

**BROADBAND DUAL-SEGMENT RECTANGULAR DIELECTRIC
RESONATOR ANTENNA FOR 5.8 GHz APPLICATIONS**

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**BROADBAND DUAL-SEGMENT RECTANGULAR DIELECTRIC
RESONATOR ANTENNA FOR 5.8 GHz APPLICATIONS**

By

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List of Abbreviations

DR	Dielectric Resonator
DRA	Dielectric Resonator Antenna
MPA	Microstrip Patch Antenna
CST	Computer Simulation Technology
PCB	Printed Circuit Board
BZT	Barium Zinc Tantalum
CCTO	Calcium Carbonate Titanate
DSRDRA	Dual-segment Rectangular Dielectric Resonator Antenna
DSDRA	Dual-Segment Dielectric Resonator Antenna
TE	Transverse Electric
TM	Transverse Magnetic
GHz	Giga Hertz
BW	Bandwidth
XRD	X-ray Diffraction
FESEM	Field Emission Scanning Electron Microscopy
ATM	Antena Tampilan Mikrostrip
APD	Antena Penyalun Dielektrik
TKS	Teknologi Komputer Simulasi

ANTENA JALUR LEBAR PENYALUN DIELEKTRIK SEGIEMPAT SEGMENT-DUAAN UNTUK APLIKASI 5.8 GHz

Abstrak

Antena Penyalun Dielektrik (APD) jalur lebar adalah satu antenna yang boleh memancar dan menerima signal elektromagnetik dalam julat frekuensi yang lebar untuk telekomunikasi berkapasiti tinggi. Bahan-bahan dielektrik dengan ketelusan dan faktor kualiti yang rendah boleh menyimpan kurang tenaga elektromagnetik dan seterusnya mengalami gandingan lemah daripada sumber teruja. Sebaliknya bahan-bahan dengan ketelusan tinggi mempunyai faktor kualiti dan medan elektrik dan magnetik tinggi boleh terhasil dalam penyalun, seterusnya boleh beroperasi dalam lebar jalur sempit dengan gandingan yang kuat. Untuk APD yang mempunyai gandingan elektromagnetik kuat dimana boleh beroperasi dalam julat frekuensi yang lebar, dua bahan ketelusan yang berbeza digunakan untuk merekabentuk antenna. Bahan dielektrik berbentuk segiempat tepat digunakan untuk kedua-dua segmen APD kerana mod kemerosotan boleh dikawal dengan memilih nisbah aspek yang sesuai dalam penyalun. Untuk segmen atas penyalun lapis dielektrik gelombang mikro Roger RT 6010 dari Roger Cooperation digunakan sebagai penyalun utama. Untuk segmen bawah yang bertindak sebagai pengubah galangan, diantara segmen atas dan talian suapan, dua bahan dielektrik yang berbeza iaitu Barium Zinc Tantalum (BZT) dan Calcium Copper Titanate (CCTO) dibina. Untuk antenna unsur tunggal dan antenna dua unsur teratur BZT digunakan sebagai pengubah manakala untuk empat unsur dan lapan unsur antenna teratur CCTO digunakan bagi mengawal gandingan sepunya diantara penyalun terdekat. Pada mulanya, frekuensi

antena yang direka diramalkan dengan menggunakan model pandu gelombang dielektrik yang diubahsuai dan simulasi dijalankan menggunakan perisian Computer Simulation Technology (CST). Untuk mengesahkan rekabentuk prototaip kehilangan balik antenna (S_{11}) dan corak sinaran dalam kedua-dua satah-E dan satah-H diukur dan dibandingkan dengan Antena Tampalan Mikrostrip (ATM). Bagi antenna unsur tunggal sebanyak 50% kehilangan balik galangan lebar jalur 10dB diperolehi. Untuk antenna dua unsur teratur sebanyak 24% lebar jalur dicapai manakala antenna empat unsur menghasilkan lebar jalur galangan sebanyak 19%. Bagi antenna lapan unsur lebar jalur galangan sebanyak 17% dicapai dengan 13.8dBi direktiviti dan juga hampir 13dB gandaan dicapai untuk antenna lapan unsur.

BROADBAND DUAL-SEGMENT RECTANGULAR DIELECTRIC RESONATOR ANTENNA FOR 5.8 GHz APPLICATIONS

Abstract

A broadband Dielectric Resonator Antenna (DRA) is an antenna that can transmit and receive electromagnetic signals over a wide range of frequencies in high-capacity telecommunications. Dielectric materials with low permittivity and low quality factor can store relatively less electromagnetic energy and hence suffers from weak coupling to the excitation source. On the other hand high permittivity materials have high quality factor and strong electric and magnetic fields can be formed inside resonator, hence can operate in a narrower bandwidth with strong coupling. In order to have a strong electromagnetically coupled dielectric resonator antenna which can be operated in wider range of frequencies, two different permittivity materials are used to design the antenna. Rectangular shape dielectric material is used as a resonator for both segments of DRA because mode degeneracy can be controlled by choosing appropriate aspect ratios of the resonators. For top segment of the resonator a dielectric microwave laminate Rogers RT 6010 from Rogers Corporation is used as principle resonator. For bottom segment, which acts as an impedance transformer, between top segment and feed line, two different dielectric materials i.e. Barium Zinc Tantalum (BZT) and Calcium Copper Titanate (CCTO) were fabricated. For single element antenna and two element array antenna BZT is used as transformer while for four element and eight elements array CCTO were used to have control over mutual coupling between immediate resonators.

