Design of Microstrip Antenna for Detection of Adulteration in Milk Powder

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by

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Project Report Approval for B.E.

This project report entitled ***Design of Microstrip Antenna for Detection of Adulteration in Milk Powder*** by ***Momin Adnan Anis*** is approved for the degree of ***B.E. in Electronics & Telecommunication***.

Examiners

1.---------------------------------------

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Supervisor

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Declaration

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Abstract

The proposed project is aim to design a microstrip antenna for the detection of adulteration in milk powder. A microstrip antenna resonating at frequency of 865.9MHz is designed. A direct feed coaxial feeding technique is used for feeding the microstrip antenna. The microstrip antenna is miniaturized and optimized by using miniaturization techniques namely meandering of patch and shorting of the patch with ground plane. The microstrip antenna is used as a sensor rather than for communication purpose. The non-adulterated milk powder sample which is placed on the radiating patch makes the microstrip antenna sensor to radiate at a specific resonant frequency i.e. at 865.9MHz. When the non-adulterated milk powder sample is replaced by adulterated milk powder sample the resonant frequency of antenna is shifted from 865.9MHz. The resonant frequency of the microstrip antenna sensor is inversely proportional to the dielectric constant or permittivity of the sample placed on it. Thus from the resonant frequency of the microstrip antenna it is detected whether the milk powder sample is adulterated or not.

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Chapter 1

Introduction

1.1 Background

The milk powder adulteration is a serious concern in food industry of all the countries. Many adulterants are used for the adulteration of the milk powder like melamine, urea, whey powder, etc. The adulteration level of the milk powder must be under control otherwise serious health issues can emerge. The Chinese milk scandal is one of the example of adulteration in milk powder where baby food milk powder laced with melamine made several kids and citizens of the China seriously sick in 2008.

Many techniques are used to detect the adulteration in the milk powder, some commercially available spectroscopic techniques are Near-Infrared Spectroscopy (NIRS) and Laser Induced Breakdown Spectroscopy (LIBS). In this project we proposed to use a microstrip antenna as a sensor to detect the adulteration in milk powder which is inexpensive as compared to sources and detectors used in above mentioned methods. The detection of adulteration in milk powder using microstrip antenna is an electrical method as it is based on an electrical property i.e. dielectric constant of the sample. Also the method is non-invasive, portable, cost effective and easy to use.

1.2 Introduction to Microstrip Antenna

Microstrip antenna in their simplest form consist of a conducting radiating patch on one side of the substrate and a conducting ground plane on the other side. The electromagnetic waves are radiated through radiating patch to which electrical signal is feed. The top view and side view of rectangular microstrip antenna is shown in Figure1.1. The top layer is conducting patch and the bottom layer is conducting ground plane. In middle there is a substrate with permittivity or dielectric constant ε_r. The microstrip antenna radiates at a particular resonant frequency and has narrow bandwidth. Due to its size, weight, ease of manufacturing it is used in various fields such as aerospace, defence, telecommunication, etc. Besides communication, recent researches shows that the microstrip antennas can also be used as a sensor for detection of temperature, strain, dielectric, etc.

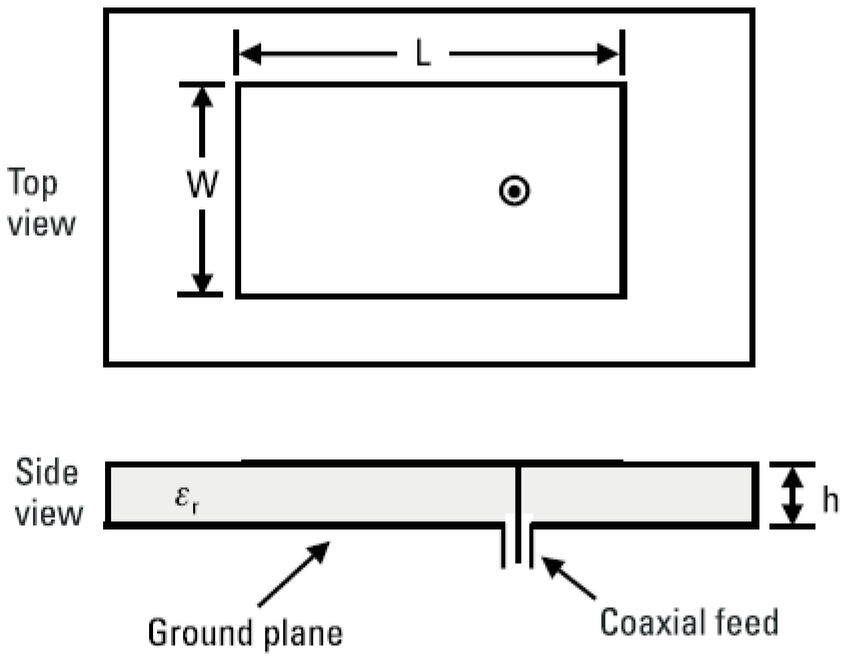


Figure1.1 *Microstrip Antenna*

1.2.1 Types of Microstrip Antenna

Microstrip antennas has different shapes of patch, most commonly used patch is rectangular. Circular and triangular patches also used widely. Microstrip antennas can be classified according to the shape of their patch. Different shapes of microstrip patches is shown in Figure1.2.

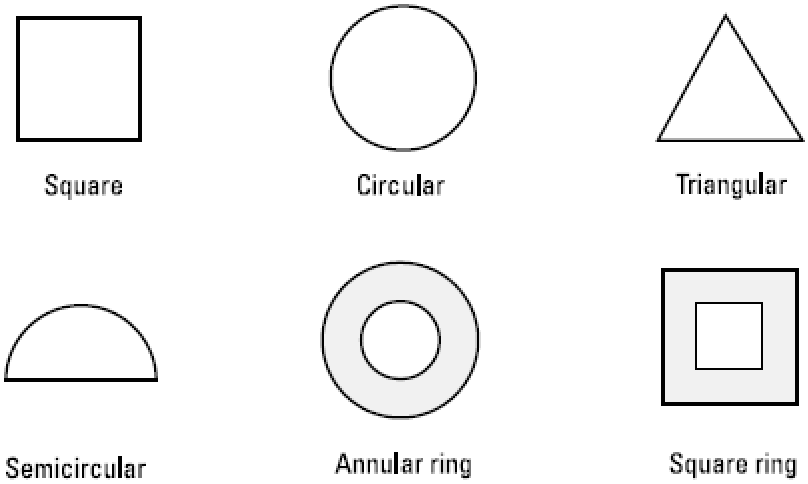


Figure1.2 *Different shapes of patches*

When the patch of microstrip antenna is shorted to the ground plane it size reduces to 50%. Now the microstrip antenna becomes Planer Inverted-F Antenna (PIFA). PIFA is used in mobile phones because of its compactness. The Planer Inverted-F Antenna (PIFA) are printed Inverted-F Antenna which monopole antenna running parallel to ground and shorted to ground at the end. It is a quarter wavelength shorted patch with limited ground plane and dielectric substrate in between. The PIFA design is shown in Figure1.3.

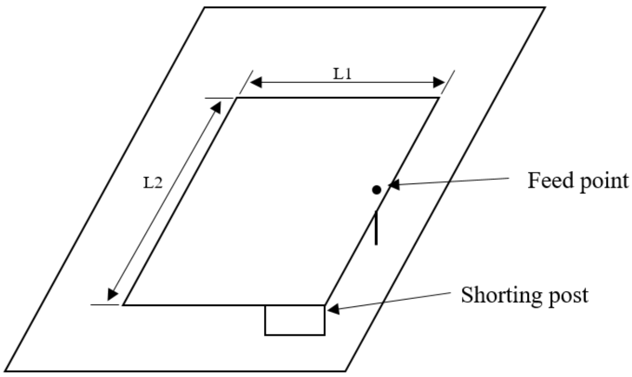


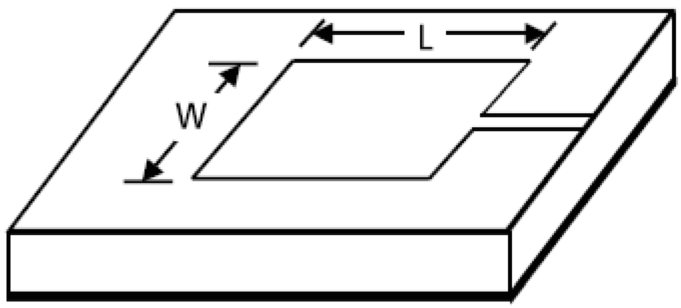
Figure1.3 *PIFA*

1.2.2 Feeding Techniques

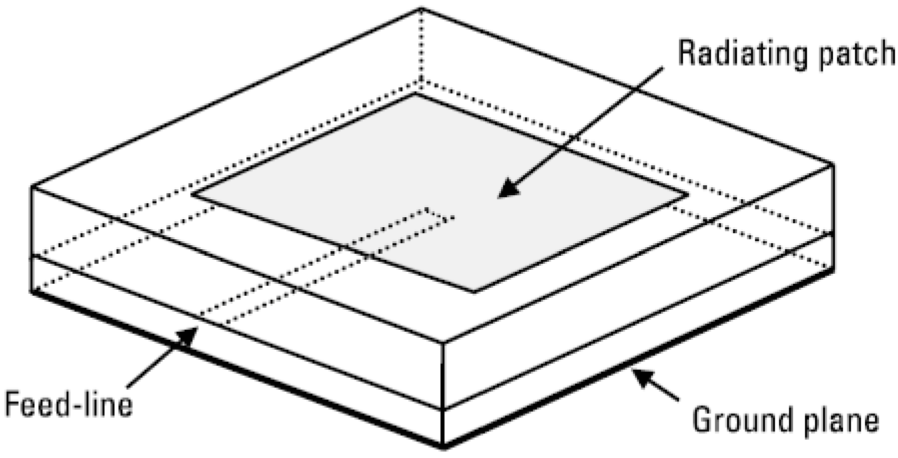
The MSA can be excited directly either by a coaxial probe or by a microstrip line. It can also be excited indirectly using electromagnetic coupling or aperture coupling and a coplanar waveguide feed, in which case there is no direct metallic contact between the feed line and the patch. Feeding technique influences the input impedance and characteristics of the antenna, and is an important design parameter.

The coaxial or probe feed arrangement is shown in Figure1.1. The centre conductor of the coaxial connector is soldered to the patch. The main advantage of this feed is that it can be placed at any desired location inside the patch to match with its input impedance. The disadvantages are that the hole has to be drilled in the substrate and that the connector protrudes outside the bottom ground plane, so that it is not completely planar. Also, this feeding arrangement makes the configuration asymmetrical.

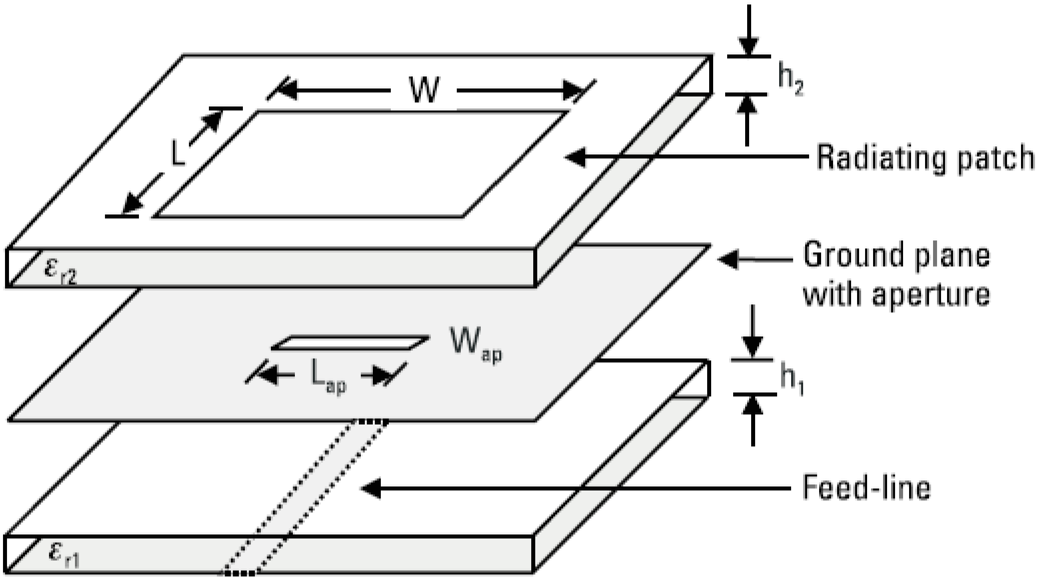
A patch excited by microstrip line feed is shown in Figure 1.4(a). This feed arrangement has the advantage that it can be etched on the same substrate, so the total structure remains planar. The drawback is the radiation from the feed line, which leads to an increase in the cross-polar level. Also, in the millimeter-wave range, the size of the feed line is comparable to the patch size, leading to increased undesired radiation.



(a)



(b)



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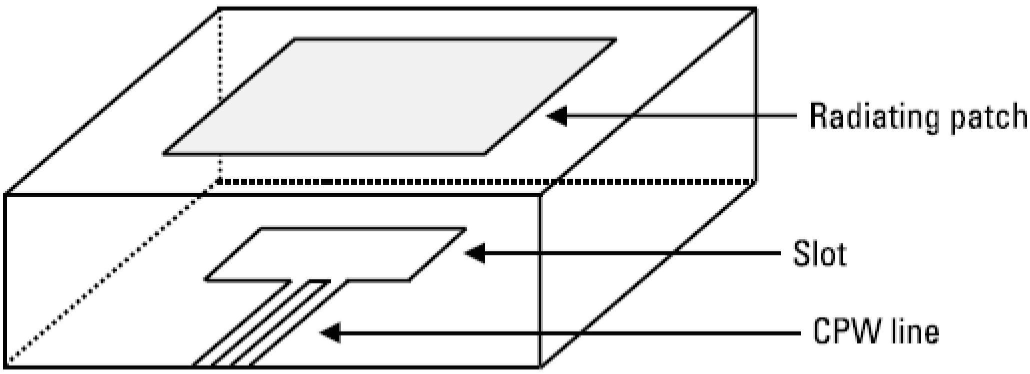


(d)

Figure1.4 *Rectangular MSA fed by (a) microstrip line, (b) electromagnetic coupling, (c) aperture coupling, and (d) coplanar waveguide (CPW).*

For thick substrates, which are generally employed to achieve broad BW, both the above methods of direct feeding the MSA have problems. In the case of a coaxial feed, increased probe length makes the input impedance more inductive, leading to the matching problem. For the microstrip feed, an increase in the substrate thickness increases its width, which in turn increases the undesired feed radiation. The indirect feed, discussed below, solves these problems. An electromagnetically coupled RMSA is shown in Figure 1.4(b). The electromagnetic coupling is also known as proximity coupling. The feed line is placed between the patch and the ground plane, which is separated by two dielectric media. The advantages of this feed configuration include the elimination of spurious feed-network radiation; the choice between two different dielectric media, one for the patch and the other for the feed line to optimize the individual performances; and an increase in the BW due to the increase in the overall substrate thickness of the MSA. The disadvantages are that the two layers need to be aligned properly and that the overall thickness of the antenna increases.

Another method for indirectly exciting a patch employs aperture coupling. In the aperture-coupled MSA configuration, the field is coupled from the microstrip line feed to the radiating patch through an electrically small aperture or slot cut in the ground plane, as shown in Figure 1.4(c). The coupling aperture is usually centered under the patch, leading to lower cross-polarization due to symmetry of the configuration. The shape, size, and location of the aperture decide the amount of coupling from the feed line to the patch. The slot aperture can be either resonant or nonresonant. The resonant slot provides another resonance in addition to the patch resonance thereby increasing the BW at the expense of an increase in back radiation. As a result, a non-resonant aperture is normally used. The performance is relatively insensitive to small errors in the alignment of the different layers. Similar to the electromagnetic coupling method, the substrate parameters of the two layers can be chosen separately for optimum antenna performance. This feeding method gives increased BW.

The coplanar waveguide feed, shown in Figure 1.3(d), has also been used to excite the MSA. In this method, the coplanar waveguide is etched on the ground plane of the MSA. The line is excited by a coaxial feed and is terminated by a slot, whose length is chosen to be between 0.25 and 0.29 of the slot wavelength. The main disadvantage of this method is the high radiation from the rather longer slot, leading to the poor front-to-back ratio. The front-to-back ratio is improved by reducing the slot dimension and modifying its shape in the form of a loop.

1.2.3 Miniaturization of Microstrip Antenna

There are many techniques for the miniaturization of microstrip antenna which is used to reduce the size of the antenna. Some of them are shortening of the radiating patch with ground plane, meandering of patch, making slots on the patch, defective ground plane, use of meta material, etc. As this project uses to miniaturization techniques among these i.e. use of shortening of patch with ground plane and meandering of patch, some details of these techniques are given below.

Miniaturization using Shorting Post

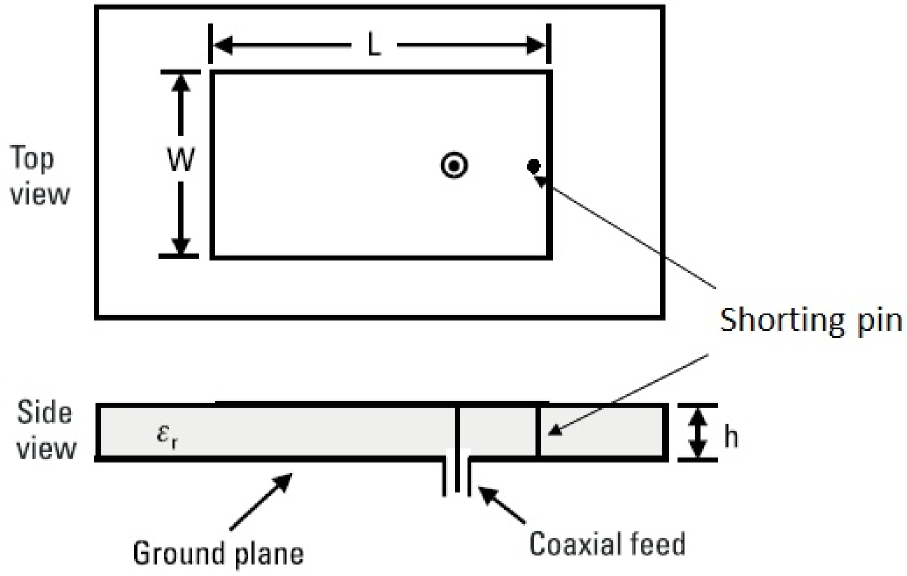


Figure1.5 *Miniaturization with shorting pin*

The size of the microstrip antenna can be reduced by shorting thr radiating patch of the antenna which is the top layer with the ground plane. The patch is shorted to ground plane either by shorting pin or a plane. Series of shorting pins are also used. By implementing shorting post the size of the microstrip antenna is reduced upto 50%.

When the microstrip antenna uses coaxial feeding technique and it is miniaturized by using shorting plane or post between the patch and ground plane it becomes PIFA (Planer Inverted-F Antenna). As this project also uses the coaxial feed technique and shorting post the microstrip antenna used in the project had taken the form of PIFA (Planer Inverted-F Antenna).

Miniaturization by Meandering of Patch

The microstrip antenna can be miniaturized by meandering the radiating patch i.e. the top layer of the microstrip antenna. Meandering of the radiating patch increases the length of the antenna thus also increases the inductivity of the antenna which can be perceive by the formula,

$$f = X_L / 2\pi L$$

Thus with the increase in inductance the frequency of the microstrip antenna decreases and it is possible to reduce the size of the microstrip antenna by maintaining the required resonant frequency.

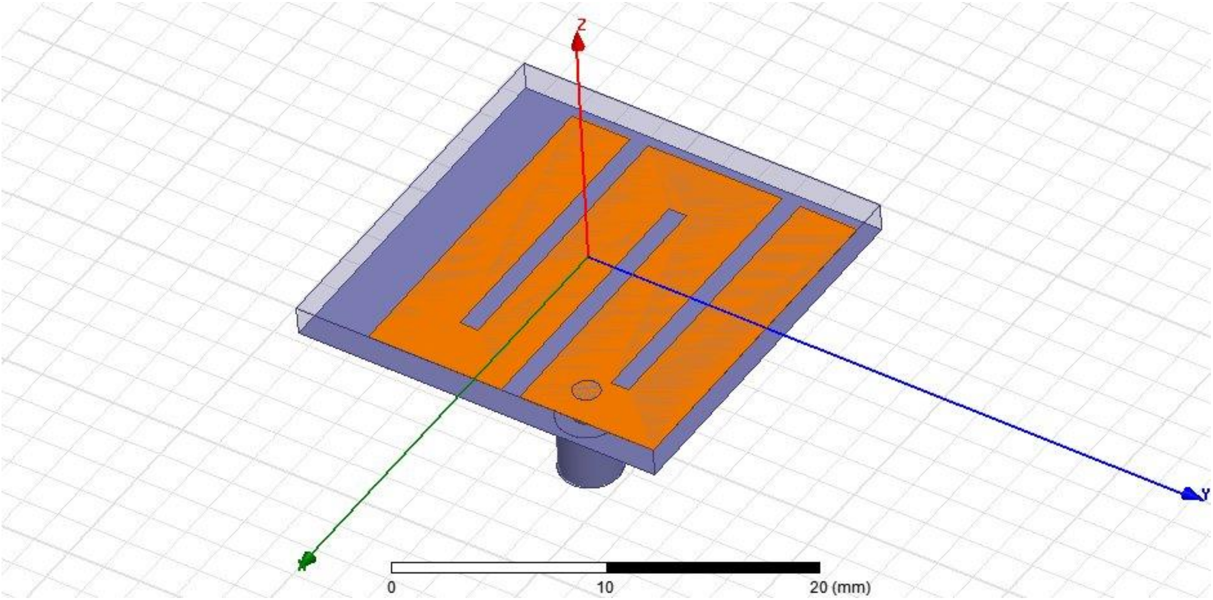


Figure1.6 *Miniaturization by Meandering of Patch*

1.3 Basic Phenomenon

The microstrip antennas has a specific resonant frequency on which it radiates efficiently. Also it has narrow bandwidth. The resonant frequency of the microstrip antenna depend upon several factors such as its dimensions, permittivity of dielectric substrate, permittivity of superstrate, and temperature. Thus the resonant frequency is effected when any of the above mention parameters are changed. In this project the change in the permittivity of superstrate material is being used.

Every matter has its dielectric constant also known as the permittivity of that material. Thus milk powder also has the dielectric constant which is about 1.9. When the milk powder is adulterated its dielectric constant is changed. So non-adulterated milk powder has a specific permittivity which is being changed when it is adulterated.

So if we place the milk powder on the microstrip antenna it will work as a superstrate. Now the adulteration of the milk powder causes its dielectric constant to change which in turn effects the resonant frequency of the antenna. Thus the adulteration of milk powder changes the resonant frequency of the antenna and we can detect whether the milk powder placed on the microstrip antenna is adulterated or not.

The aim of this project is to only detect whether the milk powder sample is adulterated or not from the resonant frequency of microstrip antenna. Due to limitation of time, resources and skill it is not aimed to explore the amount of adulteration or the details of adulteration.

In this project effort is made to design the microstrip antenna as small as possible and feasible by using various miniaturization techniques. So that the microstrip antenna would be good enough to hold milk powder. Also provide good S11 parameter with small size thus cost effective and more portable.

Chapter 2

Review of Literature

2.1 Review on Adulteration of Milk Powder and NIRS (Near Infrared Spectroscopy)

Introduction

An application note by Ben Perston & Rob Packer, *"DairyGuard: Augmenting Nutritional Testing of Milk Powder with Adulterant Screening"*, published by PerkinElmer Inc. Shelton, CT, 2013. Gives information regarding the adulterants used in milk powder and the frauds taking place for economically motivated adulteration. It explains the method known as Near Infrared Spectroscopy (NIRS) for qualitative identification of adulteration in milk powder by adulterant screening.

