Design and Analysis of Integrating Antennas for UWB and Cognitive Radio Applications

A Thesis submitted in partial fulfillment of the Requirements for the degree of

Master of Technology
in
Electronics and communication Engineering
Specialization: Communication and Networks

by
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Rourkela, Odisha, 769008
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Under the Guidance of
Prof. Santanu Kumar Behera

Department of Electronics and Communication Engineering
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Dedicated to
my parents ….

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

ROURKELA- 769008, ODISHA, INDIA

CERTIFICATE

This is to certify that the work in this thesis entitled **Design and Analysis of Integrating Antennas for UWB and Cognitive Radio Applications** by Pidugu Ananda Raju is a record of an original research work carried out by his during 2014-2015 under my supervision and guidance in partial fulfilment of the requirement for the award of the degree of Master of Technology in Electronics and Communication Engineering (Communication and Networks), National Institute of Technology, Rourkela. Neither this thesis nor any part of it, to the best of my knowledge, has been submitted for any degree or diploma elsewhere.

Place: NIT Rourkela

Date: 19/05/2015

Dr. Santanu Kumar Behera

Associate Professor

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NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

ROURKELA- 769008, ODISHA, INDIA

DECLARATION

I certify that

a) Under the supervision of my supervisor the work is done and work in this thesis is original and is done by myself.

b) The work has not been submitted to any other institute for any degree or diploma.

c) For writing the thesis I followed the institute

d) I have given credit to materials when i used them in the thesis and their details are given in the references.

Pidugu Ananda Raju
19/05 2015

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All my thanks to God, to the successful completion of the thesis

The work posed in this thesis is by far the most substantial attainment in my life and it would be unimaginable without people who affirmed me and believed in me. First and foremost I evince my profound reverence and deep regards to my guide **Prof. S. K. Behera** for exemplary guidance, supervising and constant encouragement throughout the course of this thesis. A gentleman embodied, in true form and spirit, I consider it to my good prosperity to have consociated with him.

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Pidugu Ananda Raju

Abstract

The increasing demand for improvement and organization of new services has impact the hard ware design method including radio frequency front end, antennas especially in the portable devices. Hence, novel arrangement that are multimode, multi band, low cost, low profile, and simple to integrate into the highlight compact device are needed. Integrating wideband and narrow band antennas presented for various wireless applications. The integration idea is based on the sharing few areas of the one antenna between the other antennas. In this work different antennas are presented for ultra-wide band and cognitive radio applications. The UWB is a short range radio communication that perform high speed communication with rates more than 100 Mbps. The federal communication committee (FCC) defined the UWB range from 3.1GHz to 10.6 GHz for commercial usage. The challenge is to integrate two antennas in a limited space and provide good isolation exist between the antenna ports. Microstrip antennas integrated with DRA are presented cognitive radio applications. The DRA antennas for UWB applications are presented. The DRA antenna with band notch are presented for WLAN applications.

First, a new semicircular- semi hexagon microstrip antenna is integrated with cylindrical DRA is proposed for UWB and cognitive radio applications. The proposed antenna placed on a 39mm×38mm×1.6mm fiber glass rein forced epoxy (FR4) dielectric substrate it covers the frequency range from (2.58 GHz to 14GHz) . The cylindrical DRA is aperture fed used for narrow band application. It covers the frequency range from 10.07GHz to 11.38 GHz. The design provide greatest isolation between the two antenna ports achieved.

Dielectric resonator antenna (DRA) are having wider band width, low profile, light weight, low conductor loss, low dissipation loss and wider bandwidth compare microstrip antennas. So the DRA antennas are designed for UWB applications. In the second design a new ‘T’ shape DRA is designed on a 26mm×30mm×1.3 mm substrate made up of RT-5880 having dielectric constant of 2.2. The DRA covers the UWB frequency range from 3.5GHz to 11.8GHz. The DRA is ‘T’ in shape made up off RO-3010 having dielectric constant of 10.2. To reduce the interference between the existing designs ‘T’ shape slot is presented for removing frequency at 5.6 GHz (WLAN) applications.

Contents

Nomenclature

S/N	Signal to Noise ratio
C	Capacity
B	Bandwidth
ε	Dielectric Constant
ε_r	Relative Dielectric Constant
ε_{reff}	Effective Dielectric Constant
L/h	Length to height ratio of Microstrip antenna
W/h	Length to height ratio of Microstrip antenna
Z_0	Characteristic Impedance of a Transmission line
Ω	Ohm
G	Conductance
dBi	Decibel with respect to isotropic antenna
$\tan\delta$	Loss tangent
ω	Angular frequency
λ	Wavelength
μ	Permeability
σ	Conductivity
θ	Angle
ρ	Resistivity
η	Efficiency
E	Electric Field intensity Vector
H	Magnetic Field intensity Vector
B	Magnetic Flux Density Vector

Abbreviations

UWB	Ultra-Wide Band
DRA	Dielectric resonator antenna
DRO	Dielectric resonator oscillator
CR	Cognitive radio
SDR	Software defined radio
FCC	Federal Communications Commission
WLAN	Wireless Local Area Network
GSM	Global System for Mobile communications
PDC	Personal Digital Cellular system
IS	Interim Standard
Wi-Fi	Wireless Fidelity
IC	Integrated Circuits
NLOS	Non-Line of Sight
LNA	Low Noise Amplifier
PIFA	Planar Inverted- F Antenna
PICA	Planar Inverted Cone Antenna
EBG	Electronic Band Gap
USB	Universal Serial Bus
FDTD	Finite Difference Time Domain
CST	Computer Simulation Technology
VSWR	Voltage Standing Wave Ratio
RFID	Radio-frequency identification
CPW	Coplanar Waveguide
SIMO	Serial Input Multiple Output
MISO	Multiple Input Serial Output
SISO	Serial Input Serial Output
SM	Spatial Multiplexing
TARC	Total active reflection coefficient

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Chapter 1
Introduction

Many applications like automated highways, wireless sensor, telemedicine and aircrafts have developed recently on the antenna. Wireless communication systems converted as a part of everyday life. In the first developed wireless networks signals were communicated with smoke and flashing lights and the sending information was line of sight distance. The first communication was changed by telegraph networking and after the telephone. The fast growing technologies allowed transmission over a large distance with best quality and low power, small devices encouraging private and public communication over wireless technology. The next communication was a revolution of satellite communication using the microwave frequencies to operate. In the year of 1930 the microwave communication was first started. Satellite communication provide very high data rates at high frequency. Audio and video propagation over a large area is the main application of satellites communication. Antenna is the essential components in any communication system. For the wide band applications the developed designs with low profile, low-cost, high gain and low loss antennas are desired. Recently microstrip antennas loaded with DRAs are receive attention in cognitive and satellite communication. These antennas having small dimensions, manageable properties, wide bandwidth, low volume, low metallic losses, high dielectric strength ,high power handling capability . Because of these advantages they are suitable for millimeter and microwave application. The DRA having high impedance band width and high efficiency compared to microstrip antennas.

1.1 Ultra-wideband (UWB) technology

UWB is defined by the federal communication committee (FCC) from 3.1 to 10.6 GHz bandwidth [1]. The UWB technology use low energy pulses for short range and high data rate communication by using a large portion of the spectrum. This allowed the unlicensed operation of conscious UWB within the limited frequency bands. The requirement for high data rate communication [2] [3] making the growth of advancement of UWB communication frame works. UWB is a remote invention for transmitting computerized information over a wide range with low power and convey information over short distance.

UWB draws additions of expansive range as far as bit rates it can deal with, by Shannon's hypothesis, the channel limit C is given by

$$C = B.\log_2(1 + \frac{S}{N}) \qquad (1)$$

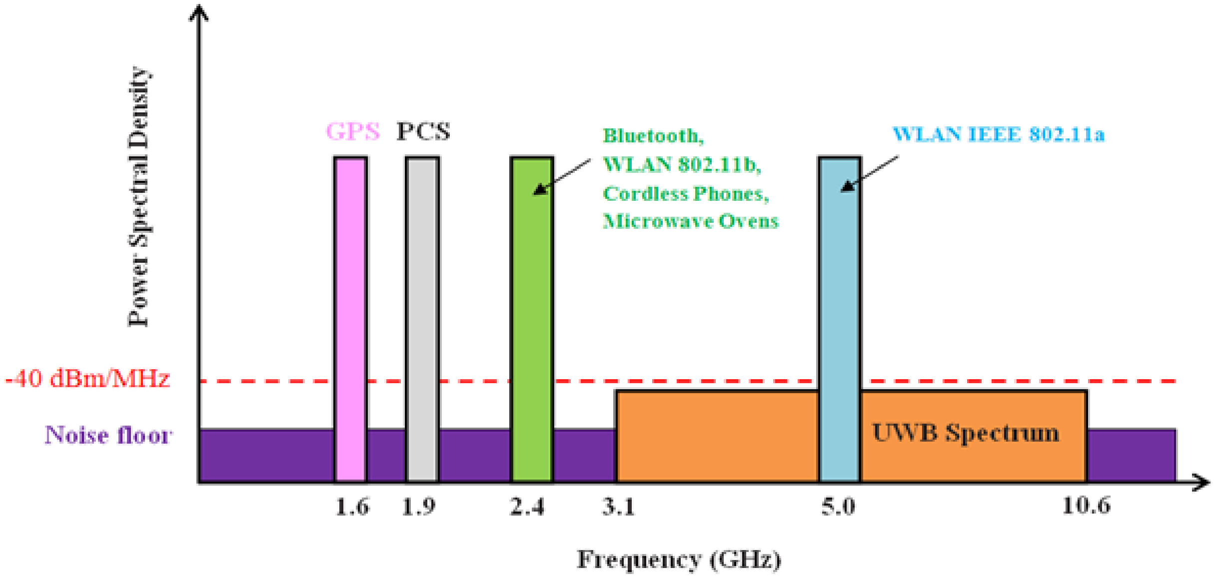


Figure 1.1 UWB Spectrum

Where B is the channel available bandwidth in hertz, N is the noise power and s is signal power The channel capacity increases with increases in available bandwidth. If the bandwidth is tends to infinite the channel capacity leads to

$$C = 1.44(\frac{S}{N_0}) \qquad (2)$$

Where N_0 is the one sided power spectral density of communication channel.

Relation between the distances, transmitted power and received power is given by

$$d \; \alpha \sqrt{\frac{P_t}{P_r}} \qquad (3)$$

Where d is the distance and P_t,P_r are the transmitted and received powers respectively.

Above equation shows that by increasing channel bandwidth channel capacity increased instead of increasing power.

1.1.1 UWB Characteristics

(1)It requires very less transmission energy (~ 1mW)

(2) Very high data rates are possible

(3)By using shot plus wide band spectrum is generated

(4) Low cost used in digital architecture

(5)Used in radar for centimeter ranging

(6) It can passes through walls and buildings (LOS is not required)

(7) By using low energy density signals interference of other devises can be minimized.

1.1.2 UWB Advantages

(1) Low cost and low power

(2) It is highly immune to multipath spreading (fading robustness)

(3) Used in WPAN within 10 meter

(4) Used in smart sensor networking.

1.2 Cognitive radio

Cognitive radio permits the system to know the information of operation band and environment autonomously and dynamically regulate the channel according to present spectrum usage and supplies and study from the results by converging most promising channel.

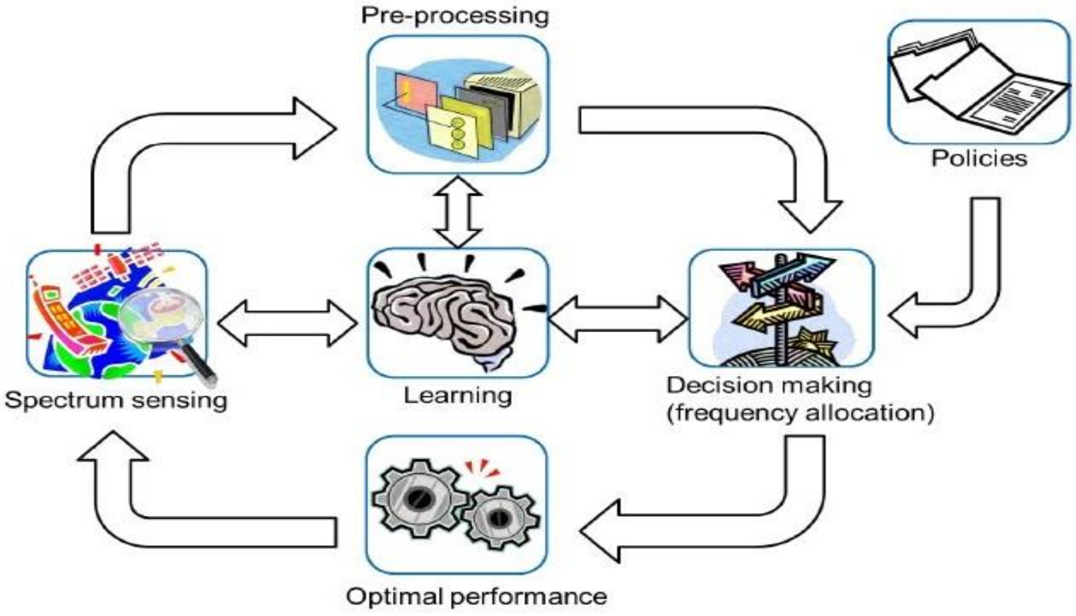


Figure 1.2 Cycle in cognitive radio network

The dynamic manage to access spectrum is characterized in three ways [4]

(1) Dynamic usage model

(2) Hierarchical access mode

(3) Open sharing mode

In the dynamic exclusive mode, exact bands are assigned for exclusive use. Some flexibility is familiarized to improve spectrum efficiency. Two methods in this category one is dynamic allocation and spectrum property rights. In first method spectrum efficiency is improved by temporal traffic statistics. And second method licenses are allocated to trade spectrum and free selected technology. In open sharing model commercial accomplishment of wireless technology working in the ISM bands, it provide all users to use the spectrum with equal opportunity. The hierarchical model provide the hierarchical importance to primary user compare to secondary user. The spectrum assigned to primary user is accessible to secondary user in anticipation of secondary user not interfere the communication of secondary user. Two models [4] are proposed in this method. (1) The spectrum overlay (2) spectrum under lay. The first model is also known as OSA. In the under lay model secondary users are acceptable to transfer with low power and undetectable to primary user. In over lay model secondary users are using the licensed bands at that time primary users are not using that bands.

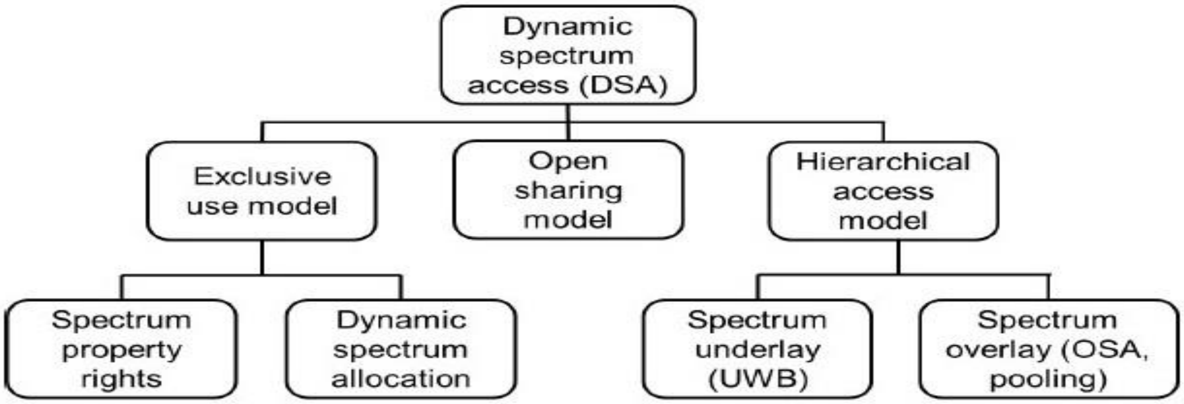


Figure 1.3 Dynamic access model

To avoid interference with primary user this method recognizing and manipulating the spectrum holes in time, space and frequency. The second method is not manipulating the white space because secondary [4] user transmitting with low power. The overlay approach added additional complexity and cost to detect spectrum holes and secondary users are transmitting with greater power. The two models are shown in below figure.

To find out the vacant space in OSA model, the cognitive radio system essential to examine the spectrum and find out the white spaces is called spectrum sensing. After finding the vacant channel is starts communication operation.

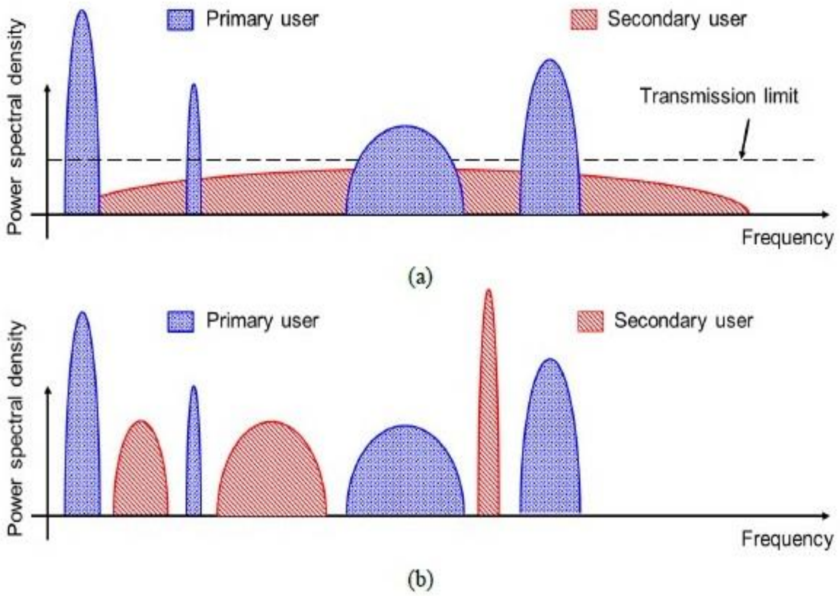


Figure 1.4 Spectrum sensing and allocation

1.3 MOTIVATION

The demand for high data rate transmission and internet access, the antennas with ultra-wide band applications [12] are more predominant. The increasing demand in the wireless applications in the microwave frequency ranges are directed the researcher to focus on high efficient antennas that have high radiation pattern, wide bandwidth, small size and low metallic losses [6]. The DRAs are used in many applications because of attractive features over the conventional microstrip antennas. Several methods are used to increase the band width of the antenna. The UWB have various advantages as high data rates with low power over a short distance it is covering the total frequency range from 3.1 to 10.6 GHz [7] [8]. The UWB technology uses modulated nano pulses relatively then the continuous waves and this is highly sensitive and transmission below the noise floor level. UWB provides suitable performance in frequency and time domains. Integration of wide band and the narrow band is useful for the reduction in size and it provide flexibility to function in multi-function mode. This model require extra pre-filtering to decrease the interference at the receiver. Major benefits of integrating wide band and narrow band antenna work as single antenna. To provide quality of service and evade the interference minimum rules should be followed. If the licensed spectrum is used sometimes spectrum resources repeatedly wasted. Occasionally the spectrum allocated is more then what is originally required. So other portion of the spectrum is not used by the service. The UWB technology is busier and less accessible because more technologies and parties using the unlicensed spectrum. Cognitive radio technology [4] provides the capability of sharing the unlicensed and licensed in resourceful way. In cognitive radio wide band sensing is running while the structure is operated in its conservative mode. The objective of the project is

(1) To develop antennas for UWB applications

(2) To develop antennas for dynamic access.

(3) Integrate microstrip and DRAs

1.4 Literature review

The microstrip antennas are used in space craft, satellite, missile applications, and high performance aircraft because of low cost, light weight, small size, high performance, and easy fabrication. The low profile microstrip antennas are designed using printed circuited technology, these antennas are robust and well-suited with MMIC designs [9] .It is easy to design antenna with necessary resonant frequency, input impedance, polarization by placing active loads between ground plane and radiating patch. Recently many designs can be reconfigurable characteristics are studied. The UWB technology has attracted for short range and high data rate transmission using the radio spectrum [7]. Several methods are used to broaden the band width of small microstrip antennas and several approaches like coplanar waveguide slot [10], antenna tuning studs with rectangular, circular, forklike shape[10][11]. The impedance matching of the MPA is improved by adjusting the shape, size of ground plane, height of the feeding gap [12] [13]. The antenna process and principal over the whole spectrum is like hybrid mode of travelling and standing waves [4].

The dielectric resonator are using in microwave circuits as a filters and oscillators. S.A.Long was investigated cylindrical, hemispherical, and rectangular [14] DRAs. Mongia and Bhartia [15] are proposed modes of DRA, Q factor, resonant frequency, and different shapes of DRA in 1994. The resent technologies and feeding methods was reported in 1998 by Petosa et al. Wa leung and kui proposed circularly polarized and linearly polarized DRAs in 2012. In recent years integrating narrowband and wide band antennas for UWB, medical imaging [16] system and cognitive radio applications are presented. Integrating antennas are used for many applications where they reduce the size required pre filtering circuit at the receiver. To reduce the interference with existing antennas band notches are introduced in the feed line or ground plane like H shaped slot [35], L shaped slot [17], and U shaped slot [18]. Another way to make band notches are adding parasitic [19] strips near the ground plane.

Joseph mitola presented the idea of relating software and hard ware defined radio in 1990s. These radios consist of software control tuner and RF front end. In the year 2000 mitola presented the cognitive radios they basically contain artificial intelligence with SDRs [20] [21]. The main challenge is to integrate antennas in limited space and provide greater isolation between the antenna ports. Cognitive radio two types of antennas are required one is for sensing [22] and one is for communication operation. Recently planar antennas integrated with DRA are studied for cognitive radios [23].

1.5 Thesis organization

The thesis organization is as fallows

Chapter 2: This chapter contains the description of fundamentals of the antennas and basics of the microstrip antennas. The basics of microstrip antenna includes the shapes of microstrip antennas, different feeding methods, equivalent circuit’s , advantages, features, disadvantages. The different calculation of the length, width of the patch are shown in this chapter.

Chapter 3: This chapter contains the basics of DRA antennas and integrating antennas. The basics includes the different shapes of DRA, feeding methods of DRA, advantages and disadvantages compare to the microstrip antenna are explained. The basics of the cognitive radio and different types of integration antennas used in cognitive radio are described.

Chapter 4: This chapter contains the design of integrating antennas for cognitive radio and UWB applications using CST studio. The semicircular- semi hexagon microstrip antennas integrating with DRA and elliptical microstrip antenna integrated with DRA are shown. The antenna parameters like reflection coefficients (S_{11}, S_{22}), gain, transmission coefficients (S_{21}, S_{12}), directivity and the radiation pattern are calculated.

Chapter 5: This chapter contains the design of DRA antennas for UWB applications**.** Semi cylindrical ring DRA and a new ‘T’ shape DRA are presented. The parameters like reflection coefficient, gain and radiation pattern and directivity are calculated. A ‘T’ shape band notch placed on the back side of ‘T’ shape DRA for WLN applications.