Initially frequency of the designed antenna is predicted using modified dielectric waveguide model (MDWM) and simulation is performed using Computer Simulation Technology (CST). To validate the prototype design of the antenna return loss (S_{11}) and radiation pattern in both E-plane and H-plane are measured and compared with Microstrip Patch Antenna (MPA). Single element antenna has shown 10dB returns loss impedance bandwidth of 50 %. For two element array antenna 24 % bandwidth is achieved while four elements array antenna yielded 19 % impedance bandwidth. For eight elements array antenna 17% impedance bandwidth is achieved with 13.8 dBi directivity and also approximately 13 dB gain is achieved for the eight elements array antenna.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Research in the field of electricity and magnetism started long ago. Experiments with reference to these two phenomena have been conducted hundreds of years BC. It was not until 1831; Faraday observed that a varying electrical current flowing in a coil induced an electrical current into another coil in the proximity. This was a vital discovery of electromagnetic induction. In the same year when Michal Faraday discovered electromagnetic induction James Clark Maxwell was born in Scotland who later found the union of electricity and magnetism, he is best known for what are currently known as Maxwell equations (1873). Maxwell envisaged the existence of electromagnetic waves decades before he was proven right by the generation and reception of radio waves. On the basis of Maxwell's theory Heinrich Rudolf Hertz in 1889 graphically represented the electric field lines, detaching themselves from the antenna. After few years of Hertz discovery on December 12, 1901, Guglielmo Marconi effectively transmitted radio signals. This occurrence was the most momentous achievement in the early radio communication. In more than hundred years between then and today wireless communication has grown at stunningly fast rate. Until the mid-seventies the research in wireless communication was only restricted to the military purposes, but in last few decades commercial wireless market drives the innovation in the field of wireless communication. Expansion in the fields of information theory,

electronics, signal processing and antenna theory have all added to the modern world wireless communication.

However, despite the remarkable progress in today's globalized world the massive success lead to the demand of bandwidth and for that reason the operating frequencies drove up to millimeter (mm) wave band. Many of the Radio Frequency (RF) electronic systems are designed for mm wave frequency range and they offer high efficiency, compactness and wide band operation. An antenna plays crucial part in wireless communication links because of the fact that antenna is the only interfacing device between guiding system and the free space adjacent to it (Balanis, 2007). The basic purpose of the antenna system is communication yet it can be used for detection of signals (Skolnik, 2001). Data transmission and reception cannot be accomplished without antenna so this directly involves antenna to achieve the desired overall performance of the RF equipment's.

Recent progress in the wireless communication has consequently developed antennas that can be embedded in to wireless equipment's. Since few decades the focus is on the two vital classes of antenna i.e. the Microstrip Patch Antenna (MPA) and Dielectric Resonator Antenna (DRA) for modern wireless communication. MPA has drawn attention of the researchers in the past decades as it has the advantages of low profile, ease in fabrication, light weight, low fabrication cost, support for both linear and circular polarization, ease of integration with microwave integration circuit and easy to excite (water house, 2003). It is a viable contender in several microwave application, both as single element and in array environment. However in the millimeter wave applications metallic losses and dielectric losses are associated with the patch antenna when it is printed on the dielectric substrates. MPA's are also accompanied by low

impedance bandwidth, surface wave excitation and size of microstrip patch antenna in some applications where the size is too large to be used.

On the contrary the DRA is an excellent radiator as it don't have or very negligible metallic losses, other advantages of the DRA includes its small size, broadband compare to MPA's reasonably low cost easy to excite with the existing feeding techniques such as microstrip feed line, aperture feed, probe feed etc. Different shapes such as cylindrical, rectangular, and hemispherical of Dielectric material with different dielectric permittivity and size can be used for different applications at millimeter (mm) wave frequencies (Petosa, 2007).

1.2 Problem statement

In communication broadband is an expression used to illustrate a wide range of frequencies in the spectrum. The wider the operating bandwidth of the antenna means high data rate and greater the information sending and receiving capacity maintaining the same channel quality. Antenna being the only interfacing device between the guiding system and free space needs to feature the requirement of the bandwidth for contemporary wireless communication. By means of broadband antenna not only communication data rate sets off elevated but also preserve better understanding of the data transmitted and received, can handle multi-lingual, longer conversation without being episodic by the flow of traffic, less system fatigue due to wide spectrum availability, ease of speech and voice data recognition, transcription, voice biometrics and can easily have multiple channels in a system(SAUNDERS, 1999)

An antenna may be defined as a transducer between a guided wave propagating in a transmission line and an electromagnetic wave propagating in an unbound medium (usually free space), or vice versa (Fawaz.T.Ulaby, 2004). Although any conducting or dielectric pattern can serve as transition between the waveguide and free space, an antenna is designed such as to radiate or receive electromagnetic energy having properties of directivity and polarization suitable for the intended application.

Microstrip antennas were substituted by Dielectric Resonator Antennas (DRA's) which have the properties of negligible losses as compare to microstrip antennas, smaller size by a factor of $(\sqrt{\epsilon_r})$, high radiation efficiency and increased bandwidth. For the different values of the dielectric constant of the material the size can be controlled. For $10 < \epsilon < 100$, the antenna size can be 5-10 times smaller than that of conventional antenna. In order to reduce the size of the DRA it can be done by increasing its Q-factor and hence increasing the dielectric constant value. By using high dielectric value of the material the bandwidth of the antenna is severely degraded which is a drawback of high dielectric value materials (K.M.Luk 2003) furthermore by using low dielectric values of the dielectric material for resonator a wide bandwidth can be achieved at the cost of low Q factor and low coupling between feed line and the resonator. The losses for dielectric materials are dielectric losses which are due to non-ideal materials, ohmic losses which are the cause of imperfect coupling between the feed line and the DR, ground plane currents. Beside that DRA's offers number of advantages over the conventional antennas in different appealing aspects like, due to well match resonances the DRA's are characterized by exceptional return losses, high gain, omni directional radiation pattern, linear and circular polarizations. DRA also have flexibility to be fed with different

techniques like microstrip line, aperture feed, probe feed, waveguide feed etc, DRA can be facilitated with different design constrains for different requirement.

