DESIGN AND OPTIMISATION OF DRA ARRAY USING PSO TECHNIQUE

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF TECHNOLOGY IN ELECTRONICS AND COMMUNICATION

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CERTIFICATE

This is to certify that the thesis entitled, "Design and Optimisation of Dielectric Resonator Antenna array using PSO Technique" submitted by **Mr. Anwesh Mishra** and **Mr. D. Hema Kumar** in partial fulfilment of the requirements for the award of Bachelor of Technology Degree in Electronics and Communication Engineering during the session 2013-2014 at the National Institute of Technology, Rourkela (Deemed University) is a genuine work carried out by them under my supervision and guidance. To the best of my knowledge, the content represented in the thesis has not been submitted to any other University/ Institute for the award of any degree or diploma.

S.K.BEHERA

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Abstract

This thesis presents design and optimization of Dielectric Resonating Antenna array using PSO technique for wireless application. The designing of the DRA is done in Computer Simulation Technology(CST) microwave studio. The DRA is designed using two disk shaped resonator made from a ceramic material(Ceramic batch #QC1266470) whose dielectric constant is 34.73, FR-4 substrate whose dielectric constant is 4.5 and copper patch. Two dielectric resonators are represented as an array. The resonators are fed by Microstrip transmission line model. The resonating frequency of resonators is 2.4 Ghz. The length of the Microstrip transmission line is $\lambda/4$ where λ is the resonator wavelength. The simulation process is done using the same Computer Simulation Technology (CST) Microwave Studio Suite and then the design has been optimized using a Particle Swarm Optimization (PSO) technique to get the desired resonating frequency. The DRA is operating at the frequency bands used for IEEE 802.11b/g Wireless LANs.

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Chapter 1

Thesis overview

Thesis Motivation

Bandwidth enhancement and high radiation efficiency are some of the major design considerations for most practical applications of Dielectric resonator antennas. Microstrip antennas have limitations compared to dielectric resonator antennas(DRA) as they have narrow bandwidth, lower gain, lower power handling capacity etc. For that reason, dielectric resonator antennas(DRA's) are preferred over microstrip and conventional antennas. In recent few decades, research scientists have developed several techniques to increase the bandwidth and obtain high radiation efficiency for an antenna. Making DRA arrays by using different types of feeding techniques is one of the most popular bandwidth enhancement approach. The recent advancements in wireless communication industry, especially in the area of mobile communication and wireless data communication(WiFi), which promoted the study and design of DRA arrays.

1.2 Literature Review

The dielectric resonators were primarily been used in microwave circuits, such as oscillators and filters. And because of this dielectric resonators were treated as energy storing devices. Dielectric resonator was first discussed as an antenna by S. A. Long in a paper entitled, "The resonant cylindrical dielectric cavity antenna," IEEE Transactions on Antenna and Propagations. At that time, it was observed that the frequency range of interest for many systems has gradually progressed upward to the mm and near mm range (100–300 GHz). The conductor loss of metallic antennas becomes severe and the efficiency of the antenna is reduced significantly at these frequencies. But the only loss for a DRA is that due to the imperfect dielectric material, and its value is almost negligible. After the cylindrical DRA has been studied, Long and his colleagues subsequently investigated the rectangular and hemispherical DRAs. Analysis of their resonant modes, radiation patterns, and method of excitation made it clear that these dielectric resonators could be used as antennas and offered a new and attractive alternative to traditional low gain radiators. In the early 1990, emphasis was placed on realizing various analytical or numerical techniques for determining the input impedance and Q-factor. Focus was mainly on individual elements. A significant amount of this characterization was carried out by two research teams; one was led by Kishk, Glisson, and Junker and the other by Luk and Leung. Much of the early work to characterize the performance of the basic DRA elements was summarized in a 1994 review paper by Mongia and Bhartia. They also proposed different modes for DRA, and provided a set of simple equations for predicting the resonant frequency and the Q-factors for several DRA shapes. By the mid-1990s more attention was being given to linear and planar DRA arrays, ranging from simple two element arrays, up to complex phased arrays of over 300 elements with beam-steering capability. The development of ferrite resonator antennas, DRAs operating at 40 GHz, and DRAs with nearly 40% impedance bandwidth also occurred in this period. Many of the recent advances were reported in a 1998 paper by Petosa et al. K. W. Leung proposed a new excitation scheme in year 2000 which employs a conducting conformal strip for dielectric resonator antenna excitation by using a hemispherical DRA . M.S.M. Aras, M.K.A. Rahim, Z.Rasin, M.Z.A. Abdul Aziz proposed an array of Dielectric resonator Antenna for wireless application in 2008 . Wael M. Abdel Wahab, Safieddin Safavi Naeini, and Dan Busuioc Modelled and Designed a Millimeter-Wave High Q-Factor Parallel Feeding Scheme for Dielectric Resonator Antenna Arrays in 2011. Yong Mei Pan, Kwok Wa Leung and Kai Lu Proposed Omnidirectional Linearly and Circularly Polarized Rectangular Dielectric Resonator Antennas in 2012.

1.3 Scope of the Project

The scope of this project is to design a dielectric resonator array and optimize the design so that it can be used for wireless applications operating at the frequency bands used for IEEE 802.11b/g Wireless LANs. The operating frequency of the design is 2.4 GHz and the dielectric constant of the resonator used is 34.73. The antenna must be designed in such a manner that it should be small in size and the manufacturing cost must be as low as possible. The return loss must be less than 10dB within the wireless range. Other aspects such as directivity, beam width and side lobes were evaluated using optimization technique Particle swarm optimization.

1.4 Introduction to Wireless Local Area Network(WLAN)

WLANs are based on IEEE 802.11 standards, marketed under the Wi-Fi brand name. The 802.11 covers mainly three different frequency range. Those are 2.4 GHz, 3.6 GHz and 4.9/5

GHz. Since we are interested in the 2.4 GHz range, we would focus on this particular type. The 2.4 GHz channel comes under 802.11b/g/n standards.

1.5 Thesis Outline

In Chapter 1 the thesis overview is shown. The literature review for the project work is done in this chapter and the introduction to WLAN and its different standards are shown in this chapter. Chapter 2 represents basic theory of DRAs which includes the basic characteristics of the DRAs, its advantages and its applications in comparison with Microstrip antennas. At last this chapter shows the study of Disk DRA and some of its modified shapes for bandwidth enhancement. Chapter 3 focuses on the study of DRA array and shows the different feeding techniques for DRA arrays. It also shows the study of mutual coupling between the resonating elements and how to avoid its occurrence. In chapter 4 design of two elements disk shaped dielectric resonator antenna array is presented for 2.4 GHz wireless applications. The DRA array is excited by microstrip line coupling arranged in a corporate feed technique. Simulation result shows that the proposed antenna achieves an impedance bandwidth from 2.18 GHz to 2.43 GHz covering 2.4 GHz wireless band. This chapter also shows the PSO technique used and its effect on the design to improve the results like directivity, side lobe levels and bandwidth. Chapter 5 describes the Particle Swarm optimization(PSO) technique and its application on the design used. Chapter 6 is about matlab linking with CST.

Optimization of the design and the following results of the thesis is given in chapter 7.

CHAPTER2

DIELECTRIC RESONATOR ANTENNA

2.1 INTRODUCTION

Dielectric resonator antenna consists of dielectric materials in its radiating patch also called as dielectric resonators (DRs) on one side of the substrate and has a ground plane (metal) on the other side . The dielectric constant of the dielectric resonators on the DRAs can vary from 2 to 100. The dielectric resonators have three basic shapes i.e. circular, rectangular and triangular, but rectangular shape is generally used because the design and analysis of rectangular shape is comparatively easy. As compared to the microstrip antenna, the DRA has a much wider impedance bandwidth (~10% for dielectric constant ε_r ~ 10). This is because the microstrip antenna radiates only through two narrow radiation slots, whereas the DRA radiates through the whole DRA surface except the ground part. Avoidance of surface waves is another attractive advantage of the DRA over the microstrip antenna. However, many characteristics of the DRA and microstrip antenna are common because both of them behave like resonant cavities. For example, since the dielectric wavelength is smaller than the free-space wavelength by a factor of √ , both of them can be made smaller in size by increasing . Preferably, the relative permittivity $\varepsilon_r$of the substrate should be low (ε_r < 2.5), to enhance the fringing fields that account for the radiation. However, as per the performance requirements, the value of the dielectric constant of the substrate may vary and can be of some greater value (say 4.4). 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 or the dielectric resonators (DRs) there is chance to increase the performance of the antenna, but materials with higher dielectric constant values may or may not be available for fabrication. Fig.1 shows the basic shapes of the DRAs. There are a number of effective excitation methods that can be used for DRAs. Some of the examples are the coaxial probe, aperture-coupling with a microstrip feed line, aperture-coupling with a coaxial feed line, direct microstrip feed line, co-planar feed, soldered-through probe, slot line, strip line, proximity coupled microstrip feed, conformal strip, and dielectric image guide feed. Microstrip feeding technique is most general and simple method of feeding. Here the DRAs are fed with 50 Ω microstrip lines.

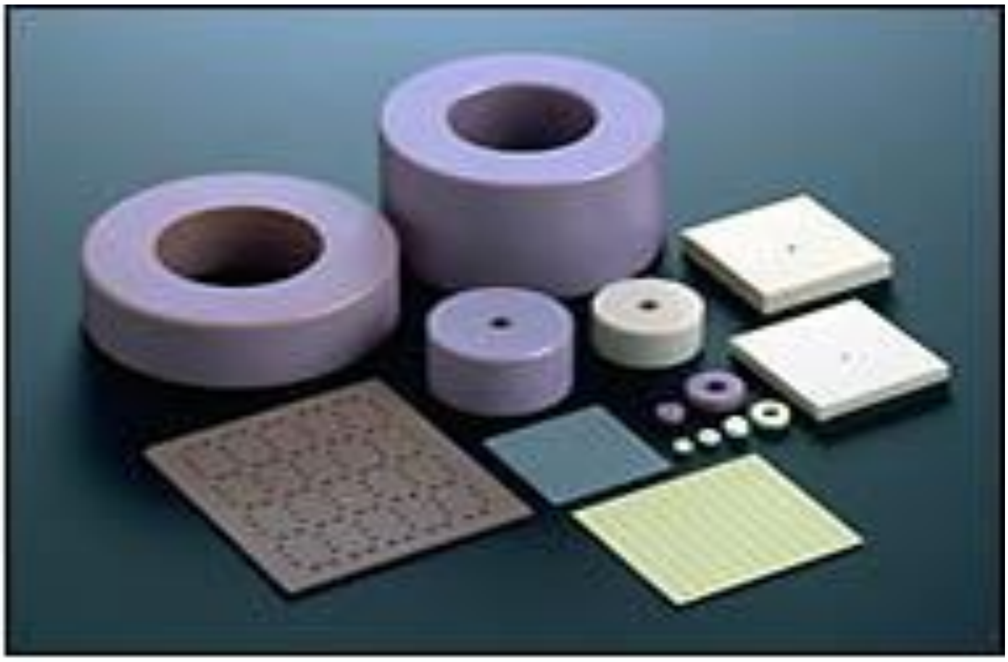


Fig.2.1 DRAs of various shapes

2.1.1 MAJOR CHARACTERESTICS

Some of the main characteristics of the dielectric resonator antennas are summarized below;

1. The size of the DRA is proportional to $\lambda_0 / \sqrt{\varepsilon_r}$.

2. The resonant frequency and radiation Q-factor is also affected by the aspect ratio of the DRA for a fixed dielectric constant.

3. A wide range of dielectric constants can be used.

4. By selecting a dielectric material with low loss characteristics, a high radiation efficiency can be maintained in DRAs.

5. DRAs can be designed to operate over a wide range of frequencies from 1 GHz to 44 GHz.

6. DRA has much wider impedance bandwidth compared to microstrip antennas.

7. Depending upon the resonator shape, various modes can be excited within the DRA producing either broad side or omnidirectional radiation patterns for different coverage requirements.