Adulteration in Milk Powder

The application note in introduction provide information on importance of control on milk powder adulteration and economically motivated adulteration. As Milk powder is one of the most widely traded food commodities, with over 2.5 million metric tons exported annually, and is used in a huge array of food products, from infant formula to baked goods and confectionary. Unfortunately, dairy products are also a frequent target of food fraud, with 137 cases of economically motivated adulteration worldwide recorded by the United States Pharmacopoeia in 2011-20122. The value of milk powder is linked to its protein content, and standard methods for protein analysis rely on a simple nitrogen assay, with the protein concentration inferred from the nitrogen content. Consequently, the addition of chemicals rich in nitrogen can artificially increase the apparent protein and thus the price demanded.

These known incidences of economically motivated adulteration have led to strict limits on melamine content. For example, the U.S. FDA states that melamine or cyanuric acid should not be present in foods at levels greater than 2.5 ppm, or 1 ppm for infant formula. Establishing the absence of these materials above such levels requires highly sensitive techniques such as LC/MS/MS. While it is important to have laboratory methods with the highest possible sensitivity, often such methods are comparatively expensive and time-consuming to run and this may limit their ability to obtain representative samples. Moreover, there are two additional concerns that are specific to economically motivated adulteration. The first is that ppm-level adulteration is not economically worthwhile, so genuinely adulterated samples are likely to have higher concentrations. For example, to increase the total nitrogen in skim milk powder by 0.16% (corresponding to an apparent protein increase of 1% total mass), it is necessary to add 2400 ppm of melamine. Second, and more troubling, is that while there are published cases of adulteration with melamine, "chemical space" is vast and there are many more high-nitrogen compounds that could potentially be used in the same way5. To stay ahead of the criminals, it's important to look beyond currently known adulterants and consider other possibilities. Adulteration of food and food ingredients for economic gain is an old practice and, sadly, one that is unlikely to be eliminated in the near future. This problem needs to be tackled with all the analytical techniques at our disposal: NIR spectroscopy clearly has a role to play, given its ubiquity in raw materials testing.

Conclusion

The application note attracts our minds towards economically motivated adulteration of milk powder and towards hazard adulterants like melamine. It present NIRS method for qualitative identification of adulteration in milk powder. The algorithm and identification process in itself is complicated but gives detail results. The drawback is that the method is costlier and the basic elements used as source and detector for infrared are also costly. The microstrip antenna is comparatively inexpensive if it is used as basic sensor element.

2.2 Review on Dielectric Measurement of Milk powder

Introduction

The paper authored by Usman A. Khan, Nicholas Nguyen, and Mohammed N. Afsar, *"Millimeter- and Submillimeter- Wave Dielectric Measurements of Household Powders Using Fourier Transform Spectroscopy"*, IEEE Transactions On Instrumentation And Measurement, Vol. 57, No. 2, February 2008. Provide information on measurement of electrical properties such as absorption coefficient, refractive index, loss tangent and dielectric constant of household powder such as flour, dry milk, cornstarch, pesticide, baking soda, and talc.

Effect of Hoax on Dielectric of the Sample

A modified two-beam polarizing interferometer and custom-made sample holders were utilized to obtain the refractive index (RFI), absorption coefficient, complex real and imaginary permittivity, and loss tangent of flour, dry milk, cornstarch, pesticide, baking soda, and talc as a continuous function of frequency in the range of 400–1200 GHz.

Powders, as well as liquids and solids, can be identified whether they are in a heterogeneous media or isolated through their unique resonance or absorption signature. If a mail package is scanned for its dielectric properties, one can theoretically determine which materials or powders are contained in the package by recognizing the resonance signatures. If a database containing the resonance peaks of most of the common household powders and of hazardous materials such as anthrax existed, one would easily be able to conclude whether a package would be safe or not.

Conclusion

This paper successfully examined the dielectric behavior of common household powders, such as talc, cornstarch, baking soda, flour, pesticide, and dry milk in the millimeter- and submillimeter-wave range. Information obtained in this paper can now be used to build a database comprising the broadband dielectric properties of hoax powders. Data acquired can also be utilized to facilitate the classification of other powders. More specifically, the RFI and real part of permittivity were found to be highly accurate and preferred for identification and detection purposes. The real permittivity of the powders is in the range of 2.4–3.4 for densities of 1.5 g/cm3. This is an important property that can be valuable when investigating or estimating the permittivity of other powders used as hoax materials.

2.3 Review on Microstrip Antenna as a Sensor for Permittivity Measurement

Introduction

The paper authored by Mirjana Bogosanovich, *"Microstrip Patch Sensor for Measurement of the Permittivity of Homogeneous Dielectric Materials"*, IEEE Transactions on Instrumentation and Measurement, VOL. 49, NO. 5, OCTOBER 2000. Suggest that the microstrip patch antenna can be used to measure permittivity of dielectric material.

Microstrip Antenna as a Sensor

An application of a small air-spaced coaxially fed rectangular microstrip patch antenna as a sensor for permittivity measurement is presented. The models used for the calculation of the permittivity from the shift in the resonant frequency for solid and liquid materials are described. The models are experimentally verified by measurements for several liquid and solid samples. In this work, for the first time, a patch antenna is used as a sensor for permittivity measurement. In comparison with microstrip line structures, the advantages of the microstrip patch are low profile, relative simplicity, ease of fabrication, and low price. For the solid material permittivity measurements, the sample under test is positioned on the top of the patch, forming the cover or superstrate material with thickness. The shift in resonant frequency due to the change in superstrate dielectric constant has been calculated. As the reference value, the PTFE resonant frequency is taken. The calculated shift in resonant frequency shows good agreement with the experimental result.

Conclusion

The microstrip patch antenna structure has been modeled by means of a modified cavity model, which offers approximative closed-form equations and a fast procedure for the determination of material permittivity. The structure has very good sensitivity, particularly for liquids, where the space between the patch and ground plane, and the space above the patch are filled with the liquid under test. It is well suited for remote measurements of low-loss materials. It is particularly well suited for monitoring changes in the dielectric constant of a material. The sensor is capable of permittivity measurement for a wide range of materials/permittivity values.

Chapter 3

Design of Microstrip Antenna

The design of microstrip antenna for this project has certain stages which includes both design by using and formulae as well as design by using iteration method. It follows several stages. The stages for designing microstrip antenna sensor initiate with the design of PIFA (Planer Inverted-F Antenna) which include a miniaturization technique i.e. shorting radiating patch with ground plane, then meandering of the top layer to achieve the expected resonant frequency. The iteration method is carried to make the antenna to radiate at 865.9MHz in which the width of the shorting post is varied and dimensions of the slots for meandering is also varied. The iteration method is performed in the simulation software known as HFSS (High Frequency Simulation Software).

3.1 Design of PIFA (Planer Inverted-F Antenna)

The general steps carried in the design of the PIFA (Planer Inverted-F Antenna) is as follow:

- Specify:
    - Resonant frequency (f_r);

The resonant frequency of the microstrip antenna is the frequency at which the antenna radiates very efficiently. For this project the resonant frequency chosen is 866 MHz because it lies within a ISM (Industrial, Scientific & Medical) band which has the range of 865 MHz to 867 MHz.

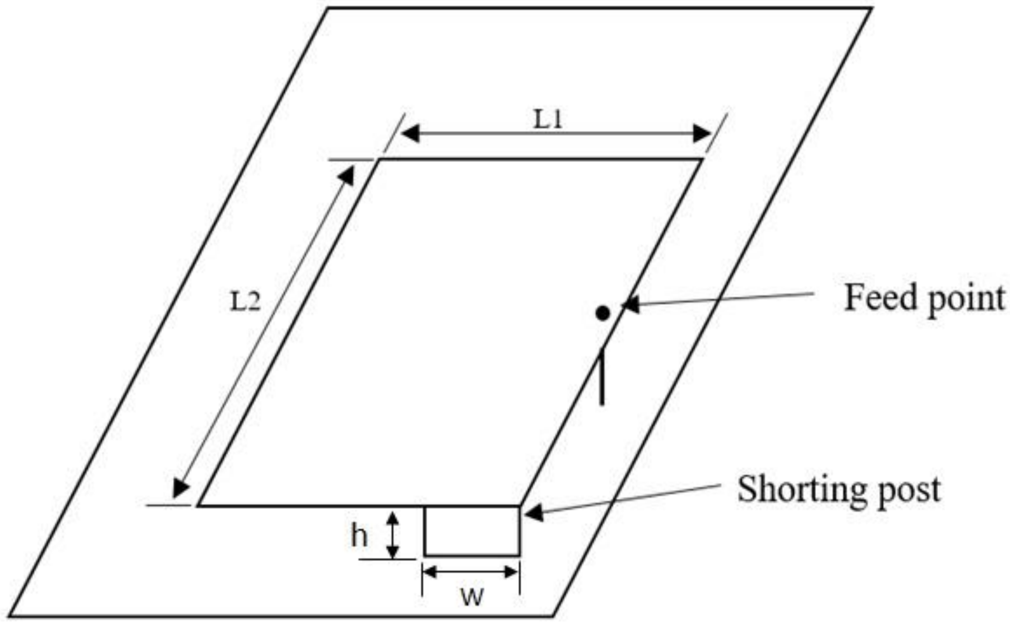


Figure3.1 *Structure of PIFA*

- Permittivity of the substrate (ɛ);

The permittivity of the substrate is the dielectric constant of the material used as the middle layer in microstrip antenna. In this project FR4 Epoxy is used as a substrate which has permittivity $\varepsilon = 4.4$.

- Height of the substrate (h);

It is the distance between the top layer i.e. radiating patch and bottom layer i.e. ground plane.

After specifying the resonant frequency, substrate material and height of the substrate certain parameter is to be calculated that are as follow.

- Calculate:
  - Wavelength (λ);

Wavelength is calculated by the resonant frequency and the permittivity of the substrate. The formula for calculating wavelength (λ) is given in further section.

- Length of the patch (L1);

It is the length of the top layer i.e. length of rectangular radiating patch. The formula for calculating L1 is given in further section.

- Width of the patch (L2);

It is the width of the top layer i.e. width of the rectangular radiating patch. The formula for calculating L2 is given in further section.

3.2 Formulae for Design of PIFA (Planer Inverted-F Antenna)

Following are the formulas for calculating and estimating dimensions of PIFA:

Step1: Calculate wavelength (λ) from resonant frequency & permittivity of the substrate from the formula given below,

$$\boldsymbol{\lambda = \frac{c_0}{f.\sqrt{\varepsilon_r}}}$$

Step2: Estimating Length (L1) & Width (L2) of the patch and shorting post width (W) of the PIFA from the formula given below.

$$\mathbf{L1 + L2 - W = \frac{\lambda}{4}}$$

- When W/L1=1; $\mathbf{L1 + H = \frac{\lambda}{4}}$

- When W=0; $\mathbf{L1 + L2 + H = \frac{\lambda}{4}}$

Where,

L1 = Length of the Patch.

L2 = Width of the Patch.

W = Width of the Shorting Post.

H = Height of the Shorting Post/Height of the substrate.

3.3 Calculations of Microstrip Antenna

The above given procedure and steps are the general method to estimate the design of PIFA (Planer Inverted-F Antenna). However, for the presented project the procedure followed is other way round i.e. first the dimension of the PIFA (Planer Inverted-F Antenna) is decided and then frequency is calculated from the frequency given above. This approach is chosen because the aim of the project is to design an antenna with minimum dimension and at a specific frequency which is 865 MHz. So if we first design our PIFA at 866 MHz and then if we perform meandering for miniaturization then our expected frequency 866 MHz get shifted after meandering. Thus first the PIFA is design of desired dimension and after that with the help of meandering and adjusting width of the shorting post the resonant frequency of 866 MHz is tried to achieve.

The following step are followed while designing the microstrip antenna sensor:

1. Deciding the dimension of the microstrip antenna.

The Microstrip antenna sensor must be well optimized and of small size. Thus, the overall dimension decided is 25mm×25mm arbitrarily. The length (L1), Width (L2) and width of the shorting post (W) are as follow,

L1 = 20mm,

L2 = 16mm,

W = 4mm.

2. Calculating wavelength and then frequency of the PIFA.

By using formula,

$$\mathbf{L1 + L2 - W = \frac{\lambda}{4}}$$

$$\mathbf{20 + 16 - 4 = \frac{\lambda}{4}}$$

We get Wavelength (λ), $\boldsymbol{\lambda = 128\text{mm}}$

By using formula,

$$\boldsymbol{\lambda} = \frac{\boldsymbol{c_0}}{\boldsymbol{f}.\sqrt{\boldsymbol{\varepsilon_r}}}$$

Where, λ = 128mm, c_0 = 3.10^8 m/s, and $\boldsymbol{\varepsilon_r} = \mathbf{4.4}$ (for FR4-Epoxy).

$$\mathbf{128} = \frac{\mathbf{3.10^8}}{\boldsymbol{f}.\sqrt{\mathbf{4.4}}}$$

We get resonant frequency (f), $\boldsymbol{f} = \mathbf{1117.34\ MHz}$

3. Applying meandering on the patch of the antenna.

Meandering on the patch is performed which reduces the resonant frequency of the microstrip antenna sensor. After meandering the resonant frequency fall in the range of 850 MHz to 900 MHz.

4. Achieving the desired frequency (866 MHz) by using iteration method.

By varying the dimensions of the meandered top layer and adjusting the width of the shorting post the desired resonant frequency of 866 MHz is achieved. The width of the shorting post is increased from 4mm to 4.3mm. The meandered top layer dimension is given in Figure3.2 below.

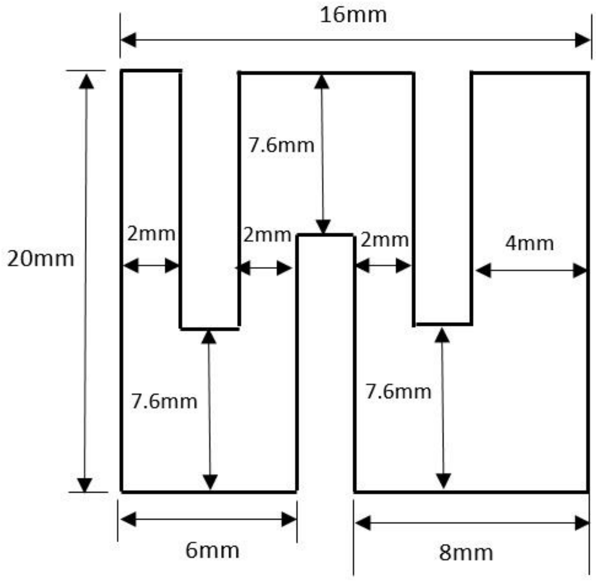


Figure3.2 *Meandered Patch*

5. Achieving good S11 parameter by varying the position of the feed point.

For the purpose of impedance matching and for good reflection coefficient the feed point is achieved iteratively which gives good S11 parameter (about -40dB). The position of the feeding point is given in Figure3.3 below.

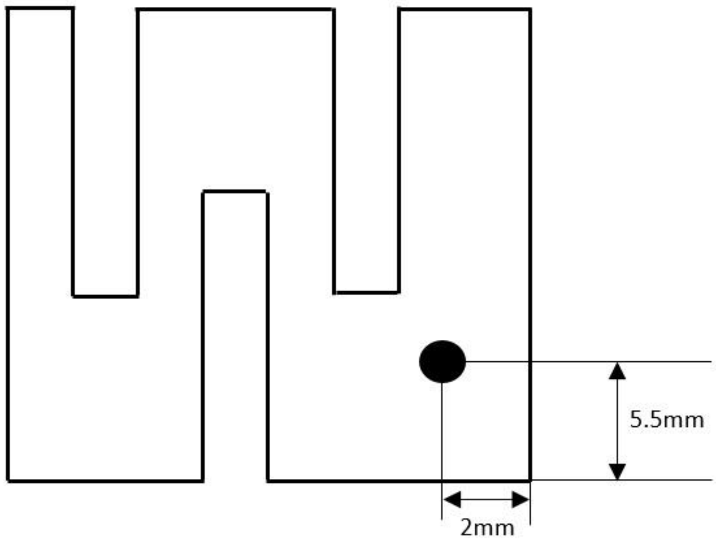


Figure3.3 *Feed point position*

Chapter 4

Methodology

The design of microstrip antenna sensor for this project include calculation and simulation, sometime in the process of design both calculation and simulation going simultaneously and also when iterations are carried out. The software used for simulation is HFSS (High Frequency Simulation Software). The iteration method is carried in the HFSS simulation method to get the expected results. In the proceeding section introduction to HFSS is given which is followed by the simulation procedure in HFSS.

4.1 Introduction to HFSS

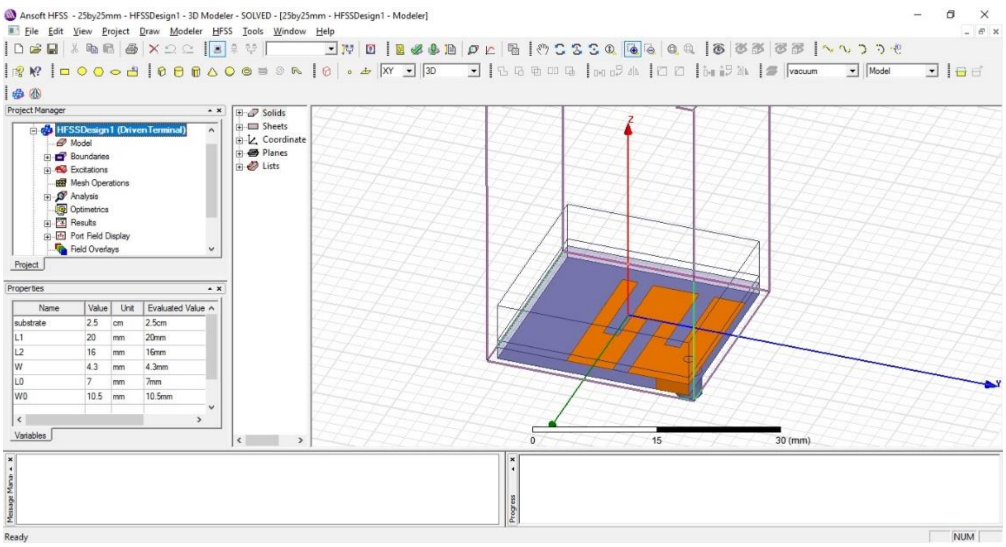


Figure4.1 *HFSS Window*

HFSS is an interactive software package for calculating the electromagnetic behavior of a structure. The software includes post-processing commands for analyzing this behavior in detail. The work window of HFSS software is shown in Figure 4.1.

Using HFSS, we can compute:

• Basic electromagnetic field quantities and, for open boundary problems, radiated near and far fields.

• Characteristic port impedances and propagation constants.

• Generalized S-parameters and S-parameters renormalized to specific port impedances.

• The eigenmodes, or resonances, of a structure.

We are expected to draw the structure, specify material characteristics for each object, and identify ports and special surface characteristics. HFSS then generates the necessary field solutions and associated port characteristics and S-parameters.

HFSS uses a numerical technique called the Finite Element Method (FEM). This is a procedure where a structure is subdivided into many smaller subsections called finite elements. The finite elements used by HFSS are tetrahedra, and the entire collection of tetrahedra is called a mesh. A solution is found for the fields within the finite elements, and these fields are interrelated so that Maxwell's equations are satisfied across inter-element boundaries. Yielding a field solution for the entire, original, structure. Once the field solution has been found, the generalized S-matrix solution is determined.

The six general steps in an HFSS simulation

There are six main steps to creating and solving a proper HFSS simulation.

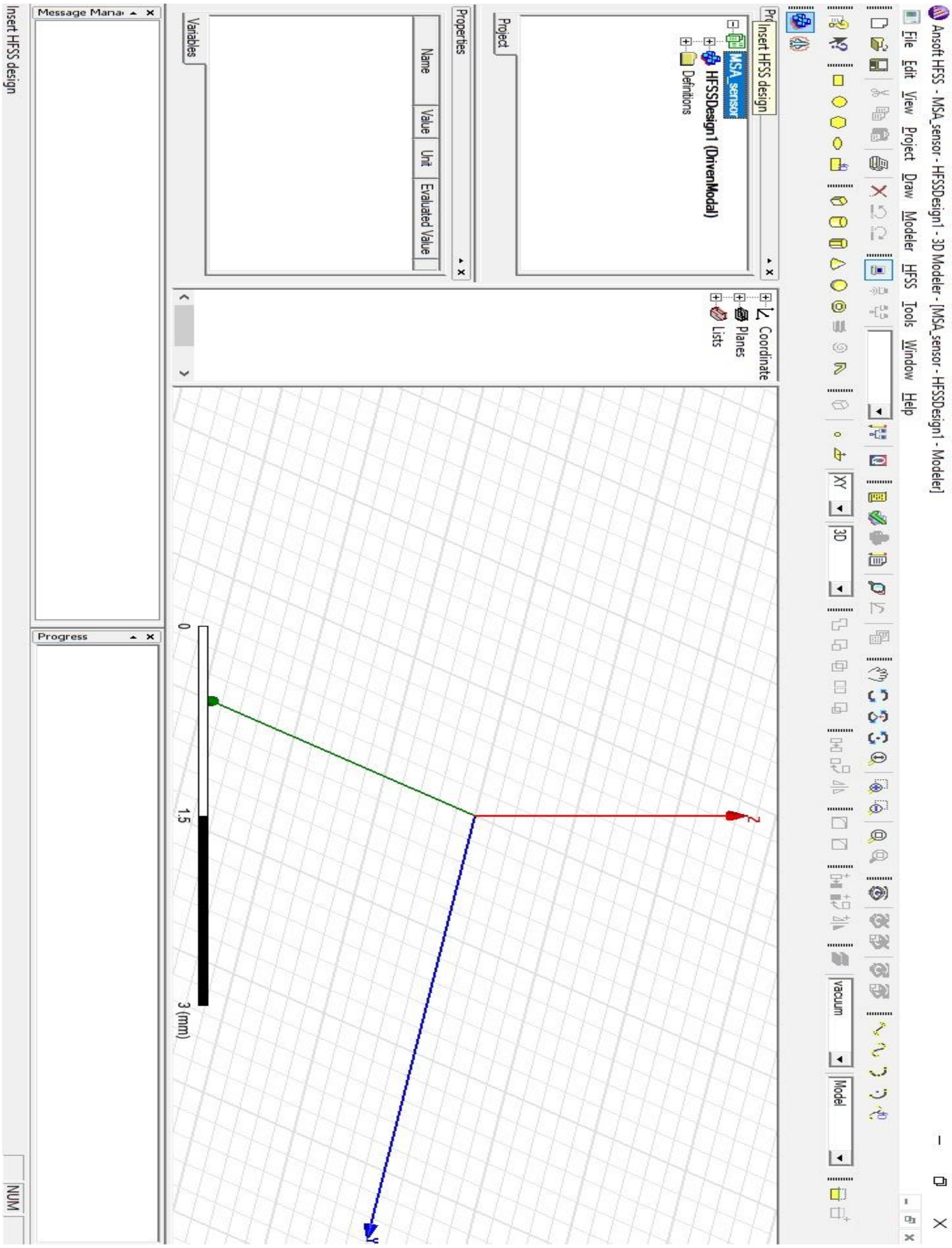
They are:

1. Create model/geometry
2. Assign boundaries
3. Assign excitations
4. Set up the solution
5. Solve
6. Post-process the results

