DESIGN OF NOVEL 1×2 DIAMOND SHAPED MICROSTRIP PATCH ARRAY FOR WLAN AND UWB APPLICATIONS

A Thesis submitted in partial fulfillment of the

Requirements for the degree of

MASTER OF TECHNOLOGY

IN

COMMUNCATION AND SIGNAL PROCESSING

BY

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National Institute of Technology Rourkela-769008

2013

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UNDER THE GUIDANCE OF

PROF. S K BEHERA

Department of Electronics and Communication Engineering

National Institute of Technology Rourkela-769008

2013

Dedicated to My Family

Department of Electronics & Communication Engineering

National Institute of Technology Rourkela

Date:29-05-2013

CERTIFICATE

This is to certify that the thesis entitled, “ **DESIGN OF NOVEL 1×2 DIAMOND SHAPED MICROSTRIP PATCH ARRAY FOR WLAN AND UWB APPLICATIONS**” submitted by Mr. **SAIKUMAR B** in partial fulfillment of the requirements for the award of Master of Technology Degree in Electronics and Communication Engineering with specialization in “**Communication and Signal Processing**” during session 2012-2013at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any degree or diploma**.**

Prof. S.K.BEHERA

ACKNOWLEDGEMENTS

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

I would like to extend my gratitude and my sincere thanks to my honorable, esteemed supervisor Prof. **S K Behera**. He is not only a great teacher/professor with deep vision but also and most importantly a kind person. I sincerely thank for his exemplary guidance and encouragement. His trust and support inspired me in the most important moments of making right decisions and I am glad to work with him. My special thank goes to Prof**. S K Meher** Head of the Department of Electronics and Communication Engineering, NIT, Rourkela, for providing us with best facilities in the Department and his timely suggestions.

I want to thank all my teachers Prof**. S.K Patra, K.K Mahapatra and A.K Sahoo** for providing a solid background for my studies and research thereafter. They have been great sources of inspiration to me and I thank them from the bottom of my heart.

I would like to thank all my friends and especially Prasanna, Sumanth and Avinash babu for all the thoughtful and mind stimulating discussions we had, which prompted us to think beyond the obvious. I have enjoyed their companionship so much during my stay at NIT Rourkela. I would like to thank all those who made my stay in Rourkela an unforgettable and rewarding experience.

Last but not least I would like to thank my parents, who taught me the value of hard work by their own example. They rendered me enormous support during the whole tenure of my stay in NIT Rourkela.

SAIKUMAR B

CONTENTS

ABSTRACT:

This thesis presents two antenna designs one is used for ultra wide band applications and other is used for only WLAN applications. UWB is a short distance radio communication technology that can perform high speed communications with speeds of more than 100Mbps modern communication system requires single antenna to cover several wireless bands. The UWB systems have received great attention in indoor and handheld wireless communication. Both antennas are designed and simulated and the simulation process has been done using CST software. FR4 substrate used for both antennas the feeding technique used here is microstrip line feed with dielectric constant of 4.4 and the substrate height of 1.6mm and loss tangent is 0.001. The presented antenna simulated and various parameters such as return loss, vswr, gain and radiation pattern has been investigated.

In this thesis the first antenna presents a 1×2 diamond shaped patch array for WLAN applications. the main purpose of this design is to enhance the gain of the antenna. The presented antenna fabricated on a 44×48×1.6mm on thick FR4 substrate and covers the frequency range from 2.4 to 5.6GHz. The maximum gain achieved here is 7.22dB at 5.5GHz.this antenna used for applications such as Bluetooth operating at 2.4GHz and WLAN frequency bands at 3.3GHz, 3.5GHZ and WiMAX applications.

The second antenna in this thesis presents 1×2 compact diamond shaped patch array for UWB applications. Modern antennas require single antenna to cover several wireless bands. The proposed antenna consists of 18×24×1.6mm with FR4 substrate. The proposed antenna covers the wide range 4 to 10.6GHz with max gain of 6.5dB at 10GHz. The presented antenna well suited for UWB applications.

Both antennas are successfully designed and simulated and its showing broadband matched impedance stable gain and radiation pattern over the operating bandwidth.

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TABLE OF FIGURES

CHAPTER-1

Thesis Overview

1.1 LITERATURE REVIEW:

Literature review is one of the main process for developing this antenna. As for the basic operation of an antenna, it is apparent that the size of an antenna is inversely proportional to frequency. A relatively small antenna can efficiently radiate high frequency electromagnetic waves, for low frequency waves, it require relatively large antennas. There are different techniques that enhance the bandwidth, one way to increase the bandwidth is done by either increase the height of the dielectric or decrease the dielectric constant. By increasing the height of the substrate it is unsuitable for low profile structures, decreasing the dielectric constant causes fringing fields[**1**]. Modern communication systems require a compact single antenna to cover several allocated wireless frequency bands. As the gain of microstrip antenna is very low, microstrip array is used to increase the gain. Ali Foudazi, Hamid Reza Hassani, and Sajad Mohammad alinezhad they proposed Small UWB Planar Monopole Antenna With Added GPS/GSM/WLAN Bands[**14**]. Naimulhasan proposed Design Of Single & 1x1 Microstrip Rectangular Patch Antenna Array Operating At 2.4 GHz [**20**].K. Shambavi suggested Gain and Bandwidth Enhancement Technique in Square Microstrip Antenna for WLAN Applicationsin that she used an air gap to increase the gain[**9**]. Mohammed Al-Husseini, Member, IEEE, Youssef Tawk, Ali El-Hajj, and Karim Y. Kabalan they presented a A Low-Cost Microstrip Antenna for 3G/WLAN/WiMAX and UWBApplications in that they used fractal geometry for cutting slots[**10**]. Mohamed A. Hassanien and Ehab K.I.Hamad proposed compact rectangular U-shaped slot microstrip antenna for UWB applications in that The use of U-shaped slot and the finite ground plane are studied to achieve an excellent impedance matching to increase the bandwidth[**11**]. Horng-Dean Chen, Chow-YenDesmondSim, Jun-Yi Wu, and Rsung-Wen Chiu proposed broadband high gain microstrip array antennas for WiMAX base station in that he presented two novel array antennas with broadband and high gain characteristic are proposed for the application of WIMAX base station[**15**]. Azizan Mat Hashim proposed development of microstrip patch array antenna for wireless local area network in that he designed 4×1 rectangular microstrip patch array, In that he used various methods for optimize the microstrip antenna[**7**].

1.2 SCOPE OF THIS PROJECT:

The project is divided into few phases as follows:

- Understanding the basic fundamentals of the microstip antenna
- Design a microstrip diamond shaped patch array antenna
- Simulate the microstrip diamond shaped patch array antenna using CST microwave studio software
- Fabricate the design

1.3 INTRODUCTION TO UWB :

Ultra wideband (UWB) communication systems can be broadly classified as any communication system whose bandwidth is many times larger than the other applications like WLAN, Wifi. This large bandwidth is the smart characteristic of UWB to use in many applications i.e. satellite and military[**4**] .

Within the past 40 years, advances in electronics in both analog and digital and UWB signal theory have enabled system designers to propose some practical UWB communications systems. Over the past years, many individuals and corporations started asking permissions for ultra wide band frequency range from federal communication commission(FCC),then In 2002, the FCC decided to change the rules to allow UWB system operation in a broad range of frequencies.

UWB is a short distance radio communication technology that can perform high-speed communication with speeds of more than100 Mbps. The UWB systems can be divided into two categories: direct sequence UWB (DS-UWB) and multi-band orthogonal frequency division multiplexing (MB-OFDM). The DS-UWB proposal has two different carrier frequencies at 4.104 (low band: 3.1–5.15 GHz) and 8.208 GHz (high band: 5.825–10.6 GHz), while the MB-OFDM format in IEEE 802.15.3 a has an interval between 3.1 and 10.6 GHz and is divided into 14 subintervals. Each subinterval covers 528 MHz of bandwidth[**14**],[**4**].

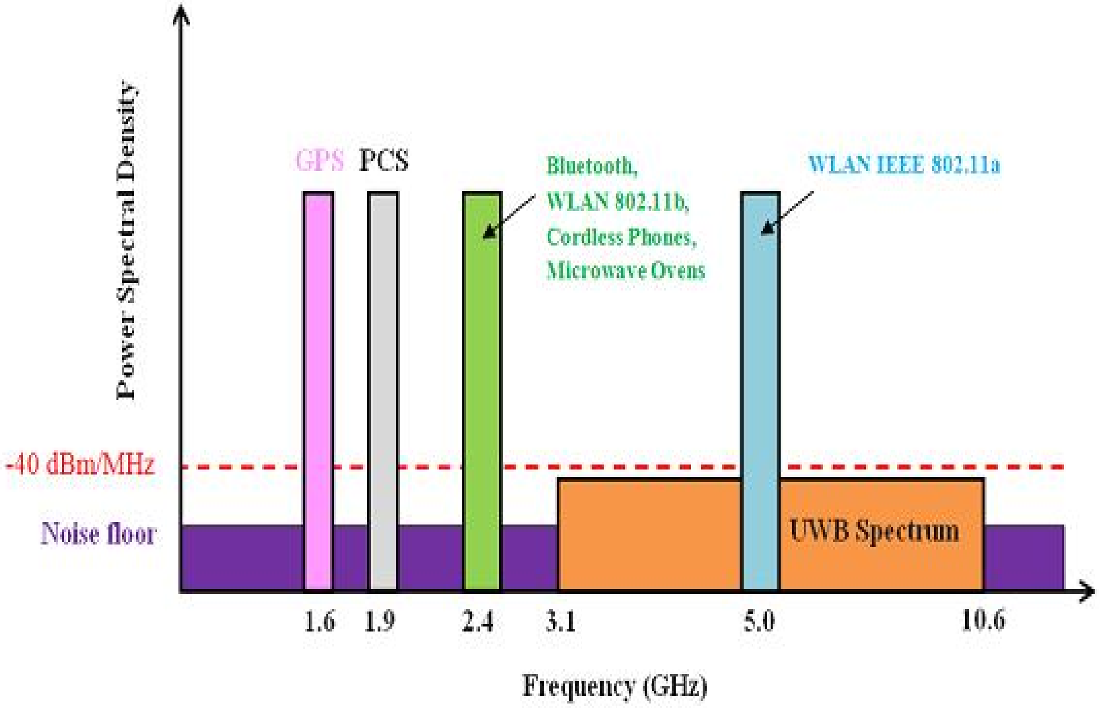

fig 1.1 UWB vs other radio communication systems

UWB has several advantages that makes differentiate it from conventional narrowband systems:

1. Large bandwidth enables fine time resolution for network time distribution, precision location capability, or use as a radar.

2. Short duration pulses are able to provide robust performance in dense multi-path environments by exploiting more resolvable paths.

3. Low power spectral density allows coexistence with existing users and has a Low Probability of Intercept (LPI).

4. Data rate may be traded for power spectral density and multipath performance.[**21**]

1.4 ORGANIZATION OF THESIS:

The outline of this thesis has organized in five chapters. The first chapter is an introduction, that provides information regarding literature review, scope of the project, project background and layout of thesis.

The second chapter will presents the fundamentals of microstrip antenna and different feeding techniques that used in microstrip antenna.

The third chapter will discuss about basics of antenna parameters i.e gain, directivity, polarization, vswr, bandwidth and return loss.

The fourth and fifth chapter shows the design and simulation results of diamond shaped patch array using CST microwave studio software.

The last chapter shows conclusion and future work needed. This chapter will conclude and provide recommendations for future work.

CHAPTER-2

Microstrip Antenna

2.1 INTRODUCTION:

Microstrip patch antenna in its easiest configuration consists of a radiating patch on one side of a substrate filled with dielectric($\varepsilon_r \leq 10$), which has a ground plane(metal) on the other side. The patch conductors are used normally of copper or gold, can assume virtually any shape i.e, circle, rectangular, square, triangle, but regular shapes are generally used to simplify analysis and performance prediction, Ideally, the relative permittivity ε_r, of the substrate should be low($\varepsilon_r <$ 2.5),to enhance the fringing fields that account for the radiation.

