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Conical Shaped Dielectric Resonator Antenna Using HFSS

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ABSTRACT

Here we have Designed a Conical shaped dielectric resonator (DRA) using HFSS which is radiating at two bands, Assigning the materials with two different dielectric materials are merges to have cone shaped in this design three dielectrics are used, two form the cone shape and the other one is the substrate. This structure is also exited with the microstrip feed. The dielectrics used for cone are Arlon AD 1000(tm) with dielectric constant (er1) 10.2 and Arlon Di clad 880 with dielectric constant (er2) 2.2. The substrate is economical FR4 with dielectric constant (er3) 4.4. In this the cone height is 33mm.Starting frequency set to 1Ghz and End Frequency 50Ghz we have simulated our project. From the result it can be observed that the antenna resonates at nearly 13.788GhZ which comes under X-band and it will continue up to 50Ghz.So it will work in Two bands and the antenna is useful in different applicant VSAT [very small aperture terminal].

KEYWORDS: *Dielectric Antenna, Resonator, VSAT, HFSS*

I. INTRODUCTION

A dielectric resonator antenna has a dielectric layer and a conducting layer formed on a main surface of the dielectric layer. An electrical contact is formed on the main surface for connecting the dielectric layer to a transmission line for transferring a signal between the dielectric layer and the transmission line. The electrical contact is insulated from the conducting layer. A conducting strip is connected to the electrical contact and is on a side surface of the dielectric layer. The side surface is not on the same plane of the main surface. Rather, the side surface is perpendicular to the main surface of the dielectric layer. A dielectric resonator antenna (DRA) is a radio antenna mostly used at microwave frequencies and higher, that consists of a block of ceramic material of various shapes, the dielectric resonator, mounted on a metal surface, a ground plane. Radio waves are introduced into the inside of the resonator material from the transmitter circuit and bounce back and forth between the resonator walls, forming standing waves. The walls of the resonator are partially transparent to radio waves, allowing the radio power to radiate into space.[1] An advantage of dielectric resonator antennas is they lack metal parts, which become loss at high frequencies, dissipating energy. So these antennas can have lower losses and be more efficient than metal antennas at high microwave and millimeter wave frequencies

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STRUCTURE OF PAPER

The paper is organized as follows: In Section 1, the introduction of the paper is provided along with the structure, important terms, objectives and overall description. In Section 2 we discussed literature survey. In Section 3 we discussed Basic of HFSS. In Section 4 designs is discussed. In Section 5 ALGORITHM is discussed. Section 6 gives the results and comparison. Section 7 gives the conclusion of the entire design.

OBJECTIVES

The main objective of the design A Conical shaped dielectric antenna using HFSS and To increase the efficiency of the output

II. LITERATURE SURVEY

The Dielectric Resonator Antenna was proposed by Longand al. for the first time in 1983. It has many advantages such as small size, simple excitation by classical methods of patch antennas and high efficiency due to the absence of metal losses. It also has a relatively wide frequency band and simple coupling. Several excitation modes can be obtained by changing the type and the location of the feeding line without changing the geometry or the dimensions of the DRA [1, 2]. Broadband circular polarization antenna applications include many areas such as satellite, radar, RFID and mobile telecommunications. For satellite systems, the CP is used to overcome the effects of the polarization rotation caused by the atmosphere. For radar applications, the circular polarization waves are used to get more information about targets. The CP system allows great antenna orientation flexibility in transmission mode as well as in reception mode [3]. It is a combined excitation of two degenerates and orthogonal modes. There are many methods to create a CP: a set of longitudinal slots loaded with depth in a cylindrical DRA and a coaxial probe excites the structure where the slots are properly oriented relative to the feed. This method ensures the production of two orthogonal electric field components with loading phase quadrature [4]. The excitation of a conical DRA with a simple tilt of 45° slot can produce a circular polarization [5].Several researches have been made to improve the bandwidth of a DRA as the use of stacking dielectric resonator elements. Decreasing the used permittivity or reduces the quality factor and increases in return the bandwidth. That is why we usually use a low dielectric constant for the DRA. The change of two rectangular dielectric sections in an appropriate arrangement is also used to improve the bandwidth of the DRA [6]. Many other techniques have been introduced to increase the bandwidth such as the multilayer configuration [7] and the use of a conical shape. Dielectric resonators are made of high dielectric constant materials and have been used efficiently as microwave components in filter design because of their high-quality factor. Therefore, many engineers have doubted their usefulness as radiators, thinking that they would not be efficient radiators and that they would have very small radiation bandwidth. It has been shown, however that some modes have a small radiation -factor [8]. The radiation efficiency has also been predicted experimentally for the HEM mode of a cylindrical dielectric resonator with. The radiation efficiency was found to be better than 98% [9].