DRAs offer several attractive features including:

- We can get a high radiation efficiency since DRA's radiate throughout the surface.
- We can get high quality factor
- Wider frequency range can be obtained

2.1.2 LIMITATIONS

1. The fabrication price is more as compared to microstrip antenna.

2. Drilling may be required and the DRA has to be bonded to a ground plane or substrate.

3. Compared to the printed circuit antennas, the fabrication is generally more complex and more costly, especially for array applications.

4. Difficult to get dielectric materials of desired dielectric constants, so have to work with limited available sources.

2.1.3 APPLICATIONS

1. Satellite communication, direct broadcast services.
2. Doppler and other radars.
3. Missiles and telemetry.

4. Mobile radio (pagers, telephones, man pack systems).

5. Biomedical radiators and intruder alarms.

2.2 FEEDING METHODS

Feeding techniques are required to energize the antenna i.e. to transfer the power into the antenna. Dielectric resonator antennas have radiating elements on one side of dielectric substrate and for these designs a number of new feeding techniques have been developed. Some feeding techniques are easy to fabricate where as other are difficult, and some feeding techniques can enhance the bandwidth. For example, aperture and proximity feeds are used to increase the bandwidth but fabrication is the major problem because these two feeding techniques useful when two substrate are present.

2.2.1 MICROSTRIP FEED

The Microstrip feed line is also a conducting strip, usually of much smaller width compared to the patch. It is easy to fabricate, simple to match by the inset position and rather simple to model. However as the substrate thickness increases, surface waves increases which for practical reasons limits the bandwidth.

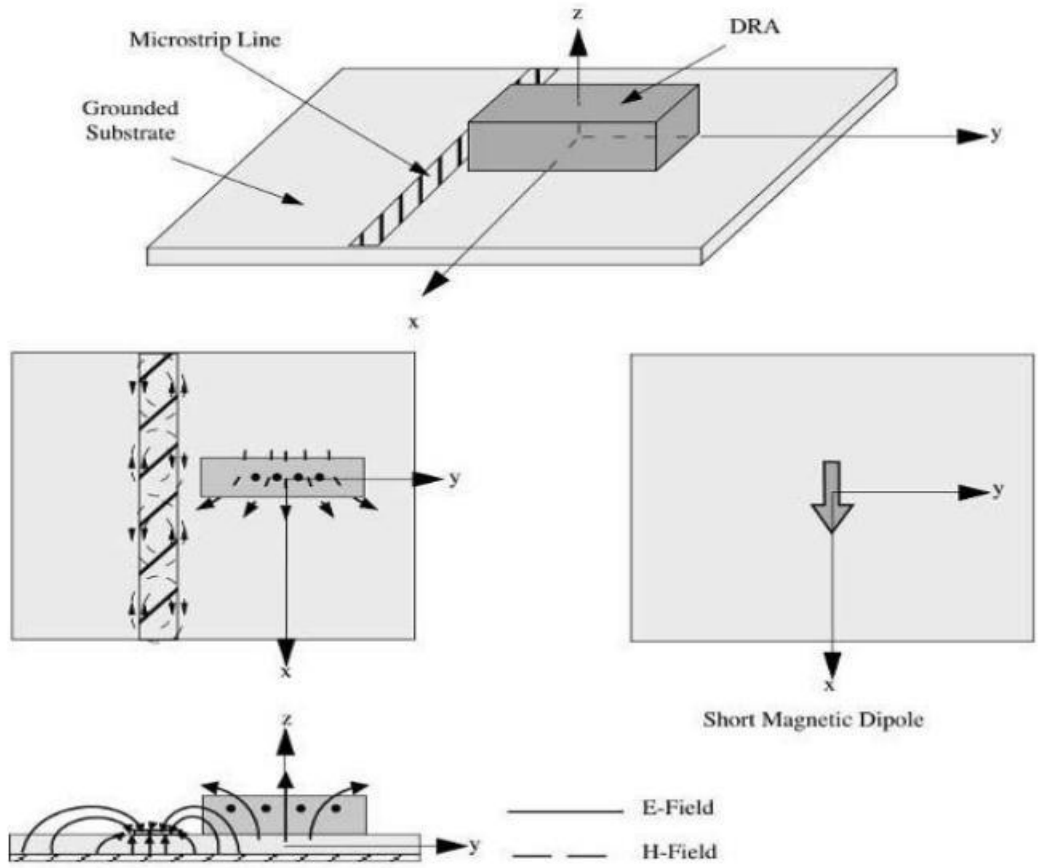


Fig.2.2 Microstrip feed

2.2.2 COAXIAL/PROBE FEED

Coaxial-line feeds, where the inner conductor of the coax is attached to the radiation patch while the outer conductor is connected to the ground plane, are also widely used. It is easy to fabricate and match and it has a low spurious radiation. However it also has narrow bandwidth and it is more difficult to model, especially for thick substrate($h>0.02\lambda$**).**

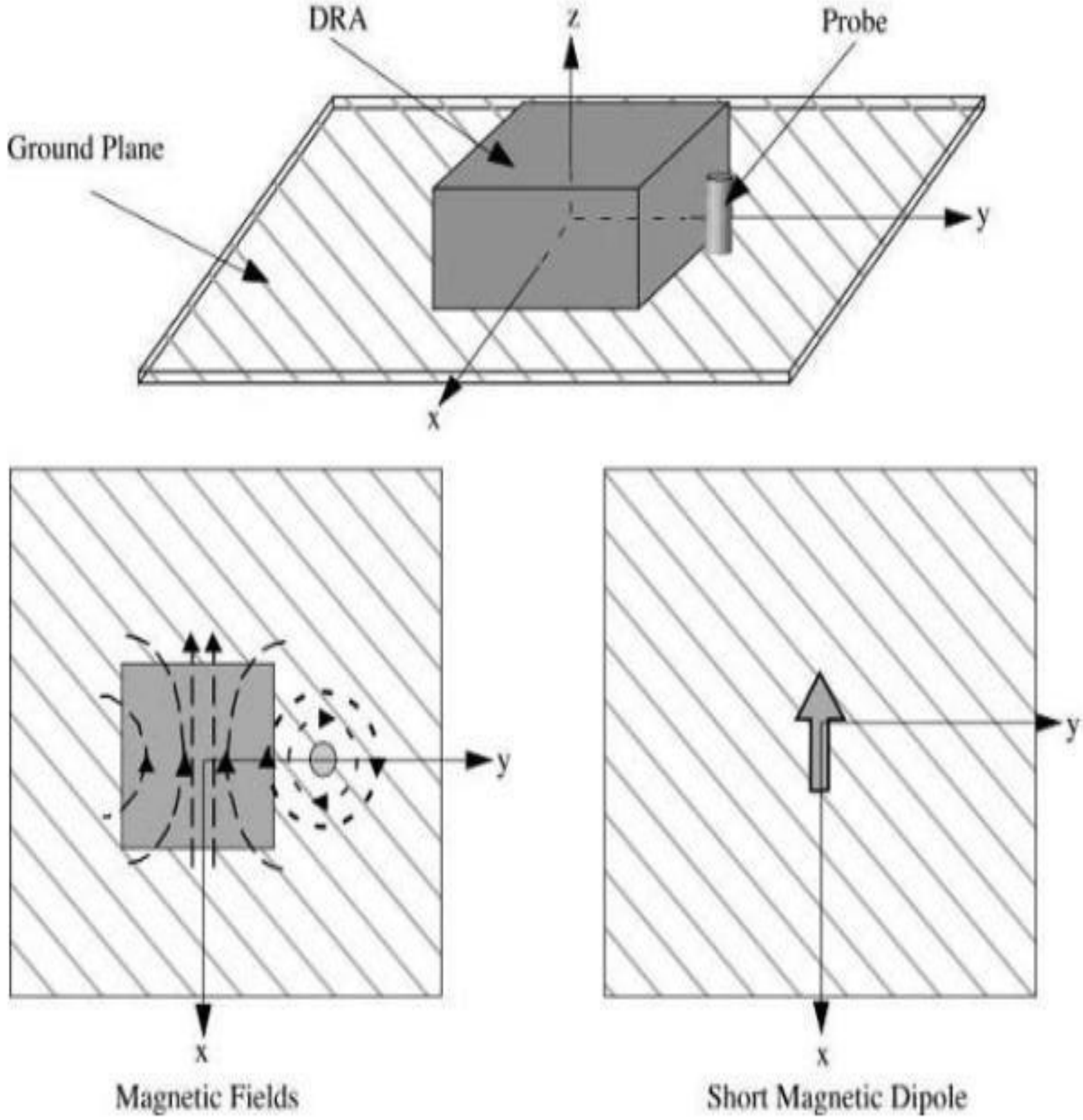


Fig.2.3 Probe feed

2.2.3 APERTURE FEED

To overcome cross polarized radiation which is common in the above mentioned methods, aperture feed model has been introduced. It is the most difficult to fabricate and it also has narrow bandwidth. However it is somewhat easier to model and has moderate spurious radiation. It consists of two substrates separated by a ground plane. On the bottom side of the lower substrate there is a Microstrip feed line whose energy is coupled to the patch through a slot on the ground plane separating the two substrates. This arrangement allows independent optimization of the feed mechanism and the radiating element. Typically a high dielectric material is used for the bottom substrate, and thick low dielectric constant material for the top substrate.

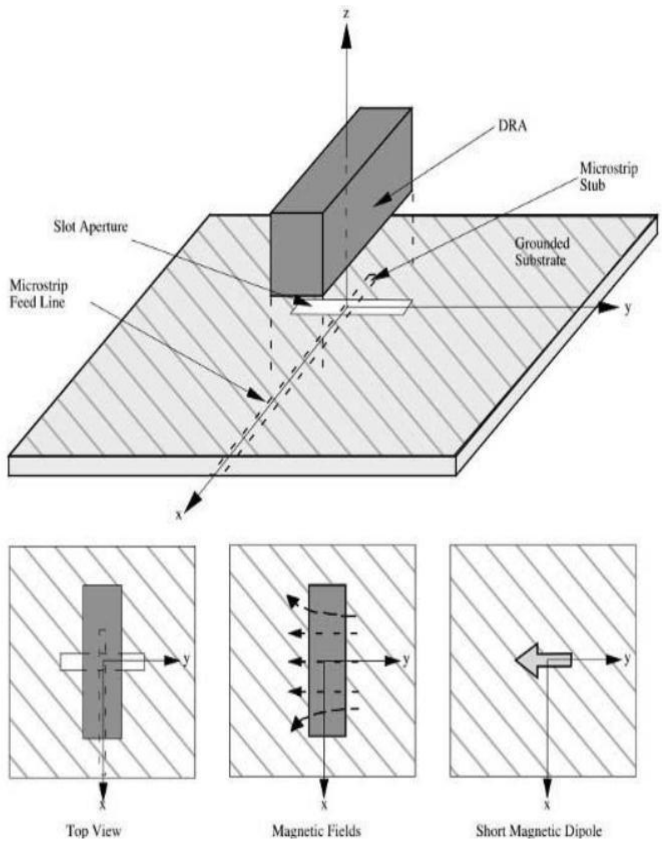


Fig.2.4 Aperture feed

2.2.4 PROXIMITY COUPLED MICROSTRIP FEED

In this type of feeding two layer substrate is used and the DRA is placed on the upper layer. This feed is also known as an electromagnetically coupled feed. To design this feed two substrates are required, and the feed line should be in between the two substrates. The fabrication of the antenna is difficult and the thickness of the antenna is increased due to the presence of two substrates. By using this feeding technique bandwidth of the antenna can be improved. The substrate parameters of the two layers can be selected to increase the bandwidth and to reduce spurious radiation, for this the lower substrate should be kept thin.