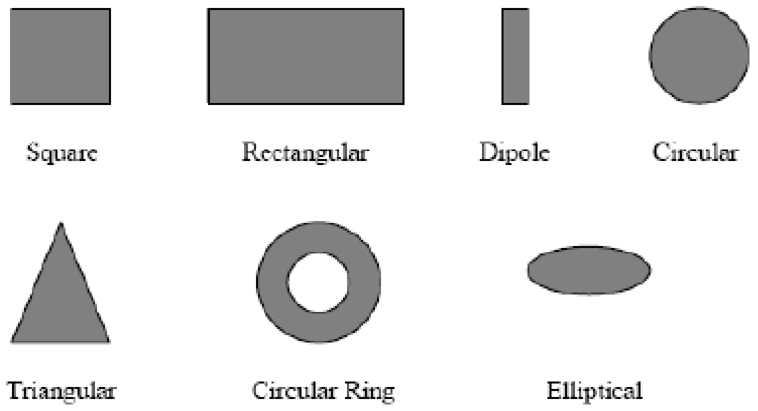

Fig 2.1 Different shapes and sizes of patch

However, other performance requirements may dictate the use of substrate materials whose dielectric constants can be greater than, say, four. Various types of substrates having a large range of dielectric constant and loss tangent values have been developed. Sometimes if we increase the dielectric constant or relative permittivity of the substrate there is chance to increase the performance of the antenna but high value of dielectric constant substrate may or may not be available to fabricate. The figure shown below is the basic structure of microstrip patch antenna in the center of the figure there is a patch which is metal in nature which can be any shape, and bottom of the figure 2.1 is ground plane which is metal in nature i.e substrate is sandwiched between two metals, so microstrip patch antenna consists two metals and one substrate. To energies this structure you need to feed this antenna with different feeding techniques that are discussed in the next topic.[**1**]

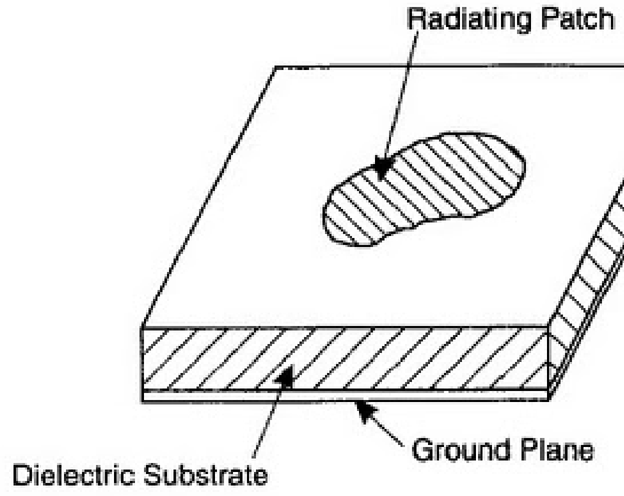

Fig 2.2 micro strip patch antenna structure

Advantages:

Microstrip antennas have many useful advantages compared to other microwave antennas, and therefore many applications cover the broad frequency range from 100 MHz to 100GHz[**1**].Some of the principle advantages of microstrip antennas compared to conventional microwave antennas are:

- Light weight and low volume
- Low profile planar configuration which can be easily made conformal to host surface
- low fabrication cost; readily amenable to mass production;
- Linear and circular polarizations are possible with simple feed.
- Dual frequency and dual polarization antennas can be easily made;
- Can be integrated with microwave integrated circuits.
- Mechanically robust when mounted on a rigid surface.

Disadvantages :

- Narrow bandwidth
- Low gain up to 6dB
- Low efficiency
- These antennas radiate into half space
- Extraneous radiation from feeds and junctions
- Low power handling capacity
- Surface wave excitation.

APPLICATIONS:

- Satellite communication, direct broadcast services
- Doppler and other radars
- Missiles and telemetry
- Mobileradio (pagers,telephones, man pack systems)
- Biomedical radiators and intruder alarms.

2.2 FEEDING METHODS:

To energize the antenna feeding is required, i.e. To transfer the power into the antenna feeding technique is required. Microstrip antennas have radiating elements on one side of dielectric substrate, and thus early microstrip antennas were fed either by a microstrip line or a coaxial probe through the ground plane. Microstrip antennas are fed by a variety of methods that are broadly classified into two main categories, namely, contacting and non conctacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. In the non contacting method, electromagnetic field coupling is done to transfer power between the microstrip line and radiating patch. Since then a number of new feeding techniques have been developed. The four most popular feed techniques used are the microstip line, coaxial probe, aperture coupling and proximity coupling Some feeding techniques are easy to fabricate where as other are difficult, and some feeding techniques are increase band width and others are not, whereas aperture and proximity is used to increase the bandwidth but fabrication is the major problem because these two feeding techniques useful when two substrates are present[**1**].

2.2.1 Coaxial Feed technique:

The inner conductor of the coaxial connector extends through through the substrate and soldered to the patch. Coaxial feed has the advantage of simplicity of design through the positioning of the feed point to adjust the input impedance level. But it has several limitations. First, coaxial feeding of an array requires a large number of solder joints, which makes fabrication difficult and compromises reliability. To increase bandwidth of patch antenna, a thicker substrate is used and therefore requires a longer probe, increased surface wave power, and increased feed inductance which leads to mismatch. Coaxial feeding is easy to fabricate. Equivalent circuit of this figure is shown in 2.6.

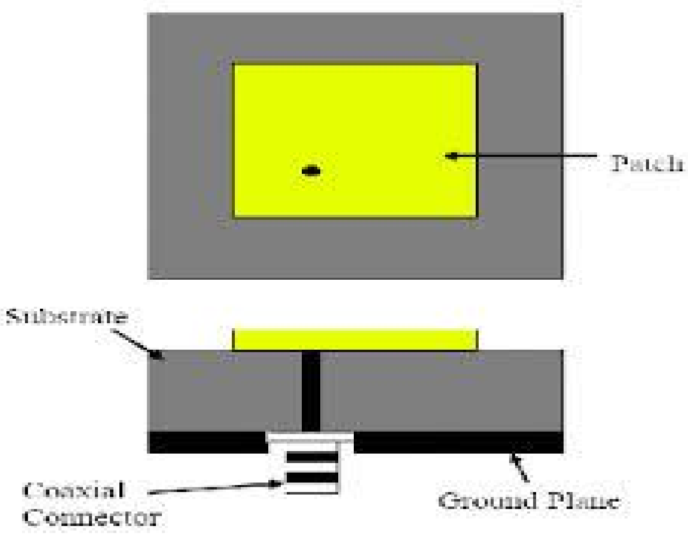

Fig 2.3 coaxial fed patch antenna

2.2.2 Microstrip line feed:

Excitation of the microstrip antenna by a microstrip line on the same substrate appers to be a natural choice because the patch can be considered an extension of the microstrip line, and both can be fabricated simultaneously. The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without the need for any additional matching element.

This is achieved by properly controlling the inset position. Hence this is an easy feeding scheme, since it provides ease of fabrication and simplicity in modeling as well as impedance matching. However as the thickness of the dielectric substrate being used, increases, surface waves and spurious feed radiation also increase. Equivalent circuit diagram of this type of feeding technique is presented in fig.2.6

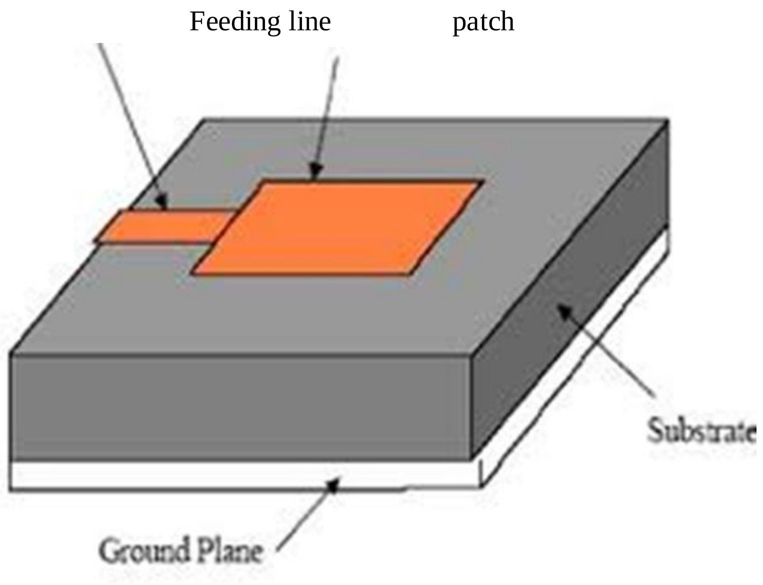

Fig 2.4 microstrip feed

\2.2.3 Proxmity coupled Microstrip feed:

A configuration of this nonconducting noncoplanar substrate with the microstrip feed shown in fig.2.4.It uses a two layer and the patch antenna on the upper layer.The feed line terminates in an open end underneath the patch.This feed is better known as an “electromagnetically coupled”microstrip feed.To design this feed two substrates are required, and the feed line shoud be in between the two substrates to the metal patch.It has an advantage to get 13% bandwidth ,which is useful, using of two substrates the fabrication is difficult.And the thickness of the antenna is increased.The substrate parameters of the two layers can be selected to increase the bandwidth of the patch, and to reduce spurious radiation from the open end of the microstrip,For this lower substrate should be thin.The equlent circuit diagram for this type of feeding is shown in fig.2.5

Some advantages are:

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

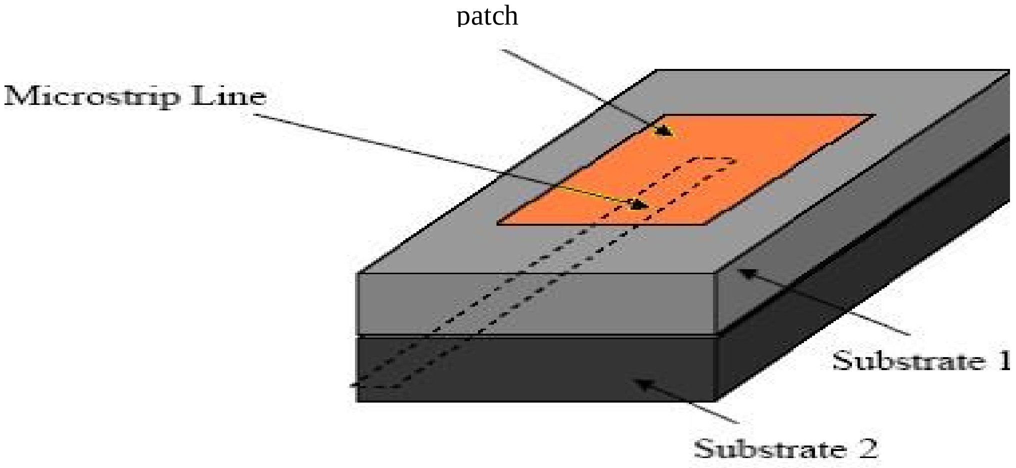

Fig 2.5 proxmity coupled feed

2.2.4 APERTURE COUPLED MICROSTRIP FEED:

In this type of feed technique, the radiating patch and the microstrip feed line are separated by the ground plane as shown in Figure 2.6. Coupling between the patch and the feed line is made through a slot or an aperture in the ground plane. The coupling aperture is usually centered under the patch, leading to lower cross-polarization due to symmetry of the configuration. The amount of coupling from the feed line to the patch is determined by the shape, size and location of the aperture. Since the ground plane separates the patch and the feed line, spurious radiation is minimized. Generally, a high dielectric material is used for bottom substrate and a thick, low dielectric constant material is used for the top substrate to optimize radiation from the patch. The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness. This feeding scheme also provides narrow bandwidth.