Harnessed effectively DRA's can have a very wide bandwidth which refers to the ability of the single access line, wireless or satellite link, connected to a telecommunication network ,to provide support for the fast, always on, access to digital content applications and a range of services, some or all of which can occur simultaneously. Many wireless devices needs further increase in the functionality of the devices in terms of application in different frequency spectrum with the same single antenna to make the system more compact and multi functional. There are already numbers of antennas for broadband application but they are not considering adequate to accomplish all the constraints of the systems. They suffers with respect to either their size limitations of the systems or bandwidth of the antenna in which the systems operates.

1.3 Aims and Objectives

The objectives of this research study are listed below.

1. To design and investigate low Profile, High Quality (Q) DRA for broadband applications.
2. To design an antenna which could compensate for the predicament of weak coupling and narrow bandwidth by combining two different permittivity materials in such a way that, it operates in wider bandwidth with strong electromagnetic coupling.

3. To formulate, fabricate and characterize high dielectric constant materials which can store strong electromagnetic fields inside it, and integrate them in to the microwave planer geometry circuits.
4. To study electromagnetic field pattern of rectangular dielectric resonators, and design a dual-segment single element antenna and several elements array antennas.

1.4 Scope of the Project

The work that needs to be accomplished to deliver a single element and array elements dielectric resonator antennas for 5.8 GHz broadband applications is explained in this portion of the dissertation.

A profound study of the current research and an in-depth literature review of the dielectric materials and their applications as microwave devices will be performed. Number of methods used by the previous researchers for designing broadband antennas and to get an insight of the broadband antennas and its application in the microwave wireless communication will also be investigated. Further detailed study on different feeding techniques, coupling phenomenon between feed line and resonator, electromagnetic field pattern and wide impedance bandwidth are addressed.

In the first stage of the project literature review of dielectric materials and dielectric resonator antenna in parallel with simulation of the different design techniques were performed to smooth the progress of the fabrication process. After passing through the simulation phase the next was to search for the material of the desired dielectric

characteristics and formulate them. Fabrication of the high dielectric constant materials were performed using, steps as, Formulating, mixing of different composition, calcinations, pressing to shape, sintering and finally polishing of fabricated material. After successful fabrication of high dielectric constant material different characterization test will be performed to make sure the fabricated material match with the requirements. For the synthesis of dielectric material, Field Emission Scanning Electron Microscopy (FESEM) for the microstructure and grain size exploration of the material, X-Ray Diffraction (XRD) for phase formation analysis and dielectric characterization of the material for the dielectric properties.

The next step is to integrate the dielectric material in to the microwave circuit and perform the different feature i.e. return loss, impedance bandwidth, radiation pattern analysis of the antenna. Finally step is documentation of the entire project in the form of publication and thesis.

Summary

In this chapter a brief introduction to recent trends of dielectric resonator antennas (DRA's) is given. Different aspects of DRA's are addressed concisely in light of current state of wireless communications. In addition a problem exists in dielectric resonator antenna are highlighted under problem statement of the project. Aims and objectives of the current research study and its expected outcomes are also presented. Finally scope of this current research project and how will the research be conducted in different phases is presented.

1.5 Thesis Organization

This dissertation is divided into total number of five chapters, and organized into a coherent order of proper perspectives. Chapter 1 commences with brief historical perspectives on the development of dielectric material and its uses as dielectric resonator antenna for broadband application.

Chapter 2 further prolong the study on dielectric resonators and an in-depth and rigorous analysis of dielectric material and literature related to the broadband antennas which have the properties of being low profile, small in size and compact formations, different size and shapes of dielectric materials and various feeding techniques.

Chapter 3 comprises of detailed work out on the design of broadband antenna. This includes the implementation of the simulation software CST, detailed fabrication

process of the dielectric material from the ceramic composition of different materials, which is used as dielectric resonator in the antenna arrangement.

Chapter 4 this chapter is more on the comprehensive discussions on the results of both simulation and measurements made in the labs. The result generated in the fabrication of materials includes FESEM, XRD testing and electrical characterization results, magnitude of return loss, S-parameters of the antenna, bandwidth and radiation pattern of the antenna. Comparison between simulated and measured results has been made.

Chapter 5 is on the executive summary of the whole dissertation. It goes over the main points of the previous chapters. It provides analysis of all the simulated and measured results and conclusion about the entire project is made and future perspective of the dielectric resonator antenna is presented.

CHAPTER 2

LITERATURE REVIEW AND THEORETICAL BACKGROUND

2.1 Introduction

Antenna plays a mandatory part in any wireless communication system. Nowadays as the whole world is like a global village, communications have to have high capacity so that it can endow with excellent feature of multimedia services such as video conferencing, video messaging, multiple lingual, voice biometrics, better understanding, longer conversation, less system fatigues and multiples channels. The wider or broader the bandwidth of the system channels the superior the information carrying capacity of the system while maintaining the same high quality of channel transmission. Antenna is the only transducer between a guided wave propagating in a transmission line and an electromagnetic wave propagating in an unbound medium (usually free space), or vice versa (Fawaz.T.Ulaby, 2004). As all wireless communication devices are equipped with antenna so it needs to operate in wide range of frequency so as to cover sufficient part of the frequency spectrum in order to have wider information bandwidth. Although any conducting or dielectric pattern can serve as transition between the waveguide and free space, an antenna is designed such as to radiate or receive electromagnetic energy having properties of directivity and polarization suitable for the intended application. Furthermore, as contemporary communication systems should have a tendency to be mobilized and personalized, the design of small size and compact portable communication devices are imperative. This makes indispensable the employment of small and low profile antennas. There are few inventions in the world of wireless

