation from the microstrip line is avoided. Isolation of the feed network from the radiating element is another advantage of the aperture coupling method [5].

DRAs have been extensively used for numerous applications since they have many attractive characteristics such as low profile, light weight, low cost, and inherently wide bandwidth. They could be used for numerous applications as both individual elements and in an array environment. In addition, wide bandwidth, low cost, low dissipation loss at high frequency, and high radiation efficiency are the inherent advantages of DRAs over conventional patch antennas. Compared with Microstrip antennas, which suffer from higher conduction loss and surface waves in antenna array applications, DRAs have high radiation efficiency and high power handling capability due to lack of metallic loss. Unlike the microstrip antenna, DRA does not support surface waves if placed on a ground plane directly. In recent years, DRAs have been considered as potential antennas for mobile phone applications. A general problem in the miniaturization of RF resonators used in filters and small antennas is decrease of efficiency, due to conductor losses. In DRAs, lower conductor losses, compared to those in typical metal antennas such as microstrip patches can be expected because DRAs have fewer metal parts. Thus, DRAs are good potential alternatives, especially when very small antenna elements are needed. In addition, they can be easily incorporated into microwave integrated circuits because they can be fabricated directly on the printed circuit board (PCB) of the phone. Specific features of DRAs have made them suitable for a variety of applications specially MMW applications. DRAs have small size and low cost. They can be easily coupled to almost all types of transmission lines [1], [5].

DRA have several advantages compared to conventional microwave antennas, and therefore many applications cover the broad frequency range. Some of the principal advantages of dielectric resonator antennas compared to conventional microstrip antennas are:

- DRA has a much wide impendence bandwidth than microstrip antenna because it radiates through the whole antenna surface except ground port while microstrip antenna radiate only through two narrow radiation slots.
- Higher efficiency.
- Avoidance of surface waves is another attractive advantage of DRAs over microstrip antennas
- However, dielectric resonator antennas have some advantages:
- Light weight, low volume, and low profile configuration, which can be made conformal;

- DRA has high degree of flexibility and versatility, allowing for designs to suit a wide range of physical or electrical requirements of varied communication applications.
- Easy of fabrication
- High radiation efficiency
- High dielectric strength and higher power handling capacity
- In DRA, various shapes of resonators can be used (rectangular, cylindrical, hemispherical, etc.) that allow flexibility in design.
- Low production cost
- Several feeding mechanisms can be used (probes, slots, microstrip lines, dielectric image guides, and coplanar waveguide lines) to efficiently excite DRAs, making them amenable to integration with various existing technologies [1], [3], [6] - [8].

3.4 Problems with Microstrip patch antenna

1) Narrow Bandwidth for Electrically thin substrates
2) High frequencies Results in,
    a) More ohmic losses
    b) Electrically thicker substrates which support surface waves and decrease radiation efficiency.
3) Low gain
4) Poor polarization purity
5) Spurious feed radiation
6) MPA having low dielectric strength, hence they cannot handle as much output power as other antennas

3.5 Advantages of DRA over Microstrip Antenna

In general Dielectric Resonator antennas having more attractive features compared to general microstrip patch antennas. The list of key advantages of DRAs over Microstrip patch antennas listed as fallows [2].

- Much wider Bandwidth

  - ✓ More over operating Bandwidth of a DRA can be varied by the permittivity (ϵ_r) of the resonator material and its dimensions.
- ➢ Radiation efficiency is more
  - ✓ Because DRA radiates through the whole antenna surface but in case of microstrip patch antenna radiates only through patch.
- ➢ Avoidance of surface wave and metal losses.
- ➢ DRA’s have high dielectric strength
  - ✓ Hence DRA’s having higher power handling capacity.
  - ✓ DRA’s can operate in a wide temperature range

More over the temperature stable ceramics enables the antenna to operate in a wide temperature range.

3.6 Bandwidth Enhancement by Using DRA’s

The key attractive feature in Dielectric Resonator antennas is Bandwidth Enhancement. By choosing proper structure for DRAs we can easily increase the bandwidth. The important techniques used in Bandwidth Enhancement by using DRA’s as listed below [1].

- ➢ Optimizing the feeding mechanisms and the DRA parameters.
- ➢ Use of modified feed geometries (stub matching).
- ➢ Changing the shape of DRAs.
- ➢ Using Stacked Dielectric Resonators in DRA designs.
- ➢ Introduction of air gap between the ground and Dielectric Resonator.
- ➢ Changing the dielectric constant of Dielectric Resonator.
- ➢ Use of parasitic coupling with different resonators.

In present DRA structures the stacked method used to enhance the Bandwidth.

3.7 Basic-shaped Dielectric Resonator Antenna

Three basic shapes of the DRA as Cylindrical, rectangular and hemispherical are the most commonly used. Here, we studied about different shapes of DRAs and their various field mode configurations. These analyses can be used to predict the resonant frequency, radiation Q-factor, and radiation pattern of DRA [1].

3.7.1 Cylindrical DRA

Cylindrical DRA has advantages over hemispherical and rectangular shape DRA. It offers greater design flexibility, where the ration of radius/height controls the resonant frequency and the quality (Q) factor. By varying the DRA‘s dimensions different Q-factor can be obtained. In cylindrical DRA fabrication is much easier than hemispherical DRA and various modes can be easily excited which results in either broadside or Omni-directional radiation patters. It offers one degree of freedom more than the hemispherical shape; it has aspect ratio a/h which determines the Q factor for a given dielectric constant [1].

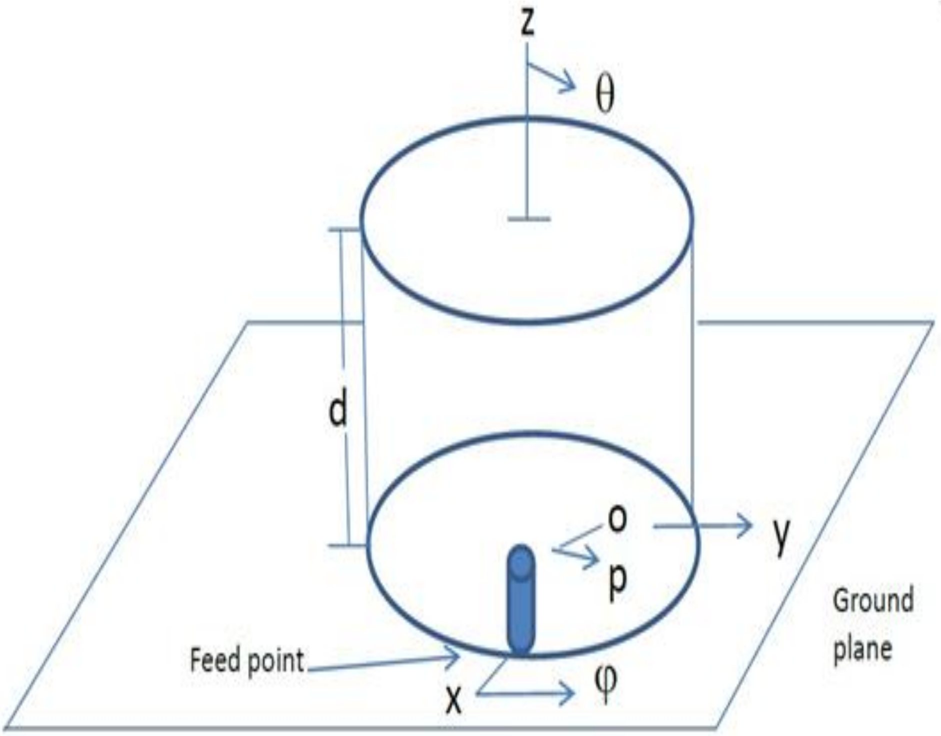


Figure 3.2 The geometry of cylindrical DRA

Different subclasses of DRAs can be derived from cylindrical shape such as split-cylindrical DRA, cylindrical-ring DRA, electric monopole DRA, disk-loaded cylindrical DRA, sectored cylindrical and ring DRAs, elliptical DRA, conical DRAs. Ring DRA which is a subclass of the cylindrical DRA that offers increased impedance bandwidth performance. Cylindrical dielectric resonators are used in circuit applications, filters, and oscillators and especially in microstrip technology, where resonant waveguide cavities are not very practical. The geometry of the cylindrical DRA is shown in figure 3.2. It consists of a material with a height h, radius a, and dielectric constant (ϵ_r). This shape offers one degree of freedom more than hemispherical shape because it has aspect ratio a/h, which determines k_0a and the Q-factor for a given dielectric constant [1].

3.7.2 Hemispherical DRA

Hemispherical shape DRA offers an advantage over the rectangular and cylindrical shapes as the interface between the dielectric and air is simpler. By that, a closed form expression cab obtained for the Green‘s function.

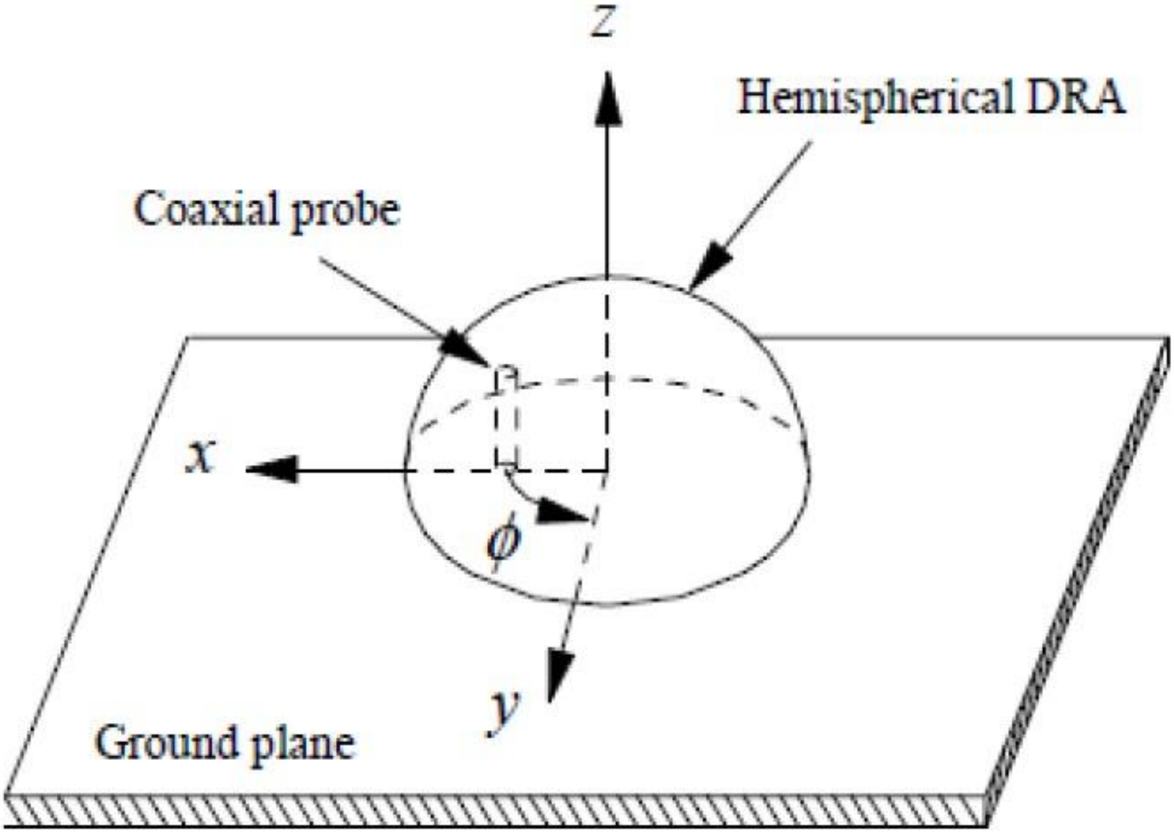


Figure 3.3 Configuration of a probe-fed hemispherical DRA

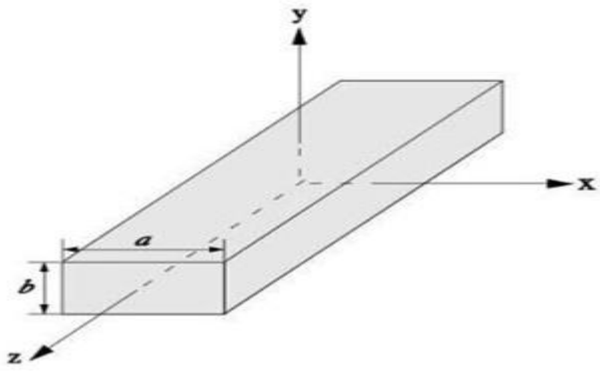
The hemispherical DRA is characterized by a radius a, a dielectric constant as shown in figure 3.3. Here, we assumed that the hemispherical DRA which is mounted on ground plane has infinite conductivity and infinite extent. Image theory is useful to equate the hemispherical DRA of radius =a‘ to an isolated dielectric sphere having the same radius. Transverse electric (TE) and transverse magnetic (TM) are different modes in dielectric sphere. Transverse electric (TE) modes having a zero value for the radial component of the Electric field (E_r=0), while transverse magnetic(TM) modes have a zero radial component of the magnetic field (H_r=0). The two fundamental modes for hemispherical DRA are TE_{111}, whose radiation pattern is similar to a short horizontal magnetic dipole and TM_{101}, whose radiation pattern is similar to a short electric monopole [1].

3.7.3 Rectangular DRA

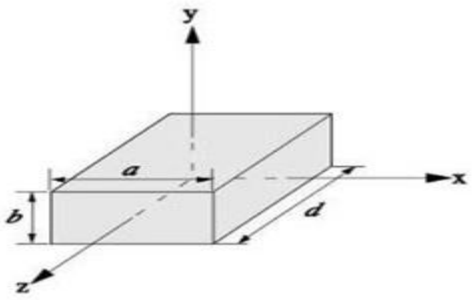
The rectangular shape DRA has more advantages over cylindrical and hemispherical shape DRA. It offers a second degree of freedom which is one more than cylindrical shape and two more than hemispherical shape. It provides designer to have a greater design flexibility to achieve the desired profile and bandwidth characteristics for a given resonant frequency and dielectric constant. In an isolated rectangular dielectric guide, the various modes can be divided into TE and TM, but with the DRA mounted on the ground plane only TE mode can typically excited. The rectangular DRA can maintenance TE modes (TE_x, TE_y and TE_z) which would radiate like short magnetic dipole. The resonant frequency of each of these modes will be a function of the DRA dimensions. By properly choosing the DRA dimensions, the designer can avoid the unwanted modes to appear over the frequency band during operation. Resonant frequency of TE modes can be calculated by solving the transcendental equation [1].

3.7.3.1 Dielectric waveguide model

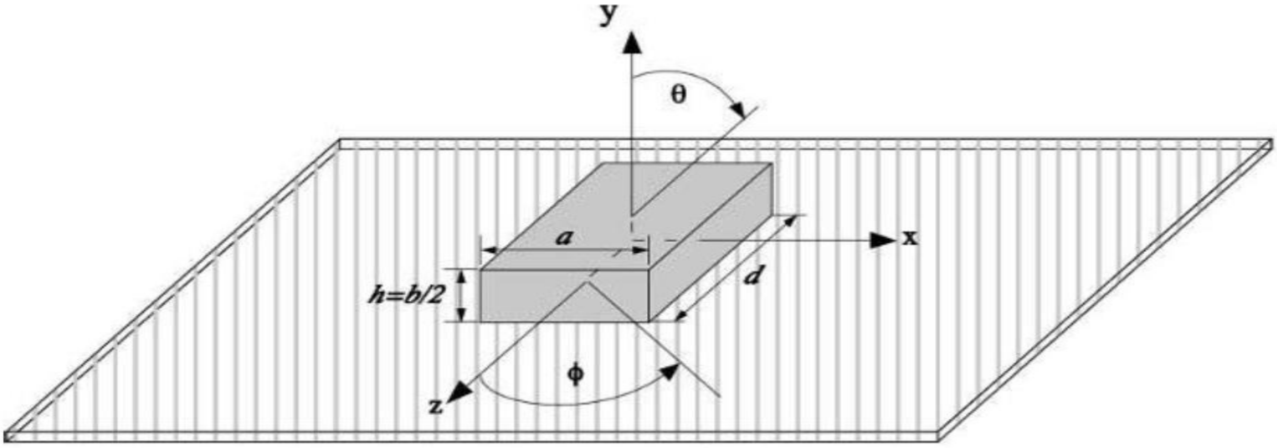
Dielectric waveguide model can be used for an isolated DRA in free space. Here we studied about field configuration, resonant frequency and Q-factor [1].