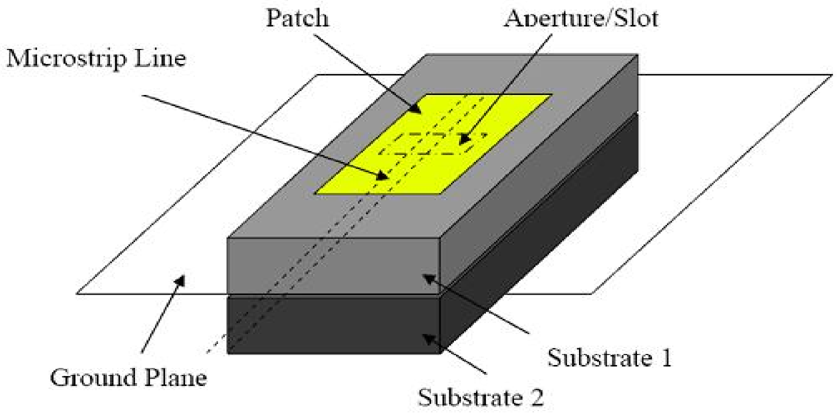

Fig 2.6 aperture coupled microstrip feed

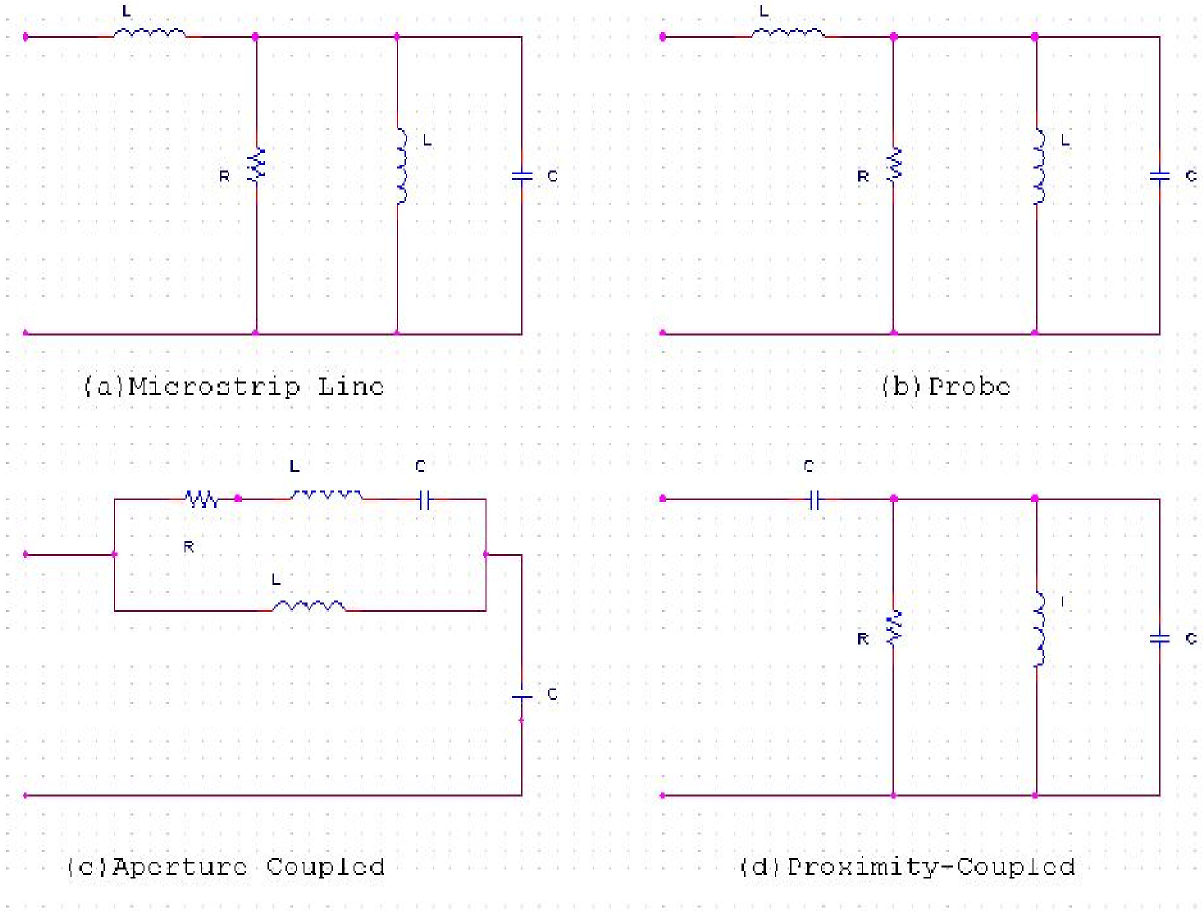

Fig 2.7 Equalent circuits for typical feeding techniques

2.2.5 COMPARISION OF DIFFERENT FEEDING TECHNIQUES:

Table 1:comparision of different techniques

Characteristics	**Microstrip line feed**	**Coaxial feed**	**Aperture coupled feed**	**Proximity coupled feed**
Spurious feed radiation	More	More	Less	Minimum
reliability	Better	Poor due to soldering	Good	Good
Ease of fabrication	Easy	Soldering and drilling required	Alignment required	Alignment required
Bandwidth achieved	2-5%	2-5%	2-5%	13%

2.3 FRINGING EFFECTS:

Because of the dimensions of the patch are finite along the length and width, the fields at the edges of the patch undergo fringing.The amount of fringing is a function of the dimensions of the patch and the height of the substrate.For the principal E-plane(xy-plane) fringing is a function of the ratio of the length of the patch L to the height h of the substrate and the dielctric constant of the substrate. Due to fringing electric field lines travels in non-homogeneous material, typically substrate and air, that is why effective dielectric constant introduced[**1**].

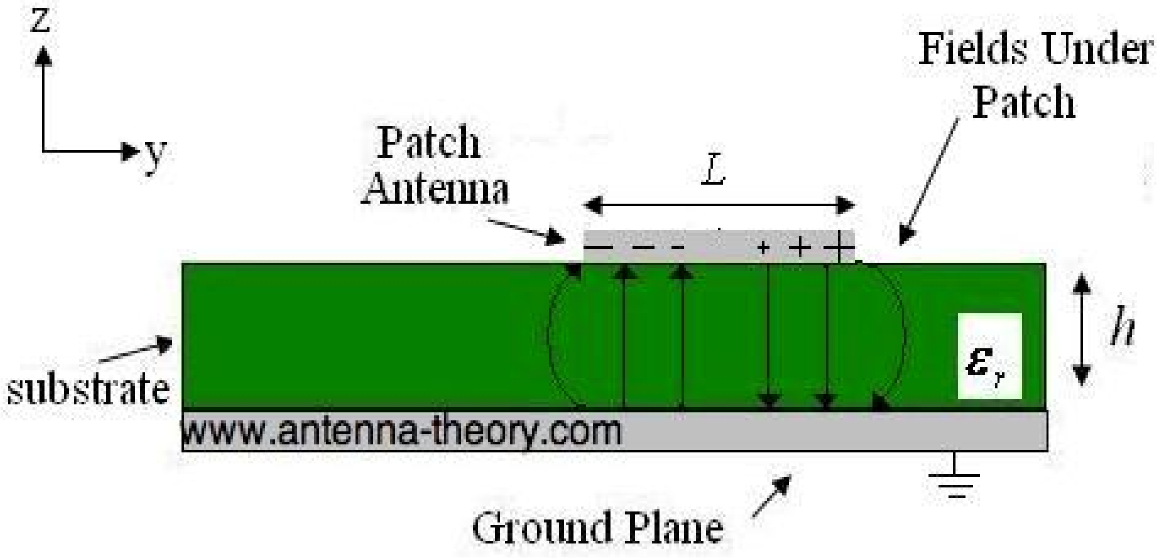

Fig 2.8 Fringing fields

2.4 METHODS OF ANALYSIS

2.4.1 TRANSMISSION LINE MODELING:

Transmission line model is the eaisest of all but it yields the least accurate results and it lacks the versatility.However, it does shed some physical insight.A rectangular microstrip antenna can be represented as an array of two radiating narrow apertures(slots), each of width W and height h, seperated by a distance L.Basically the transmision line model represents the microstrip antenna by two slots by a low impedance Z_O transmission line of length L.The microstrip is essentially a non-homogeneous line of two dielectrics, typically the substrate and air. A typical microstrip line is shown in Fig. 2.8 while the electric field lines associated with it are shown in

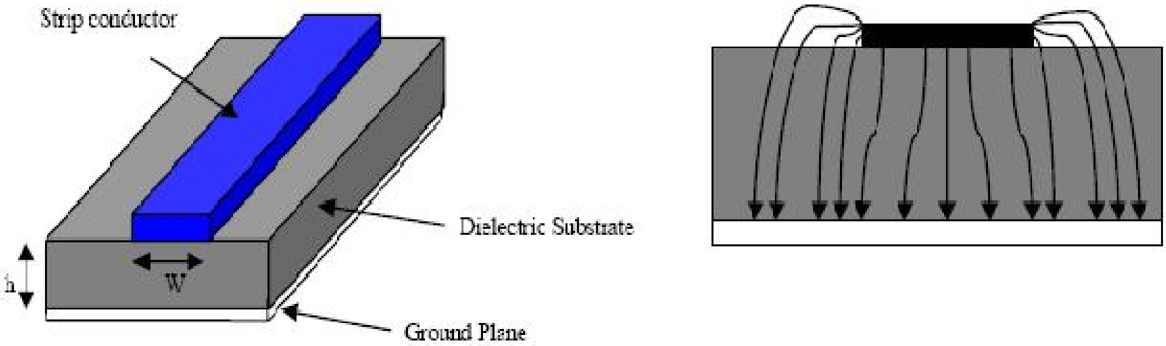

Fig 2.9 Micro strip line and Electric field lines

As seen in the fig 2.9 the electric field lines reside in the substrate and parts of some lines exist in air.As L/h >>1 and ε_r>>1,the elctric field lines concentrate mostly in the substrate.Fringing in this case makes the microstrip look wider elctrically comapred to its physical dimensions.Since some of the waves travel in the substrate and some in air,an effective dielectric constant ε_{reff} is introduced toaccount for fringing and the wave propogation in the line.

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

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

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

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

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

2.4.2 CAVITY MODEL:

Although the transmission line model discussed in the previous section is easy to use, it has some inherent disadvantages. Specifically, it is useful for patches of rectangular design and itignores field variations along the radiating edges. These disadvantages can be overcome by using the cavity model. A brief overview of this model is given below.In this model, the interior region of the dielectric substrate is modeled as a cavitybounded by electric walls on the top and bottom. The basis for this assumption is the following observations for thin substrates ($h << \lambda$)

Since the substrate is thin, the fields in the interior region do not vary much in the z direction.i.e. normal to the patch.

The electric field is z directed only, and the magnetic field has only the transverse components x H and y H in the region bounded by the patch metallization and the ground plane. Thisobservation provides for the electric walls at the top and the bottom.Consider Fig. 2.10 shown above. When the microstrip patch is provided power, a charge distribution is seen on the upper and lower surfaces of the patch and at the bottom of the ground plane. This charge distribution is controlled by two mechanisms – an attractive mechanism and a repulsive mechanism .

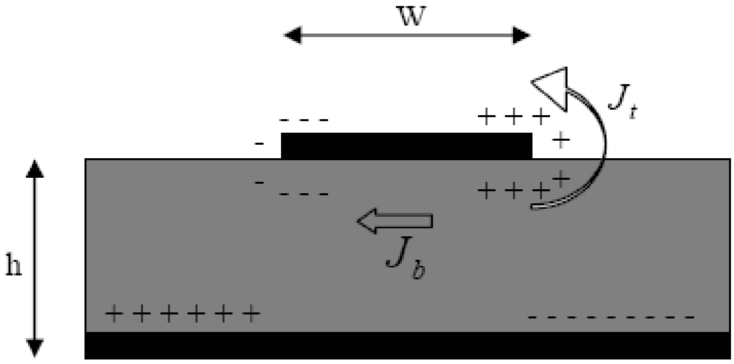

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Fig 2.10 Charge distribution and current density creation on the microstrip patch

The attractive mechanism is between the opposite charges on the bottom side of the patch and the ground plane, which helps in keeping the charge concentration intact at the bottom of the patch. The repulsive mechanism is between the like charges on the bottom surface of the patch, which causes pushing of some charges from the bottom, to the top of the patch. As a result of this charge movement, currents flow at the top and bottom surfaces of the patch[**1**].

2.5 ANTENNA ARRAY THEORY:

Although a single element patch antenna may provide the desired antenna characteristics, combinations of many microstrip antennas into an array enable the designer to fabricate microstrip antennas with high gain, beam shaping and beam steering capabilities. Control over such characteristics is only possible with the formation of antenna arrays.

