DESIGN OF SWASTIKA SHAPED DRA ANTENNA FOR C-BANDAPPLICATIONS

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Submitted by:

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I, Kumar Shivam, Roll No. 2K17/MOC/05 student of M. Tech. (MICROWAVE AND OPTICAL COMMUNICATION), hereby declare that the project Dissertation titled **"DESIGN OF A SWASTIKA SHAPED DRA ANTENNA FOR C-BAND APPLICATIONS"** which is submitted by me to the Department of ELECTRONICS AND COMMUNICATION ENGINEERING, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associate ship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the Project Dissertation titled **"DESIGN OF A SWASTIKA SHAPED DRA ANTENNA FOR C- BAND APPLICATIONS"** which is submitted by KUMAR SHIVAM, Roll No 2K17/MOC/05, Department of Electronics And Communication Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place: Delhi **PROF. N.S. RAGHAVA**
Date: **SUPERVISOR**

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ABSTRACT

There has been rapid increase in the demands of the antennas for different systems and standards with many properties like reduced shape, high gain, better efficiency etc. because the use of wireless communications and satellite communications have been increased in the last thirty years. So, the planar and dielectric resonator antenna are the most trending antenna nowadays. In this project, the main objective is to design and fabricate a Swastika shaped Dielectric Resonator Antenna (DRA).

In this antenna, a dielectric material ceramic is used in it having high relative permittivity of 9.8 and dielectric loss tangent is 0. This antenna is designed using ANSYS HFSS software version 16.

In this project single element and dual element swastika shaped Dielectric Resonator antenna is designed. The single element antenna is designed on the top of FR4 epoxy substrate of dimensions 55mm×55mm and having a height of 1.6 mm which have relative permittivity of 4.4 and dielectric loss tangent of 0.02 while the dual element antenna is designed on the top of FR4 epoxy substrate of dimensions 90 mm × 50 mm and having a height of 1.6 mm. In this antenna, aperture coupled feeding technique is used in which H-shaped slot is cut from the ground. This leads to better gain and radiation efficiency.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

From the last 30 years, the telecommunication applications like wireless and satellite communication got spread across all over the globe. Because of this, the communication system across all over the world has become very easy [1]. So, we can say that these wireless and satellite communication provides very good flexibility in the today's communication systems [2-3]. These communication systems are used in many applications, for example they are used in hospitals, banks, airports, defence sectors, space sectors etc. The recent technology always expects a continuous development in the communication system which is functioning in the RF and microwave spectrum. So these arrangements are outlined so that we can get much higher efficiency, wider bandwidth, reduced size of the particular antenna or the system which you are designing.

The IEEE C-band (4-8 GHz) frequency range are mainly used for various satellite communication transmissions. As compared to the other frequency bands, the frequency range of C-band performs much better even in the different weather conditions. WiMAX as well as WLAN are two mainly used quality level methodology which process delivery of the messages from one place to another in a very short period of time. WiMAX is also called the inter operably implemented and based on IEEE 802.16 wireless communication standard which mainly works for the larger data transmission speeds for longer transmission distance. In the WLAN standard whose frequency will be around 2.4 GHz is growing in the business and thus it provides internet or data speed which are limited up to few Mbps.

From the last two decades, two types of antennas are mostly used across all over the world, these are microstrip antenna and the other one is the dielectric resonator antenna (DRA). Both of these types of antenna are sufficient for the design of modern applications of wireless communications. In the microstrip antenna, because of the simple and low profile features, it can be used for many different applications. But in this type of antenna, there is an issue of its narrow bandwidth i.e. [2-5%] [1]. In this type of antenna there are many metallic and surface wave loss. In this antenna many conductors or metallic elements are used in it, so these type of losses takes place in it. Because of these losses, antenna gain and efficiency decreases at the millimeter wave frequencies.

These problems can be resolved by using dielectric resonator antenna (DRA). Dielectric Resonator Antenna was developed in the early 1980's by Prof. Stuart Long [4]. DRA overcomes the problem of metallic losses because the DRA are made up of the dielectric material of higher dielectric constants (10-100). So it has minimum metallic losses and surface wave losses because no metals or conductors are used in it [7]. These types of losses can be reduced at the millimeter wave frequencies. So we can define DRA as other type of resonant antenna which is fabricated with a low loss dielectric material. Dielectric Resonator Antenna has many peculiar uses and utilizations in the microwave and millimeter wave communication systems [7-8]. We can say that Dielectric Resonator Antenna is the best radiator because there is very low metallic losses in it.

DRA has many other benefits like its small size, much better efficiency, wider bandwidth, low profile, higher dielectric strength, higher power handling capacity, low cost [5-6] and also many types of feeding methods can be used in it such as coaxial feed, aperture coupled feed, microstrip feed when performed at the millimeter wave frequencies. DRA antenna can be used frequently due to its easy fabrication.

There are many shapes of DRA for example, hemispherical, cylindrical, triangular, rectangular etc. We can also say that the resonant frequency of DRA antenna depends on its size, shape and the material permittivity. The overall length of the DRA is proportional to $\lambda 0/\sqrt{\epsilon}$, $\lambda 0 = c/f$, $\lambda 0$(free-space wavelength) for resonant frequency $f0$ and where $\mathcal{E}r$ denotes the relative permittivity of material of radiating structure.

1.2 MOTIVATION TO THEWORK

The main motivation of this thesis is the rapid increase in the use of wireless mobile communication systems as well as the satellite communication systems across all over the globe. These two, wireless mobile communication as well as the satellite communication are very popular in the last two decades. So, the demand of antenna which is used for different systems and for different standards with many peculiar characteristics like high gain, much better efficiency, reduced size, wider bandwidth etc. have been increased. It is very difficult to fulfill the frequency requirement of many communication systems. So with the help of this antenna we will try to fulfill the bandwidth requirements of different communication systems. We will design the antenna for the ultra wideband feature.

Nowadays, it is clear that any wideband monopole antenna is quite better to use in different types of wireless devices like laptops, notebooks and mobile phones. Wide band applications using microstrip patch designs are limited, which has low bandwidth. Some other drawbacks of these microstrip patch design are low efficiency, limited power capacity, lesser bandwidth, bad polarization, higher metallic losses and different manufacturing tolerance problems.

Several scientists are working on microstrip patch antenna so that there will be improvement in the bandwidth and efficiency of this antenna from few years. The motivation here is to use the dielectric resonator antenna more and more for many different purposes so that we can get the multiband antenna and much higher efficient antenna.

The dimension of the DRA is of the order $\lambda 0/\sqrt{\varepsilon r}$ where $\lambda 0$ which is the (free space wavelength) and εr which is (relative permittivity) of the resonator material. So it is concluded that when we choose a high value of εr (5-100), it will result in the decrement of size of DRA drastically. Also, there will be negligible conducting loss as no conductors are used in the dielectric resonator antennas, which thus provides very high radiation efficiency , but in other millimeter wave antennas, the radiation efficiency found is quite low because of the higher metallic losses in metal fabricated antennas.

To further enhance bandwidth of the antenna and for dual band frequency of antenna, antenna researchers have invented many important methods in the last few years. Some of these methods include the modifications of measurements of ground and substrate material with the help of different dielectric materials having higher dielectric constant using maximum amount of DRAs.

1.3 LITERATURE REVIEW AND OBJECTIVE

Dielectric Resonator Antenna was developed in the early 1980's by Prof. Stuart Long [4]. The biggest advantage of the DRA is that it overcomes the problem of metallic losses because the DRA are made up of the dielectric material of higher dielectric constants (10-100). So we can that it has minimum metallic losses and also minimum surface wave losses because no metals or conductors are used in it [7].

In [9] they investigated Swastika shaped wideband microstrip patch antenna for different GSM/WLAN applications. In this paper they have used low dielectric constant material substrate so that the bandwidth will be much larger. If we use high dielectric constant material, then the bandwidth will be much lower. In this antenna much higher radiation efficiency of 95% is achieved.

In [10] they investigated a compact modified swastika shaped patch antenna for WLAN/WIMAX applications. This paper consists of a simple structure with square slots in the ground with four slits and Swastika shape radiation patch with a rectangular slot in it. Because of these four slits and square slots, 3 resonant modes and good impedance performance are achieved.

In [11] they investigated the different types of feeding mechanisms in the dielectric resonator antenna. There are many types of feed like coaxial feed, aperture coupled feed, microstrip feed which can be used in the dielectric resonator antenna.

In [12] they investigated the two segments rectangular dielectric resonator antenna (DRA). In this antenna microstrip feed line technique is used. We are getting the two resonant frequencies and both these frequencies can be merged into a broadband which can be further used for WLAN applications at [5-6] GHz band.

In [13] we studied more about the basics of dielectric resonator antennas (DRA) and different types of dielectric resonator antenna like rectangular, hemispherical, cylindrical, triangular.

The main important objective of my thesis is to suggest some methods to improve bandwidth as well as overall gain with higher radiation efficiency. The other important work objective is to design and analyze the swastika shaped DRA array for applications in C-band. In this antenna, ceramic is used as the dielectric material which has high dielectric constant i.e.10. All of the simulation results are attained by operating the elementary and very important software i.e. HFSS (High Frequency Structure Simulator). It is an important software for different electromagnetic modeling and analyzing various 3-D structures. HFSS uses the Finite Element Method (FEM) for electromagnetic analysis of different 3-D structures including antennas. FEM is a flexible numerical technique which is capable of being adapted to problems dealing with complex geometries and material distributions. HFSS uses the finite element method to divide the entire volume of the three dimensional structure into a large amount of tetrahedra. The group of many tetrahedrons is called the Finite Element Mesh.

This HFSS software can also be very much useful in different sectors like telecommunications, defense, automotive equipment, electronics. HFSS is specialized software for the 3D Electro Magnetic simulation which is made up of high frequency elements. In the most Research & Development departments, HFSS is the first choice for technologies due to its superb performance. These technologies enable the efficient and exact analysis of high frequency devices such as antennas, filters, couplers, and multi-layer structures. HFSS also provides more flexibility to deal with the difficulties of wide application range, with the help of varieties of available technologies.

1.4 THESIS OUTLINE

The thesis is branched into five chapters and outline of my thesis is :

The **1st chapter** focuses about the overview of the thesis. The motivation behind the thesis and literature review have been discussed here. The basic introduction of different uses of wireless and satellite communications have been discussed here. We have also discussed the software HFSS which I have used for the simulation of my antenna.

The **2nd chapter** focuses on the basics of antenna, its definitions, different antenna parameters, microstrip antenna and different types of feeding techniques which can be used in the antenna. It provides the basic foundation of the terms which is used later in the thesis.

The **3rd chapter** explains the dielectric resonator antenna in much detail. In this chapter we see the history of DRA, various different merits and demerits of DRA, types of DRA, different feeding techniques which are used in DRA.

The **4th chapter** is all about antenna geometry and design part. In this chapter we can see how the single element and dual element swastika shaped DRA antenna is simulated using HFSS Software. We will see the different dimensions of the antenna which we have designed.

The **5th chapter** focuses on the results obtained after simulation on HFSS Software. Various parameters such as return loss, gain, efficiency, VSWR are shown. The chapter ends with the conclusions and applications.

CHAPTER 2

ANTENNA THEORY

2.1 BASICS OFANTENNA

2.1.1 Antenna Definition

Antenna is very important element of communication system. It is basically used for the motive of sending or accepting the electromagnetic waves. According to the IEEE definition, antenna is defined as [32]:

"That part of a transmitting or receiving system that is designed to radiate or receive radio waves".

Therefore, it is a passive element with the help of which a connection between two or more than two devices is created. Antennas have the same properties either in transmitting or in receiving mode hence also called as the reciprocal devices.