(a) Infinite dielectric waveguide



(b) Truncated dielectric waveguide



(c) DRA on ground plane

Figure 3.4 Geometry of the dielectric resonator model

3.7.3.2 Resonant frequency

By using transcendental equation, the value of kH_z is calculated. The normalised frequency is:

$$\boldsymbol{F = \frac{2\pi a f_o \ \overline{\varepsilon_r}}{c}} \tag{4.1}$$

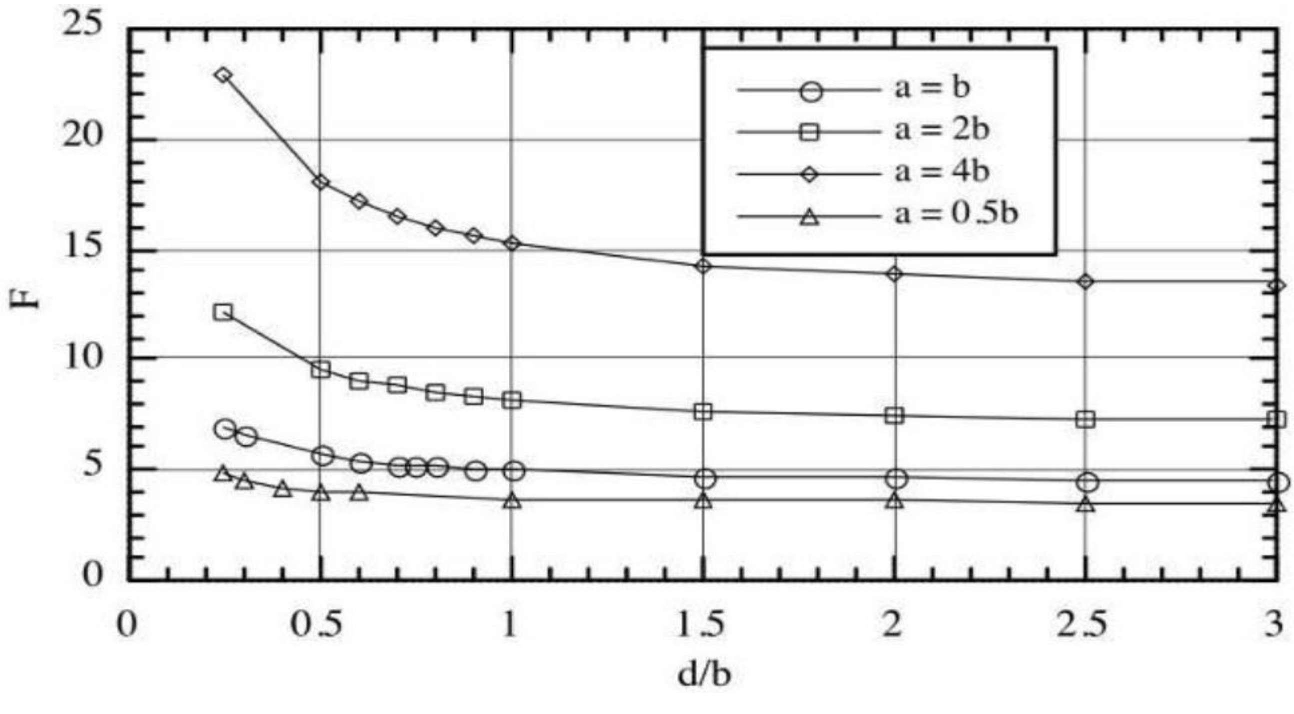


Figure 3.5 Normalized frequency of a rectangular DRA

In figure 3.5, the curves plot the normalised frequency (F) versus the ratio of DRA dimensions d/b for various ratio of a/b. Here, these curves are used to calculate resonant frequency of DRA without using transcendental equation. In example, the different dimensions have taken for calculating resonant frequency are ε_r=10, a= b= d= 10 mm, at d/b=1, the value of F=5 and f_0= 7.55 GHz [1].

3.7.4. Stacked method

A method for enhancing bandwidth in DRAs is stacking DRAs a top one another. In many cases with a single element DRA, desired specifications cannot be achieved. For example a high gain, directional pattern cannot be synthesized with a single DRA of any shape. In these applications, a DRA with appropriate element arrangement and feed configurations can be used to provide desired specifications. Dielectric Resonator Antennas (DRA's) have become popular in recent years because of many advantages they offer. The dominant mode radiation patterns in most of the probe-fed or slot fed structures are in the broadside direction of the elements. In DRAs stacked method is one of the highly efficient for bandwidth enhancement. Figure 3.6 shows a cylindrical stacked dielectric resonator antenna. The DRA stacked configuration contains two cylindrical discs of different materials vertically stacked, one atop the other, placed above a ground plane. Lower DRA is excited by a probe feed while the upper DRA is electromagnetically coupled, where the cylindrical DRA has radius (a), height (h) and relative dielectric permittivity (ε_r) [1].

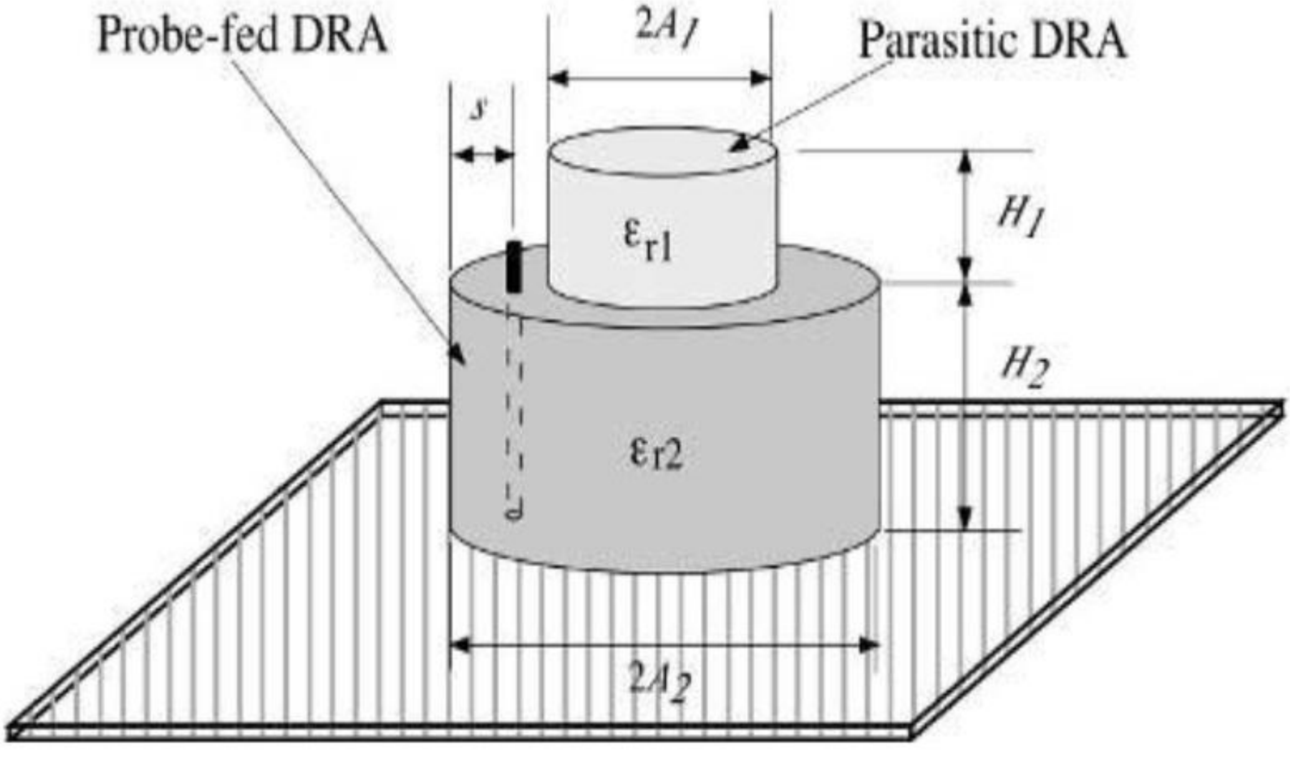


Figure 3.6 Geometry of Stacked cylindrical DRAs

Air gaps can also be introduced in between DRAs to enhance the impedance bandwidth. The parameters corresponding to the cylinders can take as per requirement. The main disadvantage of this method is that the DRA geometry is not very low profile [1].

3.7.4.1. Co-planar parasitic method

Regarding the mechanical structures and fabrications, Microstrip antennas have the advantage since etching can be used and the feeding mechanism and the antenna can be structured in one process with great accuracy in the alignment. The advantages become more appreciated in the structure of the arrays. DRA requires adhesive to mount the DR over the ground plane and more manual effort in the alignment of the DRA with the feeding structure.

Another method to enhance the impedance bandwidth of DRA is by using array technique. In stack method, DRAs are stacking on top of each other that will add increment to the overall height of the antenna [1], [4]. For certain applications, there is height restriction in DRA design. An alternative method is used to enhance bandwidth of DRA called a co- planar parasitic method where DRAs can also be placed on the same plane. Here, the centre element is excited by using any feeding method and adjacent elements are electromagnetically coupled. The main drawback is that here the problem becomes more pronounced in the structure of the array, where alignment of the individual elements and the array becomes more critical. The possible misalignment of the array elements could cause deterioration in the radiation characteristics of the antenna. To overcome this problem, it was suggested that the DRA array could be fabricated from a single sheet by perforating the area between the DRA elements with a lattice of holes [4].

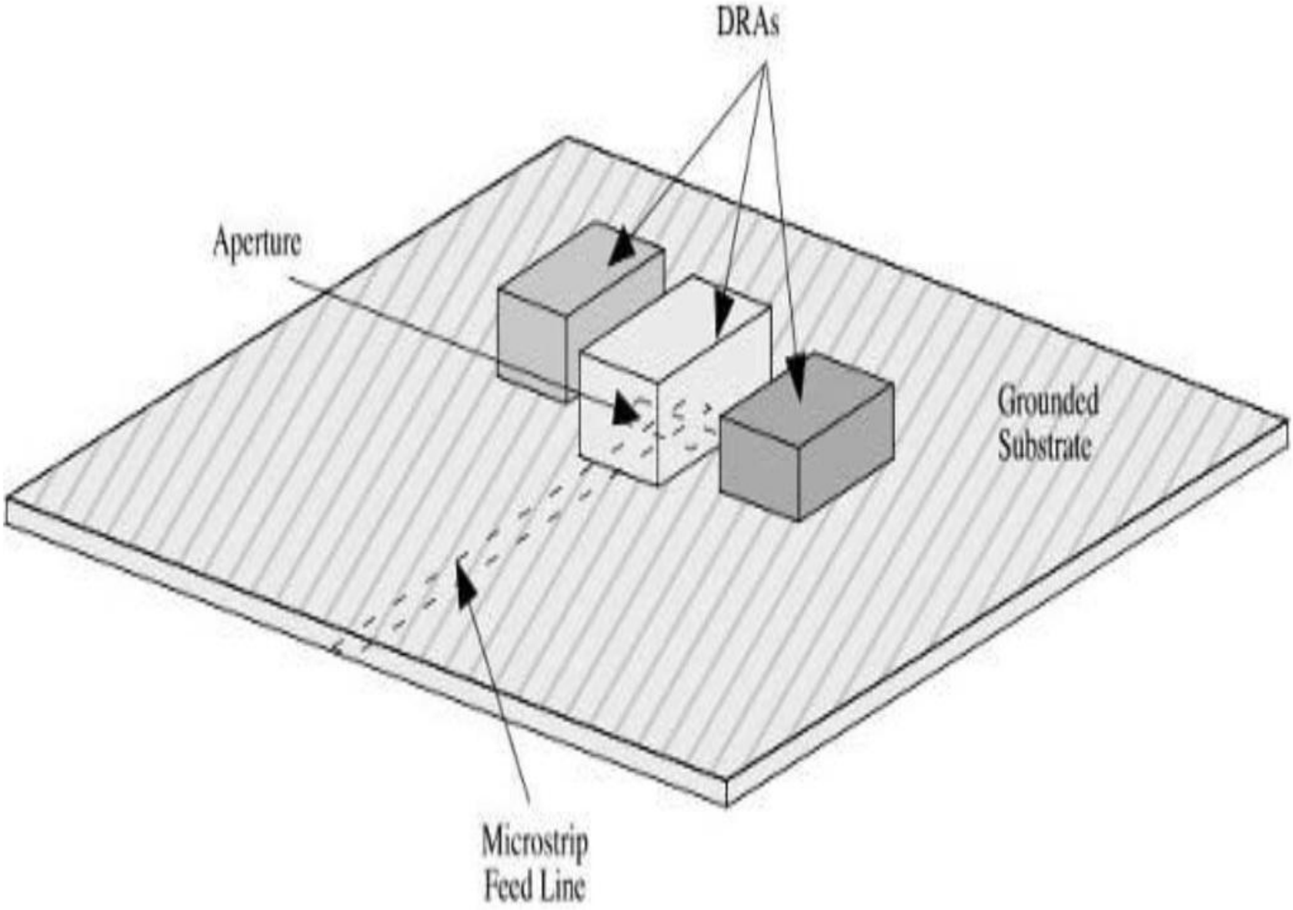


Figure 3.7 Configurations of 3-DRAs using co-planar parasitic method

Figure 3.7 shows the wideband configuration of three DRAs. Here, centre DR is connected with microstrip feed line. At the bottom there is ground and above it substrate placed. DRs placed above the substrate material [1].

Even though compared to stacked method, the Co-planar parasitic method facing few disadvantages like,

- Feeding process becomes complex compared to single feed stacked DR method.
- DRA requires more manual effort in the alignment of the DRA with the feeding structure
- Size requirements also very high, compared to single substrate stacked DR method.

Based on above factors generally we will prefer Stacked Dielectric Resonators for Bandwidth Enhancement.

3.7.4.2. Embedded method

The bandwidth of DRA can be enhancing by using embedded technique where DRAs can also embedded within one another [1].

Even though compared to stacked method, the Co-planar parasitic method facing few disadvantages like,

- Using multiple dielectric constant Dielectric Resonators making this method as complex, when compared to single dielectric constant stacked method.
- Dielectric Resonator positioning is less flexible compared to stacked method.

Based on above disadvantages generally we will prefer Stacked Dielectric Resonators for Bandwidth Enhancement at millimetre wave frequencies.

Chapter 4

Feeding Methods

There are several techniques available to feed or transmit electromagnetic energy to a dielectric resonator antenna. The five most popular feeding methods are the coaxial probe, slot aperture, microstrip line, co-planar coupling and dielectric image guide [1].

4.1 Coaxial Feed

The Coaxial feed or probe feed is a very common technique used for feeding dielectric resonator antennas as shown in figure 4.1. In this method, the probe can either be placed adjacent to the DRA or can be embedded within it. The amount of coupling can be enhanced by adjusting the probe height and the DRA location. In DRA, various modes can be excited depending on the location of the probe,. For the probe located adjacent to the DRA, the magnetic fields of the TE11δ mode of the rectangular DRA are excited and radiate like a horizontal magnetic dipole. For a probe located in the centre of a cylindrical DRA, the TE011 mode is excited and radiating like a vertical dipole. Another benefit of using probe coupling is that one can couple directly into a 50Ω system, without the requirement for a matching network. Probes are suitable at lower frequencies where aperture coupling may not be applied due to the large size of the slot required [2].

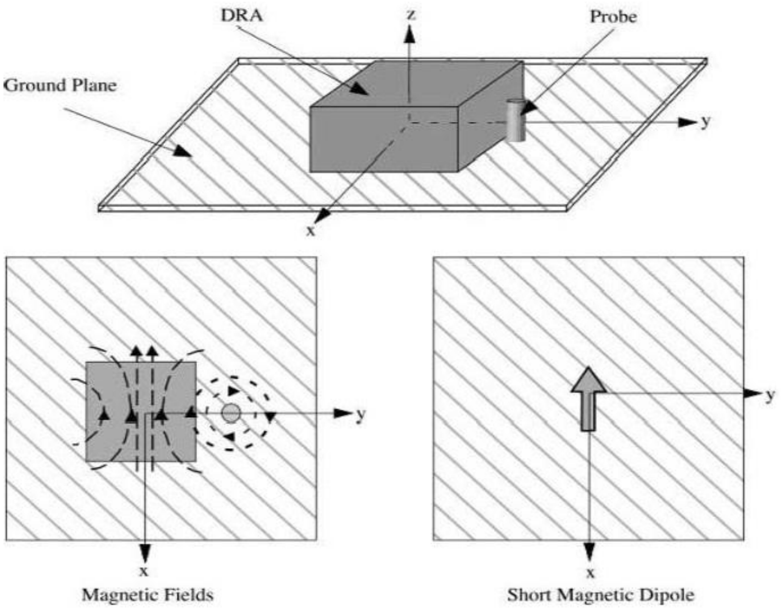


Figure 4.1 Probe-fed Dielectric resonator antennas

4.2 Slot Aperture

In slot aperture method, a DRA is exciting through an aperture in the ground plane upon which it is placed. Aperture coupling is applicable to DRAs of any shapes such as rectangular, cylindrical or hemispherical. The aperture works like a magnetic current running parallel to the size of the slot, which excites the magnetic fields inside the DRA. The aperture type of feeding consists of a slot cut in a ground plane and fed by a microstrip line below the ground plane. For avoiding spurious radiation, feed network is located below the ground plane. Moreover, slot coupling is an attractive technique for integrating DRAs with printed feed structures. The coupling level can be changed by moving the DRA with respect to the slot. Generally, a high dielectric material is used for the substrate and a thick, low dielectric constant material is used for the top dielectric resonator patch to optimize radiation from the antenna. The main drawback of this feed technique is that it is problematic to fabricate due to multiple layers, which also increases the antenna thickness. This feeding method also provides narrow bandwidth (up to 21%) [2].

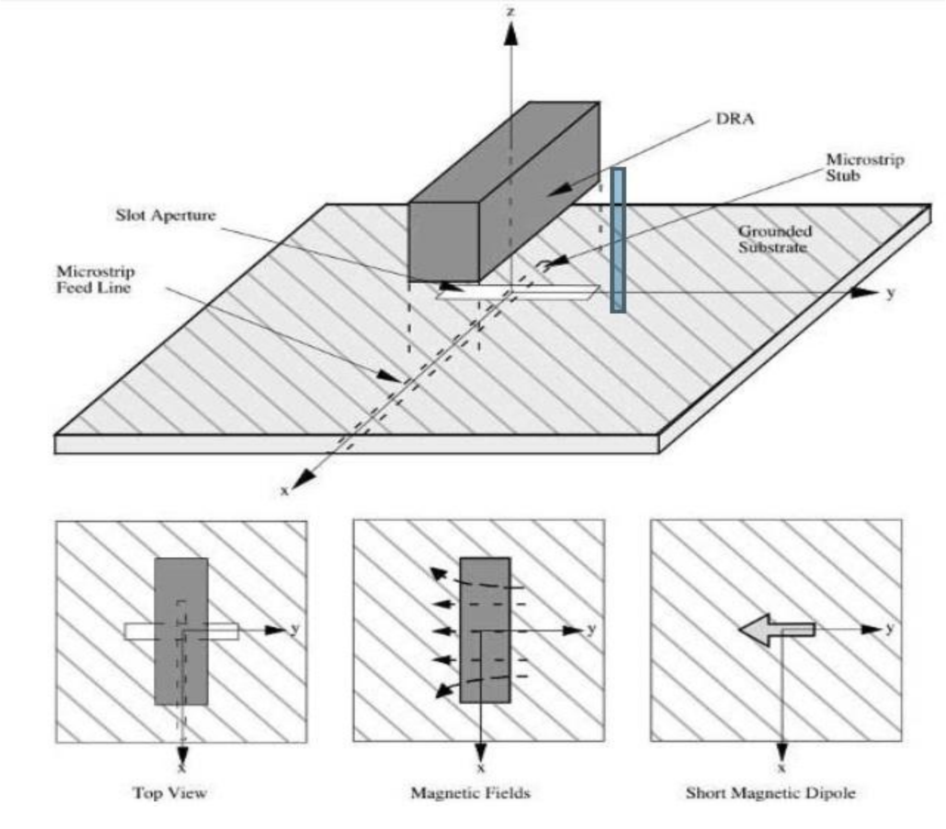


Figure 4.2 Slot Aperture-fed Dielectric resonator antennas

4.3 Microstrip Line Feed

In this type of feed technique, a conducting strip is connected directly to the edge of the patch as shown in figure 4.3. A common method for coupling to dielectric resonators in microwave circuits is by proximity coupling to microstrip lines. Microstrip coupling will excite the magnetic fields in the DRA to create the short horizontal magnetic dipole mode. The level of coupling can be changed by the lateral location of the DRA with respect to the microstrip line and on the relative permittivity of the DRA [2].