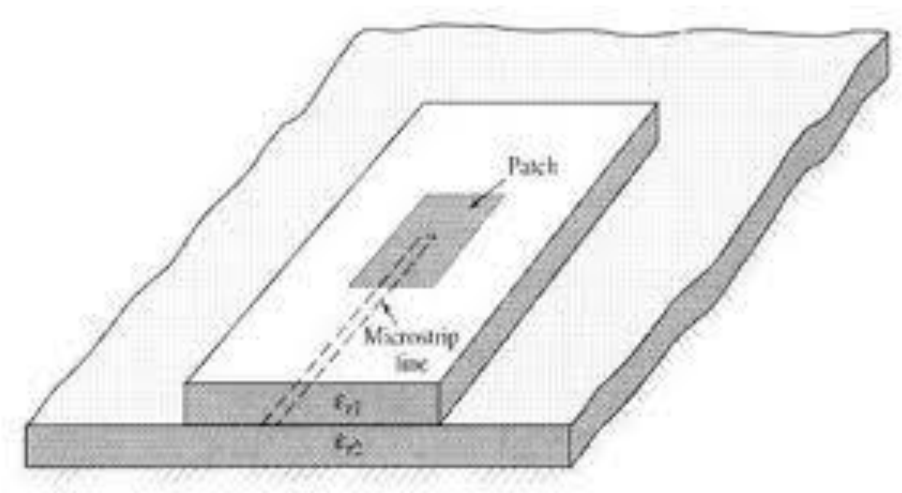


Fig.2.5 Proximity feed

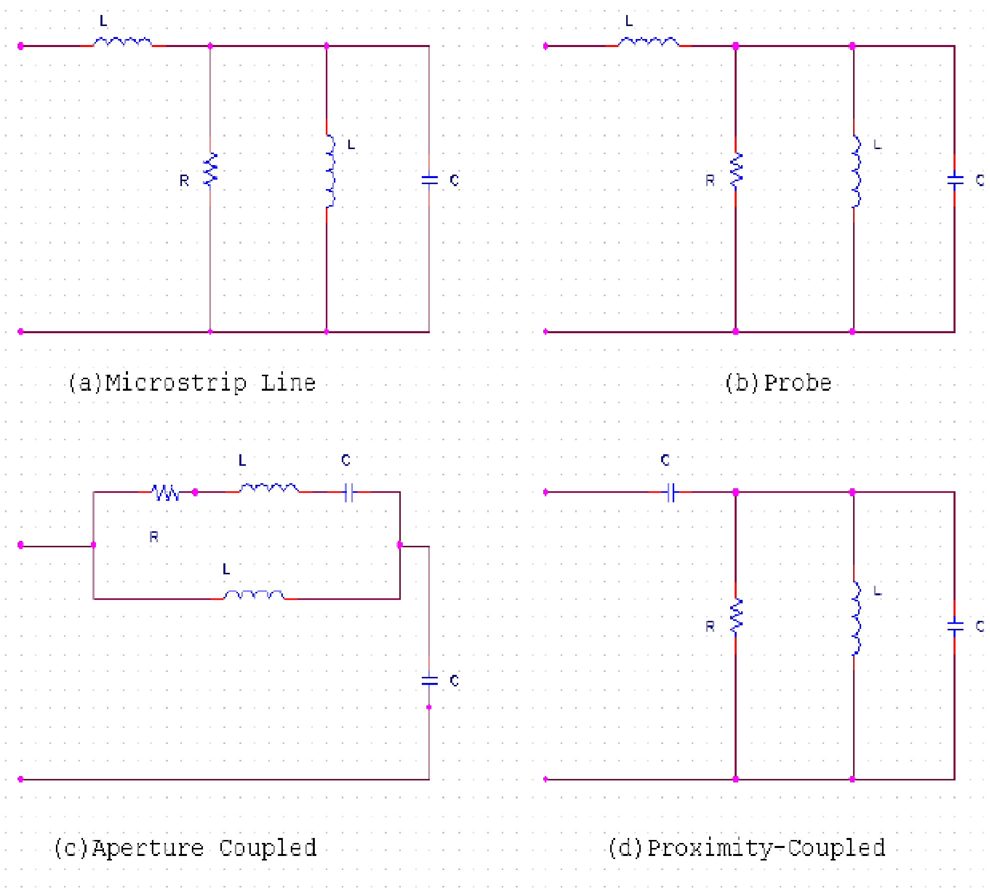
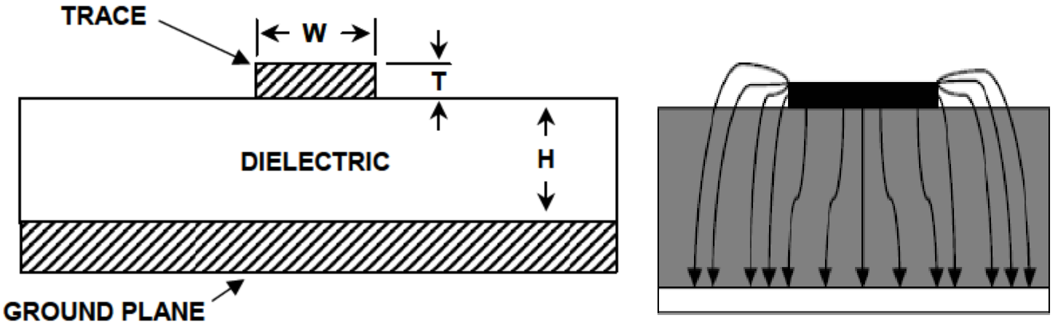


Fig.2.6 shows the equivalent circuits of some of the feeding techniques used for DRAs

Since our design is based on Microstrip line feeding, we only focus on this technique

2.3 TRANSMISSION LINE MODELING

Transmission line model is the easiest modelling technique for microstrip antennas, but it is not versatile. It also doesn't give accurate results. It does give a good understanding on microstrip line. In case of DRA this model is generally used to design and analyse the microstrip line feeding.



(a) (b)

Fig.2.7 (a) Microstrip line and (b) Electric field lines

When (W/H) < 1

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[\left(1+12\left(\frac{H}{W}\right)\right)^{-0.5} + 0.04\left(1-\left(\frac{W}{H}\right)\right)^2\right]$$

When (W/H) ≥ 1

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[\left(1+12\left(\frac{H}{W}\right)\right)^{-0.5}\right]$$

2.4 Cylindrical DRA

Cylindrical DRAs are the most effective for radiation. It has low Quality factor.

Cylindrical DRA's offer good design freedom since the resonant frequency and the quality factor are in relation with radius to height ratio. There are three types of modes in cylindrical DRA and they are TE, TM and EH modes.

amount of literature is devoted to their field configurations, resonant frequencies and radiation properties. This part will present a complete and concrete study of a cylindrical DRA.

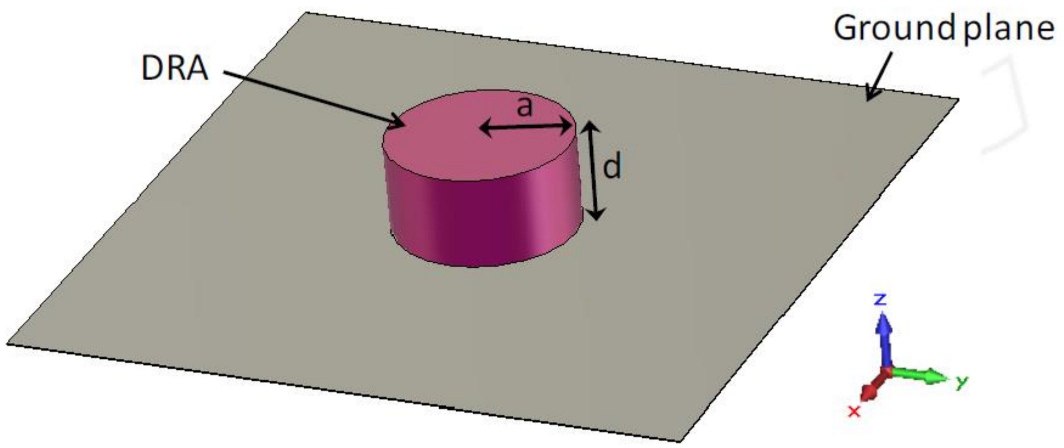


Fig 2.8 Cylindrical DRA

EH mode is dependent on azimuth φ but TE and TM are independent of azimuth φ. To realise field changes due to r(radial), Z(axis)directions and azimuth φ , subscripts p, m and n are used respectively in mode notations. n=0 for TE and TM modes as they do not have azimuthal variation modes. And lastly, all the cylindrical DRA modes are defined as:TE0pm+δ, TM0pm+δ, HEnpm+δ and EHnpm+δ. The δ value of the δ is in between 0 and 1, and as ε_r reaches high values, δ approaches 1. All the subscripts m , p and n are natural numbers. analytical calculations or CST Microwave Studio (CST MS) are used for analysing the modes of the cylindrical array.

The general equation for resonant frequencies is given by:-

$$\begin{pmatrix} f_{TMnpm} \\ f_{TEnpm} \end{pmatrix} = \frac{c}{2\pi a\sqrt{\varepsilon_r \mu_r}}\sqrt{\begin{pmatrix} X'_{np} \\ X'_{np} \end{pmatrix}^2 + \left(\frac{(2m+1)\pi a}{2d}\right)^2}$$

Where X'_{np} and X'_{np} are Bessel's solutions. The parameters 'a' and 'd' are the radius and height of the dielectric resonator.

CHAPTER 3
DRA ARRAY

3.1 DRA ARRAY THEORY

Common antenna array elements include monopole, dipole, helixes, micro strip patches, printed tapered slots and waveguide slot apertures. Each has their own strengths and weaknesses and are generally selected to meet specific needs. Adding DRAs to the list of potential array elements, we can get certain advantages for specific applications not available with other conventional elements. DRAs are typically low gain antennas with broad radiation patterns, so they can be arrayed to achieve higher gain or shaped radiation patterns like other conventional antenna .

3.2 ARRAY THEORY

The radiation pattern of an antenna of N-identical elements evaluated at a location (θ,ø) in the far field can be approximated by the product of the radiation intensity of the element and the array factor using:

$$\text{Radiation pattern} = 20\log(\text{Radiation intensity of element} \times \text{Array Factor})$$

Where,

$$\text{Array Factor} = \sum_{n=1}^{N} A_n e^{j\Psi_n}$$

And,

$$\Psi_n = k_0 x_n \sin\theta \cos ø + k_0 y_n \sin\theta \sin ø$$

Where,

k_0= free space wave number $\frac{2\pi}{\lambda_0}$

(x_{n,y_n})= location of the nth element

A_n= complex voltage excitation

The above equation for array factor is the general equation and applicable to arrays where the elements are arbitrarily located and excited. For a linear array of N-elements where the elements are uniformly spaced a distance d apart, the array factor simplifies to:

$$\text{Array Factor} = \sum_{n=1}^{N} A_n e^{jnk_0 d \sin\theta}$$

In this case a uniform amplitude excitation (A1 = A2 = ….. = A0) is chosen in order to obtain maximum directivity, and a linear phase progression ($\beta_1 = \beta, \beta_2 = 2\beta \ldots\ldots \beta_n$=Nβ) is selected to scan the beam to a desired angle. The array factor is further simplified to:

$$\text{Array Factor} = \frac{A_0 \sin(\frac{N\psi}{2})}{\sin(\frac{\psi}{2})}$$

Where,

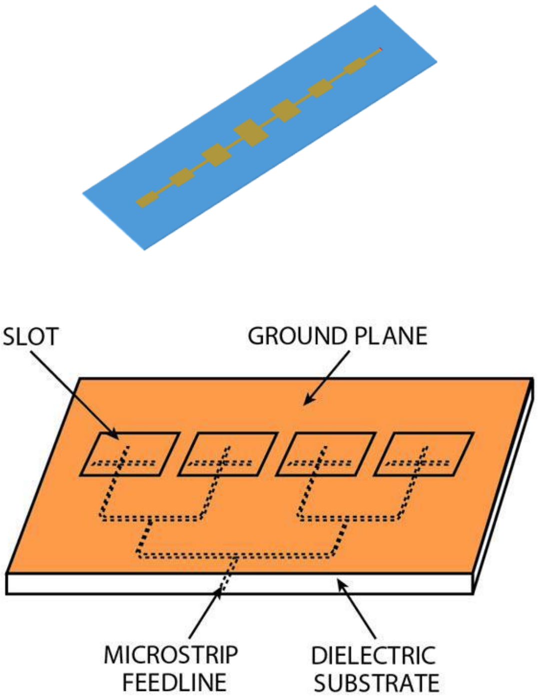
$$\psi = k_0 d \sin\theta + \beta$$

And $$\theta_0 = \sin^{-1}(\frac{-\beta}{k_0 d})$$

3.3 FEED NETWORK FOR DRA ARRAY

A feed distribution network is required to achieve the required amplitude and phase excitation for each radiating element. Feed network design and its implementation is the most important part of the array design. By properly designing the feed network junctions we can achieve the desired amplitude excitation for each element. To get the desired power split at the junctions the impedances of the transmission line must be designed properly. The phase excitation for the array elements can be obtained by using passive phase delays within the feed network .