2.1.2 Radiation Pattern

According to [1,7] the radiation pattern is defined as "a mathematical function or graphical representation of the radiation properties of the antenna as a function of space coordinates. Mostly radiation pattern is determined in the far field region. It basically defines the variation of the power which is generated by an antenna as a function in the direction away from antenna.

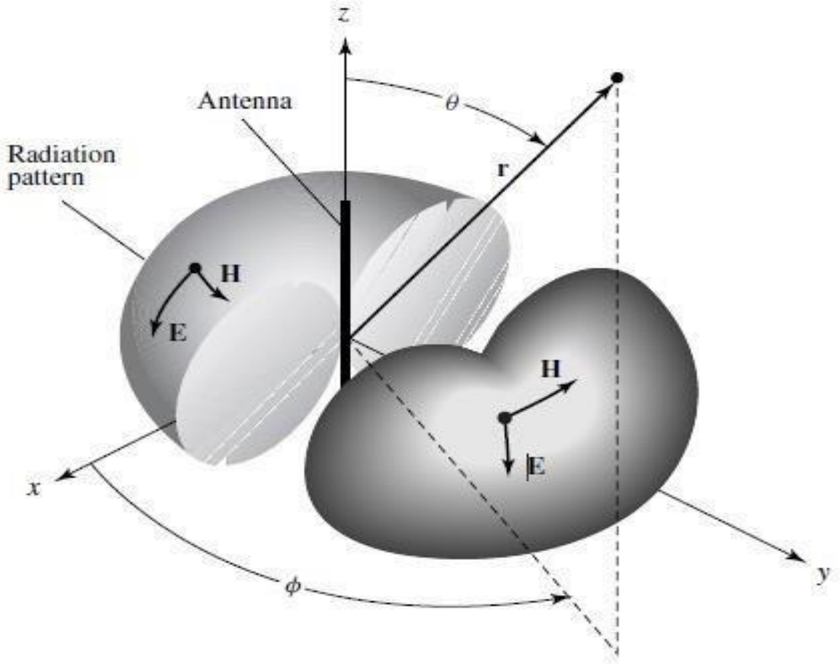

Fig.1 Omnidirectional Radiation Pattern [1]

2.1.3 Return Loss

Return loss is the measurement of how less your return or reflection is. If your return loss is smaller, then it is not good and it means that a less amount of energy is going into your antenna. If it is higher, then more amount of energy is going into your antenna. We know that for the maximum transfer of power, the input impedance and the source impedance of the antenna should be matched. If there will be mismatch between these two impedances then some transmitted power is reflected back. "So the return loss of antenna is defined in terms of power as the ratio of reflected power and the transmitted power of antenna. Usually a threshold for return loss in an antenna is -10 dB which means that 90% of the incident power is transmitted into the antenna and 10% of the power is reflected back"[1,8].

$$RL(dB) = -20 \log |\Gamma| \quad (2.1)$$

Where, Γ is the reflection coefficient.

Voltage Standing Wave Ratio

VSWR can be explained as how well your antenna is impedance matched to the radio or the transmission line to which it is connected to. VSWR can be also defined as "the ratio of maximum voltage to minimum voltage" [1]. VSWR is dimensionless as it is a ratio. For an antenna VSWR will be always a real and positive number. If the VSWR value is smaller, then it implies that the antenna is better coordinated to the transmission line and furthermore additional power will be conveyed to the antenna. The base estimation of VSWR is 1; it implies that no power will be reflected once again from the antenna which is the perfect case.

$$\text{VSWR } V(\rho) = \frac{V_{max}}{V_{min}} = \frac{1+\Gamma}{1-\Gamma} \qquad (2.2)$$

2.1.4 Bandwidth

The Bandwidth of antenna can be defined as the particular range of frequency in which your antenna can properly radiate or receive energy. The range of frequency can be defined as the actual difference between the highest cut-off frequency and the lowest cut-off frequency." Percentage bandwidth can be written as [1],

$$\text{BW } (\%) = \frac{2 \text{ x}(F_{upper} - F_{lower})}{(F_{upper} + F_{lower})} \qquad (2.3)$$

2.1.5 Gain and Directivity

The directivity of an antenna is defined as the antenna's radiation pattern's concentration in a particular direction. It can be expressed in dB. If the directivity is higher, it means that the beam which is radiated by the antenna will be more focused or concentrated. An antenna will be said to 100% efficient if the directivity of the antenna will be equal to the power gain of the antenna.

Gain of antenna is basically defined as the by-product of directivity and efficiency. It additionally communicates the total amount of power which can be sent in supervision of top radiation when contrasted with the isotropic source. The gain of antenna also expresses how effectively the antenna is converting the input power into the radio waves in a specific direction.

G and D can be related to each other by the following formula [1]

$$G = kD \tag{2.4}$$

Where, k is antenna efficiency.

2.2. MICROSTRIP PATCH ANTENNA

Microstrip patch antenna plays a very important role in the field of wireless communication. These types of antenna have become so useful because these antennas can be lithographed precisely on the circuit board. It comprises a radiating patch which is situated on the side of the dielectric substrate and there will be ground plane which is attached to the opposite side. The radiating parts of microstrip patch antenna are generally made of conductors like copper which are commonly photo-etched. Different geometrical shapes of patches can be formed. These shapes are rectangular, square, circular etc. The fringing fields which are formed in the midway of the patch and ground plane lead to the radiation as depicted in Fig.2. In this form of antenna, in most of the cases the radiation pattern will be perpendicular to plane of the radiating patch [1].

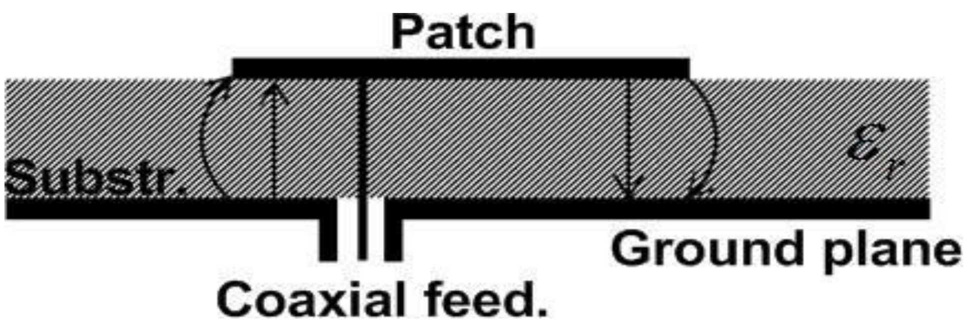

Fig.2: Microstrip patch antenna (Cross-section view)

For feeding in the microstrip patch antennas, different structures are used like coaxial probe, microstrip line, aperture coupling [1].

ADVANTAGES	DISADVANTAGES
• Less Weight and Volume.	• Less Efficiency.
• Less Cost of fabrication.	• Less Gain.
• Follows Linear and Circular Polarization.	• Bandwidth will be narrow.
• Multiband frequency operations can be done.	• Power handling capacity will be lower.
• Integrability is good.	• Surface wave excitation.
• Mechanically Robust.	

Table 2.1: Advantages & Disadvantages of microstrip antenna.

2.2.1 Feeding Mechanism

Basically, feeding in an antenna means coupling of power in or out from a particular antenna which can be done by number of techniques. The two main techniques which are mostly used are contacting and non-contacting techniques [33]. In the Contacting feed there will be a direct connection of transmission lines. In this contacting feed, the RF power will be provided directly to the radiating patch with the help of a connecting element such as microstrip line or in coaxial feed. The input impedance is decided by the position of the particular connection with the boundaries of the patch [33]. And in the Non Contacting feed, the Electromagnetic field coupling is used for the transfer of power among radiating patch and feed lines. This particular feeding technique provides more freedom as compared to the connecting feed. But it has one disadvantage that it is quite harder to design. There are many different types of feeding techniques which are used in the antenna design, but in most of the cases these type of feeding techniques are used. These are microstrip lines, coaxial probe, aperture coupling and proximity coupling.

In the Microstrip line feed, conducting strip can be directly attached with the border of microstrip patch. This microstrip line feed is depicted in fig.3. In this feeding technique, the breadth of the strip is quite less as contrasted to patch of the antenna. The biggest merit of this type of feeding technique is that the strip of an antenna can be carved on the same substrate and because of this it will provide a planar assembly. So, it can be easily fabricated.

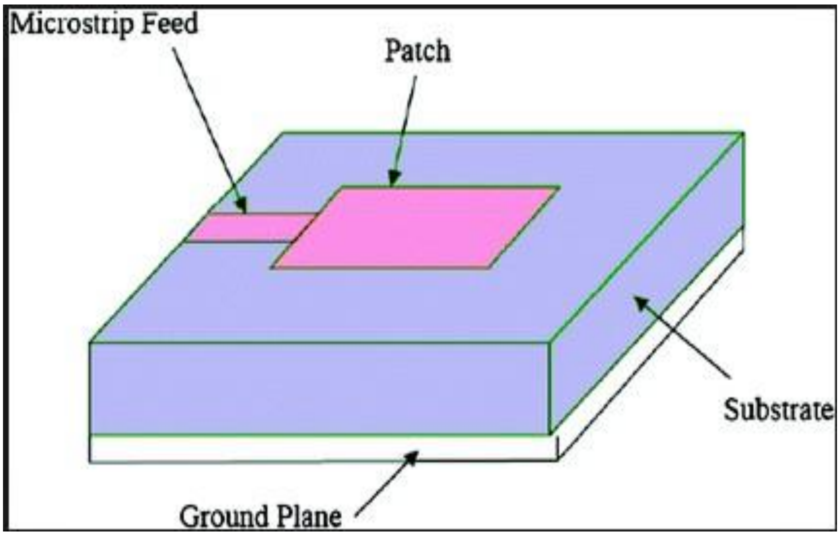

Fig.3: Microstrip Feed

In the coaxial cable there will be two concentric cylindrical wires which are divided by a type of dielectric material. This coaxial feed method is the most common feeding method in microstrip patch antenna. In this type of coaxial feed method, outer conductor of coaxial cable is attached to ground plane while inner conductor of the cable is soldered with radiating element. This feeding method is used because in this feeding mechanism, the location of the feed can be easily adjusted to match the impedances in any of the location inside the patch. This feeding technique has lower radiation and can be easily fabricated.

This feeding has also some disadvantages like it has narrow bandwidth.

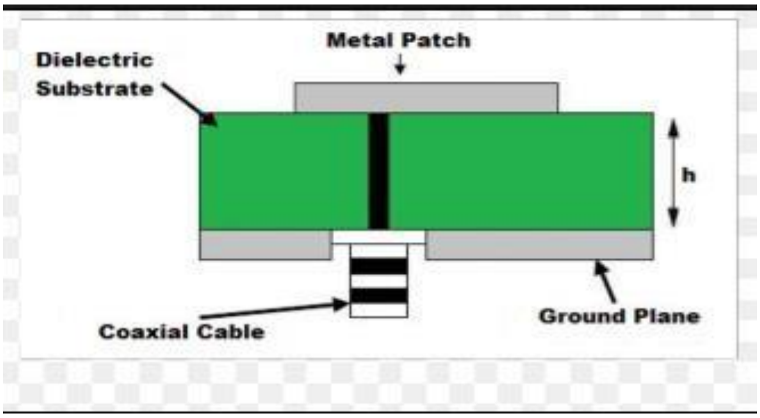

Fig.4: Coaxial Feed

CHAPTER 3

About Dielectric Resonator Antenna (DRA)

3.1 INTRODUCTION

Wireless communication has played a very important role in improving the quality of the communication system across all over the globe in a very short span of time. There are basically two types of antenna which is frequently used. One is microstrip antenna and the other one is dielectric resonator antenna. Both of the antennas are very popular and easily adoptable and have a lot of uses. Dielectric Resonator antennas have much broader impedance bandwidth in comparison to the microstrip antenna. DRAs are also much more efficient than the microstrip antenna. These DRAs have a lot of uses as these antennas are utilized in airports, electronic wars, missiles, radar and communication system. Both of these antennas have played a very significant role in the military and different business applications. Dielectric resonating antennas are basically derived from the dielectric resonator, which depends upon different types of feeding mechanisms [7].