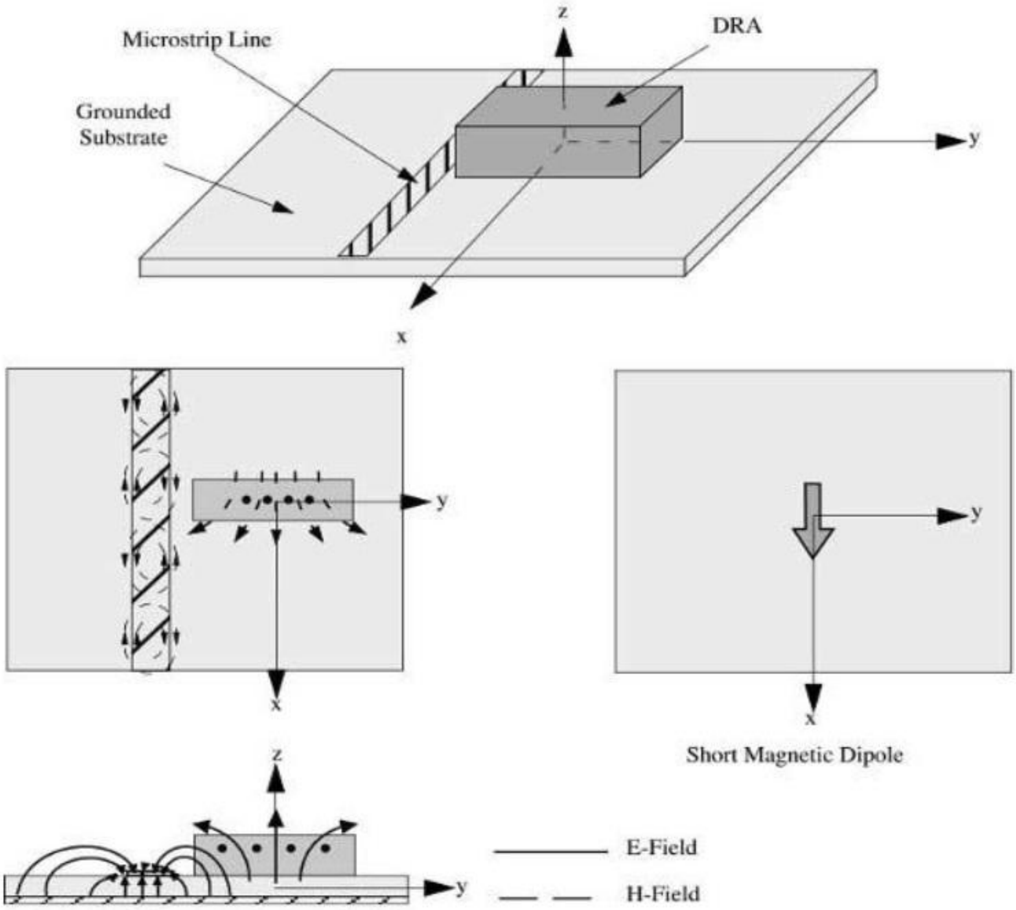


Figure 4.3 Microstrip-fed DRA

In DRAs, the amount of coupling is generally quite small for requiring wide bandwidth. Microstrip lines can be used as a series feed for a linear array of DRAs. This is an easy feeding technique, since it offers ease of fabrication and simplicity in modelling along with impedance matching. However as the thickness of the dielectric substrate being used, rises, surface waves and spurious feed radiation also rises, which hampers the bandwidth of the antenna [1]. One drawback of this method is that the polarization of the array is analysed by the orientation of the microstrip line such as the direction of the magnetic fields in the DRA will be parallel to the microstrip line [2], [4].

4.4 Dielectric Image Guide

Dielectric image guide is another attractive coupling technique in DRAs, as shown in figure 4.4. Dielectric image guides offer advantages over microstrip at millimetre –wave frequencies since they do not suffer as severely from conductor losses. As with microstriplines, the amount of coupling to the DRA is generally quite small, especially for DRAs with Slower permittivity values, although it may be possible to increase the coupling by operating the guide closer to the cut-off frequency. The dielectric image guide is thus best utilised as a series feed to a linear array of DRAs [2].

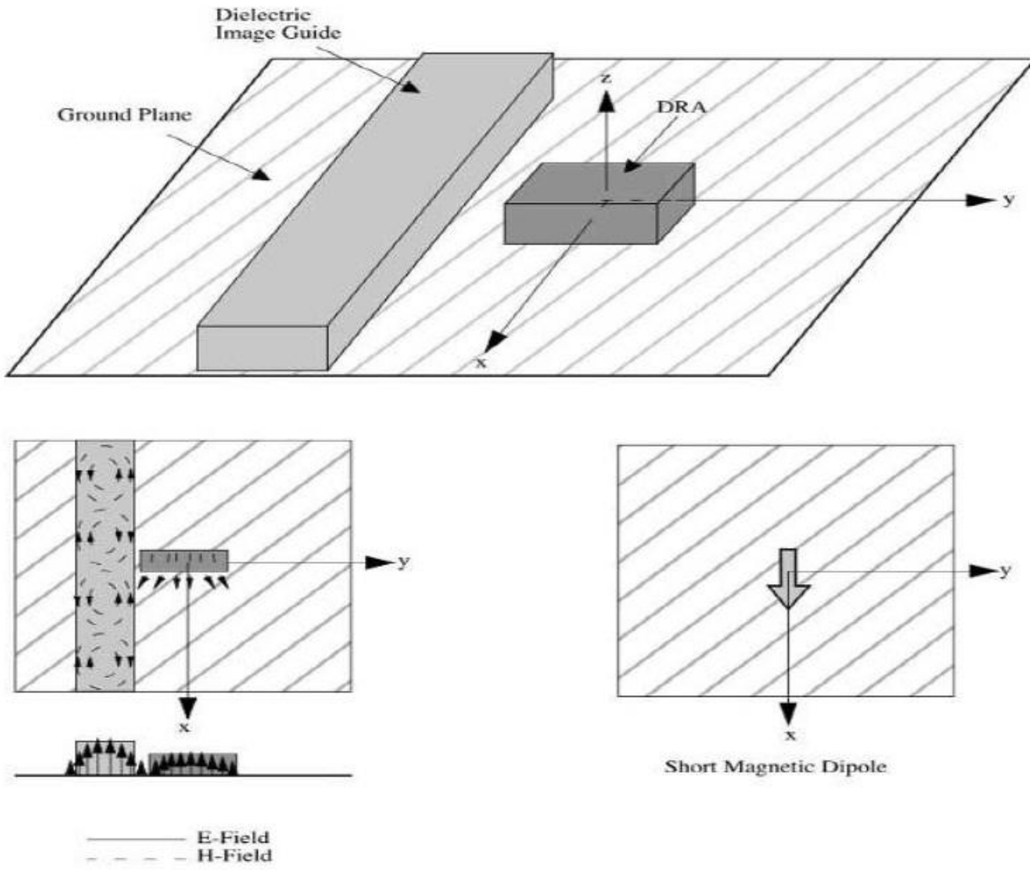


Figure 4.4 Dielectric image guide-fed DRA

4.5 Analytical Evaluation of Dielectric Resonator Antenna

In designing, input impedance is the important parameter which is a feed to excite the DRA. Input impedance as a function of frequency is to determine the bandwidth of operation and for matching the antenna to the circuit. Unfortunately, there are no simple closed-form expressions for predicting the input impedance of the DRA when excited by a particular feed and rigorous analytical. Here, some of the techniques that have been used to predict the input impedance for DRAs excited by the various feed [2].

4.5.1 Green’s function analysis

For a probe-fed DRA, the input impedance (Z_{in}) can be determined using the following equation:

$$Z_{in} = \frac{-1}{I_O^2} \quad (E.J_S)ds \tag{4.1}$$

E= Electric fields of the DRA

J_s = Applied source current density on the probe

I_O = Magnitude of the current on the probe

The electric fields of the DRA depend on the source excitation and determined by using:

$$(E.J_S)ds \tag{4.2}$$

Here, G represents Green‘s function for the DRA. By using some simple assumptions about a single-mode operation and the currents on the probe, the Green‘s function for a hemispherical DRA was first derived and was then used to predict the input impedance of the probe-fed DRA operating in the TE111 mode. This technique was also applied to a probe–fed hemispherical DRA operating in the TM101 mode. The input impedance of conformal strip feeds and aperture feeds can also be analysed using Green‘s function. The advantage to this technique is the relatively fast computation time required to obtain the input impedance. It is useful method for analysing the effects of altering probe dimensions and probe location and can be used for optimizing the input impedance. The main drawback is its limitation only to hemispherical DRA geometries. For other DRA shapes, different analytical techniques are required [2].

4.5.2 Numerical methods for analysing DRAs

Numerical methods for analysing DRAs can be categorized into two groups, frequency domain technique and time domain technique. Each category offers advantages for particular antenna geometries [2].

4.5.2.1 Frequency domain analysis

Two common frequency domain techniques that have been used to analyse DRAs are the method of moments (MOM) and the finite element method (FEM). The MOM was first developed for wire or metal antennas of arbitrary shape, but can be extended to include dielectric materials by introducing equivalent currents. The MOM involves discretizing the antenna into a number of small segments and solving for a set of unknown coefficient representing the current on one segment due to a known incident field. Analysis of DRAs is not limited to a hemispherical shape, and the technique can be used to also analyses simple cylindrical and rectangular DRA shapes. Determining the DRA input impedance using the MOM technique will require more computer memory and time than applying Green‘s function. Thus, MOM technique is not convenient tool for optimizing the DRA performance. MOM is used to investigate the effect of the air gaps and calculate internal field pattern of various modes of cylindrical DRAs [1], [2].

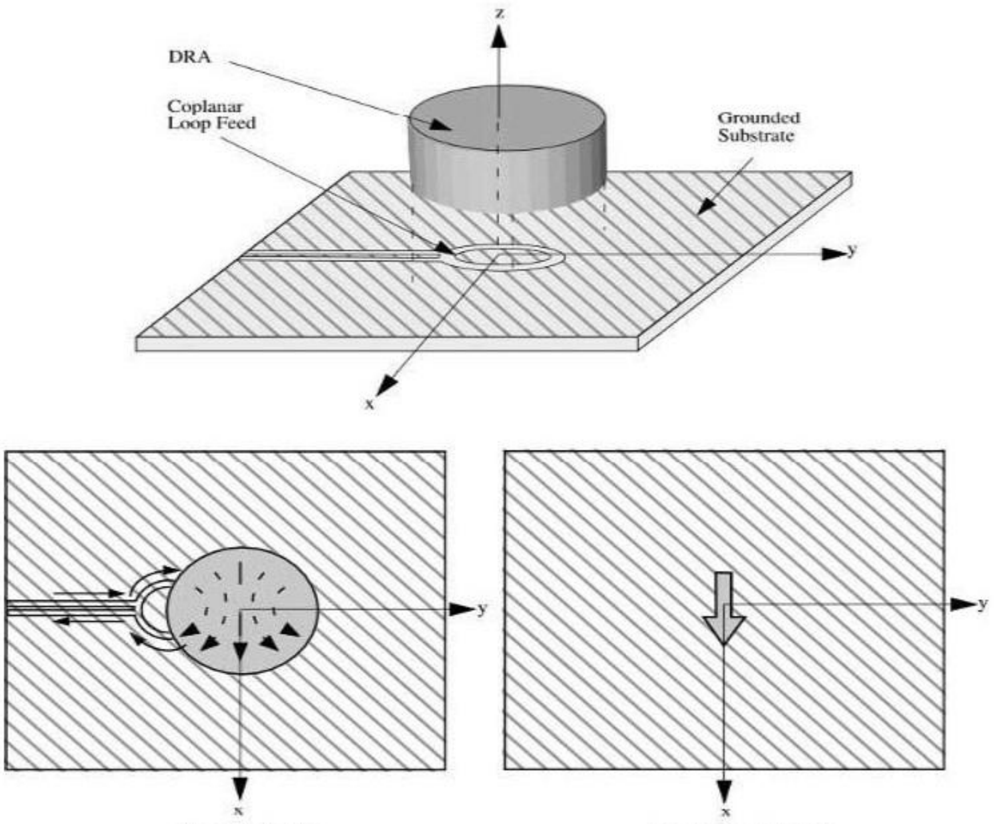
The FEM (Finite element method) can be used to analyses DRAs of arbitrary shape. Similar to the MOM, it involves a discretization of the geometry but whereas in the MOM only the DRA and the ground plane require segmentation , in the FEM the entire volume surrounding the DRA must also be discretized, thereby increasing the computational size of the problem. The advantage of the FEM is that it does not require the formulation of equivalent currents and can thus be readily applied to arbitrary shapes. Another advantage of the FEM is its availability as commercial software where graphical user interfaces are provided to simplify the geometrical definition of the problem. FEM is used to determine the effects of a finite ground plane on the radiation pattern of a DRA [1], [2], [7].

4.5.2.2 Time domain analysis

There are two time domain techniques that have been applied to analysing DRAs are the finite difference time domain (FDTD) method and the transmission line method (TLM). These techniques require the entire volume around the DRA to be discretized and thus can be memory and time intensive. In it, wideband pulse used to excite the DRA, and by transforming the solution into the frequency domain, the input impedance can be determined over a wide frequency range. For frequency domain techniques, the problem would have to be re-simulated at each frequency of interest and finding the impedance response over a broad frequency range could be very time consuming. With the frequency domain methods, the time domain methods are good tools for analysing the performance of a given DRA geometry, but are less useful for optimizing the performance of DRAs. FDTD is used to calculate circular polarization patterns of cross-shaped DRAs and input impedance of slot-fed rectangular DRA. Transmission line method used to calculate input impedance of microstrip-fed multi-segment DRAs [1], [2].

4.6 Co-Planar waveguide Feed

The Co- planar feed is a very common technique used for coupling in dielectric resonator antennas. Here, figure 4.5 shows a cylindrical DRA coupled to a co-planar loop. The coupling level can be adjusted by locating the DRA over the loop [1], [5].



Magnetic Fields

Short Magnetic Dipole

Figure 4.5 Co-planar loop-fed DRA

The coupling behaviour of the co-planar loop is similar to coaxial probe, but the loop offers the advantage of being non-obtrusive. By moving the feed loop from the edge of the DRA to the centre, one can couple into either the HE11δ mode or the TE011 mode of the cylindrical DRA [1], [2].

Co-planar waveguide (CPW) feeding technique is also referred as planar strip line feeding. CPW feeding technique more advantageous compared to other feeding techniques, because it having the fallowing attractive features.

They are

- Lower radiation leakage
- Less dispersion than microstrip lines

- Active devices can be mounted on top of the circuit like on microstrip.
- It can provide extremely high frequency response (100 GHz or more). Since connecting to CPW does not involve or require any parasitic discontinuities in the ground plane [2].

The coplanar waveguide (CPW) is such a transmission line that can achieve high radiation efficiency demands. In addition, the CPW has lower loss than the microstrip line. One promising application with the coplanar waveguide fed antenna techniques is that a fibre optics system can be integrated with the slot antenna. Recently, different types of CPW-fed slot antennas have been designed for wideband applications, achieving 50% bandwidth in a multi-slot design and 60% and width by optimizing a tuning stub As with microstrip line excitation, slot antennas excited by coplanar waveguides also have bidirectional radiation characteristics[11].

Planar printed antennas fed by coplanar waveguides (CPW) have various benefits, because it is constructed on one-layer design, low cost, low profile and uncomplicated to integrate to the transceiver circuit board [13].