Chapter 6: This chapter contains the design of Ultra-wide band antenna integrated with wide band antenna using microwave studio. A new ‘U’ shape DRA antenna integrated with rectangular microstrip antenna are presented for cognitive radio applications. The gain, efficiency and directivity are improved compare with normal antennas.

Chapter 7: This chapter contains the scope of the project, contribution of the project, conclusions, limitations, and future work.

CHAPTER 2

FUNDAMENTALS of ANTENNAS AND MICROSTRIP ANTENNAS

2.1 Antennas fundamentals

Antenna is a coupling device. It can be radiate and receive band of frequencies .active elements associated with antennas are called as active antennas otherwise they are passive antennas. By reciprocity theorem proved that the properties of antenna are identically same weather the antenna used for transmission purpose or reception purpose.

2.1.1 Isotropic radiator

It is capable of radiating equally in all directions. It is an example of impractical antenna. It is having efficiency of 100%   in all directions of three dimensional space.

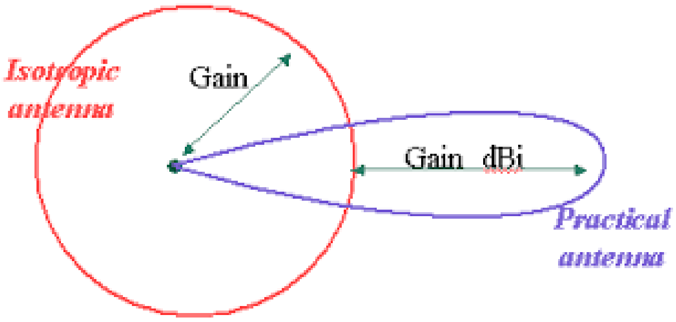


Fig 2.1 Isotropic radiator

Directional radiator

All practical antennas are directional antennas .They have the capable of radiating and receiving electromagnetic radiation through particular directions.

Omni directional radiator

It is a special kind of directional radiator capable of radiating uniformly in the azimuthal plane and having non uniform radiation in the elevation plane

2.1.2 Radiation pattern

It is the locus of received field strength at a fixed far distance as a function of special coordinates. If the received quantity is field strength then it is called field strength. If the received quantity is power then it is called power pattern. If R > $2*(D^2/\lambda)$ then it is called fraunhofer field pattern. Where D is the antenna dimension and the λ is operating wavelength. If R < $2*(D^2/\lambda)$ then it is called reactive near fields [9] these fields are not useful of radiation purpose. Fraunhofer fields are useful for radiation purpose.

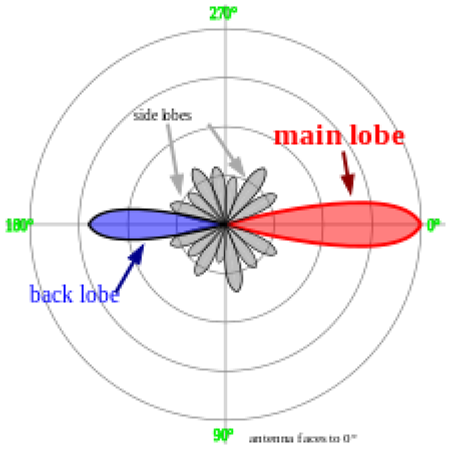


Fig 2.2 Radiation pattern

2.1.3 Average radiation density

It is defined as average power radiated per unit area .This also known as average pointing vector. The power associated with electromagnetic wave is the pointing vector defined as

$$W = E * H \tag{2.1}$$

Where E is the electric field intensity (V/m) and H is the magnetic field intensity (A/m).

The power coming from the closed surface is obtained by integrate the normal component of power density over the closed surface is given by the equation

$$P = \iint W \,.\, ds \tag{2.2}$$

W is instantaneous power density (Watt/m^2) and P is total power crossing in (Watts).

2.1.4 Directivity and gain

Directive gain in a given direction defined as the radiation intensity of practical antenna whose directive gain want to calculate to the radiation intensity of isotropic radiator [9] . The isotropic antenna also called as reference antenna. The reference antenna having unity gain in all directions. The dipole antenna is also used as other reference antenna in measurements and it has the gain of 1.64 compared to the isotropic radiator. The gain of antenna generally measured in decibels (dB).

$$D_g = U/U_0 \tag{2.3}$$

Where D_g is the directive gain, U is an electric field intensity of the test antenna and U_0 is the electric field intensity of isotropic radiator. The relation between the gain and directivity of antenna is given by below equation. The directivity and gain are same when the antenna is 100% efficient.

$$G = e_t D \tag{2.4}$$

Where e_t is the efficiency of the microstrip antenna.

2.1.5 Polarization

The tip of the electric field wave vector traces a patch is called polarization. It is the property of the electromagnetic wave in the time varying direction. Polarization can be defined as received or transmitted wave in a given direction having maximum gain. Polarization is mainly classified in three ways [9]

1. Linear polarization
2. Circular polarization
3. Elliptical polarization

If the electric field vector contained horizontal or vertical component then it is linearly polarized. The phase difference between the components is 180^0 or multiples of 180^0 .In case of circular polarization consist of two orthogonal components having phase difference of odd multiples $(\frac{\pi}{2})$. Based on direction of electric field of wave it can be classified as left circular or right circular polarization. If the magnitude of the orthogonal components are different and the phase difference of two components is odd multiples of ($\frac{\pi}{2}$)then it is elliptically polarized. Based on direction of electric field of wave it can be classified as left elliptical or right elliptical polarization. The wave is like tilted ellipse then the ratio of major to minor axis is called axial ratio. It have range from one to infinite.

Bandwidth

It is defined as the range of frequencies over which the antenna parameters like impedance, polarization, gain, and radiation pattern of the antenna have tolerable values within the band limit.it can is explained on the base of VSWR, gain, and axial ratio bandwidth. If the input impedance is equal to characteristic impedance then it is matched antenna. In case of broad band antennas the bandwidth define based on the ratio of upper and lower frequency bands. If the ratio is 15:1 means that the upper frequency is 15 times more than lower frequency. In the case of narrowband antennas the bandwidth is in percentage of frequency difference over operating center frequency.

2.1.6 Voltage standing wave ratio (VSWR)

It is defined as the ratio of the maximum voltage to minimum voltage of standing wave. It is also known as standing wave ratio.

$$\mathrm{SWR} = \frac{V_{max}}{V_{min}} \qquad (2.5)$$

It is varied from one to infinity. If the load is matched to input impedance then VSWR is equal to 1 and reflections are equal to zero. Any antenna can be accepted when the SWR is less than 2.

2.1.7 Efficiency

It is the ratio of radiated power to the incident power. It is also defined as ratio of power delivered to radiation resistance to the power delivered to loss resistance and radiation resistance.

$$e_{cd} = (P_r / P_{in}) \qquad (2.6)$$

$$e_{cd} = (R_r / (R_r + R_l)) \qquad (2.7)$$

Where P_r is radiating power and P_{in} is incident power. e_{cd} is the efficiency of the antenna.

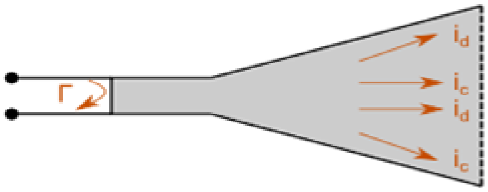
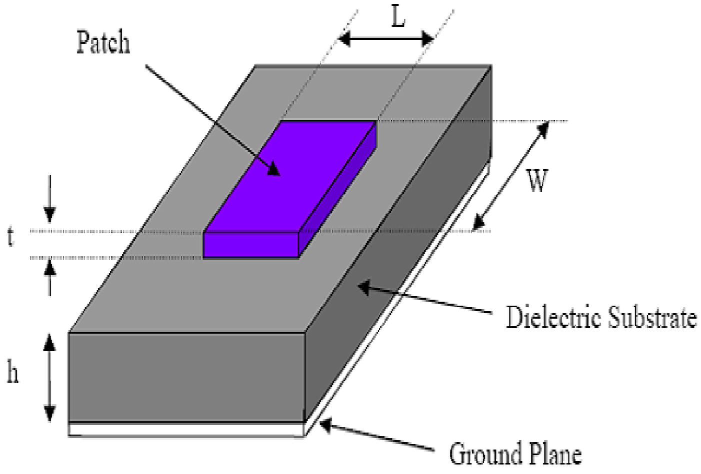


Fig 2.3 Efficiency of antenna

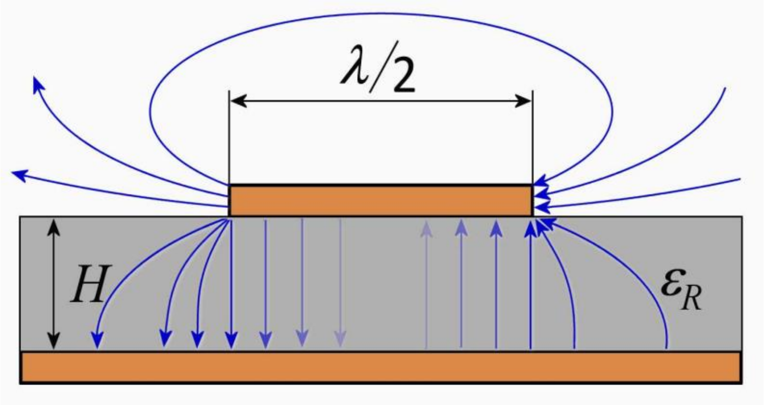
2.2 Microstrip Antenna

The considered microstrip apparatus was started in 1953 [15] and a patent in 1915 .Anyway the microstrip antenna consideration begin in 1970. Microstrip antenna consists of a patch placed on aground plane. The applications where size and weight installation is key requirement we are using the microstrip antennas in automobiles, rockets, space craft and satellite applications [26]. The DRA antennas are 3-dimensional antennas which required more space and bulky in nature. The usage of low cost low size antennas has carried microstrip antennas are using in personal and hand mobiles. They are also called as patch antennas because they have radiating patch. The microstrip antennas mainly consist of radiating patch, ground plane and substrate. The radiating patch is above the substrate and ground plane is below the substrate. The views of the microstrip antennas are shown in the Fig.2.4. The patch is in circular, rectangular, square, elliptical, ring shapes [9] shown in Fig.2.4. The rectangular antennas and circular antennas are regularly using because they can be easily analyzed and fabricated. The rectangular antennas having low cross polarization and smart radiation properties.

They are two type of radiators (1) broadside radiator (2) end fire radiator. In the case of broadside radiator the pattern maximum concentrating normal to the axis of microstrip patch antenna. In the case of end fire radiator the pattern maxim occurred along the axis of microstrip patch. By choosing the configuration of field excitation below the patch the broad side pattern is achieved .by choosing prudent selection the end fire radiation is achieved. The radiating patch and ground plane are separated by dielectric material range from 2.2 to 12.



(a) Microstrip antenna



(b) Side view

Fig.2.4 Microstrip antenna and (b) side view

For good antenna performance we are choosing thick dielectric substrate of low dielectric constant is desirable. The dielectric constant is inversely proportional to bandwidth so low dielectric constant provide high bandwidth and also it provide loosely bounded fields it leads to much radiation into free space. If the dielectric constant is very high and thickness is low it produces tightly bounded fields these are used in applications like microwave circuits and waveguides. Because of high dielectric constant it causes low efficiency more losses and less bandwidth. The microstrip dipoles antennas are smart because they possess larger bandwidth and require less space which can be used in arrays .linear and circular polarization are possible by using single element or arrays of antennas. Different shapes of MPA shown in below figure.

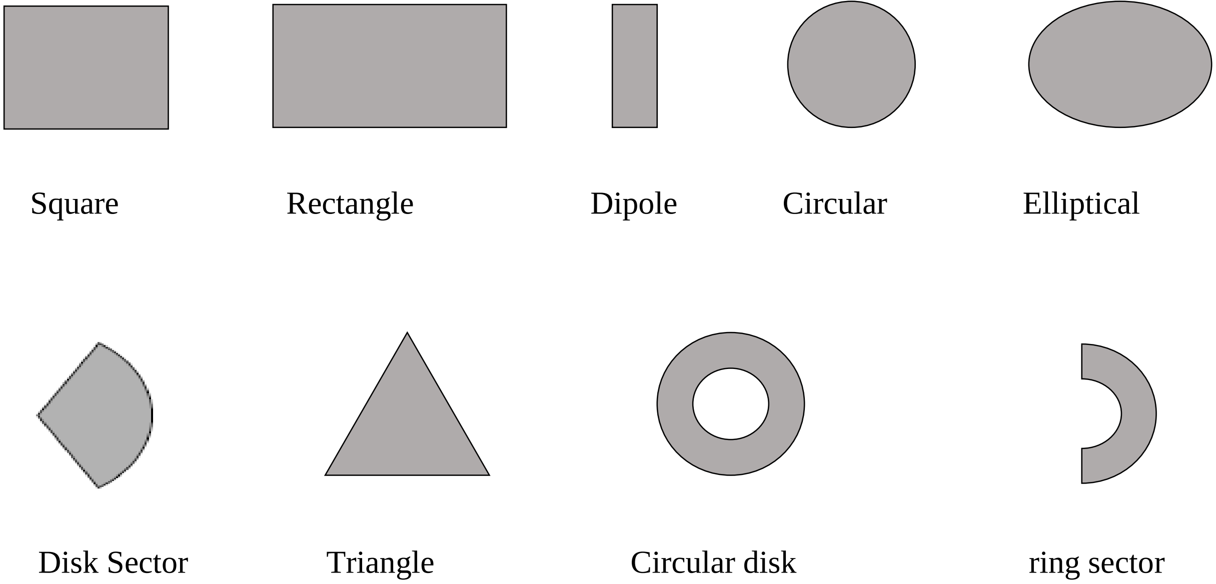


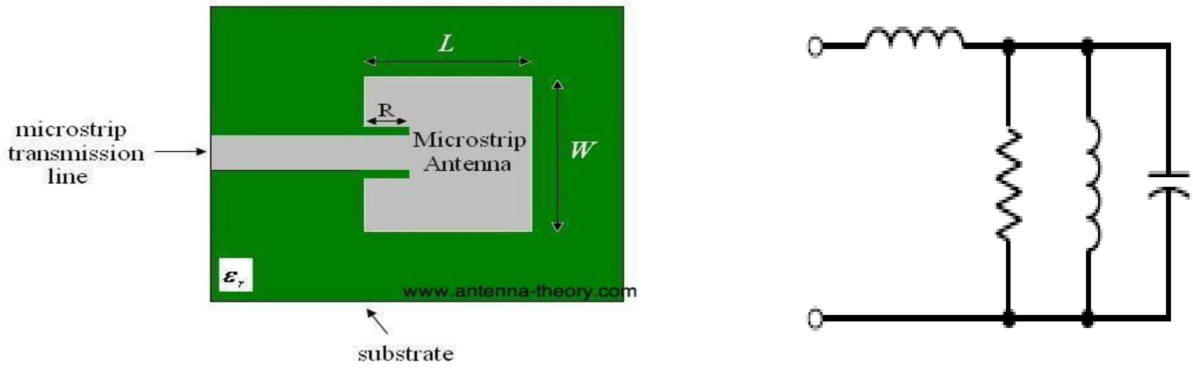
Figure 2.5 Different shapes of microstrip elements.

2.2.1 Feeding Methods

Different feeding methods are exists to feed the microstrip antenna they are given below

1. Microstrip line
   (a) Inset feed
   (b) CPW feed [27] [28]
2. Coaxial feeding
3. Proximity feed
4. Aperture coupling

In microstrip line coupling [9] also called direct coupling because feed line is directly contact with microstrip patch. It can easily fabricate because feed line along with radiating patch placed on the substrate. Impedance matching was not done in the direct method so we are using inset feed method. In inset feed method feed line is inserted to 50 Ω section of MPA patch. This method suffers from spurious radiations and surface waves. The MPA feed line and its equivalent circuits shown in Figs.2.6.

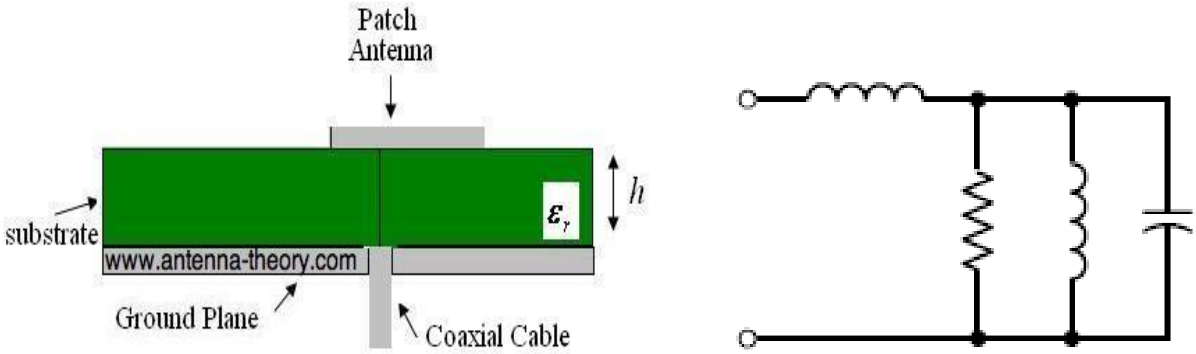


(a) (b)

Figure 2. 6 Microstrip line (a) feed (b) Equ. Circuit of MPA feed

In coaxial probe feeding [9] inner conductor is inserted directly to patch trough ground plane and substrate. The outer conductor connected to the ground plane. In this method impedance matching was easily achieved we can directly inserted to 50 Ω section. It is easy to design but fabrication was difficult because of inserting of inner conductor to the patch.it is has low unwanted radiation. It is having very less bandwidth around (2 ~ 5 %). The coax feed line and its equivalent circuits shown in Figs.2.7.

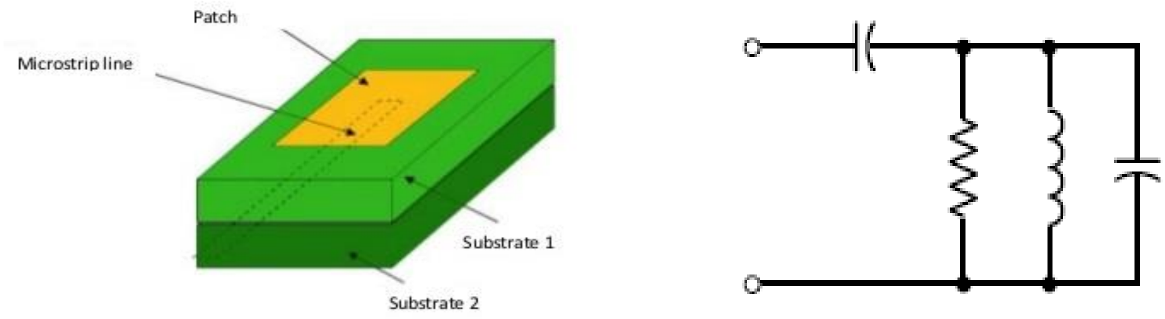
Above two methods [9] are contacting feeding methods which produce generation of other higher modes.



(a) (b)

Figure 2.7 (a) Coaxial probe feed (b) Equu. Circuit of coaxial line

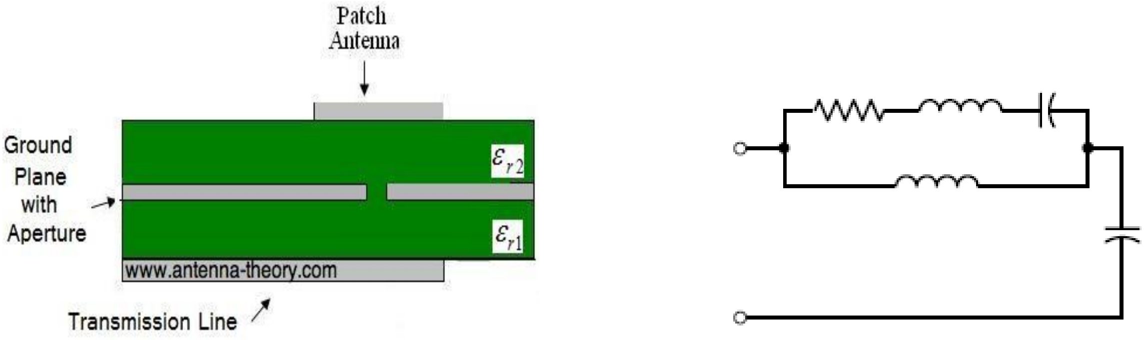
To avoid the above problem we are using non contacting feeding methods. In proximity coupling uses two types of substrates having different dielectric constant. Feed line is placed between the two substrates. Ground plane is placed below the second substrate. In all feeding methods it has high bandwidth around (13 %) achieved. The Proximity feed line and its equivalent circuits shown in Figs.2.8



(a) (b)

Figure 2.8 (a) Proximity coupling (b) Equ. Circuit of proximity coupled

The aperture coupled feed is most difficult to fabricate among four feeding techniques. But, it is easy to model and having less unwanted radiation. In aperture coupling [9] ground plane is placed between the two substrates. To excite the microstrip patch slot was placed on the ground plane and different shape of slots used in this method .Lower substrate is made up of high dielectric constant to provide tightly bounding fields. The upper substrate is made up of low dielectric constant it is liberating the electromagnetic waves into free space. The lower substrate is coupling energy from feed line to MPA patch so thin substrate of high dielectric constant is desirable. The energy coupled depends on the position of feed line and the slot dimensions. The feed having less spurious radiation and it is highly difficult to fabricate among the all methods. It is having less spurious radiation



(a) (b)

Figure 2.9 (a) Aperture coupling (b) Equ. Circuit of Aperture coupled

2.2.2 Analysis of antenna

The general models are cavity model, transmission model, and full wave model. Among all design models transmission model is easy to analyze and less accurate it working on thin substrate. Cavity model is more accurate compare to Transmission line model. The rectangular microstrip antenna by using transmission line model can be treated as an array of two narrow slots each of height H, width W and length of L shown in figure. Full wave models are very accurate, they treat single elements, stacked elements, arbitrary elements, finite and infinite arrays and coupling.

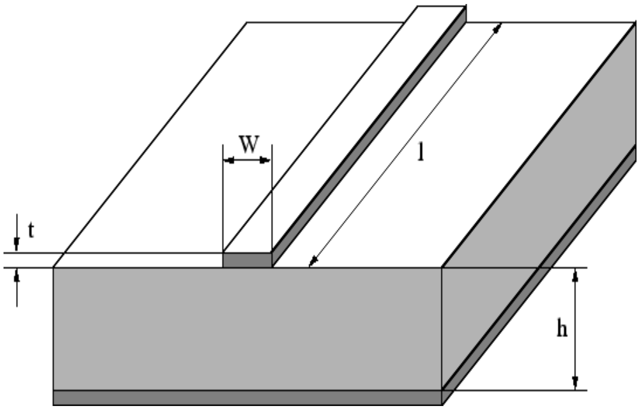


Figure 2.10 Microstrip line

2.2.3 Fringing fields

The dimensions of the microstrip radiating patch are finite along the width and length, the fields undergoes fringing at the edges. The above figure 2.4 (a, b) shows the two radiating slots of the microstrip antenna .The fringing field radiating from the edges mainly depends on the height of the substrate and the dielectric material. Lower the dielectric constant produce more fringing fields [9] and leads to good radiation. The electric field lines shown in the figure 2.11. Fringing fields can travel through substrate and air so effective dielectric constant exist at the edges of the antenna. The effective dielectric constant is nearer to actual dielectric constant and it is a function of frequency.