Arrays of antennas usually consist of a repetition of radiating elements in a regular fashion. The elements may be identical or different and the structure may be configured as a linear, planar or volume array. Each element is also located at a specific distance from the other. The spacing between each element causes the fields from each element add or subtract in the far field to produce the desired radiation pattern. A practical reason supporting the feasibility of microstrip antenna arrays is the fact that conventional printed circuit etching processes are accurate, repeatable and relatively low in cost.

In the simple array theory, each radiator is first treated as a point isotropic source. Thecontributions from each point is derived in the far field and expressed as an array factor (AF). The array factor may be said to be the ‘standard’ pattern and depends only of the geometry of the array and the phase between each element. Each point is then replaced by the actual radiator and the far field radiation pattern is then determined by pattern multiplying the array factor with the pattern of the radiator. Mutual coupling is ignored in the process since the radiators are treated separately also their influence on each other are not considered. The simple array theory also does not account for the presence of other objects such as feed lines or obstructions[**2**]

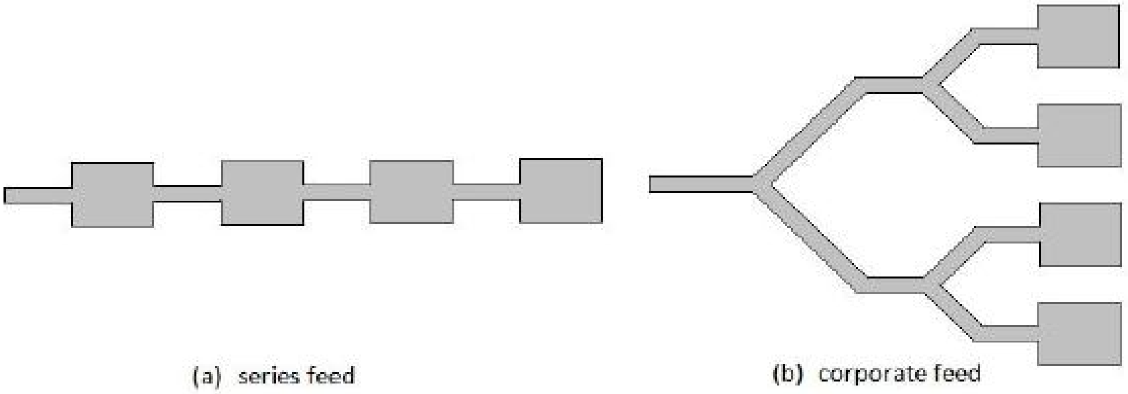


Fig 2.11 Feed arrangement for microstrip patch array

The spacing between the antenna elements plays a important role in design. If the spacing between two elements is too large it creates grating lobes that is undesirable, whereas too small spacing leads to broader beam width that also undesirable. But if the spacing is too small then the amount of space for the feed network reduces, So that the spacing between elements should be adjust properly.

2.5.1 Two Element Array:

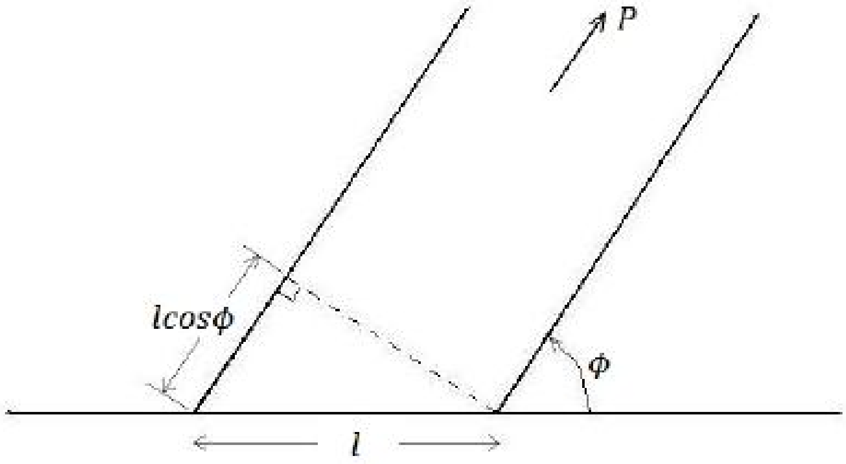


Fig 2.12 two- element array

Suppose two antenna elements to make an array as in figure 2.12 above. The two elements are fed with current i1and i2.

i1and i2are equal in magnitude but out of phase

$$i1 = i2\angle\alpha \qquad (2.3)$$

the point of observation is in the far field, the path length difference is $\boldsymbol{l}\cos\alpha$ where $\boldsymbol{l}$ is the distance between the two elements. the radiation of element 1 at $\boldsymbol{P}$will lead the radiation of element 2 with angle Ψ where

$$\Psi = \beta\boldsymbol{l}\cos\phi + \alpha \qquad (2.4)$$

β=phase constant of the transmitted wave

The total field at $\boldsymbol{P}$ is

$$\boldsymbol{E} = \boldsymbol{E}_1[1 + exp(j\Psi)] \qquad (2.5)$$

Where $\boldsymbol{E}_1$ is the field at $\boldsymbol{P}$ due to element 1

The magnitude of the field at $\boldsymbol{P}$ is

$$|E_\phi| = 2E_1\cos\left(\frac{1}{2}\Psi\right)$$

$$= 2E_1\cos\frac{1}{2}(\beta l\cos\phi + \alpha)$$

$$= 2E_1\cos\left(\frac{\pi l}{\lambda}\cos\phi + \frac{\alpha}{2}\right) \qquad (2.6)$$

From above equation we can see that for a given phase difference and a given distance we can change the radiation pattern by changing $(\frac{l}{\lambda})$.

2.6.2 Linear Array:

In above topic we have studied a simple array consists of two elements, now If we put more elements in the line of our two elements array, we construct a linear array.

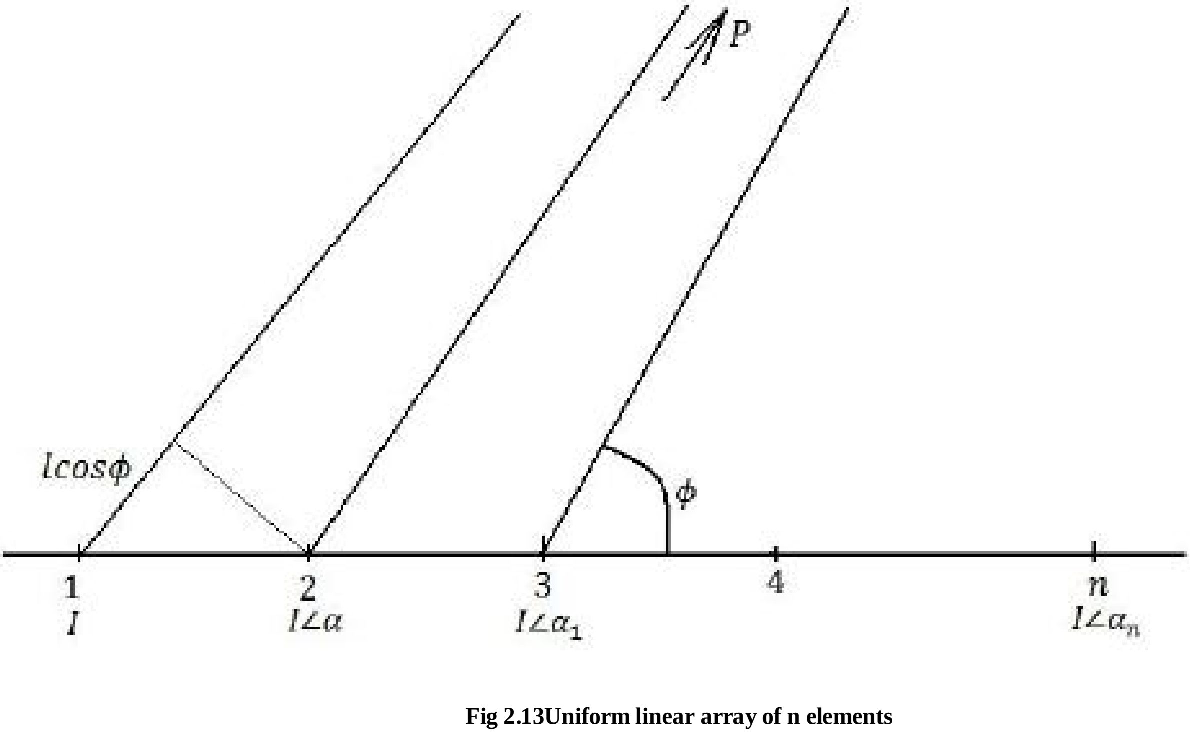


Fig 2.13Uniform linear array of n elements

Now consider above figure of a simple linear array with equal separation between elements $\boldsymbol{l}$ and equal current in magnitude and equal difference in phase i

$$\mathrm{i},\ \mathrm{i}\angle\alpha, \mathrm{i}\angle\alpha_1, \mathrm{i}\angle\alpha_2, \ldots\ldots \mathrm{i}\angle\alpha_n$$

field at point $\boldsymbol{P}$

$$\boldsymbol{E} = \boldsymbol{E}_1[1 + e^{j\Psi} + e^{j2\Psi} + e^{j3\Psi} + \ldots e^{jn\Psi}] \qquad (2.7)$$

The magnitude of $\boldsymbol{E}$ is

$$\boldsymbol{E} = \boldsymbol{E}_0 \left| \frac{\sin\frac{n\Psi}{2}}{\sin\frac{\Psi}{2}} \right| \qquad (2.8)$$

$$\text{Where } \Psi = \beta \boldsymbol{l} \cos\phi + \alpha \qquad (2.9)$$

The quantity $\left| \frac{\sin\frac{n\Psi}{2}}{\sin\frac{\Psi}{2}} \right|$ is known as array factor it determines the shape of the radiation pattern.

CHAPTER-3

Antenna Parameters

3.1 GAIN & DIRECTIVITY:

Directivity is the ability of an antenna to focus energy in a particular direction. “Directivity (of an antenna) is the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions”. Note that the radiation intensity is equal to the total power radiated by the antenna divided by 4π. Directivity is always greater than one[**2**].

The directive gain is “the ratio of the radiation intensity, in a given direction to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically”. We can obtain gain from directivity of the antenna:

$$G = e\boldsymbol{D}$$

e is the efficiency of the antenna. Gain is always less than directivity because efficiency is between 0 and 1. The directivity increases with increase in substrate thickness h and patch width W.

3.2 ANTENNA POLARISATION:

Polarization is an important factor for RF antennas and radio communications in general. Both RF antennas and electromagnetic waves are said to have a polarization. For the electromagnetic wave the polarization is effectively the plane in which the electric wave vibrates. This is important when looking at antennas because they are sensitive to polarization, and generally only receive or transmit a signal with a particular polarization. For most antennas it is very easy to determine the polarization. It is simply in the same plane as the elements of the antenna. So a vertical antenna (i.e. one with vertical elements) will receive vertically polarized signals best and similarly a horizontal antenna will receive horizontally polarized signals.

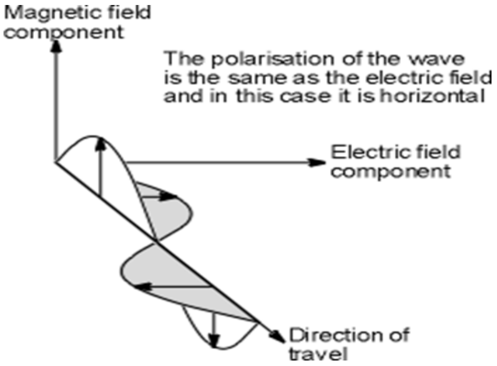


Fig 3.1 polarisation of wave

3.3 VOLTAGE STANDING WAVE RATIO:

The standing wave ratio (SWR), also known as the voltage standing wave ratio (VSWR), is not strictly an antenna characteristic, but is used to describe the performance of an antenna when attached to a transmission line. It is a measure of how well the antenna terminal impedance is matched to the characteristic impedance of the transmission line. Specifically, the VSWR is the ratio of the maximum to the minimum RF voltage along the transmission line. The maxima and minima along the lines are caused by partial reinforcement and cancellation of a forward moving RF signal on the transmission line and its reflection from the antenna terminals.

Theoretically VSWR can have values between 1 to infinity, If u want to comment on performance of an antenna if it maintains VSWR <2 then it is good antenna over the range of frequencies which it maintains VSWR <2.If the values are below 1.5 then it is excellent antenna, if VSWR is >2 then its unacceptable[**2**].