4.6.1 Finite Ground CPW Feeding Method (FG-CPW):

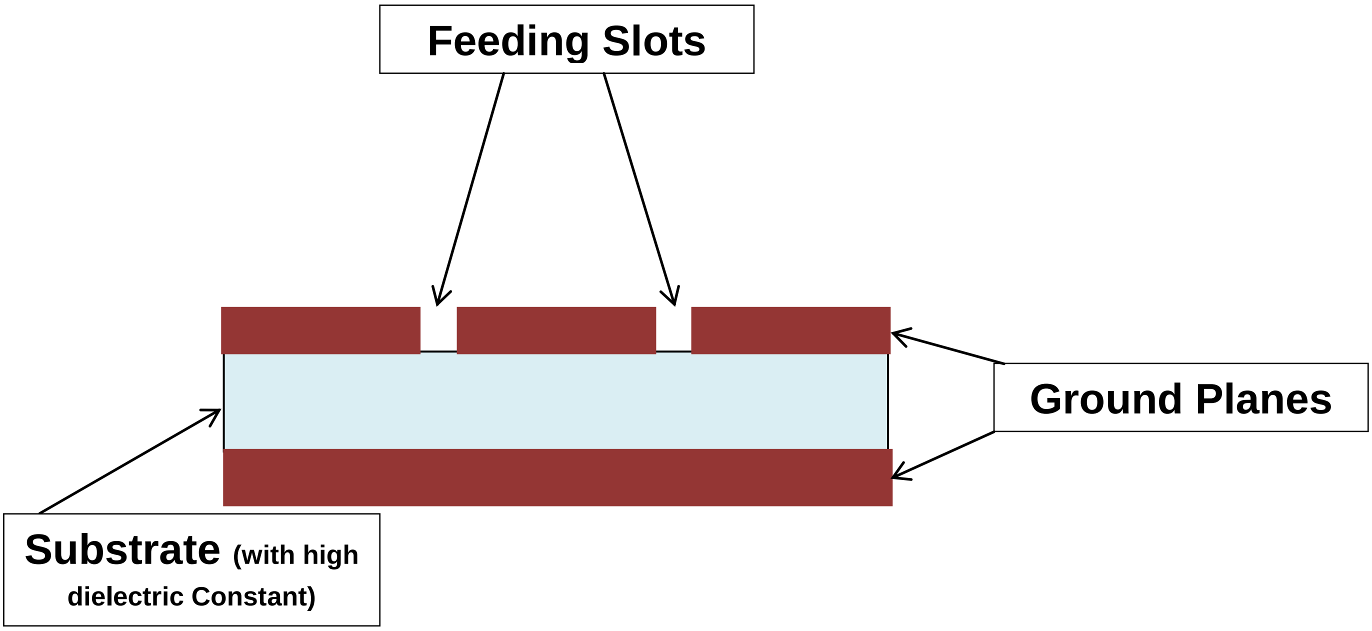


Figure 4.6 Finite Ground Co-planar feeding technique

The above figure represents the clear view of finite ground coplanar waveguide method. It has feeding slots like same as coplanar waveguide feeding and it also having ground plane in bottom side of the substrate [1].

Chapter 5

Compact CPW fed Cylindrical DRA for Wi-Fi/Bluetooth Application

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5.1. INTRODUCTION:

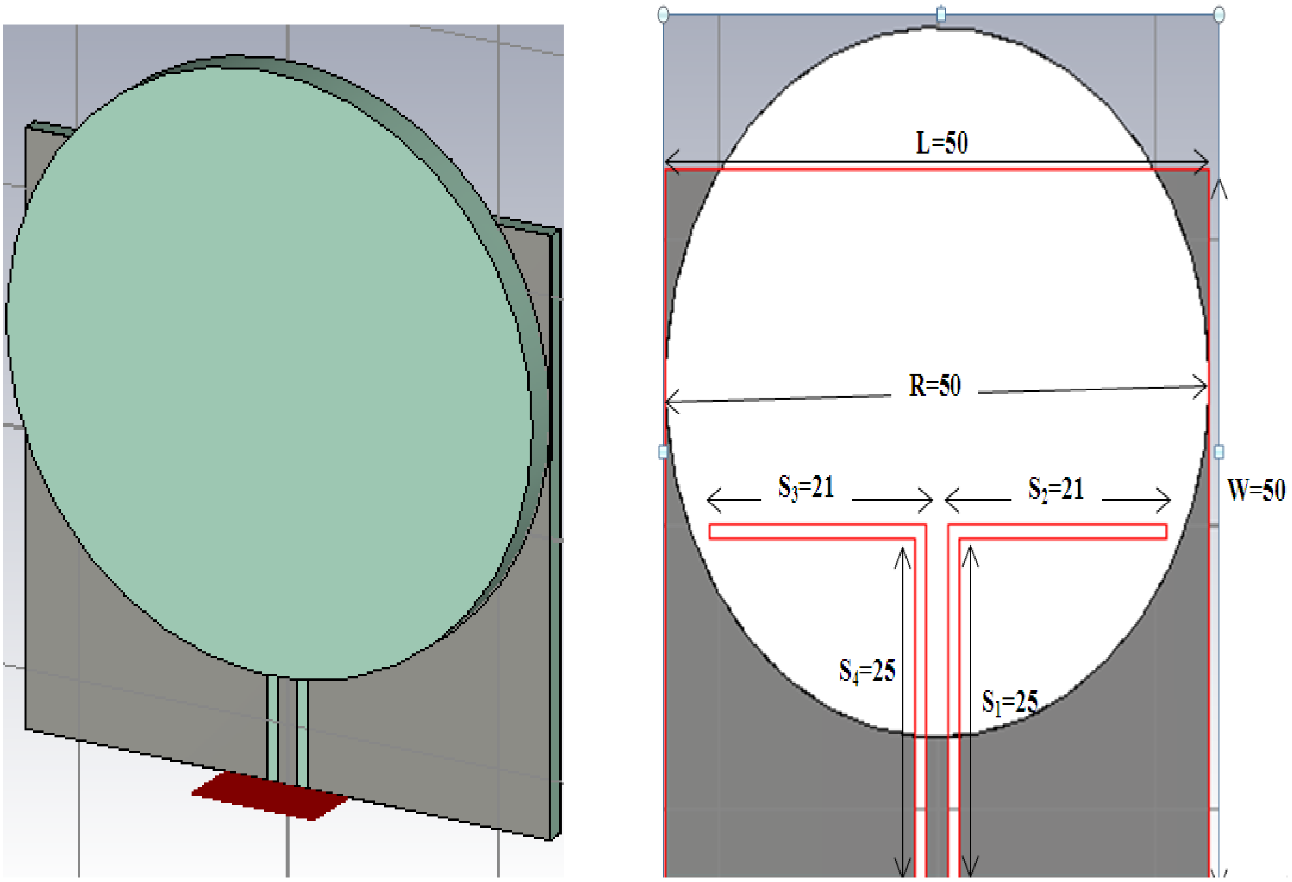
Among the different shapes DRA, the cylindrical shaped DRA offers greater design flexibility, where the outer and inner radii control the resonant frequency. Various modes can be easily excited within the cylindrical DRA, which results in either broadside or Omni-directional radiation pattern [1]. The new cylindrical type DRA designed for Wi-Fi/Bluetooth applications. As a result of which a new type of stacked cylindrical DRA is obtained. The DRA is excited by using CPW feeding. The Co-planar waveguide (CPW) feeding is an inductive slot simultaneously acts as an effective radiator and the feeding structure of the DR. The major advantages of CPW feeding are, provides the lower radiation leakage and less dispersion than microstrip lines [7]. With these features, this design of cylindrical DRA is suitable for wireless communication systems and especially for Wi-Fi/Bluetooth applications.

Wi-Fi is a popular technology that allows an electronic device to exchange data wirelessly (using radio waves) over a computer network, comprising high-speed Internet networks. The Wi-Fi Alliance defines Wi-Fi as any "wireless local area network (WLAN) products that are based on the Institute of Electrical and Electronics Engineers (IEEE- 802.11a/b/g) standards".

In this compact design the new cylindrical dielectric resonator used and this dielectric resonator excited by Co-planar waveguide (CPW) feeding technique.

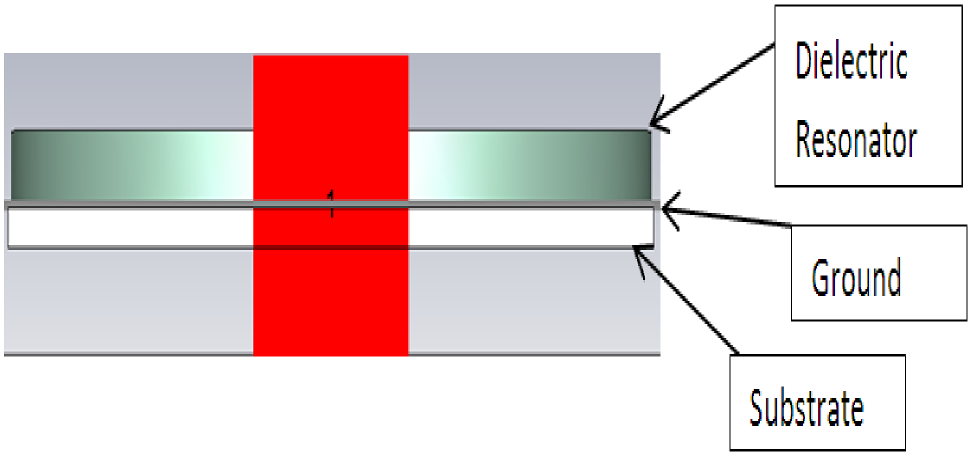
5.2 Antenna Design

The proposed new Cylindrical DRA structure [6] is shown in Fig. 5.1. This antenna consists of a Cylindrical DR and a center-fed CPW inductive slot which is etched on a FR4 substrate ($\varepsilon_r = 4.3$, T = 1.6mm), with L and Wdenote the length and the width of the substrate, respectively. DR is placed above the substrate etched with ground plane from the slot to the lower edge of the DR. The 50Ω CPW line is designed with the center metal strip width $Wc = 2mm$ and a gap width $= 1.0mm$. The resonator material used is Teflon has a dielectric constant of 2.1. The Cylindrical DR has dimensions $L \& W$ and the dielectric constant$\varepsilon_{dr} = 2.1$ [2-7]. On the other hand, the optimal slot length for DR excitation is dependent on the resonance frequency of DR [5], thus the slot length should be optimized so as to achieve narrowband resonance for Wi-Fi applications.



(a) Proposed DRA Structure

(b) Top view



(c) Front view

*Figure 5.1**(a)** Proposed DRA Structure, **(b)** Top view and **(c)** Front view of the proposed antenna structure*

5.3 Results and Discussion

As discussed in the previous section that a Wi-Fi band can be achieved by modifying the arm length of the feeding and basic shape of the Dielectric Resonator. So the first design step was to modify the shape of Cylindrical DR. To achieve optimal performance, a parametric study is performed to investigate the characteristics of the proposed antenna. The antenna parameters are Radius R=25mm thickness of DR= $3mm$, $\varepsilon_{dr} = 4.3$, $L = W = 50mm$, $S_1 = 25mm$, $S_2 = 21mm$ and The simulated resonance frequency of DR and inductive slot is approximately 2.4 GHz. For the case $S_2 = 21mm$, a narrow bandwidth with less **S_{11}** $(-33.66dB)$ is observed. This DRA is simulated using a CST microwave studio suite^{TM} 2011.

A. *Parametric Results*

The proposed DRA is analyzed using CST Microwave studio suite^{TM} 2011. The simulated return loss of the Cylindrical DRA plotted against frequency is shown in Fig. 5.2. By varying the slot length S_2 we can easily change the resonant frequencies. The proposed antenna achieves14.46 percent of impedance bandwidth from 2.25 GHz to 2.6 GHz covering 2.4 GHz Wi-Fi band for $S_2 = 21mm$.Based on the information gathered from the parametric study, a prototype antenna for 2.4 GHz (IEEE-802.11a, Wi-Fi) application is designed.

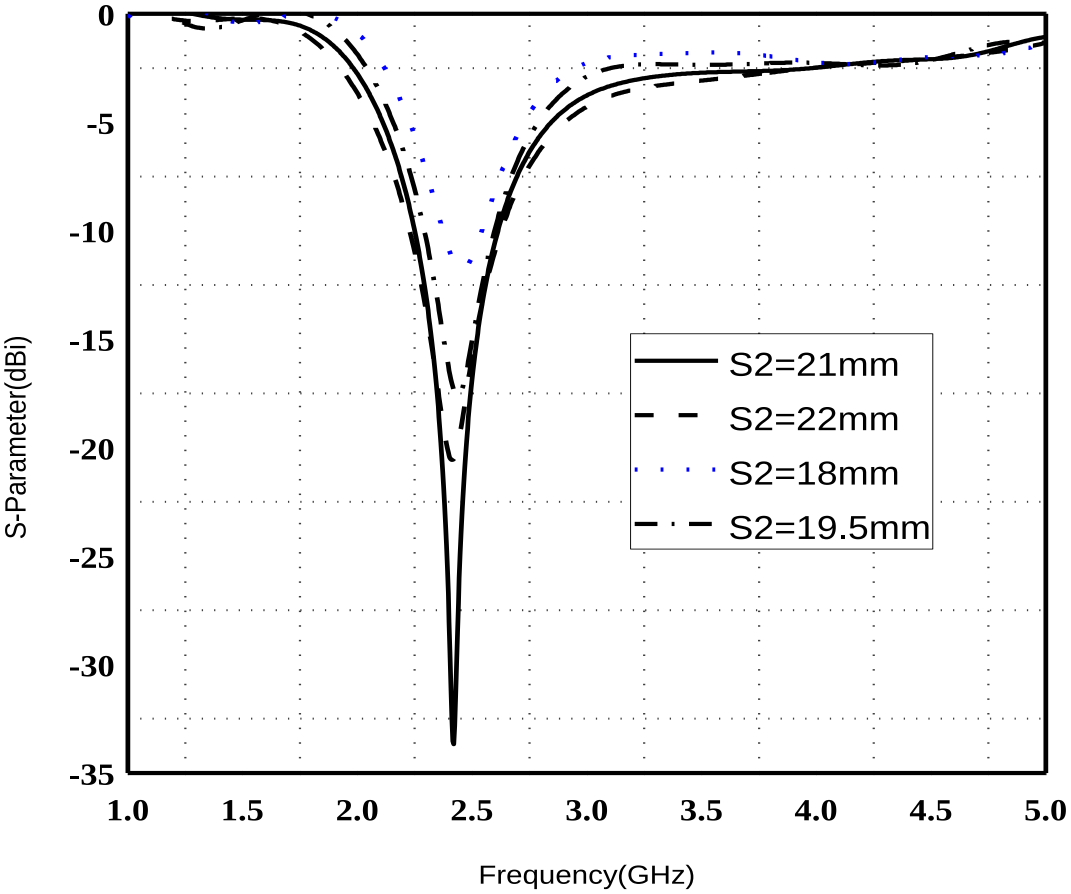


Figure 5.2 Simulated Return Loss of the Cylindrical DRA versus Frequency

B. *Gain and Directivity*

The Peak Gain of antenna is 9.968dBi. It is observed from Fig. 5.3 that the simulated peak directivity is 9.179dBi at 2.4 GHz frequency range. The Gain curve follows the Directivity curve over the entire frequency range. It is observed from 2 GHz to 3.6 GHz range.

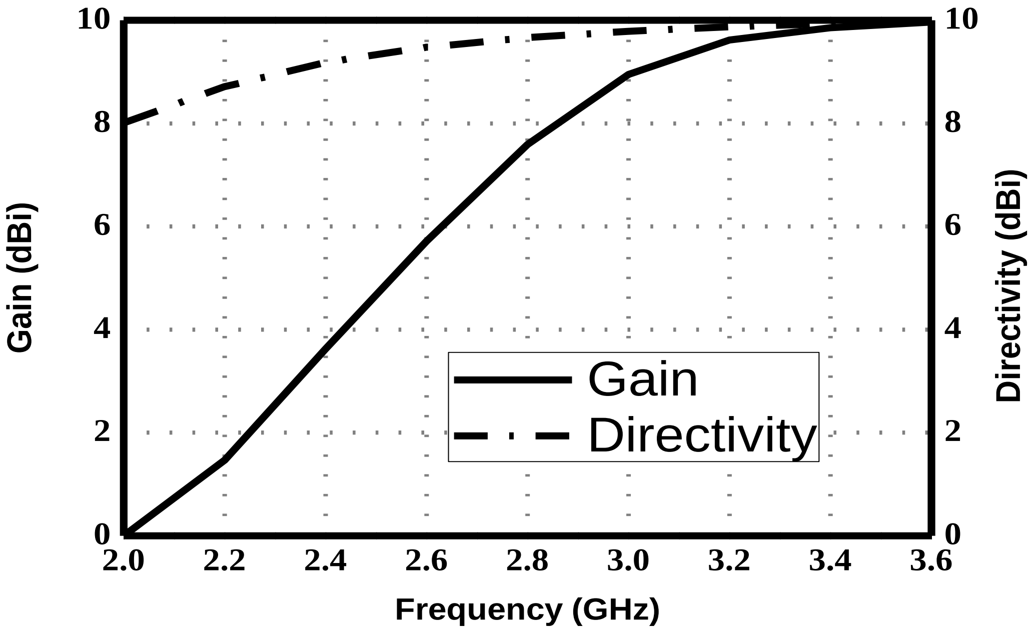


Figure 5.3Simulated Gain and Directivity of the Cylindrical DRA versus Frequency

C. *Radiation Pattern Characteristics*

The simulated far field radiation patterns of E-Plane and H-Plane of the proposed cylindrical shaped DRA are shown in Fig. 5.4. The simulated radiation patterns at resonant frequency (2.4GHz) show that the E-Plane radiation pattern is in broadside direction against frequency and H-Plane in Omni-directional.