The effective dielectric constant is range from $1 < \varepsilon_{\text{reff}} < \varepsilon_r$. If the frequency of operation is high fringing fields disappear because electric field line exists inside the substrate. For higher frequency effective and actual values are reaches same value. The variation of $\varepsilon_{\text{reff}}$ with frequency shown in below figure 2.12.

Effective dielectric constant is calculated by using the below equation for W/h >1.

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left(\frac{1}{\sqrt{1 + \frac{12h}{W}}} \right) \qquad (2.8)$$

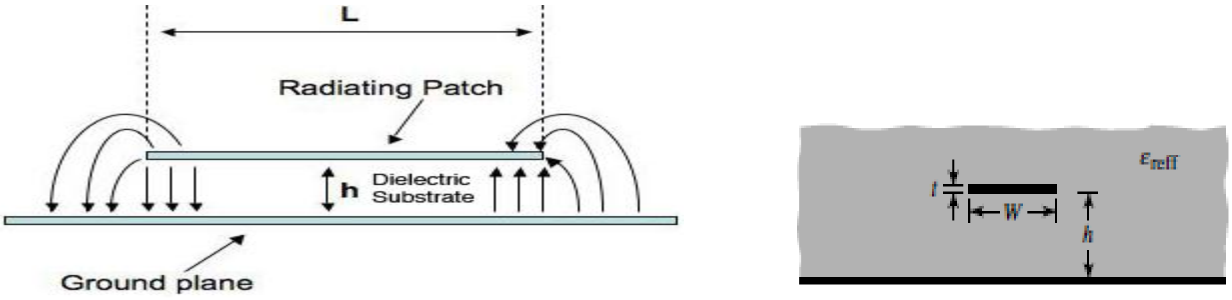


Figure 2.11 Elecric field lines and effective dielectric constant

Where W is width an ‘h’ is height of substrate. The dimensions of patch are calculated by using below formulas. The effective length is increased by a length of ΔL shown in figure 2.16 and it is function of W/h and $\varepsilon_{\text{reff}}$.

$$\frac{\Delta L}{h} = 0.412 \frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)} \tag{2.9}$$

$$L_{eff} = L + 2\,\Delta L \tag{2.10}$$

$$W = (V_0/(2 * f_r))\,(2/\varepsilon_r + 1)^{1/2} \tag{2.11}$$

Where V_0 is velocity of light and f_r is resonating or operating frequency respectively.

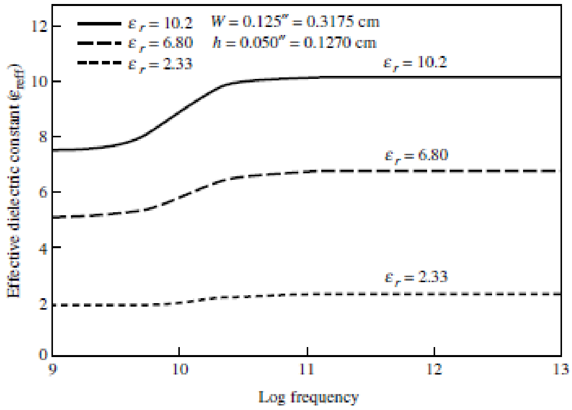


Figure 2.12 Effective dielectric constant Vs Frequency

2.3 Advantages and disadvantages of MPA

Microstrip antenna having more advantages over other microwave antennas .It can be operated wider frequency range, some of advantages [26] given below.

2.3.1 Advantages

(a) Low fabrication cost

(b) Low size, light weight and low volume

(c) Support both liner as well as circular polarizations

(d) Dual frequency antennas

(e) Appropriate for microwave integrated circuits (MICs)

(f) Various excitation techniques

2.3.2 Disadvantages

(a) Low gain (nearly 5 dB)

(b) Narrow bandwidth (5% - 8%)

(C) Low power handling capability

(d) Excitation of surface waves

(e) Low efficiency (due to ohmic and conductor losses)

(f) Polarization purity is less.

2.3.3 Applications

(a) Medical imaging system

(b) WiMAX

(c) Satellite and mobile applications

(d) GPS

(e) Radar applications

(f) RFID

(g) Bluetooth and wireless LAN

Chapter 3

DRA AND INTEGRATING ANTENNAS

Dielectric resonator antenna (DRA) is also called as Dielectric resonator oscillator (DRO). It is a ceramic material of different dielectric constant mounted on a ground plane or substrate. In DRA radiating patch is dielectric material on one side of substrate and ground plane other side. It is a resonating antenna made up of low loss ceramic material of dielectric constant 2 to 100. The DRA were first proposed in 1939 by Richtinger and modes were analyzed in 1960 by Okaya and Barash. The low loss ceramic materials are released for the use of resonators as high quality elements for the operation. The DRAs are characteristically in different shape of materials having permittivity of more than 35 to maintain compactness. If the DRs made with low dielectric constant used in microwave circuits as tuning elements, filters and oscillators .they can be excited by transmission lines. Metallic cavities are the good substitutions they offer reduction in size without deprivation of performance. DRA with dielectric constant 2-100 used in microwave high frequency applications. The high permittivity present at the interface of DRA and free space provide standing waves in the resonator. S.A.Long presented in the year of 1983 DR as a radiating element [29]. The basic shapes of DRA are cylindrical, hemispherical, and rectangular [6]. Usually rectangular shape is used because the analysis and design of rectangular shape is relatively easy. The DRA having wider bandwidth compare to microstrip antenna around 10% when dielectric constant is 10. The microstrip antenna radiating through narrow slots but in case DRA radiates total surface except the DRA on the ground plane. Many features of DRA and microstrip antenna are same because both have the resonant cavities. If we want to increase the performance antenna the dielectric constant of substrate or dielectric constant of DRA can be increased but for fabrication the DRA materials are not available. The basic shapes of DRA are shown in the below figure 3.1. Different methods are used to excite the DRA antenna. The examples are microstrip line, slot line, coaxial line, coplanar feed, conformal strip, aperture coupling with MPA line, proximity coupled MPA line, and image waveguide methods [30]. The feed line is a microstrip line having the impedance of 50 Ω. These methods described by Bhartia and Mongia in 1994 later aldo petosa in 2007 [14], [15].

Figure 3.1 Basic shapes of DRA

3.1 Characteristics of DRA

(1) The DRA size is proportional to $\lambda_0/\sqrt{\varepsilon_r}$ where ε_r is the dielectric constant and λ_0 is the operating free space wave length.

(2) The operating resonant frequency and quality factor are effected by aspect ratio of DRA for a particular dielectric constant.

(3) The dielectric constant of 8 to 100 can be used over a wide range of frequencies. It allows the user to control over size and bandwidth of DRA.

(4) The DRA can be operated over a range of frequencies from 1.3 GHz to 45 GHz.

(5) By properly choosing the dielectric material of low loss features, high radiation can be achieved, due to non-presence of conductor and surface wave losses

(6) Many feeding methods are available to excite DRAs, making them cooperative to integration with existing methods

(7) DRAs having higher bandwidth compare to microstrip antennas

(8) Different modes excited in the DRA which radiate similar to magnetic or electrical dipole and producing radiation pattern like Omni directional or broad side radiation patterns.

3.2 Advantages and limitations

DRA has several features which made it very useful elements over a wide operating frequency range. Dielectric material has low loss it provide high radiation efficiency which is very important feature in a mobile unit for power saving. Compare to other geometries rectangular DRAs [31] are more appropriate and more flexible due to independent aspect ratios. By considering dielectric constant 10 easily 10 % of bandwidth achieved. To improve the bandwidth of DRA many methods are developed like stacked DRA, embedded DRA and array DRAs. To get chosen dielectric constant is very difficult to get so we have to work on limited sources. Fabrication of antennas is difficult and costly compared to PCB antennas

3.2.1 Applications

DRA used in electronics missiles, radar and warfare communication systems. In modern communication applications ultra-wide band DRA operation is desirable to provide the high data rates necessary for the services like direct digital broadcast, video conferencing, EHF portable satellite communication, multipoint communication and wireless indoor communication [30] . They can be used in burglar alarms, biomedical radars and military applications. The bands X, Ku, K and Ka bands are used for satellite communication from (8-40 GHz).

3.3 Feeding methods

To energize the antenna feeding techniques are used. Several methods to excite the DRAs like microstrip line, coaxial probe, coplanar lines, dielectric image wave guide, aperture coupling and proximity coupling [30]. To excite the DRA energy coupled through one or more ports by feed line. Electrical source or magnetic source should be placed where the field strength maximum. Aperture and proximity coupling methods are used to improve bandwidth.

3.3.1 Aperture coupling

The DRA is excited through slot presented in the ground plane. It can be appropriate for any shapes of DRA like rectangular, hemispherical and cylindrical. The slot (aperture) works as a magnetic current running parallel to length of the slot. It excite the electric or magnetic field in the DRA. The microstrip line presented below the ground plane it excite DRA through narrow slot. It is a smart technique for DRAs integrated with printed structures. The coupling level depends on position of DRA with reference to slot. Spurious radiation is less because the feed line is below the substrate. Low dielectric constant and thick dielectric material is used for top substrate.

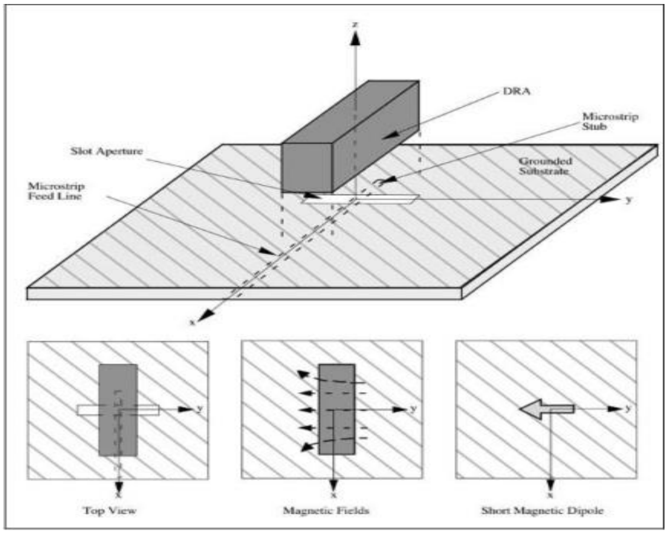


Figure 3.2 Aperture coupling

3.3.2 Proximity coupling

Two substrates of different dielectric constant are used and DRA is located on the upper layer. This is electromagnetically coupled feed because there is no physical contact between the feed line and ground plane. The feed line is placed between the two substrates. Thickness of the antenna is increased because of two substrates and fabrication is difficult. This method improves the bandwidth and suppression of higher modes. This feeding also called as non-contacting feed.

3.3.3 Microstrip line

The radiating patch and feed line exist on the same side of substrate. The microstrip line [30] is directly connected to the edge of DRA antenna. By varying the position of microstrip line and spacing between the DRA energy couplings can be varied. Amount of coupling depends on the permittivity of DRA. Dielectric constant is high amount of coupling is higher. Fabrication of these method is easy. If the thickness of substrate increases surface waves and spurious radiation increases. So for good antenna performance thin dielectric substrate is desirable.

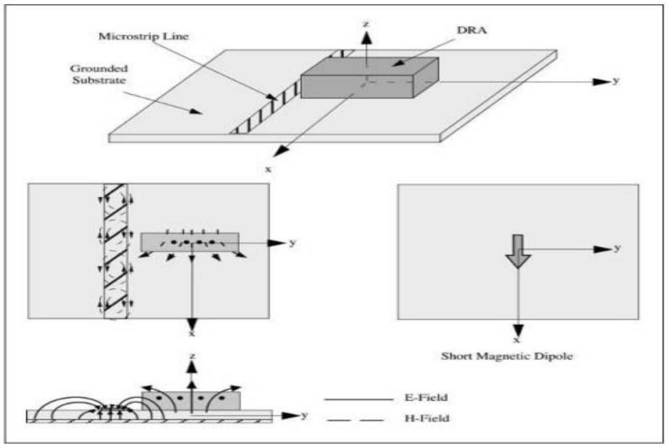


Figure 3.3 Microstrip line coupling

3.3.4 Coaxial probe

Commonly used method to excite DRAs. It excites the magnetic field in the DRA. The inner conductor of coaxial probe is attached to back side of DRA and outer conductor attached to ground plane. Coupling energy depends on probe height and location of DR. Without need of a coupling network we can directly couple to 50 Ω section.

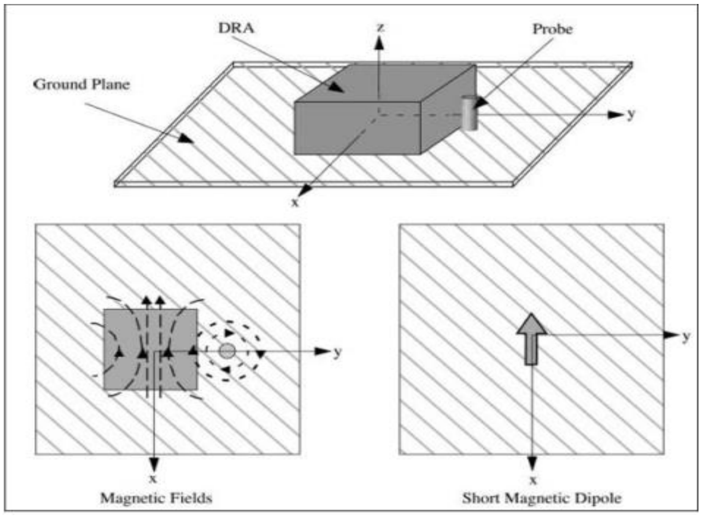


Figure 3.4 coaxial probe coupling

3.3.5 Image guide feed

This method is like microstrip line but dielectric material is used as a feed line. Image wave guide method [30] have advantages at millimeter frequencies, because they do not have conductor losses. The coupling depends on the spacing between the DRs and the guide. In liner array of DRAs it is used as a series feeder.

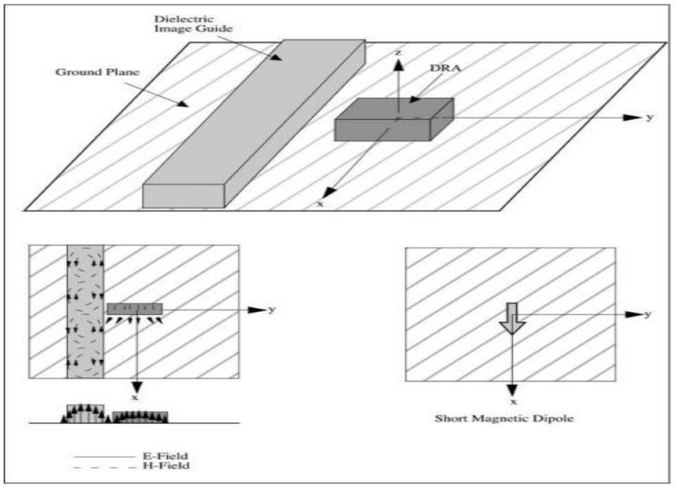


Figure 3.5 Image guide feed coupling

3.4 Integration of antennas

Mainly four methods on integration of antennas these are also called hybrid antennas.

(1) Micro strip antenna integrated with DRA

(2) DRA antenna integrated with DRA

(3) Microstrip integrated with microstrip

(4) DRA integrated with DRA antennas.

These antennas mainly used in cognitive radios. In cognitive radio two antennas are required one antenna is used for sensing the spectrum and another antenna a used for communication operation [32]. Wide band microstrip integrated with narrow band microstrip antenna [33] shown in the below figure in this antenna microstrip antenna is used for sensing the whole spectrum from 3.1 GHz to 10.6 GHz [5] and the tapered shape microstrip antenna used for communication operation. In the case of Microstrip antenna integrated with DRA anteena, the microstrip antenna will provide ultra-wide band and DRA [34] antenna is provide narrow band for communication. The microstrip antenna having elliptical base with rectangular patch provide wide band operation .The DRA is rectangular in shape excite in back side to provide narrow band. The primary idea is to utilize one radio antenna or a piece of it is a feature of extra receiving antennas. Along these antennas an area of one antenna can be integrated with another antenna. For example a receiving wire with generally expansive metallization region can be utilized as a ground plane for an extra reception apparatus which accommodates huge ground plane.

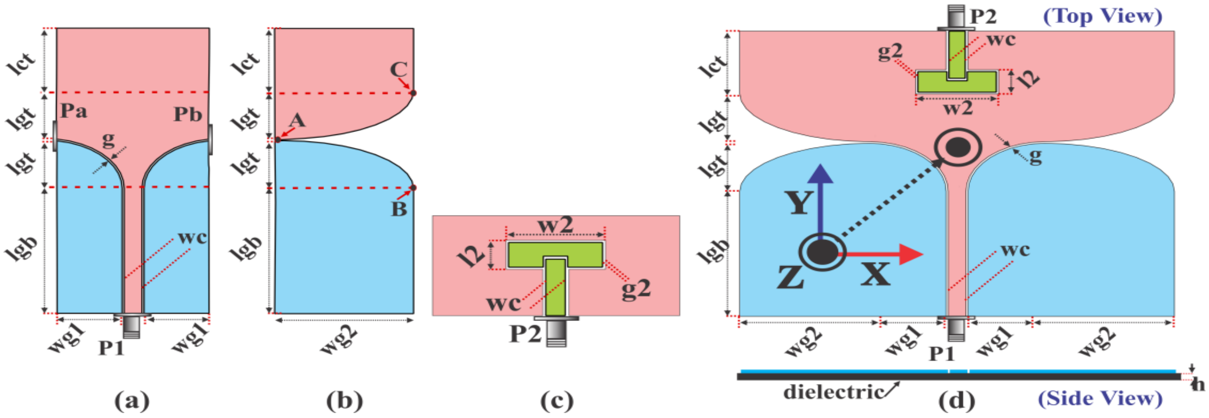


Figure 3.6 Microstrip integrated with microstrip

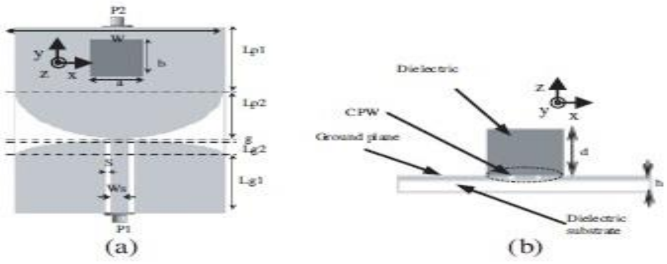


Figure 3.6 Microstrip integrated with DRA

Contingent upon the application and measure of accessible space, the second receiving antenna can be chosen from an extensive variety of radio wires, for example a vertical routine monopole ,or extremely mainstream rearrangement L or F reception apparatus or an opening radio antenna [34] along others. A segment of one receiving antenna can be likewise be utilized as parasitic components or reflections for the other reception antenna. Accordingly this strategy offers an assortment of mixes to effectively use the space. This reconciliation strategy can be connected to different sorts of receiving antennas including printed reception apparatuses to incorporate more administration in the constrained space particularly for little versatile devices. For an effective integration the operation standards of every receiving antenna ought to be considered. Essentially, so as to ambiguity plan complex nature the collaboration between the reception apparatus segments ought to be considered.in the following section the outline methods of wide band –narrowband receiving antenna will be investigated.

Chapter 4

Microstrip antennas integrated with DRA

This chapter contains design of semicircular- semi hexagon microstrip patch antenna integrated with cylindrical DRA antenna is presented. The designed microstrip antenna consist of 39mm×38mm×.05mm on a fiber glass rein forced epoxy (FR4) dielectric substrate. This antenna covers the total UWB range (2.58 GHz to 14 GHz).The narrow band DRA is cylindrical in shape made up of RT -6002.

4.1 Semi hexagon – semicircular microstrip integrated cylindrical DRA for UWB and cognitive radio applications

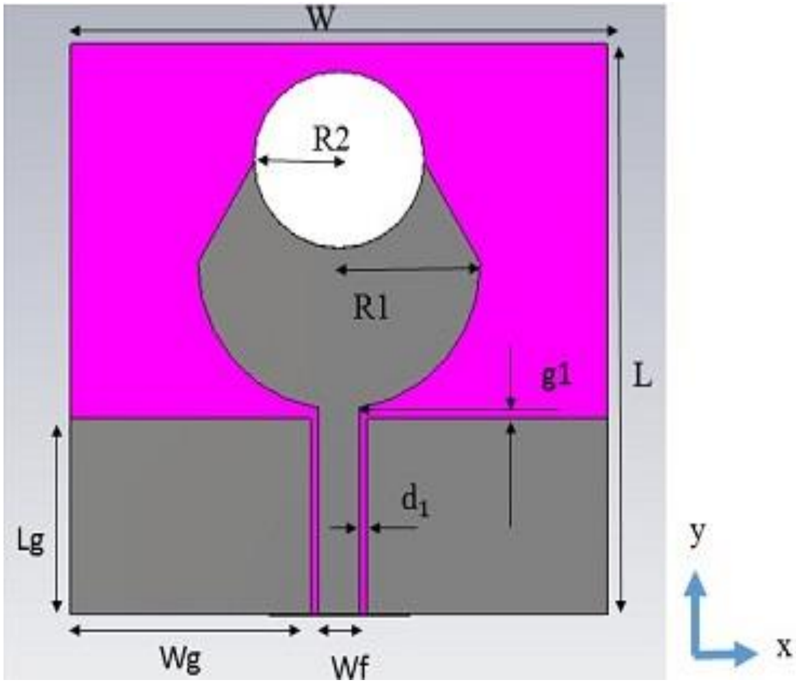


Figure 4.1 Geometry of antenna

4.1.1 Geometry of antenna

The planner semicircular-semi hexagon antenna integrated with DRA is shown in the above figure. The microstrip antenna is fed by coplanar waveguide method to detecting the range from 2.58 GHz to 14 GHz. The DRA is excited by a slot present on microstrip patch antenna which works from 10.07 GHz to 11.38GHz. The slot energizes HEM mode which display narrow band characteristics. The suggested design provides great isolation among the two antenna ports.