communication which brought about a chronological change in the congregate devices. For example mobile phones loaded with Wi-Fi can easily have access to internet; TV programs, global positioning system (GPS) services and internet browsing (Conti, 2007). Innovative congregate devices for wireless communication applications are outfitted with the properties of wide bandwidth so can easily handle high data rates and covers sufficient frequency spectrum. In addition to this both size and operating bandwidth of the antenna should go incorporation with each other i.e. small size and wideband simultaneously. The size become more noticeable when it is needed to add in an antenna to monolithic integrated circuit (A. V. P. Kumar, 2006).

Antenna not only have vital role in daily use communication devices but also have a strong hold in radar and satellite communications. In radar systems without antenna no object can be identified by the system. In far distanced military operations radar has a major role to capture moments and activities of the opponents. Reduction in the size of the antenna and enhancement in the bandwidth of the antenna will bring about tremendous improvement in the size and weight of the entire radar system. Antenna also has a part to play in the multiple-input-multiple-output (MiMo) systems. If individual antennas are assigned to a specific band of frequency for particular purpose the configuration of the communication system will not only become more bulky, but it will realize high capacity and high data rates. And the entire system will be equipped with multiple antennas especially at the transceiver communication (Yan Xin and Guosen Yue, 2010). When the spot is on the handhelds MiMo systems then different aspects of the antenna like compactness, operation of the antenna in wideband and simple geometry configuration of the antenna should be brought into considerations.

Consequently it can be said that small size, simple geometry, operation of the antenna in millimeter wave frequency band with high transmission rates and wide bandwidth are most favorable properties of the current antennas.

2.2 Executive summary of low profile Antennas

The most popular type of small and low profile antennas are microstrip patch antennas. They have the advantage of low cost, light weight, small size, easy to fabricate and conformability to different surfaces. But when it comes to the millimeter wave frequencies microstrip patch antennas experiences number of shortcomings like low radiation efficiency due to enormous conductor losses and robust excitation of surface waves, narrow bandwidth operations (Sabban, 2007, Sabban, 1997). To prevail over these unendurable disadvantages of patch antenna as, *S.A long et al* introduced a new type of antenna which makes use of low loss dielectric material as resonator (S. A. Long, 1983). This antenna was given the name of Dielectric Resonator Antenna (DRA). Prior to the beginning of Dielectric Resonators (DRs) as antenna element it was extensively used for the design of diminutive microwave filters and oscillators. A Dielectric Resonator (DR) is an electronic component usually comprises of a puck of low loss ceramic materials that have a dielectric constant value and reveal resonance for a constricted range of frequency, mainly in the millimeter (mm) wave frequency bands. The resonance of the dielectric material is almost similar to that of a hollow waveguide made of metal, with the exception of the change in boundary with dielectric permittivity of the material rather than by a conductor. The resonance frequency of the DR is determined by the puck size, height h , width w , depth d and the permittivity of the

material. Different aspect ratios (w/h and w/d) for the dimensions of the ceramic puck generate resonance at different frequencies.

2.3 Chronological overview of Dielectric Resonators (DRs)

In the late nineteenth century Lord Rayleigh demonstrated that a dielectric material rod of infinitely long cylindrical shape may serve as waveguide (Rayleigh, 1897). In the 20th century more research took place on the dielectric material in Germany which presented supplementary imminent through theoretical and experimental investigations into the behavior of electromagnetic waves in dielectric rod waveguides (Hondros, 1909). In 1939 Robert D. Richtmyer exposed a study on the dielectric structure which shows that dielectric material act as metallic cavity resonator and he name these dielectric materials as dielectric resonator (Richtmyer, 1939). He stated that dielectric resonators must radiate for the reason that the boundary conditions at the dielectric to air interface. These were the results which were used later for the initiation of new antenna called DRA. After the initial investigation of Robert D. Richtmyer there was no further adequate research in the field for few decades due absence or lack of low loss advance ceramic materials. Nevertheless, in the 1960s a significant progress has been made in the high-frequency electronics and modern communication industries new manufacturing techniques for dielectric materials were introduced and in result dielectric resonators achieved in significance. In addition to the features like, size-reducing design alternative to bulky waveguide filters and lower-cost alternatives for electronic devices i.e. oscillators, frequency selective limiter and slow wave circuits (Guillon, 1986, Pospieszalski, 1979) dielectric resonators offered the

advantage of lower weight, material availability and ease of fabrication over the conventional metal cavity resonators (Birand and Gelsthorpe, 1981). Moreover there are numbers of dielectric material with different unloaded Q factor from low to high on the order of 10000s are available vastly in the present day market. In this project two different dielectric materials i.e. Barium Zinc Tantalum (BZT) and calcium copper titanate CCTO ($\text{CaCu}_3\text{Ti}_4\text{O}_{12}$) were fabricated and used. The reason for using two different dielectric materials is explained in chapter 3.

2.3.1 Dielectric Resonator Antenna's (DRA's) and its features

As dielectric materials operates as dielectric resonators when energized by any of the feed mechanism. If we place or expose the dielectric resonator in an open environment, due to radiated fields in the resonator power will be lost. This phenomenon of the dielectric materials makes them valuable element for the antenna. A number of features dielectric resonator antenna offers are illustrated as follows.