Dielectric resonator (DR) was invented in the year 1939. It was invented by Richtinger, the renowned scientist from Stanford University. He had also exhibited the hypothesis about the unmetallized dielectric things in form of triodes which can work similar to microwave resonators [8]. But the theoretical research work was not appropriate to induce any appropriate ideas. So, not any practical knowledge about DR evolved over the next 20-30 years. Two researchers from Columbia University, Okaya and Barash in the early 1960s had introduced the Dielectric Resonator first time in the shape of single crystal, TiO2. Dielectric resonators became famous for the very first time in the shape of filter devices which were further applicable in different microwave circuit.

It is used as radiating elements in 1980's for the very first time when the smaller size potential and high frequency application identified this research and transformed into dielectric resonator antenna.

3.2 BASIC CHARACTERISTICS

Dielectric Resonator Antennas have many important features which made DRA a very important and special antenna, especially in the case of millimeter wave applications. There are many characteristics of DRA, for example, much higher radiation efficiency, better bandwidth, polarization flexibility which made DRA a more useful and important antenna as compared to the conventionally used microstrip patch antennas.

In the DRA materials, a much higher dielectric constant is present, which shows an important property which is increased quality factors and is placed on dielectric substrate with lesser permittivity. These antennas are simply manufactured from less loss and a high dielectric constant material which comes in unique shapes and sizes. Its resonant frequency depends on the size of the antenna, shape which we are using and relative permittivity of its dielectric material. There are many types of DRAs. On the basis of its shape and size these are differentiated as Spherical, Cylindrical, Disk, Rectangular, and hemispherical DRA [7]. There are many other important properties of DRAs which make DRAs very important and unique as compared to other antennas which are its compact less size, small phase noise, frequency stability according to temperature, ease of integration with numerous MIC circuits. These antennas have many other important features such as its fabrication can be done easily, it has very high radiation efficiency which is very important characteristics of any type of antenna, wider bandwidth and also the most important is its cost of manufacturing is quite low as compared to other antennas. DRA is mostly used for different applications of mobile telecommunication [1],[7].

DRA includes many more important features such as:-

- ✓ In DRA, one can use wider range of dielectric constants i.e.in the range of (εr= 10 – 100), because of this there will be full control on the size of DRA as well as on the bandwidth.

- ✓ The size of this type of antenna will be directly proportional to $\boldsymbol{\lambda o}/\sqrt{\varepsilon r}$ in which λo (free space wavelength) , εr (dielectric constant) which we are using in DRA.

- ✓ DRA can function on a wide frequency range (1.3 GHz - 40 GHz)[1].

- ✓ In the DRA, the radiation efficiency will be in higher range (upto 95%).

- ✓ Different types of feeding methods can be applied in this type of antenna

- ✓ When we use any dielectric material with low-loss characteristics then there will be more efficiency mainly at the millimeter-wave frequency, as there will be the lack of surface waves and there is very less conductor loss [1][7].

- ✓ In the DRA, the size and the bandwidth is most important parameters and played a vital role.

- ✓ There will be Greater tolerance: ± 1- 5% .
- ✓ Quality factor is good.
- ✓ The temperature coefficient is more in the range (-12…+30) ppm/ °C.
- ✓ There is greater tolerance ± 0.5; ±1.0 ppm/°C.

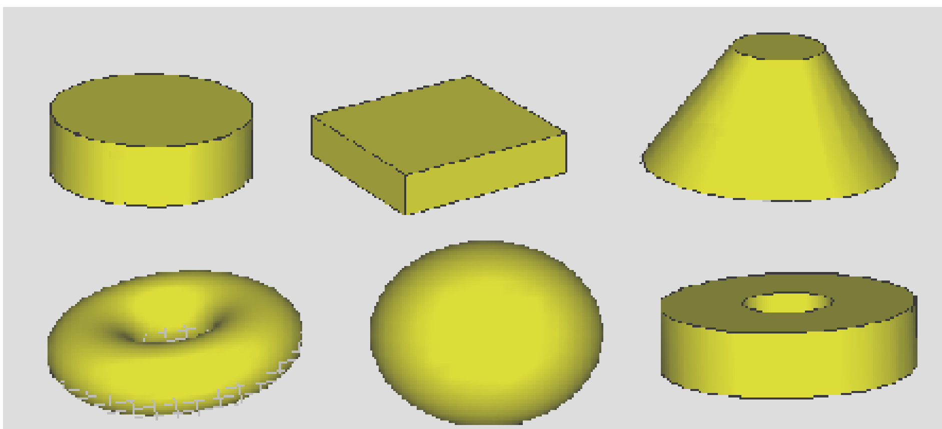

Fig .5: Dielectric Resonator Antennas of many different geometries.

3.3 ADVANTAGES

From the last some years, rigorous research on the DRA have been done in various institutes and universities in different areas like applying various types of resonators, using most efficient feeding techniques as well as the measures to be taken so that the bandwidth improves. So because of these important features this antenna has become very important for many applications especially in the millimeter wave (MMW) applications. These antennas can be easily couple with various transmission lines. In the MMW applications, there will be more conductor loss for the metallic antennas and therefore the antenna efficiency decreases. But when we use DRA, as no conductors or metals are used in it so the loss will be very low as compared to the other antennas in which conductors or metals are used.

Therefore these antennas have high radiation efficiency. Also, DRAs shows wider impedance bandwidth in comparison with microstrip antennas. There will be impedance bandwidth of 10% and dielectric constant of 10. Avoidance of any type of surface waves are the other benefits of Dielectric Resonating Antenna over the microstrip antenna. Dielectric Resonating Antennas are found in many geometries such as Cylindrical, Hemispherical, Triangular, Rectangular. Out of these, Rectangular and Cylindrical DRA are mostly used. There are many different types of feed configurations. These are listed as follows: Coaxial, Slot Aperture, Microstrip line, Coplanar and Dielectric image guide. Out of these, Slot aperture will be the most suitable and mostly used type of the feeding technique.

Dielectric resonator antennas are continuously utilized for a large number of applications from a very long period of time across all over the globe. Because this type of antenna shows a large number of essential and required features like low profile of the antenna, comparatively lesser weight, comparatively wider bandwidth and most important its low cost. So, this type of antenna can be efficiently utilized for many applications such as either for single element or for a different array of antennas. And also less dissipation loss, much larger radiation efficiency comprises of some of the other advantages of this type of antenna over other antennas. As we know that in the microstrip antennas, it has relatively larger conduction loss and surface waves.

While the DRAs have much higher radiation effectiveness as well as power controlling capacity because of the absence of metallic loss in it. DRA will not show the surface waves when it will be positioned over the ground plane [7], [8]. From the last some years, DRAs have been considered as the most insignificant antenna for the communication system. This type of antenna is made up of dielectric resonators of higher permittivity. So we can say that no conductors are used in this type of antennas. Thus we get negligible metallic losses as well as conductor losses in it. So we can say that there are many insignificant benefits of this type of antenna because of that this type of antenna had become the most important as well as efficient and thus these antennas are used widely across all over the globe. So we have listed few important benefits of dielectric resonator antennas which is as follows:

.

- ✓ Much Higher Radiation Efficiency.
- ✓ Negligible surface waves in it.
- ✓ Less weight, Low class profile, Low volume.
- ✓ This antenna is more flexible, because of which it can be used for any types of different physical as well as electrical requirements for many communication applications.
- ✓ Fabrication is quite easy in the DRA.
- ✓ Much higher dielectric strength.
- ✓ Its capacity of handling the total power is good.
- ✓ Production cost is quite low in the DRA.

3.4 FEEDING METHOD

There are many feeding methods in the Dielectric Resonator Antennas (DRAs). These are as follows:

3.4.1 Coaxial Feed:

This type of feed technique is also recognized as the probe feed . This is an extremely basic feed method which is used in antennas as depicted in figure 6. In this type of feed technique, the DRA is positioned above ground plane of antenna and it has a cylindrical probe which is attached to the outer conductor of the DRA. For impedance matching, we can shift the inner conductor of the DRA in the middle so that there will be impedance match. There are many advantages of probe fed method. Some of these advantages are it is easy to fabricate, easy to model, easy to impedance matching. There are few disadvantages also. These are, the bandwidth will be low in this case and there will be cross polarization also in it. Different types of modes depends on the probe position.

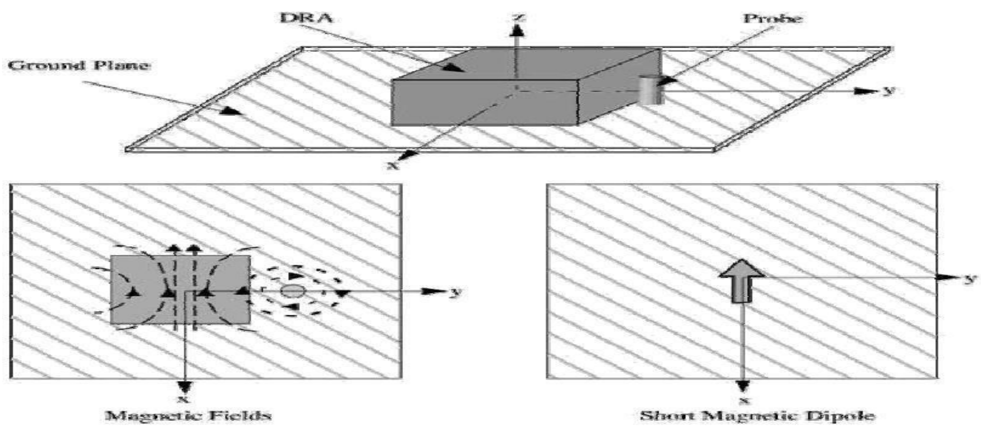

Fig 6: Coaxial-fed Dielectric Resonator Antenna

3.4.2 Slot Aperture:

In this type of feed method, aperture is used in it. This aperture is present in ground plane of the antenna. The excitation of the antenna can take place with the help of this aperture only. This aperture comprises of slot which can be cut from the ground of the antenna. In this method, feed is also present beneath the ground so that it can take more radiation. After cutting the slots, some of the antenna parameter will be improved. This type of feed methods can be easily applicable in every shapes of DRA. There is one disadvantage of this type of feeding method is that it is very difficult to fabricate the antenna because there is numerous layers present in it. So the fabrication is a bit tough in this type of feeding technique. This feeding method is depicted in the figure 7.