4.2 Simulation Steps of Microstrip Antenna Sensor

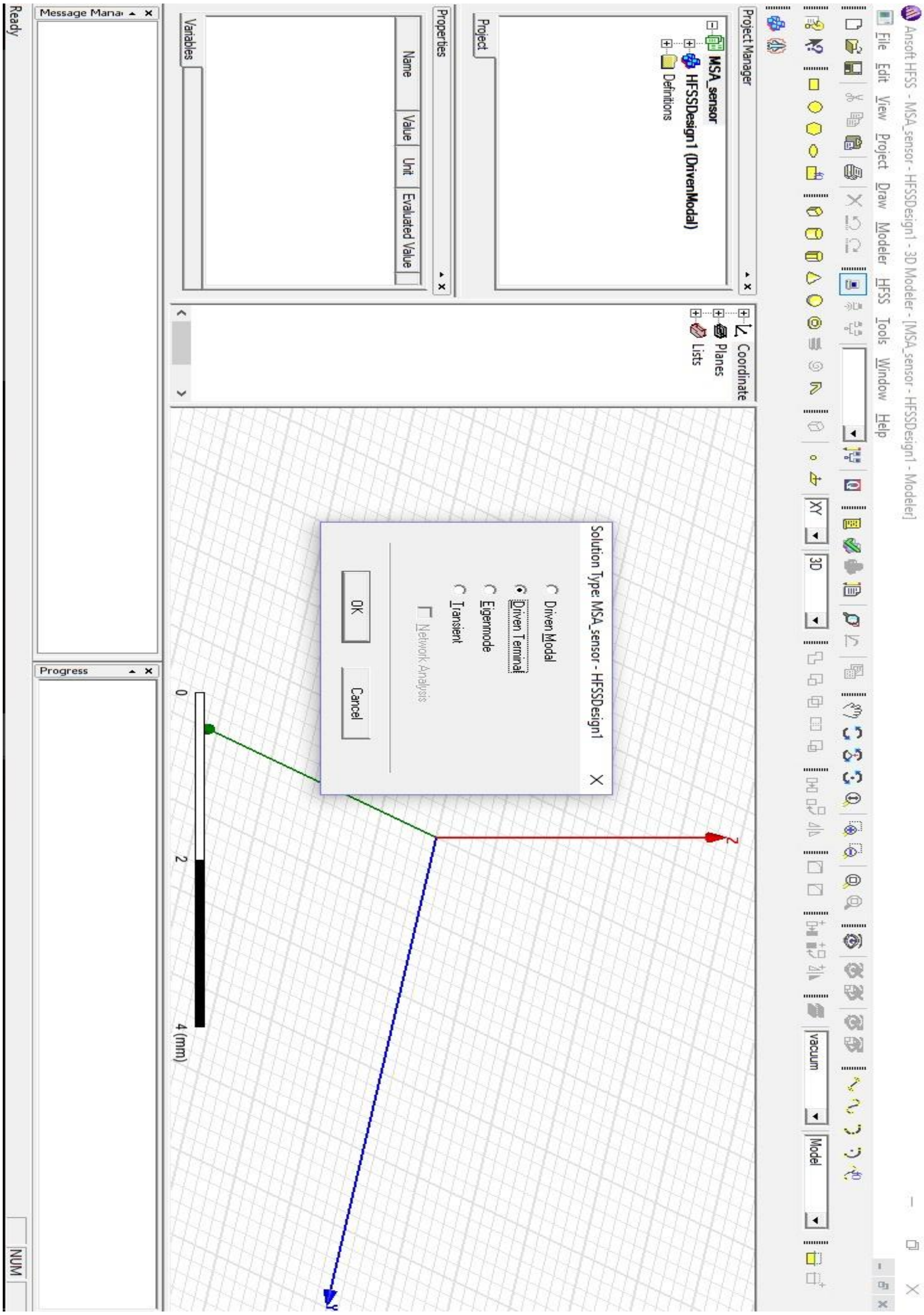
Step1: Create model/geometry

- Before creating model we have to select insert HFSS design, which opens the window in which model is to be drawn:



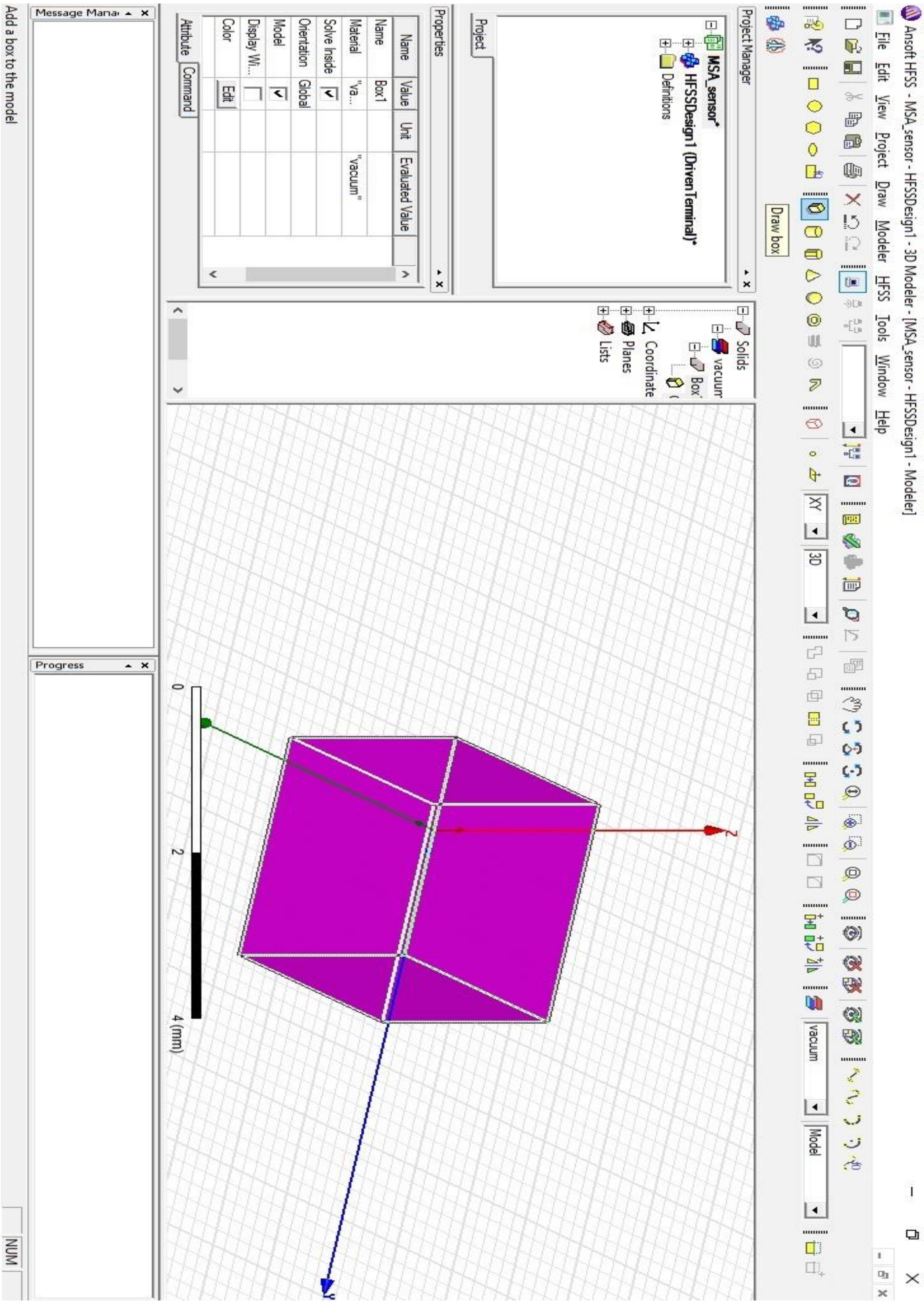
➢ Now we have to select solution type for our project i.e. *Driven Terminal*.

Go to HFSS ⟶ Solution type ⟶ Select Driven Terminal ⟶ Ok.



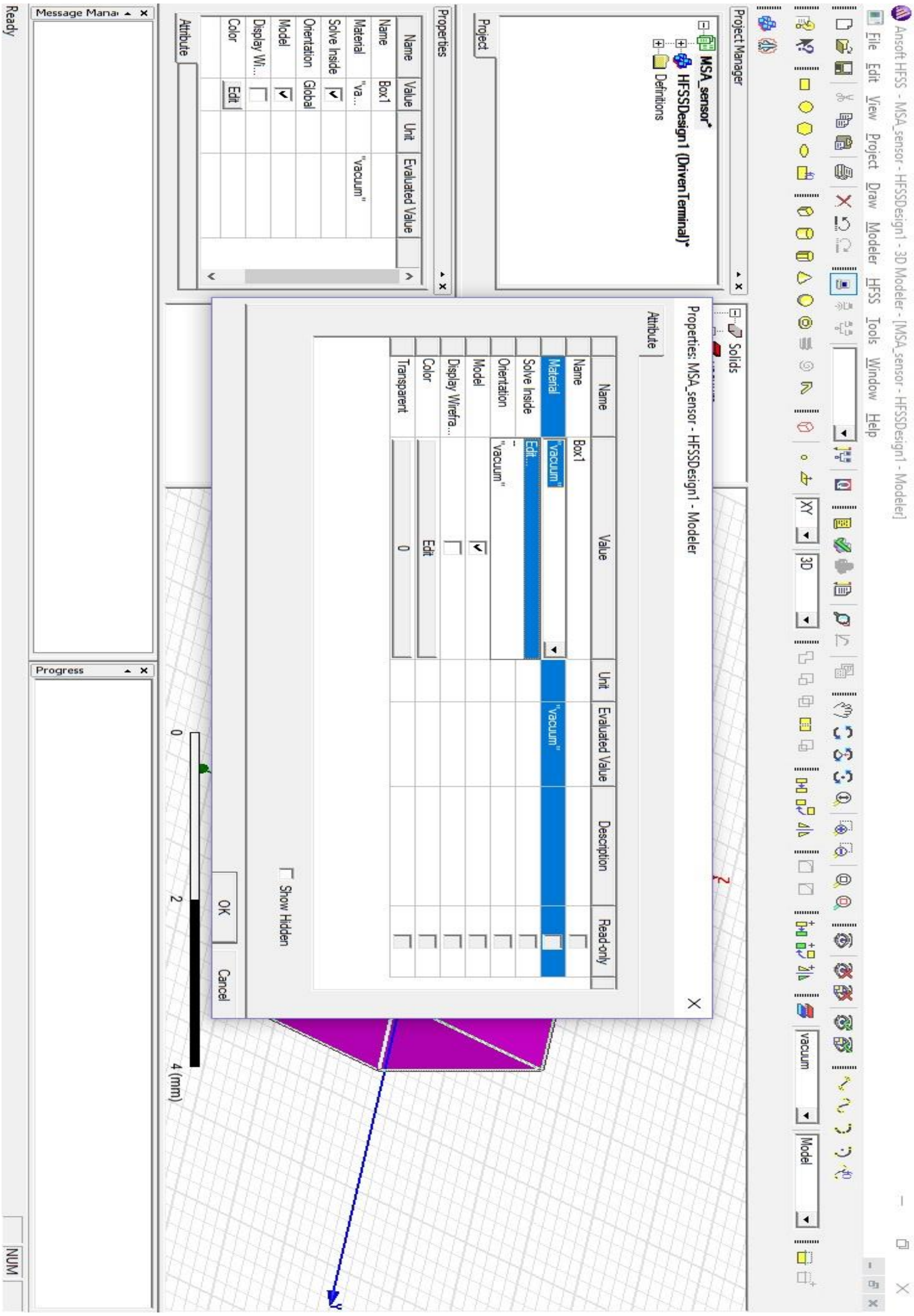
➢ Placing Substrate in the drawing window.

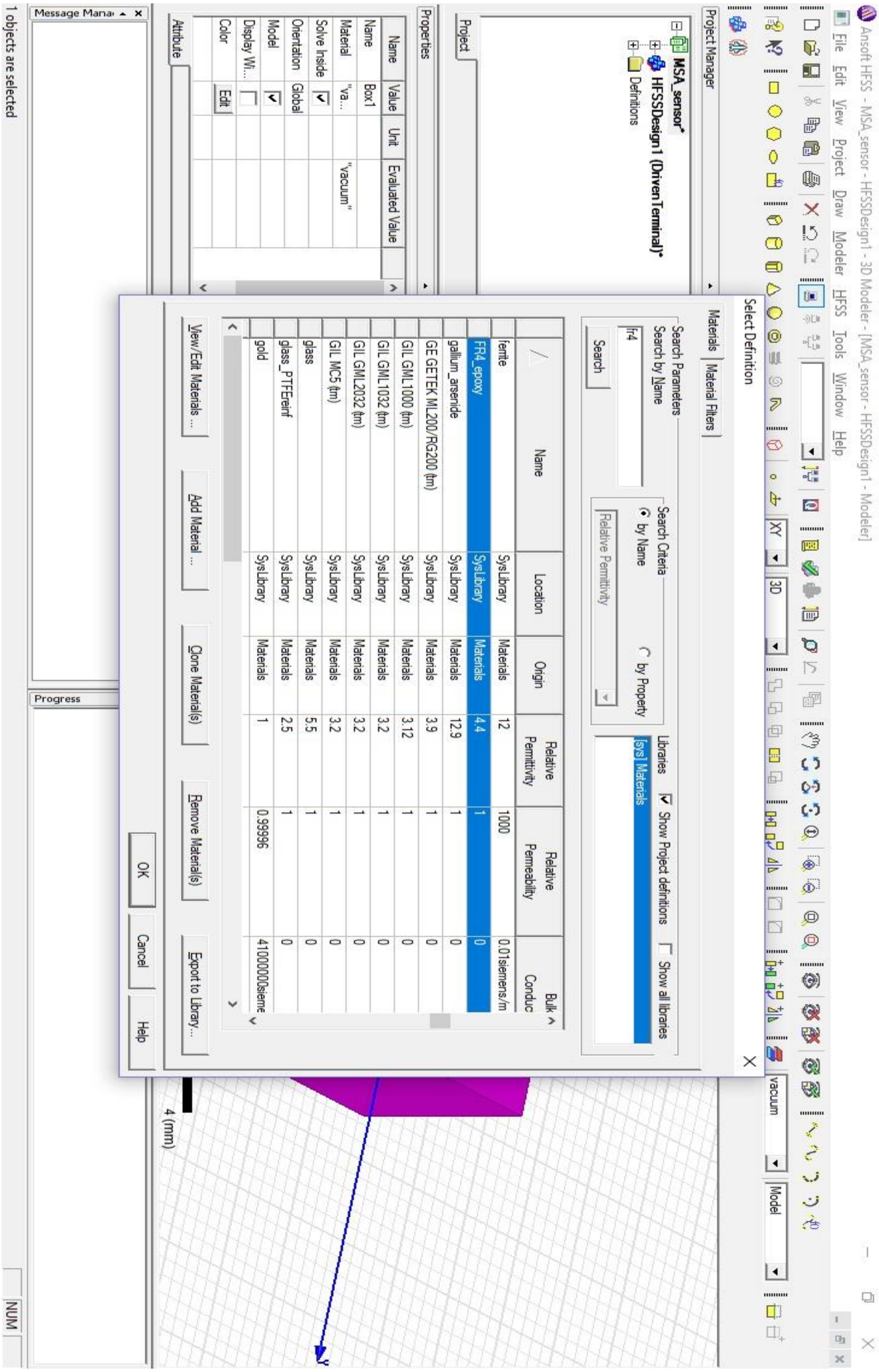
Select “Draw box” ⟶ Place in the drawing window



➢ Setting box properties (Name, Material, Color and transparency)

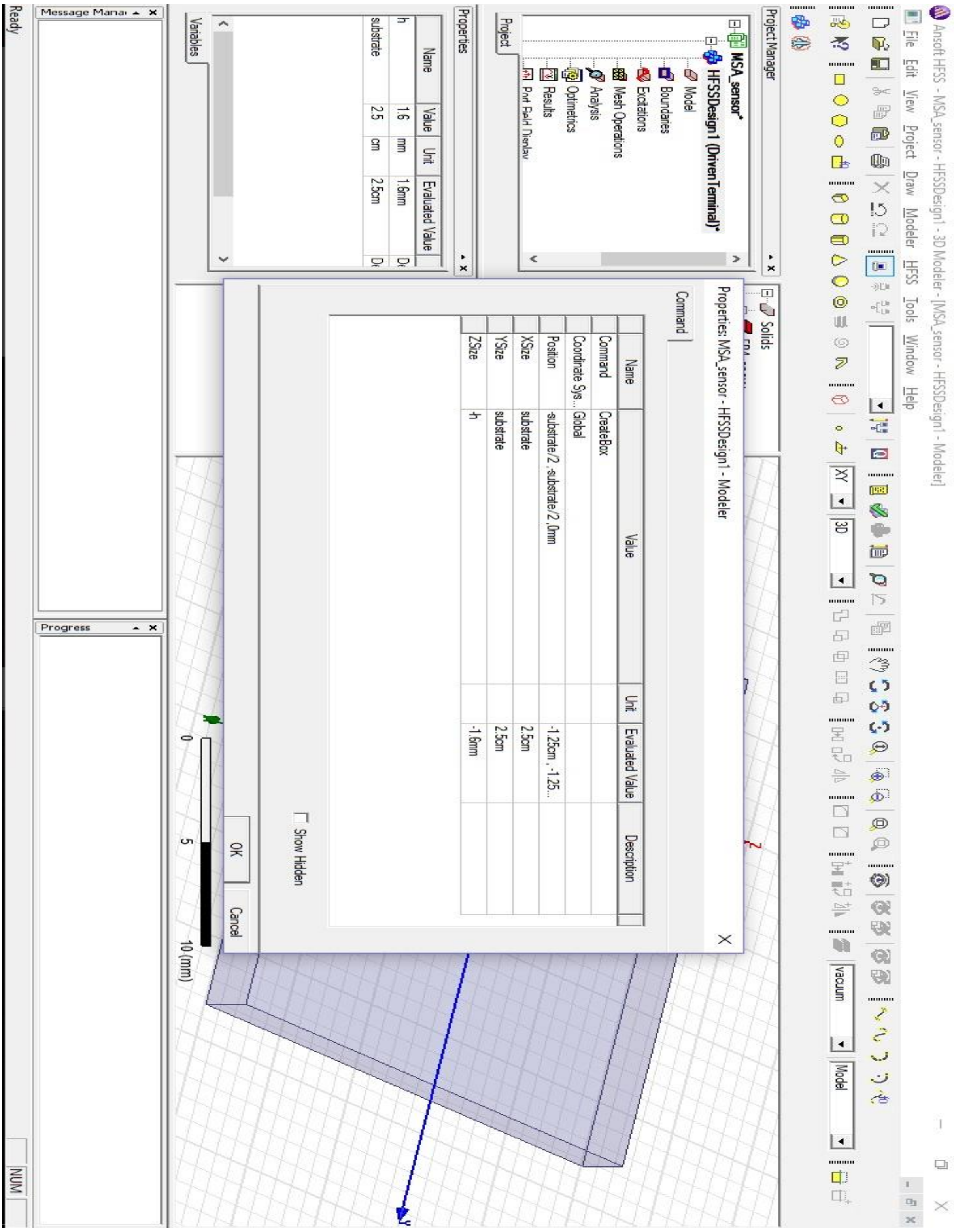
Right click on Box1 ⟶ Properties ⟶ Material ⟶ FR4_epoxy ⟶ Ok.




Ansoft HFSS - MSA_sensor - HFSSDesign1 - 3D Modeler - [MSA_sensor - HFSSDesign1 - Modeler]
File Edit View Project Draw Modeler HFSS Tools Window Help
Project Manager
MSA_sensor*
HFSSDesign1 (DrivenTerminal)*
Definitions
Project
Properties
Name Value Unit Evaluated Value
Name Box1
Material "va... "vacuum"
Solve Inside
Orientation Global
Model
Display Wi...
Color Edit
Attribute
Message Mana
Progress
1 objects are selected
NUM
Select Definition
Materials
Material Filters
Search Parameters
Search by Name
fr4
Search
Search Criteria
by Name
by Property
Relative Permittivity
Libraries
Show Project definitions
Show all libraries
[sys] Materials
Name Location Origin Relative Permittivity Relative Permeability Bulk Conduc
ferrite SysLibrary Materials 12 1000 0.01siemens/m
FR4_epoxy SysLibrary Materials 4.4 1 0
gallium_arsenide SysLibrary Materials 12.9 1 0
GE GETEK ML200/RG200 (tm) SysLibrary Materials 3.9 1 0
GIL GML1000 (tm) SysLibrary Materials 3.12 1 0
GIL GML1032 (tm) SysLibrary Materials 3.2 1 0
GIL GML2032 (tm) SysLibrary Materials 3.2 1 0
GIL MC5 (tm) SysLibrary Materials 3.2 1 0
glass SysLibrary Materials 5.5 1 0
glass_PTFEreinf SysLibrary Materials 2.5 1 0
gold SysLibrary Materials 1 0.99996 41000000sieme
View/Edit Materials ...
Add Material ...
Clone Material(s)
Remove Material(s)
Export to Library ...
OK
Cancel
Help
vacuum
Model
XY
3D
4 (mm)

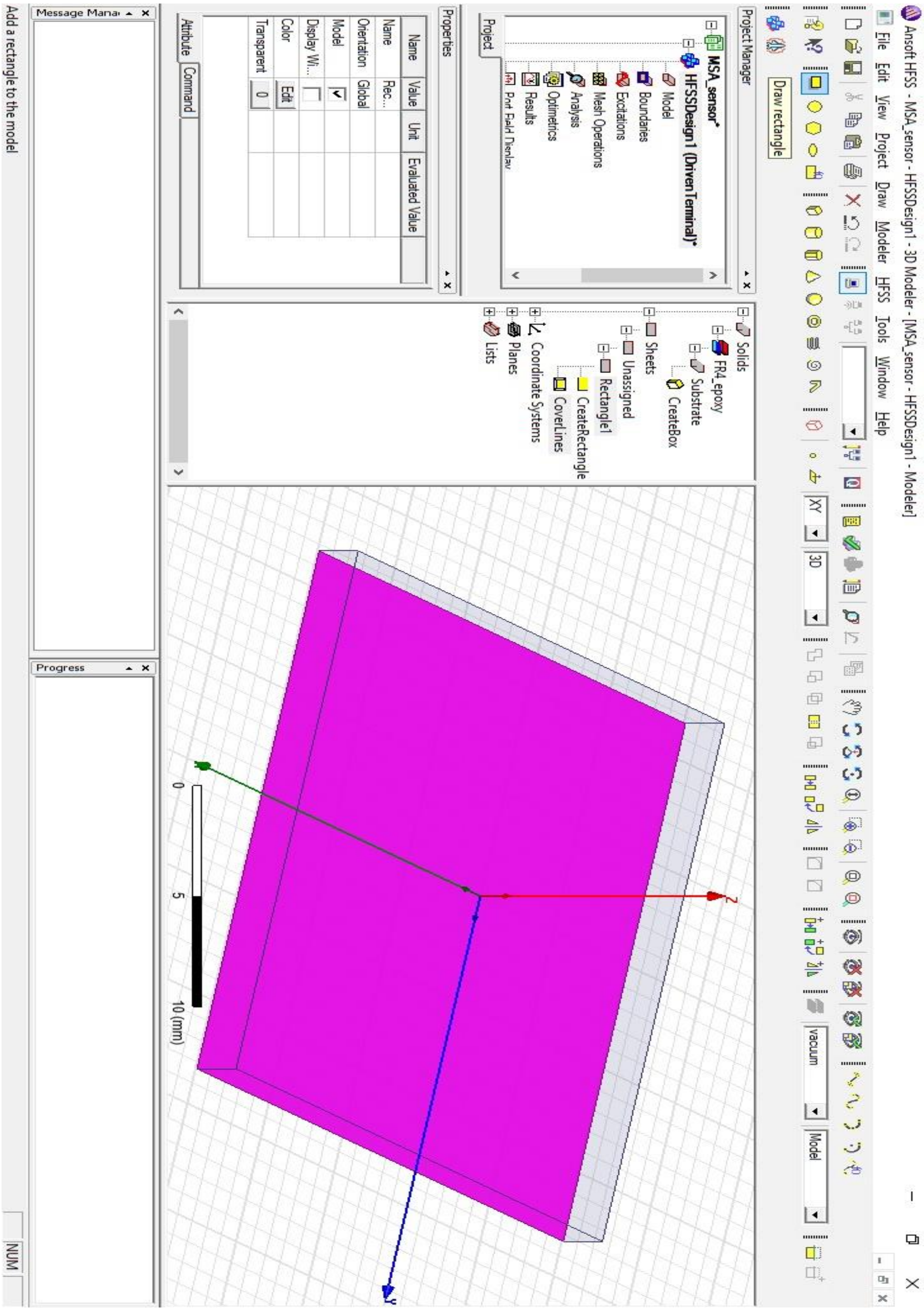
- ➢ After setting “Name”, “Color” and “transparency” the size and position of the substrate is edited.