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III. INTRODUCTION TO HFSS

HFSS is a high-performance full-wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device modeling that takes advantage of the familiar Microsoft Windows graphical user interface. It integrates simulation, visualization, solid modeling, and automation in an easy-to-learn environment where solutions to your 3D EM problems are quickly and accurately obtained. Ansoft HFSS employs the Finite Element Method (FEM), adaptive meshing, and brilliant graphics to give you unparalleled performance and insight to all of your 3D EM problems. Ansoft HFSS can be used to calculate parameters such as S-Parameters, Resonant Frequency, and Fields.
Typical uses include:

Package Modeling: BGA, QFP, Flip-Chip

PCB Board Modeling: Power/Ground planes, Mesh Grid Grounds, Backplanes Silicon/GaAs: Spiral Inductors, Transformers

EMC/EMI: Shield Enclosures, Coupling, Near-Field or Far-Field Radiation Antennas/Mobile Communications: Patches, Dipoles, Horns, Conformal Cell Phone Antennas, Quadrafilar Helix, Specific Absorption Rate(SAR), Infinite Arrays, Radar Cross Section(RCS), Frequency Selective Surfaces(FSS)

Connectors: Coax, SFP/XFP, Backplane, Transitions

Waveguide: Filters, Resonators, Transitions, Couplers
Filters: Cavity Filters, Microstrip Dielectric

HFSS is an interactive simulation system whose basic mesh element is a tetrahedron. This allows you to solve any arbitrary 3D geometry, especially those with complex curves and shapes, in a fraction of the time it would take using other techniques. The name HFSS stands for High Frequency Structure Simulator. Ansoff pioneered the use of the Finite Element Method (FEM) for EM simulation by developing/implementing technologies such as tangential vector finite elements, adaptive meshing, and Adaptive Lanczos- Pade Sweep (ALPS).

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Today, HFSS continues to lead the industry with innovations such as Modes-to-Nodes and Full wave Spice. Ansoft HFSS has evolved over a period of years with input from many users and industries. In industry, Ansoft HFSS is the tool of choice for high-productivity research, development, and virtual prototyping.

IV. Dielectric Resonator Antenna design

1 DRA design:

The design of DRA start with design of rectangular shaped DRA. This is ery simple and the design steps are

$$f_0 = \frac{c}{2\pi\sqrt{\epsilon_r}}\sqrt{k_x^2 + k_y^2 + k_z^2},$$

$$k_x = \frac{\pi}{a}, \qquad k_z = \frac{\pi}{2b}, \qquad \text{-------(3.1)}$$

$$d = \frac{2}{k_y}\tanh\left(\frac{k_{y0}}{k_y}\right), \quad k_{y0} = \sqrt{k_x^2 + k_z^2},$$

-------- (3.2)

Based on the relation between rectangular and circular patch connections, the final model can be obtained.

d_e = 1.30 (a b)0.625 / (a + b)0.25 ------ (3.3)

Where

d_e = equivalent diameter (mm)

a = length of major or minor side (mm)

b = length of minor or major side (mm)

The commercial design tool HFSS is used to design the final model.

Ansoft Terms:

The Ansoft HFSS window has several optional panels: A Project Manager Project Manager Project Manager which contains a design tree which lists the structure of the project. A Message Manager Message Manager Message Manager that allows you to view any errors or warnings that occur before you begin a simulation. A Property Window Property Window Property Window that displays and allows you to change model parameters or attributes. A Progress Window Progress Window Progress Window that displays solution progress. 3D Modeler Window ,3D Modeler Window ,3D Modeler Window which contains the model and model tree for the active design.

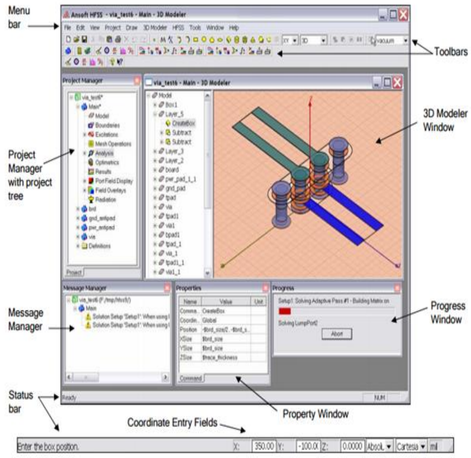

Fig1) 3D Modeler

Project Manager:

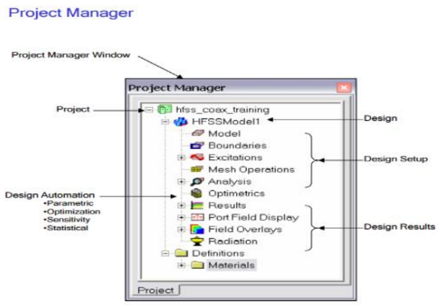

Fig 2) Project Manager

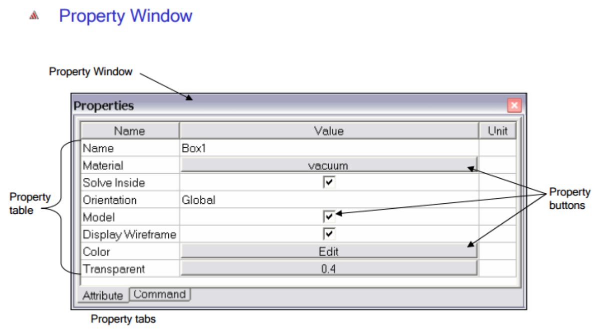

Figure 3) Property Window

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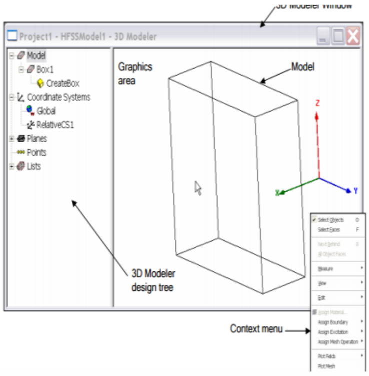
Ansoft 3D Modeler



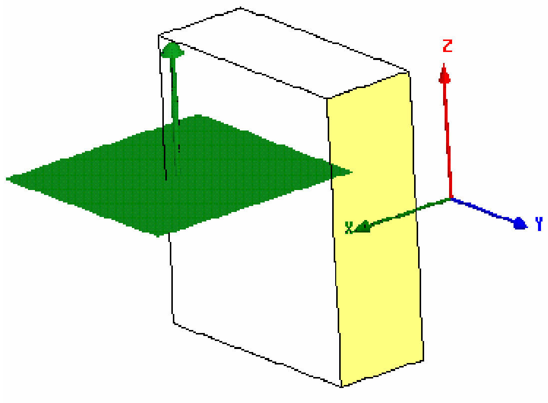


Fig 4) 3D Doppler

3D Modeler Design Tree:

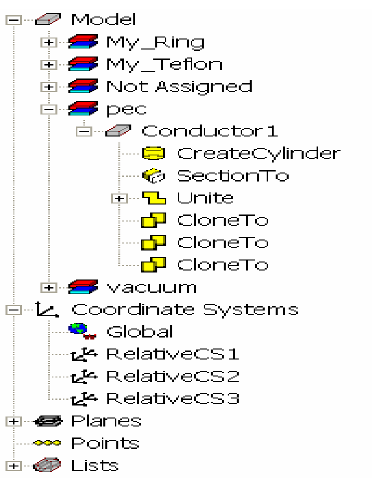


Figure 5) Design tree

Design Windows:

- In the Ansoft HFSS Desktop, each project can have multiple designs and each design is displayed in a separate window.
- You can have multiple projects and design windows open at the same time.Also, you can have multiple views of the same design visible at the same time.
- To arrange the windows, you can drag them by the title bar, and resize them by dragging a corner or border. Also, you can select one of the following menu options:

Window >Cascade, Window >Tile Vertically, or Window > Tile Horizontally

- To organize your Ansoft HFSS window, you can iconize open designs. An Icon appears in the lower part of the Ansoft HFSS window. If the icon is not visible, it may be behind another open document. Resize any open documents as necessary. Select the menu item **Window > Arrange Icons** to arrange them at the bottom of the Ansoft HFSS window.
- Select the menu item **Window > Close All** to close all open design. You are prompted to **Save** unsaved designs.