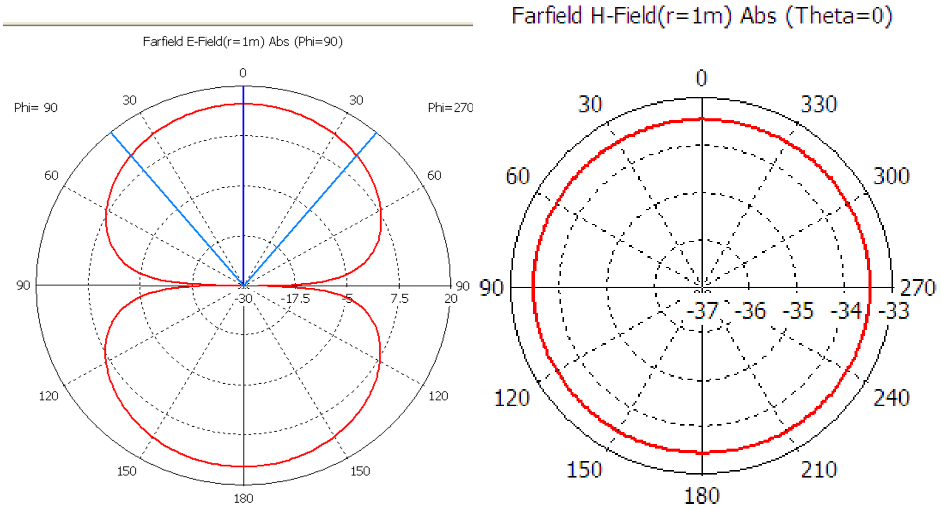
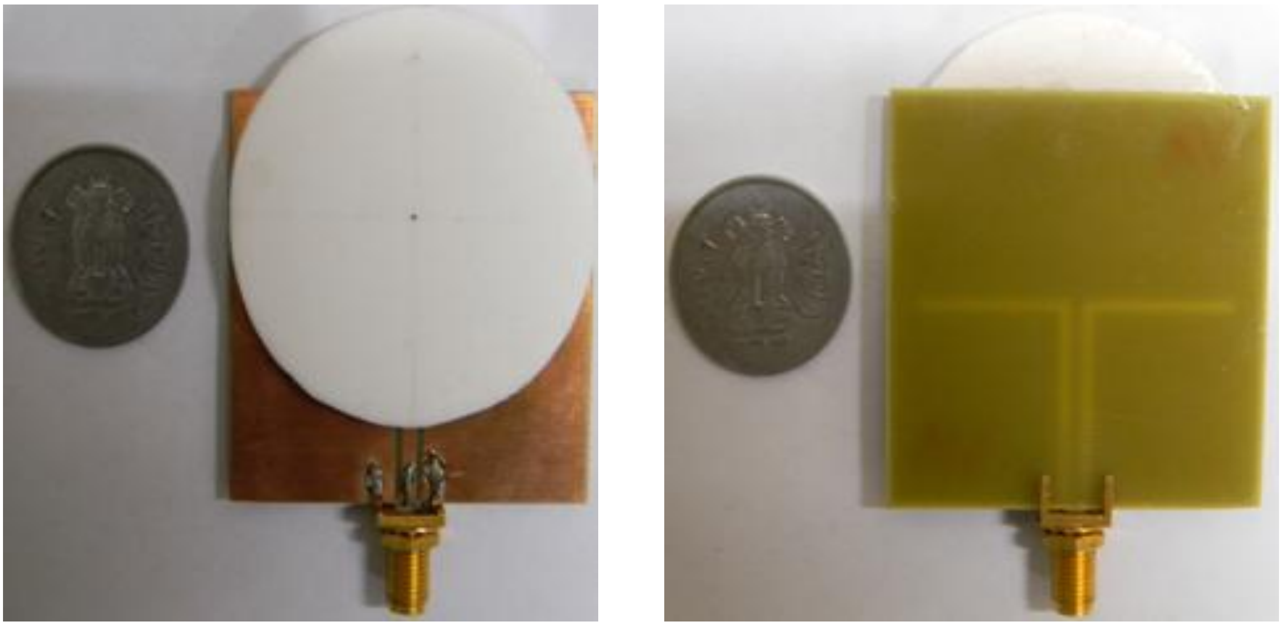


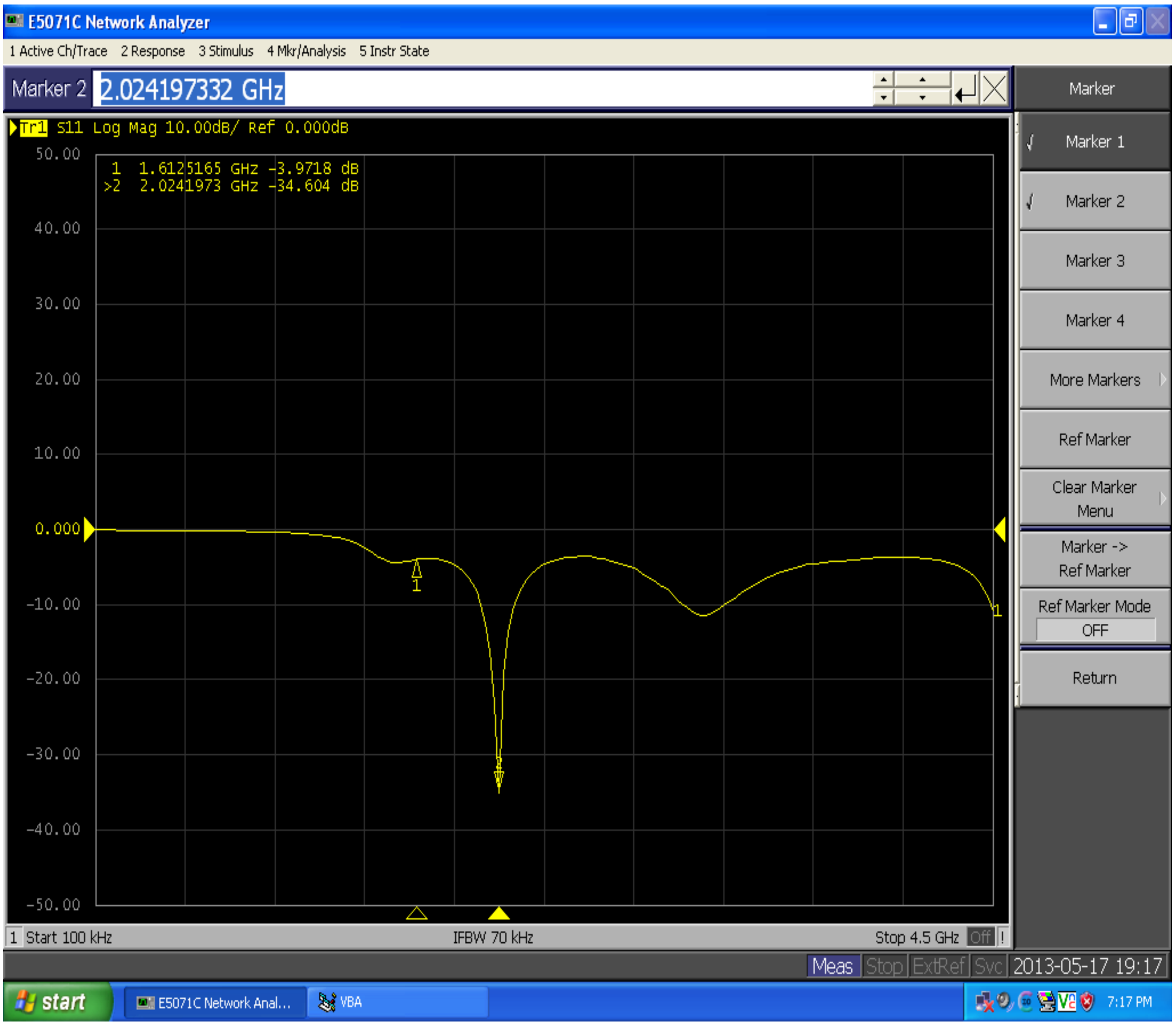
Figure 5.4 Simulated radiation patterns of proposed Cylindrical DRA at 2.4 GHz (a) E-Plane and (b) H-Plane

D. Practical Measurements:



(a) Front view (b) Back view

Figure 5.5 Physical (a) front and (b) back views of Proposed Cylindrical DRA



```
Marker 2 2.024197332 GHz
Tr1 S11 Log Mag 10.00dB/ Ref 0.000dB
 1  1.6125165 GHz -3.9718 dB
>2  2.0241973 GHz -34.604 dB
1 Start 100 kHz          IFBW 70 kHz          Stop 4.5 GHz
2013-05-17 19:17
```

Figure 5.6 Practical Return Loss of the proposed Cylindrical DRA versus Frequency

The practical return loss of the proposed Cylindrical DRA plotted against frequency is shown in the above figure. The practical measurements are carried out by using E5071C ENA Series Network Analyzer having measurement range of frequency from 9 KHz to 4.5 GHz from Agilent Technologies.

5.4 Summary

A new cylindrical dielectric resonator antenna is realized by using Teflon and FR4 materials. The resonance of a CPW inductive feeding slot is merged with that of a Cylindrical DR so as to achieve required band for Wi-Fi operation. The simulated results show that the designed antenna offered desired resonant frequency at 2.4GHz, which covers the Wi-Fi application bands. This antenna provides maximum Gain of 9.968dBi. The proposed very compact Cylindrical DRA design is overall suitable for wireless local area networks (WLAN).

Chapter 6

Compact CPW fed DRA for WLAN Applications

6.1 INTRODUCTION:

Due to the flexibility in Dielectric Resonator Antenna, they can be designed with different shapes as per our coverage requirements depending upon the applications in the wireless world. DRAs can also be excited with different feeding methods, such as microstrip lines, probes, slots, and co-planar lines [1]. The DRAs are good replacement for the Microstrip antenna, because the DRA has a much wider impedance bandwidth due to their many advantageous and attractive features. These include their compact size, less weight, the versatility in their shape and feeding mechanism, easy fabrication, simple structure and wide impedance bandwidth [4].

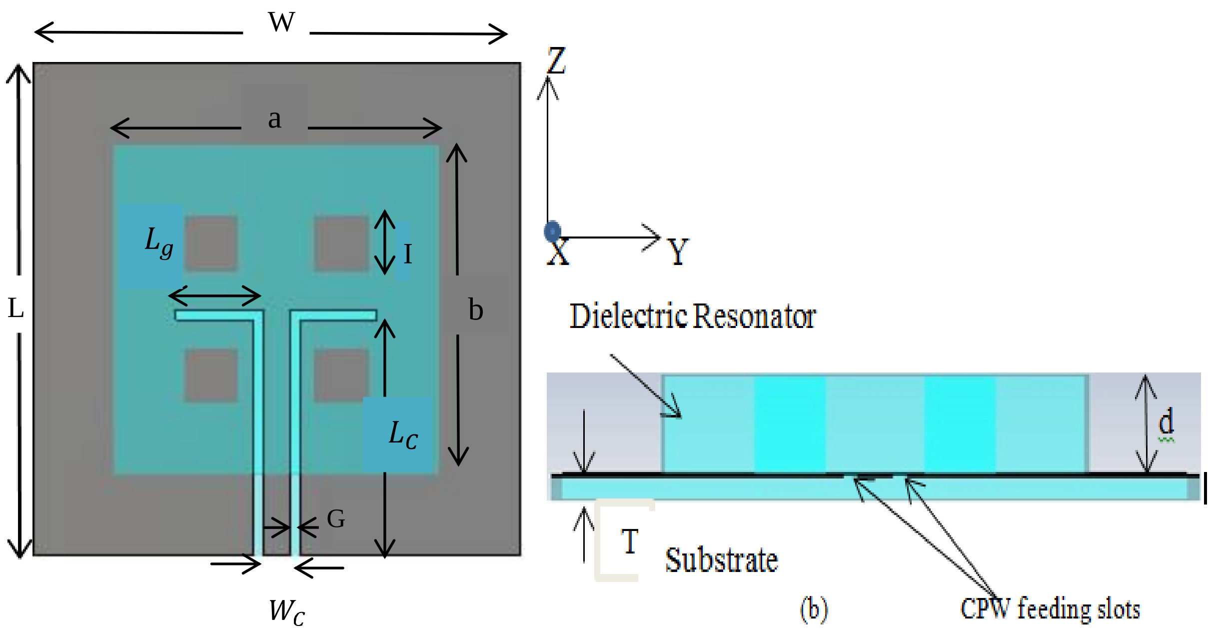
Among the different shapes DRA, the rectangular [24] shaped Dielectric Resonator offers greater design flexibility, where the slots length controls the resonant frequency. Various modes can be easily excited within the rectangular DRA, which results in either broadside or Omni-directional radiation pattern [1].

In this design, the new rectangular type DRA designed for WLAN applications by removing the four square shaped similar parts from the resonator of the DRA. As a result of which a new type of rectangular DRA is obtained. The DRA is excited by using CPW feeding. The Coplanar waveguide (CPW) inductive slot simultaneously acts as an effective radiator and the feeding structure of the DR. The major advantages of CPW feeding are, provides the lower radiation leakage and less dispersion than microstrip lines [2]. With these features, this design of rectangular DRA is suitable for wireless communication systems and especially for WLAN applications at 5.8GHz frequency.

6.2 Antenna Design

The proposed rectangular [7] DRA structure is shown in Fig. 6.1. This antenna consists of a rectangular DR and a center-fed CPW inductive slot which is etched on a Rogers Duroid 5880 substrate ($\varepsilon_r = 2.1$, T = 1.25mm), with L and Wdenote the length and the width of the substrate respectively.

DR is placed above the inductive slot with an offset L_C from the slot to the lower edge of the DR. The 50Ω CPW line is designed with the center metal strip width $Wc = 2.5mm$ and a gap width $= 1.0mm$. The resonator material used is RT/duroid 6010LM laminate has a dielectric constant of 10.2. The rectangular DR has dimensions $a, b\ , d\ and\ I$ and the dielectric constant$\varepsilon_{dr} = 10.2$ [2-7]. And the four square shaped similar wholes on the DR have the dimension I.The center-fed CPW inductive slot has two arms of equal lengthL_g. The slot resonates at approximately one guided wave length $(2L_g + W_C \approx \lambda_g)$ where $\lambda_g$is the guided wavelength of the slot is with DR placed on it. On the other hand, the optimal slot length for DR excitation is dependent on the resonance frequency of DR [5], thus the slot length should be optimized so as to achieve narrowband resonance for WLAN applications.



(a)

Figure 6.1(a) Top View and (b) Front view of the proposed antenna structure

6.3 Results and Discussion

As discussed in the previous section that a narrow band can be achieved by modifying the basic shape of the DRA. So the first design step was to modify the shape of rectangular DRA. To achieve optimal performance, a parametric study is performed to investigate the characteristics of the proposed antenna. The antenna parameters are$a = b = 30mm$,$d = 5mm$,$\varepsilon_{dr} = 10.2$,$L = W = 45mm$,$L_C = 21.5mm$,$L_g = 10.15mm$and $I = 5.0mm$. The simulated resonance frequency of DR and inductive slot is approximately 5.8GHz.For the case$L_g = 10.15mm$, a narrow bandwidth with less $\mathbf{S_{11}}$ $(-34.5dB)$ is observed. This DRA is simulated using a CST microwave studio suite$^{\text{TM}}$ 2011.

A. *Parametric Results*

The proposed DRA is analyzed using CST Microwave studio suite$^{\text{TM}}$ 2011. The simulated return loss of the rectangular DRA plotted against frequency is shown in Fig. 6.2. By varying the slot length L_g we can easily change the resonant frequencies. The proposed antenna achieves an impedance bandwidth from 5.45GHz to 6.22GHz covering 5.8GHz WLAN bands for L_g=10.15mm. Based on the information gathered from the parametric study, a prototype antenna for 5.8GHz 802.11a WLAN application is designed.

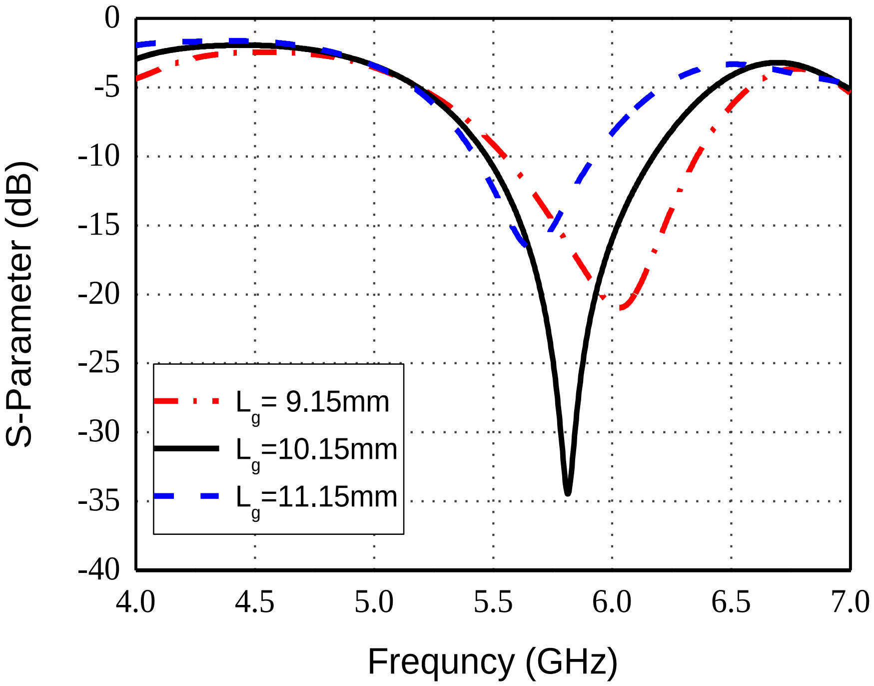


Figure 6.2 Simulated Return Loss of the Rectangular DRA versus Frequency

B. Gain and Directivity

The Peak Gain of antenna is 7.27 dBi at 5.8 GHz. It is observed from Fig. 6.3 that the simulated peak directivity is 7.82 dBi at 5.8 GHz frequency range. The Gain curve follows the Directivity curve over the entire frequency range. It is observed from 5.5 GHz to 6.2 GHz range.