Right click on “create box” ⟶ Properties ⟶ edit x, y, z position ⟶ edit X, Y, Z size ⟶ Ok.



➢ Now we have to place ground, which is a rectangle, in the window.

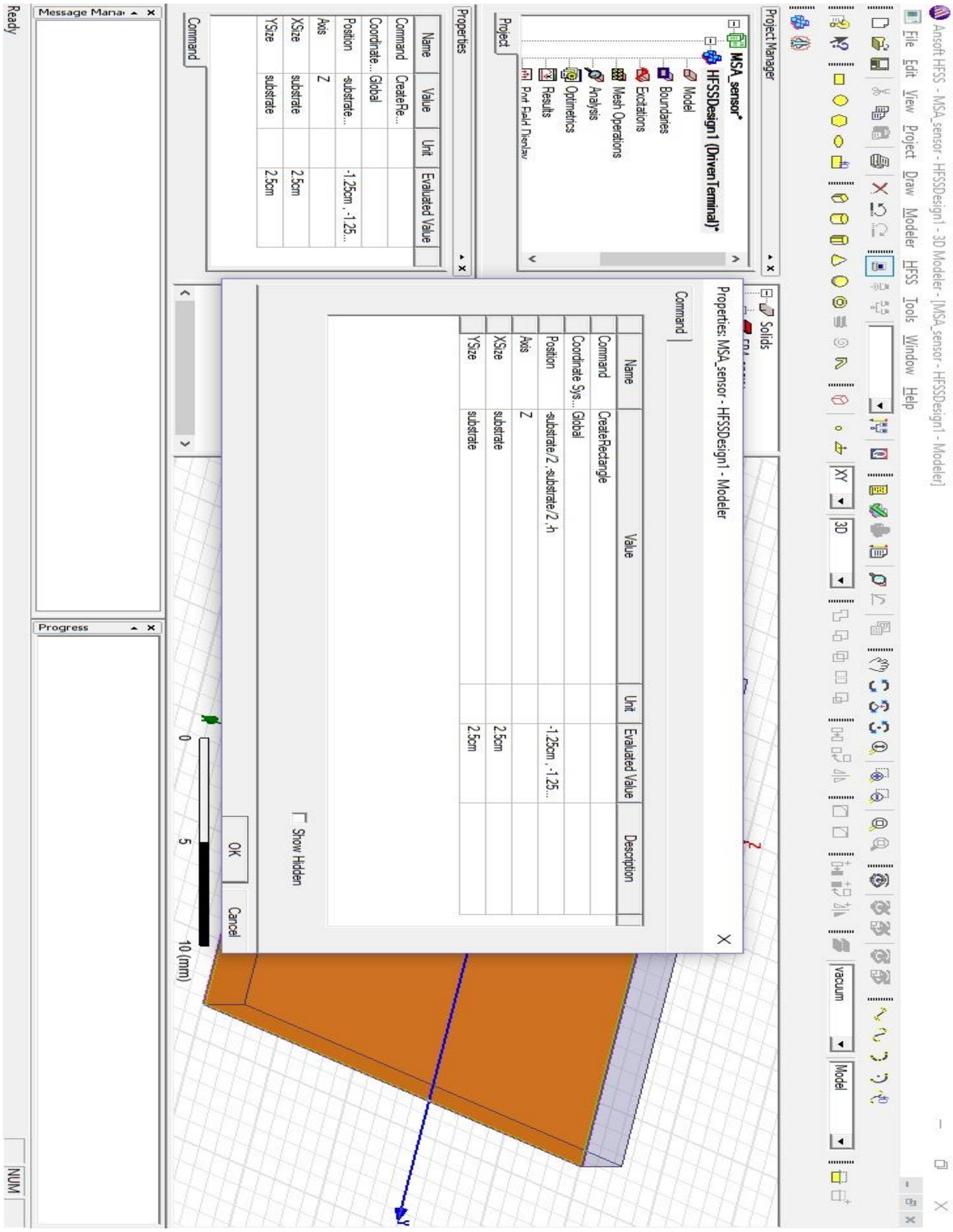
From tool bar, Select “Draw Rectangle” ⟶ Place in the window.



➢ Now edit properties of the rectangle drawn (Name, Color, and Transparency). And then its size and position.

Right click on “Rectangle1” ⟶ Properties ⟶ Edit Name, Color & Transparency.

Right click on “Create Rectangle” ⟶ Properties ⟶ Edit Size & Position.

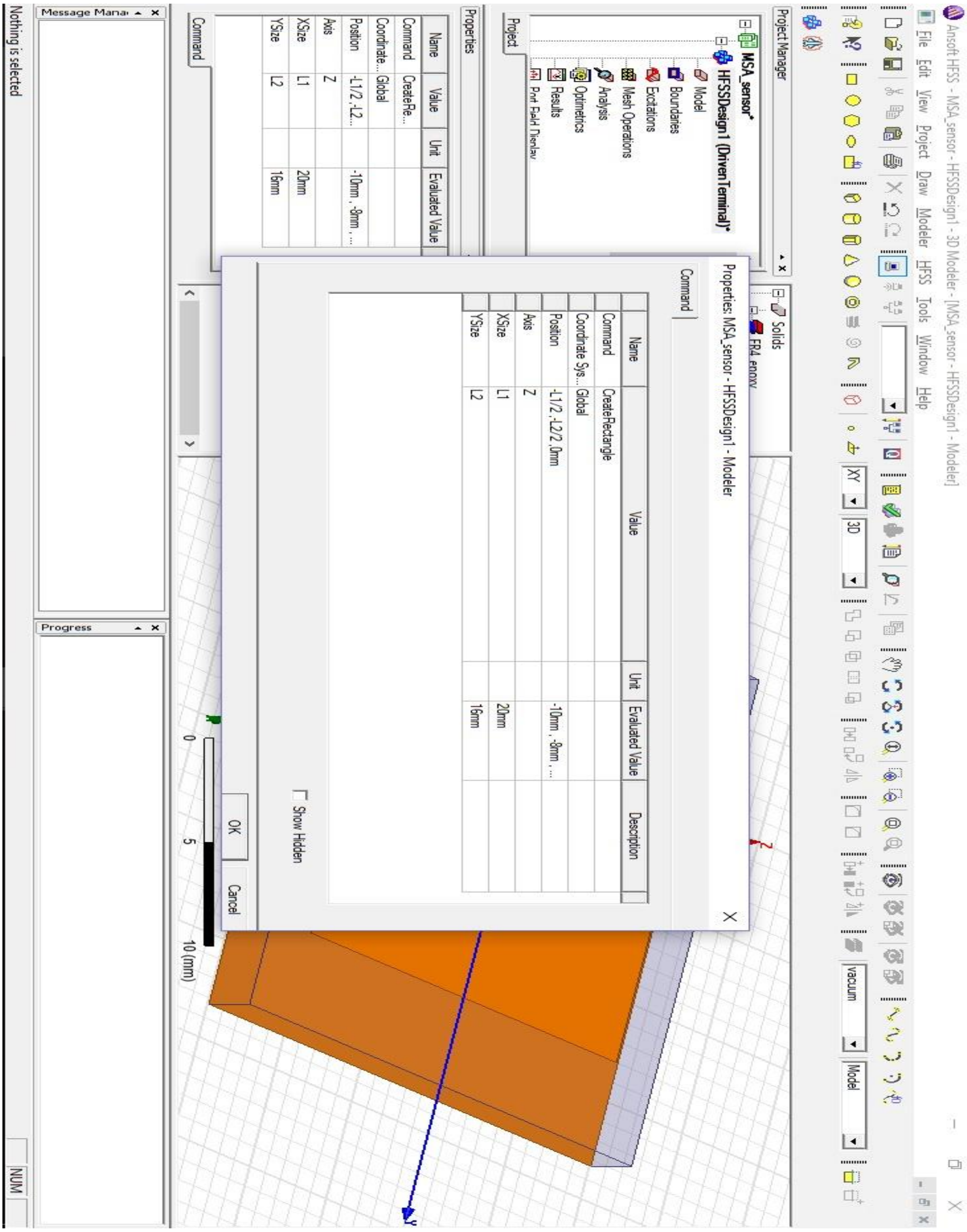


- ➢ Placing rectangle for patch.

From tool bar, Select “Draw Rectangle” ⟶ Place it in the Window.

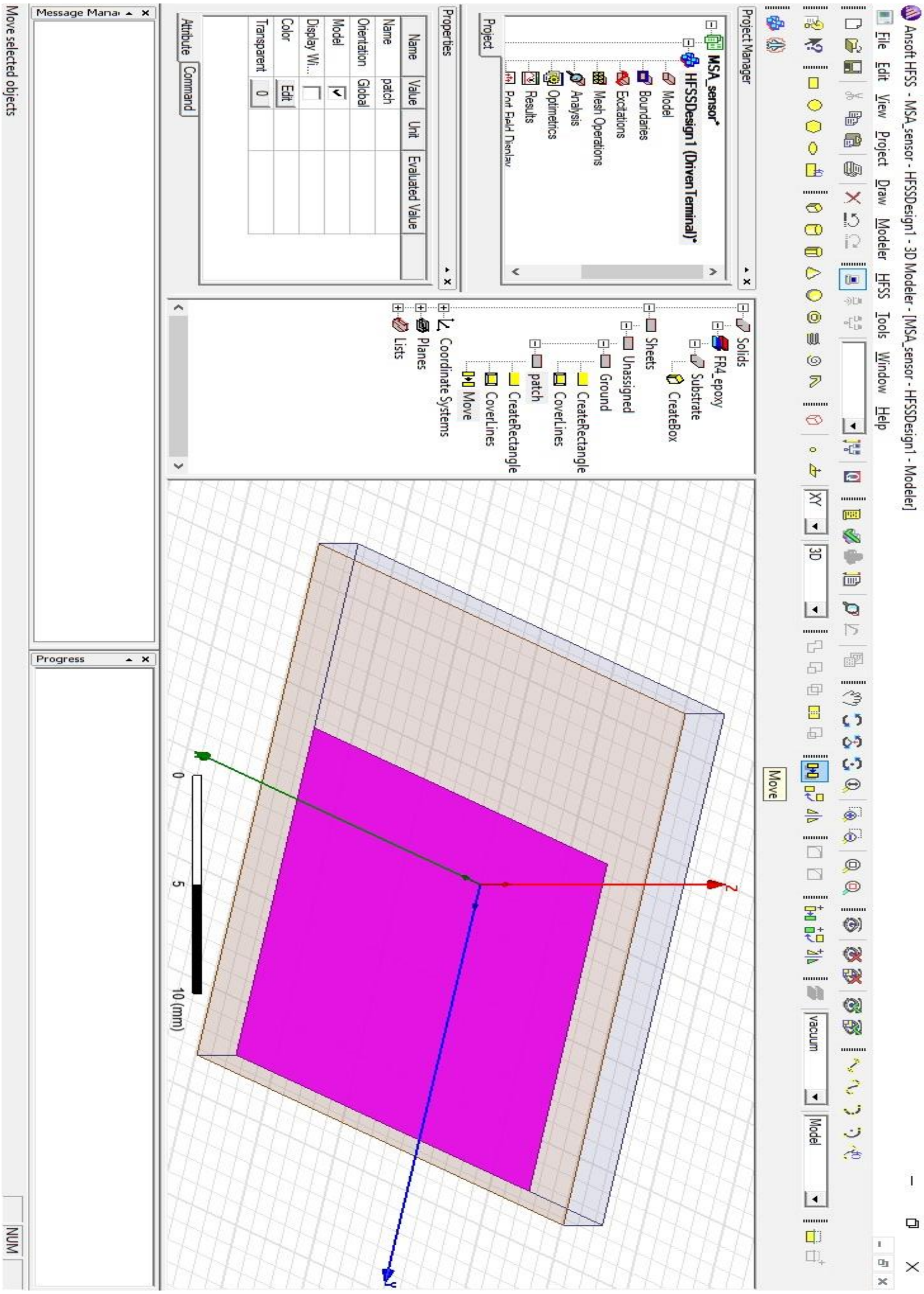
Right click on “Rectangle1” ⟶ Properties ⟶ Edit Name, Color & Transparency.

Right click on “Create Rectangle” ⟶ Properties ⟶ Edit Size & Position.



➢ Moving patch towards corner of the substrate.

Select patch ⟶ Select “Move” ⟶ Drag patch at the corner of the substrate.



➢ Placing shorting post.

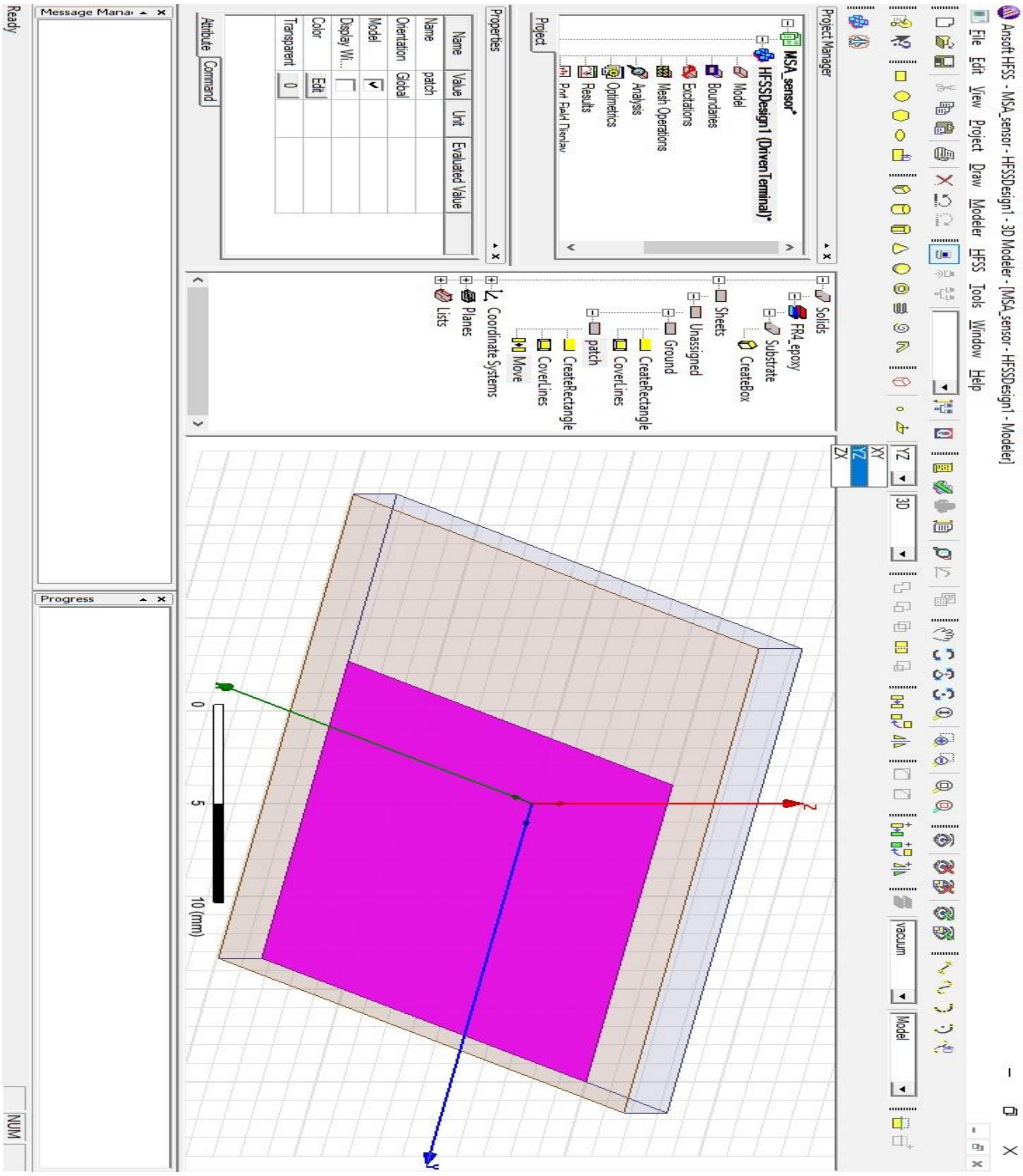
Change “Drawing Plane” from “XY” to “YZ” as we have to place our shorting plane vertically.

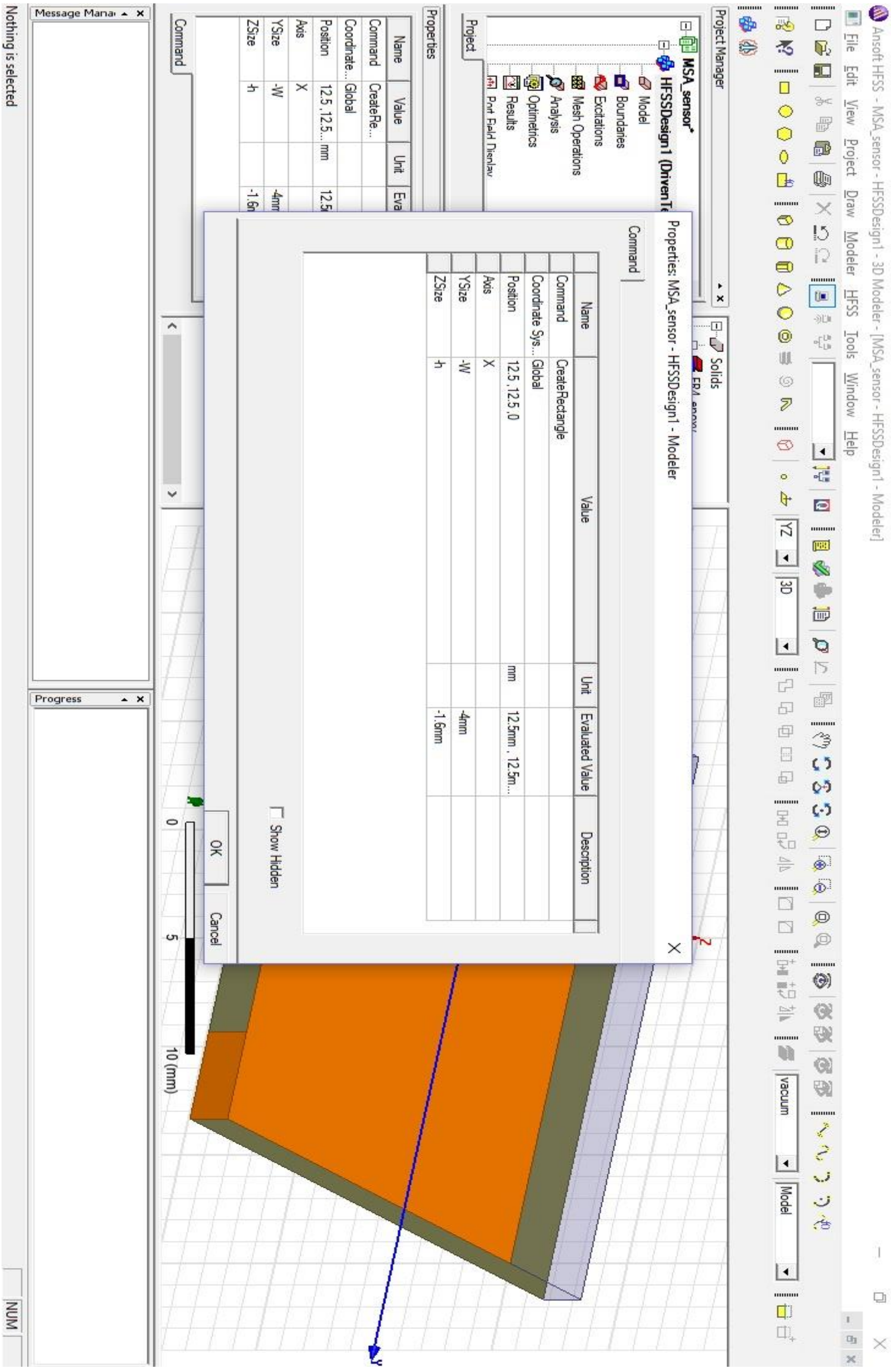
Then, Select “Draw Rectangular” ⟶ Place Shorting post.

Right click on “Rectangle1” ⟶ Properties ⟶ Edit Name, Color & Transparency.

Right click on “Create Rectangle” ⟶ Properties ⟶ Edit Size & Position.

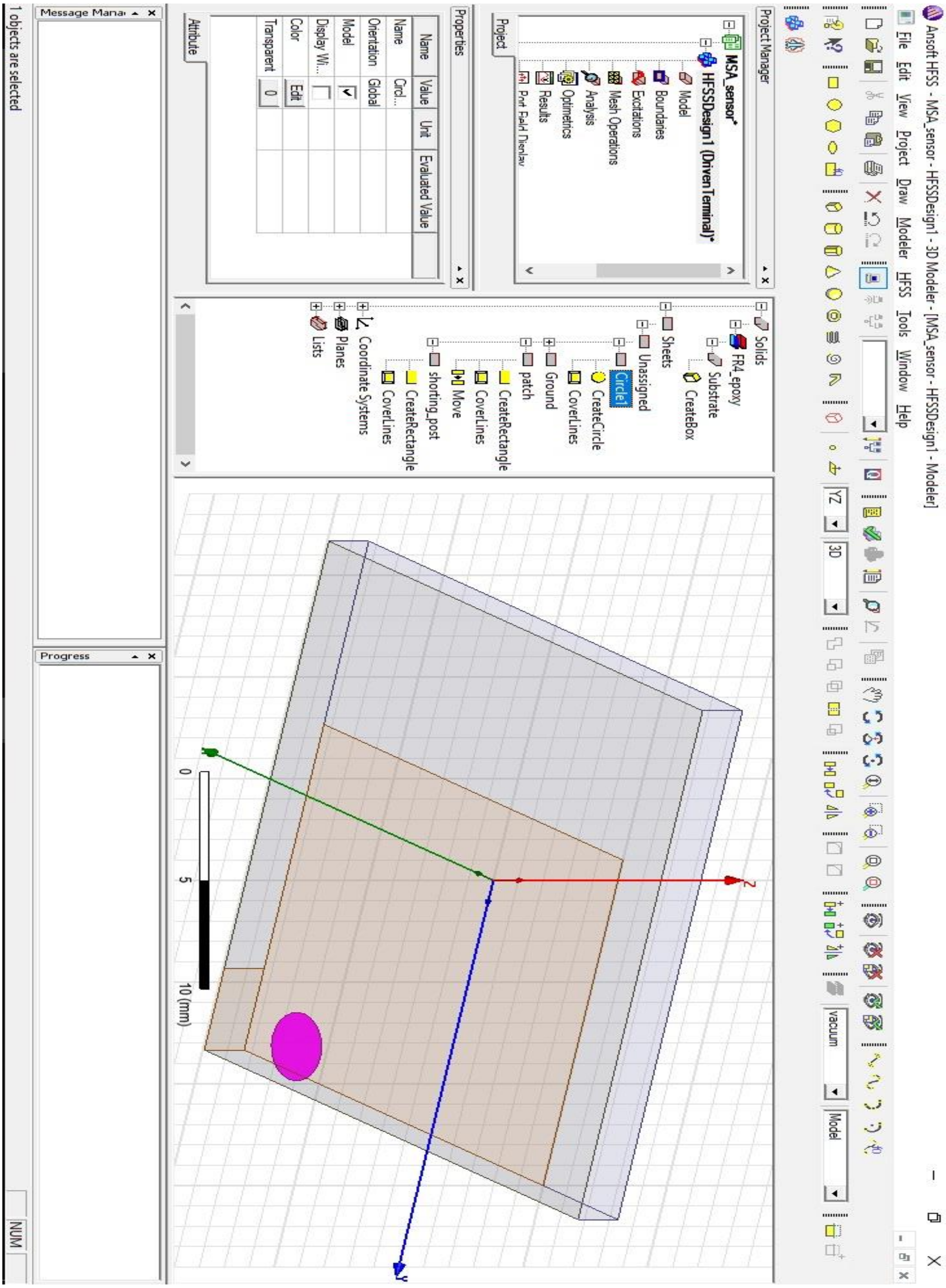
Moving it and placing it at the corner of the patch. Change “Drawing Plane” again to “XY”.