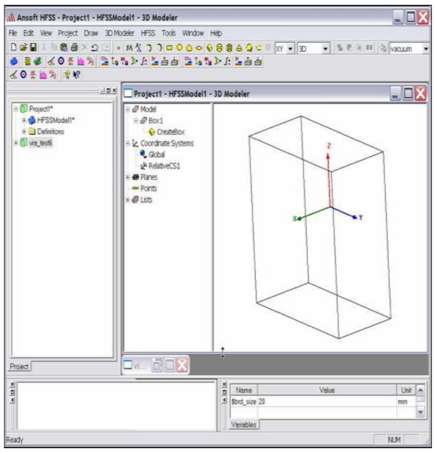


Fig 6) 3D Modeler Window

To set the solution type:

1. Select the menu item **HFSS > Solution Type**
2. Solution Type Window:
   I. Choose one of the following:
      i. **Driven Modal**
      ii. **Driven Terminal**
      iii. **Eigen mode**
   II. Click the **OK** button

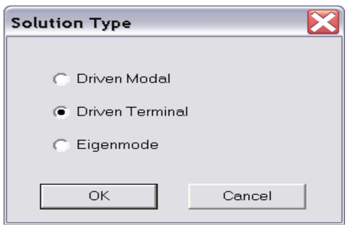


Fig. 7. Solution Type

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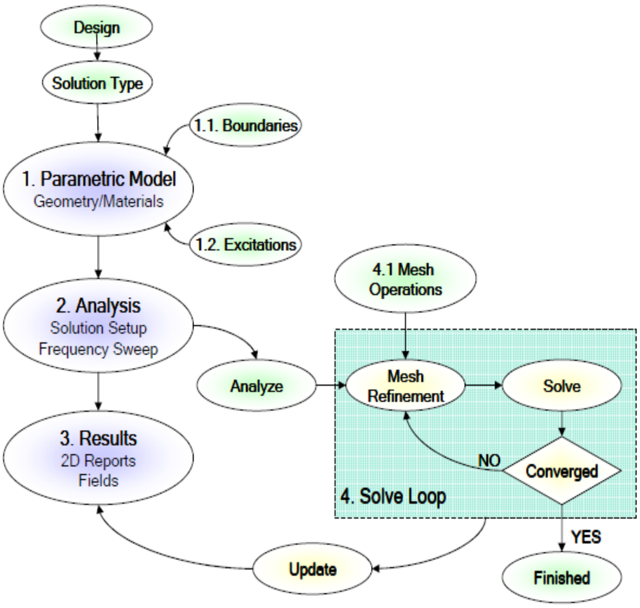

Figure 8) Ansoft HFSS Desktop

Parametric Model Creation:

The Ansoft HFSS 3D Modeler is designed for ease of use and flexibility. The power of the 3D Modeler is in its unique ability to create fully parametric designs without editing complex macros/model history.

The purpose of this chapter is to provide an overview of the 3D Modeling capabilities. By understanding the basic concepts outlined here you will be able to quickly take advantage of the full feature set offered by the 3D Parametric Modeler.

Excitations:

Ports are a unique type of boundary condition that allows energy to flow into and out of a structure. You can assign a port to any 2D object or 3D object face. Before the full three-dimensional electromagnetic field inside a structure can be calculated, it is necessary to determine the excitation field pattern at each port. **Ansoft HFSS** uses an arbitrary port solver to calculate the natural field patterns or modes that can exist inside a transmission structure with the same cross section as the port. The resulting 2D field patterns serve as boundary conditions for the full three-dimensional problem.

By default **Ansoft HFSS** assumes that all structures are completely encased in a conductive shield with no energy propagating through it. You apply **Wave Ports** to the structure to indicate the area were the energy enters and exits the conductive shield.

As an alternative to using **Wave Ports**, you can apply **Lumped Ports** to a structure instead**.** **Lumped Ports** are useful for modeling internal ports within a structure.

Wave Port:

The port solver assumes that the **Wave Port** you define is connected to a semi-infinitely long waveguide that has the same cross-section and material properties as the port. Each **Wave Port** is excited individually and each mode incident on apart contains one watt of time-averaged power. **Wave Ports** calculate characteristic impedance, complex propagation constant, and generalized S parameters.

Modes and S-Parameters:

When the Wave Ports are defined correctly, for the modes that are included in the simulation, there is a perfect matched condition at the Wave Port. Because of this, the S-Parameters for each mode and Wave Port are normalized to a frequency dependent impedance. This type of S Parameter is referred to as Generalized S-Parameter.

Laboratory measurements, such as those from a vector network analyzer, or circuit simulators use a constant reference impedance (i.e. the ports are not perfectly matched at every frequency).

To obtain results consistent with measurements or for use with circuit simulators, the generalized s-parameters calculated by **Ansoft HFSS** must be renormalized to a constant characteristic impedance. See the section on Calibrating Wave Ports for details on how to perform the renormalization.