- Different aspect ratios for the size of the DRA's entirely depends on the free space wavelength (λ_0) and dielectric constant (ϵ_r) of the materials, as dimensions of the DRAs is of the order $\frac{\lambda_0}{\sqrt{\epsilon_r}}$. The free space wavelength for a particular frequency remains constant but preferring different values of dielectric constant in the wide range of ($\epsilon_r \approx 10 - 1000$) for meticulous purpose, the size of the DRA can be in command of the designer.
- Dielectric resonators have literally no inherent conductor losses, this leads to the high radiation efficiency of the dielectric resonator antenna, while in the case of

metal fabricated antennas where the conductor losses are ruthless especially when they operate in the millimeter (mm)-wave bands of the spectrum and this results to the degradation in the radiation efficiency.

- Dielectric resonators can be easily integrated in to any of the different planner technologies because of the reason that DRAs have the capability of simple coupling schemes to almost all the transmission/feed lines used at microwave and millimeter (mm)-wave frequencies. The coupling of the DRA to the planner transmission/feed line can be controlled easily just by changing the position of the dielectric resonator with respect to the open end and along the feed line. Experimentally the performance of the dielectric resonator antenna can be optimized very easily.
- The operating bandwidth of a DRA can be easily controlled by changing resonator parameters. For example for wide bandwidth operation of the antenna the material with low dielectric constant can be chosen and vice versa. The bandwidth of the lower order modes of the DRA can be varied easily from fraction value of percentage bandwidth to about 10% or even more is possible but if the appropriate value of the electric constant for particular application is selected.
- DRA can be operated in different number of modes. Each mode has distinctive internal fields and associated to those internal fields there is an external field distribution in the vicinity of the DRA. By exciting different modes of the DRA different radiation characteristics can be obtained prominently.

2.4 Different Geometries of DRAs

As described in the previous section that dielectric resonator antenna (DRAs) have distinctive features of different shapes, sizes and also resourcefulness in coupling techniques. The different design parameters for DRAs such as permittivity, resonant frequency, input impedance, radiation pattern and coupling mechanism for different shapes varies and consequently different mathematical models are used for the analysis of the geometrical configurations. Depending on the particular applications and requirements for different frequencies of operation, the type of excited modes, the desired impedance bandwidth and radiation characteristics of the antenna for a communication system the DRA shape and size can be selected (Petosa and Ittipiboon, 2010, Petosa et al., 1998). Few of the most prominent shapes in used are; hemisphere or Hemispherical Dielectric Resonator Antenna HDRA, the parallelepiped or Rectangular Dielectric Resonator Antenna RDRA and the cylinder or Cylindrical Dielectric Resonator Antenna CDRA. These shapes are relatively easy to fabricate, their resonance frequencies and radiation Q-factors can be precisely calculated using closed form expression (Mongia and Bhartia, 1994). For the given resonance frequency the DRA with rectangular cross section is characterized independently by different aspect ratios of width w to height h (w/h), width to depth d (w/d) and a dielectric constant. Thus either tall and slender or thin and wide aspect ratio can be selected according to the particular application, so rectangular dielectric resonator has two degree of freedoms as two of the three parameters of dimension can be selected. In case of CDRA there is only one degree of freedom different ratios of radius and height of CDRA gives different values of bandwidth, directivity and total volume occupied by DRA. While for HDRA there is

none, only the radius determines the resonant frequency and hence the bandwidth of the HDRA remains fixed and difficult to optimize for a particular application. Moreover there are number of shapes like ring, hexagon, triangular etc which were also investigated and used as resonator for different application. In 2004 it was proven that with different shapes of dielectric resonator frequency of the resonator can be varied effectively (Mridula et al., 2004).

2.5 Broadband Dielectric Resonator Antenna's

Number of broadband antennas has been reported in the literature by different researchers. Different approaches were opted to achieve the ultimate result in the form of antenna operating in broadband of frequency spectrum.

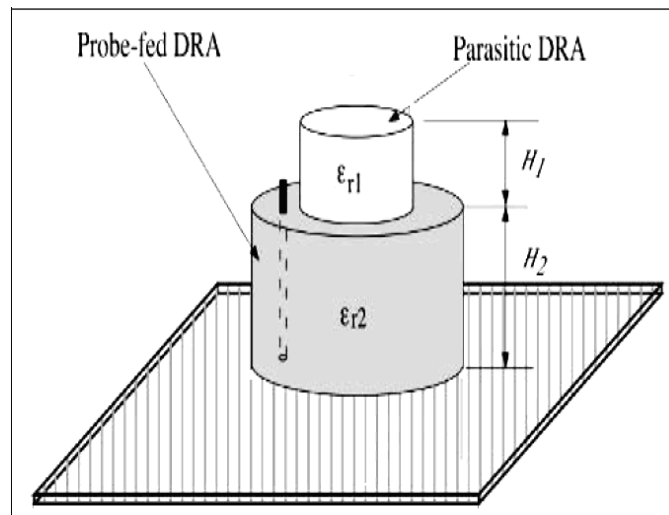


Figure 2.1: Cylindrical stacked DRA (Kishk et al., 2003)

For the first time Kishk *et al* started his exploration of the DRA as a broadband antenna by stacking two cylindrical DRA and energized them by probe feed (Kishk et al., 2003) . Figure 2.1 shows the structure of the antenna.

This antenna was feed by probe vertical feed by drilling a hole in the DRA in the bottom and the second DRA was stacked on top in order to get multi resonances from individual DRA's. This approach was used to get broadband operation of the DRA but optimizing the DRA to resonate closely together in the frequency bands and joining both resonances was always the matter of concern for the researchers.