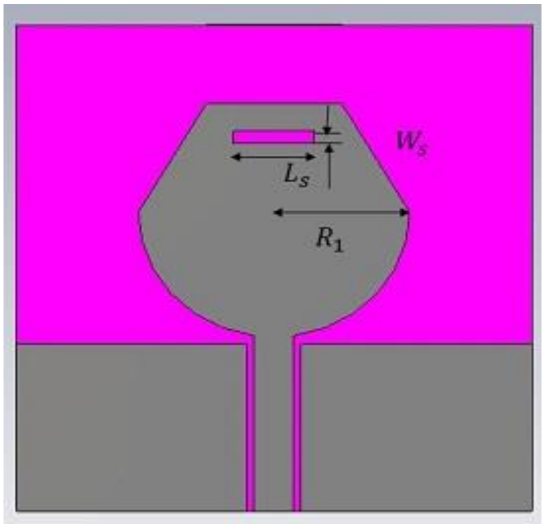


Figure 4.2 Microstrip without DRA

Port 1 CPW feed with 50 Ω character stick impedance. Port 2 aperture feed having 50 Ω impedance on back side. The design is presented on FR-4 substrate. It is having ε_r= 4.4, thickness of 1.6 mm and loss tangent tan δ =.025.The final dimension of antenna are L =39mm, W = 38mm, R_2 =6mm, W_f =2.9mm, W_g =17mm, W_s =1mm, H_d =5mm, d_1=0.55mm, W_{f2} =1.5mm, L_g =13.4mm, $L_s = 6$ mm, g_1=0.4mm, Hs=1.6mm, L_f =14mm.

4.1.2 Simulation Results

The simulation was done by CST microwave studio .The reflection coefficient of antenna plotted Vs frequency in figure 4.4. Figure 4. 4 demonstrate that the MPA have impedance width of 151.83% and covers (S_{11}< -10 dB) from 2.58 GHz to 14 GHz. The DRA works at 10.6 GHz having the impedance width of 12.30% and covers (S_{22} < -10 dB) from 10.07 GHZ to 11.38 GHz. The DRA is used for 'X' band applications. The integrated antenna used in the cognitive radio by using the filter section at receiver or in the feed line. The transmission coefficient shown in figure 4.5. It shows that both ports are isolated perfectly. The S_{11} parameters are varying by vary the ground length shown in the figure 4.6.

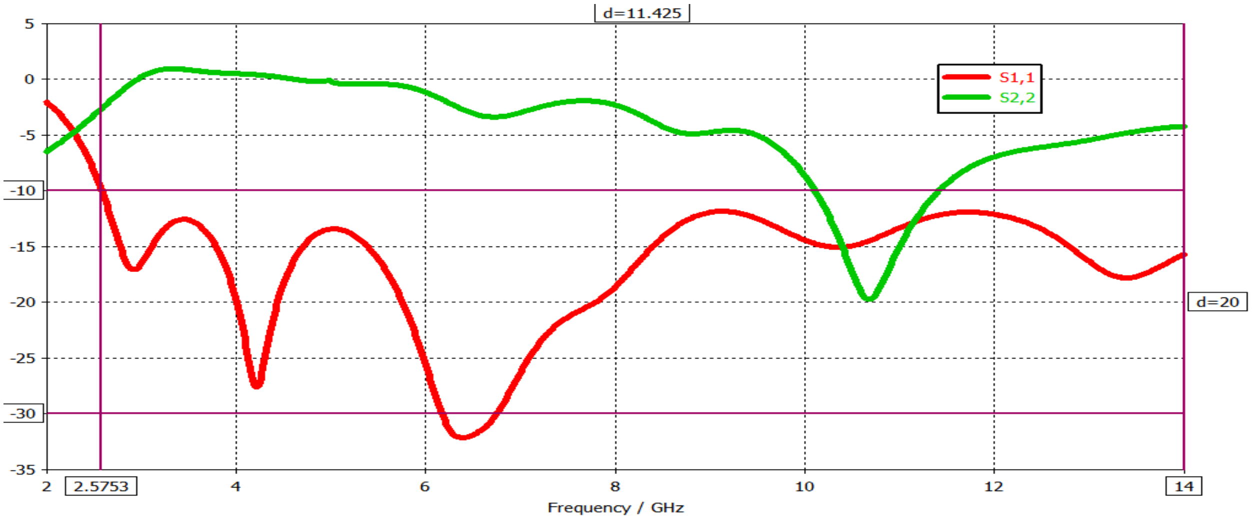


Figure 4.3 Reflection coefficient Vs frequency of integrating antenna

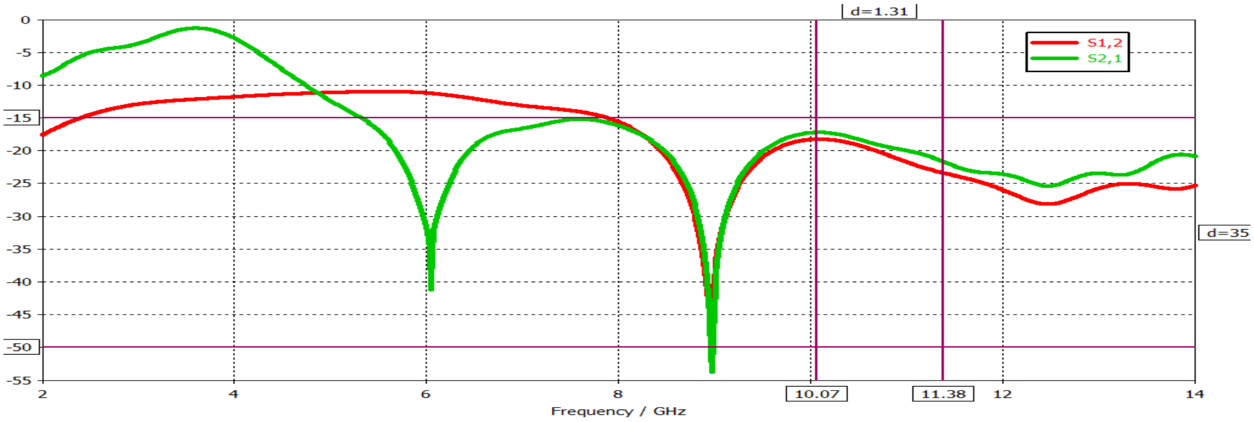


Figure 4.4 Transmission coefficient Vs frequency of integrating antenna

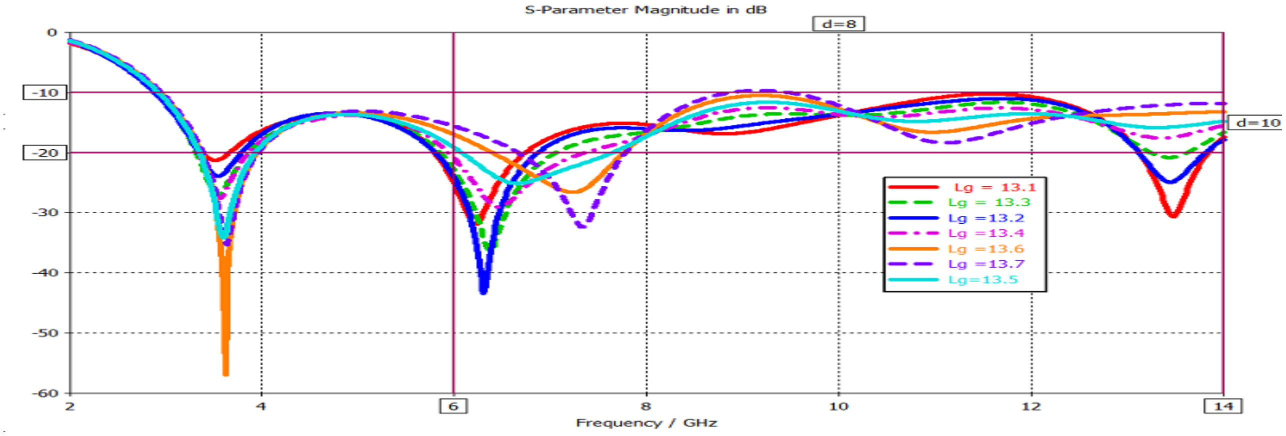
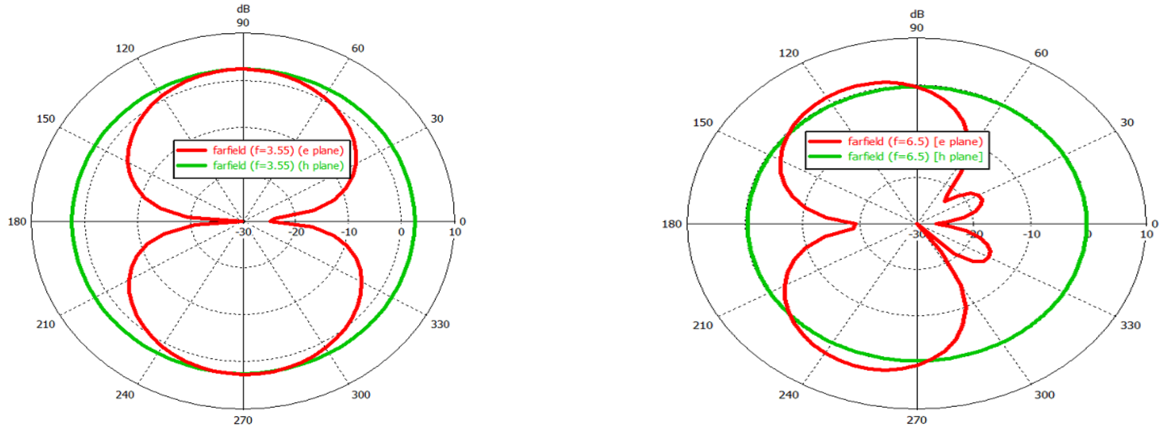


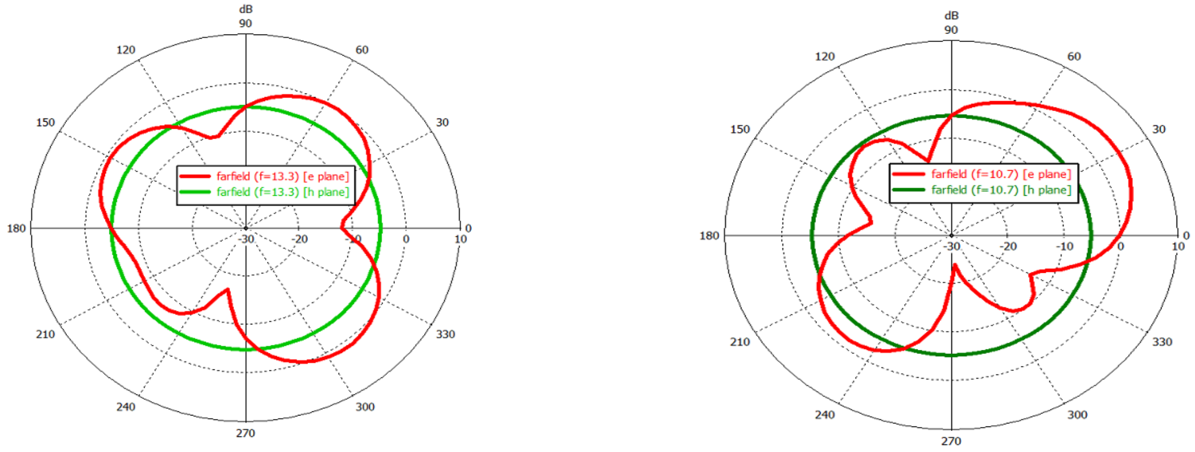
Figure 4.5 Reflection coefficient Vs frequency for different Lg values

The 2 -dimensional radiation pattern of antenna in E plane, H plane at different resonant frequencies shown in the figure 4.7.when port 1 is excited port 2 is shot with 50 Ω impedance. H plane exhibits omnidirectional radiation pattern whereas E plane exhibit broad side pattern. The gain and directivity of microstrip antenna, DRA shown in the figures 4.8, 4.9 respectively.



(a) (b)

Figure 4.6 Radiation pattern of microstrip antenna at (a) 3.55GHz (b) 6.5GHz



(c) (d)

Figure 4.6 Radiation pattern of MPA at (c) 13.3GHz (d) 10.6 GHz by DRA

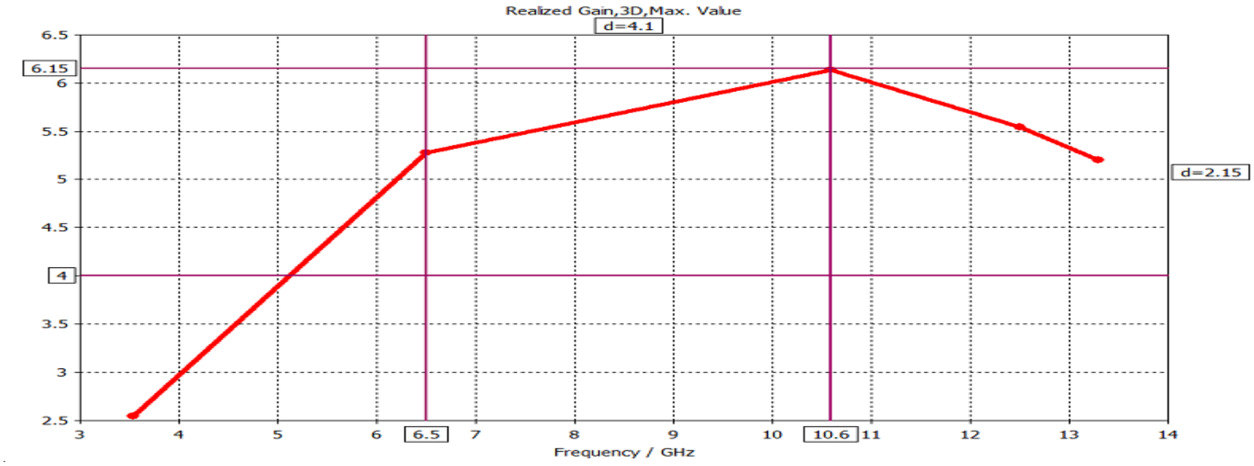


Figure 4.7 Gain of microstrip antenna

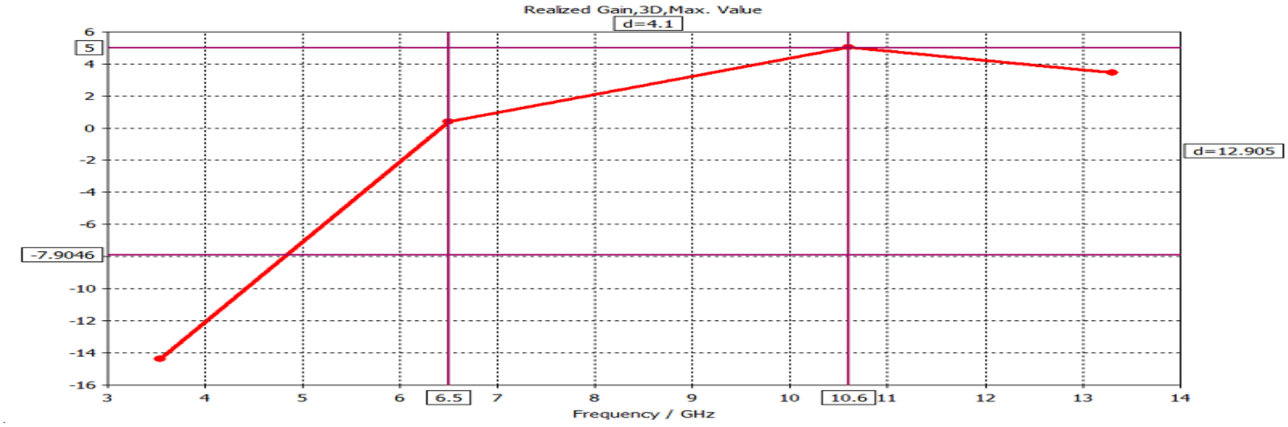
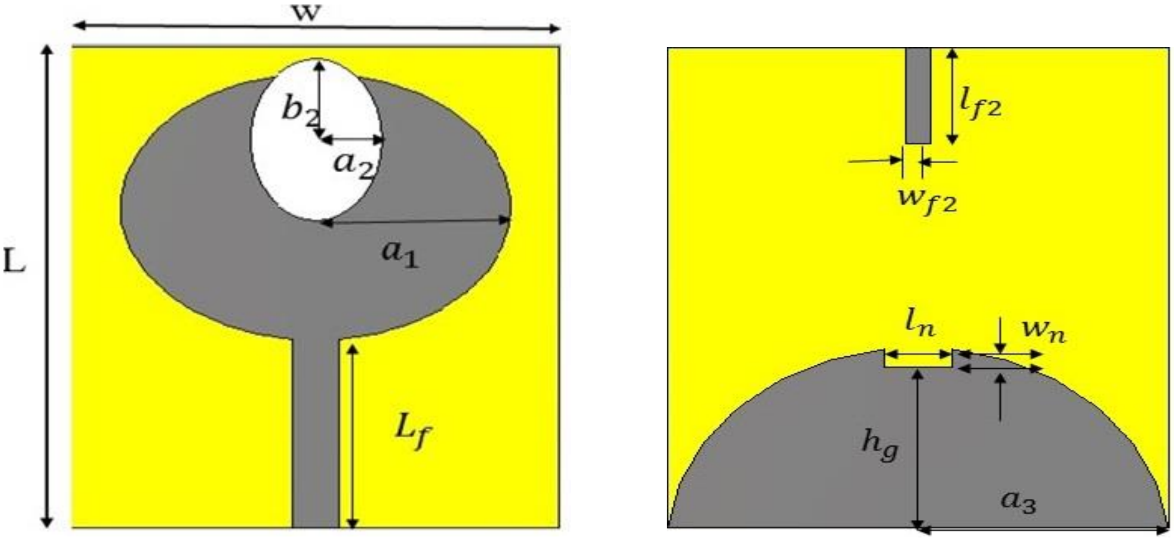


Figure 4.8 Directivity of DRA

4.2 Elliptical microstrip antenna integrated elliptical DRA for cognitive radio applications

In this design the elliptical shape microstrip antenna integrated with elliptical DRA is presented. The designed size of MPA consist 30mm×36mm×.05mm on a FR4 dielectric substrate. This MPA covers the range from 2.5 GHz to 14 GHz. The DRA is elliptical in shape made by RT -6010. The DRA have the dielectric constant of 10.2. The elliptical microstrip antenna integrated with DRA shown in below figure 4.10. The microstrip antenna used to sense the UWB spectrum it covers the band 2.5 GHz to 14 GHz. Aperture slot present on the microstrip patch to excite the DRA. Multi band DRA operates on two different frequencies at 3.6 GHz and 11.4 GHz. The DRA is used for WMAX and X band application. Great isolation exist between the two antenna ports around -13 dB achieved through out the band.



(a) Integrated antenna (b) back view

Figure 4.9 Proposed antenna geometry

The final dimensions of the proposed antenna are given below .The substrate is having thickness of 1.6 mm and dielectric constant of 4.4w= 30 mm, L=36 mm, a_1=12 mm, a_2=4 mm, b_1=10 mm, b_2=6 mm, a_3=13 mm, Hd=5mm, h_g=13.5mm, w_f=2.9mm, lf2=7.2mm, Ln=4mm, Wn=1.5mm, Hs=1.6mmLs=6mm, Ws=1 mm, Hs=1.6mm, Wf2=1.5mm,l_f=14.2 mm.

4.2.1 Simulation Results

The simulation was done by CST microwave studio .The reflection coefficient of antenna plotted Vs frequency in figure 4.11. Figure 4. 11 demonstrate that the MPA have impedance width of 170% and covers ($S_{11} < -10$ dB) from 2.5 GHz to 14 GHz. The DRA operates at 3.6 GHz and 11.6 GHz. It have impedance width of 30 % ($S_{22} < -10$ dB) from 10.2 GHZ to 11 GHz. The DRA is used for WiMAX and 'X' band applications. The integrated antenna can used in the cognitive radio by placing the filter section at receiver or in the feed line. The transmission coefficient shown in figure 4.12. It shows that both ports are isolated perfectly. The S_{11} parameters are varying by vary the ground plane length values shown in the figure 4.12.

By varying the radius of elliptical antenna how the S_{11} parameters varying shown in the figure 4.13. The 2 -dimensional radiation pattern of antenna in the H plane, E plane at resonant frequencies are shown in figure 4.14. The port 1 is excited with microstrip line coupling at that time port 2 is sort with characteristic impedance.