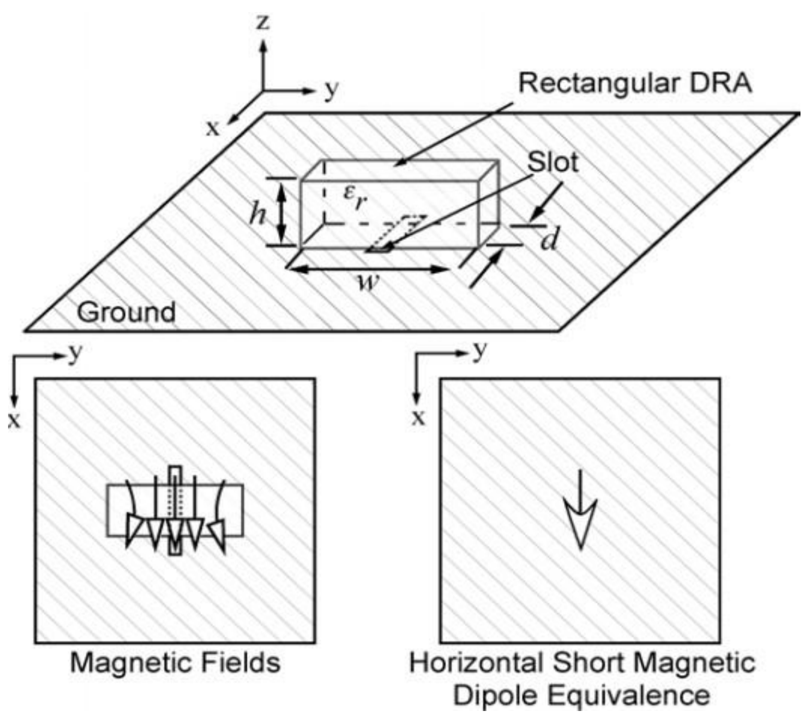

Fig 7: Aperture feed

3.4.3 Microstrip Line Feed:

This is one of the important and mostly used feeding technique which is used in various antennas. In this type of feeding method, microstrip transmission line is used for feeding the antenna. For the impedance matching, the microstrip transmission line can be also injected inside the antenna. This is very simple feeding method as the fabrication can be done very easily in it. The impedance matching between the transmission line and the antenna is very simple to match. It is also very easy to model and implement in the antenna. There are also some disadvantages like the bandwidth becomes very low and also there will be cross polarization in the antenna. Microstrip fed method is depicted in the figure 8.

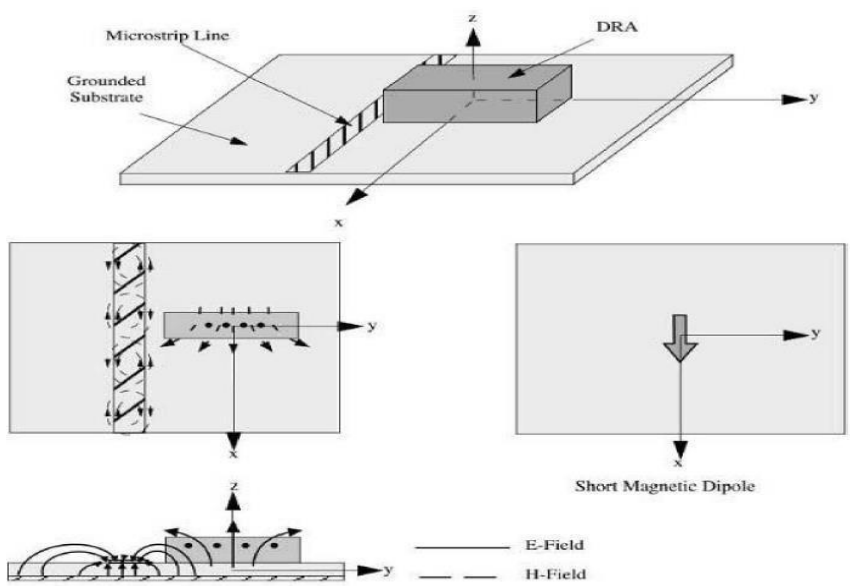

Fig 8: Microstrip Fed

3.4.4 Co-Planar Feed:

It is also one of the important feeding methods which is widely used in the antennas. In this type of feeding method, there will be the presence of the coplanar loop feed at the middle of the grounded substrate. The DRA is placed at the middle of the grounded substrate. We can also observe dual band for the coplanar feed in some of the cases. This type of feeding method is mostly used in rectangular and hemispherical DRA. It has some important advantage like it is non-prominent in nature. Coplanar feed method is depicted in the figure 9.

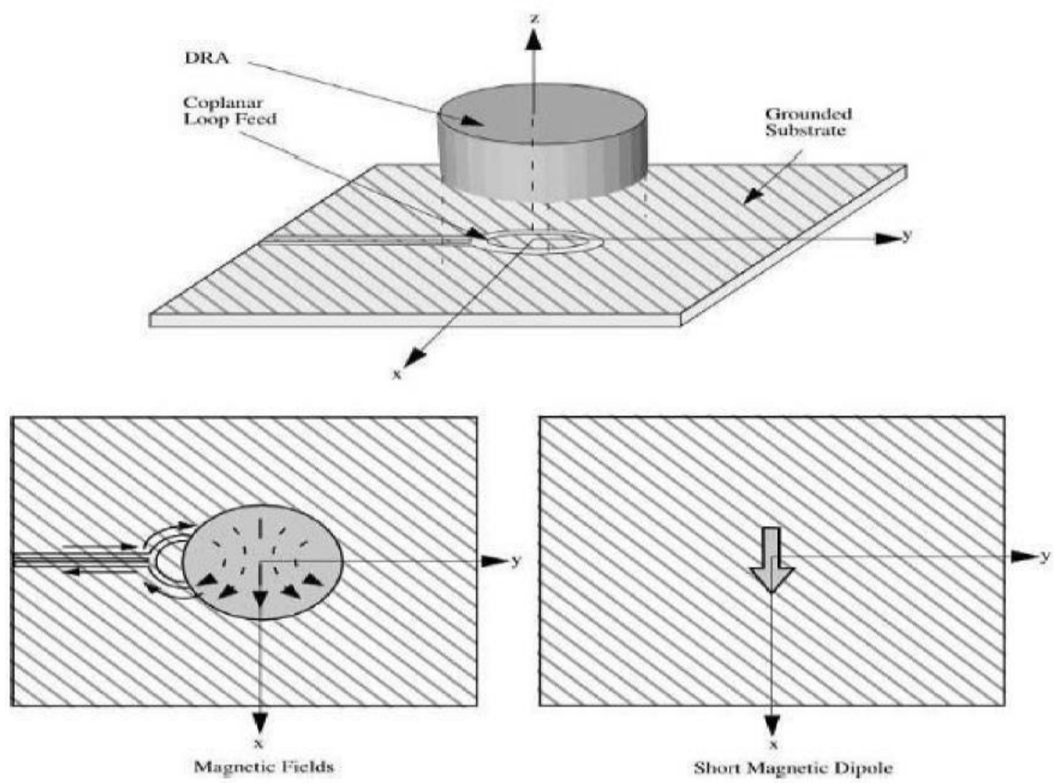

Fig 9: Co-planar feed

3.4.5 Dielectric Image Guide:

This feeding method is one of the appealing feeding methods. In this method, dielectric image guide to provide coupling especially in the case of DRA. This method of feeding can be especially used for the DRA which is using the low permittivity dielectric material. So the coupling can be improved by using the dielectric image guide that is quite closer with the cut off frequency of the antenna. This feeding method is depicted in the figure 10.

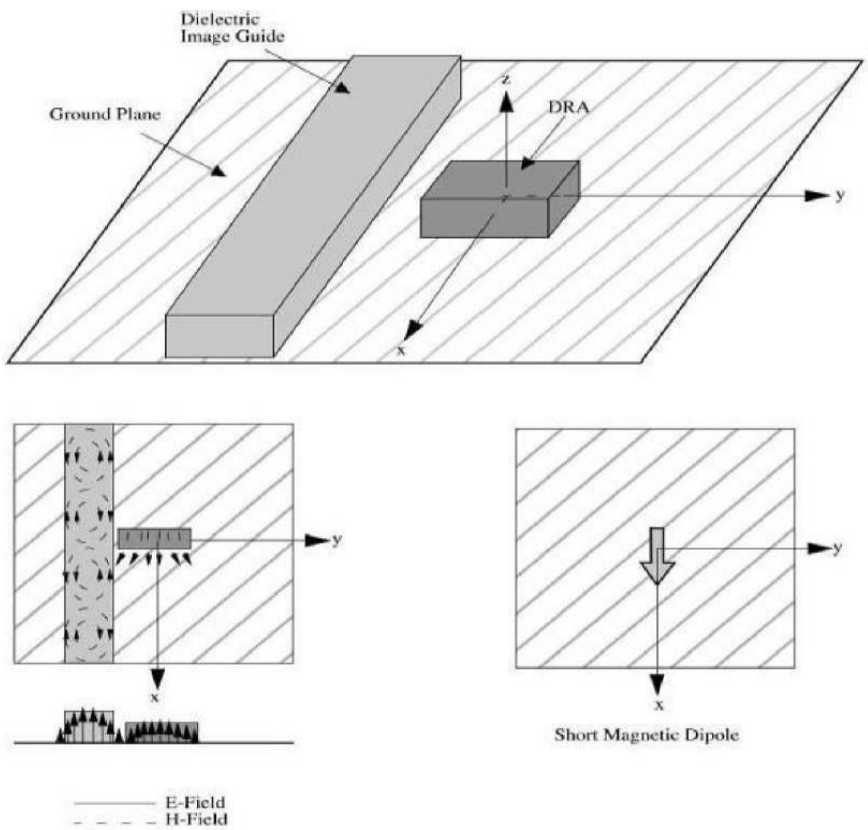

Fig. 10: Dielectric image guide-fed

3.5 BASIC SHAPES OF DIELECTRIC RESONATORANTENNA:

There are basically three shapes of DRAs which are mostly utilized. These three shapes are cylindrical, rectangular and hemispherical. These are explained below:

3.5.1 Cylindrical DRA:

This antenna is one of the most used antenna and also it has a lot of advantages over other shapes of DRA. Its design is easier to make and also easier to fabricate. In this antenna many modes can be successfully applied in it. So the radiation pattern which we get will be very broad and in many cases we can get the omnidirectional radiation pattern also.

Various different classes of DRAs are obtained from cylindrical shaped DRA, for example, split cylindrical, cylindrical ring, electric monopole, ring, elliptical, conical. Ring antenna is one of the example of cylindrical DRA. In the ring antenna, it provides larger bandwidth. Cylindrical DRA has many applications as these antenna are utilized for oscillators, microstrip antenna, filters etc. This antenna is depicted in the figure 11.

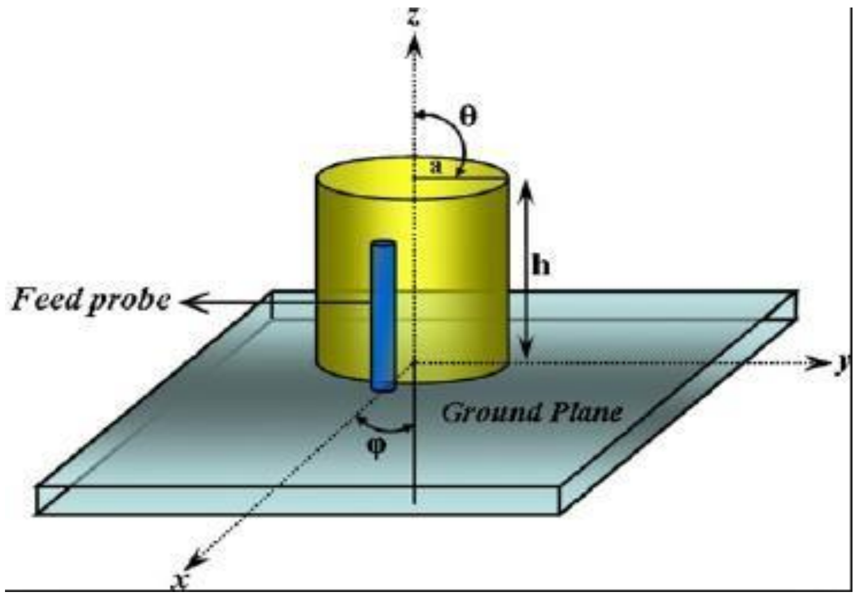

Fig 11: Geometry of cylindrical DRA

3.5.2. Resonant frequencies:

The resonant frequency of DRA can be defined as that frequency at which the radiation of any particular antenna will be maximum. It is that frequency at which ones particular device can perform at its highest level. The transverse electric and the transverse magnetic functions of this antenna is given below:

$$\psi_{TE_{nmp}} = J_n\left(\frac{X_{np}}{a}\rho\right)\left(\begin{matrix}\sin n\phi \\ \cos n\phi\end{matrix}\right)\sin\left[\frac{(2m+1)\Pi z}{2d}\right]$$

$$\psi_{TE_{nmp}} = J_n\left(\frac{X_{np}}{a}\rho\right)\left(\begin{matrix}\sin n\phi \\ \cos n\phi\end{matrix}\right)\cos\left[\frac{(2m+1)\Pi z}{2d}\right]$$

Jn = Bessel's function

Resonant Frequency for npm mode :

$$f_{nmp} = \frac{1}{2\Pi a\sqrt{\mu\varepsilon}}\sqrt{\left(\begin{matrix} X^2_{np} \\ X'^2_{np} \end{matrix}\right) + \left[\frac{\Pi a}{2d}(2m+1)\right]^2}$$

Resonant frequency for TM mode :

$$f_{TM_{110}} = \frac{1}{2\Pi a\sqrt{\mu\varepsilon}}\sqrt{X'^2_{11} + \left(\frac{\Pi a}{2d}\right)^2}$$

X’11 = 1.841.