There are two types of feeding network used in DRA array. One is **series feed** and the other one is **parallel feed** or corporate feed. These are the part of the constrained feed. The series feed is a more compact network requiring less transmission line lengths and fewer junctions and resulting in a lower insertion loss than parallel feed. However the series feed has less bandwidth than parallel feed. The bandwidth of the end-fed series network is limited by the gain degradation. Another factor limiting the bandwidth of this feed is the mismatch loss that occurs due to the in-phase addition of the reflections from the various branches. For the parallel feed the path length to each element is identical. The parallel or corporate feed has a relatively wide bandwidth since it does not suffer from high mismatch losses. The corporate feed is much less compact than the series feed. More losses are associated with corporate feed than series feed due to the radiation from the discontinuities and longer line length. Fig.12 shows the series and corporate feeds respectively.



(a)

(b)

Fig.3.1 (a) Series and (b) Corporate feed

The most common method to provide the desired excitation to the DRA elements is to use a microstrip feed network. If the elements are to be excited with equal amplitude and phase, a corporate feed network is usually selected. Microstrip lines suffer from increased conductor and surface wave losses at high frequencies. The parallel feed network although offering the broader bandwidth, suffer from higher losses due to the longer path lengths. The parallel feeding technique cannot be used in antennas where the physical spacing between the dielectric elements is very small. In microstrip series feeding method, power is transferred from the lines to the DRAs by electromagnetic coupling, which can be controlled by adjusting the spacing between the DRA and the line. In case of series feed network the spacing between the dielectric resonators is kept equal to the guided wavelength of the unloaded microstrip line in order to avoid coupling

Another method to feed the DRA array is by using low loss dielectric image guide in series feed technique. One disadvantage in microstrip feed is the losses due to conductor and surface waves at high frequencies. This will not occur in dielectric image guide feed. The dielectric material of dielectric constant is used as dielectric image guide line. The height and width of the image guide line is taken as H and W respectively. The spacing between the DRAs will be related to the guided wavelength of the dielectric image guide as similar to microstrip feed line, and the separation between the DRAs and the dielectric image guide will control the amount of coupling.

3.4 MUTUAL COUPLING

In a transmitting array, power transmitted from each element will imping on the other elements in the array or in a receiving array, some of the scattered power from each element will imping upon nearby elements. The interaction between the elements of the array is referred to as mutual coupling. It causes distortions in the radiation pattern of the array and can also affect the input impedance of each element, resulting in mismatch losses. The type of antenna element used in the array, its feed network and its design parameters like gain, radiation pattern etc. affect the mutual coupling. The closer the dielectric elements placed in the antenna, the higher is the mutual coupling. To get the amount of mutual coupling in an array, the mutual interaction between two elements is often examined. The dielectric element spacing is kept normally from 0.5λ to 0.1λ to avoid mutual coupling in the antenna.

The mutual coupling is mostly dependent upon the shape of the DRA and the feed mechanism. The E plane coupling is stronger than H plane coupling and it decreases less quickly with increasing element separation.

Chapter 4

Designing of Disk shaped DRA

4.1 DIELECTRIC RESONATOR ANTENNA DESIGN

The summary of the design for an array DRA is shown in Figure 4.1. In simulation, two methods have been introduced such as layout design which is called Method of Moments.

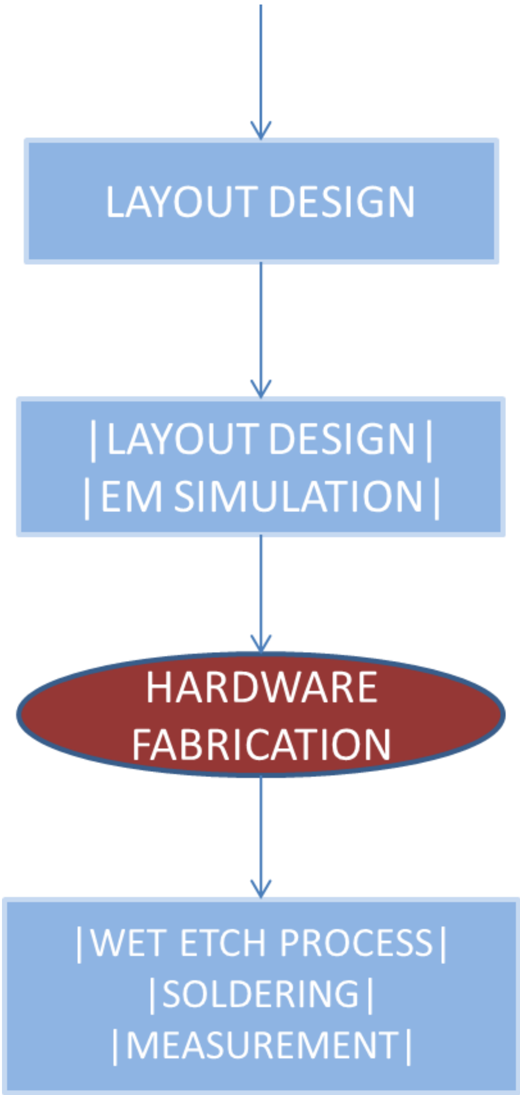


Figure 4.1: The Design Workflow

For MoM, the design was done using CST Microwave studio software. Simulated results were been analysed to obtain optimized results .The fabrication can be done on the FR-4 micro strip board with a dielectric constant (epsilon = 4.5), the thickness of substrate (h = 1.6 mm) and loss tangent (tan δ =0.019) using the wet etching technique.

Figure 4.2 shows the prototype of array DRA. The DRA is located on top of micro strip line. This procedure is simple to fabricate and also cheap, since Microstrip feed line method has been used. Both the DRA elements are coupled and the amount of coupling is based on its permittivity. The amount of coupling is directly proportional to its permittivity. But bandwidth is effected when high permittivity materials are been taken. So it is a trade of between bandwidth and coupling. The specification chart of the dielectric resonator used is shown in Table 4.1.

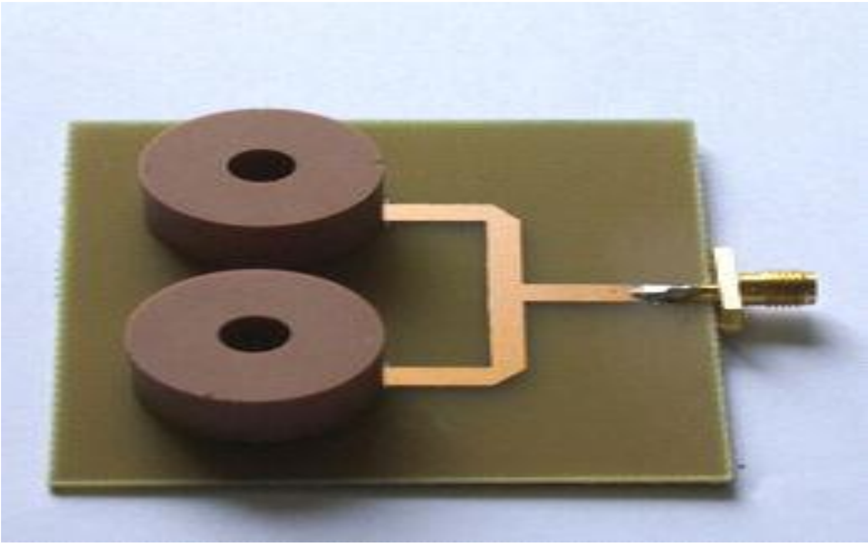


Figure 4.2: The disk shape of DRA

Table 4.1: Data of the Dielectric Resonator

Parameters	Values
Part Name	C8371-0945-438-262, Ceramic batch #QC1266470
Outer Radius R_o	12 mm
Inner Radius R_i	3.3 mm
Height of Resonator	11.1 mm
Dielectric Constant ε_r	34.73
Resonating Frequency fr	2.415 GHz

We need to define the resonating frequency of the DRA which is calculated as follows:-

$$f_r \approx \frac{c}{2\pi\sqrt{\varepsilon_r}}\sqrt{2\left(\frac{\pi}{a}\right)^2 + \left(\frac{\pi}{2b}\right)^2} \qquad (1)$$

Where,

f_r: resonant frequency of TE_{mnp}- mode

a: diameter of the dielectric resonator

b: height of the dielectric resonator

ε_r: permittivity of the dielectric

c: velocity of light

From equation (1) the resonance frequency of a dielectric resonator depends on the dimensions of the resonator and its dielectric constant. Therefore, we can see that when ε_r is increased the dimensions of the DRA elements can be subsequently decreased but cost of DRA increases when high permittivity materials are chosen.

Using the above equation and Table 1 we get the resonant frequency of the DRA as

f_r = 2.415 Ghz

- Wavelength of the dielectric resonator is an important parameter because this is used further to determine the dimensions of the microstrip circuit. The equation of the wavelength is given by:

$$\lambda = \frac{c}{f_r \sqrt{\varepsilon_r}}$$

Where

f_r - Resonant Frequency

ε_r- Dielectric constant of the Substrate

$$\lambda = 56 \text{ mm}$$

The guided wave length has been calculated for resonant frequency 2.4 GHz. This length is used to ensure that the dielectric resonator will resonate upon excitation by a magnetic field. Now, input Impedance is given by:-

$$Z_{o(\Omega)} = \frac{87}{\sqrt{\varepsilon_r + 1.41}} \ln\left[\frac{5.98H}{(0.8W + T)}\right]$$

Where

H – Length of the Microstrip (λ/4)

W- Width of the Microstrip

T- Thickness of the micro strip(0.1 mm)

Z_o - Input Impedance (50 Ω)

The parameter of the micro strip line obtained from the calculation is 3 mm for the width and 14 mm for the length of the micro strip line.