Analysis Setup:

This chapter provides details on Analysis in the Ansoft HFSS v.10.0 software such as:

- Add Solution Setup
  - Adapt Frequency
  - Convergence Criteria
  - Initial Mesh Options
  - Adaptive Options
  - Low-Order Basis Functions
- Setup
  - Properties
  - Add Sweep
  - Sweep – Properties and Types of Sweeps

Adding a Solution Setup:

- In order to perform an Analysis in Ansoft HFSS a Solution Setup must be added.
- To do this, right click on Analysis in the Ansoft HFSS model tree.

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- By default, the General Tab will be displayed. The Solution Frequency and the
Convergence Criteria are set here.

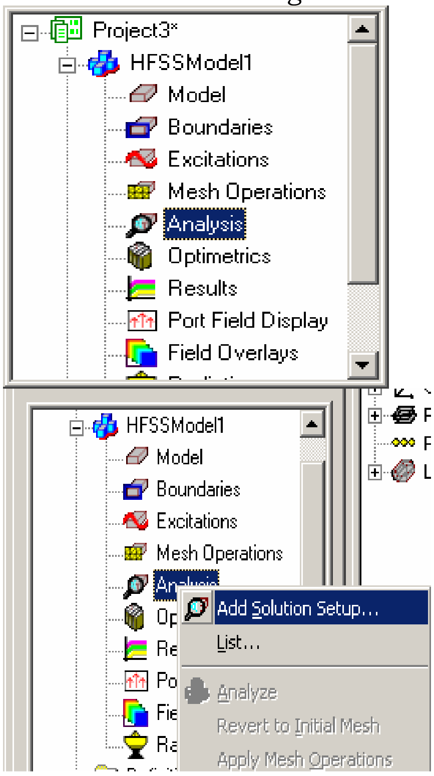


Figure 9) Analysis setup

Frequency Sweeps:
Using the converged mesh or initial mesh if no adaptive passes were requested, the swept frequency response of the device can be obtained. Ansoft HFSS provides several methods for calculating the frequency response:

- **Discrete:** performs a full solution at every frequency using the current mesh. The time required is the single frequency solve times the number of frequency points. Fields can be displayed at any frequency within the sweep range if the Save Fields Box is checked.
- **Fast:** uses an Adaptive Lanczos – Pade Sweep (ALPS) based solver to extrapolate an entire bandwidth of solution information from the center frequency. Very good for high-Q devices but it cannot be used to solve for devices that pass-through cut-off. Once the band has been extrapolated, a high number of frequency points can be calculated without a penalty. In addition, the Fields can be displayed at any frequency within the sweep range. The time and memory required to solve a fast frequency sweep may be much larger than the single frequency solve.
- **Interpolating:** performs solves at discrete frequency points that are fit by interpolating. Ansoft HFSS determines the frequency points to solve at based on the error in the interpolation between consecutive passes. The interpolation error and maximum number of points is defined by the user in the Edit Sweep. As with the fast frequency sweep, the Interpolating Sweep can generate a larger number of frequency points. But you only have the field solution for the last solved frequency. The maximum solution time is the single frequency solve times the maximum number of points.

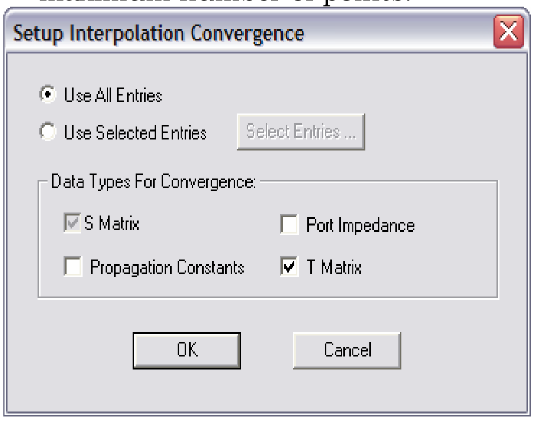


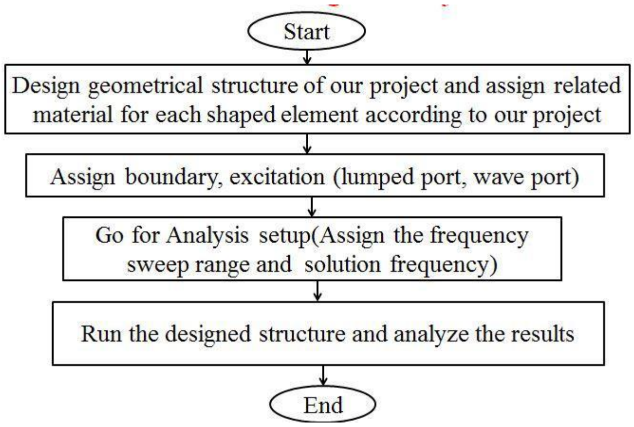
Figure 10) Setup implementation

Fig 5

V.ALGORITHM

Ansoft HFSS employs the Finite Element Method (FEM), adaptive meshing, and brilliant graphics to give you unparalleled performance and insight to all of your 3D EM problems. Ansoft HFSS can be used to calculate parameters such as S Parameters, Resonant Frequency, and Fields.