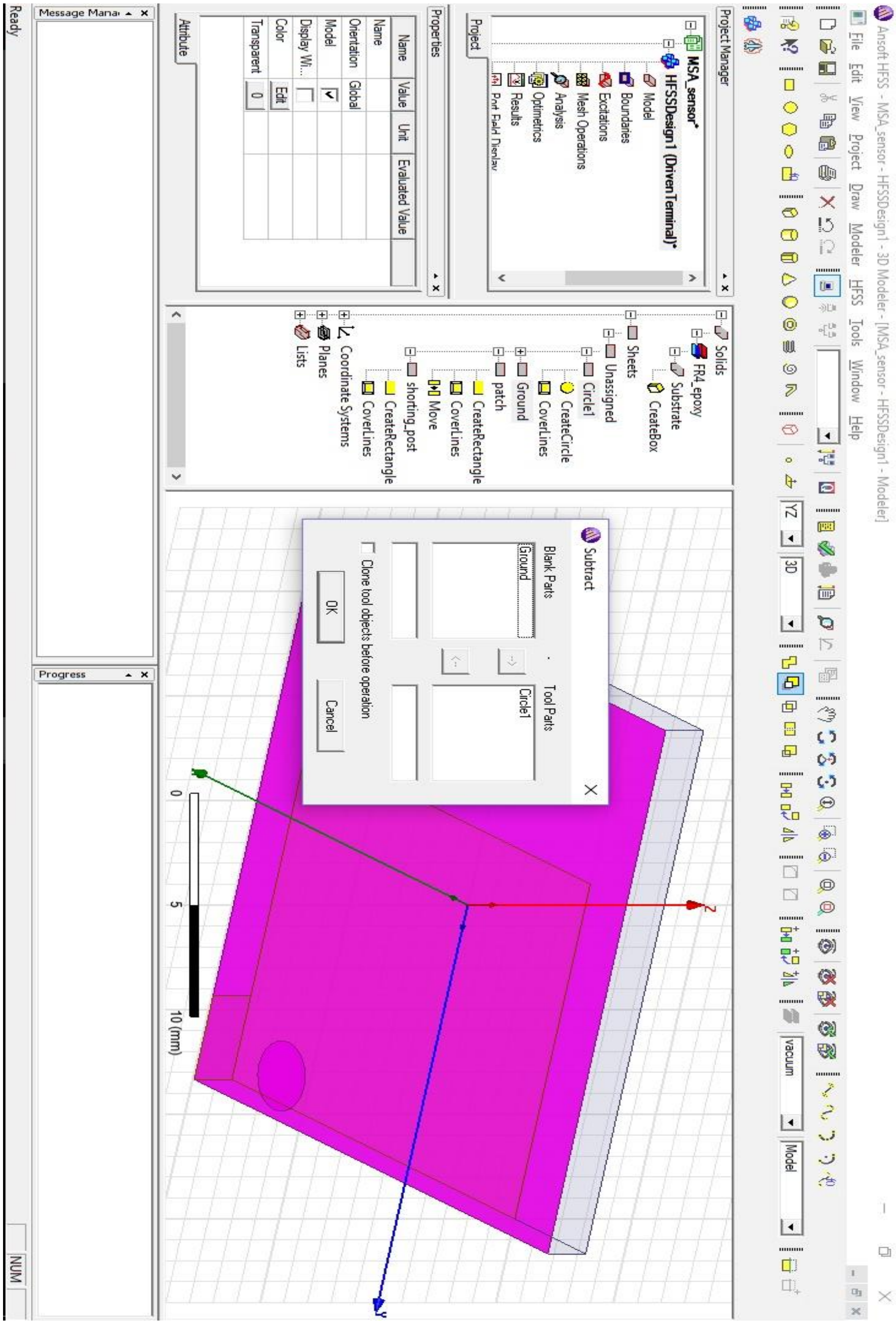

Ansoft HFSS - MSA_sensor - HFSSDesign1 - 3D Modeler - [MSA_sensor - HFSSDesign1 - Modeler]
File Edit View Project Draw Modeler HFSS Tools Window Help
Project Manager
MSA_sensor*
HFSSDesign1 (DrivenT
Model
Boundaries
Excitations
Mesh Operations
Analysis
Optimetrics
Results
Properties: MSA_sensor - HFSSDesign1 - Modeler
Command
Name
Value
Unit
Evaluated Value
Description
Command
CreateRectangle
Coordinate Sys...
Global
Position
12.5 ,12.5 ,0
mm
12.5mm , 12.5m...
Axis
X
YSize
-W
-4mm
ZSize
-h
-1.6mm
Show Hidden
OK
Cancel
Message Manager
Progress
Nothing is selected
NUM
vacuum
Model
0
5
10 (mm)

➢ Now there must be circular cut in the ground plane where coaxial pin is to be inserted and slot cuts on the patch for meandering.

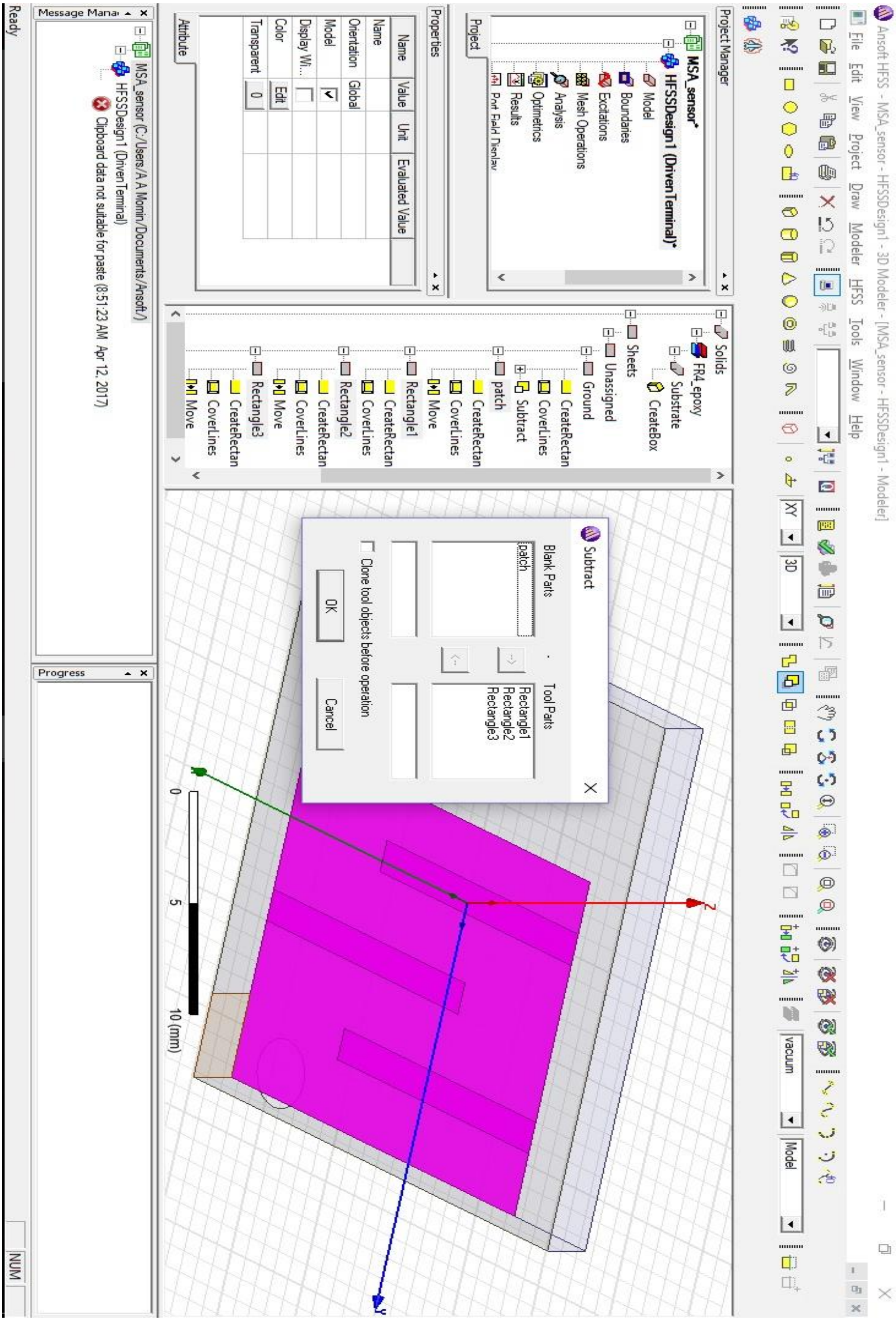
Select "Draw Circle" ⟶ Placing it at the position of circular cut ⟶ Edit its dimension.

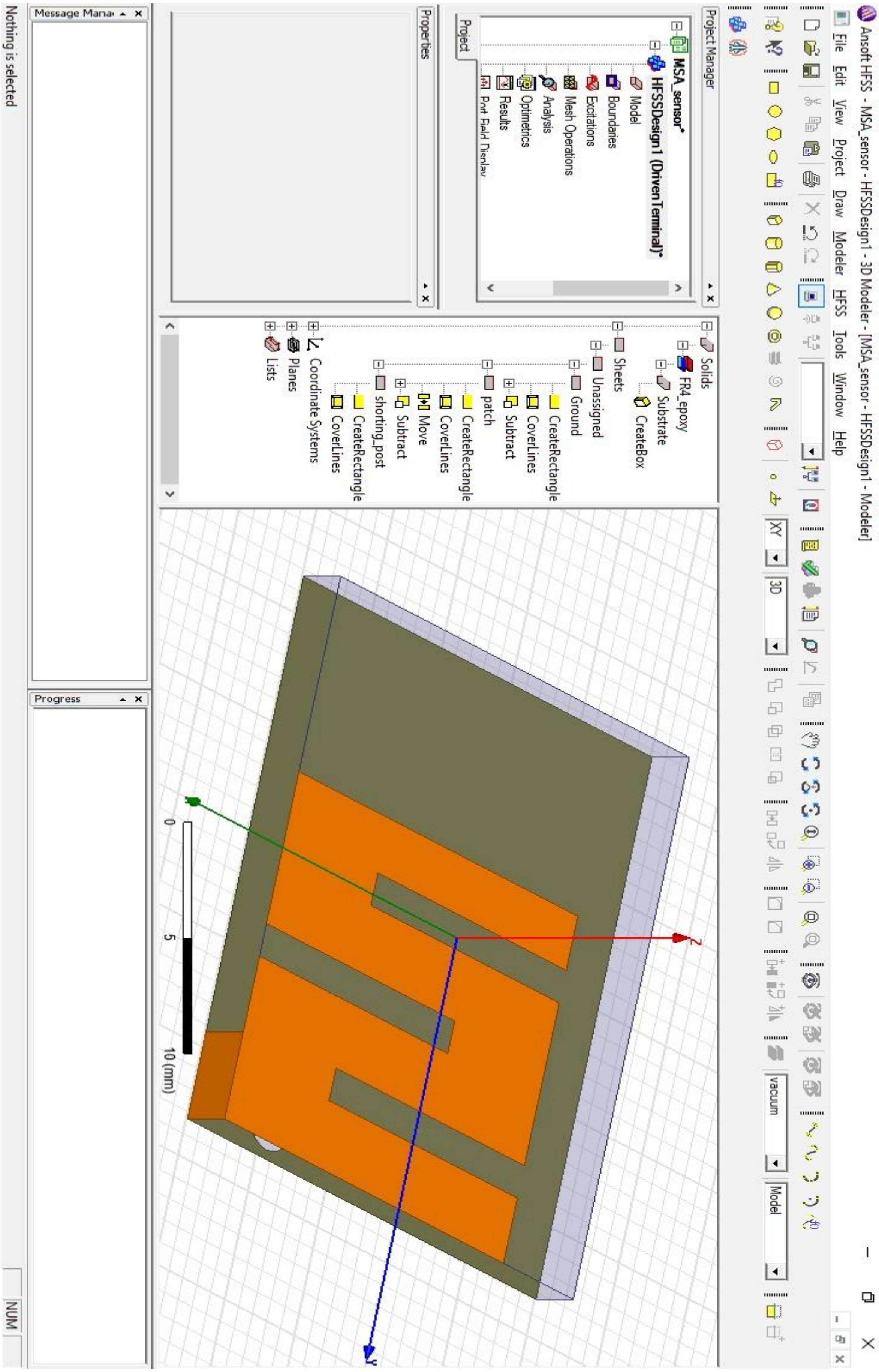


Select “Ground” ⟶ Ctrl+ Select “Circle1” ⟶ Select “Subtract” ⟶ Ok.

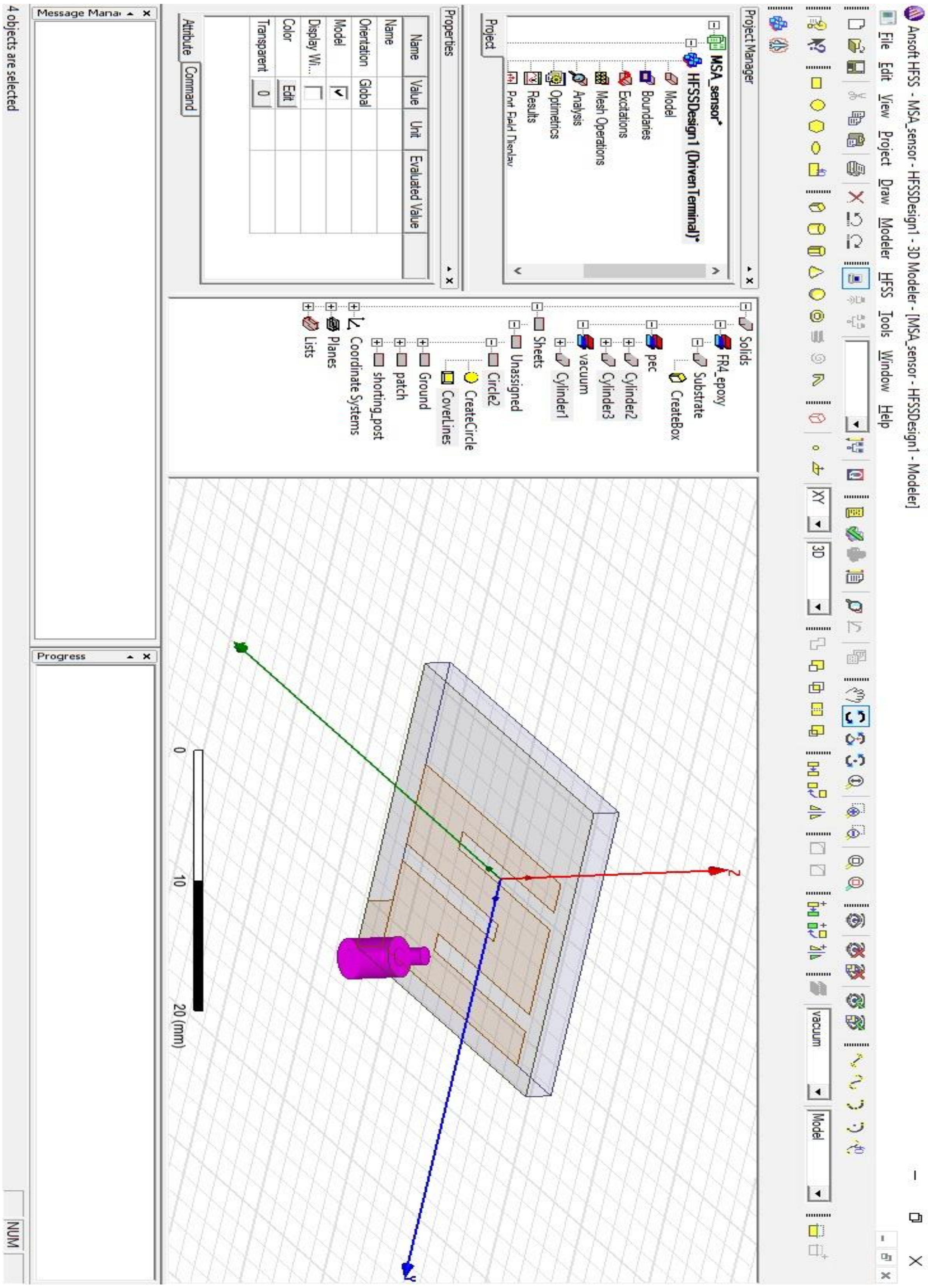


Similarly slot rectangles are made and subtracted from Patch.

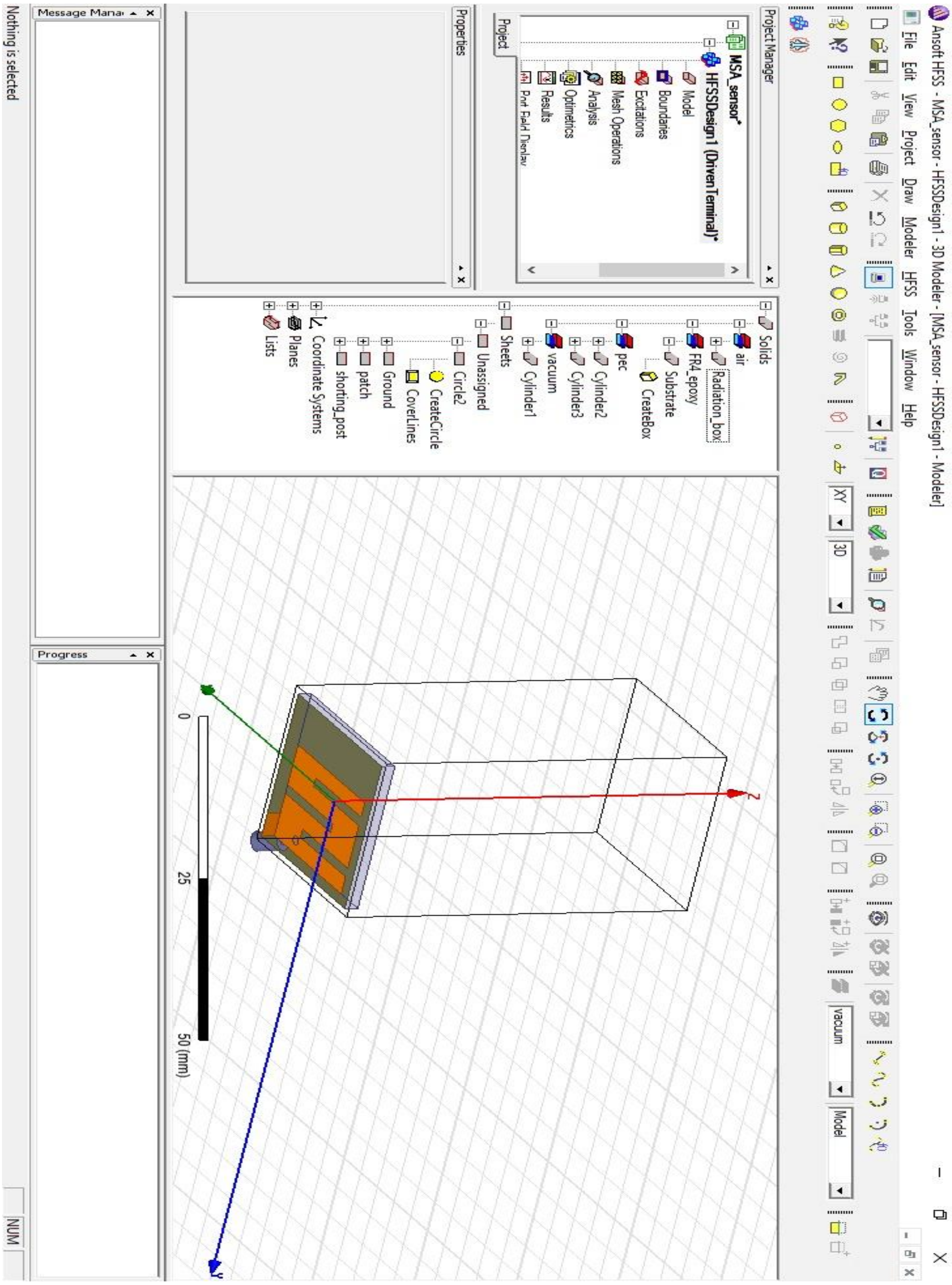



Ansoft HFSS - MSA_sensor - HFSSDesign1 - 3D Modeler - [MSA_sensor - HFSSDesign1 - Modeler]
File Edit View Project Draw Modeler HFSS Tools Window Help
Project Manager
MSA_sensor*
HFSSDesign1 (DrivenTerminal)*
Model
Boundaries
Excitations
Mesh Operations
Analysis
Optimetrics
Results
Project
Properties
Solids
FR4_epoxy
Substrate
CreateBox
Sheets
Unassigned
Ground
CreateRectangle
CoverLines
Subtract
patch
CreateRectangle
CoverLines
Move
Subtract
shorting_post
CreateRectangle
CoverLines
Coordinate Systems
Planes
Lists
XY
3D
vacuum
Model
0
5
10 (mm)
Message Manager
Progress
Nothing is selected
NUM

➢ Making coaxial connector using cylinders (“Draw Cylinder”) and placing a circle at the back of it. The central Cylinders is to be assign “pec” material. And outer cylinder is assigned “vacuum”.



➢ Drawing air box by selecting “Draw box” and assigning it Material “air”. And editing its properties (Name, Color, and Transparency).