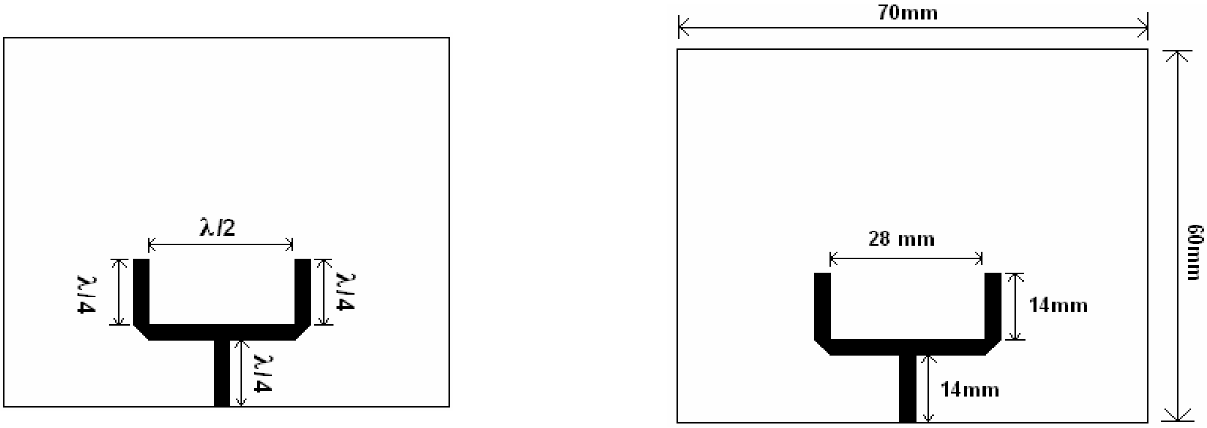


Figure 4.3: The size of the substrate

The design of an array of Dielectric Resonator Antenna is as shown above. From the Figure 4.3, the micro strip line for array is one fourth of wavelength (λ/4), which is also called as quarter wavelength , from the wavelength calculated (λ) so as to get the required resonating frequency that is 2.4 GHz. The lengths are chosen to ensure that the DRA will resonate upon excitation. That means the $f_{input}=f_r$ for resonance.

4.2 Front View Of the Design

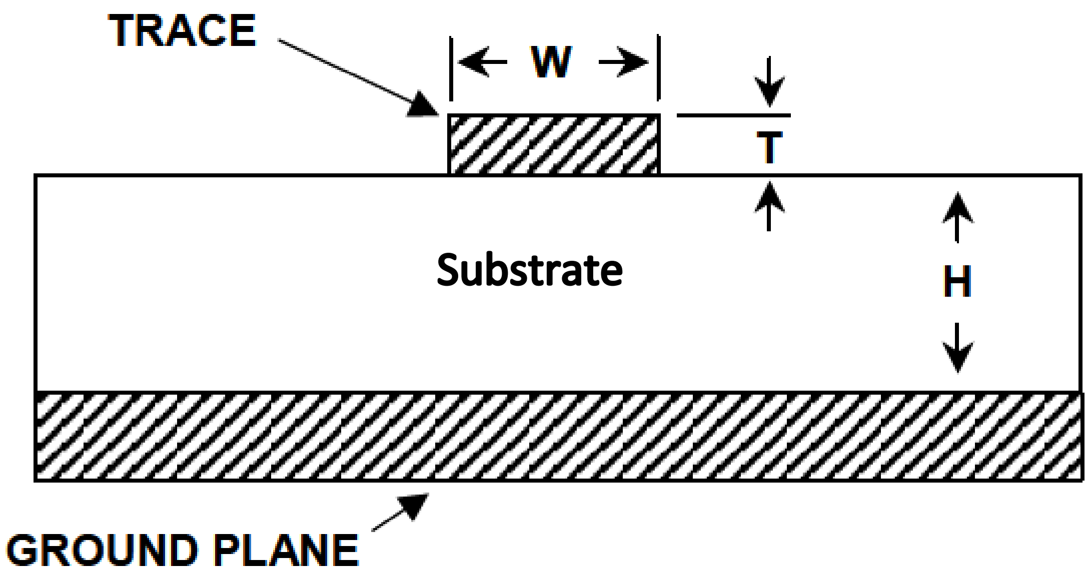


Fig 4.4: Front View Of The Design

- Width and Height of the substrate must be twice the microstrip length. So width(W) should be 70 mm and length(L) should be 60 mm along with height(H)=1.6 mm and thickness(T)=0.1 mm. Thickness of the ground plane is 0.1mm.

4.3 Calculated parameters

4.3.1 Substrate

- Dielectric Constant (ε_r) =4.5
- Width of the Substrate W_s = 70 mm
- Length of the substrate L_s= 60 mm
- Thickness of the substrate T_s = 1.6 mm

4.3.2 Microstrip Patch

- Width of the Patch W= 3mm
- Thickness of the patch T = 0.1mm

4.3.3 Dielectric Resonator

- Height H_r=11.1 mm
- Outer Radius R_o= 12 mm
- Inner Radius R_i=3.3 mm
- Dielectric Constant (ε_{rr})=34.73

4.3.4 Parameters Of Port

The designed DRA has to be fed to a power source through port and it is designed as follows:-

- The length of the port is given by:-

  L_p = 6*(Width of the Microstrip)=6*3=18mm

- Height Of the Port is given by

  H_p = 5*Thickness of the Substrate + Thickness of the ground Plane
  =5×1.6+0.1=8.1m

4.4 Design And Simulation In CST Mirowave Studio

A) Design of the DRA

B) Simulation

   a. Magnetic Field and surface current

   b. VSWR, Radiation Pattern

   c. Return Loss, Input Impedance and Admittance

Design Of the DRA Array in CST

Microstrip Patch design

$$Z_{o(\Omega)} = \frac{87}{\sqrt{\varepsilon_r + 1.41}} \ln\left[\frac{5.98H}{(0.8W + T)}\right]$$