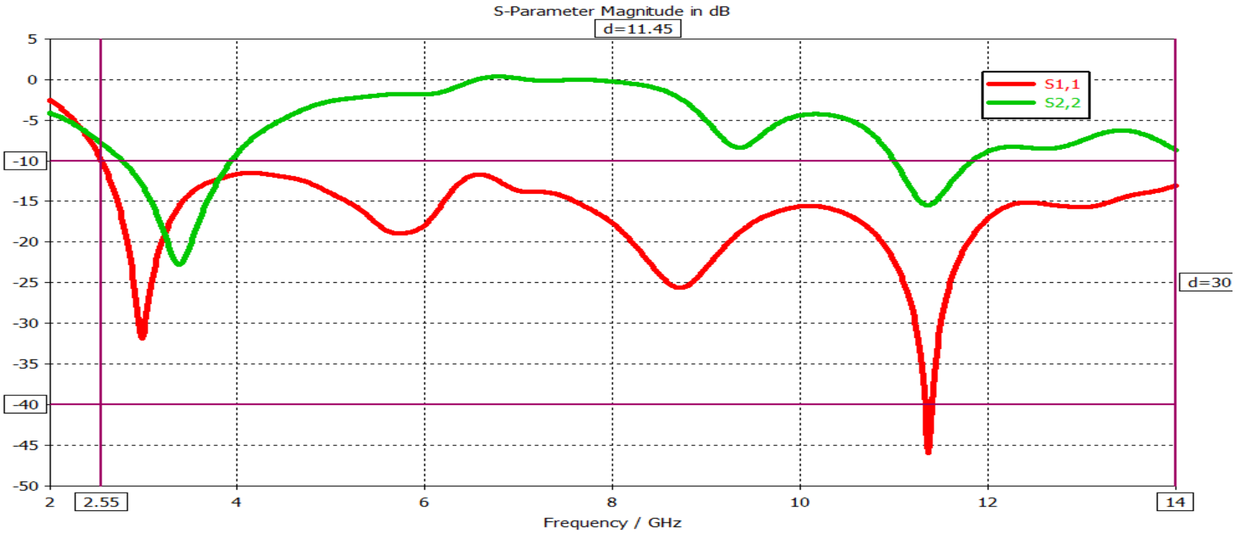


Figure 4.10 Reflection coefficent Vs frequency of integrated antenna

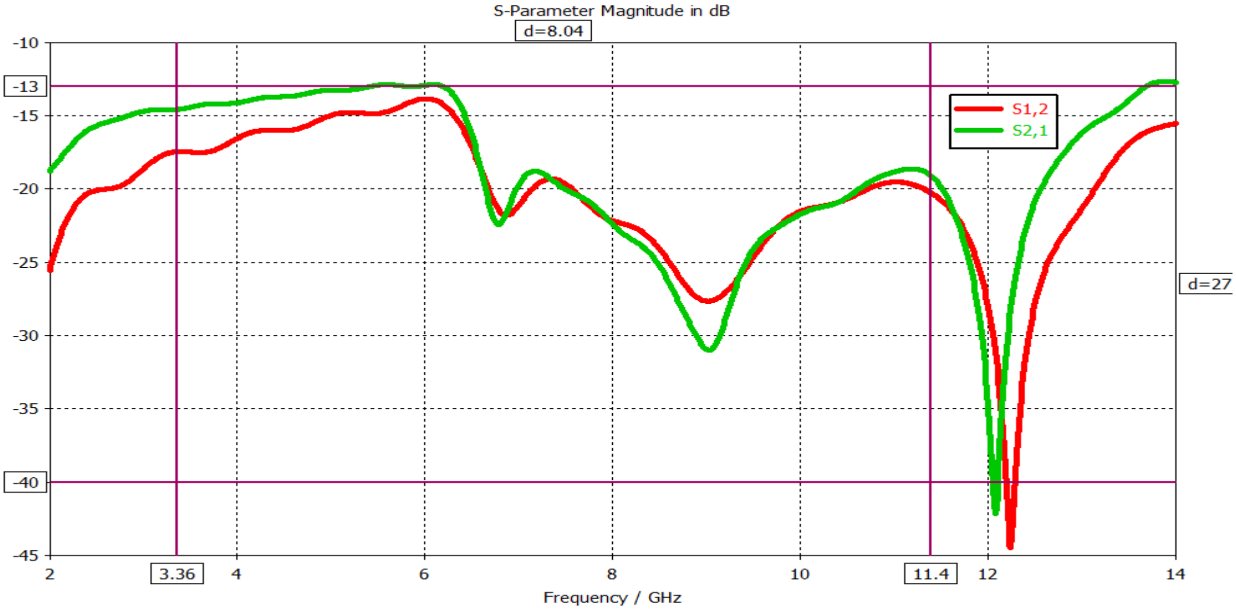


Figure 4.11 Transimission coefficent Vs frequency of integrated antenna

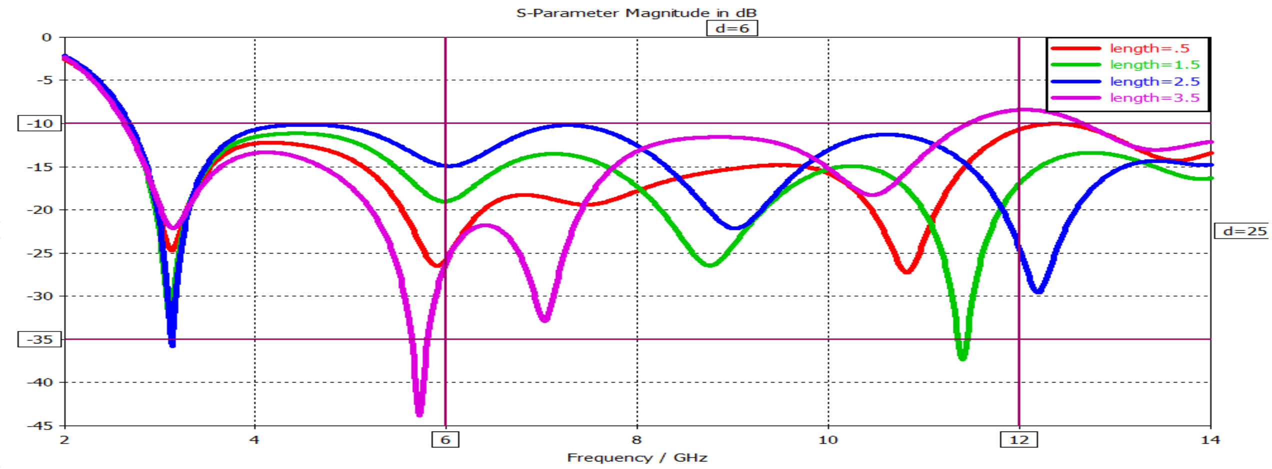


Figure 4.12 Reflection coefficent Vs frequency by varying ground length

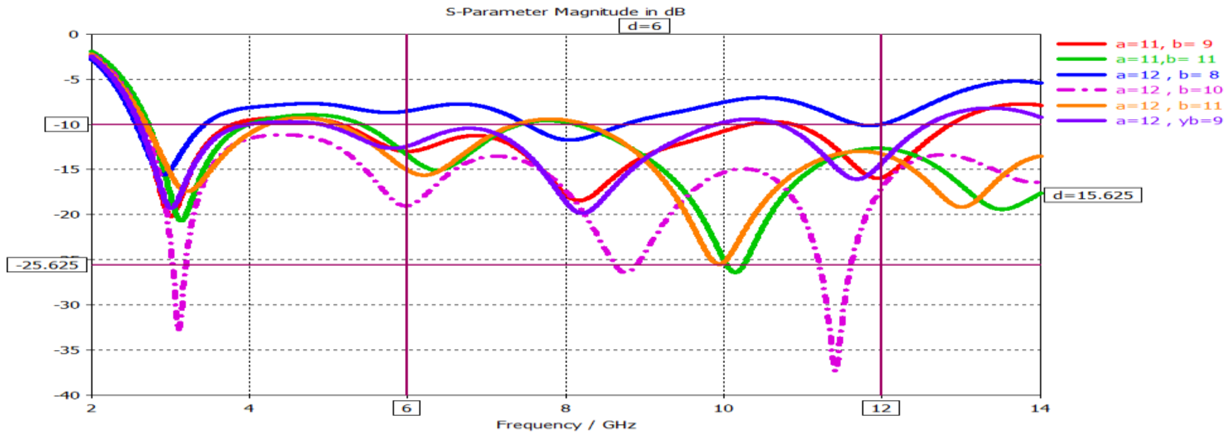
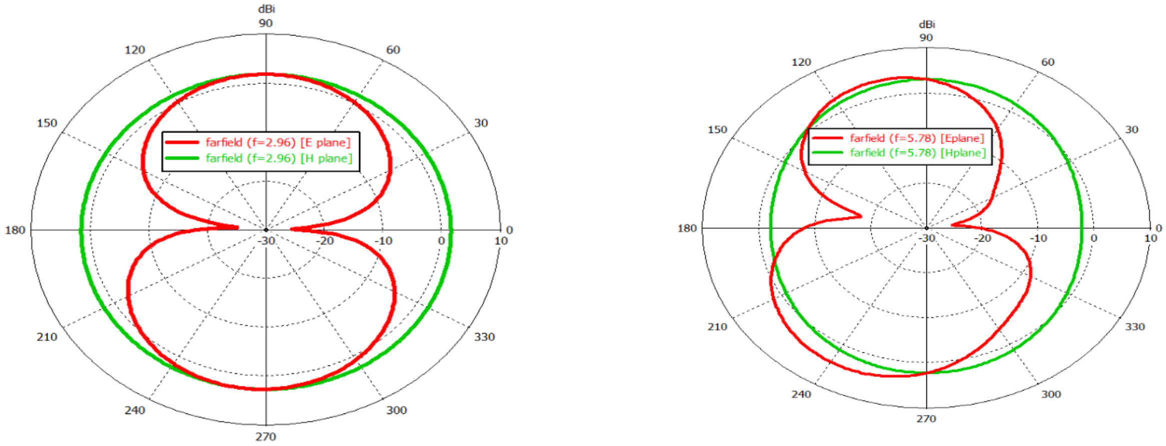
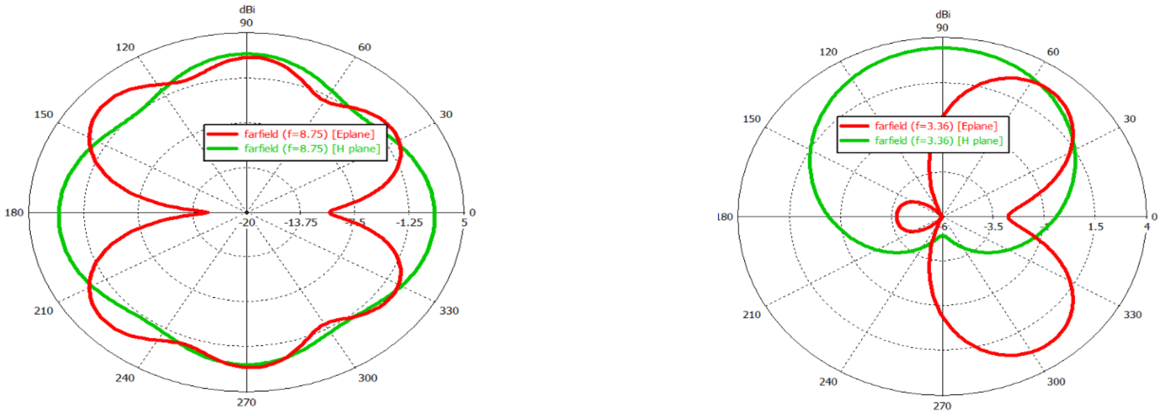


Figure 4.13 Reflection coefficient Vs frequency by varying ground length



(a) (b)



(c) (d)

Figure 4.14 Radiation pattern (a) 2.96 GHz (b) 5.78GHz (c) 8.75 GHz for microstrip antenna (d) 3.36 GHz by DRA

The gain of the integrated antenna is shown in the figure 4.15. The figure shows that the gain maximum of 6 dB achieved. The directivity of integrated antenna shown in the figure 4.16. The figure demonstrations that the maximum directivity of 6.25 achieved.

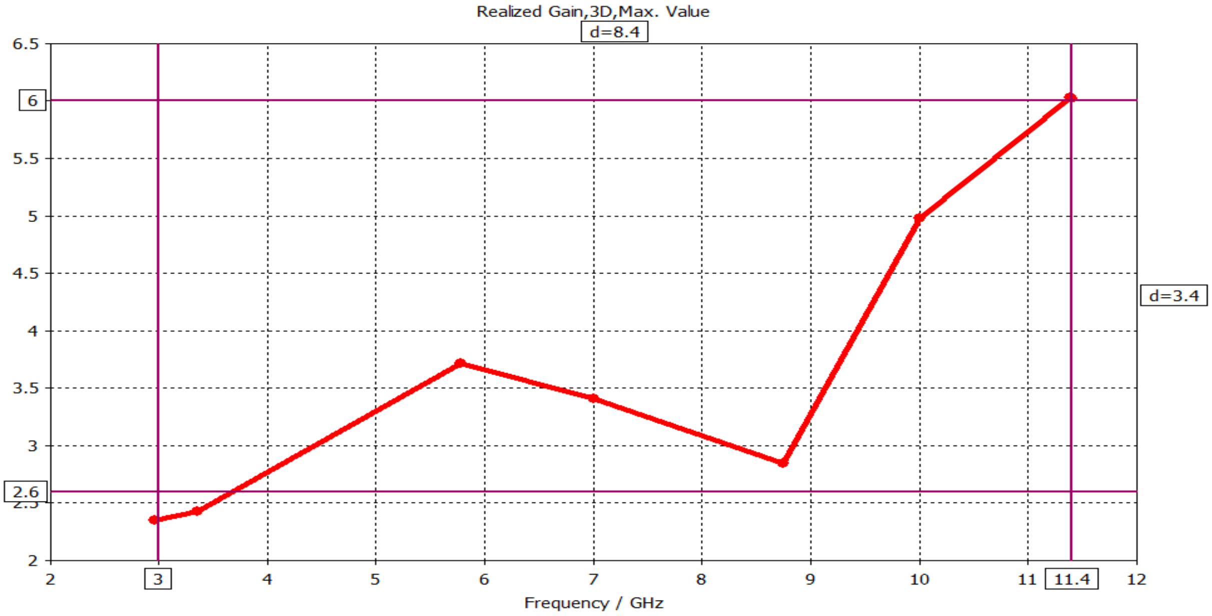


Figure 4.15 Realized gain of integrated antenna

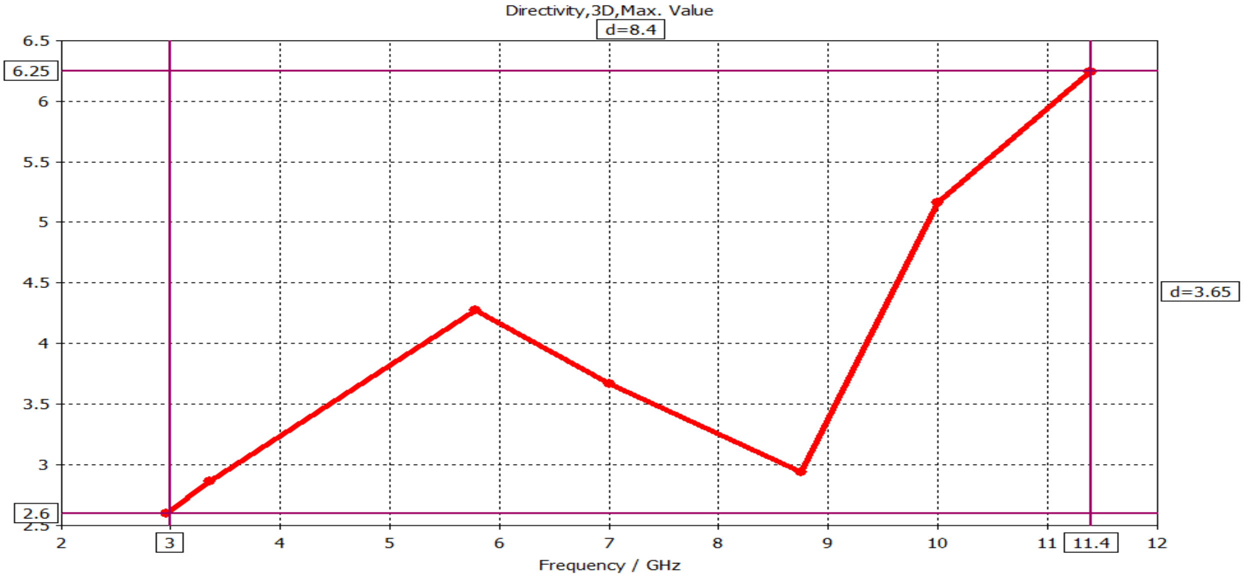


Figure 4.16 Directivity of integrated antenna

4.2.2 Summary

Semicircular-semi hexagon microstrip antenna integrated with DRA is presented for cognitive radio applications are presented. The microstrip antenna provides ultra-wide band and DRA antenna provides narrow band i.e. X band applications. Similarly elliptical microstrip antenna integrated with elliptical DRA presented for CRs applications. The proposed designed is 15 % reduced size compared to existing designs and it operates in two bands one is for WiMAX applications and other band for 'X' band applications. Proposed design used in cognitive radio by using filter section at the receiver.

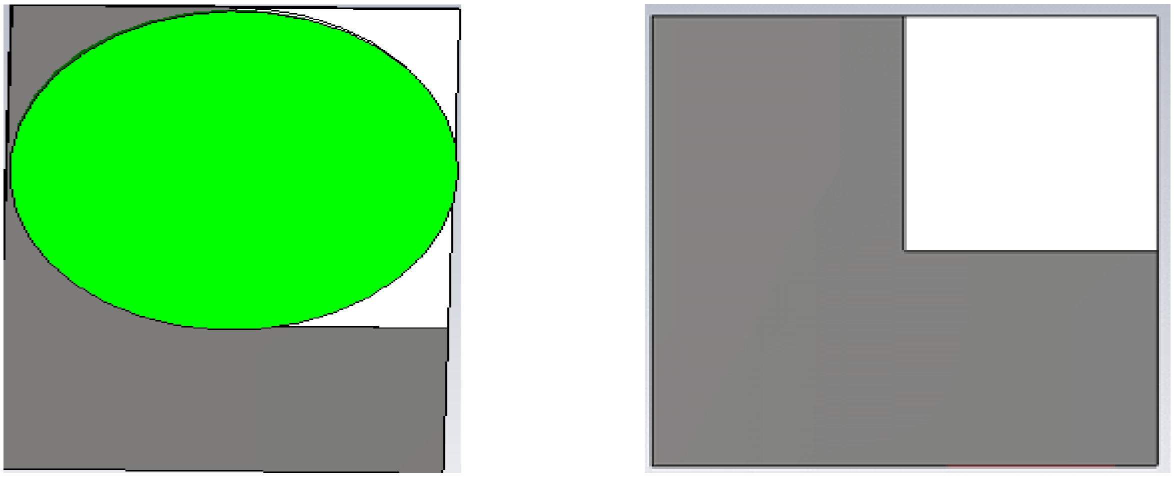
Chapter 5

The Ultra-wide band DRAs

This chapter containes design of DRA antennas for ultra wide applications. Compare to microstrip antennas DRAs having high impedance band width and high radiation efficiency. A new bond notch DRA is designed to avoide the interference with the exixting applications like WiMAX and WLAN.

5.1 Design of cylindrical DRA for UWB

In this design the cylindrical DRA is presented for UWB applications. The designed size of substrate is 24mm× 23mm×2.5mm made up of RT-5880. It is having thickness of .8 mm and dielectric constant of 2.2. The DRA antenna covers the total ultra-wide band from 3.5 GHz to 11.8 GHz. The DRA is semi cylindrical in shape made up of RO-3010 with dielectric constant of 10.2 and having the thick ness of 2.5 mm. The DRA is excited by proximity coupled method shown in below figure. At first the cylindrical DRA is designed after the size reduction and bandwidth enhancement done by parametric study.



(a) Cylindrical DRA (b) without DRA

Figure 5.1 Proposed antenna

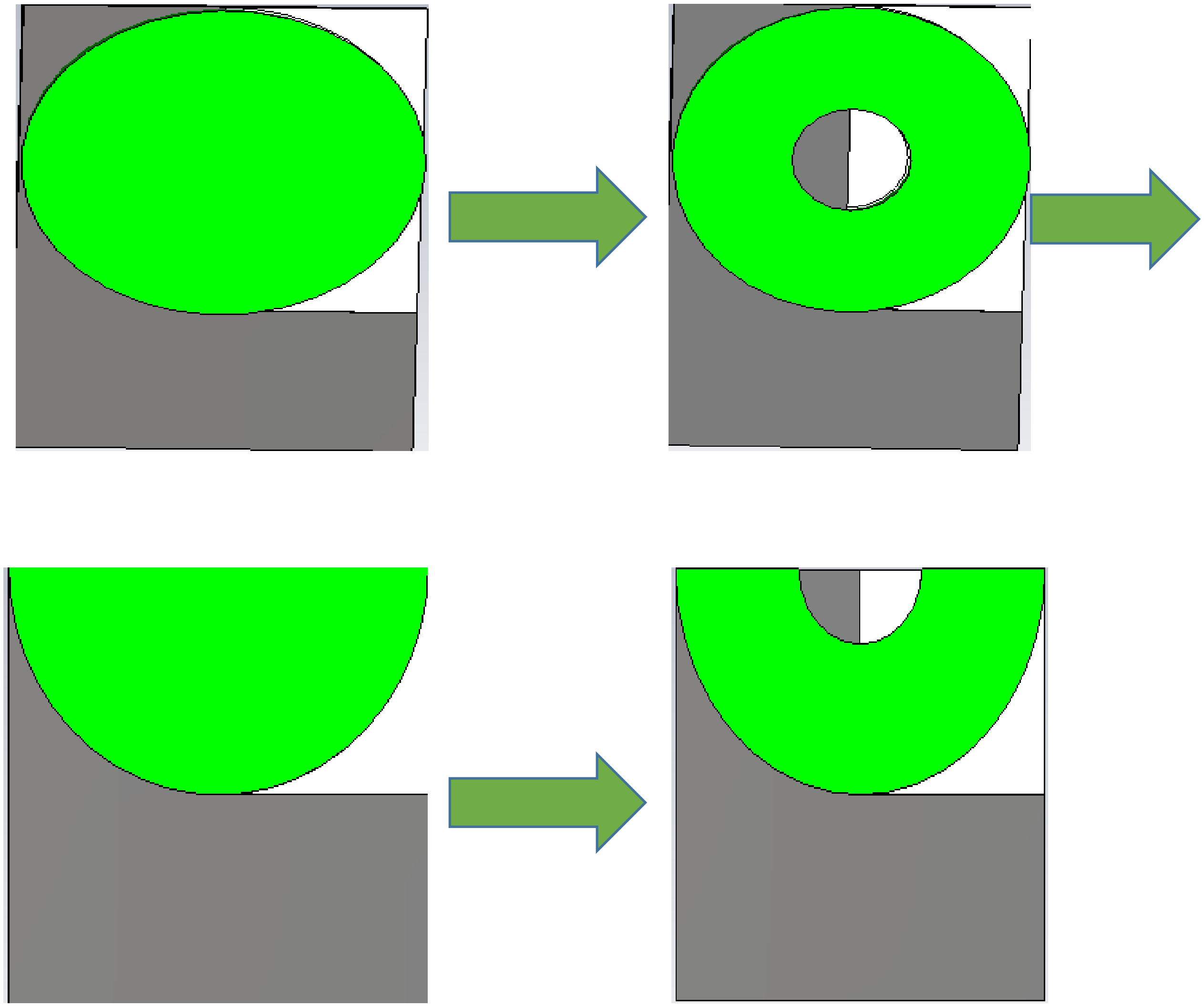


Figure 5.2 Bandwidth enhancement and size reduction

5.1.1 Simulation Results

The simulation was done using CST microwave studio. The above figure 5.1 shows the substrate with and without DRA. The size reduction of the antenna was done shown in the below figure 5.2. The simulated reflection coefficient (S_{11}) of the proposed antenna in plotted Vs frequency in the below figure 5.3. The figure 5.3 shows that DRA have impedance width of 98.77 %, and it covers ($S_{11} < -10$ dB) from 3.5 GHz to 11.8 GHz. The S_{11} parameters are varying by vary the ring radius of cylindrical DRA shown in the figure 5.4. By varying the ring radius of semi-cylindrical DRA antenna, the S_{11} parameters are varying shown in the figure 5.5. The 2 -

dimensional pattern of the radiation of the proposed antenna in the H plane, and E plane are shown in the below figure 5.6. The realized gain of the DRA antenna is shown in the below figure 5.7. The below figure shows that the gain maximum 5 dB achieved. The directivity of proposed antenna shown in the below figure 5.8. The figure demonstrations that the maximum directivity of 4.75 achieved.