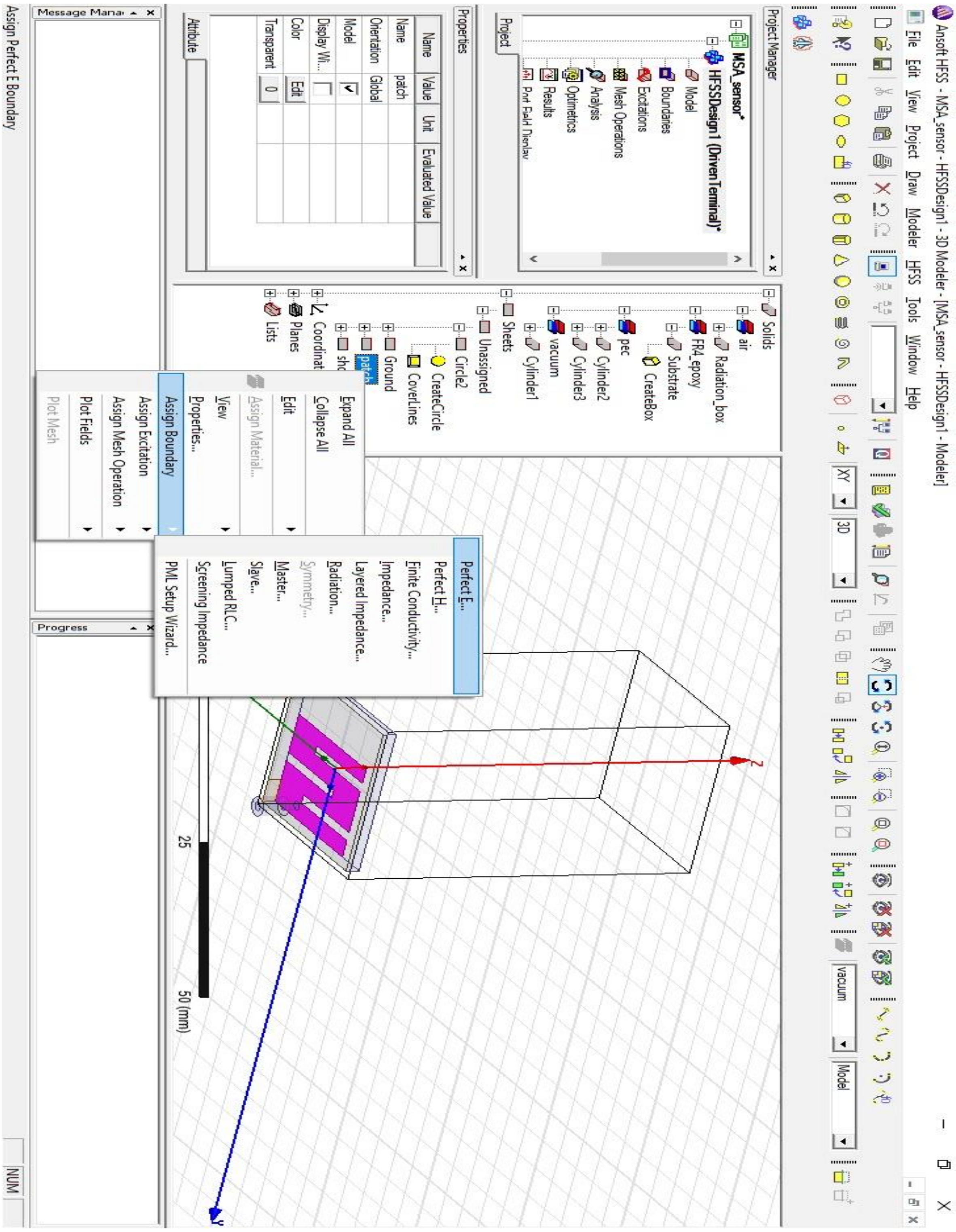
Now the model of the microstrip antenna sensor is completed i.e. Step 1.

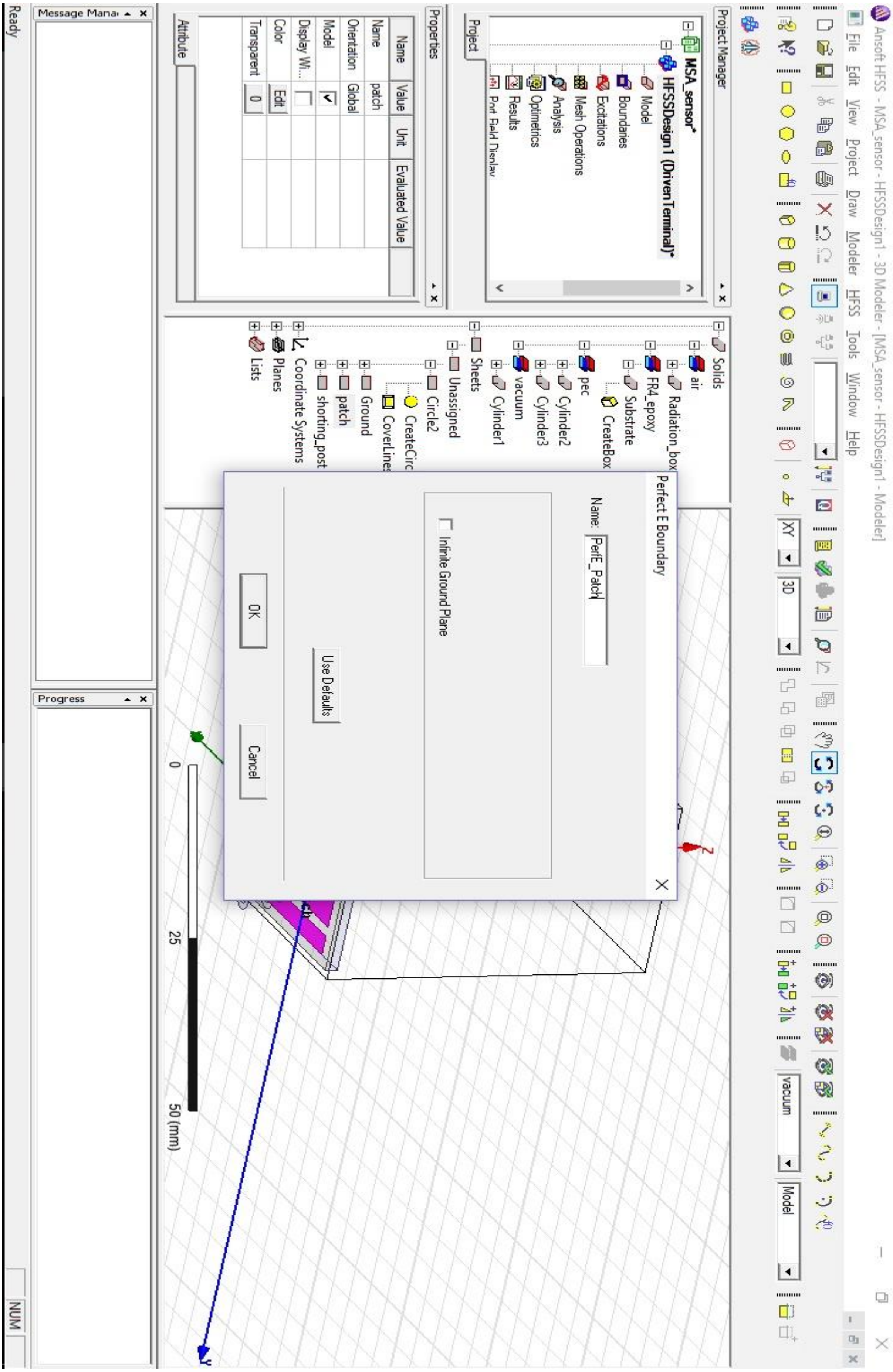
Step2: Assign boundaries

- We had to assign boundary condition to patch, ground and air box.

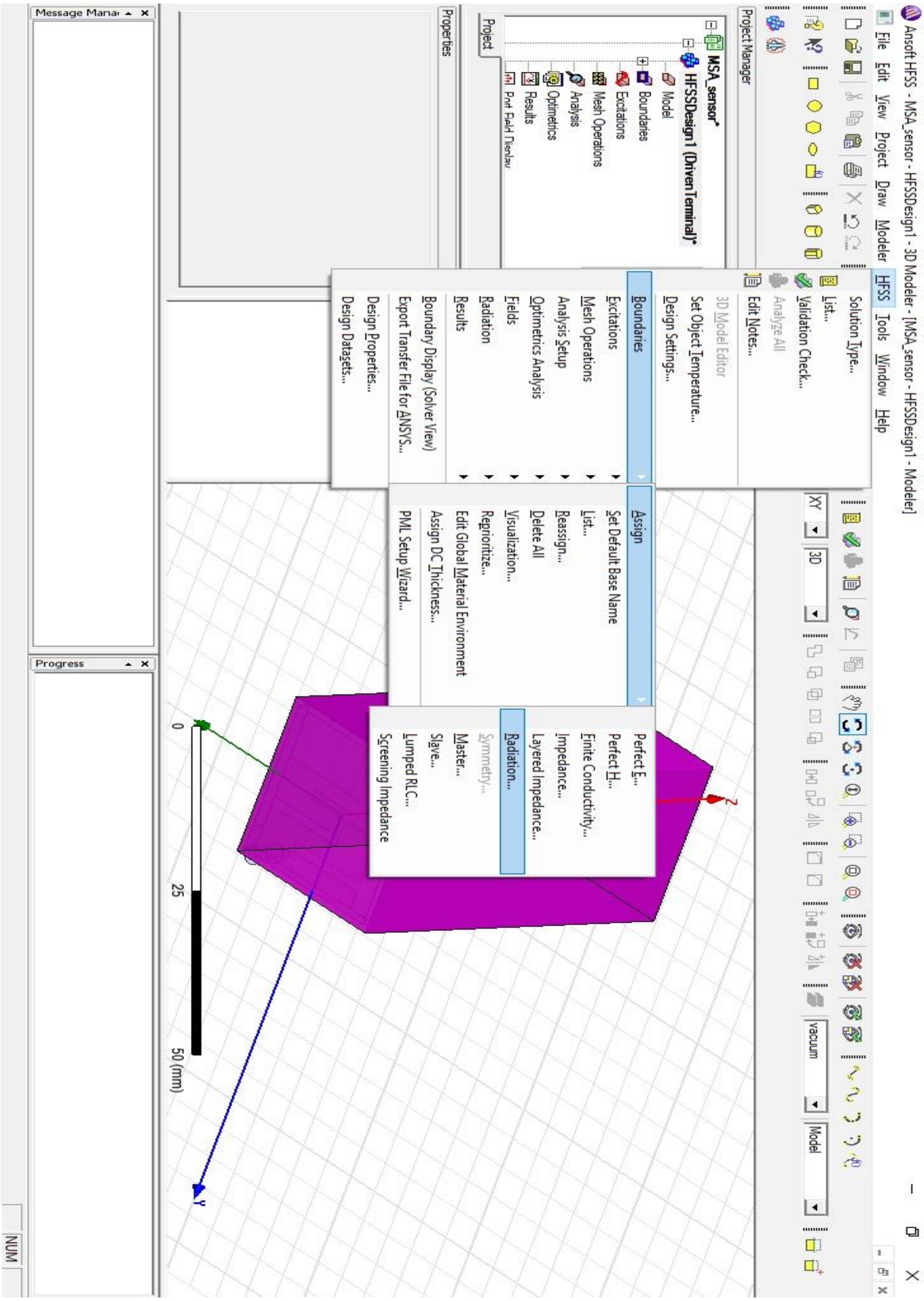
Right click on “patch” ⟶ Assign Boundary ⟶ Perfect E.

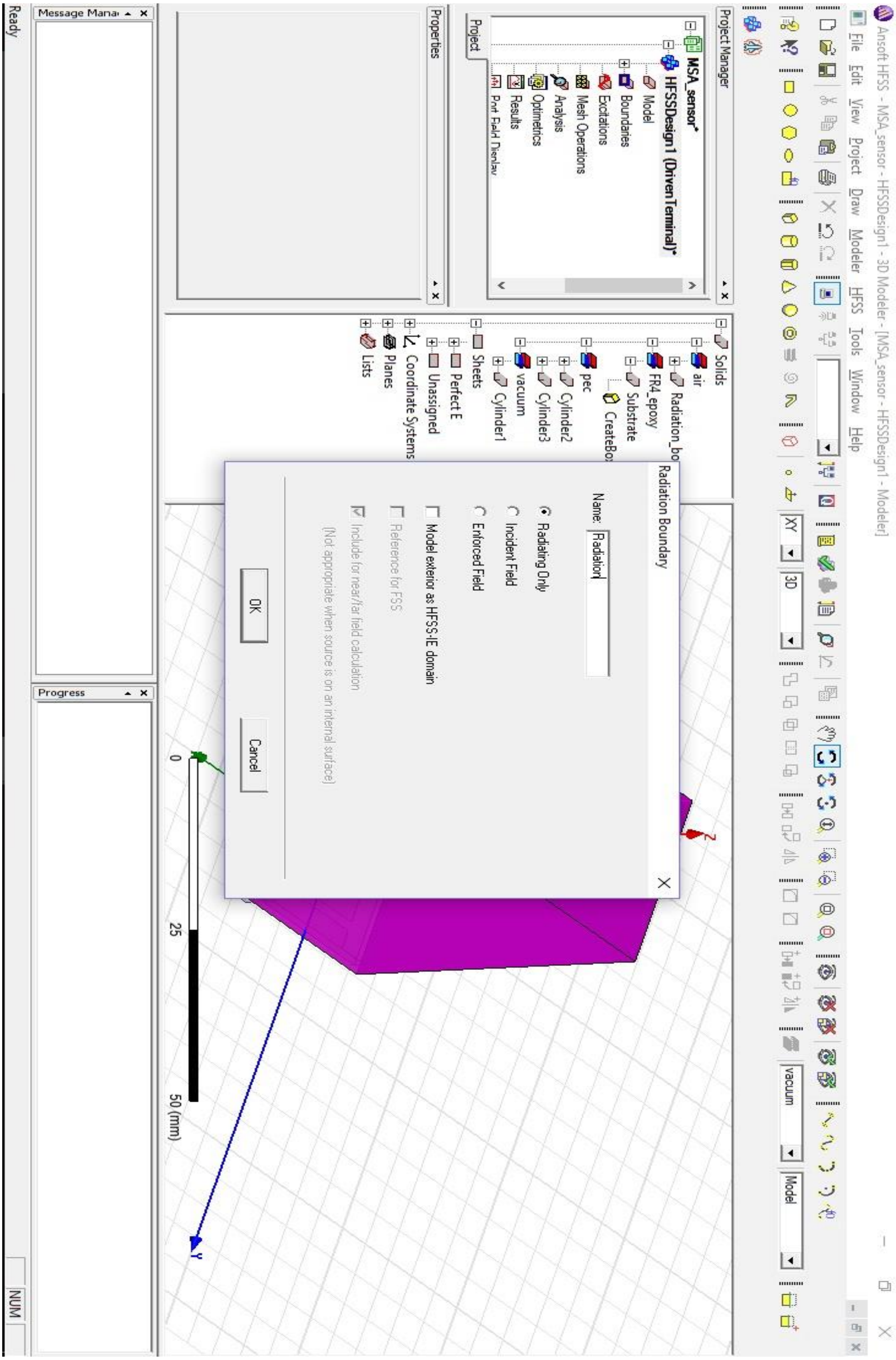
Then, Save it as Name “PerfE_patch”.



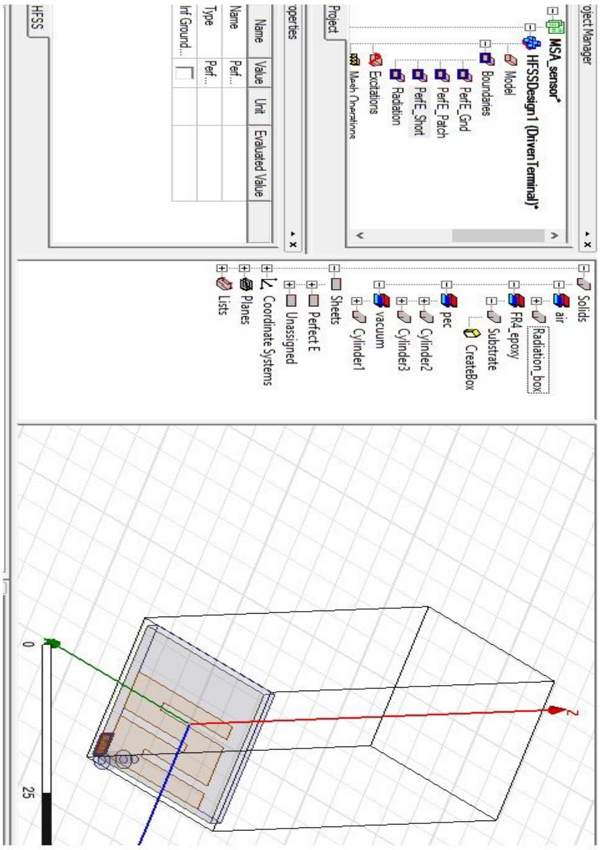

Ansoft HFSS - MSA_sensor - HFSSDesign1 - 3D Modeler - [MSA_sensor - HFSSDesign1 - Modeler]
Perfect E Boundary
Name:
PerfE_Patch
Infinite Ground Plane
Use Defaults
OK
Cancel

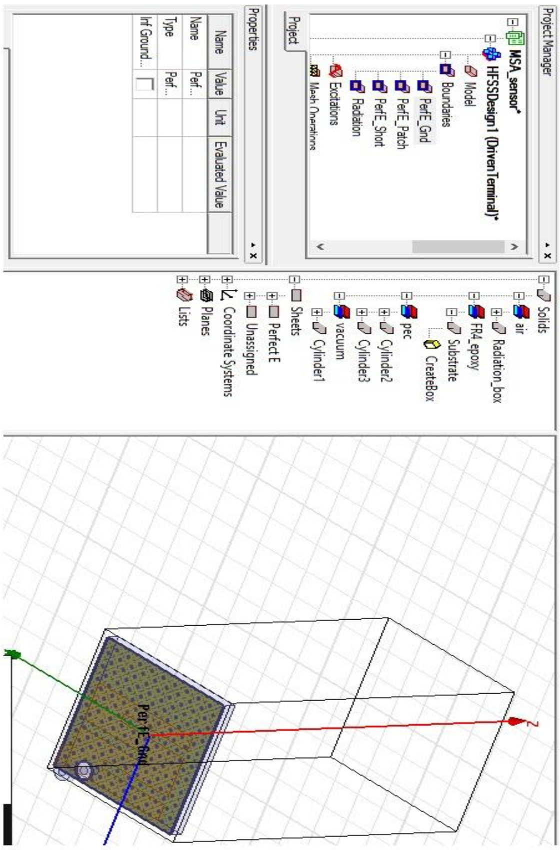
- Similarly repeat steps for Ground & Shorting Post.
- Select Faces of the air box except the face where there is micrstrip antenna is present and assign it “radiation boundary”.

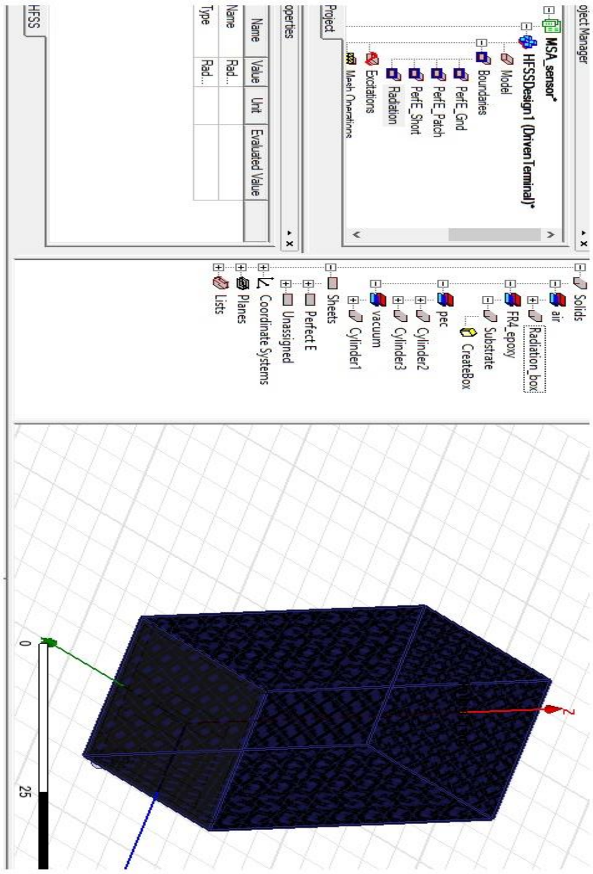


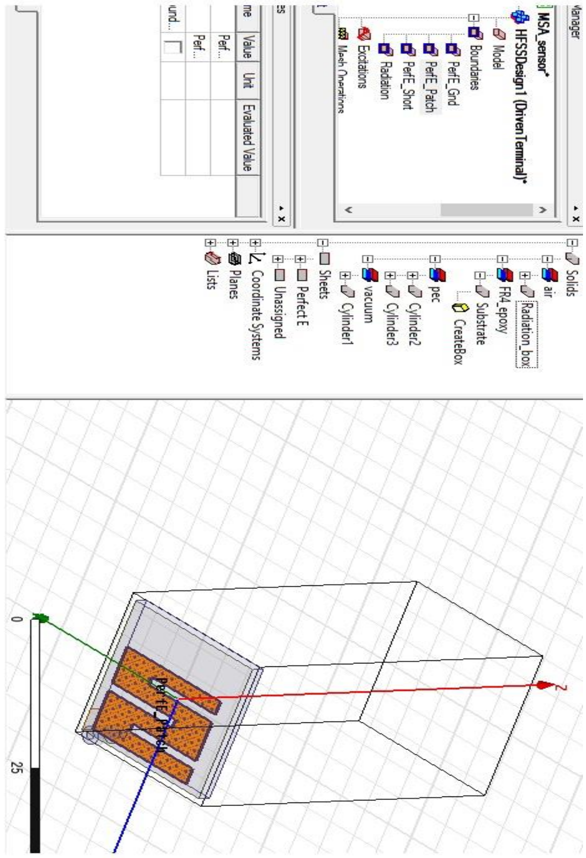

Ansoft HFSS - MSA_sensor - HFSSDesign1 - 3D Modeler - [MSA_sensor - HFSSDesign1 - Modeler]
File Edit View Project Draw Modeler HFSS Tools Window Help
Project Manager
MSA_sensor*
HFSSDesign1 (DrivenTerminal)*
Model
Boundaries
Excitations
Mesh Operations
Analysis
Optimetrics
Results
Project
Properties
Solids
air
Radiation_bo
FR4_epoxy
Substrate
pec
Cylinder2
Cylinder3
vacuum
Cylinder1
Sheets
Perfect E
Unassigned
Coordinate Systems
Planes
Lists
Radiation Boundary
Name: Radiation
Radiating Only
Incident Field
Enforced Field
Model exterior as HFSS-IE domain
Reference for FSS
Include for near/far field calculation
(Not appropriate when source is on an internal surface)
OK
Cancel
0
25
50 (mm)
XY
3D
vacuum
Model
Message Mana
Progress
Ready
NUM

- Now the boundaries have been assigned.