3.4 BANDWIDTH:

Most RF antenna designs are operated around the resonant point. This means that there is only a limited bandwidth over which an RF antenna design can operate efficiently. Outside this the levels of reactance rise to levels that may be too high for satisfactory operation. Other characteristics of the antenna may also be impaired away from the center operating frequency. The antenna bandwidth is particularly important where radio transmitters are concerned as damage may occur to the transmitter if the antenna is operated outside its operating range and the radio transmitter is not adequately protected. In addition to this the signal radiated by the RF antenna may be less for a number of reasons. For receiving purposes the performance of the antenna is less critical in some respects. It can be operated outside its normal bandwidth without any fear of damage to the set. Even a random length of wire will pick up signals, and it may be possible to receive several distant stations. However for the best reception it is necessary to ensure that the performance of the RF antenna design is optimum.

3.4.1 IMPEDANCEBANDWIDTH:

Feed line produces impedance when this impedance matches with input impedance of the patch antenna, the power transferred to the antenna over the frequencies when matching occurs that frequency range is called impedance bandwidth.

3.5 RETURN LOSS:

Return loss is one of the important parameter to calculate the efficiency of the antenna over the range of frequencies. It indicates how much power is transmitted & how much power is reflected to the origin. Theoretically return loss is 0dB but practically it is impossible to maintain 0dB,so practically if the antenna maintains less than 10db over the frequencies then it is good antenna.

3.6 IMPEDANCE MATCHING:

Looking at the current (magnetic field) and voltage (electrical field) variation along the patch, the current is maximal at the center and minimal near the left and right edges, while the electrical field is zero in the center and maximal near the left and minimal near the right edges. The figures below clarify these quantities.

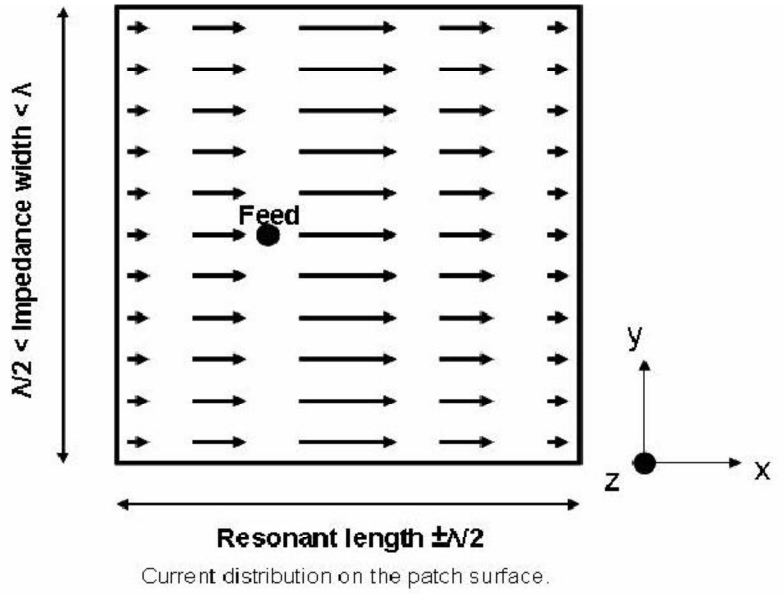


fig 3.2 current distribution on the patch

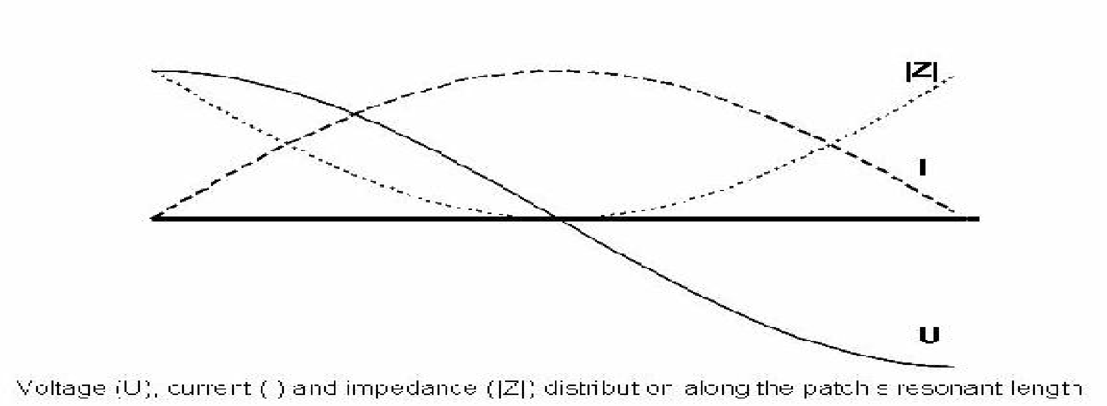


fig 3.3 voltage and current and impedance distribution along the patch

From the magnitude of the current and the voltage, we can conclude the impedance is minimum (theoretically zero W) in the middle of the patch and maximum (typically around 200 W, but depending on the Q of the leaky cavity) near the edges. Put differently, there is a point where the impedance is 50 W somewhere along the "resonant length" (x) axis of the element.

CHAPTER-4

A Novel 1×2 Diamond Shaped Patch Array for WLAN applications

4.1 INTRODUCTION:

In this design, we presents a 1×2 diamond shape patch array using microstrip line feed for WLAN applications. This antenna covers the WLAN covering 2.4,3.6 and 5GHZ bands and WiMAX covering from 3.4 to 3.7 GHz band. This antenna is simulated using CST software. In this antenna microstrip feed line is used to get desired performance. This antenna is simulated and performance of the antenna such as gain, S-parameter and radiation pattern are measured.

4.2 ANTENNA DESIGN:

FIG.4.1 shows the general configuration of proposed diamond shaped patch array. Where 1×2 diamond shaped patch array is placed over the substrate having dielectric constant of 4.4 and the thickness of substrate is 1.6mm and ground plane is printed on other side of the patch. This antenna covering bandwidth from 2.4 to 5.7GHz i.e that covers WLAN and WiMAX bands.

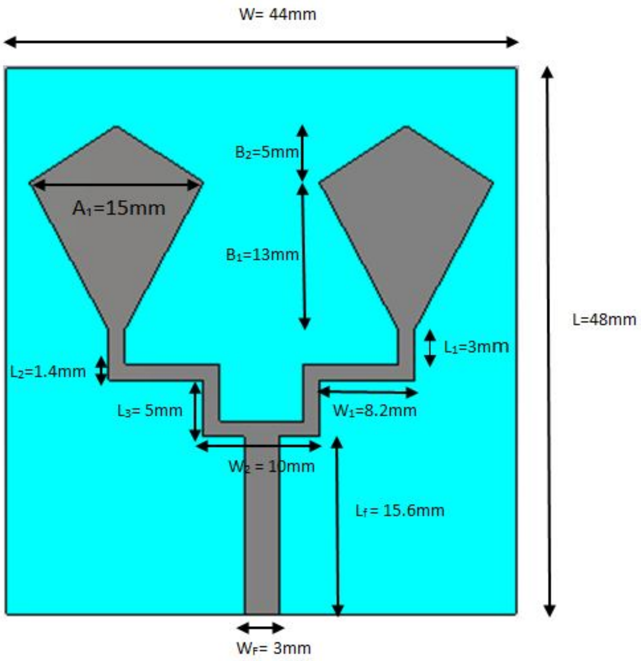


Fig 4.1 Front view of diamond shaped patch array

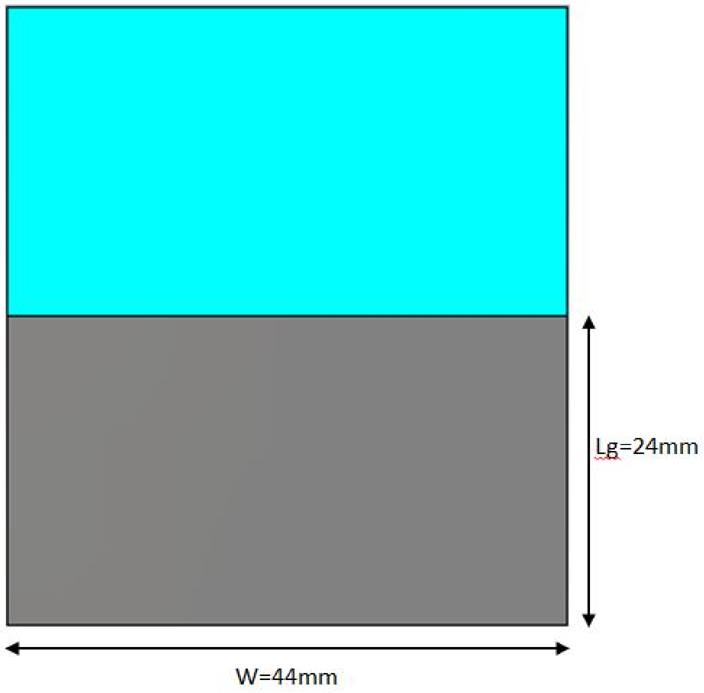


Fig 4.2 rear view of diamond shaped patch array

Table 2 shows the dimensions of the designed antenna

Design parameter	**Length in mm**
W	44mm
L	48mm
W1	8.2mm
W2	10mm
W_f	3mm
L1	3mm
L2	1.4mm
L3	5mm
L_f	15.6mm
A1	15mm
B1	13mm
B2	5mm
L_g	24mm

The antenna fabricated on a FR4 substrate with dielectric constant ε_r=4.4, loss tangent $tan\delta$=0.02 and thickness of h=1.6mm. As shown in the figure the diamond shaped patch array is fed by a 50-Ω microstrip line which is terminated with a SMA connector for measurement purpose. The width of the feed line W_f and length of the line L_f are 3mm and 15.6mm respectively. And the distance between feedline and ground plane is 1.6mm.

4.3 PARAMETRIC STUDY:

Parametric study is done by comparing different designs of diamond shaped patch array to achieve better antenna performance.