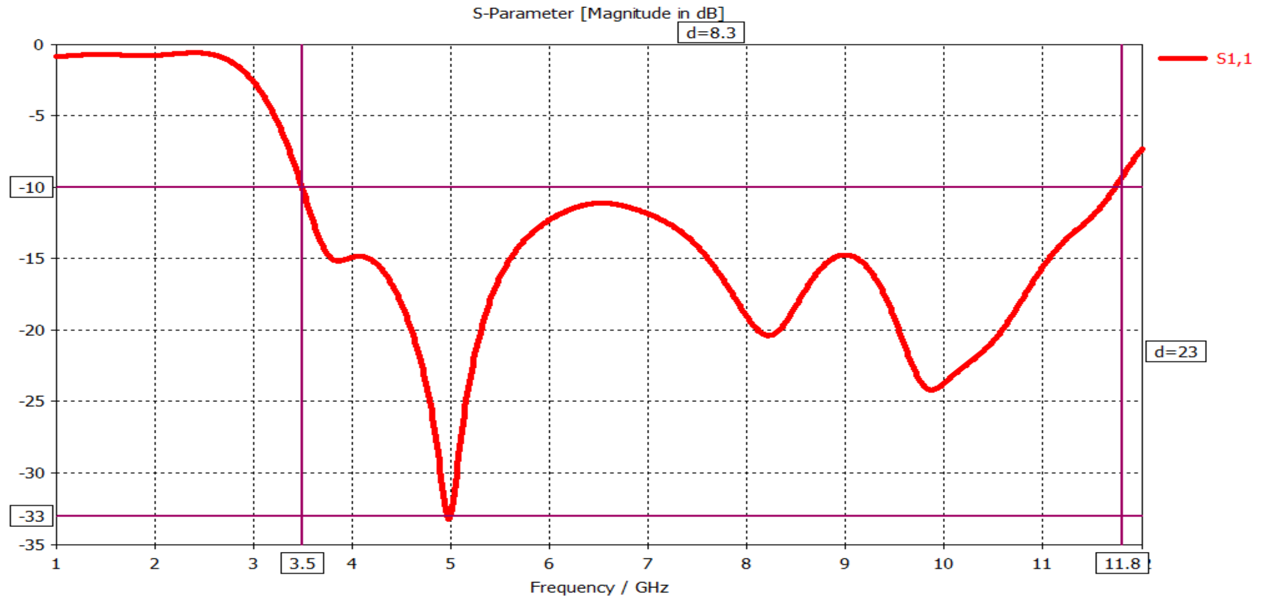


Figure 5.3 Reflection coefficient Vs frequency of DRA

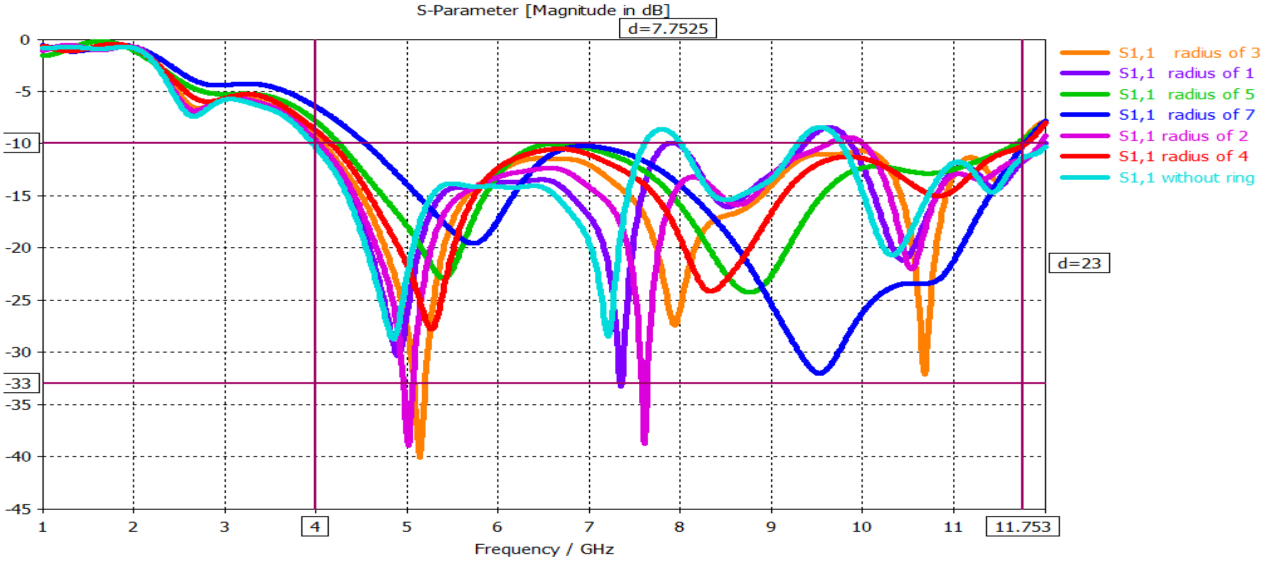


Figure 5.4 Reflection coefficient Vs frequency of DRA by varying radius of ring

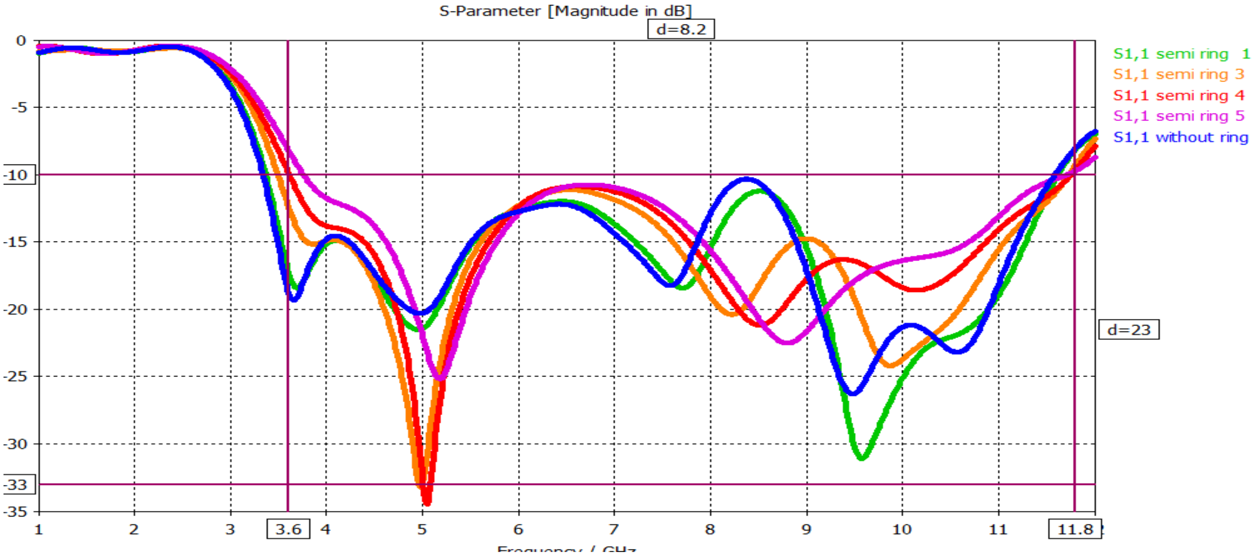
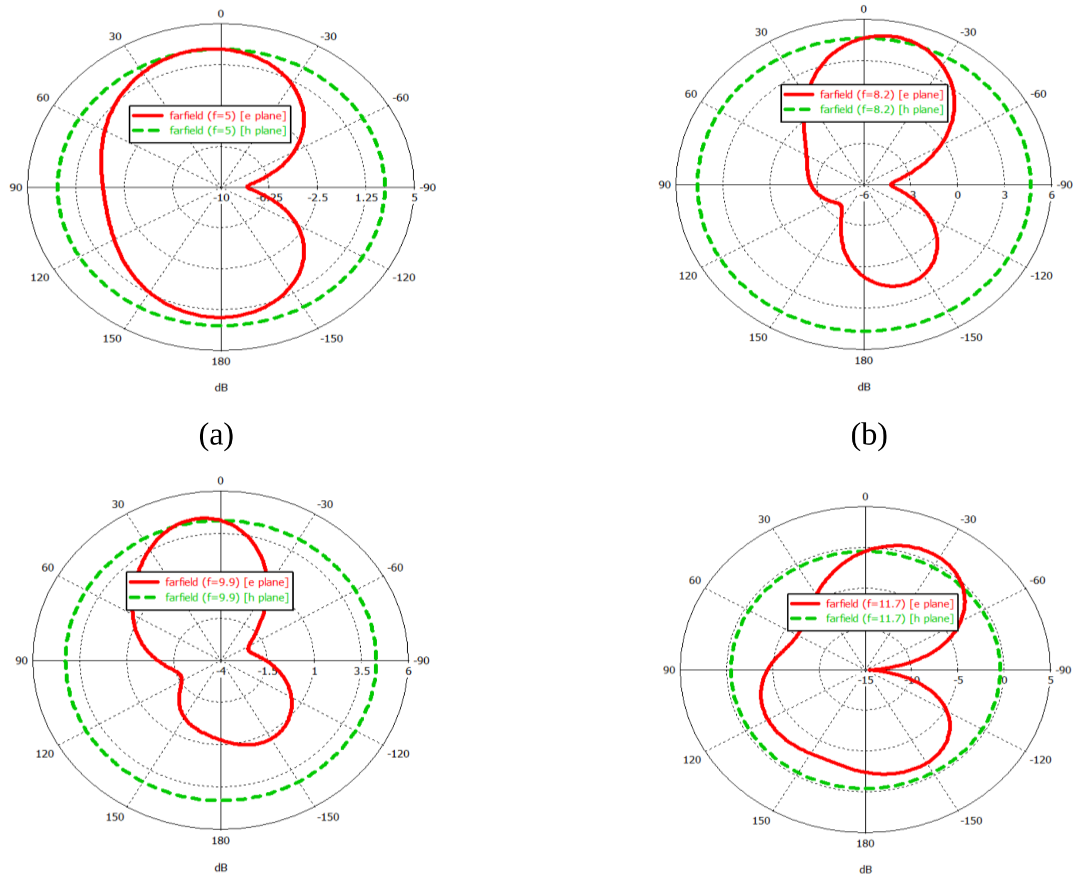


Figure 5.5 Reflection coefficient Vs frequency of DRA by varying semicircular ring



(a)

(b)

(c)

(d)

Figure 5.6 Radiation pattern of DRA (a) 5 GHz (b) 8.2 GHz (c) 9.9 GHz (d) 11.2 GHz

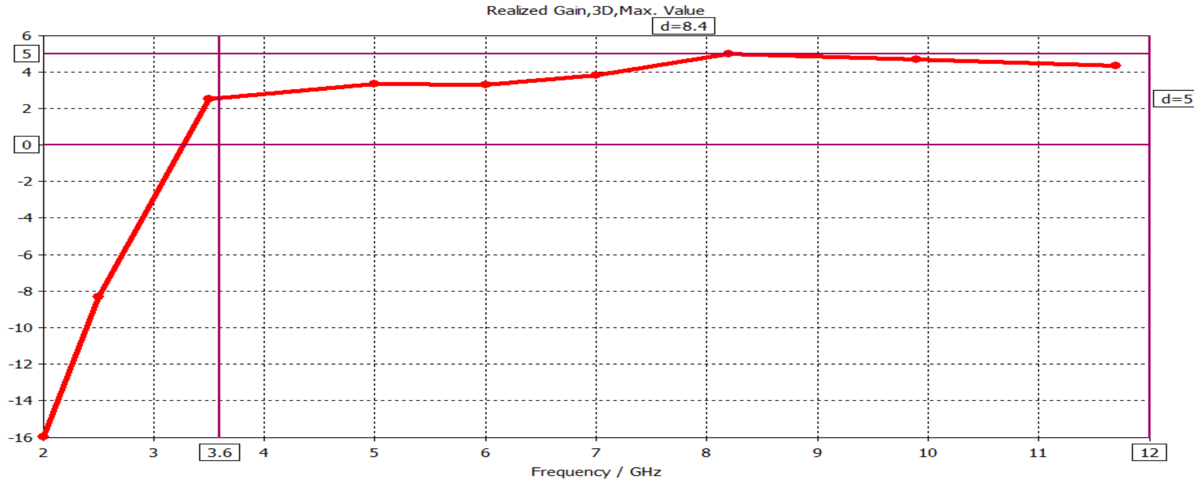


Figure 5.7 Realized gain of DRA

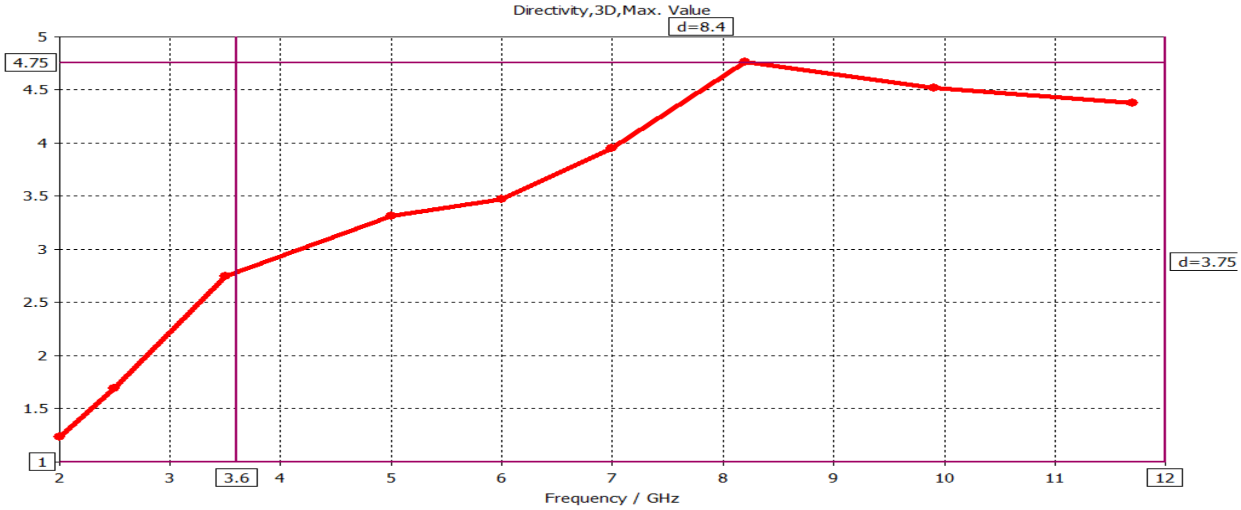
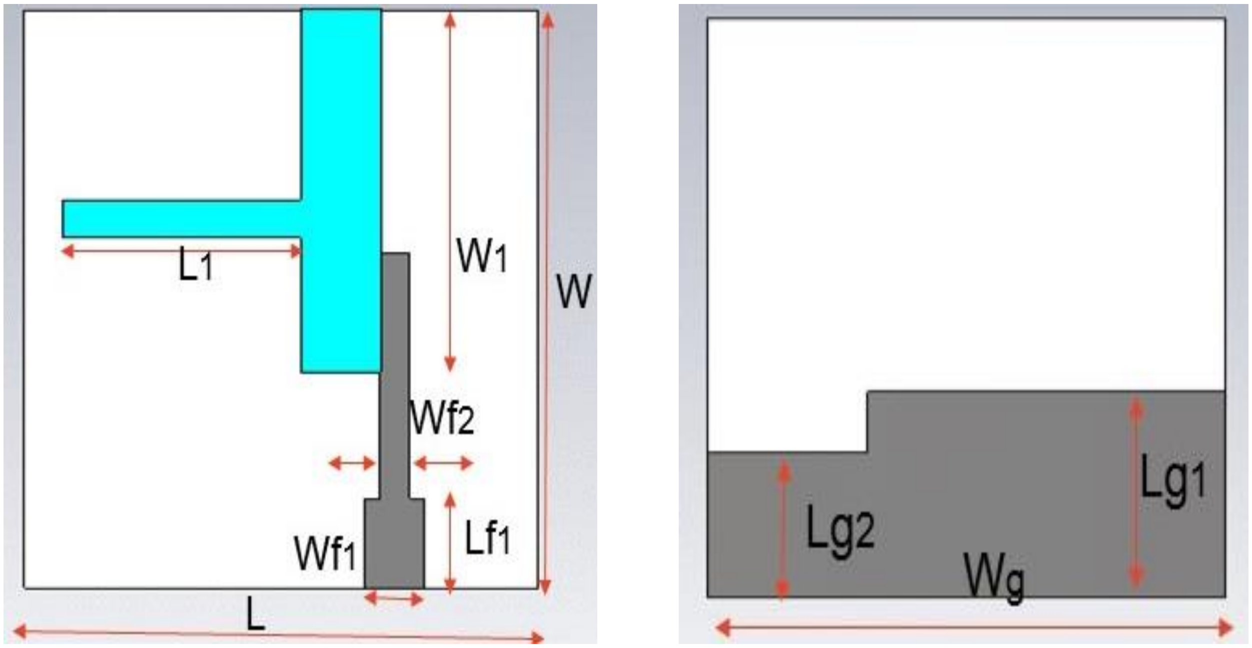


Figure 5.8 Directivity of DRA

5.2 Design of ‘T’ shape DRA for UWB applications

In this design a new shaped DRA is presented for UWB applications. The substrate size is 26mm× 30mm×6mm made up of RT-5880, having the thickness of 1.3 mm, and dielectric constant of 2.2. The DRA antenna is designed by considering rectangular shape and cut some portions such way that it will give ‘T’ shape. The DRA antenna covers the ultra-wide band from 4 GHz to 13GHz. The DRA is in ‘T’ shape made up off RT-6010 with dielectric constant of 10.2 and thickness of 6mm. The DRA is excited by direct microstrip line coupling shown in below figure. Modified ground plane has taken to improve the band width performance. The modified ground plane is ‘L’ shape to get ultra-wide band.



(a) ‘T’ shape DRA

(b) back view

Figure 5.9 Proposed antenna

5.2.1 Simulation Results

The simulation was done using CST microwave studio. The ‘T’ shape DRA is presented in the figure 5.9. The simulated reflection coefficient (S_{11}) of the proposed antenna is plotted Vs frequency shown in the below figure 5.10. The figure 5.10 shows that impedance width of 118%, and it covers (S_{11}< -10 dB) from 4 GHz to 13 GHz. The 2-dimensional and 3- dimensional pattern of the proposed antenna are shown in the below figure 5.11. H plane exhibits the omnidirectional radiation pattern whereas E plane exhibits broad side radiation pattern.

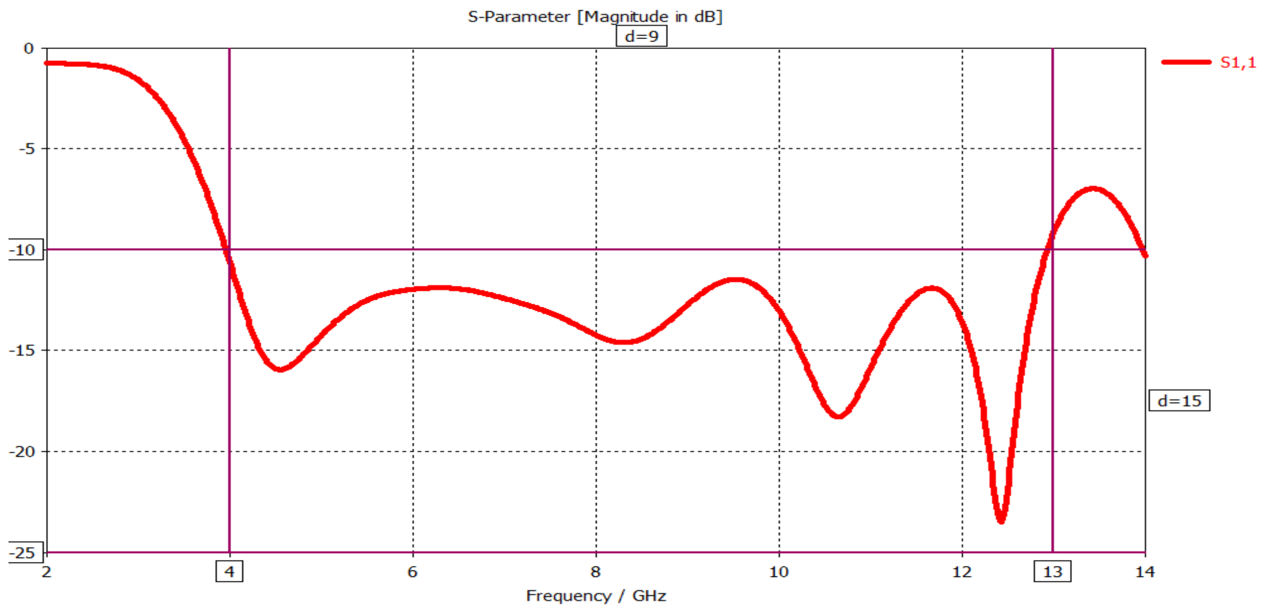
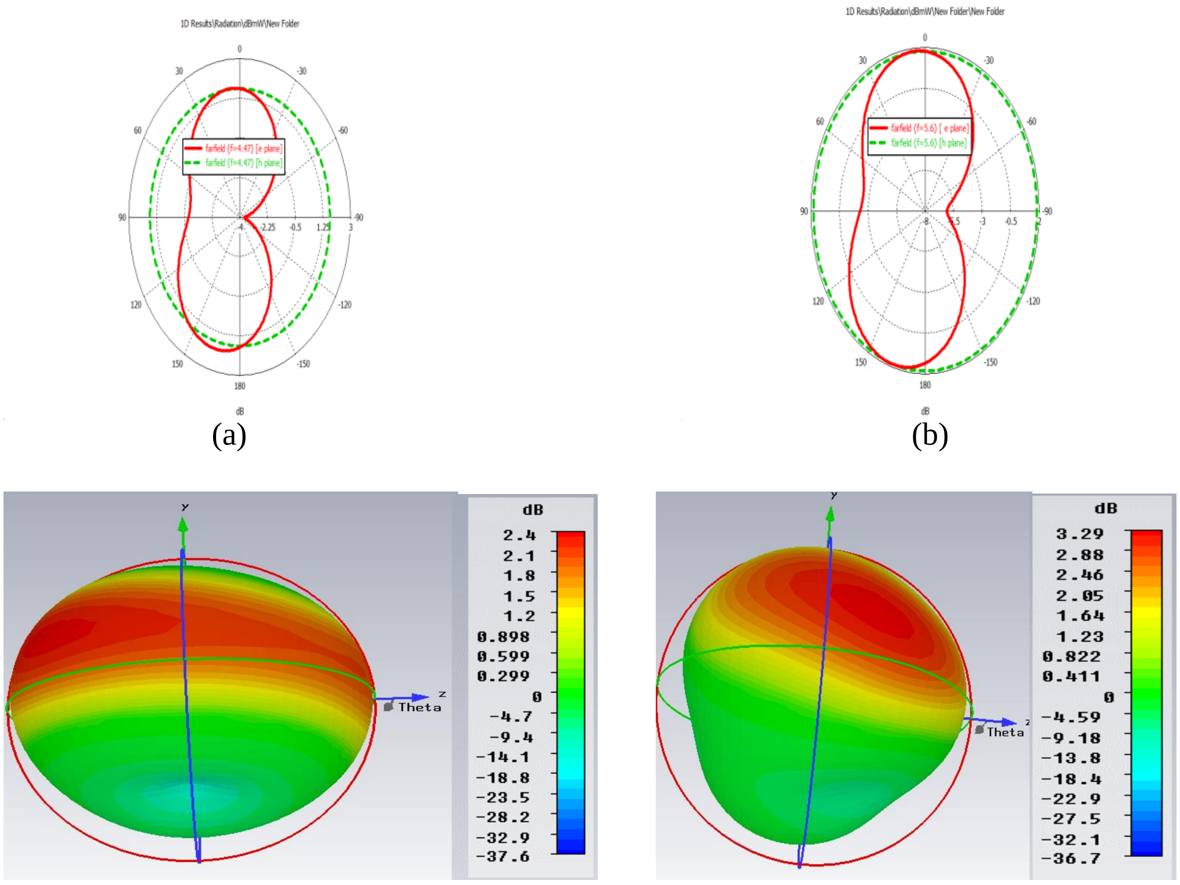


Figure 5.10 Reflection coefficient Vs frequency of ‘T’ shape DRA



(a) (b)

(c) (d)

Figure 5.11 Radiation pattern (a) 4.47 GHz (b) 5.6GHz and 3-d pattern (c) 5.6 GHz (d) 7.6 GHz

The realized gain of the DRA is shown in below figure 5.12. The below figure shows that the gain maximum of 7.15 dB achieved. The directivity of proposed antenna shown in the below figure 5.13.the figure demonstrate that the maximum directivity of 7.2dB achieved.