3.5.3 Hemispherical DRA:

Hemispherical shaped DRA provides many favorable circumstances when contrasted with cylindrical and rectangular DRAs. In this antenna hemispherical conductor can be also used.

The hemispherical DRA is depicted in the figure 12. This type of antenna has infinite conductivity as well as boundless area. This type of antenna is placed above the ground plane.

The two main modes are Transverse Electric and Transverse Magnetic. The radial component (Er=0) is zero in the transverse electric (TE) mode. While in the transverse magnetic(TM) mode, radial component (Hr=0) is zero. There are basically two modes which are found in this DRA. These are TE111 and TM101. In the TE111 mode, the radiation patterns will be equivalent to the short horizontal magnetic dipole while in the TM101 mode, the radiation patterns are equivalent to the short electric monopole.

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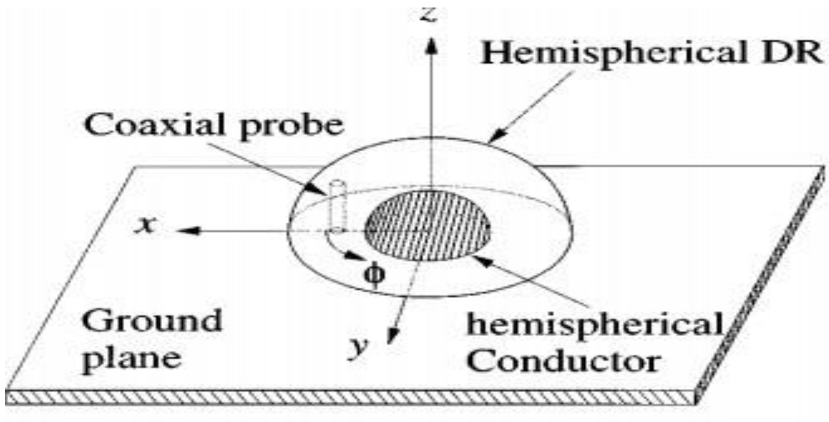

Figure 12: Probe-fed hemispherical DRA

3.5.4 TE111 mode approximation:

The smallest order mode of this type of antenna is the TE111 mode. The resonant frequency and radiation quality (Q) factor can be calculated by equating this given equation:

$$\frac{j_{1/2(\sqrt{\varepsilon_r}\,k_0 a)}}{j_{3/2(\sqrt{\varepsilon_r}\,k_0 a)}} = \frac{H_{1/2}^{(2)}(k_0 a)}{\sqrt{\varepsilon_r}\,H_{1/2}^{(2)}(k_0 a)}$$

Where J(x)=Bessel function of first type.

H2(x)= Henkel function of second type.

k0 is constant and it is the free space wave number

Resonant Frequency of this antenna is equated using this formula:

$$f_{GH_z} = \frac{4.7713 R_e(k_0 a)}{a_{cm}}$$

3.5.5 Rectangular DRA:

This type of antenna is the most important and largely used DRA across all over the globe. It is used more than the hemispherical and cylindrical DRA. Its structure is quite easy to design and thus it is also very easy to fabricate. In this antenna, we are observing broader transmission capacity when compared to different antennas. This antenna provides more degree of freedom so that the resonant frequency of the antenna can be controlled. Because of this important advantage the quality factor of the antenna can be also improved.

This type of antenna will retain its TE modes (TEx, TEy, TEz). Resonant frequency of this type of antenna is determined after equating the transcendental equation which is**:**

$$k_x \tan(\mathrm{k}_x \mathrm{d}/2) = \sqrt{(\varepsilon_r - 1)\,\mathrm{k}_0^2 - k_x^2}$$

Free space wave number is:

$$(k_0) = \frac{2\Pi f_0}{c}, \; k_x = \frac{m\Pi}{a} \quad k_y = \frac{n\Pi}{b}, \; k_z = \frac{l\Pi}{d}$$

$$k_x^2 + k_y^2 + k_z^2 = \varepsilon_r k_0^2$$

CHAPTER 4

ANTENNA DESCRIPTION

4.1 METHODOLOGY

The design and materials of the antenna have been finalized after a lot of trials and researches. First of all, research was carried out via internet, books, and research papers on wearable antennas. This was done to further develop the understanding about fundamentals, theory and properties of the antenna. Then the aim was to design a swastika shaped DRA antenna.

4.2 ANTENNA DESIGN

The designing and simulation of this antenna is done using ANSYS High Frequency Structure Simulator (HFSS) software. During the simulation, many trials were conducted to achieve the best result using different substrates materials, different substrate thicknesses, different DRA materials, different dimensions of the swastika shape, different types of slots, different dimensions and positions of slots and different types of feeding methods.

4.2.1 Single Element Swastika Shaped DRA Antenna

The shape of the proposed antenna is predicted in Fig.13. In this antenna I have designed a swastika shaped DRA Antenna in which I have used a dielectric material ceramic having high relative permittivity or dielectric constant of 9.8 and dielectric loss tangent 0. When we use high dielectric constant material, then it will improve the coupling but diminishes the overall length of the antenna and transmission capacity of the antenna. This antenna is designed on the top of FR4 Epoxy substrate of dimensions 55mm ×55 mm and a height of 1.6 mm which have relative permittivity of 4.4 and dielectric loss tangent of 0.02.

In this antenna, aperture coupled feeding technique have been used in which ground is stationed over the substrate and a slot is penetrated from the ground. There are many shapes of slots for example, ring shape, H-shape, U-shape etc. We have cut a H-Shaped slot from the ground. The dimension of the feed line which is used in the antenna is 25mm×1mm. Now the geometry of the proposed antenna is depicted in the Fig 13, in which 6 different boxes of same height are used and united them altogether.

The geometry of the single element swastika shaped DRA antenna is shown in the figure below.

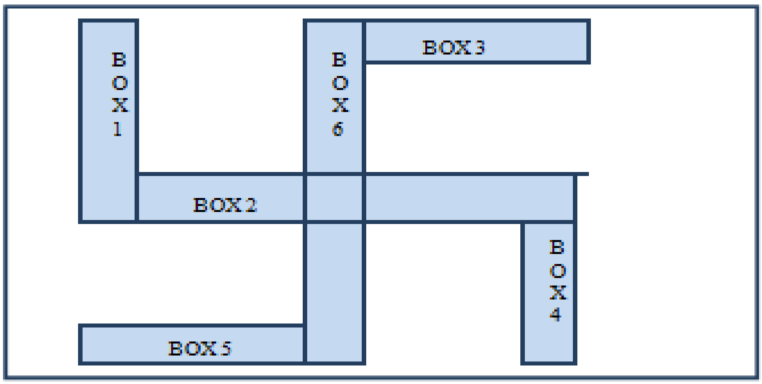

Fig 13: Geometry of single element Swastika Shaped Dielectric Resonating Antenna

In the geometry of the proposed antenna, x-axis represents the length and y-axis represents the width. The dimensions of different boxes of the above antenna are given in the table below:

BOX Name	Dimensions(L×W×H)
Box 1	20×5×8
Box 2	5×20×8
Box 3	5×10×8
Box 4	15×5×8
Box 5	5×10×8
Box 6	35×5×8

Table 2: Dimensions of different boxes of single element antenna

All the dimensions are in mm.

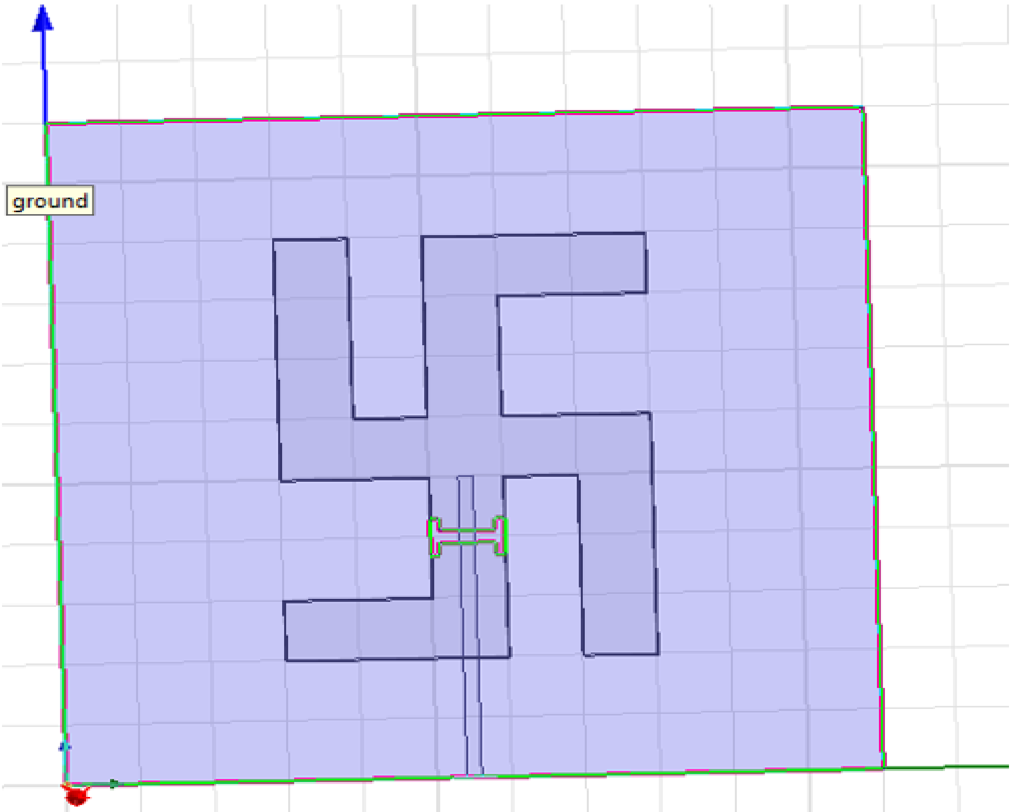

Fig 14: Top view of the single element swastika shaped DRA Antenna in HFSS.