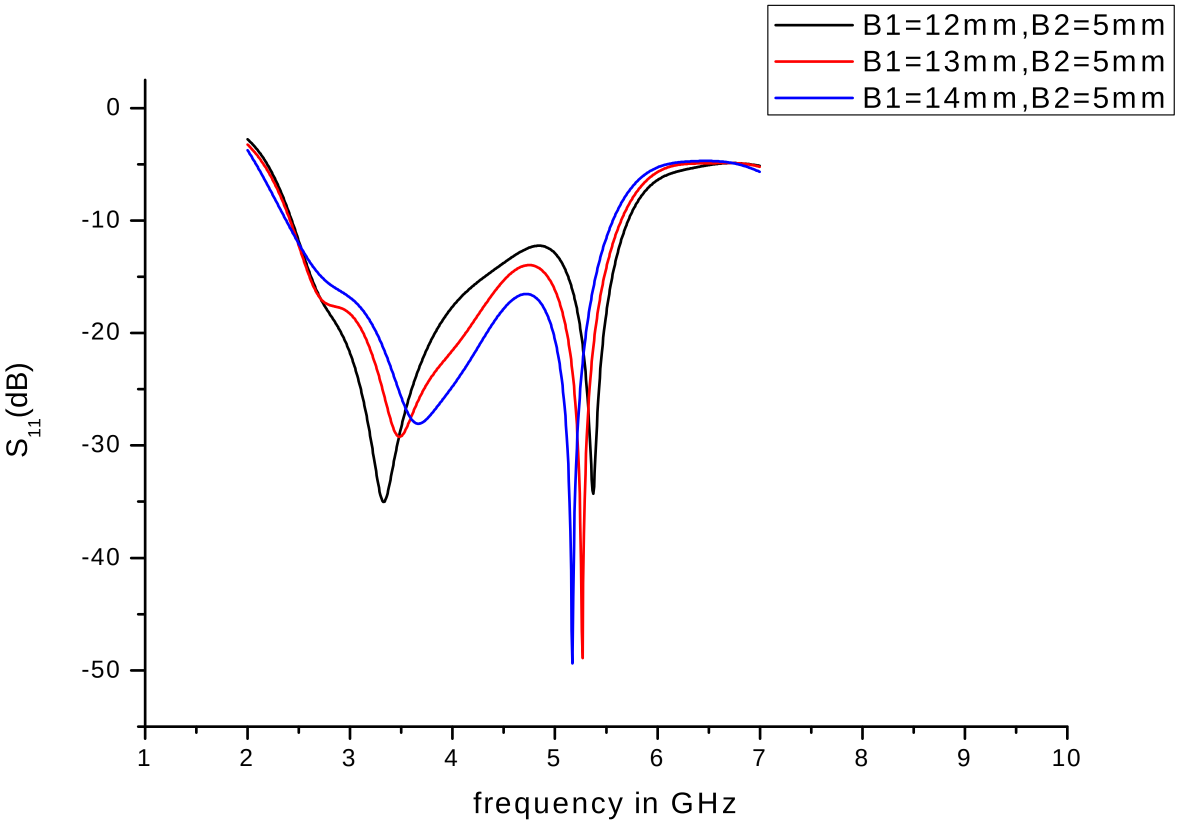
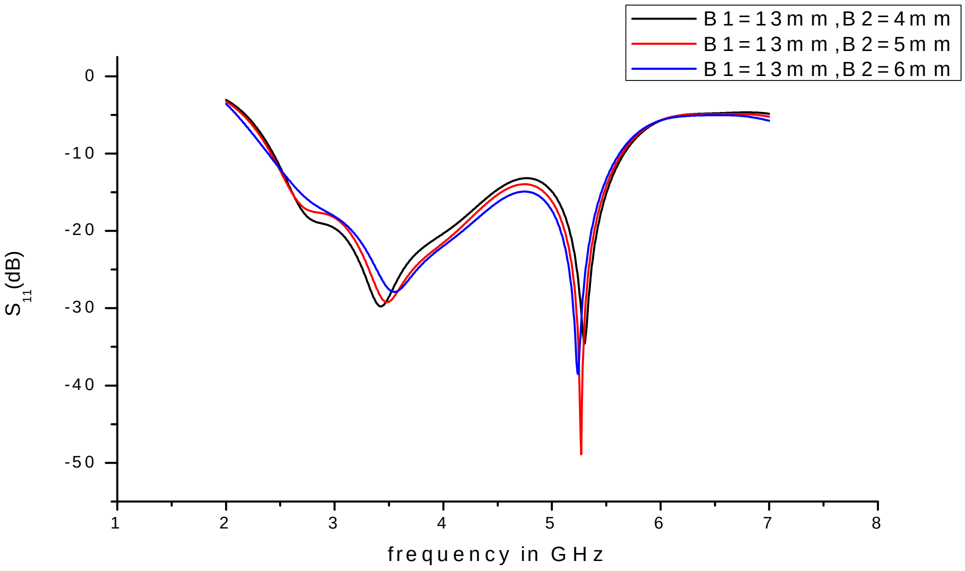
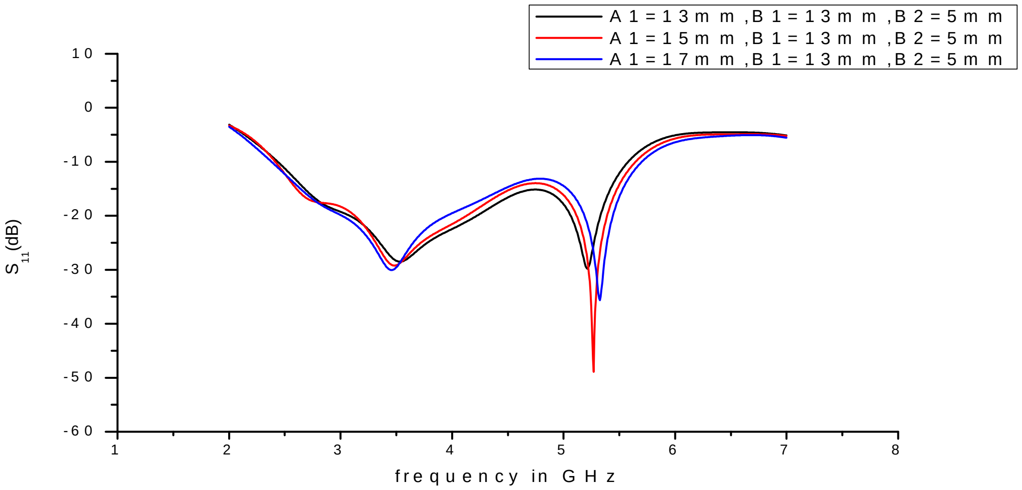


Fig 4.3 shows the simulated reflection coefficient of the diamond shaped array antenna for various values of B1

The parametric study carried out by varying B1with B2 and A1 are constant. For B1=13mm the return loss is approximately 50dB at 5.2GHz, it is observed that as B1 decreases the return loss at lower frequency is high.



(a)



(b)

Fig 4.4(a) and 4.4(b) shows the simulated reflection coefficient of diamond shaped patch array for various values of B2 and A1.

Another parametric study is carried out by varying the value of B2 while B1 and A1 are constant. It is observed that as the value of B2 increases the $_{S11is}$ moving right side

4.4 VSWR vs Frequency plot :

Voltage standing wave ratio can be evaluated by dividing maximum voltage with minimum voltage or we can find by using reflection coefficient. In the figure 4.5 it is shown that frequency range 2.4-5.7GHz the plot is maintaining VSWR <2.If VSWR is 1 that indicates reflection coefficient is maintaining value of zero which is not practically possible, always there is some amount of reflection exists for any antenna practically.So VSWR is maintaining <1.5 or 2 ,then it is good for radiation purposes.

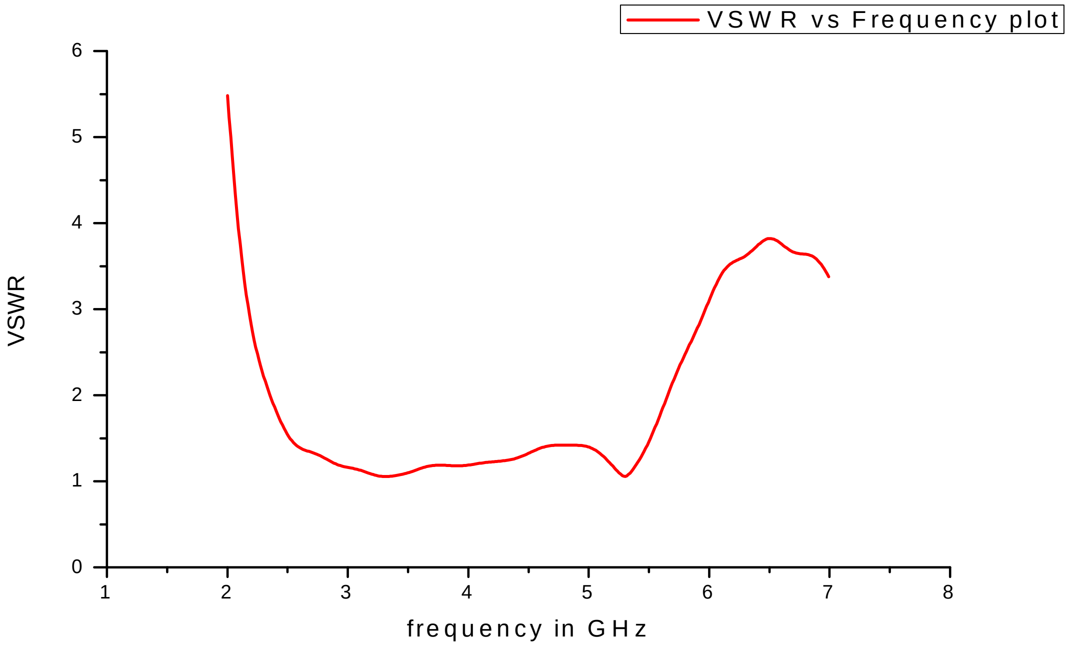


Fig 4.5 VSWR vs frequency

4.5 GAIN vs Frequency characteristics:

The simulated Gain versus frequency of proposed diamond shaped patch array is shown in the fig 4.6. the gain is increasing with different frequencies, where the gain is 3.14dB at 2.5GHz, 5.2dB at 4GHz, 7.05dB at 5GHz, 7.21dB at 5.5GHz.From which it can be seen that the antenna can provide stable gains over the operating frequency range. From the below radiation characteristics the presented antenna is a good compact antenna for the WLAN and WiMAX applications in the wireless communication system.

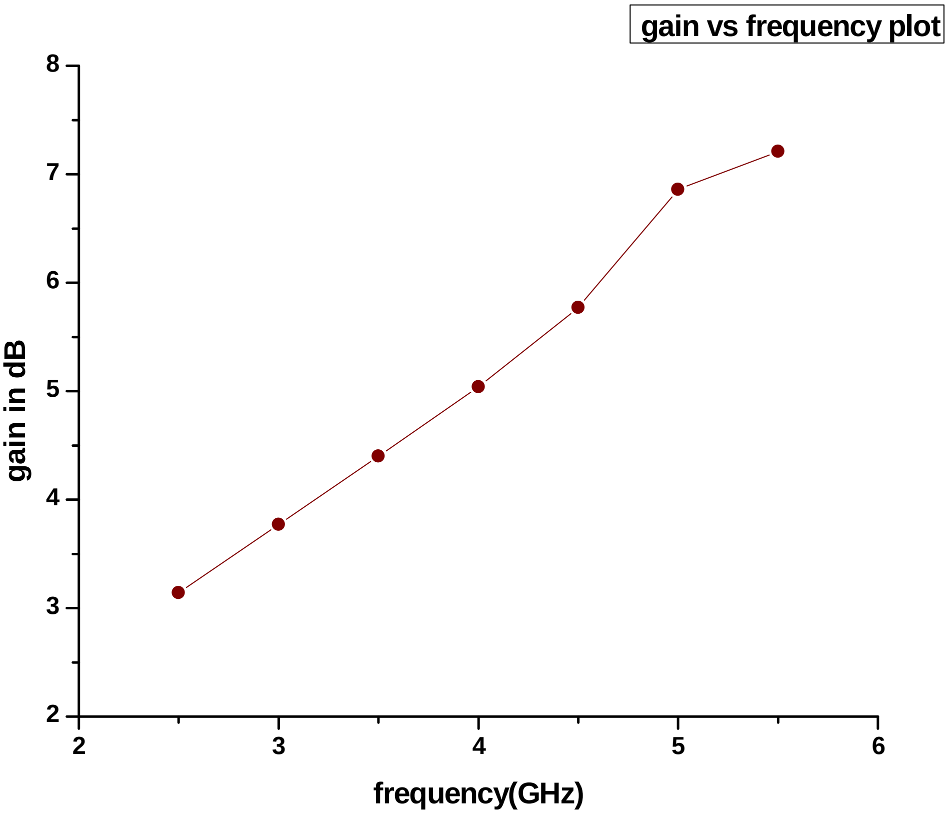


Fig 4.6 Gain vs frequency characteristics

4.6 RADIATION PATTERN CHARACTERISTICS:

Fig 4.7 illustrates the simulated radiation patterns in E and H-planes for diamond shaped patch array at 3.5, 4.5, 5.5GHz respectively. From the radiation patterns it is observed that E-planes are in broadside direction, H-plane patterns almost omnidirectional.