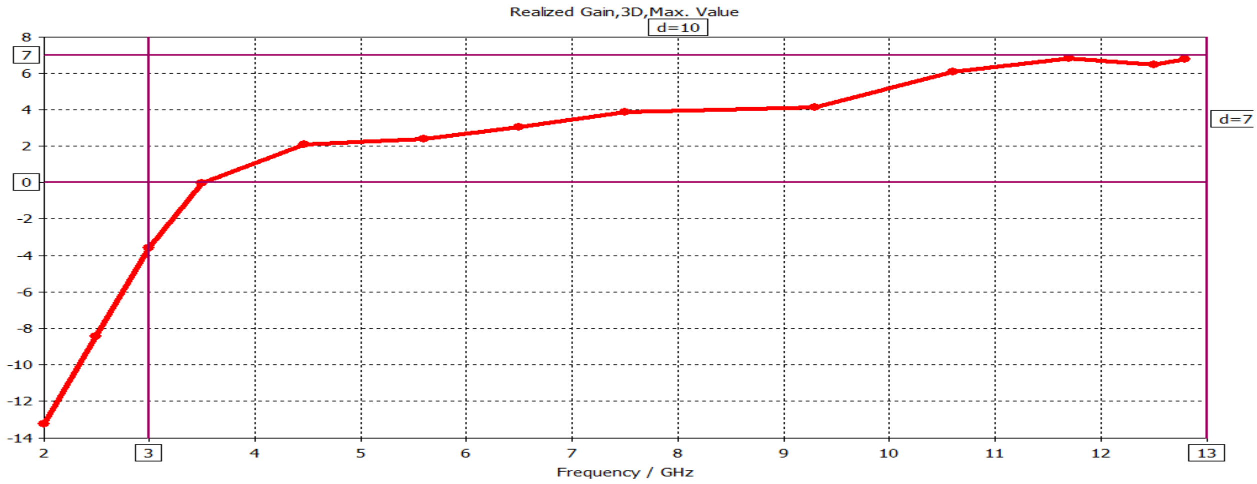


Figure 5.12 Realized gain of proposed DRA

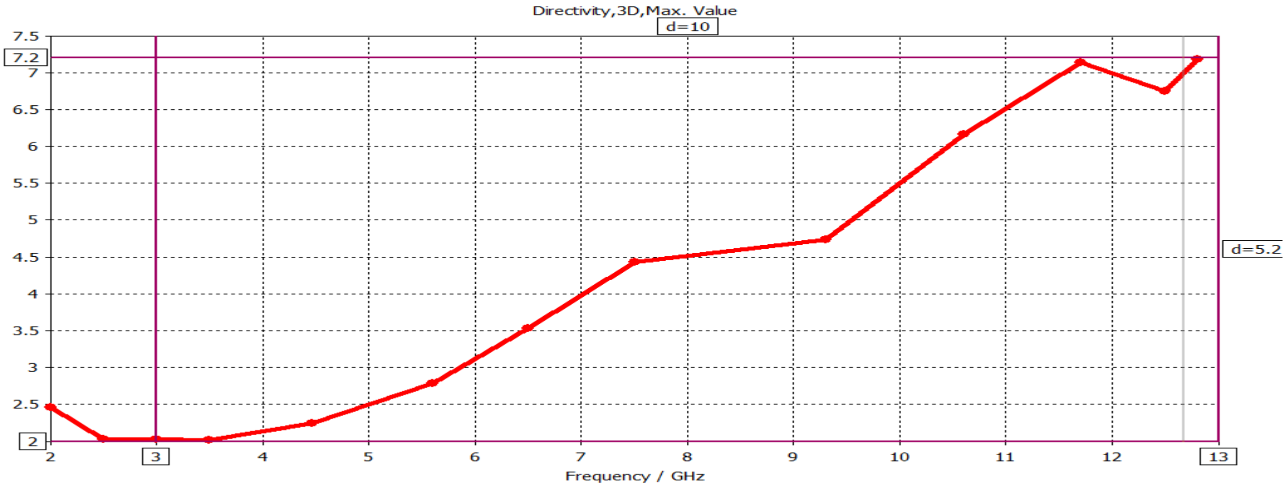


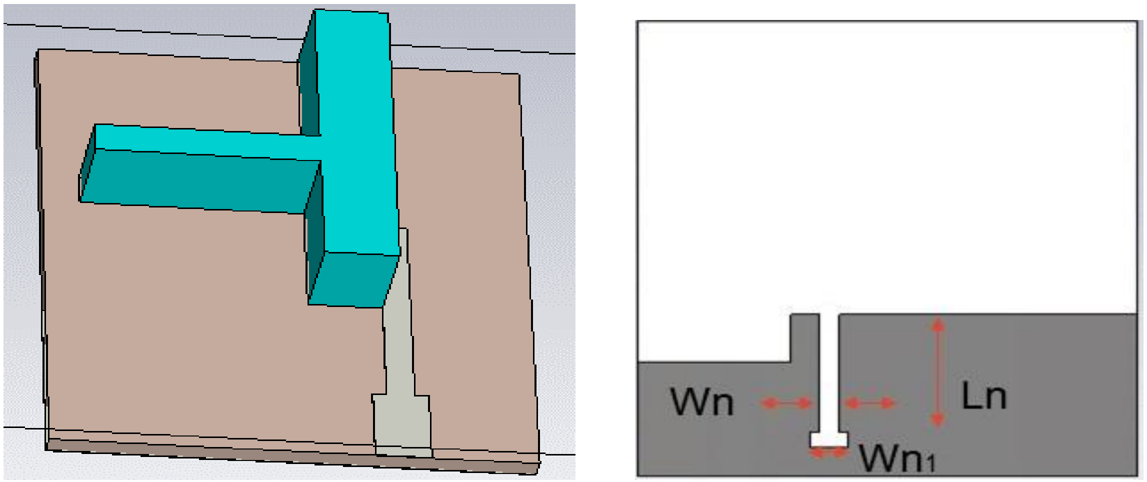
Figure 5.13 Directivity of proposed DRA

5.3 Design of band notch ‘T’ shape DRA WLAN

In this design band notched ‘T’ shaped DRA is presented for WLAN application. The notched frequency at 5.6 GHZ. The notch is in the shape of ‘T’ and to remove the frequencies from 4 GHz to 6 GHz. The designed UWB antenna is interfere the existing WLAN so to remove the interference band notches are implemented. The operating frequency of notch is calculated by using the formula given below.

$$f_{o(HEM_{11\delta})} = \frac{c\sqrt{2/(\varepsilon_r + \varepsilon_{r1})}}{2L_s}$$

Where ε_r is the dielectric constant of the substrate and ε_{r1} is the dielectric constant of the DRA. The velocity of light is represented by c,f_o is the notched frequency and L_s is the length of the slot.



(a) ‘T”shape DRA

(b) back view with notch

Figure 5.14 Proposed ‘T’ shape DRA antenna

5.3.1 Simulation Results

The simulation was done using CST microwave studio. The ‘T’ shape DRA with band notch is shown in the above figure 5.14. The simulated reflection coefficient (S_{11}) of the proposed antenna is plotted Vs frequency shown in the below figure 5.15. The figure shows that the frequencies from 4GHz to 6 GHz are removed and there is no radiation in the frequency band. The VSWR of the proposed antenna Vs frequency shown in the figure 5.16 .The figure shows that between the frequency band the VSWR is more than 2. The surface current of the proposed antenna at band notch frequency are shown the figure 5.17. The surface current shows that at 5.6 GHz maximum current is concentrating across the slot only and there is no current throughout the antenna. The 3-dimensional pattern of the proposed antenna at 5.6 GHZ are shown in the below figure 5.18. The figure shows there is no radiation at that frequency. The gain of the antenna shown in the figure 5.19. The figure shows that gain was decreased from 2.35 dB to .394 dB due to notch placed on the ground plane.

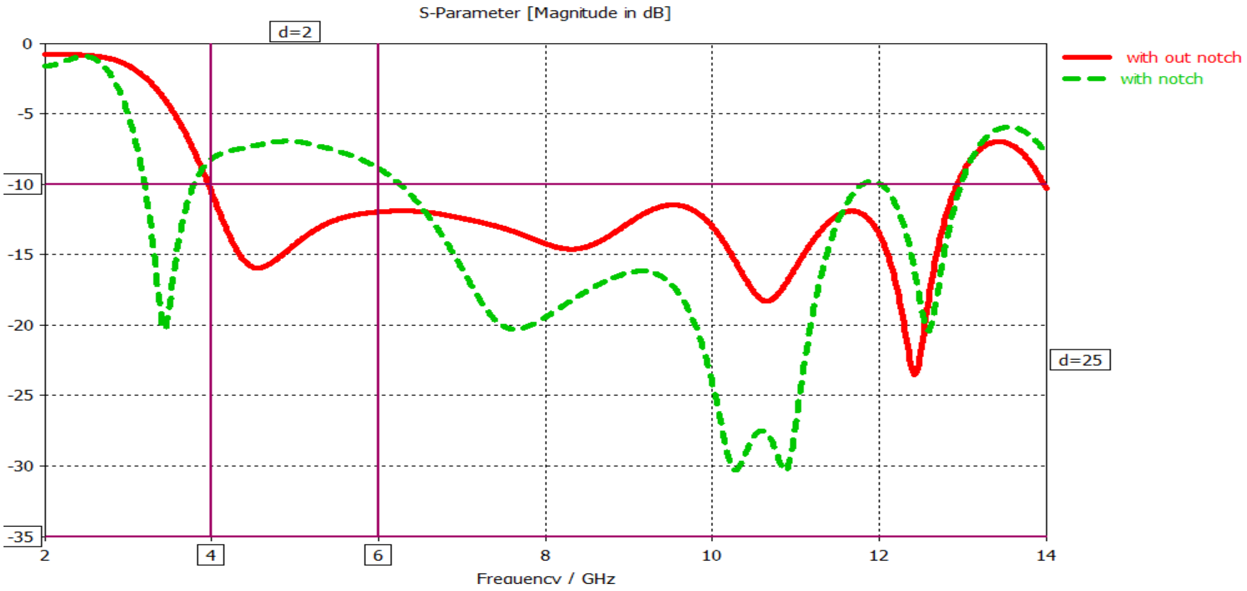


Figure 5.15 Reflection coefficient Vs frequency of ‘T’ shape DRA with band notch

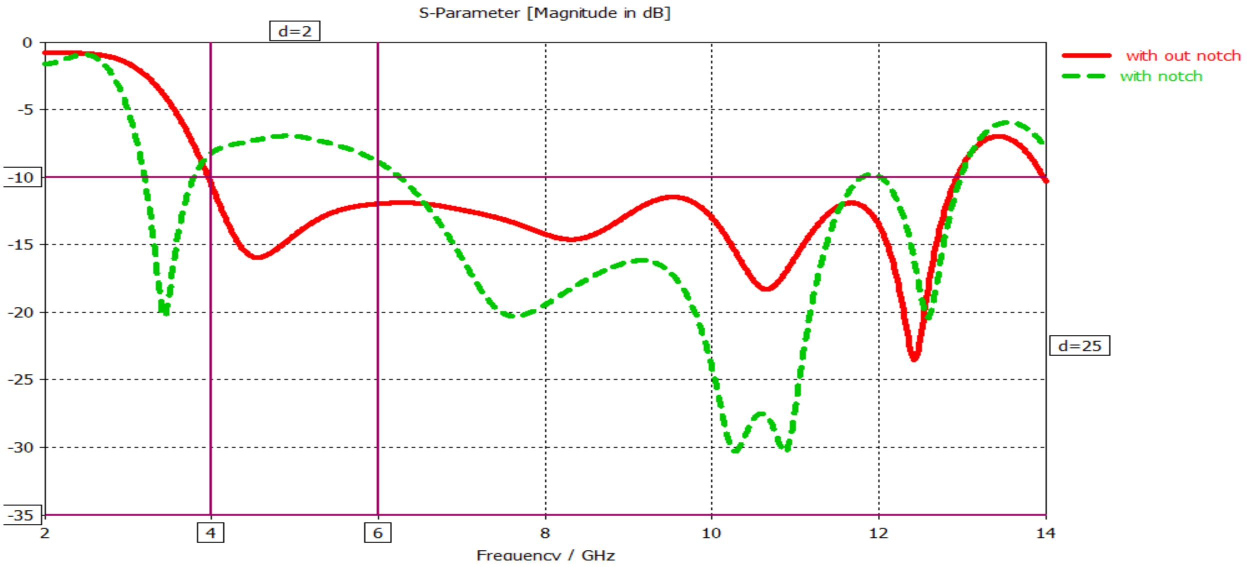


Figure 5.16 VSWR Vs frequency of ‘T’ shape DRA with band notch

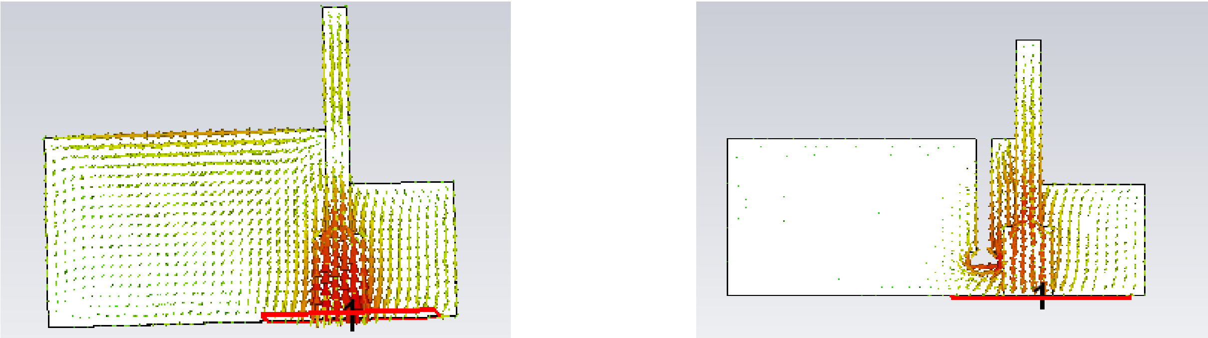
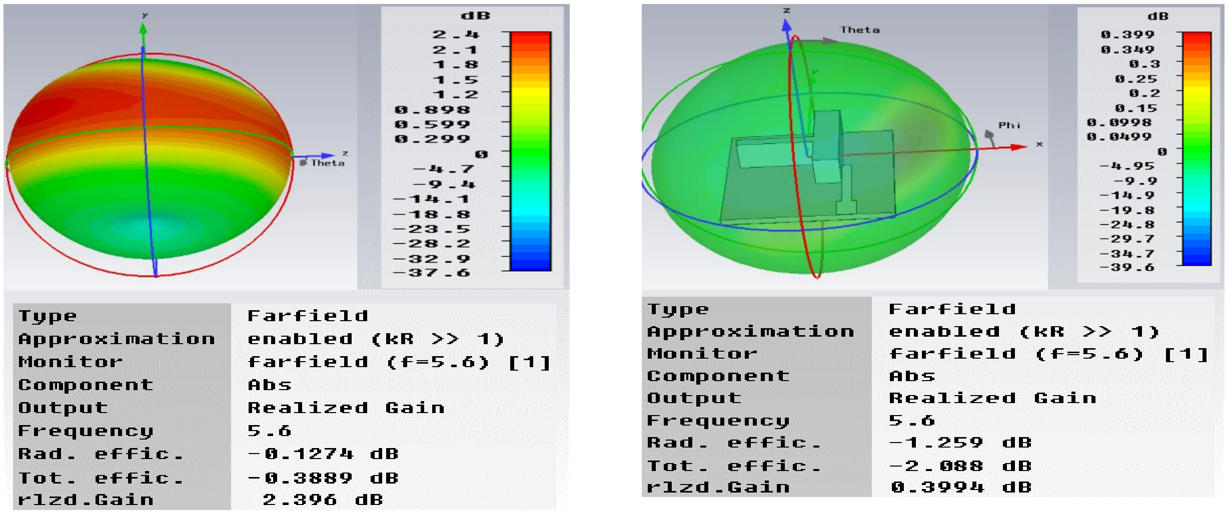


Figure 5.17 Surface current of antenna at resonant frequency 5.6 GHz



Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=5.6) [1]
Component	Abs
Output	Realized Gain
Frequency	5.6
Rad. effic.	-0.1274 dB
Tot. effic.	-0.3889 dB
rlzd.Gain	2.396 dB

Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=5.6) [1]
Component	Abs
Output	Realized Gain
Frequency	5.6
Rad. effic.	-1.259 dB
Tot. effic.	-2.088 dB
rlzd.Gain	0.3994 dB

Figure 5.18 3-d radiation pattern of the antenna at resonant frequency 5.6 GHz

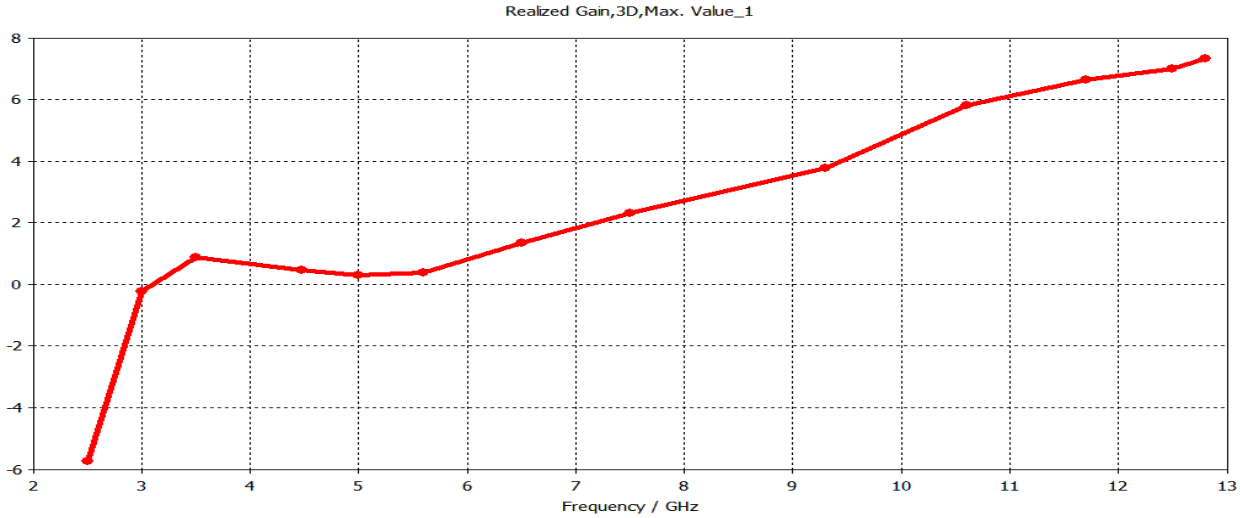


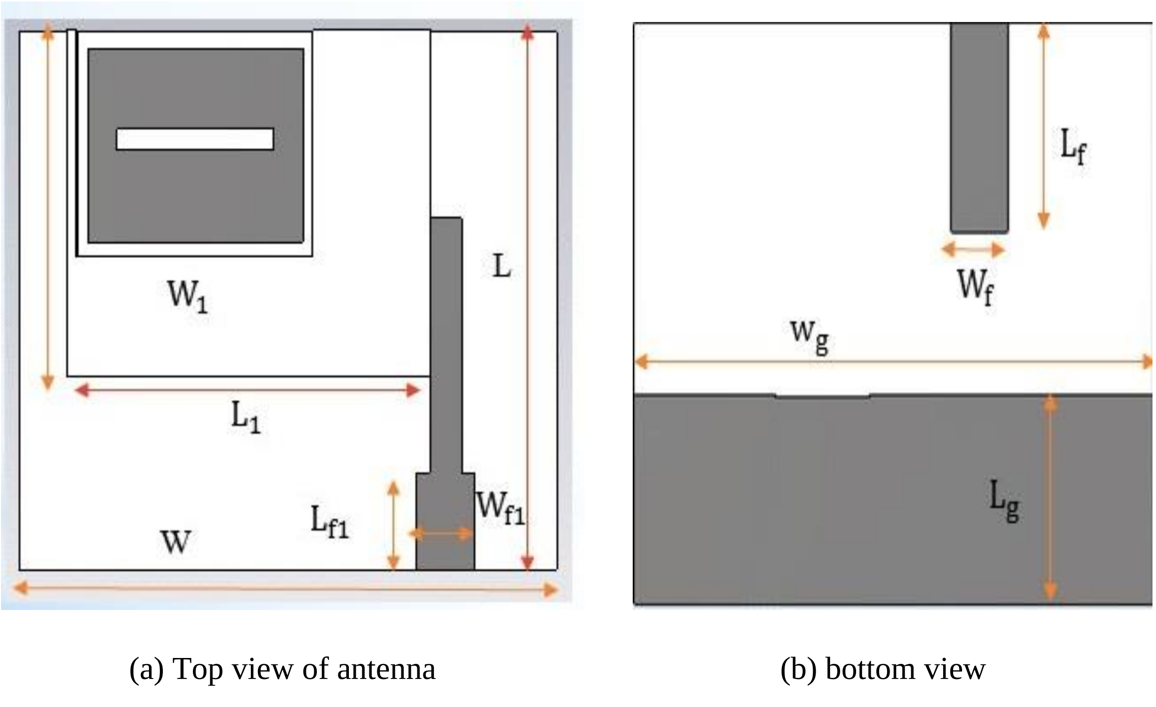
Figure 5.19 Realized gain of proposed DRA with ‘T’ shape notch

Chapter 6

DRA integrated with microstrip

6.1 The DRA is integrated with microstrip antenna for UWB and cognitive radio applications

The ‘U’ shaped DRA antenna is integrated with rectangular microstrip antenna for cognitive radio applications is presented. The designed DRA antenna is microstrip line coupled to detect the frequency range from 3.73 GHz to 12 GHz. The dimensions of the substrate are 37.5mm× 25mm×1.6mm and made up of RT-5880LZ having dielectric constant of 1.96. The DRA is ‘U’ in shape made up RT-6010 having the dielectric constant of 10.2 and thickness of 5mm. The DRA is integrated with microstrip antenna shown in the figure 6.1. The microstrip antenna is rectangular in shape and it is excited by aperture coupling. The microstrip antenna is provide wide band from 9.4GHz to 11.69 GHz. The microstrip antenna is used for ‘X’ band applications .Great isolation exist between the two antenna ports around -15dB achieved through out the band.



(a) Top view of antenna (b) bottom view

Figure 6.1 Proposed integrated antenna

6.1.1Simulation Results

The simulation was done by CST microwave studio. The reflection coefficient of antenna Vs frequency in figure 6.2 .figure 6.2 demonstrate that the DRA have the impedance width of 112.95% and covers (S_{11}< -10dB0 from 4 GHz to 12GHz .the microstrip antenna operates from 5.05 GHz to 5.45 GHz and having the impedance width of 7.63%. The microstrip antenna used for ‘WLAN’ applications. The integrated antenna used in the cognitive radio by placing the filter in the feed line. The transmission coefficient shown in the figure 6.3.