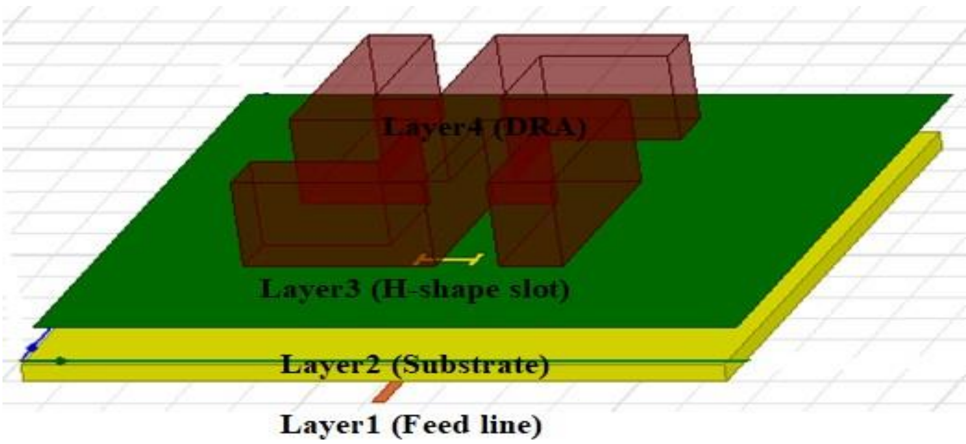

Fig 15: The 3D-layered structure of the proposed swastika shaped DRA Antenna

4.2.2 Dual Element Swastika Shaped DRA Antenna

A dual element Swastika Shaped DRA Antenna with aperture coupled feed line is chosen because of its easy designing, fabrication and analysis. The printed circuit board substrate of FR4 Epoxy with Dielectric constant of 4.4 and Dielectric Loss Tangent of 0.02 is used with dimensions of 90 mm ×50 mm×1.6 mm (L×W×H). In this dual element swastika shaped antenna also dielectric material ceramic having high relative permittivity or dielectric constant of 9.8 and dielectric loss tangent 0 is used. . When we use high dielectric constant material, then it will improve the coupling and diminishes the overall length of the antenna as well as it will also diminishes the transmission capacity of particular antenna.

Geometry of dual element swastika shaped Dielectric Resonator Antenna is predicted in the figure below.

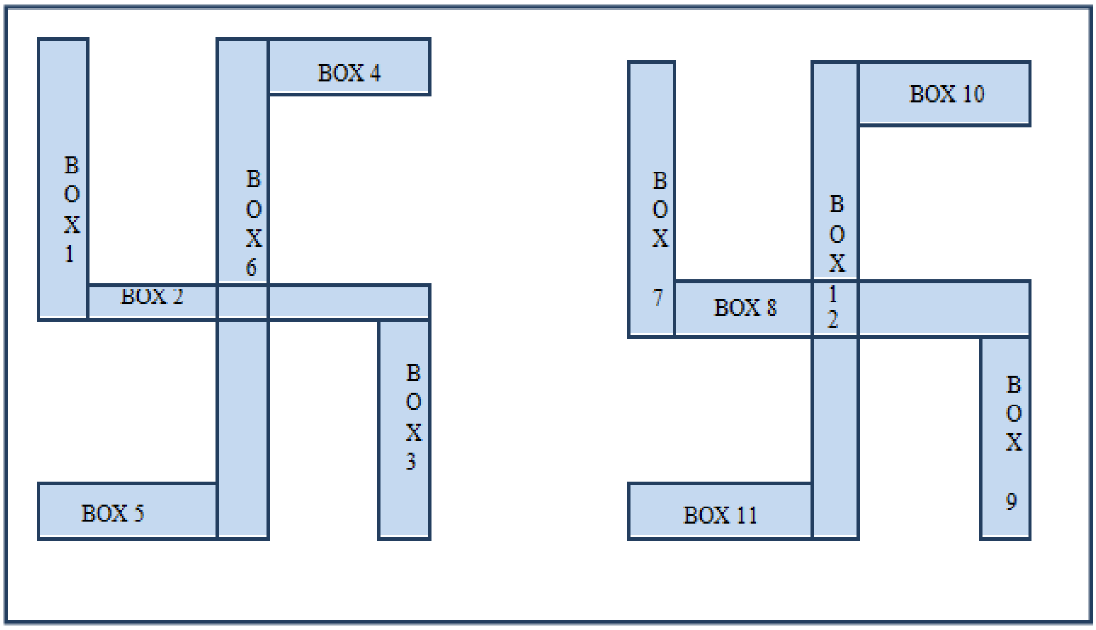

Fig 16: Geometry of dual element Swastika Shape Dielectric Resonator Antenna.

In the geometry of the proposed antenna, x-axis represents the length and y-axis represents the width.

The dimensions of different boxes of the above antenna are given in the table below:-

BOX Name	Dimensions(L×W×H)
Box 1	20×5×8
Box 2	5×20×8
Box 3	5×10×8
Box 4	15×5×8
Box 5	5×10×8
Box 6	35×5×8
Box 7	20×5×8
Box 8	5×20×8
Box 9	5×10×8
Box 10	15×5×8
Box 11	5×10×8
Box 12	35×5×8

Table 3: Dimensions of boxes of dual element antenna

All the dimensions are in mm.

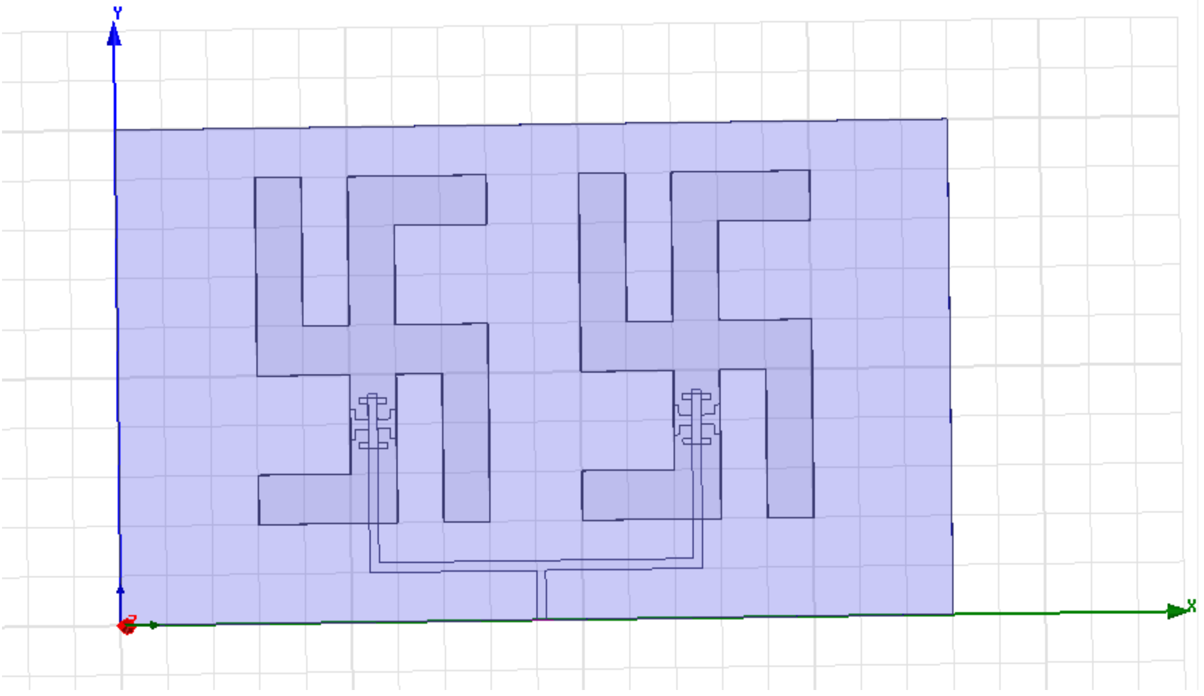

Fig 17: Top view of the dual element swastika shaped DRA Antenna in HFSS.

CHAPTER 5

RESULTS AND CONCLUSION

5.1 SIMULATION RESULTS OF SINGLE ELEMENT SWASTIKA SHAPEDDRA ANTENNA

The simulation procedures of the proposed antenna were performed using ANSYS HFSS Software of version 16. Many modifications were made and also many trial simulations were run to reach the final antenna design.

(a) S –Parameter

The S11 parameter for single element swastika shaped DRA antenna is predicted in figure 18. It is quite clear from the figure that the single element swastika shaped antenna is operating in C-Band with resonating frequency of 6.8 GHz. The bandwidth obtained is 380 MHz (6.55-6.93 GHz). Minimum return loss of -12.08 is observed at 6.8 GHz frequency.

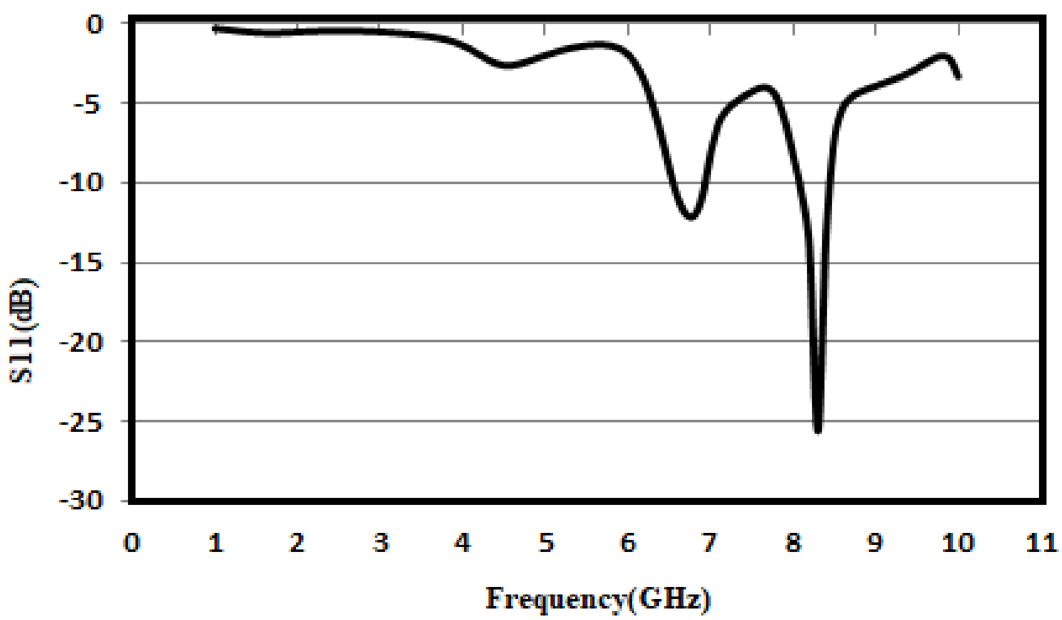

Fig 18: S-Parameter of antenna

(b) 3D and 2D simulated radiation pattern

Fig 19(a) and 19(b) represents the three dimensional and two dimensional radiation pattern of the single element swastika shaped DRA antenna for the particular resonant frequency of 6.8 GHz respectively. Overall gain achieved here is 4.46 dB.