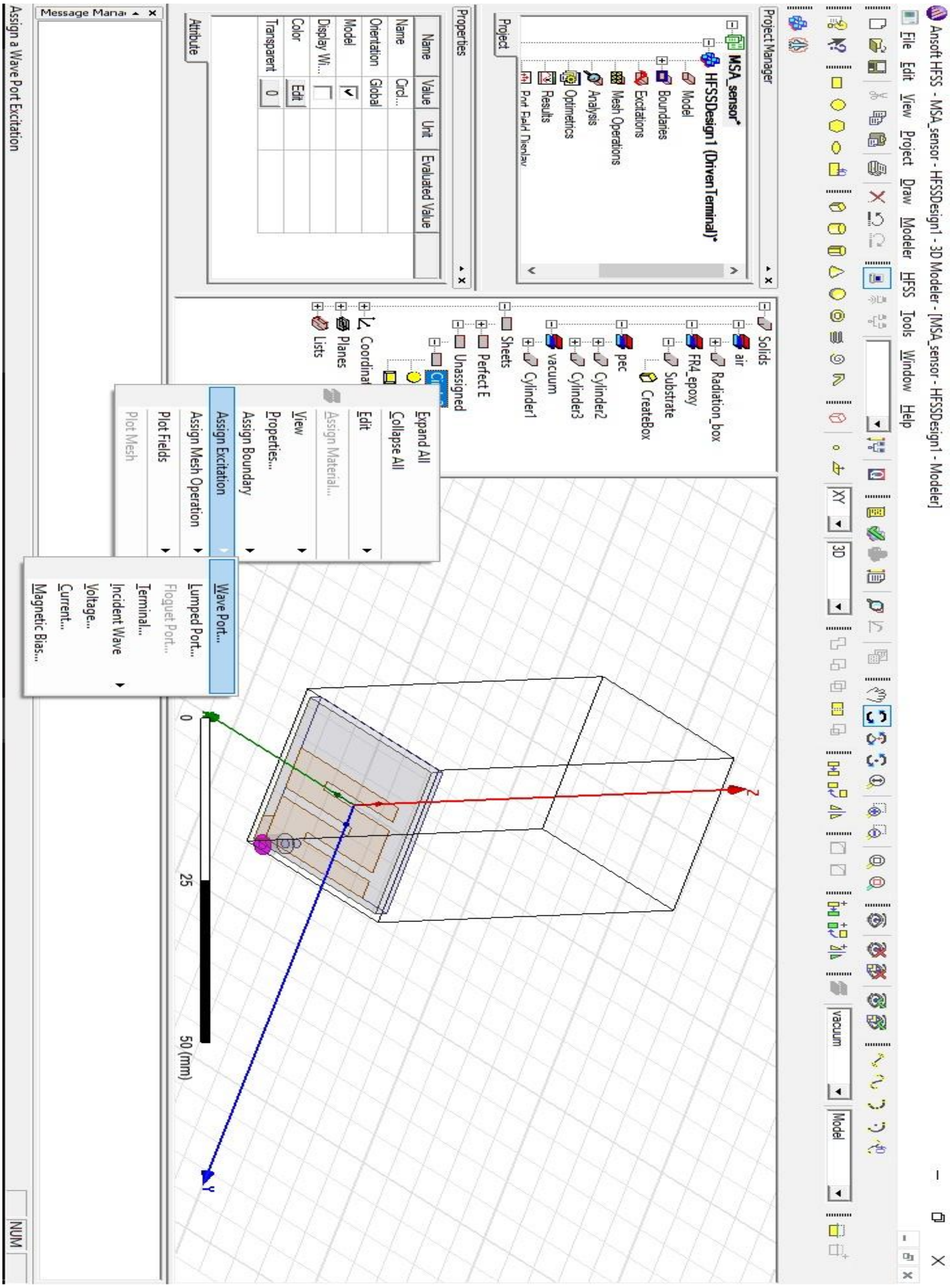


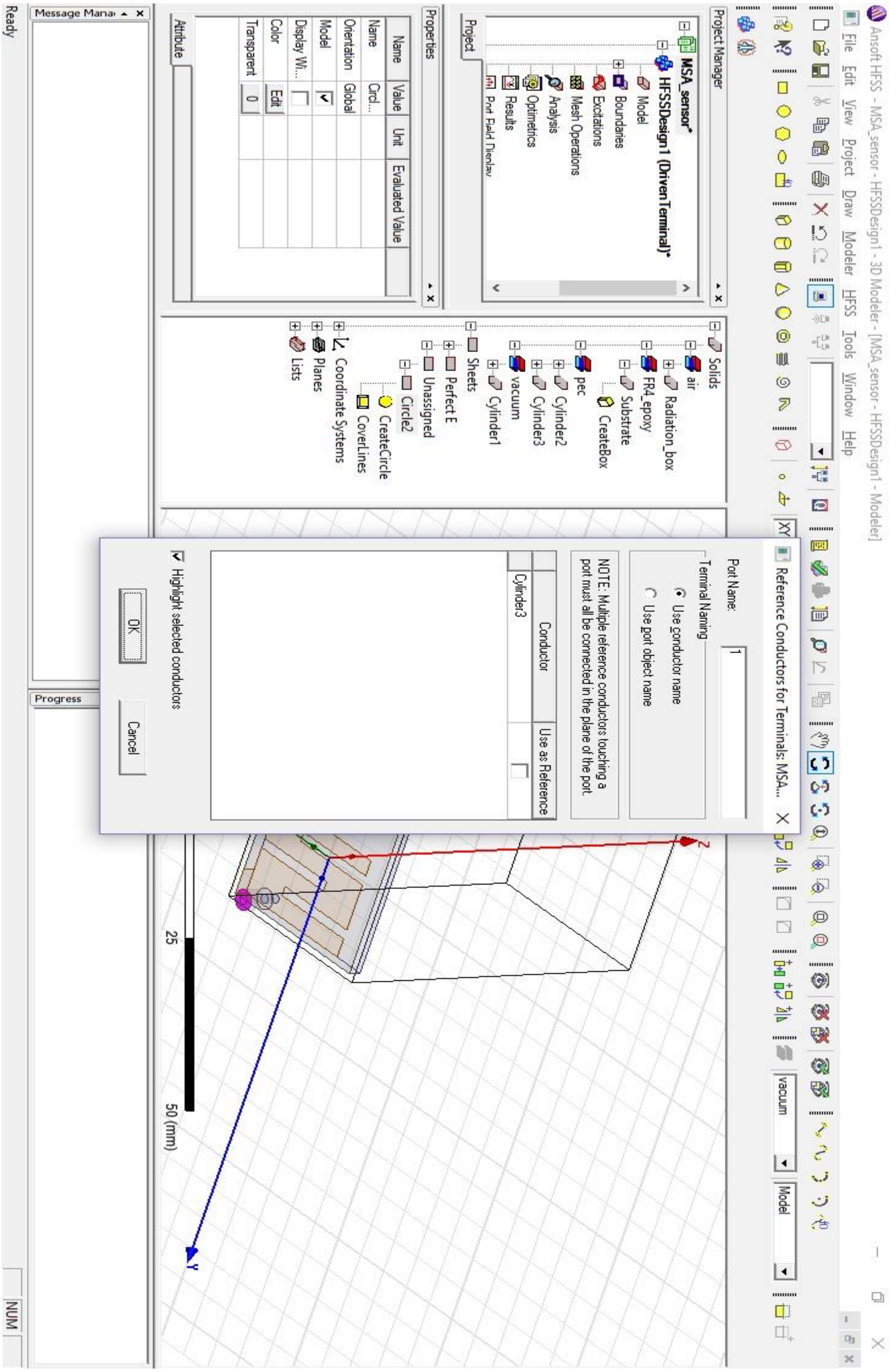


Step3: Assign excitation

➢ The excitation is assign to the circle placed at the back of the coaxial connector drawn.

Right Click on "Circle2" ⟶ Assign excitation ⟶ Wave Port ⟶ Enter ⟶ Ok.



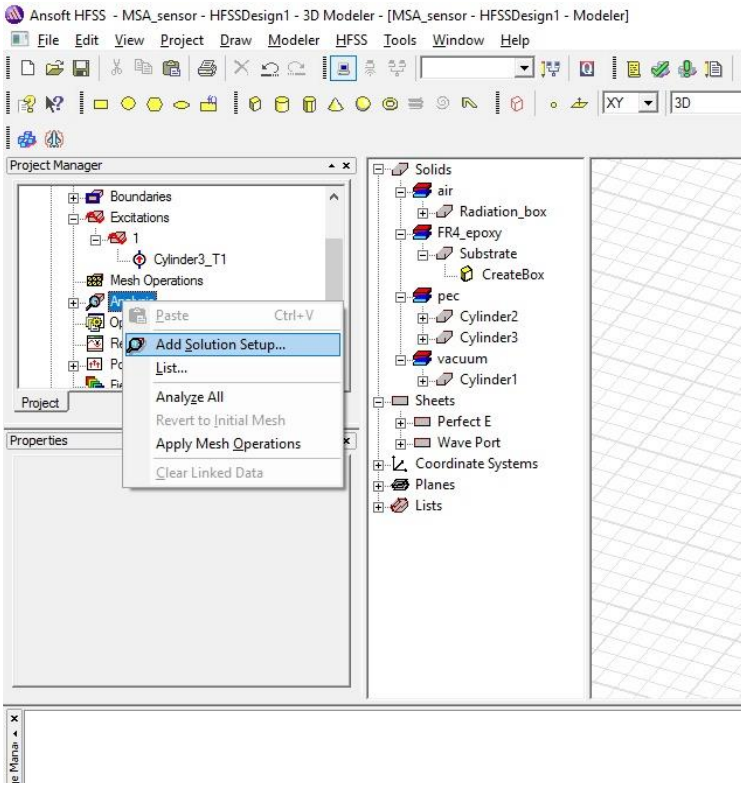

Ansoft HFSS - MSA_sensor - HFSSDesign1 - 3D Modeler - [MSA_sensor - HFSSDesign1 - Modeler]
File Edit View Project Draw Modeler HFSS Tools Window Help
Project Manager
MSA_sensor*
HFSSDesign1 (DrivenTerminal)*
Model
Boundaries
Excitations
Mesh Operations
Analysis
Optimetrics
Results
Port Field Display
Project
Properties
Name
Value
Unit
Evaluated Value
Name
Circl...
Orientation
Global
Model
Display Wi...
Color
Edit
Transparent
0
Attribute
Solids
air
Radiation_box
FR4_epoxy
Substrate
CreateBox
pec
Cylinder2
Cylinder3
vacuum
Cylinder1
Sheets
Perfect E
Unassigned
Circle2
CreateCircle
CoverLines
Coordinate Systems
Planes
Lists
Reference Conductors for Terminals: MSA...
Port Name:
1
Terminal Naming
Use conductor name
Use port object name
NOTE: Multiple reference conductors touching a port must all be connected in the plane of the port.
Conductor
Use as Reference
Cylinder3
Highlight selected conductors
OK
Cancel
vacuum
Model
25
50 (mm)
Message Mana
Progress
Ready
NUM

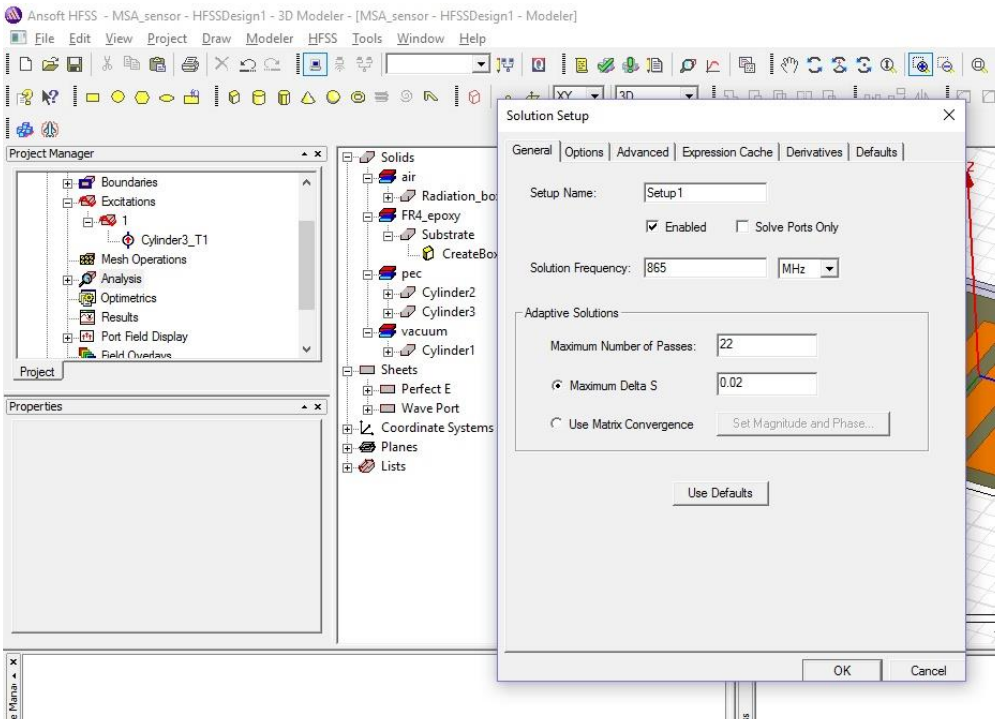

Project Manager
MSA_sensor*
HFSSDesign1 (DrivenTerminal)*
Model
Boundaries
Excitations
1
Cylinder3_T1
Mesh Operations
Analysis
Project
Properties
Name
Value
Unit
Evaluated Value
Name
1
Type
Wa...
Deembed
Deembed ...
0
mm
0mm
Num Termi...
1
Renorm All...
Solids
air
Radiation_box
FR4_epoxy
Substrate
CreateBox
pec
Cylinder2
Cylinder3
vacuum
Cylinder1
Sheets
Perfect E
Wave Port
Coordinate Systems
Planes
Lists

Step4: Setup the solution

- In this step a solution setup and sweep frequency is added.

In project manager window, Right click on “Analysis” ⟶ Add Solution Setup ⟶ enter solution frequency (866MHz) & No. of passes 22.

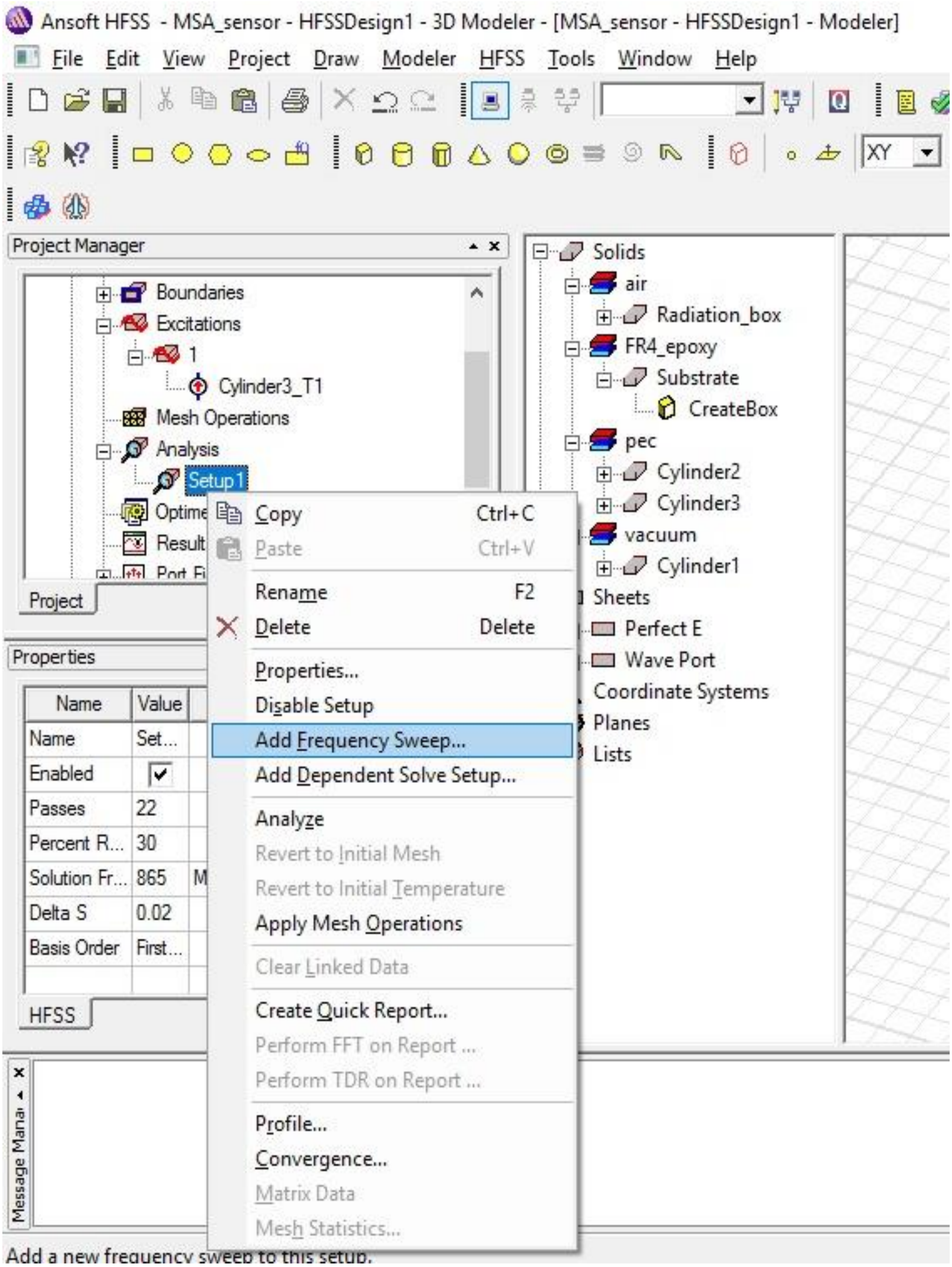


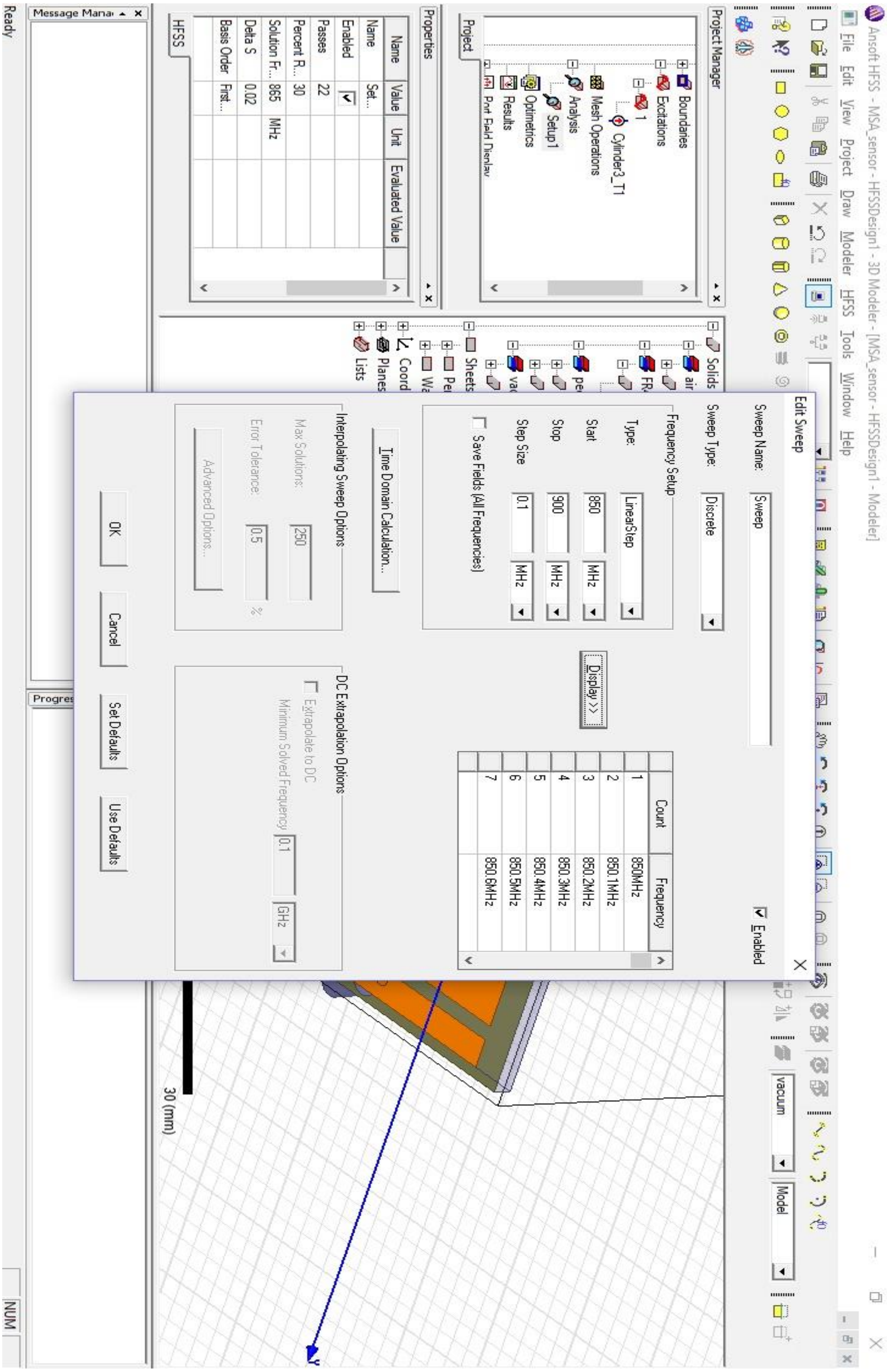


➢ Now including sweep frequency.

Expand Analysis ⟶ Right click on Setup1 ⟶ Add Frequency Sweep ⟶ Edit

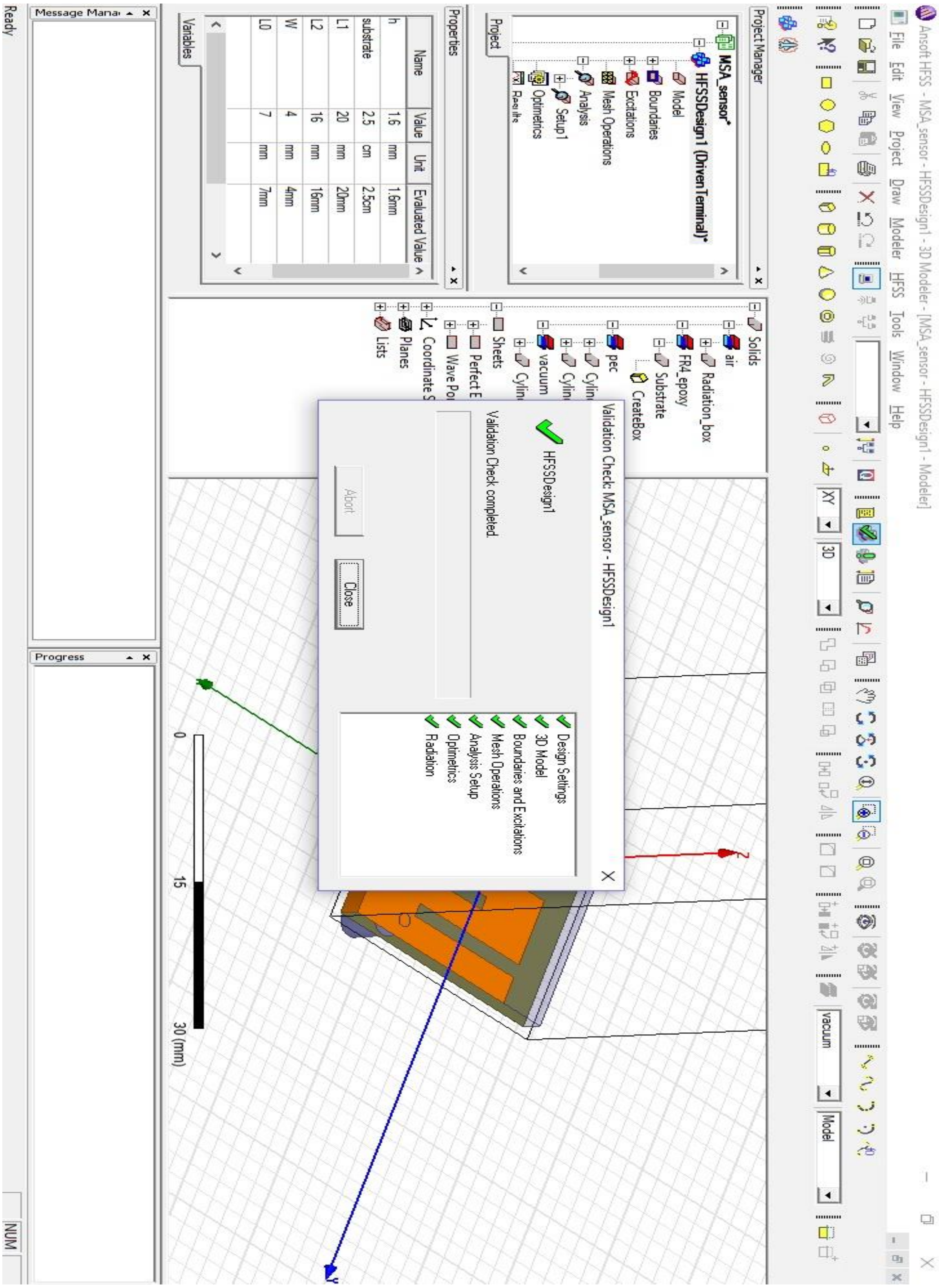
Sweep type "Discrete", Enter Start & End Frequency, and Step size.