1. Flow Chart for Design a Project in HFSS



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- Fig 11) Flow Chart for Design
- The first design dimensions and top and side view are shown below,

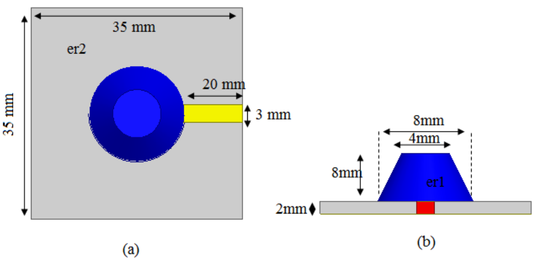
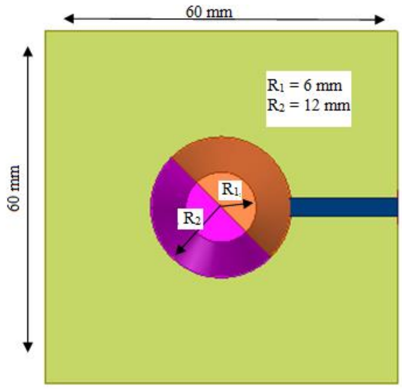
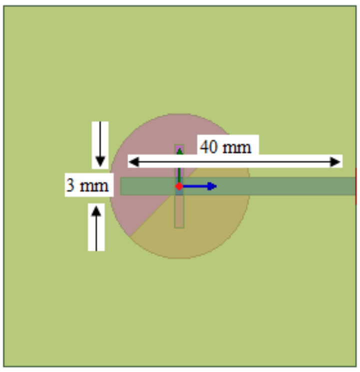


Fig 12Cone shaped DRA design 1

With Design 1 the results are not satisfactory. To improve bandwidth, instead of single ce use two different half cones. The Design2 is shown below.



Top view



Bottom view

Fig 13) Top view and bottom view of the final Design 2

The HFSS desk top view is shown below

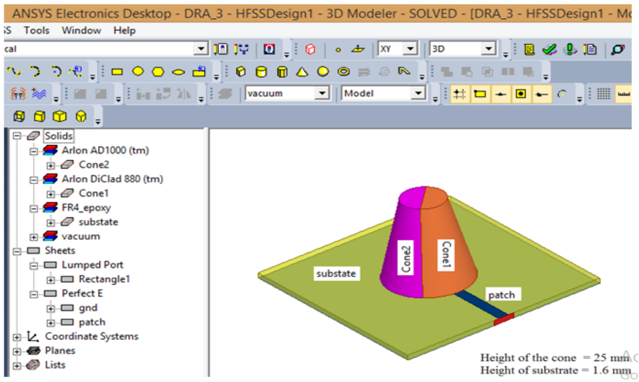
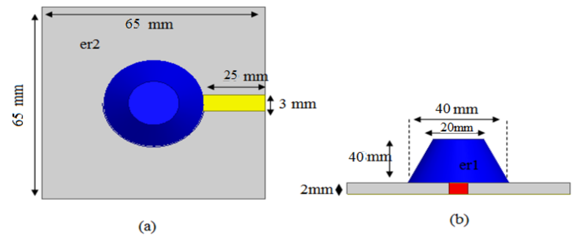


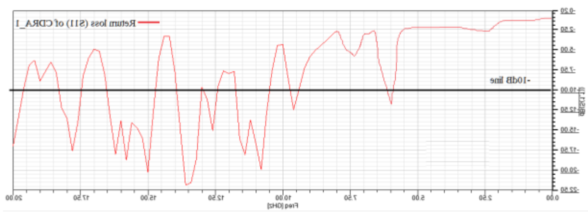
Figure 14) HFSS desktop view

VI. RESULTS AND DECLARATION

Cone shaped dielectric resonating antenna first design (CDRA_1):

The antenna dimensions and top and side view are shown in Figure 4.1. The design CRDA_1 suffers from poor return loss. The return loss (S11) 2D and 3D radiation plots are sown in the same figure. In this Arlon AD1000 (tm) with dielectric constant (er1) 10.2 used as cone over the Taconic RF-30 (tm) with dielectric constant (er2) is 3 substrate. A microstrip patch feed is used to excite the antenna.