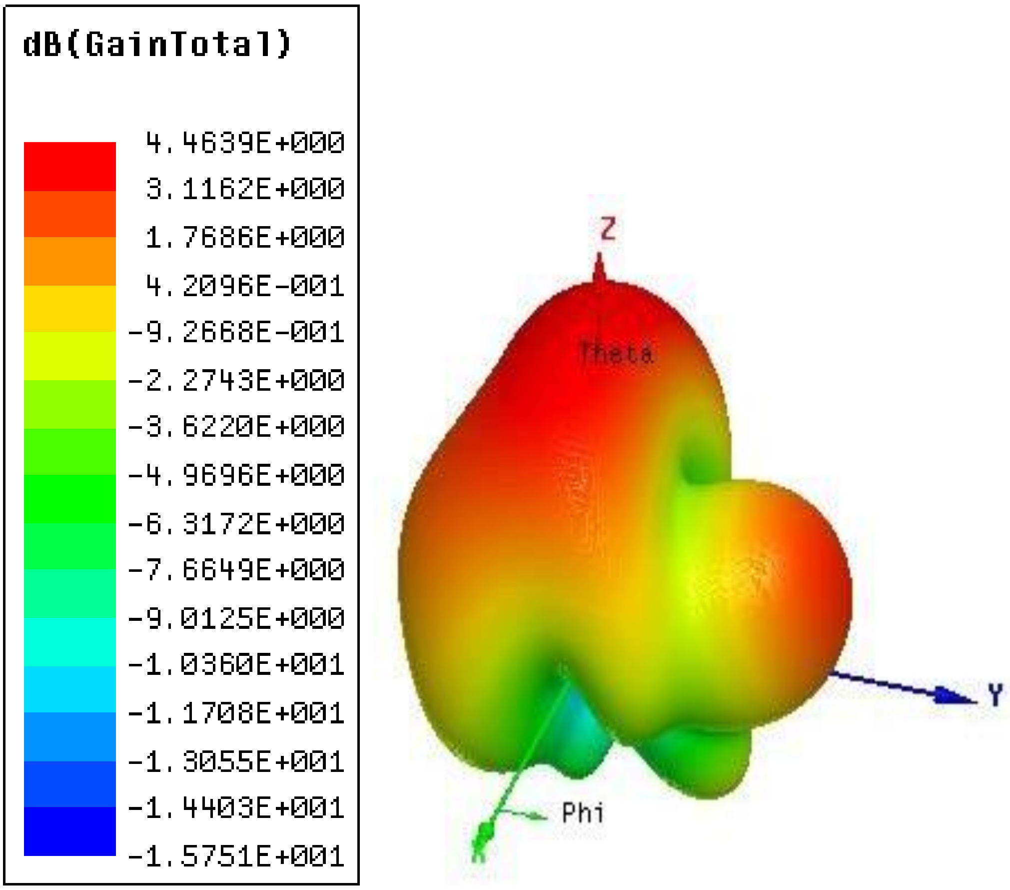

Fig 19(a): Three Dimensional radiation pattern

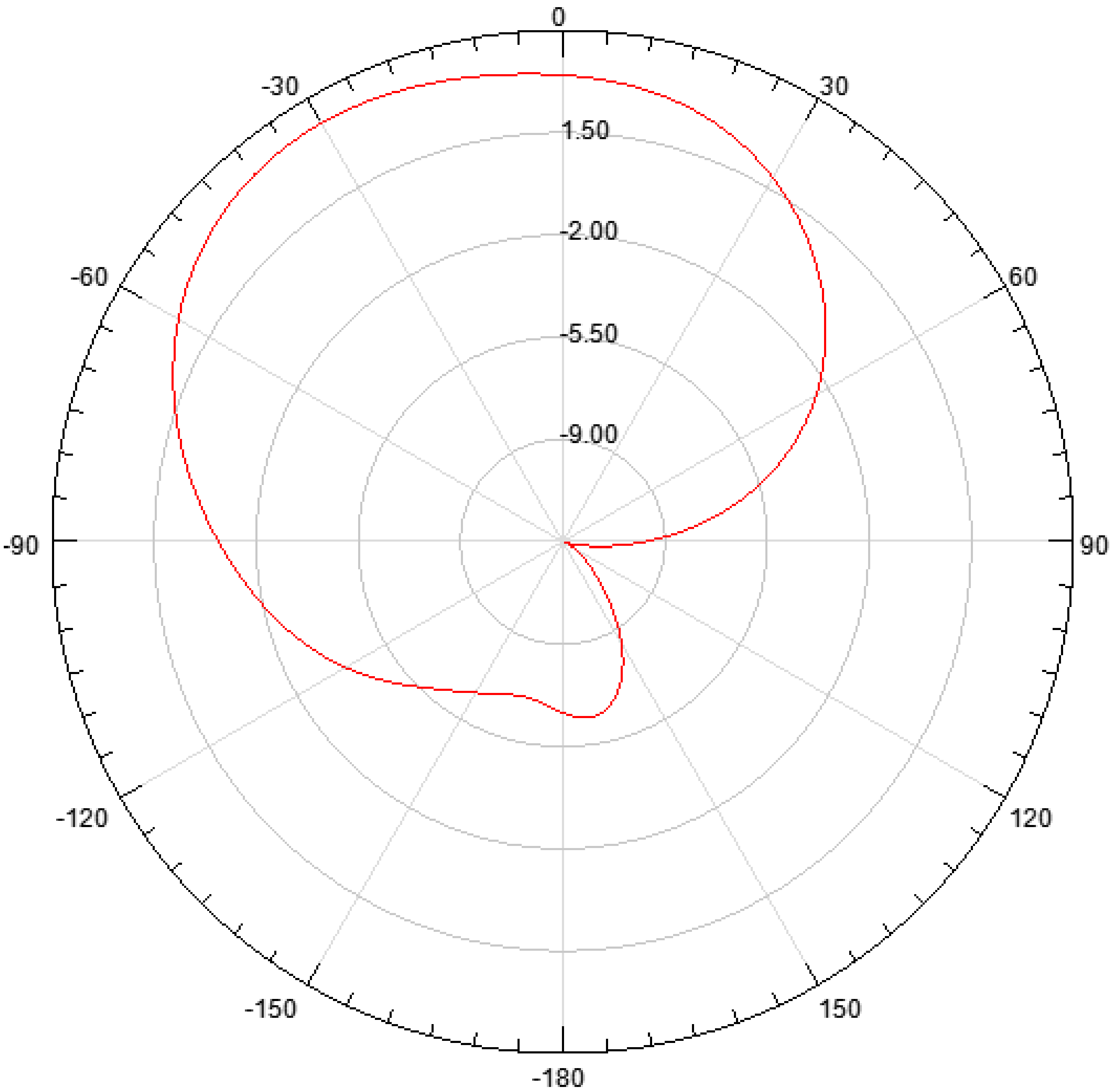

FIG 19(b): Two Dimensional radiation pattern

(c) Radiation efficiency

The simulated radiation efficiency of the single element swastika shaped DRA antenna is shown in figure 20. We are getting the radiation efficiency of 76% at the resonant frequency of 6.8 GHz.

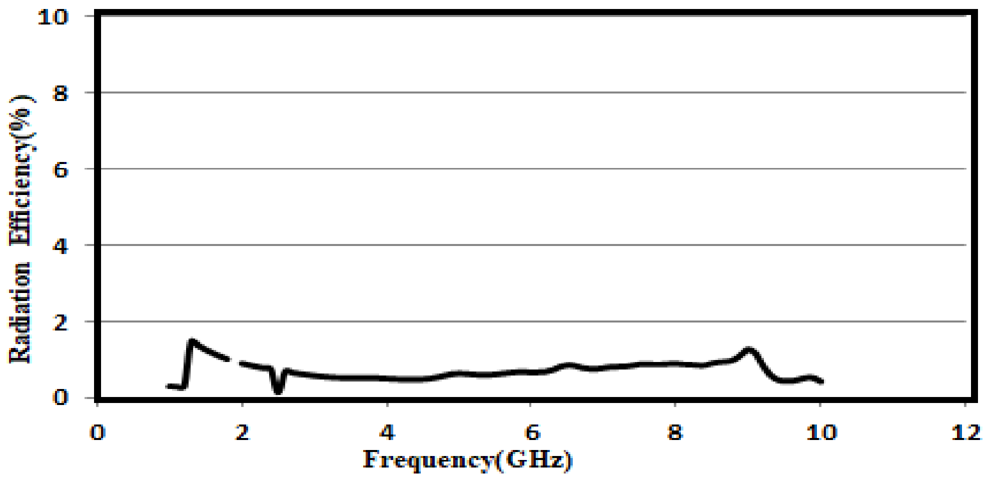

Fig 20: Radiation efficiency vs. Frequency graph

(d) VSWR

The VSWR vs. Frequency graph is shown in figure 21. We are getting the VSWR (Voltage Standing Wave Ratio) of 1.66 at the resonant frequency of 6.8 GHz. We can say that the VSWR which we are getting is less than 2, which means that there will be good adaptation between the feeding system and the antenna.

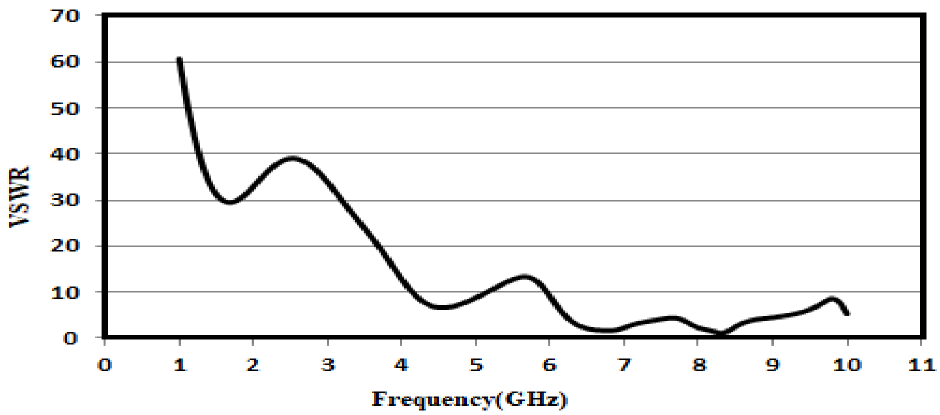

Fig 21: VSWR vs Frequency Graph

5.2 SIMULATION RESULTS OF DUAL ELEMENT SWASTIKA SHAPED DRA ANTENNA

(a) S-Parameter

The S11 parameter for the dual element swastika shaped DRA antenna is predicted in figure 22. It is quite clear from the figure that the dual element swastika shaped antenna is operating in C-Band with resonating frequency of 7.7 GHz. The bandwidth obtained is 170 MHz (7.61-7.78 GHz).

Minimum return loss of -24.46 is observed at 7.7 GHz frequency.

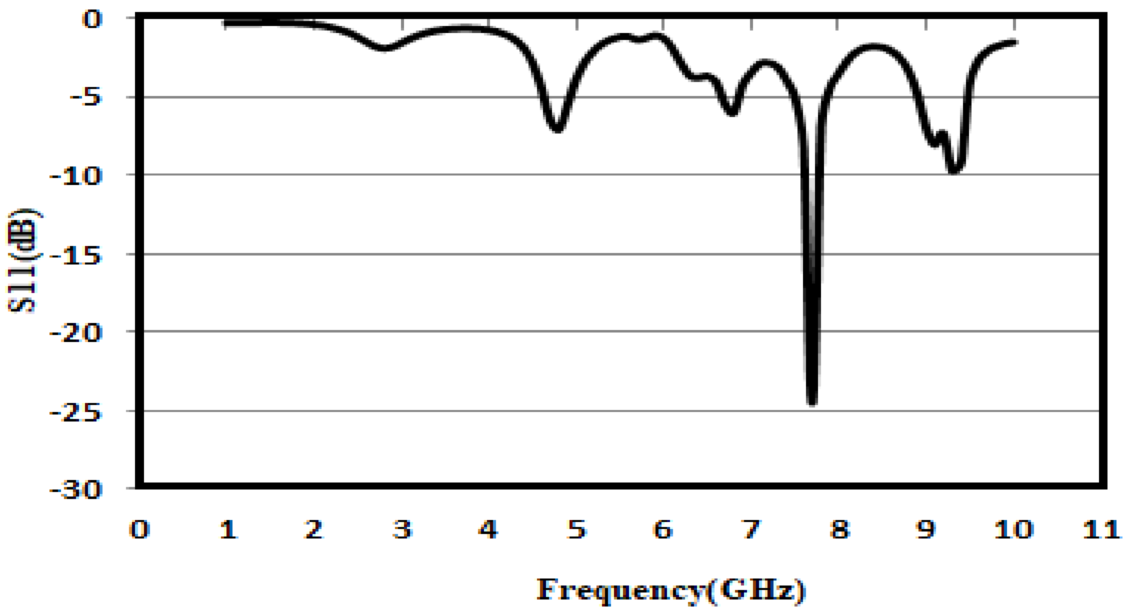

Fig 22: S11 parameter of antenna

(b) 3D and 2D Simulation Radiation pattern

Fig 23(a) and 23(b) shows the 3D and 2D radiation pattern of the dual element swastika shaped DRA antenna respectively at the resonant frequency of 7.7 GHz. The overall gain achieved is 7.85 dB.