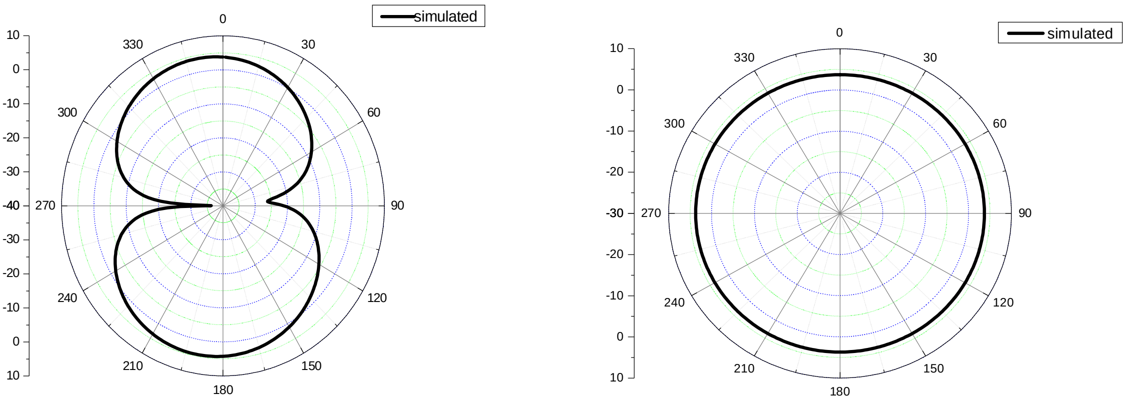


Fig 4.7(a) Simulated E and H-plane radiation pattern at 3.5GHz

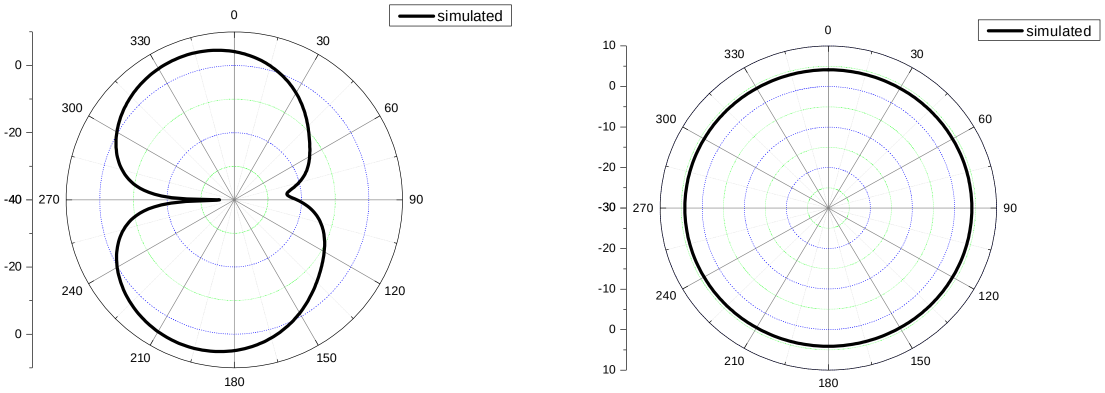


Fig 4.7(b) Simulated E and H-plane radiation pattern at 4.5GHz

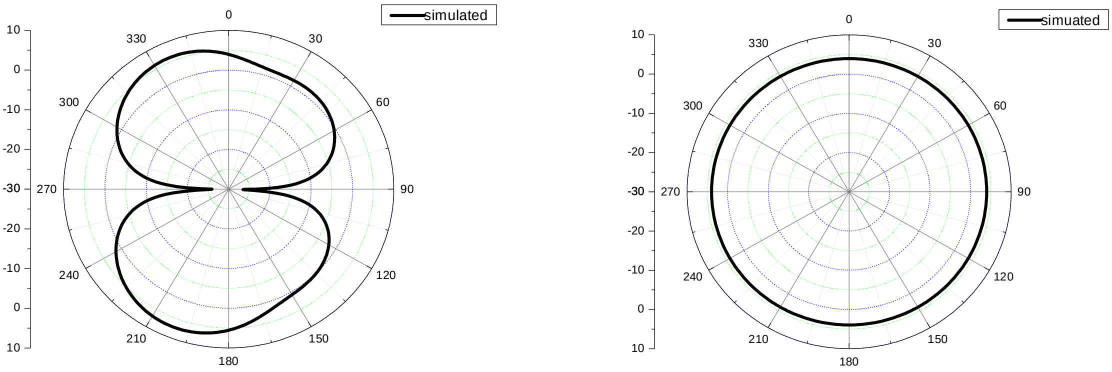
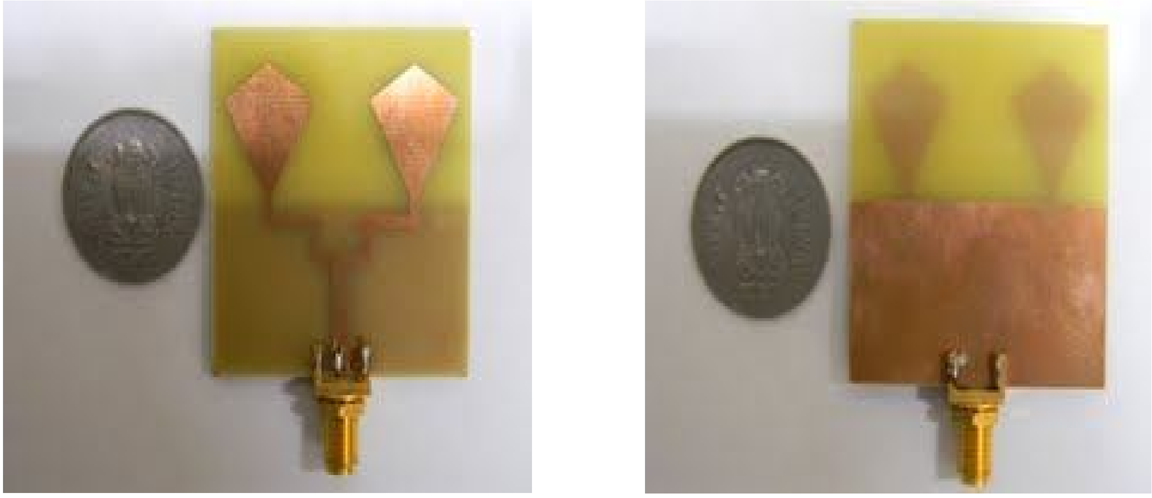


Fig 4.7(c) Simulated E and H-plane radiation pattern at 5.5GHz

H-plane radiation pattern at 5.5GHz



THE FABRICATED 1×2 DIAMOND SHAPED MICROSTRIP PATCH ARRAY

4.7 SUMMARY:

In this design a 1×2 diamond shaped microstrip patch array is presented for WLAN applications. The proposed shape of the patch is diamond. It is observed that by changing the different parameters of the antenna S_{11} curve is changing. The simulated result shows the designed antenna covers the broad range of frequencies from 2.4GHz to 5.7GHz. The maximum peak gain of the antenna achieved is 7.21dB at 5.5GHz. The proposed antenna well suited for WLAN applications.

CHAPTER-5

A Compact 1×2 Diamond Shaped Microstrip Array for UWB Applications

5.1 INTRODUCTION:

In this antenna we presents a compact size 1×2 diamond shaped microstrip patch array for UWB applications. Due to attractive merits of wide frequency bandwidth UWBreceived much attention in wireless communications. The antenna is simulated using CST microwave studio software. The designed antenna covers the frequency range from 3.8 to 10.6GHz which includes WLAN bands.

5.2 ANTENNA DESIGN:

Fig 5.1 shows the geometry of the proposed compact size 1×2 diamond shaped microstrip patch array. This array is placed over the substrate having thickness of 1mm and dielectric constant of 4.4. The antenna is excited by 50-Ω microstrip line printed on the substrate. The ground plane is designed in such a way that the antenna covers ultrawideband. A U-shaped ground plane is placed on the back side of the antenna to cover the UWB range. The dimensions of the substrate is 18×24(W×L) with thickness 1mm.

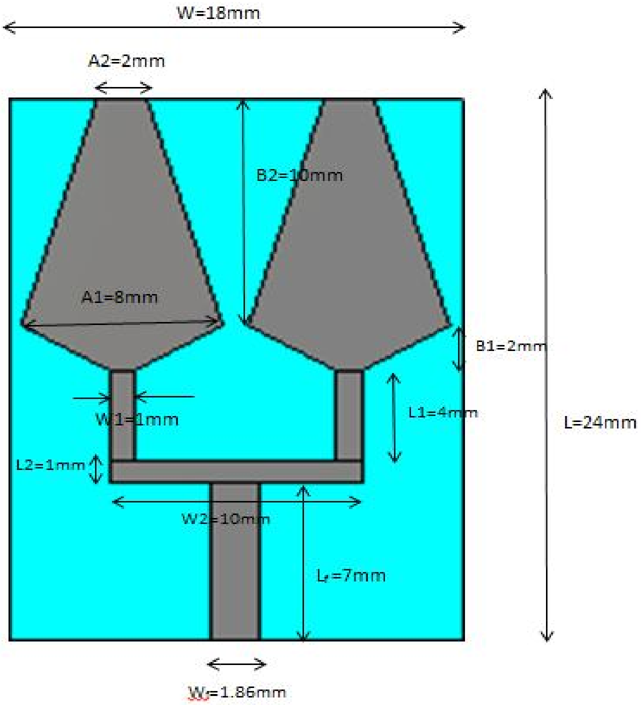


Fig 5.1 front view of the proposed antenna

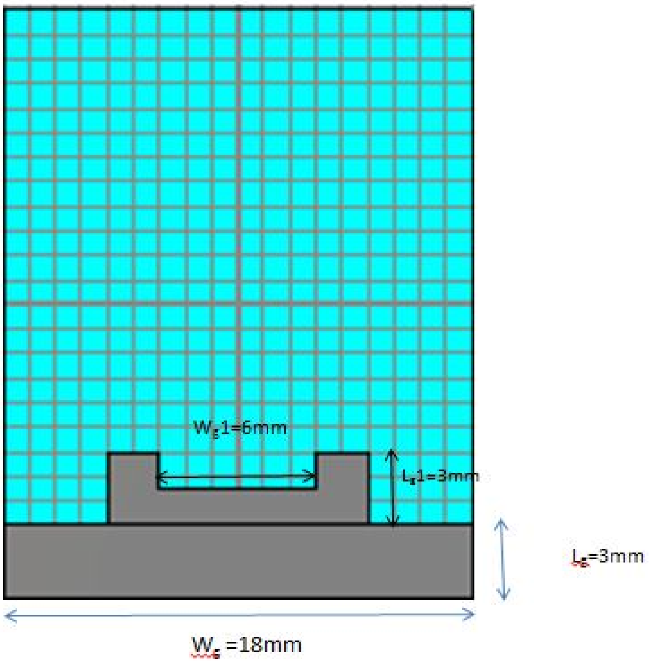


Fig 5.2 Rear view of the proposed antenna

Table 3 shows the dimensions of the compact size diamond shaped microstrip array

Parameter	Length in mm
W	18mm
L	24mm
W1	1mm
L1	4mm
W2	10mm
L2	1mm
W_F	1.86mm
L_F	7mm
A1	8mm
B1	2mm
A2	2mm
B2	10mm

5.3 SIMULATION RESULTS:

5.3.1 RETURN LOSS:

Fig 5.3 shows the simulated reflection coefficient for different ground planes. With U-shaped structure on the ground plane the antenna is covering bandwidth from 3.8 to 10.6GHz. For different values of L_g the antenna is not covering entire bandwidth for L_g=3mm and 5mm there is notch coming in the bandwidth curve so by adding U-shaped structure on the ground plane then only the antenna covers UWB range.

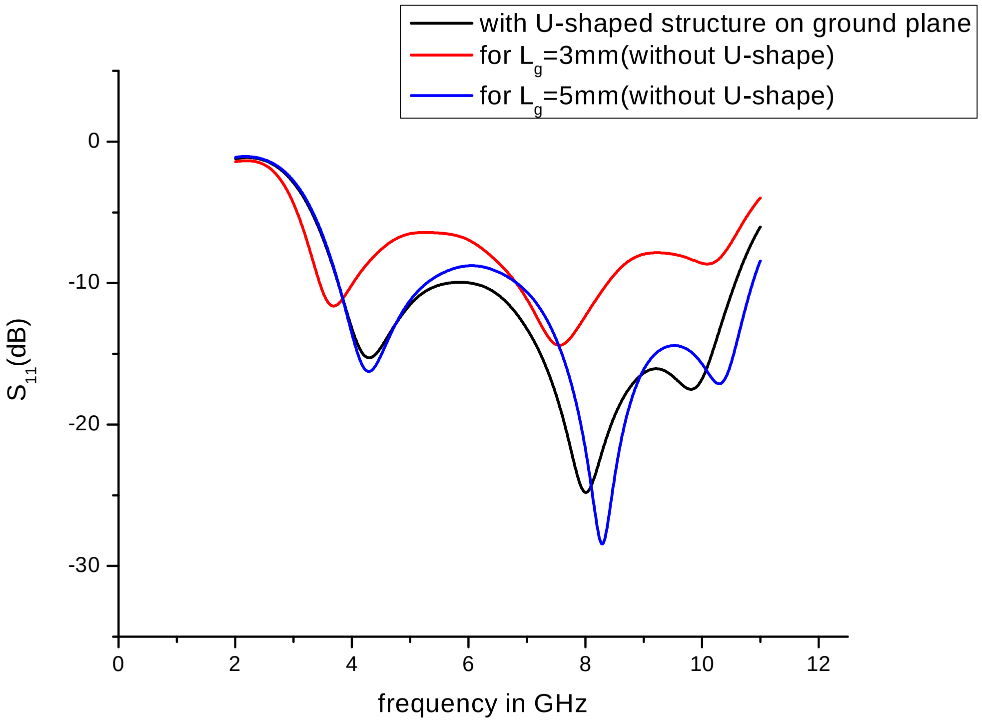


Fig 5.3 simulated reflection coefficient with different ground planes

5.3.2 GAIN vs Frequency characteristics:

The below figure 5.4 shows the simulated gain vs frequency characteristics of the compact 1×2 diamond shaped microstrip patch array. The gain is increasing with the frequency and the peak gain achieved with this antenna is 6.5dB at 10GHz. Even though size of the antenna is compact good gain is achieved.