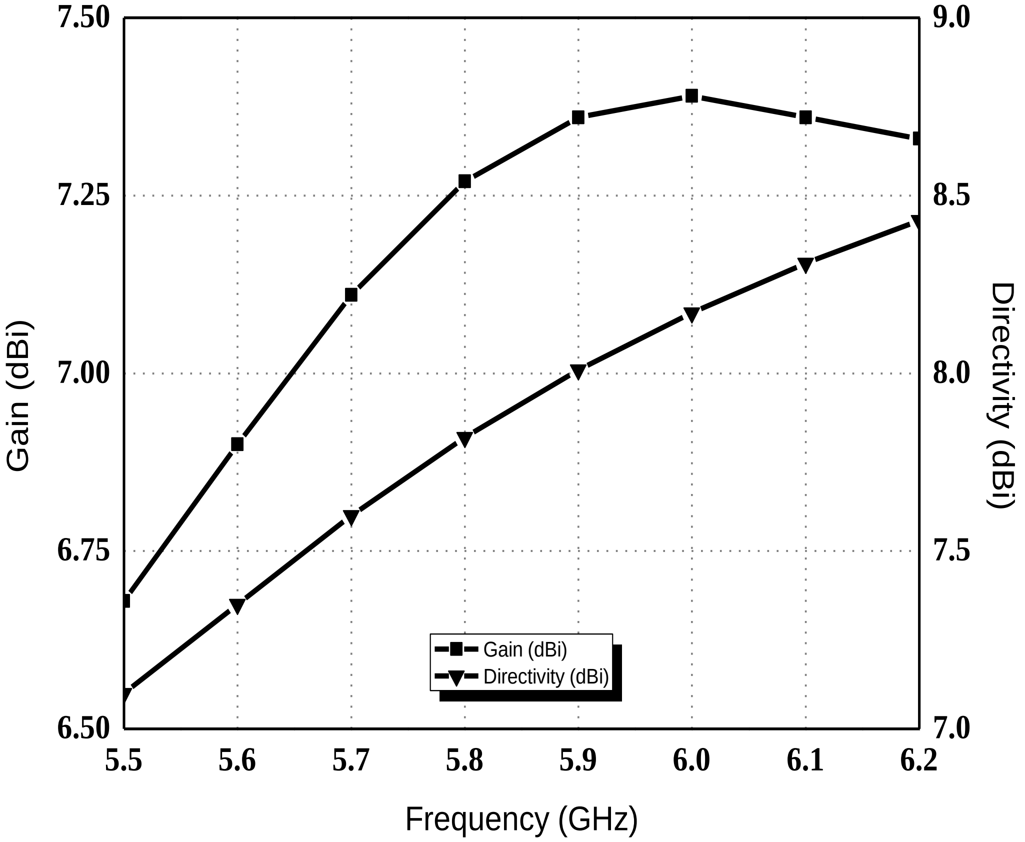
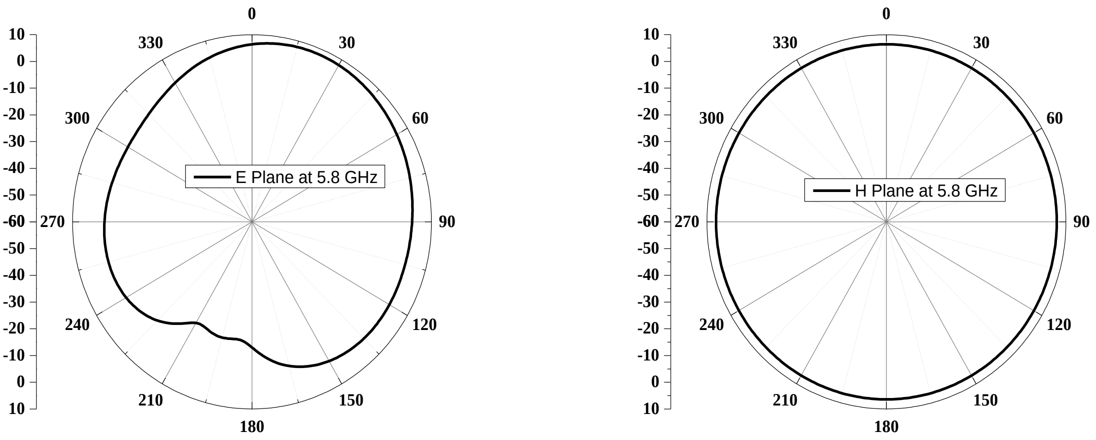


Figure 6.3 Simulated Gain and Directivity of the Rectangular DRA versus Frequency

C. Radiation Pattern Characteristics

The simulated far field radiation patterns of E-Plane and H-Plane of the proposed rectangular shaped DRA are shown in Fig. 6.4. The simulated radiation patterns at resonant frequency (5.8GHz) show that the E-Plane radiation pattern is in broadside direction against frequency and H-Plane in Omni-directional.



(a) *(b)*

Figure 6.4 Simulated radiation patterns of proposed DRA at 5.8 GHz (a) E-Plane and (b) H-Plane

However, in this configuration, DR works as a dielectric loading at the resonance frequency of the inductive slot.

6.4 Summary

A new rectangular dielectric resonator antenna is realized by drilling off the four square shaped similar portions on the DR. The resonance of a CPW inductive feeding slot is merged with that of a rectangular DR so as to achieve required band for WLAN operation. The simulated results show that the designed antenna offered desired resonant frequency at 5.8 GHz, which covers the WLAN application bands. This antenna provides maximum Gain of 7.4 dBi. The proposed very compact rectangular DRA design is overall suitable for wireless local area networks (WLAN). Fabrication of the proposed antenna will be carried out in future.

Chapter 7

Compact CPW fed Stacked DRA for WLAN Applications

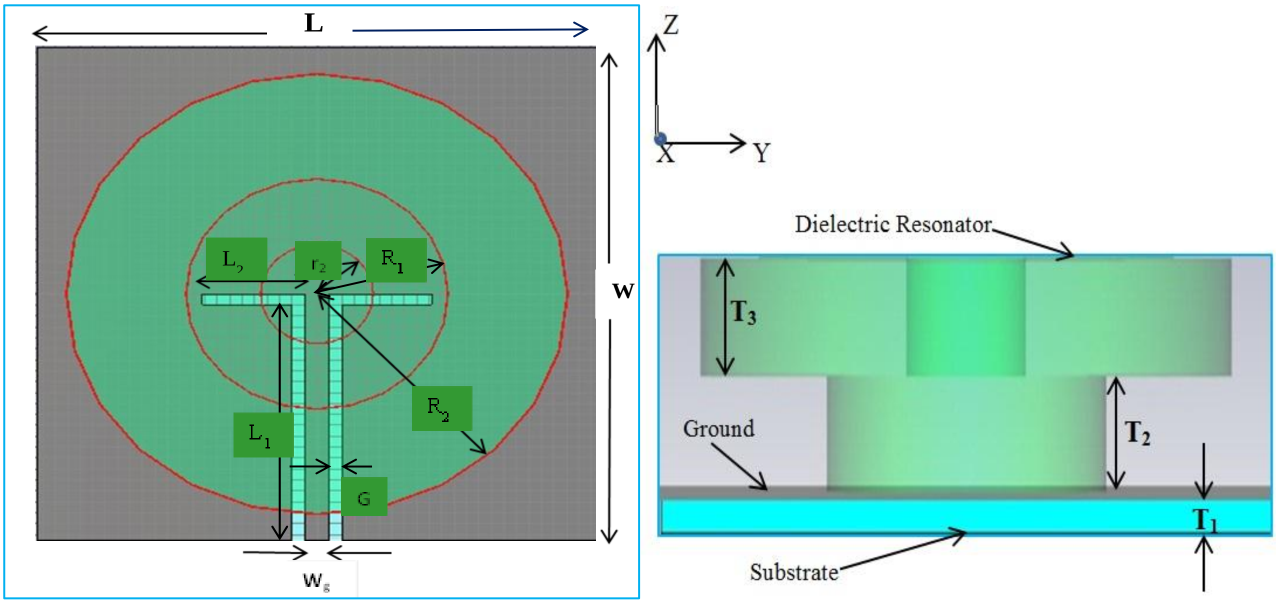
7.1 INTRODUCTION:

For a current world of wireless communications, there has required compact and wider bandwidth antenna. Dielectric Resonator Antennas (DRA)'s became very popular in the core sectors of a country like defense, military, radar and especially for millimeter wave applications. Due to this flexibility in DRAs, they can be designed with different shapes as per our requirements depending upon the applications in the wireless communications world. DRAs can also be excited with different feeding methods, such as microstrip lines, probes, slots, and co-planar lines. The DRAs are good replacement for the Microstrip antenna, because the DRA has a much wider impedance bandwidth and higher power handling capability due to their many advantageous features.

A new stacked dielectric resonator antenna (DRA) design with CPW feeding [9] is obtainable for wideband wireless local area network (WLAN) applications. The result shows that the proposed antenna achieves an impedance bandwidth above 20% from 4.96 GHz to 6.07 GHz covering complete WLAN bands and especially getting wideband with dual resonating frequencies at popular WLAN (at 5.20 GHz and 5.84 GHz) bands. For optimizing the return loss, parametric studies of the antenna are carried out by varying the length of the horizontal slot and inner radius of the upper cylindrical dielectric resonator and simulated results for WLAN application are presented here.

7.2 Antenna Design:

The proposed wideband stacked cylindrical DRA structure is shown in Figure 7.1. This antenna consists of a cylindrical DR and a center-fed CPW inductive slot which is etched on a Rogers Duroid 5880 substrate ($\varepsilon_r = 2.2$, T = 1.25mm), with L and Wdenote the length and the width of the substrate, respectively.DR is placed above the inductive slot with an offset L_1 from the slot to the lower edge of the DR. The 50Ω CPW line is designed with the center metal strip width $Wg = 4mm$ and a gap width $= 1.0mm$. The resonator material having a dielectric constant of 9.8. The cylindrical DR has dimensions R1, R_2, r2, T2 and T_3 and the dielectric constant$\varepsilon_{dr} =$ 9.8. The center-fed CPW inductive slot [6] has two arms of equal lengthL_2. The inner radius of the cylindrical dielectric resonator is should be approximately one third of the outer radius to optimize the radiation efficiency. On the other hand, the optimal slot length for DR excitation is dependent on the resonance frequency of DR [5], thus the slot length should be optimized so as to achieve wideband resonance for WLAN applications.



(a) *(b)*

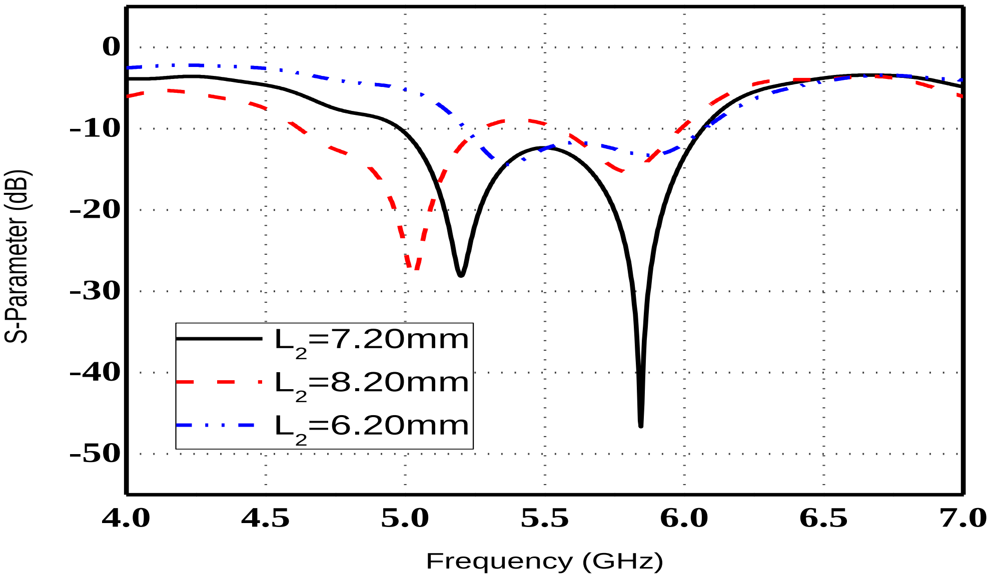
Figure 7.1 (a) Top View and (b) Front view of the proposed antenna structure

7.3 Results and Discussion

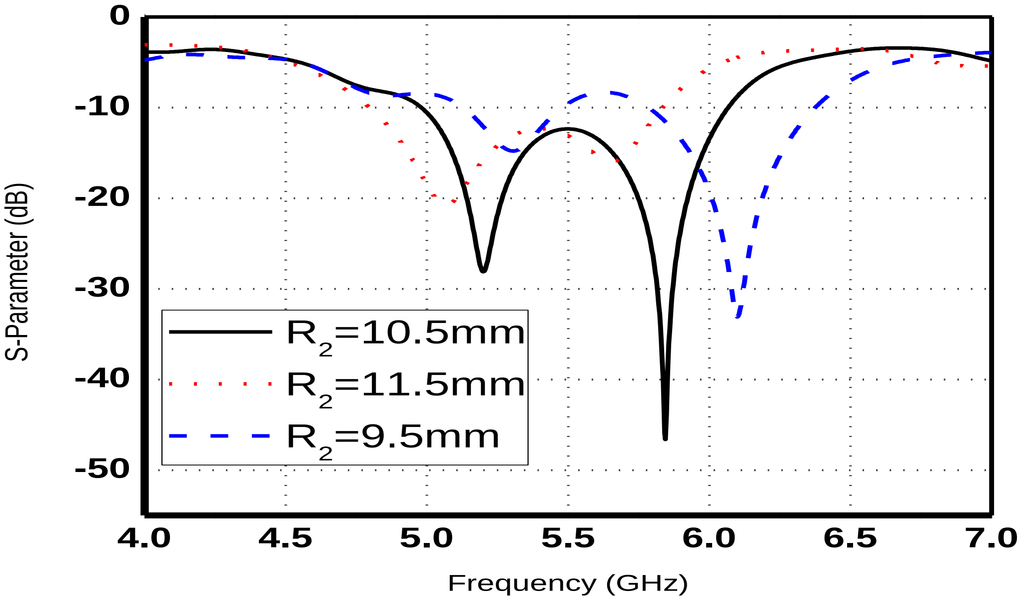
As discussed in the previous section that, a wide band can be achieved by modifying the basic shape of the DRA. So the first design step was to modify the shape of cylindrical DRA. To achieve optimal performance, a parametric study is performed to investigate the characteristics of the proposed antenna. The antenna parameters are$\varepsilon_{substrate} = 2.2 \varepsilon_{dr} = 9.8, L = W = 45mm, T_1 = 1.60mm, \ R_1 = 10.5mm \ , R_2 = 20mm, \ r_2 = 5mm, \ T_2 = T_3 = 5mm \ , \ L_1 = 22.5mm, \ L_2 = 7.20mm, G = 1mm, and\ W_g = 4mm$. The simulated dual band resonance frequencies of DR and inductive slot are at 5.20GHz and 5.84GHz.For the case$\mathrm{L}_2 = 7.20\mathrm{mm}$, a wide bandwidth with less **S_{11}** $(\text{at } 5.20\text{GHz}, \mathrm{S}_{11} = -28.2 \text{ and at } 5.84\text{GHz}, \mathrm{S}_{11} = -46.628\text{dB})$ is observed. This DRA is simulated using a CST microwave studio suite^{TM} 2011.

A. *Parametric Results*

The proposed DRA is analyzed using CST Microwave studio suite™ 2011. The simulated return loss of the cylindrical DRA plotted against frequency is shown in Fig. 7.2. By varying the slot length L_2 and outer radius R_2 of the upper cylinder we can easily change the resonant frequencies. The proposed antenna achieves an impedance bandwidth from 4.98 GHz to 6.02 GHz covering entire WLAN bands for L_2=7.20mm. Based on the information gathered from the parametric study, a prototype antenna WLAN application is designed.



(a)



(b)

Figure 7.2 Simulated Return Loss of the Cylindrical DRA versus Frequency

B. Gain and Directivity

The Peak Gain of antenna is 7.056 dBi at 5.20 GHz. It is observed that the simulated peak directivity is 7.369 dBi at 5.5 GHz. It is also observed that from the simulated results over 5.0 GHz to 6.0GHz frequency range, the Gain and Directivity values are almost same.