(c)

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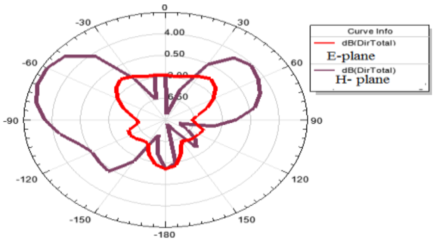
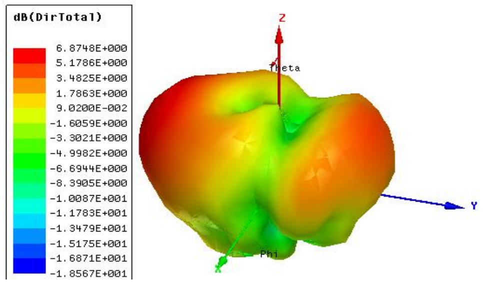
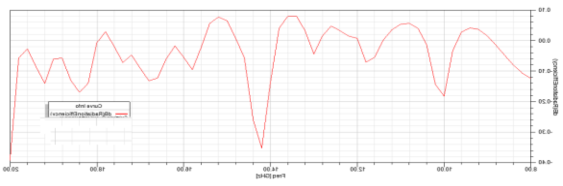


(D)



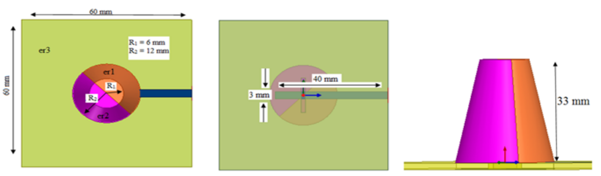
(e)



➤ (f)

Figure. 15) . Cone shaped DRA design 1(CRDA_1):
(a) Top view (b) Side view (c) Return loss (S11)
(d) E & H pane radiation patterns (e)3D-radiation pattern (f) Radiating efficiency

The second design CRDA_2 is shown in Figure 4.2. is slight modifications of the CRDA_1. In this design instead of using one dielectric cone, two different dielectric materials are merges to have cone shaped in this design three dielectrics are used, two form the code shape and the other one is the substrate. This structure is also exited with the microstrip feed. The dielectrics used for cone are Arlon AD 1000(tm) with dielectric constant (er1) 10.2 and Arlon Diclad 880 with dielectric constant (er2) 2.2. The substrate is economical FR4 with dielectric constant (er3) 4.4. The results are very much improved than CRDA_1. In this the cone height is 33 mm.



(a) (b) (c)

➤
➤
➤
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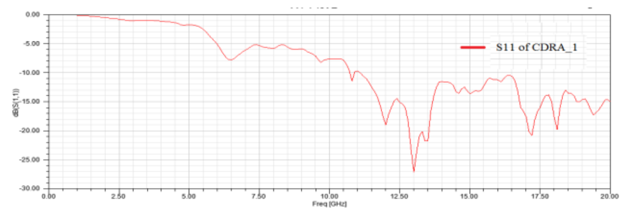

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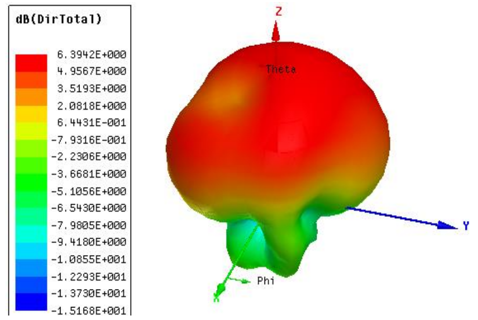
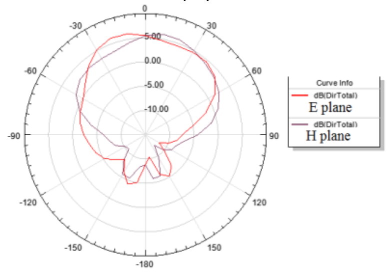
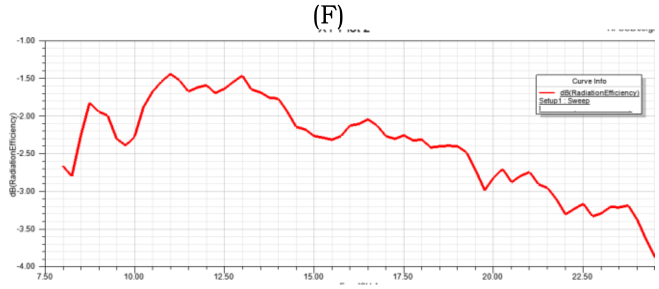