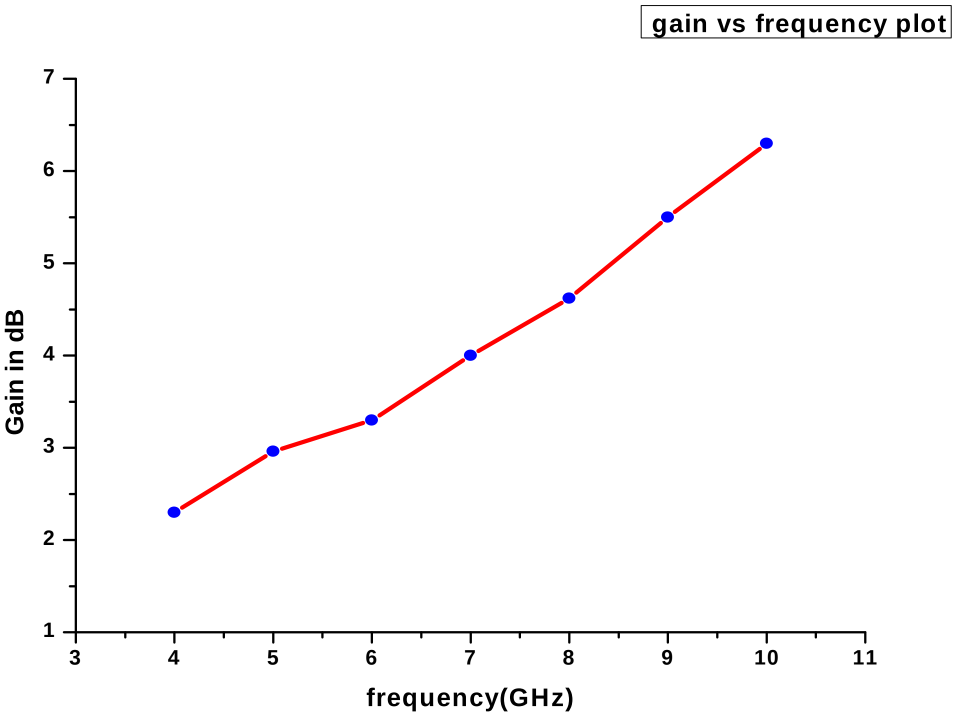


Fig 5.4 gain vs frequency plot

5.3.2 VSWR characteristics:

Fig 5.5 shows the VSWR vs frequency plot. From the plot we can observe that frequency range 3.8-10.6GHz VSWR is maintaining less than 2.

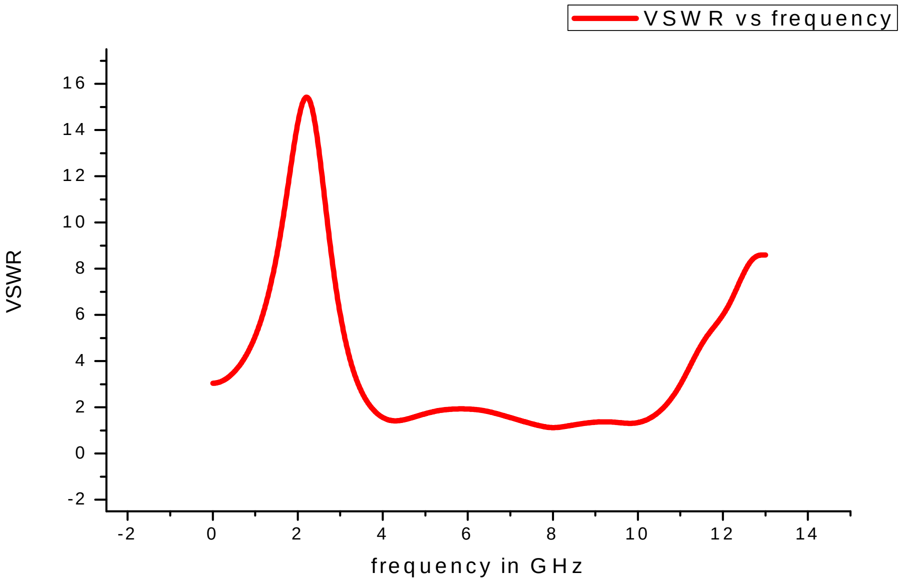
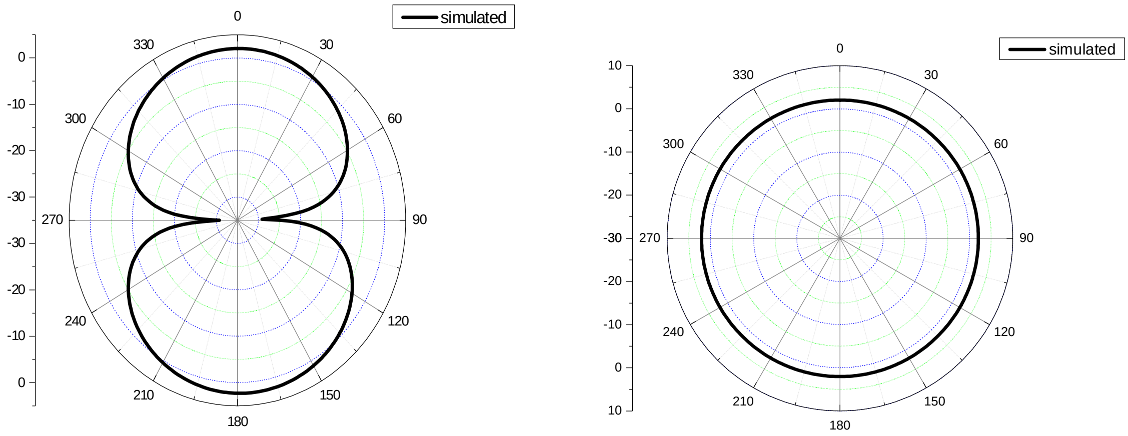


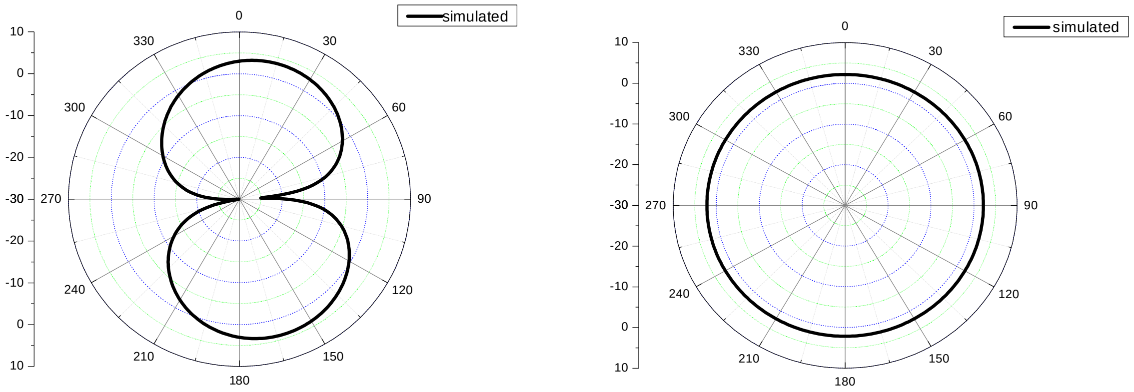
Fig.5.5 VSWR vs frequency plot

5.3.4 RADIATION PATTERN:

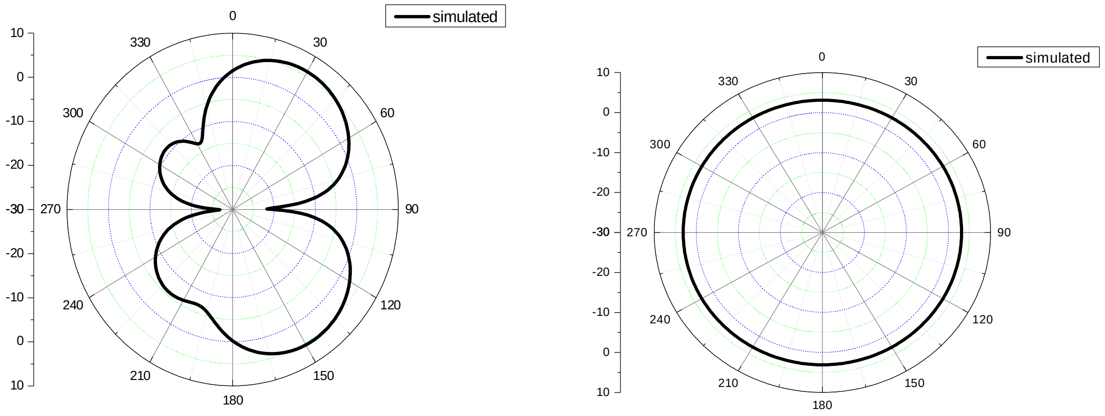
The simulated radiation patterns of the compact diamond shaped patch array is shown in fig 5.6. It has been observed that the antenna exhibits omnidirectional radiation characteristics for H-plane and E-planes are in broadside direction.



(a)simulated E and H-plane radiation pattern at 4GHz



(b)simulated E and H-plane radiation pattern at 7GHz



(c)simulated E and H-plane radiation pattern at 10GHz

Fig. 5.6 radiation pattern of compact diamond shaped patch array at (a)4GHz(b)7GHz(c)10GHz

5.4 SUMMARY:

In this design a compact 1×2 diamond shaped microstrip patch array is presented for UWB applications. The proposed shape of the patch is diamond. It is observed that by changing the different parameters of the antenna S_{11} curve is changing. The simulated result shows the designed antenna covers UWB range. The maximum peak gain of the antenna achieved is 6.5dB at 10GHz.

CHAPTER-6

Conclusion and Future work

6.1 CONCLUSION:

At first we studied about microstrip antennas, microstrip antennas are popular because of their low profile, light weight and low cost. Narrow bandwidth and gain are the main disadvantages of this antenna.

In this thesis two designs are proposed to increase the bandwidth and gain of the microstrip patch antenna. The gain of the microstrip antenna is increased by using microstrip array. The proposed antenna uses 1×2 diamond shaped array here the base of the patch is diamond shape.

In the first design the 1×2 diamond shaped microstrip array used for WLAN applications. Which covers the several WLAN bands in wireless communications i.e Bluetooth, WiFi and WiMAX. The maximum peak gain achieved with this antenna is 7.21dB at 5.5GHz. The proposed antenna well suited for WLAN applications.

In second design, a compact size antenna is designed. This antenna also uses 1×2 microstrip array. The base of the patch is diamond. This antenna covers the frequency range from 3.8 to 10.6GHz which includes WLAN bands. Although the size of the antenna is compact the maximum gain achieved is 6.5dB at 10GHz.

The design of 1×2 diamond shaped microstrip array antenna has been completed using CST software. The simulation gave results good enough to fabricate it on hardware which can be used wherever needed.

6.2 FUTURE WORK:

The following topics are helpful for further investigation.

- The future work can involve changing the feeding technique and carryout further research.
- In this thesis 1×2 array is used. In future more number of arrays can be used further to improve gain of the antenna with diamond shape patch.
- The designed antennas are single band. Dual and triple bands will be carried out in future.

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