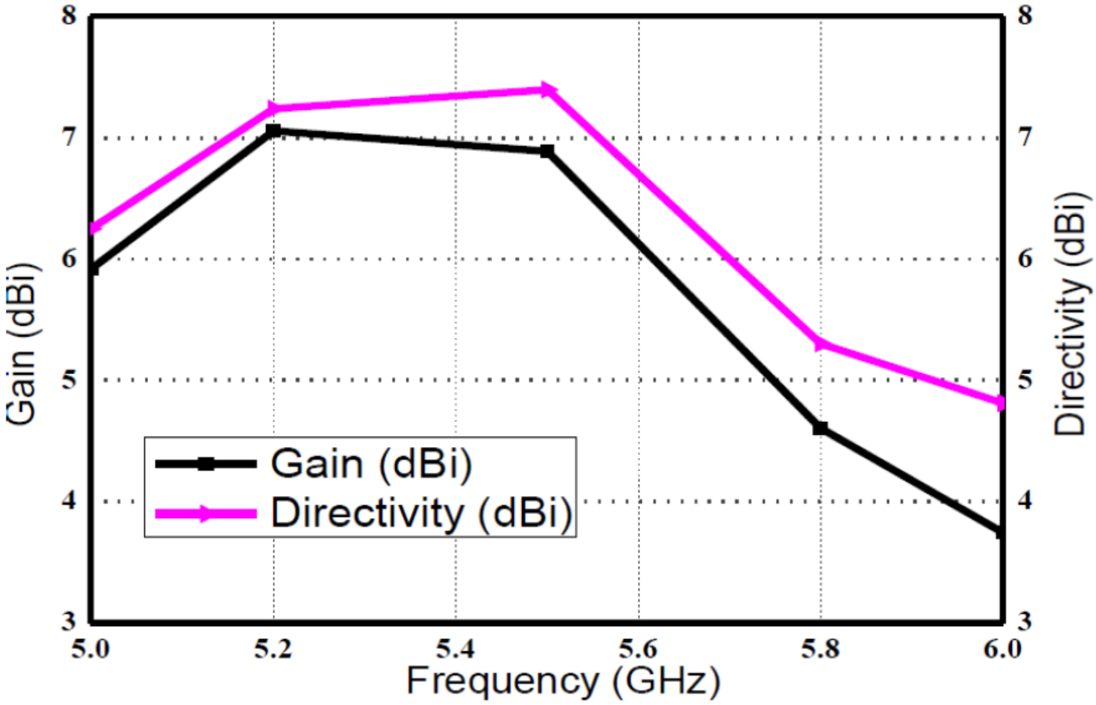
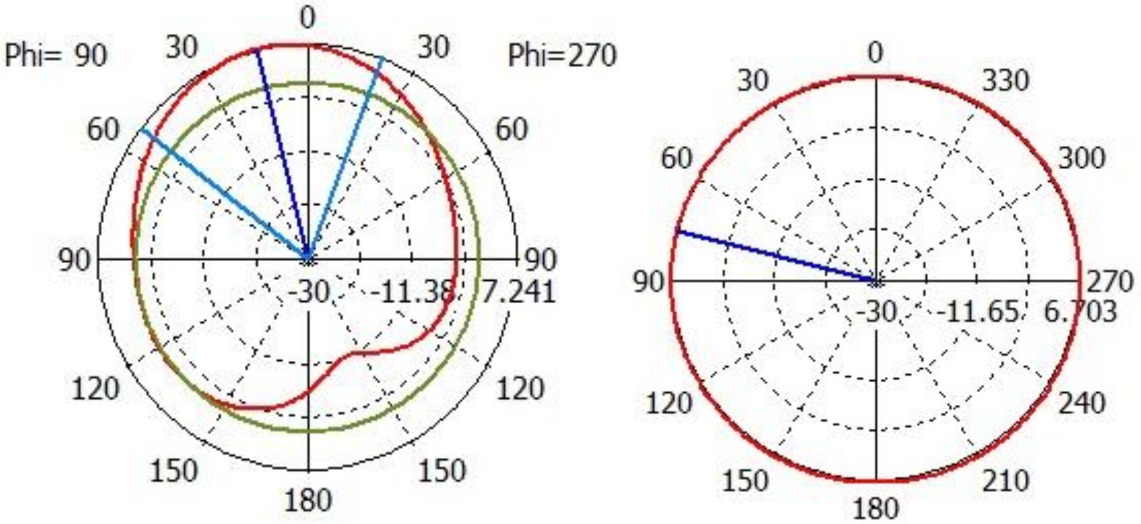


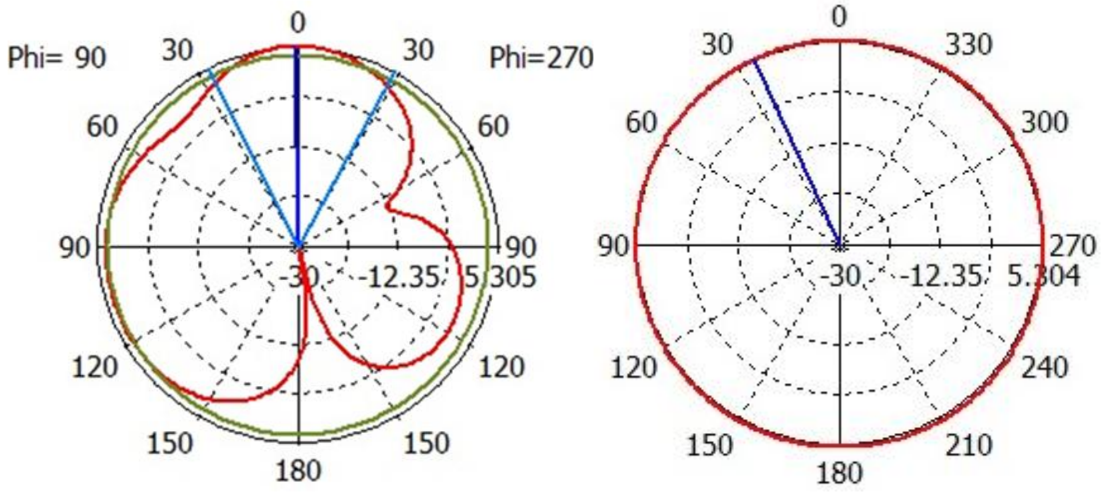
Figure 7.3 Simulated Gain and Directivity of the Cylindrical DRA versus Frequency

C. Radiation Pattern Characteristics

The simulated far field radiation patterns of E-Plane and H-Plane of the proposed cylindrical shaped DRA are shown in Fig. 7.4. The fallowing radiation patterns are simulated at resonant frequencies (5.20GHz and 5.84GHz) shows that the E-Plane radiation pattern is a partial Omni-directional pattern against frequency and H-Plane in Omni-directional.



(a) E & H- Planes at 5.2 GHz



(b) E & H- Planes at 5.8 GHz

Figure 7.4 Simulated radiation patterns of proposed Cylindrical DRA at resonant frequencies (5.2 GHz &5.8 GHz)

7.4 Summary

A new stacked dielectric resonator antenna (DRA) design with CPW feeding [9] is presented for wideband wireless local area network (WLAN) applications. The resonance of a CPW inductive feeding slot is merged with that of a cylindrical DR so as to achieve required band for WLAN operation. The result shows that the proposed antenna achieves an impedance bandwidth above 20% from 4.96 GHz to 6.07 GHz covering complete WLAN bands and especially getting wideband with dual resonating frequencies at popular WLAN (at 5.20 GHz and 5.84 GHz) bands. This antenna provides maximum Gain of 7.056 dBi. The proposed very compact cylindrical DRA design is overall suitable for wireless local area networks (WLAN). Fabrication of the proposed antenna will be carried out in future.

Chapter 8

Compact CPW fed DRA for Wi-MAX and WLAN Applications

8.1. INTRODUCTION:

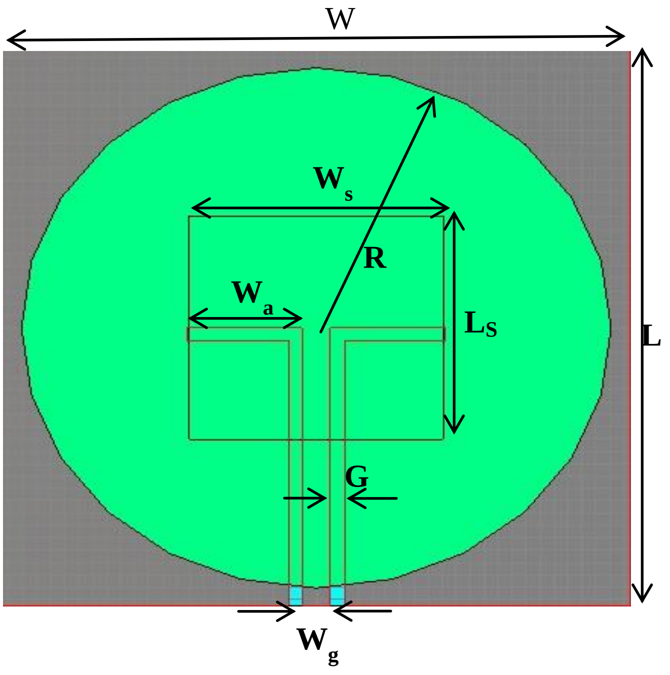
Dielectric Resonator Antennas (DRA)'s becoming promising radiators in the core sectors of a country like defense, military, radar at microwave frequencies in wireless applications. Due to flexibility in DRAs, they can be designed with different shapes as per our requirements depending upon the applications in the wireless communications world. Among the different shapes DRA, cylindrical, rectangular shaped provides various resonant frequencies apart from their degree freedoms individually and as well as both together. In this paper we designed new DRA that is the combination of the cylindrical and rectangular shaped DRA's as one DRA offers greater design flexibility, where the slots length controls the resonant frequency. Various modes can be easily excited within the cylindrical DRA, which results Omni-directional radiation pattern [4].

In this section, the new type of DRA designed for wideband Wi-MAX and WLAN applications by removing a square shaped part from the upper rectangular resonator of the DRA. In first figure the antenna designed without removing the square shaped part from the upper rectangular DR. This antenna resonating at 3.5 GHz (Wi-MAX) only and we also observed that a small radiation at 5.15 GHz. To improve radiation at this WLAN band, we drilled the square shaped part in order to improve the radiation efficiency by increasing the radiating surface of the stacked DRA [3]. As a result of which a new type of Stacked DRA is obtained. The Stacked DRA is excited by using CPW feeding. The coplanar waveguide (CPW) inductive slot simultaneously acts as an effective radiator and the feeding structure of the DR. The major advantages of CPW feeding are, provides the lower radiation leakage and less dispersion than microstrip lines. With these features, this design of stacked DRA is suitable for wireless communication systems and especially for WIMAX and WLAN applications.

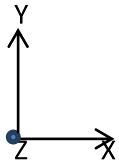
8.2 Antenna Design

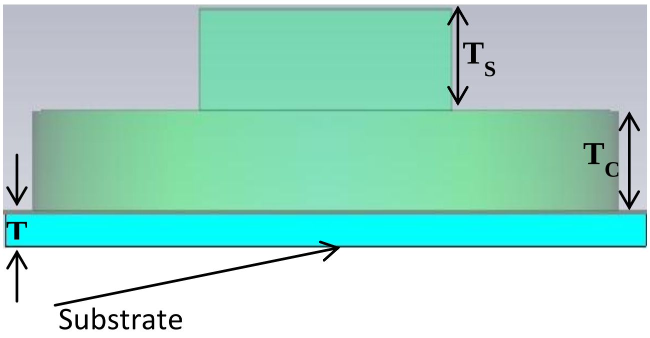
The proposed dual band stacked DRA [12], [14] structure is designed in two steps. In first step the antenna designed without drilling the square shaped part but it achieving only single band as shown in fig. 8.1. And in second step the antenna designed with drilling a square shaped part from the rectangular DR in order to achieve the dual band resonant frequencies as shown in fig. 8.1.

In first step the antenna consists of a cylindrical DR on the substrate and a rectangular DR placed on it and a center-fed CPW inductive slot which is etched on a Rogers duroid 5880 substrate ($\varepsilon_r = 2.2$, T = 1.6mm), with L and Wdenote the length and the width of the substrate, respectively. A Cylindrical DR is placed above the inductive slot with an outer radius$R$and having the dielectricconstants$\varepsilon_{cylindrical} = 9.8$. A rectangular DR is placed above the Cylindrical DR and having the dimensions as L_s and W_s with the dielectric constant same as the Cylindrical DR. The 50Ω CPW line is designed with the center metal strip width $Wg = 2mm$, gap width $= 1.0mm$, and other dimensions of CPW feeding are lengths of vertical and horizontal arms are L_a and W_a respectively. The center metal strip thickness taken as 0.05 mm. The dual band resonant frequencies are achieved by modifying the antenna as shown in fig.8.1. The antenna shown in fig 8.1 having the dielectric constant of the substrate as$\varepsilon_r = 4.4$. Thus the resonator material having a dielectric constant of 9.8. To optimize the radiation efficiency the slot length should be optimized so as to achieve wide dual band resonance for WiMAX and WLAN applications. Because the optimal slot length for DR excitation is dependent on the resonance frequency of DR.

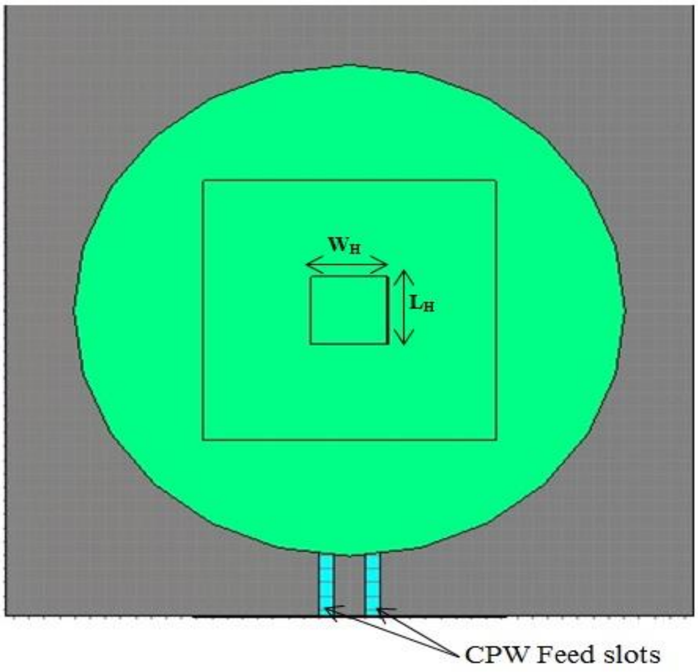


(a)





(b)



(c)

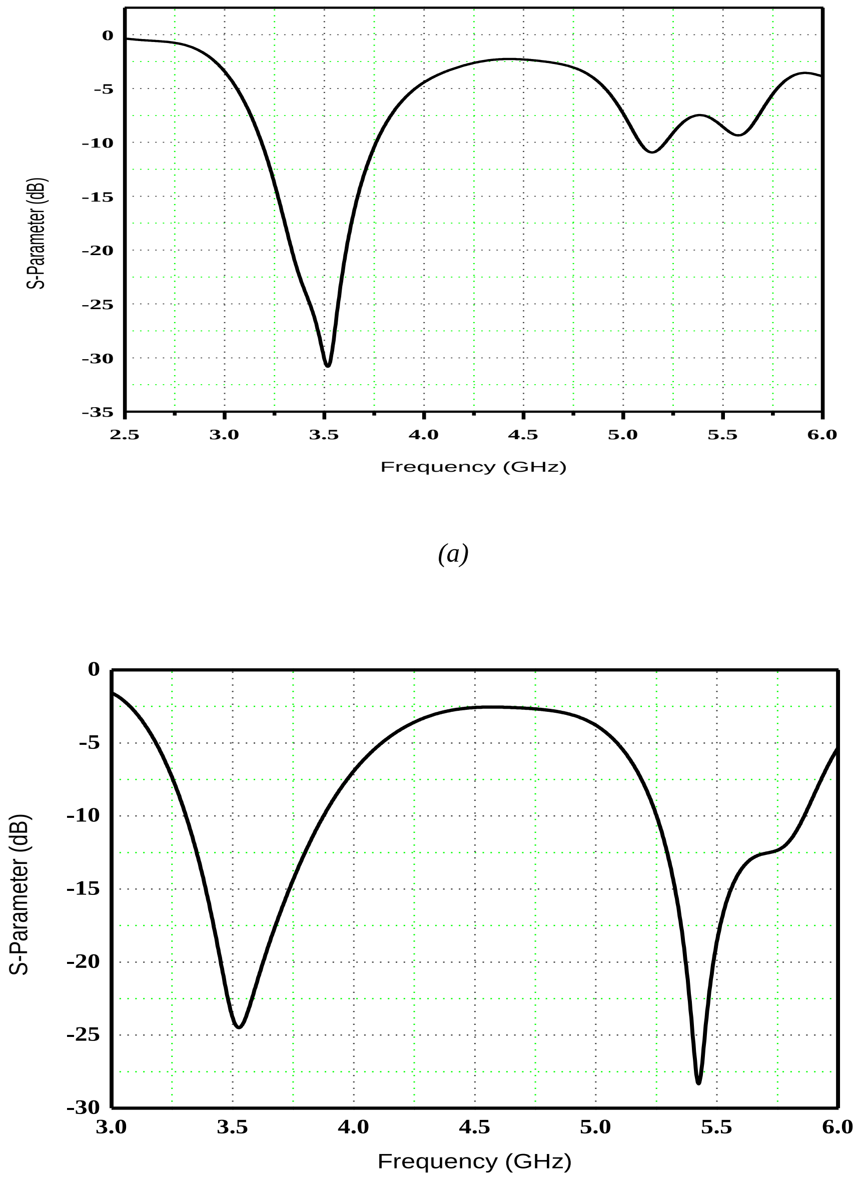
Figure 8.1 ***(a)****Top View and****(b)****Front view****(c)*** *Top view with drilled square shape of the proposed antenna structure*

8.3 Results and Discussion

As discussed in the previous section that a wide dual band can be achieved by modifying the basic shape of the DRA. So the second design step was to modify the rectangular DR. To achieve optimal performance, a parametric study is performed to investigate the characteristics of the proposed antenna. The dimensions of the proposed antenna are shown in the following Table.8.1. The simulated dual band resonancefrequencies of DR and inductive slot areat 3.5 GHz and 5.4 GHz.For the case$Wa = 7mm$,a wide bandwidth with less $\mathbf{S_{11}}$ (at 3.5 GHz, $\mathbf{S_{11}}$ = -24.36 dB and at 5.42 GHz, $\mathbf{S_{11}}$ =-28.30 dB) is observed. This DRA is simulated using a CST microwave studio suite^{TM} 2011.

A. *Parametric Results*

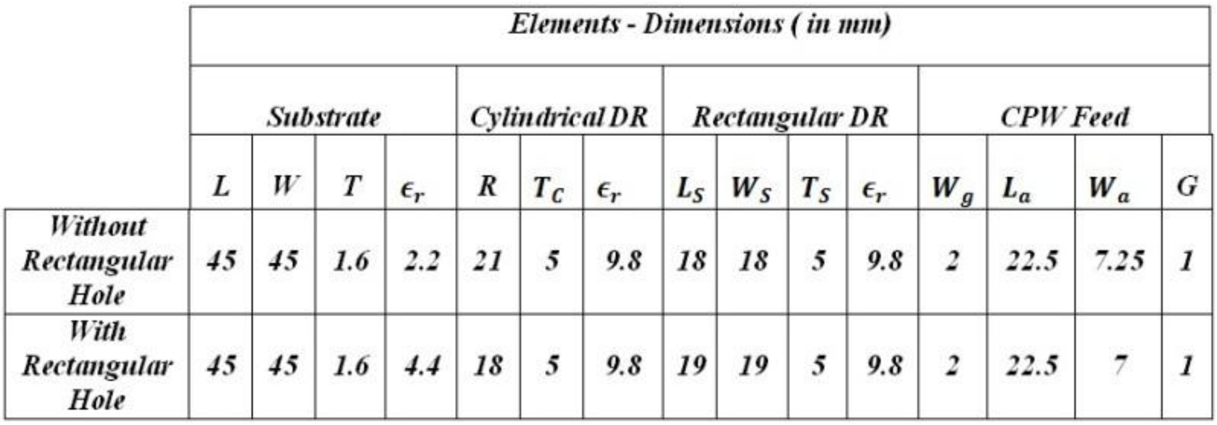
The proposed DRA is analysed using CST Microwave studio suite^{TM}2011. The simulated return loss of the stacked DRA plotted against frequency is shown in Fig.8.2. By varying the outer radius $R$of the cylinder and shape of the rectangular DR by drilling the square shape we can easily change the resonant frequencies and radiation efficiency. The proposed antenna achieves considerable impedance bandwidth for WiMAX (from 3.2 GHz to 3.8GHz) and for WLAN (from 5.25 GHz to 5.85 GHz) bands for$W_a = 7.0mm$,$L_a = W_s = 19.0mm R = 18mmand\varepsilon_r = 4.4$. Based on the information gathered from the parametric study, a prototype antenna for WiMAX and WLAN applications is designed.