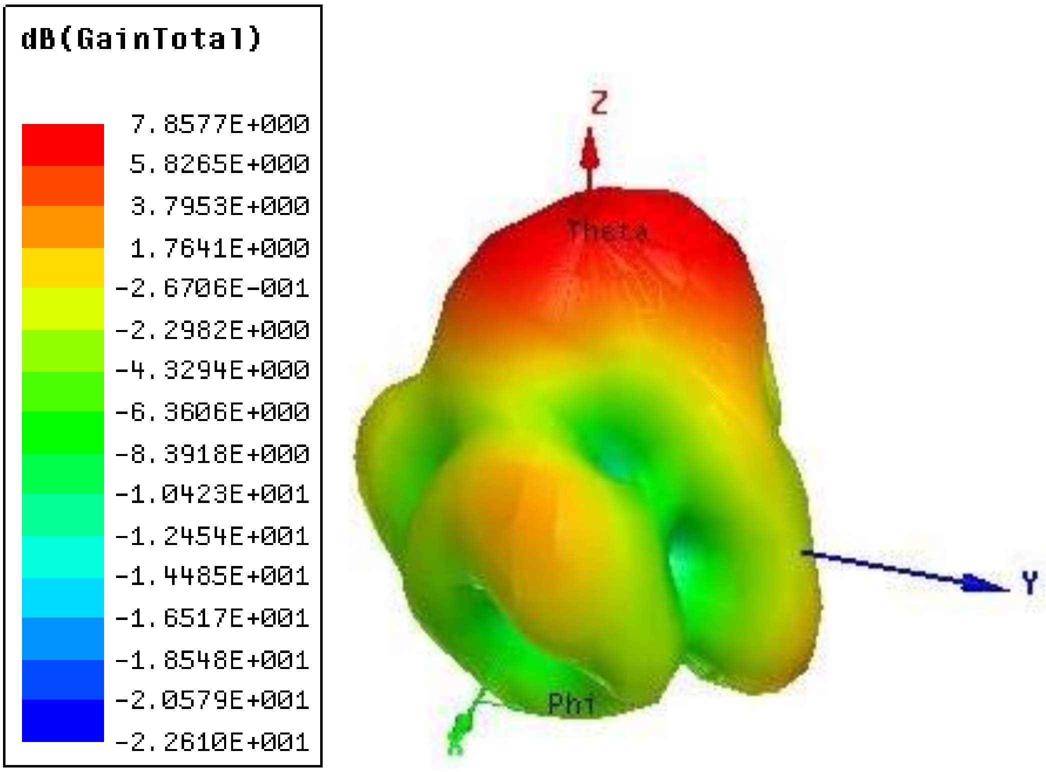

Fig 23(a):- Three Dimensional Radiation pattern

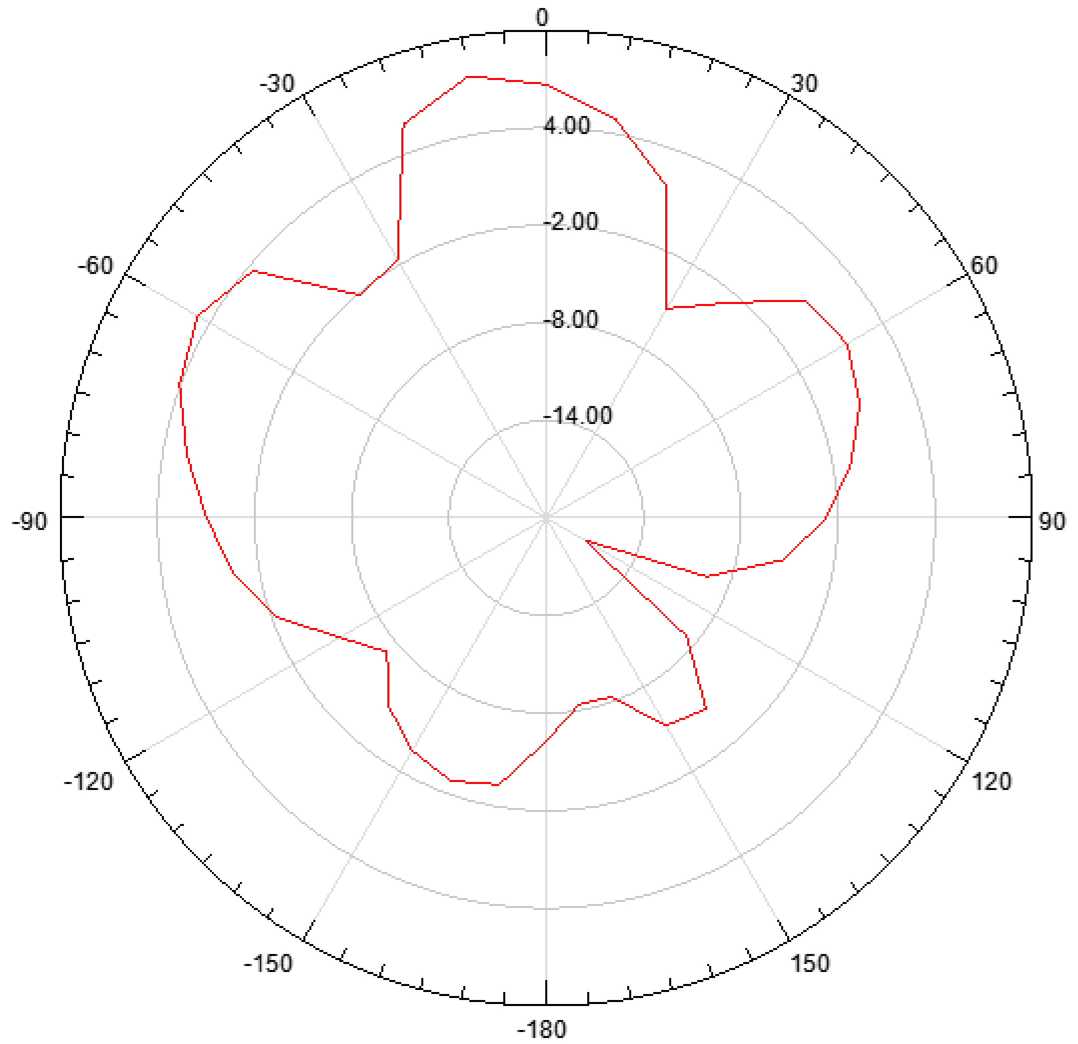

Fig 23(b):- Two Dimensional Radiation pattern

(c)Radiation efficiency

The simulated radiation efficiency of the dual element swastika shaped DRA antenna is shown in figure 24. We are getting the radiation efficiency of 67% at the resonant frequency of 7.7 GHz.

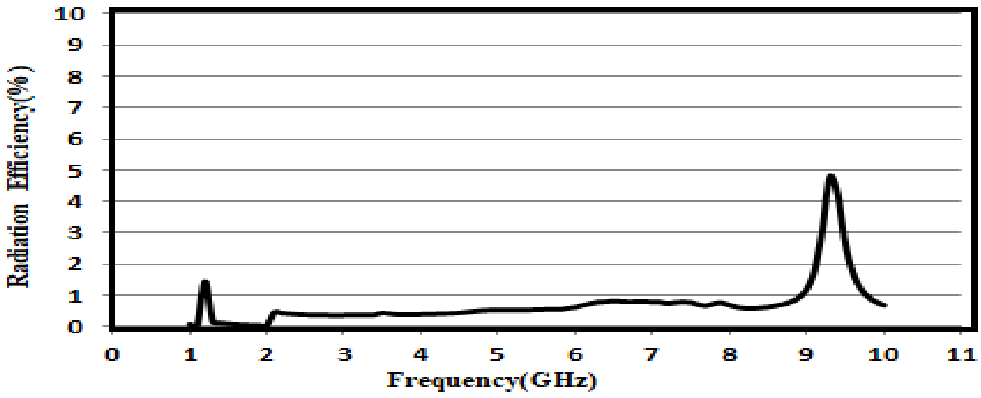

Fig 24: Radiation efficiency vs Frequency curve

(d) VSWR

The VSWR vs Frequency graph is shown in figure 25. We are getting the VSWR (Voltage Standing Wave Ratio) of 1.12 at the resonant frequency of7.7 GHz. We can say that the VSWR which we are getting is less than 2, which means that there will be very good adaptation between the feeding system and the antenna.

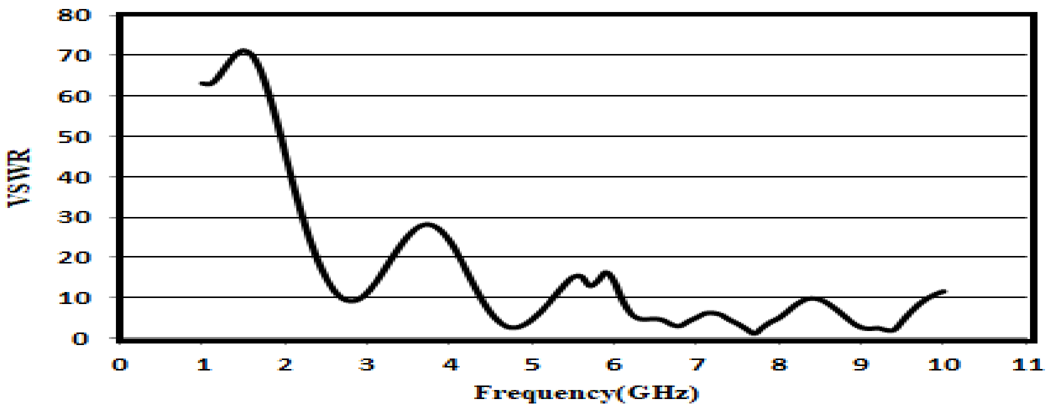

Fig 25: VSWR vs Frequency curve

5.3 CONCLUSIONS

The swastika shaped dielectric resonator antenna is designed and simulated in this project. The simulation of the antenna has been performed by ANSYS HFSS Software of version 16. Both the single element and the dual element swastika shaped dielectric resonator antenna has been designed and simulated. We have used a dielectric material ceramic whose relative permittivity is quite higher i.e. 10. The swastika shaped DRA antenna is designed by using low-cost substrate of type FR4, having height of 1.6 mm. In this antenna, a dielectric material ceramic is used and therefore, there will be negligible losses in the antenna. The simulated result analysis gives better performance in various antenna characteristics. This antenna can be used for different microwave applications especially used at C-band where use of different microstrip antenna offers the problem of very low metallic losses. This antenna is operating in C- band frequency range having various uses in satellite communications, space communications, in cordless telephones, in meteorological satellites for monitoring weather conditions.

5.4 FUTURE SCOPE

Every research work has some scope for development. In the thesis, we have discussed the design as well as analysis of swastika shaped DRA antenna. But still some part needs to be improved for better result.

- Our main objective is the better performance of the antenna. For that, human errors must be avoided or minimized during Fabrication process. It has to be minimized. Hence, the fabrication field needs to be improved so that we can achieve accurate results.
- Swastika shaped DRA antenna have low bandwidth and High gain. But our expectation is always more in both of the cases. So, this bandwidth can be improved so that our desired antenna can be used for much wider applications.

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