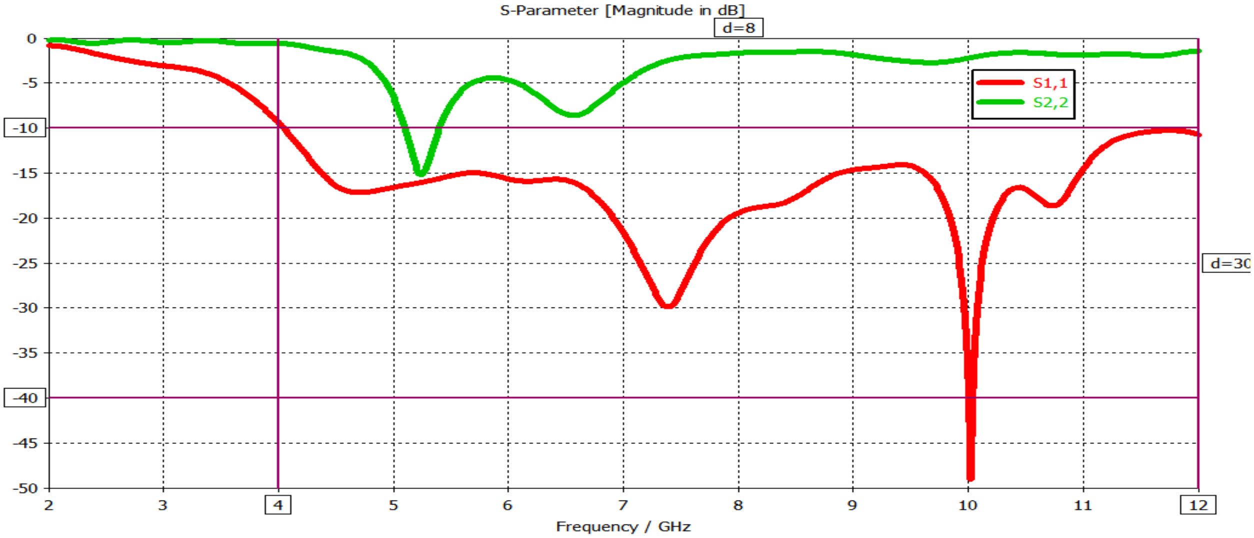


Figure 6.2 Reflection coefficient Vs frequency of integrated antenna

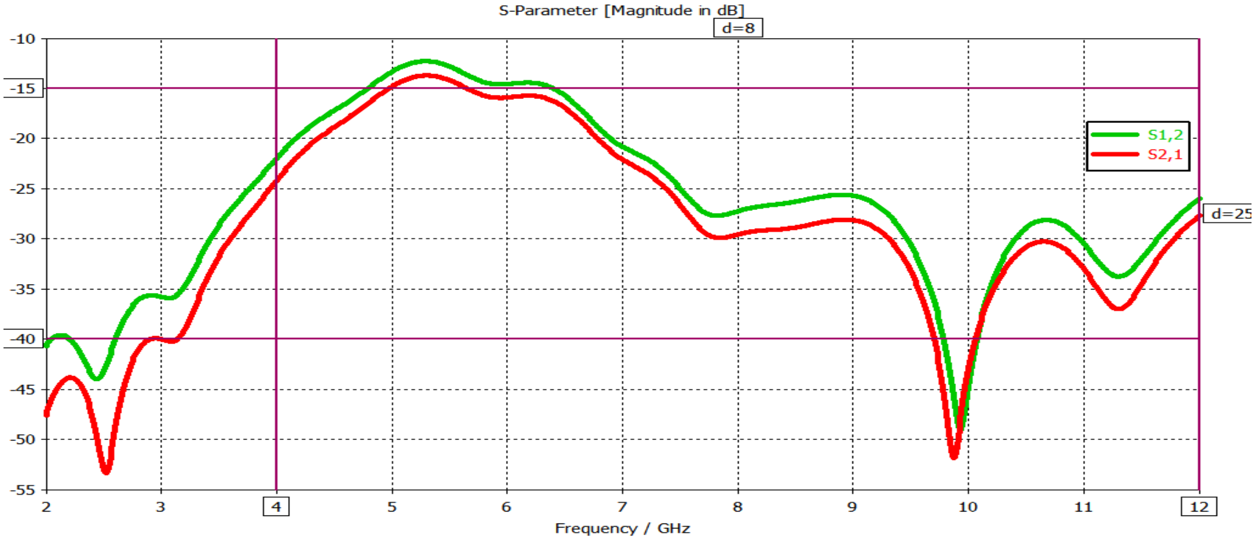


Figure 6.3 Transmission coefficient Vs frequency of integrated antenna

The transmission coefficient demonstrates that two ports are isolated perfectly. The 2-dimensinol radiation pattern of the antenna in the E plane and H plane shown the figure 6.4. If the port 1 is excited port 2 is short circuited with characteristic impedance and port 2 is excited port 1 is short circuited with characteristic impedance. The gain and directivity at different frequency by considering only port 1, only port 2 and both ports are shown in the table 6.1. The table demonstrate that the integrated antenna have improved gain and improved directivity compare to normal antenna. Surface currents at different frequencies are shown in the figure 6.5. The efficiencies at different frequencies are shown in the figure 6.6.

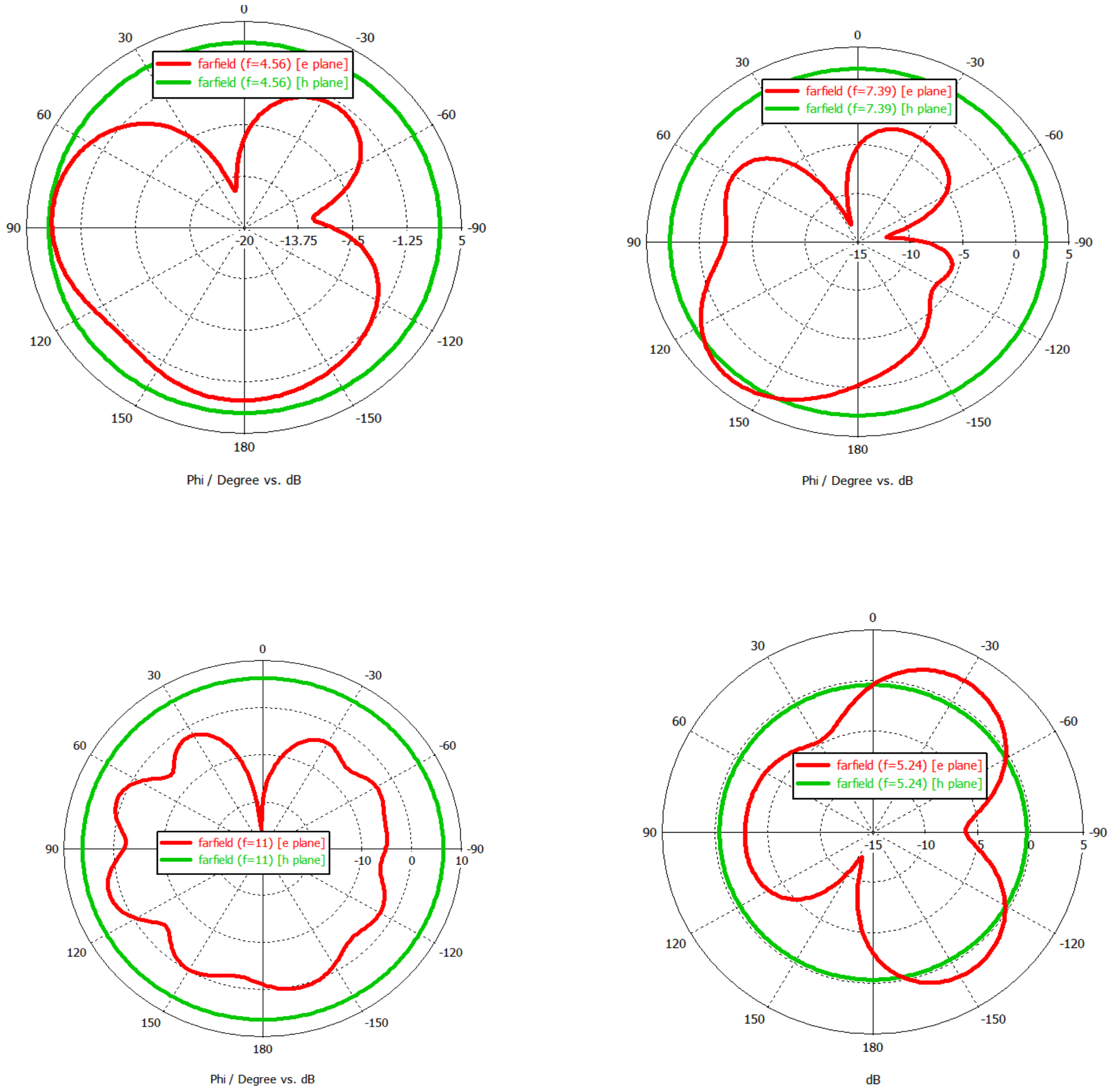
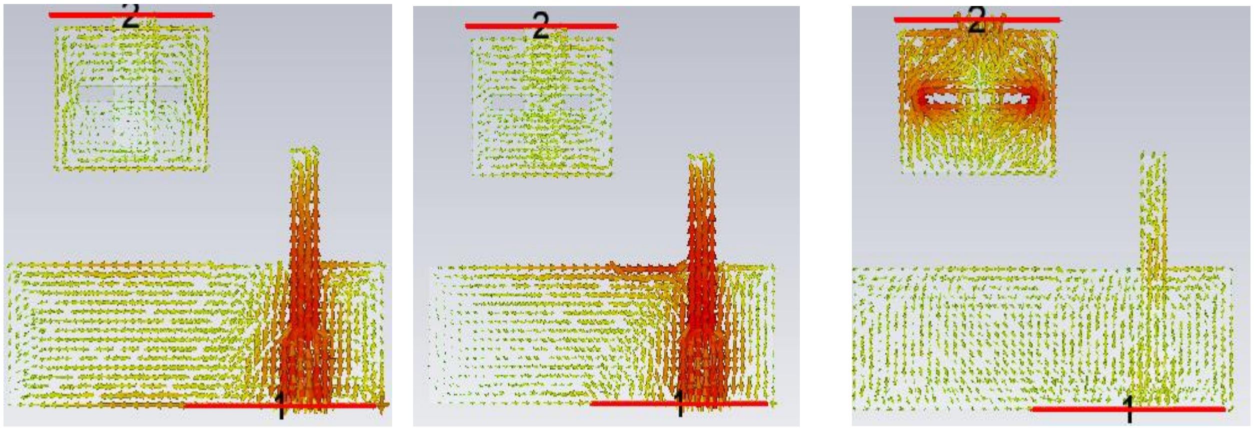


Figure 6.4 Radiation pattern (a) 4.56GHz (b) 7.39GHz (c) 11 GHz for DRA

(d) 5.24 GHz for MPA

Frequency (GHz)	Gain (dBi) MPA	Directivity MPA	Gain(dBi) DRA	Directivity DRA	Gain of integrated antenna	Directivity integrated
4.56	-.406	4.13	3.04	3.06	3.12	3.31
5.24	3.256	3.9	2.95	2.97	2.5	2.89
7.39	-.69	4.5	4.08	4.335	3.94	4.23
10.02	-26	4.03	4.46	4.57	4.27	4.46
11	-43	4.15	5.9	6.05	6.43	6.63

Table 6.1 Gain and directivity at different frequencies



(a) (b) (c)

Figure 6.5 Surface current of antenna at resonant frequencies (a) 7.39 (b) 11 (c) 5.24 GHz

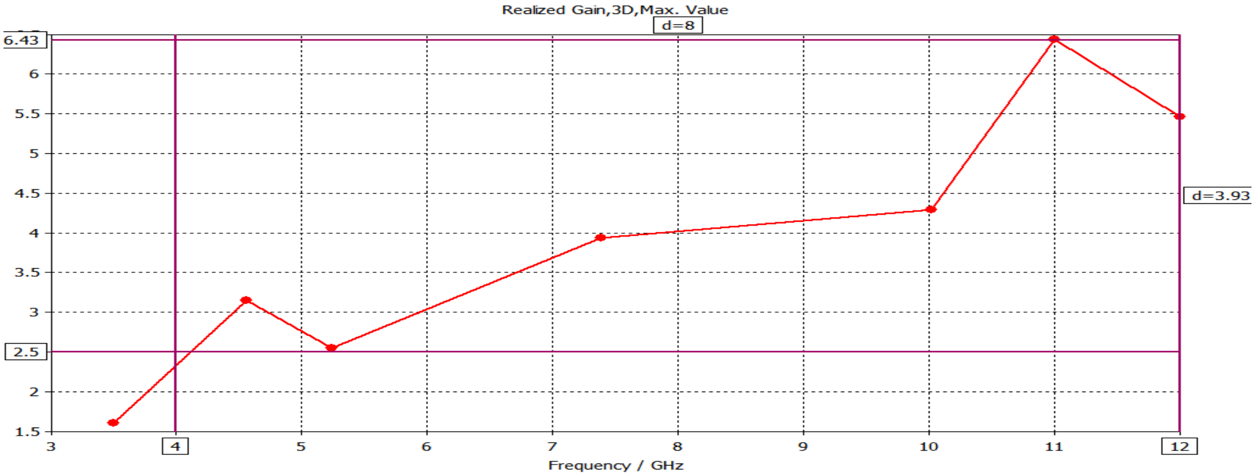


Figure 6.6 Realized gain of integrated antenna

Chapter 7

Conclusions and future work

This chapter presents the contribution and highlights of the thesis. Further investigation and research problems are discussed in the future work.

7.1 Conclusions

In this thesis work, a new microstrip antennas integrated with DRA are presented. The microstrip antennas are designed for ultra-wide band applications .The DRA antennas are presented for narrowband applications. A new DRA antenna integrated with microstrip antenna are presented for cognitive radio applications. The DRA antenna with band notch presented for WiMAX applications.

The final conclusions are

1) Semicircular –semi hexagon shape microstrip antenna integrated with cylindrical DRA for cognitive radios are presented.
2) Elliptical microstrip antenna integrated with elliptical DRA for cognitive radio are presented .The DRA is operates at two different frequencies as a multi band antenna.
3) The parentage bandwidth of 168% is achieved by elliptical microstrip antenna.
4) Semi cylindrical shape DRA is presented for ultra-wide band applications.
5) A new 'T' shape DRA is presented for ultra-wide band application with improved gain and directivity.
6) 'T' shape band notch DRA is presented for WLAN applications.
7) A new UWD DRA is integrated with rectangular microstrip antennas for cognitive radios are presented. The microstrip antenna provides wideband for 'X' band applications.
8) The parameters like reflection coefficient (S_{11}, S_{22}), transmission coefficient (S_{21} ,S_{22}), Realized gain, and directivity are calculated.

7.2 Future work

1) The antenna will be fabricated and measured in order to validate the simulation results.
2) Gain of the hybrid antenna systems designed is low, some other techniques can be used to improve the gain of the integrated antenna systems in the future.
3) The challenge is to integrate two antennas in a limited space and to provide good isolation between the ports the methods like decoupling network and hybrid coupler can be used
4) Total active reflection coefficient (TARC) and correlation coefficient of the integrated antenna can be calculated.
5) Finite difference time domain (FDTD) can be employed to solve and implement designs.

Publications

1) Ananda Raju, P., Nishant Kumar, and Santanu Kumar Behera. "Semi Circular Semi Hexagon Microstrip Antenna Integrated with DRA for Cognitive Radio Applications." IEEE International Conference on Communication and Signal Processing (ICCSP), Melmaruvathur, India, April 3-5, 2015.
2) Kumar, N., P. Ananda Raju, and S. K. Behera. "Frequency Reconfigurable Microstrip Antenna for Cognitive Radio Applications." IEEE International Conference on Communication and Signal Processing (ICCSP), Melmaruvathur, India, April 3-5, 2015.

References

1) Qing, Xianming, and Zhi Ning Chen. "Monopole-like slot UWB antenna on LTCC." *Ultra-Wideband, 2008. ICUWB 2008. IEEE International Conference on*. Vol. 2. IEEE, 2008.
2) Azenui, Ntsanderh C., and H. Y. D. Yang. "A printed crescent patch antenna for ultrawideband applications." *Antennas and Wireless Propagation Letters, IEEE* 6 (2007): 113-116.
3) H. Arslan, Z. N. Chen and M.-G. Di Benedetto, *Ultra Wideband Wireless Communication*, JohnWiley & Sons, ISBN 0-471-71521-2, New Jersey, United States of America, 2006.
4) Ebrahimi, E., J. R. Kelly, and P. S. Hall, “Integrated wide-narrowband antenna for multi-standard radio," *IEEE Trans.Antennas Propag.*, Vol. 59, 2628-2635, 2011.
5) Messaoudene, Idris, Tayeb Ahmed Denidni, and Abdelmadjid Benghalia. "Experimental investigations of ultra-wideband antenna integrated with dielectric resonator antenna for cognitive radio applications." *Progress in Electromagnetics Research C* 45 (2013): 33-42.
6) A. Petosa, Dielectric Resonator Antenna Handbook. Artech House Publishers, Norwood, USA, 2007.
7) Natarajamani, SK Behera, and SK Patra. "CPW-fed octagon shape slot antenna for UWB application." *International conference on microwaves. Antenna propagation and remote sensing*. 2009.
8) Federal Communications Commission, First report and order, revision of Part 15 of Commission’s rule regarding ultra-wideband transmission system FCC 02-48, Washington, DC, April 2002
9) C. A. Balanis, “Antenna Theory - Analysis and Design,” 2nd edition, John Wiley.
10) Liang, Jianxin, et al. "Study of a printed circular disc monopole antenna for UWB systems." *Antennas and Propagation, IEEE Transactions on* 53.11 (2005): 3500-3504.
11) T.A. Denidni, M.A.Habib, “Broadband printed CPW-fed circular slot Antenna”, Electron. Lett., 2006, vol. 42,no. 3, pp. 135–136
12) Z. N. Chen and M. Y.W. Chia, Broadband Planar Antennas: Design and Applications, John Wiley & Sons Ltd, ISBN-13: 978-0-470-87174-4, West Sussex, England, 2006.

13) B. Allen, M. Dohler, E. E. Okon, W. Q. Malik, A. K. Brown and D. J. Edwards, *Ultra-Wideband Antennas and Propagation for Communications, Radar and Imaging*, John Wiley & Sons Ltd, ISBN-13 978-0-470-03255-8, West Sussex, England, 2007.
14) A. Petosa, Dielectric Resonator Antenna Handbook. Artech House Publishers, Norwood, USA, 2007.
15) R. K. Mongia and P. Bhartia, “Dielectric resonator antennasa review and general design relations for resonant frequency and bandwidth,” Int. J. Microwave Millimeter-Wave Eng., pp. 230–247, Jul. 1994.
16) Kelly, James Robert, et al. "Reconfigurable 460 MHz to 12 GHz antenna with integrated narrowband slot." *Progress in Electromagnetics Research C* 24 (2011): 137-145.
17) Liang, X. L., T. A. Denidni, and L. N. Zhang, “Wideband L-shaped dielectric resonator antenna with a conformal inverted-trapezoidal patch feed," *IEEE Trans. Antennas Propag.*, Vol. 57,272-274, 2009.
18) Y. J. Cho, K. H. Kim, D. H. Choi, S. S. Lee, and S. O. Park, “A miniature UWB planar monopole antenna with 5-GHz band-rejection filter and the time-domain characteristics,” *IEEE Trans. Antennas Propag.*, vol. 54, no. 5, pp. 1453–1460, May 2006.
19) Y. D. Dong, W. Hong, Z.-Q. Kuai, and J. X. Chen, “Analysis of planar ultrawideband antennas with on-ground slot band-notched structures,”*IEEE Trans. Antennas Propag.*, vol. 57, no. 7, pp. 1886–1893, Jul.20
20) Mitola, J. Cognitive radio: An integrated agent architecture for software defined radio. Ph.D. Dissertation, KTH, 2000.
21) Report ITU-R SM.2152 Definitions of Software Defined Radio (SDR) and Cognitive Radio System (CRS). 2009.
22) Hall, Peter S., Peter Gardner, and Antonio Faraone. "Antenna requirements for software defined and cognitive radios." *Proceedings of the IEEE* 100.7 (2012): 2262-2270.
23) Wang, Yongfeng, et al. "Integrated Ultra-Wideband Planar Monopole with Cylindrical Dielectric Resonator Antennas." *Progress in Electromagnetics Research C* 44 (2013): 41-53
24) Ebrahimi, E., J. R. Kelly, and P. S. Hall, “Integrated wide-narrowband antenna for multi-standard radio," *IEEE Trans.Antennas Propag.*, Vol. 59, 2628-2635, 2011.
25) K.L. Wong, “Compact and broadband microstrip antennas” (John Wiley & Sons, 2002)

26) W. F. Richards, Y. T. Lo, and D. D. Harrison, “An Improved Theory of Microstrip Antennas with Applications,” IEEE Trans. Antennas Propagat. Vol. AP-29, No. 1, pp. 38–46, January 1981.

27) J. Lao, R. Jin, J. Geng, Q. Wu, “An ultra-wideband microstrip elliptical slot antenna exited by a circular patch”, Microw. Opt. Technol. Lett., 2008, vol. 50, no. 4, pp. 845–846

28) Augustin, G. and T. A. Denidni, “Coplanar waveguide-fed uniplanar trapezoidal antenna with linear and circular polarization," *IEEE Trans. Antennas Propag.*, Vol. 60, 2522-2526, 2012.

29) S. Long, M. W. McAllister, and L. Shen, “The resonant cylindrical dielectric cavity antenna,” *IEEE Transactions on Antenna and Propagations*, vol. 31, pp. 406–412, 1983.

30) A. Petosa, A. Ittipiboon, Y. Antar, D. Roscoe, and M. Cuhaci, “Recent advances in dielectric resonator antenna technology,” *IEEE Antennas Propag* Mag., vol. 40, pp. 35–48, 1998.

31) R. Mongia and A. Ittipiboon, “Theoretical and experimental investigations on rectangular dielectric resonator antennas,” *IEEE Transactions on Antennas and Propagation*, vol. 45, no. 9, pp. 1348–1356, 1997.

32) Chen, Horng-Dean. "Broadband CPW-fed square slot antennas with a widened tuning stub." *Antennas and Propagation, IEEE Transactions on* 51.8 (2003): 1982-1986.

33) Augustin, G. and T. A. Denidni, “An integrated ultrawideband/narrow band antenna in uniplanar con-guration forcognitive radio systems," *IEEE Trans. Antennas Propag.*, Vol. 60,No. 11, 5479-5484, Nov. 2012.

34) Niroo-Jazi, M. and T. A. Denidni, “Experimental investigations of a novel ultrawideband dielectric resonator antenna with rejection band using hybrid techniques," *IEEE Antenna Wirel. Propag.Lett.*, Vol. 11, 492-495, 2012

35) Liang, X. L. and T. A. Denidni, “H-shaped dielectric resonator antenna for wideband applications," *IEEE Antennas WirelessPropag.Lett.,* Vol. 7, 163-166, 2008.