Later in 2006 further research work was published by Rezaei and his co-authors (Rezaei et al., 2006) suggesting that there are three different ways which can be implemented for broadening the operation of the DRA's. i.e. by adding an external matching network to the feed line the matching can be enhance at the cast of lowering the inherent Q-factor of the resonator.

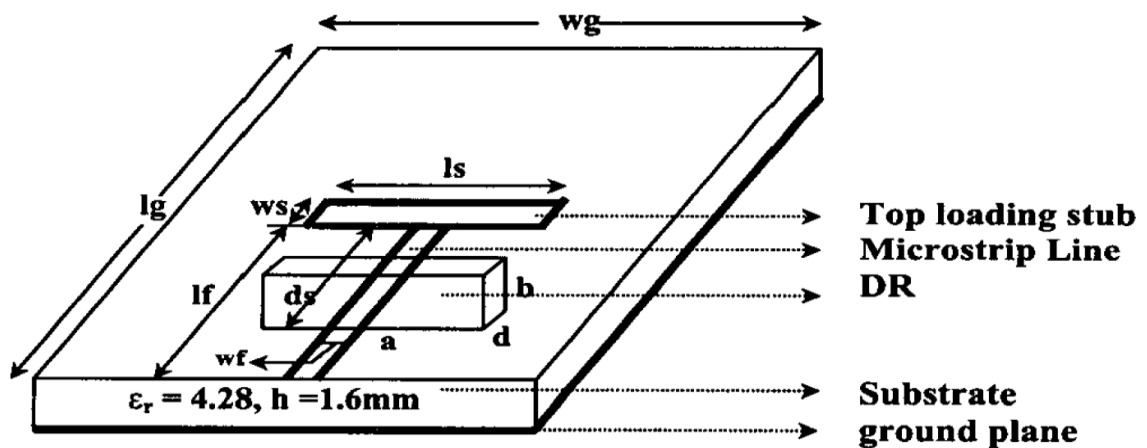


Figure 2.2: Rectangular DRA with top loaded stub (Mridula et al., 2004)

Different matching networks can be employed in order to achieve broad band operation of the DRA by transferring the coupling energy efficiently to the resonator. Matching element such as matching stub, quarter wave transformer or any active circuitry can be used to better match the input impedance. Mridula and his team presented a research on rectangular dielectric resonator antenna (Mridula et al., 2004) .

In this research his finding were described in the form that a rectangular dielectric resonator with permittivity ($\epsilon_r = 48$)proclaims a broadband impedance bandwidth of 21%, the proposed antenna is shown in Figure 2.2.

Bijumon used a different technique to achieve broadband operation of the DRA. They used a T shaped microstrip feed line to feed the cylindrical DRA and reported the bandwidth up to 26% with better gain and good radiation properties (Bijumon et al., 2005). For this design high permittivity dielectric material is used as a resonator, the proposed structure of the antenna is given in Figure 2.3

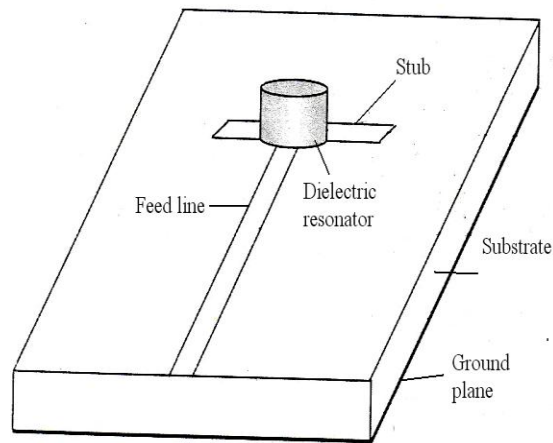


Figure 2.3: Cylindrical DRA feed with T shape microstrip(Bijumon et al., 2005)

In 2009 Ahmed Abumazwed reported a half cylindrical shaped antenna operating at broadband of 31 % (Abumazwed et al., 2009). This antenna is also feed by straight microstrip line and the geometry of the antenna is given in Figure 2.4

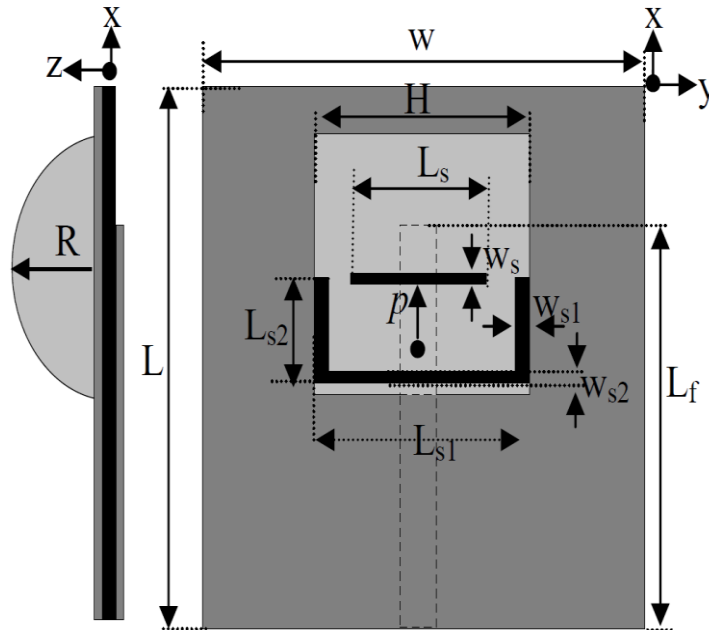


Figure 2.4: Geometry of half Cylindrical shaped DRA (Abumazwed et al., 2009)

Rao and company came out with T-shaped Dielectric Resonator Antenna (DRA) with two equilateral triangle cross sections placed on a PCB with infinite ground plane. The DRA was excited with by a coaxial probe by making a hole through the ground plane to make it resonate in the broadband. This design yielded a total bandwidth of 60% (Rao et al., 2006). The geometry of the structure is given in Figure 2.5.