- By taking the input impedance $Z_o = 50\ \Omega$, W= 3mm, T = 0.1mm and L=14mm

Final Design OF Array DRA In CST

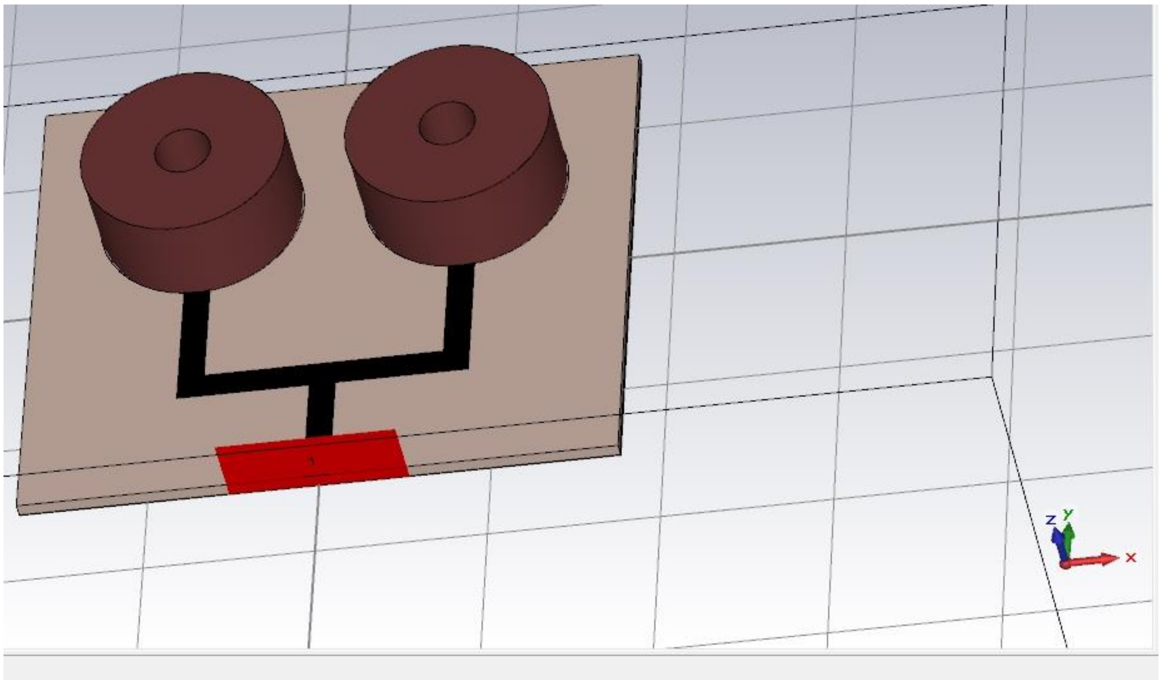


Fig 4.5: Final Design

Perspective View

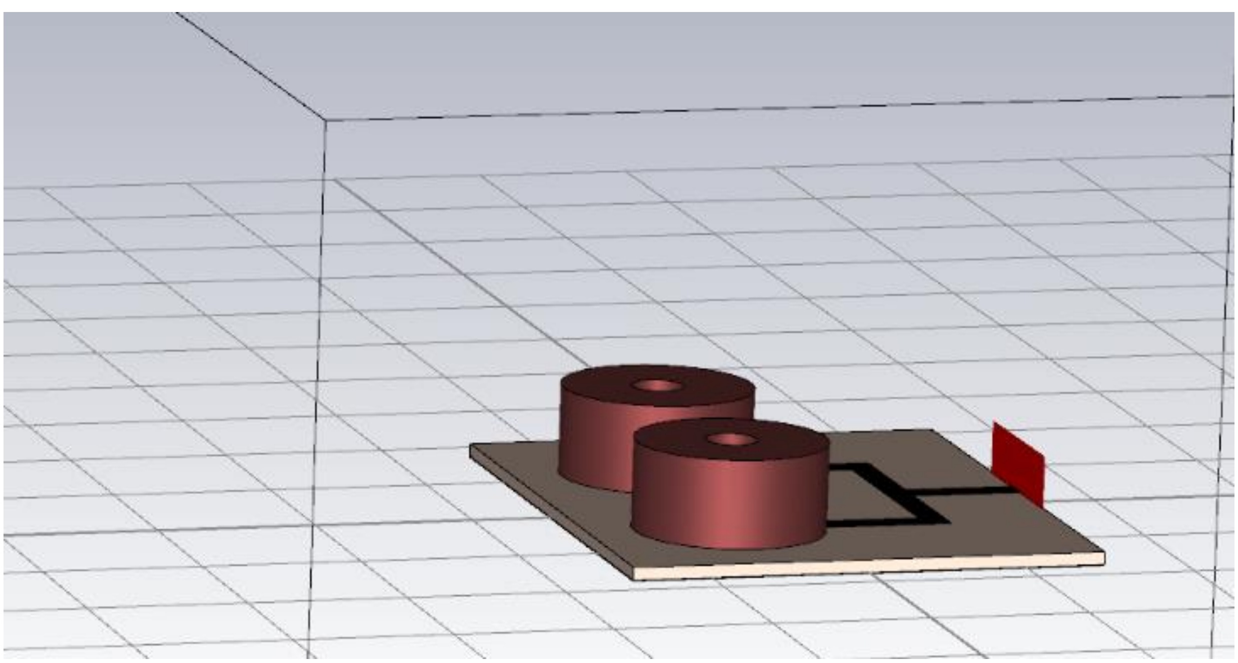


Fig 4.6: Perspective view of the design

B) Simulation

B.1 H-Field

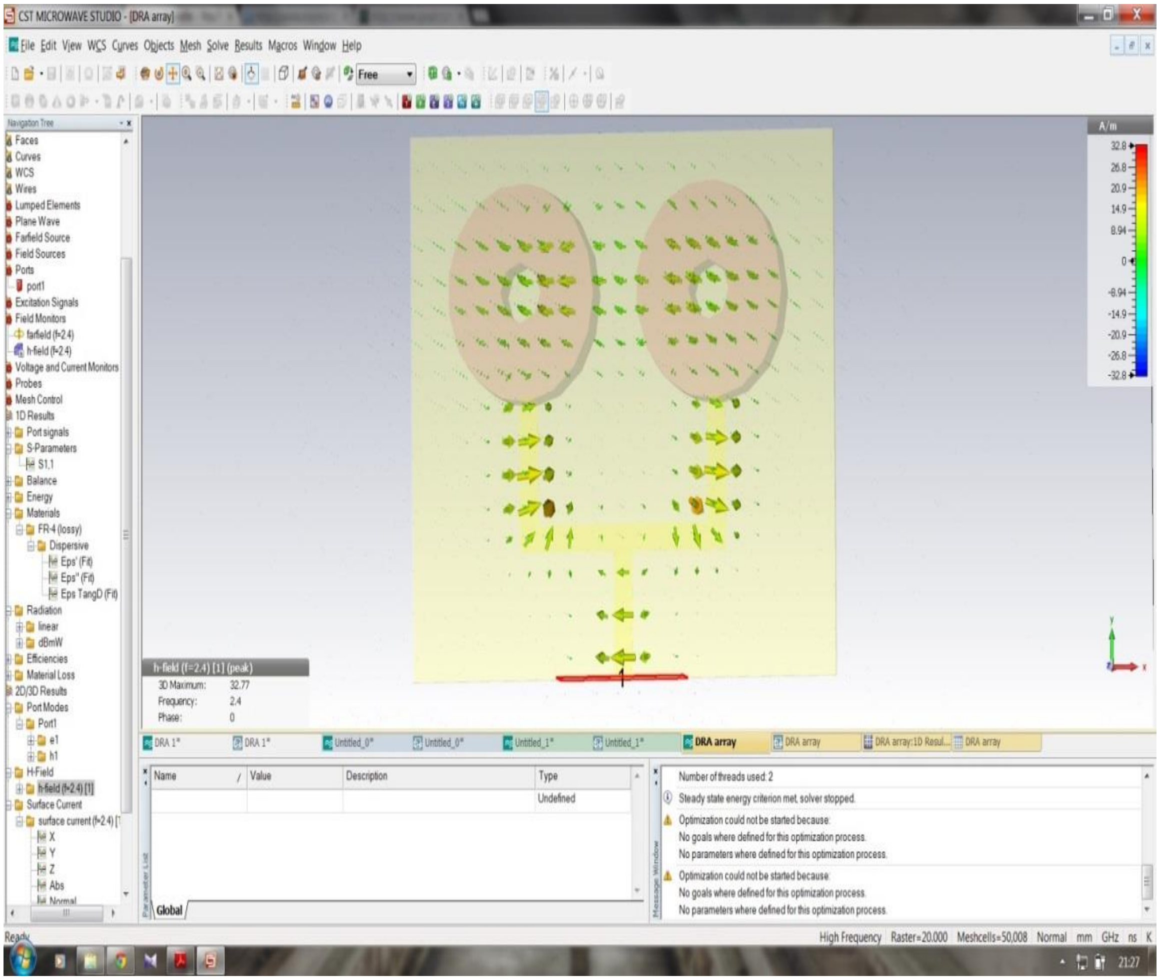


Fig4.7:H-Field

In TE mode the radial straight line going out of the resonator since we have used this in TE01 mode hence the magnetic field lines goes radially out of the resonator

B.2 Surface Current

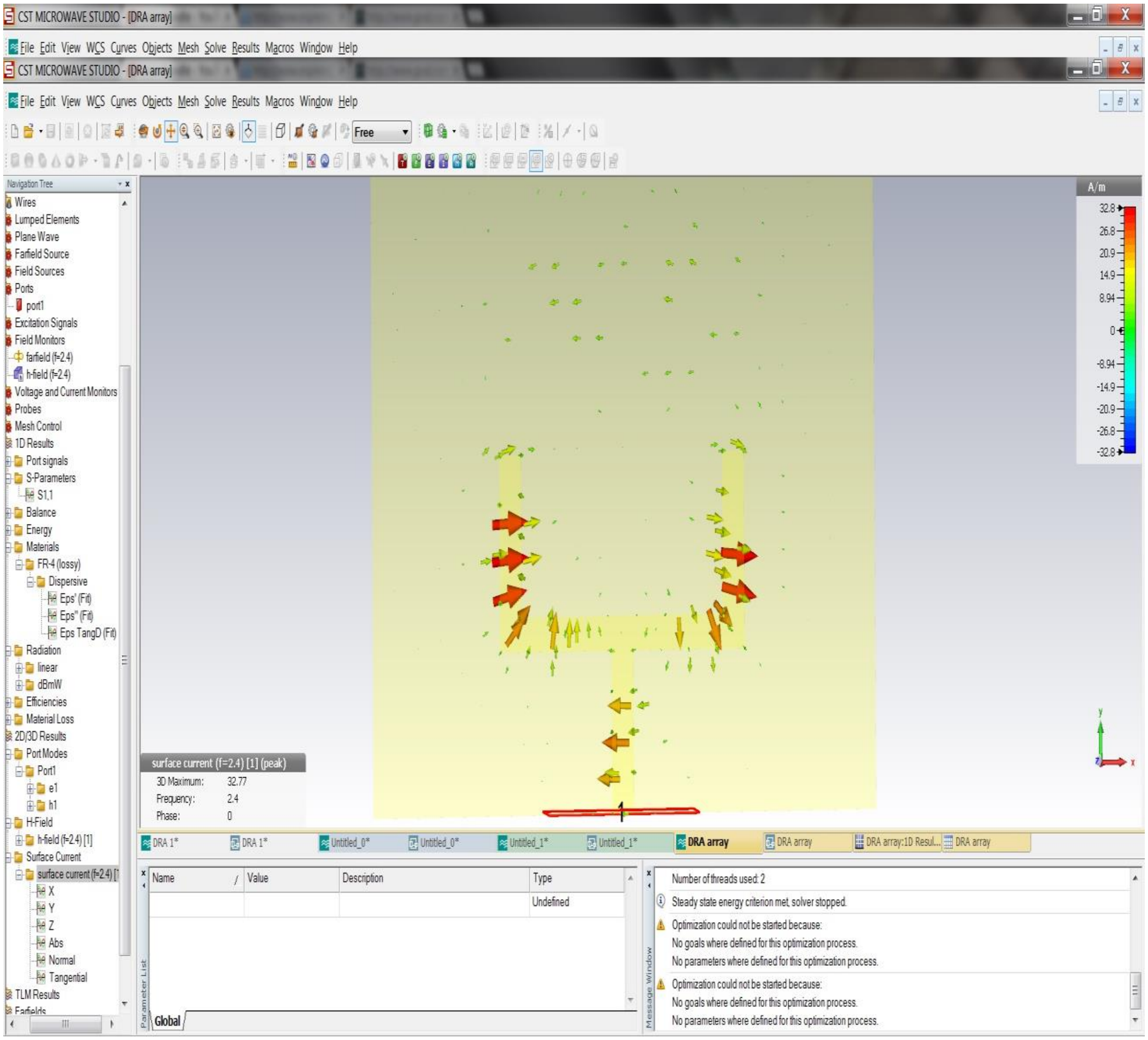


Fig 4.8 Surface Current

Surface **current** gives the value of sinusoidal current at different phases passing through the copper patch.

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B.3 Radiation Pattern

Maximum value of directivity of the design came out to be 6.578 dBi.

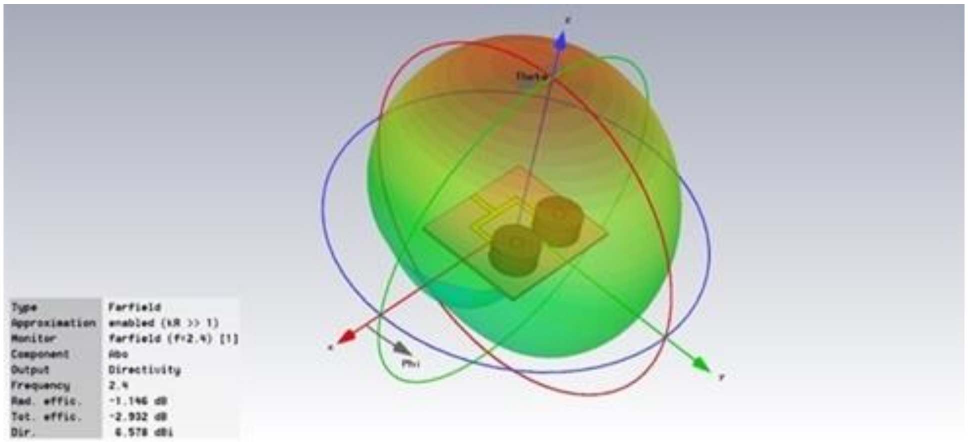


Fig 4.9 Radiation Pattern

B.4 Return Loss

Return loss=-20log|S11|.Here we have 1 port hence S11 is the only parameter. Return loss is used for single band Antenna because there is sharp deep which has crossed -10db at 2.3Ghz.

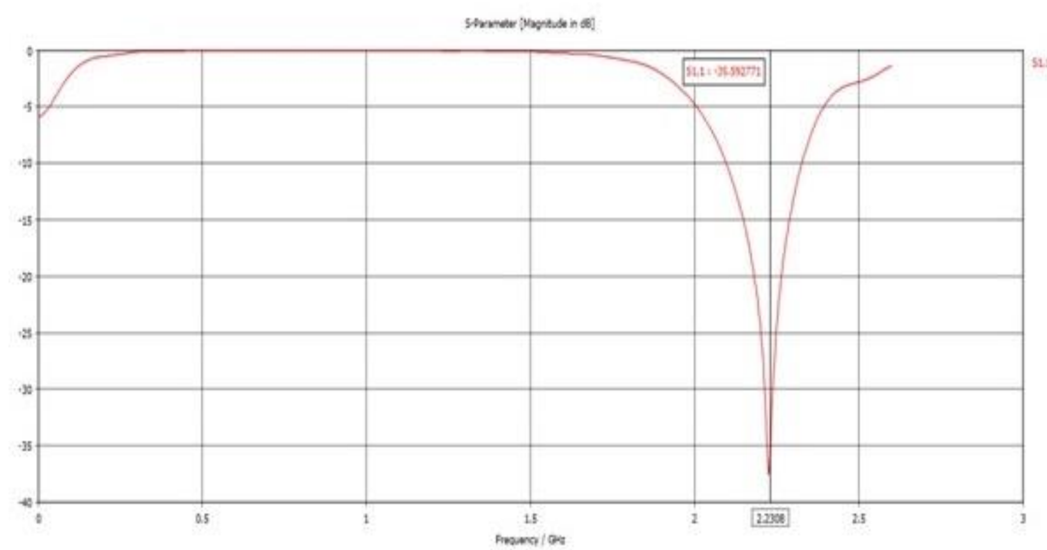


Fig 4.10 Return Loss

B.5 VSWR

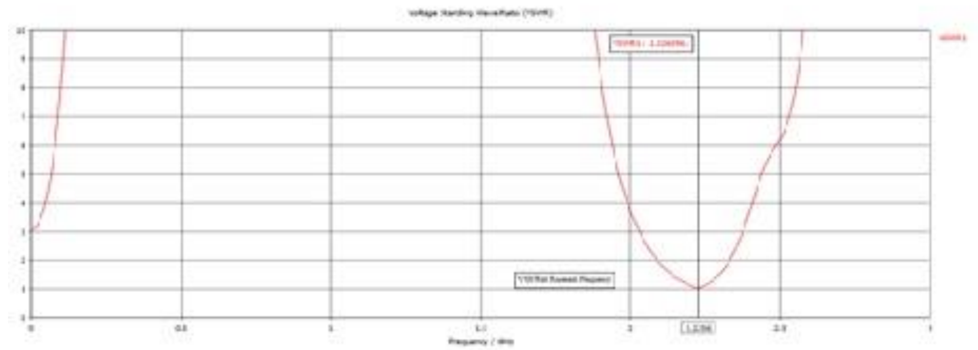


Fig 4.11 VSWR

B.6 Impedance and Polar Plot on Smith Chart

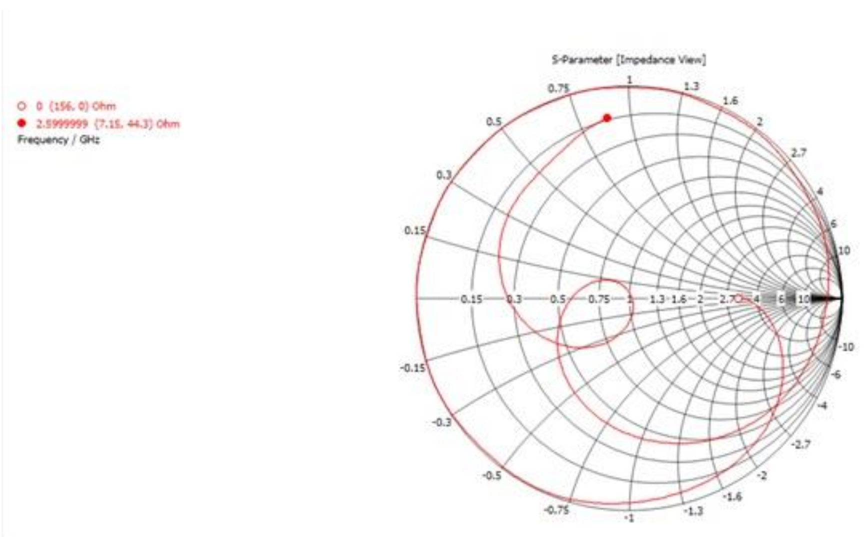


Fig 4.12 Impedance

VSWR = (1+S11) / (1-S11).