(a)

(b)

*Figure 8.**2** Simulated Return Loss of the Cylindrical DRA versus Frequency*



	Elements - Dimensions (in mm)														
	Substrate				Cylindrical DR			Rectangular DR				CPW Feed			
	L	W	T	ϵ_r	R	T_C	ϵ_r	L_S	W_S	T_S	ϵ_r	W_g	L_a	W_a	G
Without Rectangular Hole	45	45	1.6	2.2	21	5	9.8	18	18	5	9.8	2	22.5	7.25	1
With Rectangular Hole	45	45	1.6	4.4	18	5	9.8	19	19	5	9.8	2	22.5	7	1

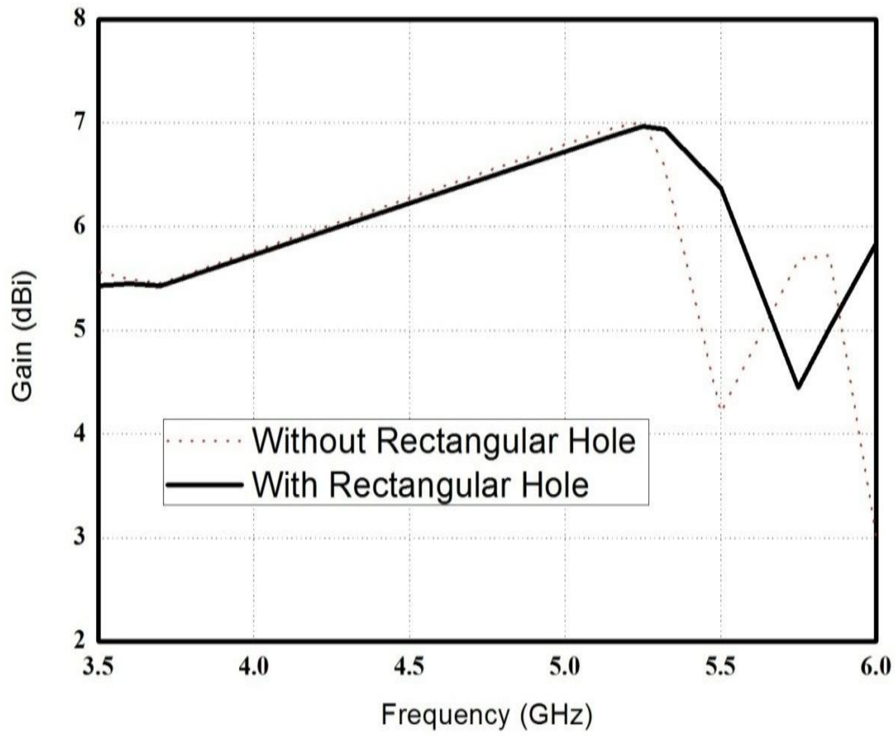
Table.8.1

B. Gain and Directivity

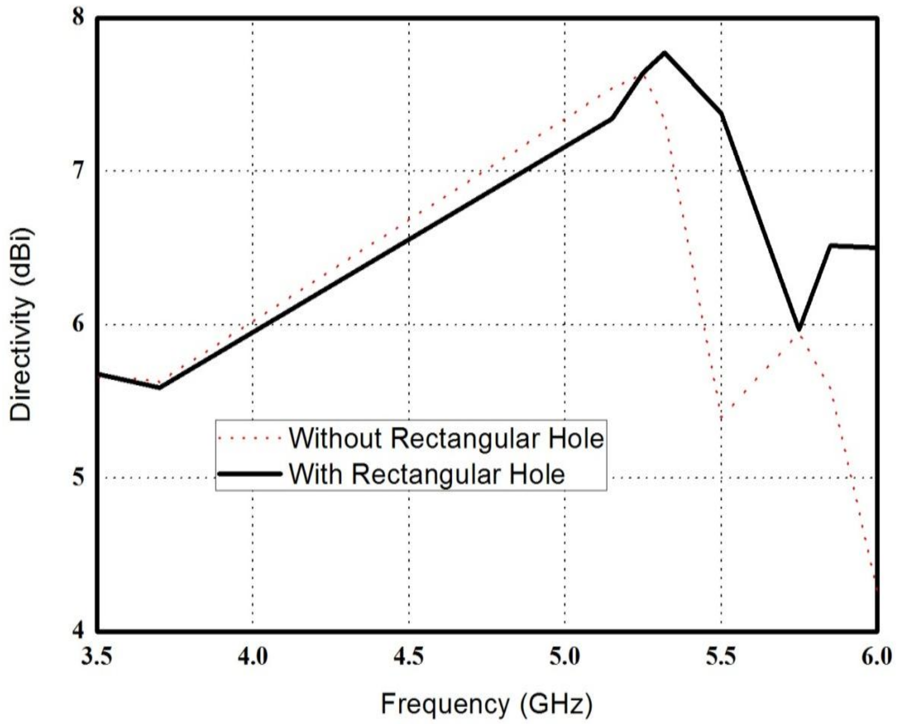
The Peak Gain of antenna with rectangular hole is 6.968 dBi at 5.25 GHz. It is observed from Table. 8.2 That the simulated peak directivity is 7.773 dBi at 5.32 GHz and frequency range. The Gain and Directivity are observed from the fallowing figure 8.3 in the operating frequency range from 3.2 GHz to 3.8 GHz and 5.25 GHz to 5.85 GHz.

Frequency (GHz)	**Without Rectangular Hole**		**With Rectangular Hole**	
	Gain (dBi)	**Directivity (dBi)**	**Gain (dBi)**	**Directivity (dBi)**
3.20	**5.185**	**5.513**	**5.308**	**5.440**
3.40	**5.549**	**5.64**	**5.351**	**5.683**
3.50	**5.565**	**5.661**	**5.428**	**5.680**
3.60	**5.492**	**5.654**	**5.448**	**5.634**
3.70	**5.455**	**5.628**	**5.430**	**5.592**
5.15	**6.946**	**7.541**	**6.872**	**7.345**
5.25	**7.013**	**7.638**	**6.968**	**7.645**
5.32	**6.582**	**7.331**	**6.938**	**7.773**
5.50	**4.207**	**5.398**	**6.373**	**7.374**
5.75	**5.687**	**5.945**	**4.449**	**5.967**
5.85	**5.723**	**5.586**	**5.021**	**6.518**
6.00	**3.021**	**4.274**	**5.841**	**6.501**

Table.8.2



(a) Simulated Gain of proposed DRA

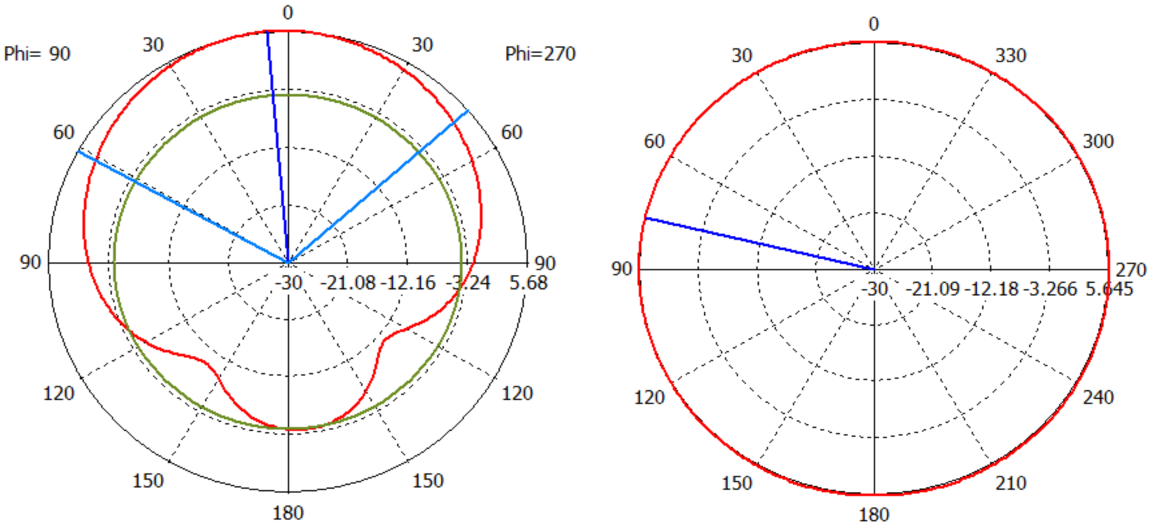


(b) Simulated Directivity of Proposed DRA

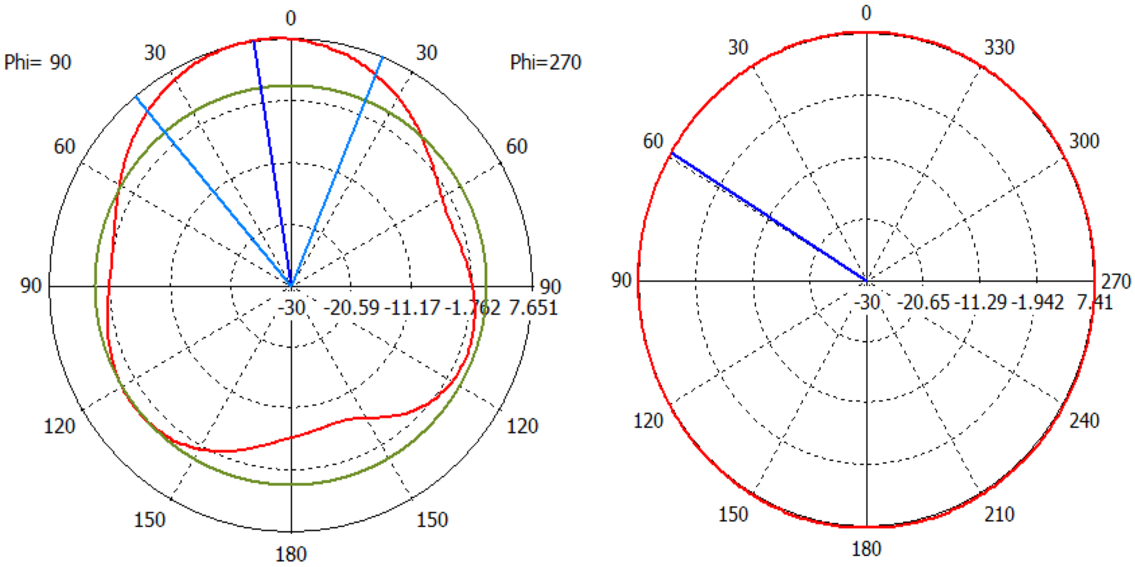
Figure 8.3 Simulated Gain & Directivity of proposed Stacked DRA at required resonant frequencies

C. *Radiation Pattern Characteristics*

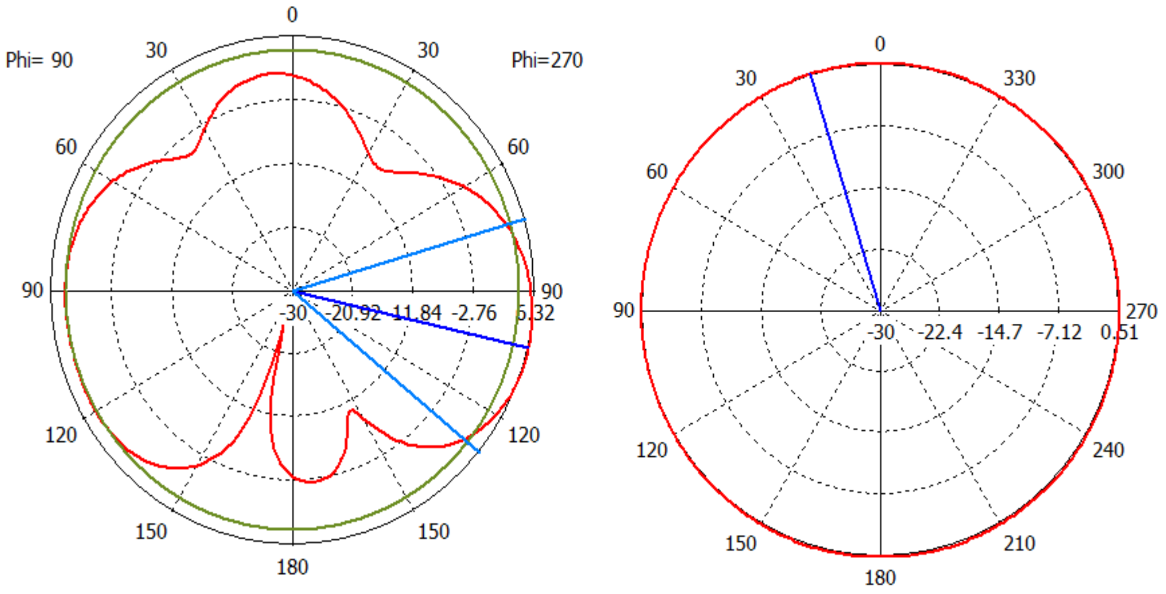
The simulated far field radiation patterns of E-Plane and H-Plane of the proposed stacked DRA are shown in Fig. 8.4. The simulated radiation patterns at required resonant frequencies (3.5GHz, 5.25GHz and 5.8GHz) show that the E-Plane radiation pattern is in broadside direction against frequency and H-Plane in Omni-directional.



(a) E & H-Fields at 3.5 GHz



(b) E & H-Fields at 5.25 GHz



(c) E & H-Fields at 5.8 GHz

Figure 8.4 Simulated radiation patterns of proposed Stacked DRA at required resonant frequencies (3.5 GHz, 5.25GHz &5.8 GHz)

8.4 Summary

A new stacked dielectric resonator antenna is realized by drilling off the square shaped portion from the rectangular Dielectric Resonator. The resonance of a CPW inductive feeding slot is merged with that of a stacked DR so as to achieve required band for WiMAX and WLAN operation. The simulated results show that the designed antenna offered desired resonant frequencies at 3.5GHz and 5.5GHz, which covers the WiMAX and WLAN application bands. This antenna provides maximum Gain of 6.968 dBi. The proposed very compact cylindrical DRA design is overall suitable for WiMAX and wireless local area networks (WLAN).Fabrication of the proposed antenna will be carried out in future.

Chapter 9

Conclusions and Future work

9.1 Conclusions

Different shapes of Dielectric resonator antennas have been studied in this thesis. In the first part of the thesis an introduction of DRA about its characteristics, advantages, applications and several bandwidth enhancement techniques have been studied. Optimizations on the antenna parameters are also explained. The fallowing conclusions made as designed structures of DRAs, the same as fallows.

A new cylindrical dielectric resonator antenna is realized by using Teflon and FR4 materials. The resonance of a CPW inductive feeding slot is merged with that of a Cylindrical DR so as to achieve required band for Wi-Fi operation. The simulated results show that the designed antenna offered desired resonant frequency at 2.4GHz, which covers the Wi-Fi application bands. This antenna provides maximum Gain of 9.968dBi. The proposed very compact Cylindrical DRA design is overall suitable for wireless local area networks (WLAN).

Different shapes of DRAs like half cylindrical DRA, rectangular shaped DRA, and stacked DRA etc. designed for different wireless applications with unique CPW feeding. TheCompact CPW Fed Dielectric Resonator Antenna having Peak Gain is 7.27 dBi at 5.8 GHz. The Gain curve follows the Directivity curve over the entire frequency range. It is observed from 5.5 GHz to 6.2 GHz range. Fabrication of the proposed antenna will be carried out in future.

A new stacked dielectric resonator antenna (DRA) design with CPW feeding [9] is presented for wideband wireless local area network (WLAN) applications. The resonance of a CPW inductive feeding slot is merged with that of a cylindrical DR so as to achieve required band for WLAN operation. The result shows that the proposed antenna achieves an impedance bandwidth above 20% from 4.96 GHz to 6.07 GHz covering complete WLAN bands and especially getting wideband with dual resonating frequencies at popular WLAN (at 5.20 GHz and 5.84 GHz) bands. This antenna provides maximum Gain of 7.056 dBi. The proposed very compact cylindrical DRA design is overall suitable for wireless local area networks (WLAN). Fabrication of the proposed antenna will be carried out in future.

A new stacked dielectric resonator antenna is realized by drilling off the square shaped portion from the rectangular Dielectric Resonator. The resonance of a CPW inductive feeding slot is merged with that of a stacked DR so as to achieve required band for Wi-MAX and WLAN operation. The simulated results show that the designed antenna offered desired resonant frequencies at 3.5GHz and 5.5GHz, which covers the Wi-MAX and WLAN application bands. This antenna provides maximum Gain of 6.968 dBi. The proposed very compact cylindrical DRA design is overall suitable for Wi-MAX and wireless local area networks (WLAN).Fabrication of the proposed antenna will be carried out in future.

9.2 Future work

Based on observations, the following topics were identified which would helpful for further investigation.

1) As operating frequencies continue to rise, DRAs becomes much more useful.
2) Need to develop integration techniques for fabrications.
3) DRA gain and directivities will be increased by using DRA Arrays.
4) Fabrications will be carried out of the remaining DRA designs.
5) Fabrication and measurements of stacked DRAs and other designed DRAs will be carried out in future.
6) 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 using DRA array, embedded technique will be carried out in future.
7) Designing the DRAs by utilizing stack shaped DRAs for getting multiple resonant frequencies for different wireless applications.
8) Especially for getting wide bandwidths and UWB bands, designing of DRAs introducing with air gap between ground and dielectric resonator will be carried out in future.
9) Someday DRAs may be as common as Microstrip antennas.

PUBLICATIONS

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