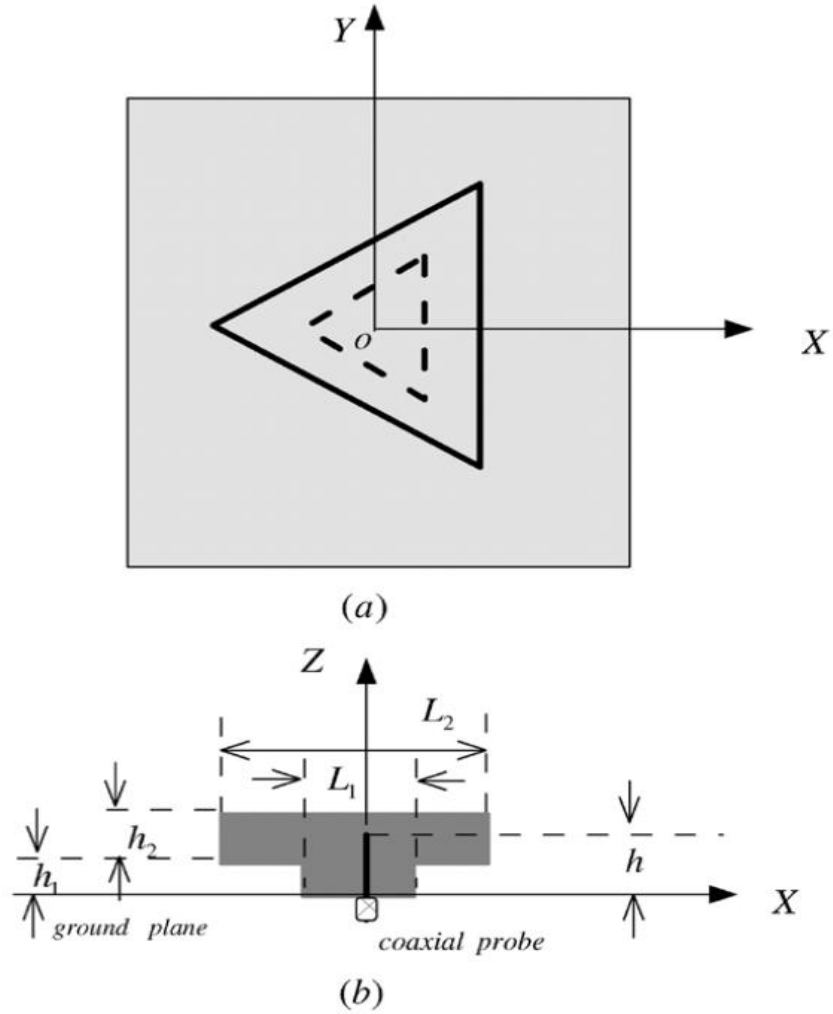


Figure 2.5: (a) Top view (b) side view of DRA (Rao et al., 2006)

In recent years coulibaly *et al* investigated rectangular shaped dielectric resonator for broadband applications in millimeter wave frequencies. An extra substrate has been used for the hybrid dielectric resonator Antenna. A coplanar waveguide feed line with resistance 50Ω is used to excite the DRA (Coulibaly et al., 2011). The structure of the antenna is given in Figure 2.6.

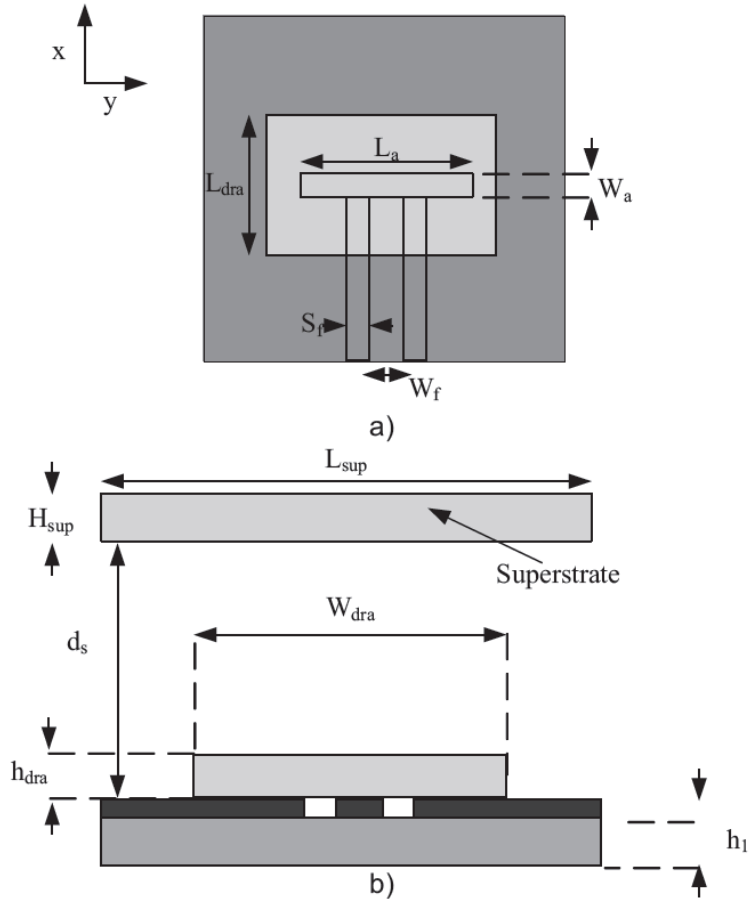


Figure 2.6: (a) Top view (b) side view of the proposed antenna (Coulibaly et al., 2011)