(E)



(F)



➤ (g)

Figure.16) . Cone shaped DRA design 2(CRDA_2):
(a) Top view (b) bottom View
(c) Side view (d) Return loss (S11)
(e) E & H pane radiation patterns (f) 3D radiation pattern (g) Radiating efficiency

➤

The third design CRDA_3 is shown in Figure 4.3. is slight modifications of the CRDA_2. In this design the height of the code is changed

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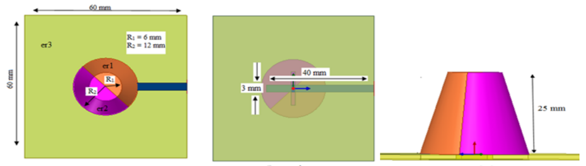
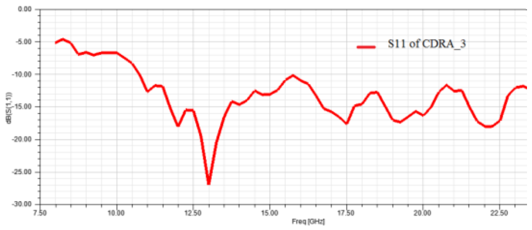
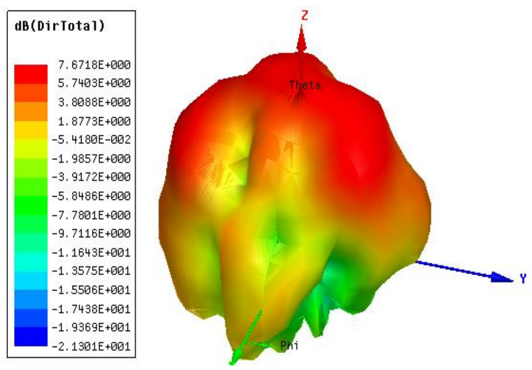
to have compactness. The new height was 25 mm. The respective simulation results are also shown in the same



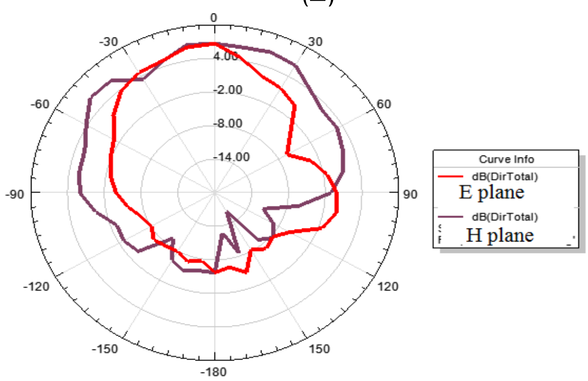
(a) (b) (c)



(d)



(E)



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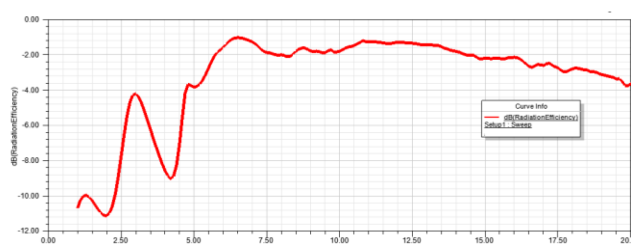

(g)

Figure.17. Cone shaped DRA design 3(CRDA_2):

(a) Top view (b) bottom View (c) Side view
(d) Return loss (S11) (e) E & H pane radiation patterns (f) 3D radiation pattern (g) Radiating efficiency

From above results, the return loss and efficiency of the CRDA_ 1 is not good. There are more fluctuations in the S11 and the efficiency is very poor. The directivity of the antenna is also low value. In CRDA_2 the return loss is improved, and all other parameters also improved. to get the compactness the height of the cone is reduced, so that there no change in the S11. But the CDRA_2 design offer better radiation characteristics and antenna efficiency.

VII. CONCLUSION

Finally, advances in the application of DRA technology at millimeter-wave frequencies have been presented, and the most recent implementation of on-chip DRAs and off-chip DRAs has been reviewed. It has been shown that DRAs realized on FR4 substrate. In this work three designs are compared. The novelty ids instead of one cone two semi cones are merged to one cone, patch feed with slot in ground is used. This improves the radiation characteristics, antenna efficiency and return loss. In this work the antenna parameters are compared by changing the height of the cone. It is noted all the simulation results, the efficiency, radiation and returns losses are improved from CRDA_1 to CRDA_3. Further the work can extend by changing other dielectric materials and shapes.

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