Ideally value of VSWR is 1.

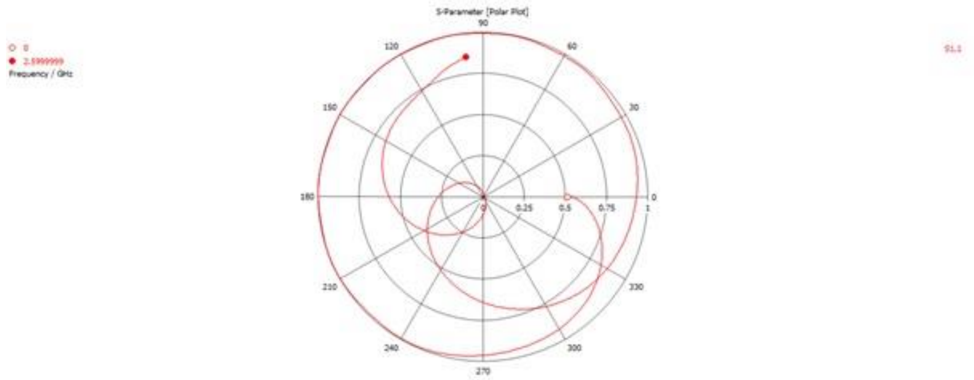


Fig 4.13 Polar Plot

0

Input Impedance is Z

Z (Real part at fr)=39.4082 Ω
Z (Imaginary part at fr)=-16.526 Ω
Z=42.733 Ω

4.5 Design discussion

If the relative permittivity of the material gets higher, both the resonant frequency(fr) and the bandwidth will go down.

The power radiates through the top surface of the DRA.

High dielectric constant ensures the size of the resonator to be small since dielectric constant is inversely proportional to the size.

4.6 CONCLUSION

The ring disk DRA was successfully implemented. The desired resonating frequency of interest is at 2.4 GHz, which is suitable for Wireless LAN application. Although the designed antennas simulation results is showing small percentage of frequency shifted from the desired frequency, radiation efficiencies of DRA are acceptable.

4.7 Results

Resonator Frequency (fr) =2.3 Ghz

VSWR at fr =1

Return loss = -37 dB

Bandwidth = 223.6 MHz

BW% = 10.07%

CHAPTER 5

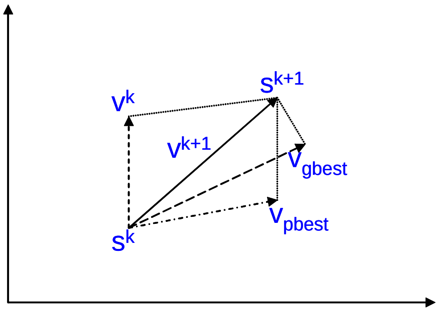
PARTICLE SWARM OPTIMIZATION

5.1 Introduction

PSO is an optimization technique based on movements of swarms or flock of birds or fish.

It uses concept of social interaction among particles in a swarm. It uses a number of particles that constitute a swarm moving in the search space looking for the best solution. The best solution of the particles is guided by the neighbourhood particles.

5.2 Concept



P_i^k : current searching point.

P_i^{k+1}: searching point for next iteration.

V_i^{k+1}: current velocity.

V_i^{k+1}: velocity for next iteration.

V_{pbest} : velocity for pbest.

V_{gbest} : velocity for gbest

$V_i^{k+1} = wV_i^k + c_1 * random() * (pbest_i - p_i^k) + c_{2*} random()\ x*(gbest - s_i^k)$ **(eq1)**

where, v_i^k : velocity of particle i at k^{th} iteration,

w: weight,

c_1 :self conjugation , c2: social conjugation

rand : uniformly distributed random number between 0 and 1,

p_i^k : current position of agent i at iteration k,

$pbest_i$: pbest of agent i,

gbest: gbest of the group.

- The following weighting function is usually utilized in (1)

w= w1-[(w1-w2) * iteration]/maxiteration **(eq2)**

where w1= initial weight,

w2 = final weight,

maxiteration = maximum iteration number,

iteration = current iteration number.

- $p_i^{k+1} = p_i^k + V_i^{k+1}$ **(eq3)**

If w is large then there is greater global search ability.
If w is small then there is greater local search ability.

5.3 Algortihm

While i=1:$n_{particles}$

$P_{initial}$=random(),$V_{initial}$=random()

While i=1:$n_{iterations}$

$FF_p=FF(p_k)$;

$FF_{pbest}=FF(p_{best})$;

If $FF_{pbest}<FF_p$, then $p_{best}=p_k$

$G_{best}=p_{best}$

Update the V_i

$P_{k+1=}p_k+V_i^{k+1}$

$V_i^k=V_i^{k+1}$

Print G_{best}

Here G_{best} is the optimal solution.

5.4 FLOWCHART

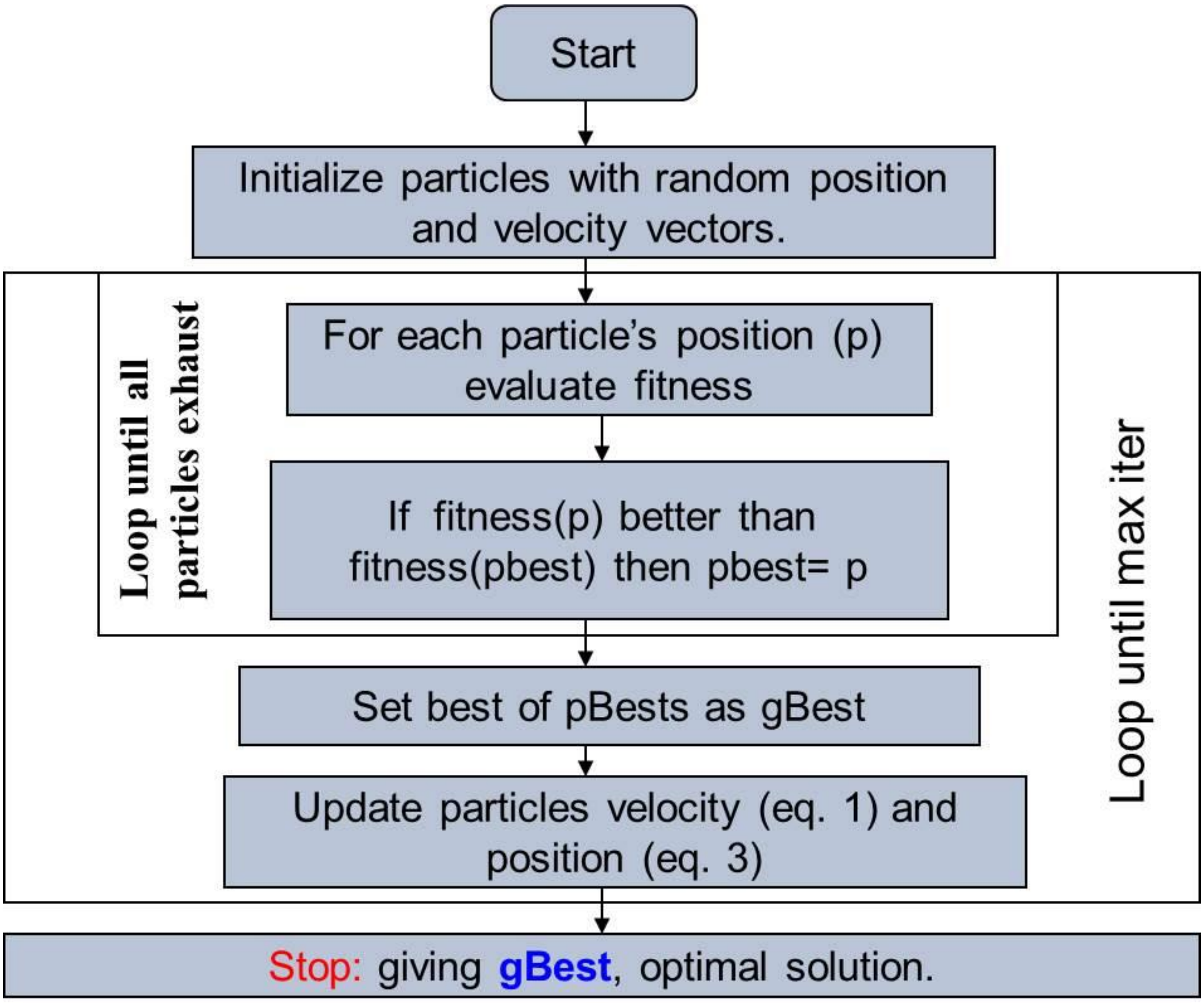


Fig 5.2 Flow Chart

5.5 Comparison with other evolutionary computation techniques.

Unlike Genetic algorithms PSO doesn't have any crossover or selection operation. Also it is controlled by weight factor(w).

5.6 Variants of PSO

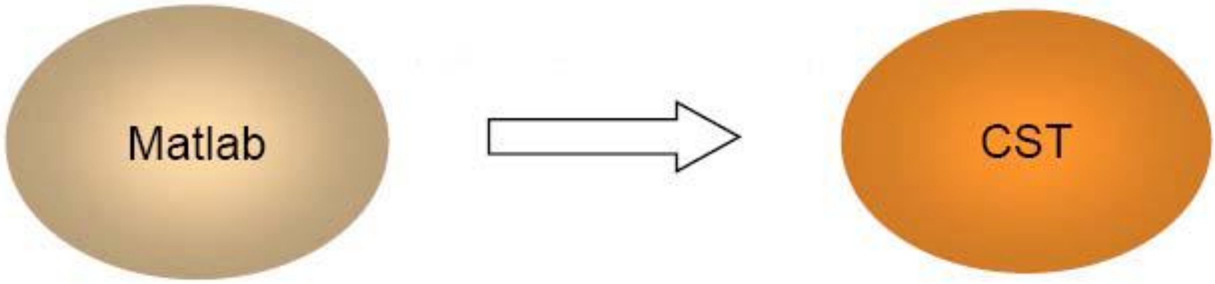
- Discrete PSO
- Gaussian PSO.
- Hybrid PSO.
- Binary PSO
- Stretching PSO

CHAPTER 6

MATLAB LINKING WITH CST

6.1 Introduction

For optimization of any DRA Array design done with the help of CST using PSO we have to first link CST with matlab. As PSO code is written in matlab and we link matlab with CST and thus we can optimize the design. Not only we have to link matlab with CST but also to the design file. We have to then the dimensions of the design programmatically with the help of matlab. The optimization is a iterative process rather an adaptive process.



6.2 Methods

There are two main ways to call CST Studio from within Matlab:

1) Launch CST from Matlab command line and use a separate VBA file to instruct CST what operations to do.