There are number of other techniques which have been employed by the researchers in order to get broadband DRA i.e. by inserting a metal plate in between the two simultaneous DRA which introduces a metallic wall with in the DRA and it behaves like two half segment rectangular DRA. In 2010 Thamae and Zhipeng reported a wideband dielectric resonator antenna with bowtie shape modification in the resonator (Thamae and Zhipeng, 2010). The antenna was formed by making notches in the cylindrical geometry of the DRA and coaxial feed was used to excite the DRA and they reported impedance bandwidth up to 49%. The structure is shown in figure 2.7

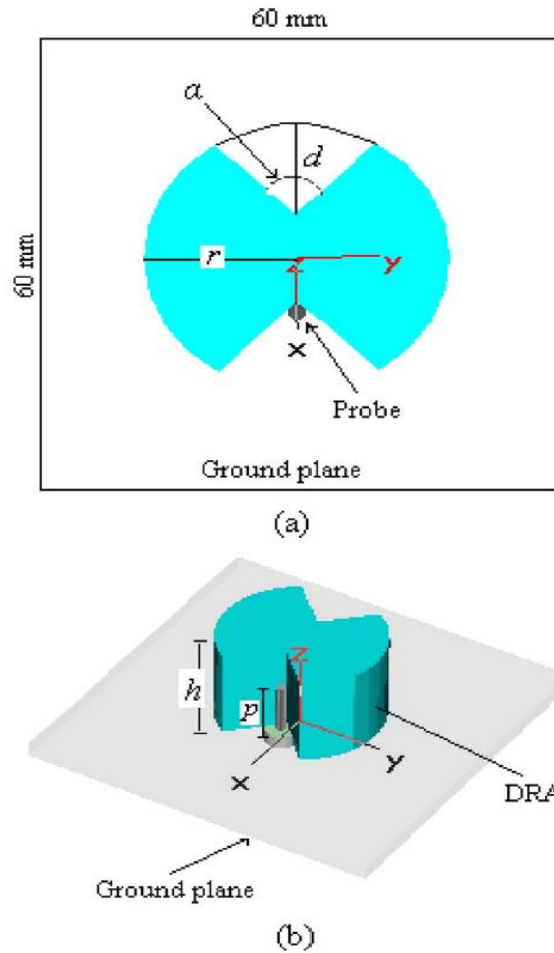


Figure 2.7:(a) Top view (b) panoramic view of the proposed bowtie Antenna (Thamae and Zhipeng, 2010)

Like many good things research does not end here in 2011 Fang *et al* came out with another broadband antenna employing notching techniques in the rectangular shape DRA. Strip fed was used to energize the antenna. The impedance bandwidth of the antenna reported was 56%(Fang et al., 2011). The configuration of the strip feed antenna is shown in Figure 2.8.

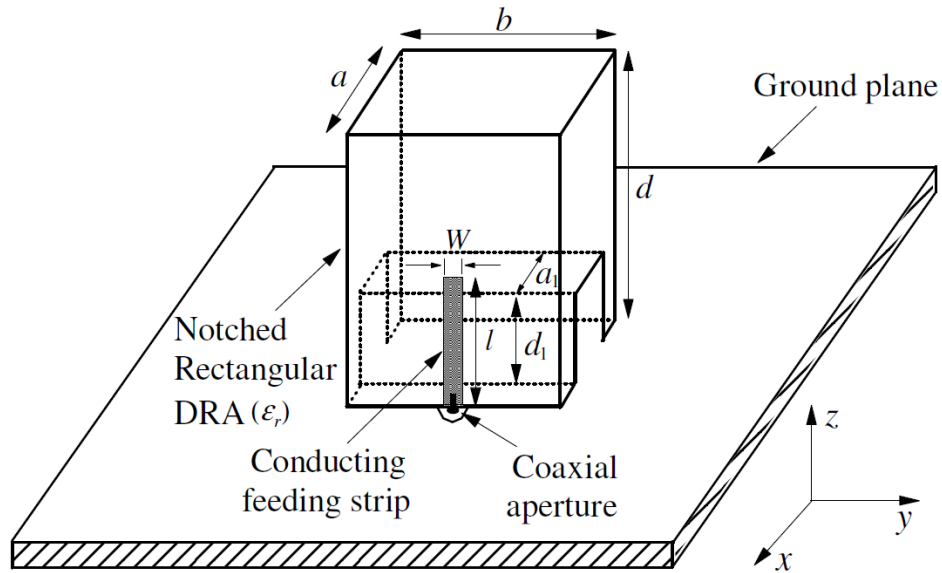


Figure 2.8: Strip-feed antenna configuration(Fang *et al.*, 2011)

Recently Ain *et al* reported a circularly polarized filed excited with a 50Ω microstrip feed line with a slot on ground plane (Ain et al., 2012). The antenna was reported to operate in X band of frequency with 9 dBi gain. In this design the dielectric resonator is designed as an RLC parallel circuit and is coupled to the source used for excitation of the antenna. Different aspect ratios of the dielectric material used in the antenna designed were employed to achieve reasonable mutual coupling between adjacent dielectric resonators. Configurations of the reported antenna can be seen in Figure 2.9.

In the light of literature it can be said that numerous research and study of the DRA is taken place in the past. Throughout -10dB is kept as reference line for the good impedance matching which also shows a VSWR with a value of 2. Some researchers have used different terms like VSWR 2:1 is considered as good impedance transformation from feed point to the resonator.