2) Run a Matlab .m file containing CST Studio commands

6.2.1. Launch CST, open an existing model, solve, save

For example, when CST_DS_Path is ProgramFiles\CSTSTUDIO SUITE 2006

and the command file name (including path) is C:\Work\Start_CST.bas

Sub Main

OpenFile("C:\work\test1.cst")

Solver.Start

Save

End Sub

6.2.2. Launch and control CST from a Matlab .m file

cst = actxserver('CSTStudio.application')

mws = invoke(cst, 'NewMWS')

here invoke is used to create an object

actxserver creates link between CSTStdio.application and matlab

To **open an existing MWS model, we can**

mws = invoke(cst, 'NewMWS')

invoke(mws, 'OpenFile', 'filename.cst');

6.2.3. Translating CST-specific VBA commands into Matlab

```
With Brick
.Reset
.Name “Brick1”
.Component “component1”
.Xrange “0”, “1”
.Yrange “0”, “1”
.Zrange “0”, “1”
.Material “Vacuum”
.Create
End With
```

translates into the following Matlab code:

```
brick = invoke(mws, 'Brick');
% create a brick in MWS
invoke(brick, 'Reset');
invoke(brick, 'Name', 'Brick1');
invoke(brick, 'Component', 'component1');
invoke(brick, 'Xrange', '0', '1');
invoke(brick, 'Yrange', '0', '1');
invoke(brick, 'Zrange', '0', '1');
invoke(brick, 'Material', 'Vacuum');
invoke(brick, 'Create');
```

Here we are creating a brick with a name and we have specified its dimensions. Similarly, we can also solve the program (invoke(mws,’Solver’)) or set the stored parameters (len1=40.00;invoke(mws, 'StoreParameter','len1',len1);) in short we can programmatically do all sort of things in CST with the help of matlab or VBA code.

We can get the s11 parameters by invoke(mws,'Result1D','d1(1)1(1)') and as we get it we can define a proper fitness function.

CHAPTER 7

OPTIMIZATION OF THE DESIGN

7.1 Introduction

In this section we'll show the algorithm needed to link matlab with CST and optimize our design. We have developed the algorithm to link with matlab. Then to simulate the design. Our design will be modified or optimized at each step we have taken a swarm of n=10 iterations till 50 and tried to optimize our design as specified above. We have varied the dimensions of the array accordingly and within a certain range. The distance between the two elements of the array should be λ/4 and height of the each element of the array should be varied between $5.6<H<18.6$.

7.2 FLOWCHART

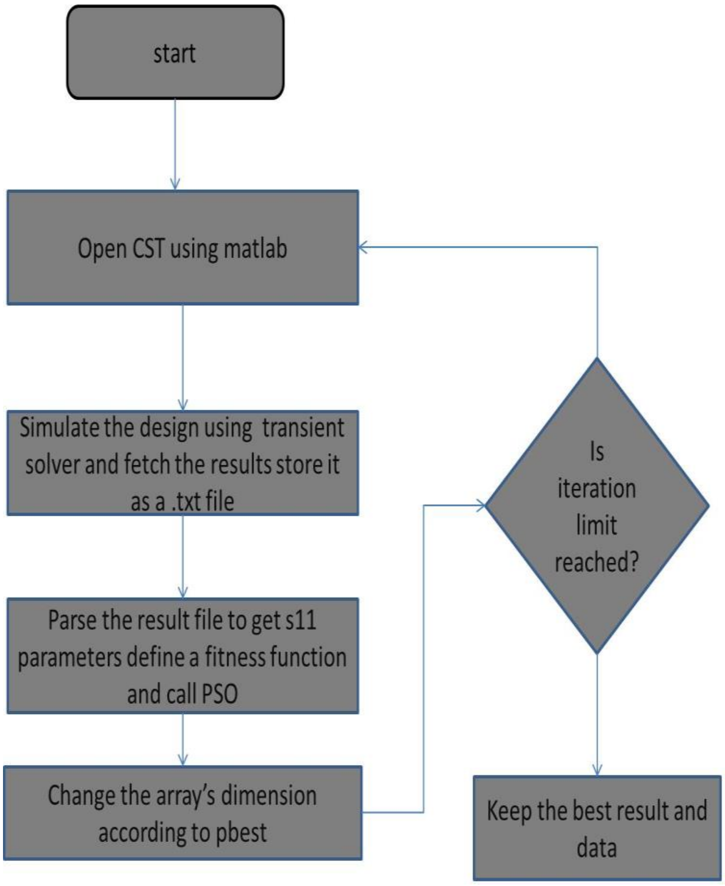


Fig 7.1 Flowchart of Optimization Algorithm

7.3 RESULTS

a. Original s11 parameters versus Optimized s11 parameters

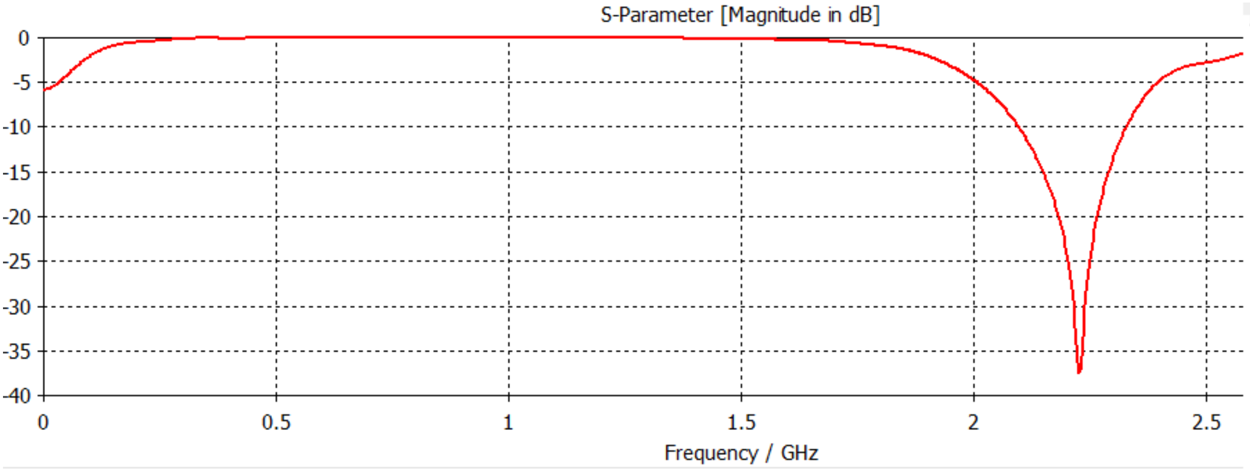


Fig 7.2 S11 parameter before Optimization

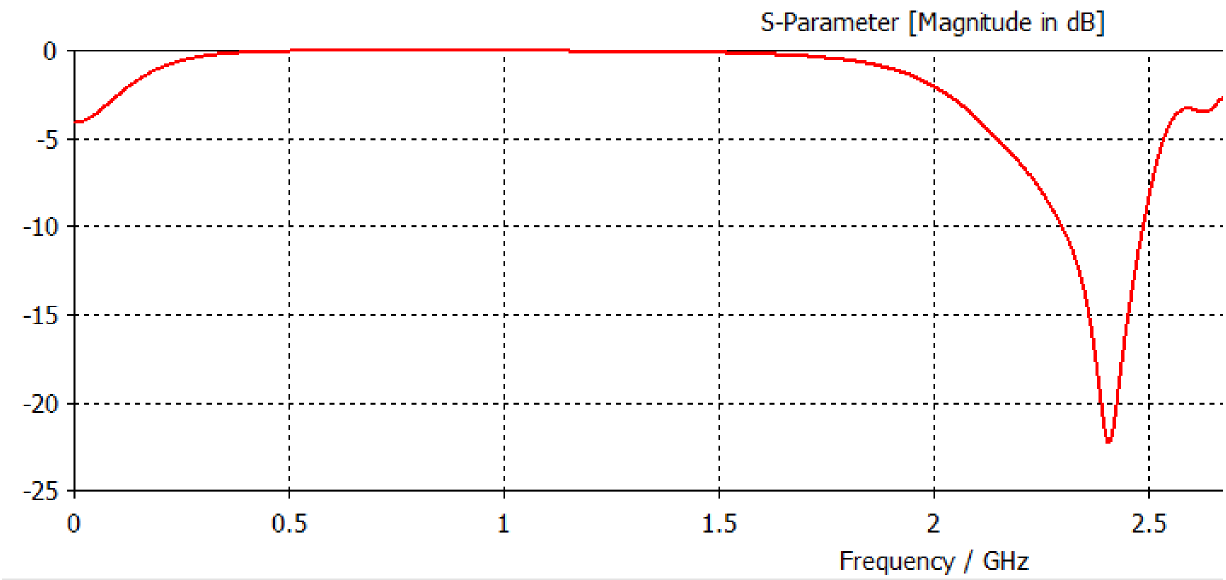


Fig 7.3 S11 Parameter after optimization

As we can see from the original s11 parameter versus frequency plot that the resonating frequency is at 2.3 GHz but in the optimized s11 parameter versus frequency plot that the resonating frequency is 2.4 GHz.

b. Original dimensions of the elements of the Disk DRA array versus optimized dimensions of the elements of the Disk DRA Array.

Parameter Name	Value(mm)	Optimized Value(mm)
Height H	11.1	9.102
Inner Radius R_i	3.3	3.3
Outer Radius R_o	12	12

Table 7.1

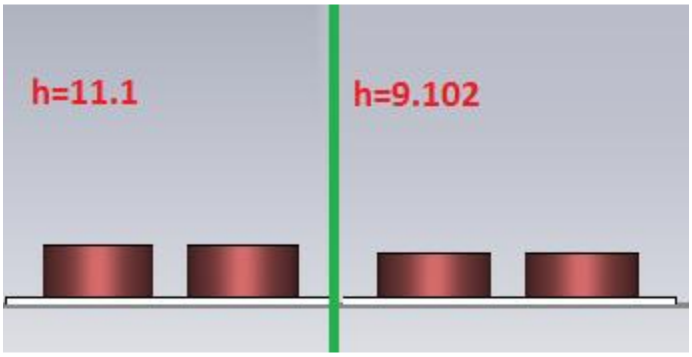


Fig.7.4 Comparison of original and optimized heights.

The optimum height of the Disk shaped resonator is found after implementation of Particle Swarm Optimisation (PSO).

C. Plot of fitness function value at each iteration versus no of iteration

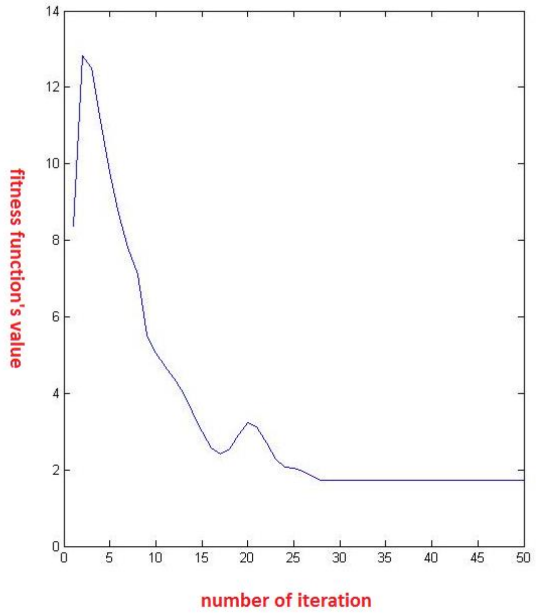


Fig 7.5 Graph between Fitness function and Number Of Iterations

Since it is a minimization problem hence the fitness function versus number of iteration is decreasing.

7.4 Conclusion

Two DRA have been designed and optimized with resonating frequency = 2.4 GHz

Before optimization simulation results provide:

s11= -35.592dBi

BW= 223.Mhz

BW= 10.07%

Resonating Frequency = 2.318Ghz

After optimization simulation results provide:

s11= -22.761dBi

BW= 113.Mhz

BW= 4.60%

Resonating Frequency= 2.4Ghz

So the **designed** and **optimized** dielectric resonator antenna can be used for wireless applications operating at the frequency bands used for IEEE 802.11b/g Wireless LANs.

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