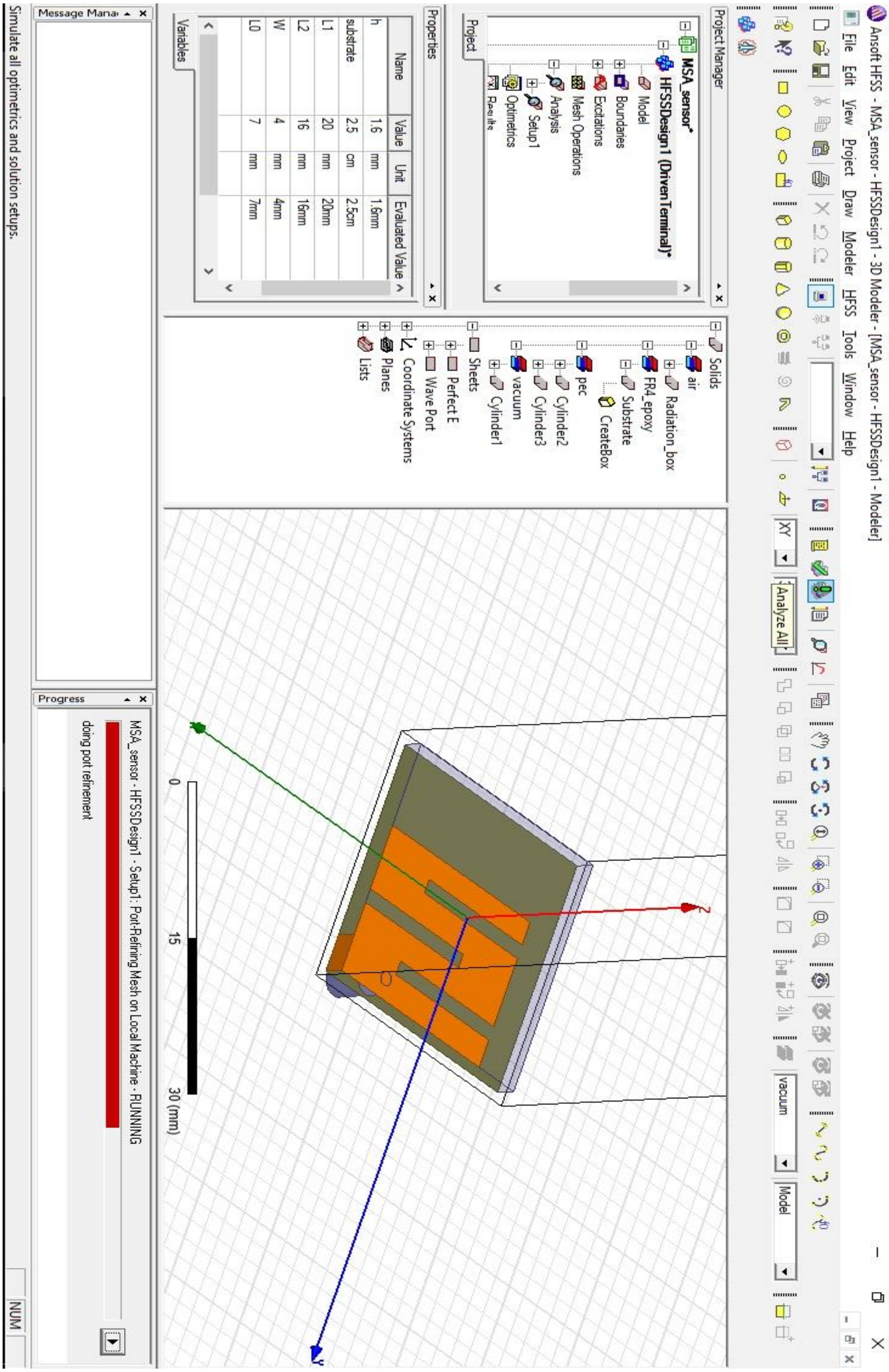



Ansoft HFSS - MSA_sensor - HFSSDesign1 - 3D Modeler - [MSA_sensor - HFSSDesign1 - Modeler]
File Edit View Project Draw Modeler HFSS Tools Window Help
Project Manager
Boundaries
Excitations
Cylinder3_T1
Mesh Operations
Analysis
Setup1
Optimetrics
Results
Properties
Name Value Unit Evaluated Value
Name Set...
Enabled
Passes 22
Percent R... 30
Solution Fr... 865 MHz
Delta S 0.02
Basis Order First...
HFSS
Message Manager
Edit Sweep
Sweep Name: Sweep
Enabled
Sweep Type: Discrete
Frequency Setup
Type: LinearStep
Start 850 MHz
Stop 900 MHz
Step Size 0.1 MHz
Display >>
Save Fields (All Frequencies)
Count Frequency
1 850MHz
2 850.1MHz
3 850.2MHz
4 850.3MHz
5 850.4MHz
6 850.5MHz
7 850.6MHz
Time Domain Calculation...
Interpolating Sweep Options
Max Solutions: 250
Error Tolerance: 0.5 %
Advanced Options...
DC Extrapolation Options
Extrapolate to DC
Minimum Solved Frequency 0.1 GHz
OK
Cancel
Set Defaults
Use Defaults
30 (mm)
vacuum
Model
Ready
NUM

Step5: Solve

➢ After adding solution setup we will do “validation” & execute our model by clicking on “Analyse”.




Ansoft HFSS - MSA_sensor - HFSSDesign1 - 3D Modeler - [MSA_sensor - HFSSDesign1 - Modeler]
File Edit View Project Draw Modeler HFSS Tools Window Help
Project Manager
MSA_sensor*
HFSSDesign1 (DrivenTerminal)*
Model
Boundaries
Excitations
Mesh Operations
Analysis
Setup1
Optimetrics
Results
Project
Properties
Name
Value
Unit
Evaluated Value
h
1.6
mm
1.6mm
substrate
2.5
cm
2.5cm
L1
20
mm
20mm
L2
16
mm
16mm
W
4
mm
4mm
L0
7
mm
7mm
Variables
Solids
air
Radiation_box
FR4_epoxy
Substrate
CreateBox
pec
Cylinder2
Cylinder3
vacuum
Cylinder1
Sheets
Perfect E
Wave Port
Coordinate Systems
Planes
Lists
XY
Analyze All
vacuum
Model
0
15
30 (mm)
Message Manager
Progress
MSA_sensor - HFSSDesign1 - Setup1: Port-Refining Mesh on Local Machine - RUNNING
doing port refinement
Simulate all optimetrics and solution setups.
NUM

Step6: Post processing the Results

- After successful analysis, the S11 parameter is retrieved and by varying the slot dimensions and the shorting post width, the expected result is achieved.
- The container layer and Sample layer (Milk powder layer with ε =1.9) is added above the microstrip antenna sensor and final result is retrieved.

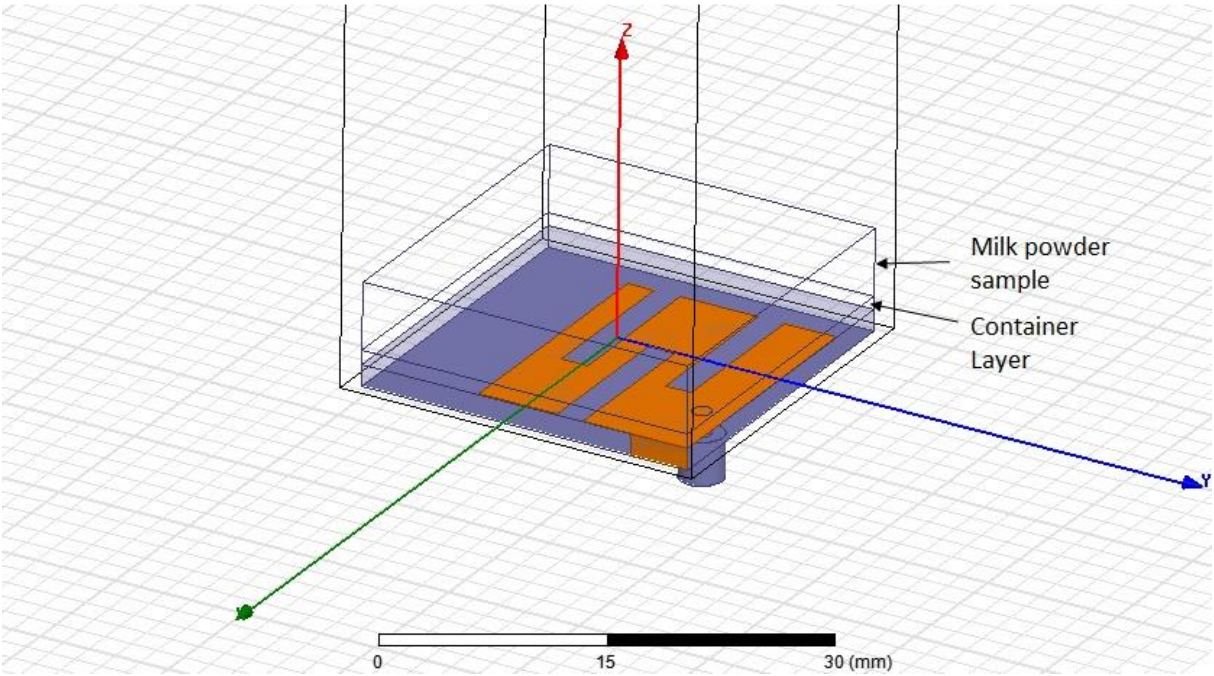
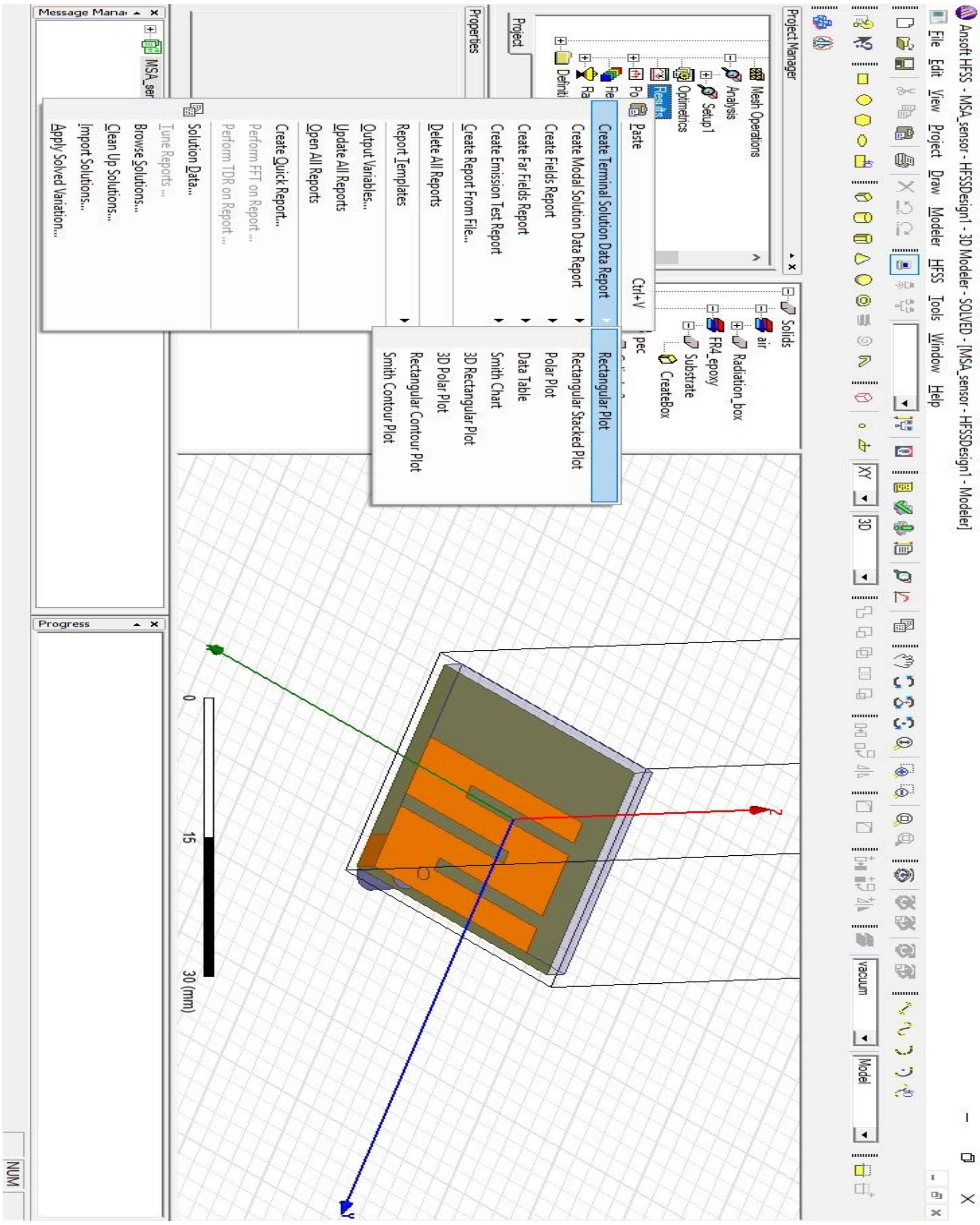
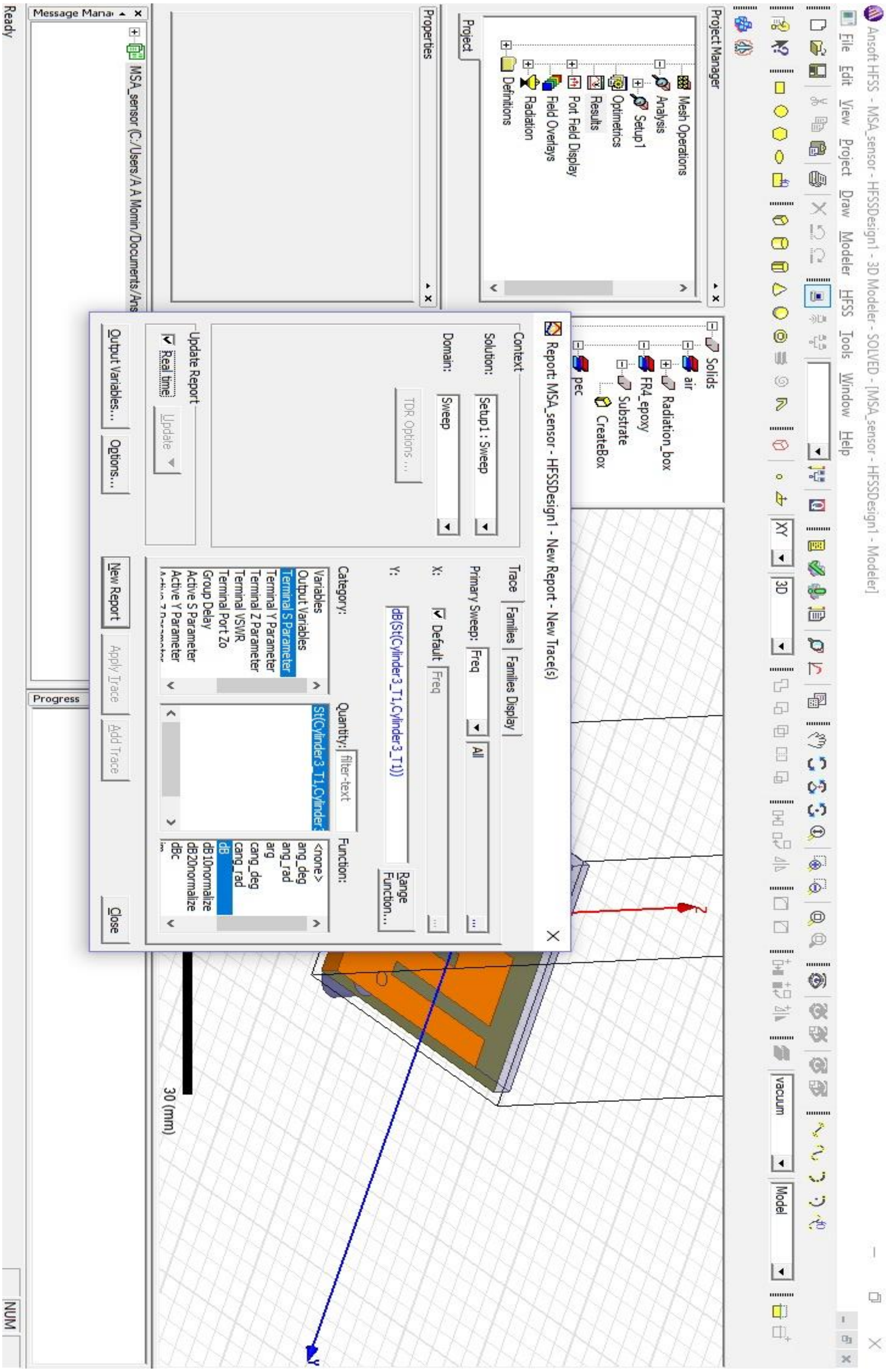


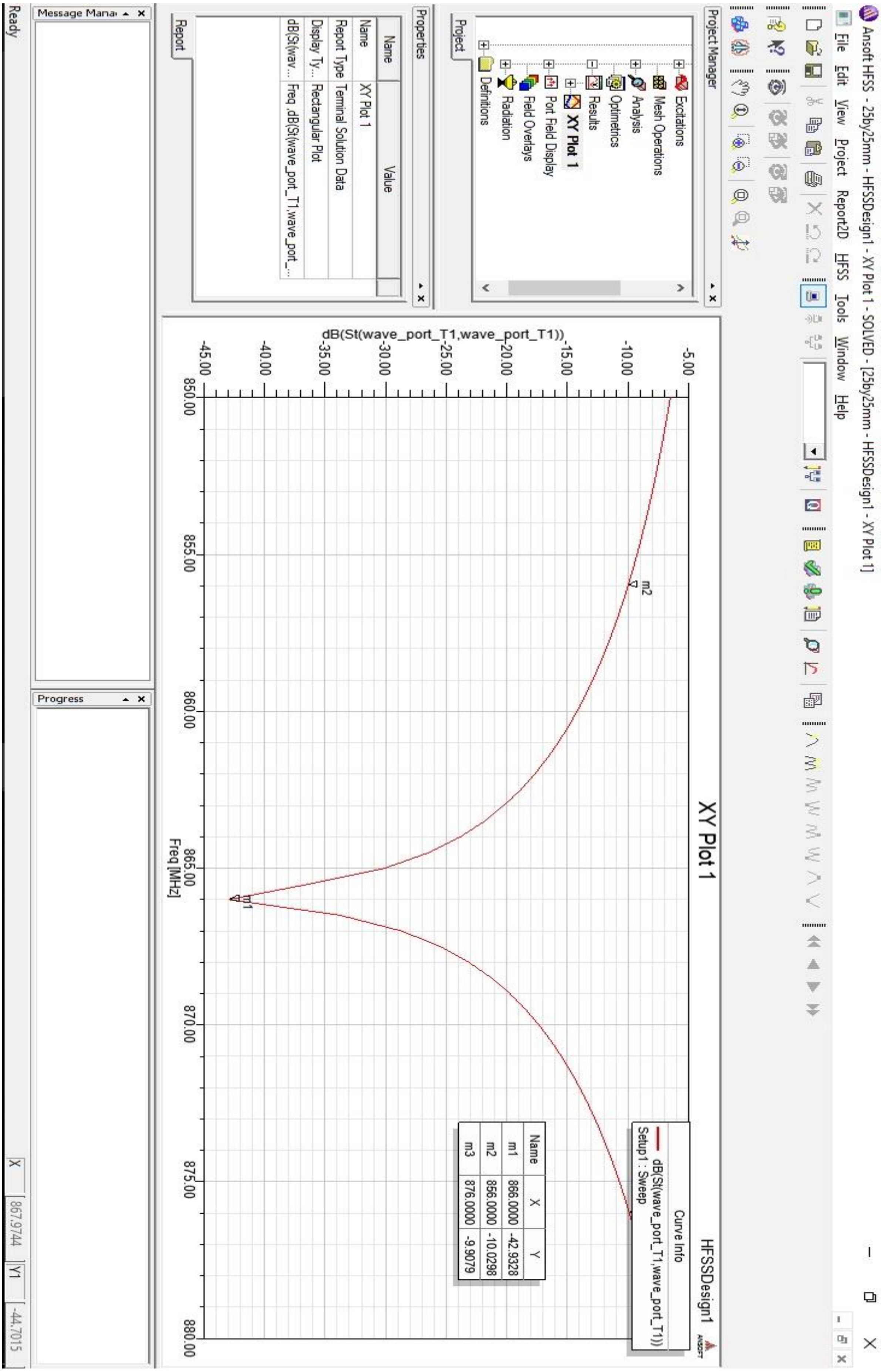
Figure4.2 *Mictrostrip Antenna Sensor*

Right click on Result ⟶ Create Terminal Solution Data Report ⟶ Rectangular Plot ⟶ New report.





Ansoft HFSS - MSA_sensor - HFSSDesign1 - 3D Modeler - SOLVED - [MSA_sensor - HFSSDesign1 - Modeler]
File Edit View Project Draw Modeler HFSS Tools Window Help
Project Manager
Mesh Operations
Analysis
Setup1
Optimetrics
Results
Port Field Display
Field Overlays
Radiation
Definitions
Project
Properties
Message Mana
MSA_sensor (C:/Users/A A Momin/Documents/Ans
Progress
Ready
NUM
Solids
air
Radiation_box
FR4_epoxy
Substrate
CreateBox
pec
Report: MSA_sensor - HFSSDesign1 - New Report - New Trace(s)
Context
Solution: Setup1 : Sweep
Domain: Sweep
TDR Options ...
Update Report
Real time
Update
Output Variables...
Options...
Trace
Families
Families Display
Primary Sweep: Freq
All
X: Default Freq
Y: dB(St(Cylinder3_T1,Cylinder3_T1))
Range Function...
Category:
Variables
Output Variables
Terminal S Parameter
Terminal Y Parameter
Terminal Z Parameter
Terminal VSWR
Terminal Port Zo
Group Delay
Active S Parameter
Active Y Parameter
Quantity:
filter-text
St(Cylinder3_T1,Cylinder3
Function:
<none>
ang_deg
ang_rad
arg
cang_deg
cang_rad
dB
dB10normalize
dB20normalize
dBc
New Report
Apply Trace
Add Trace
Close
XY
3D
vacuum
Model
30 (mm)

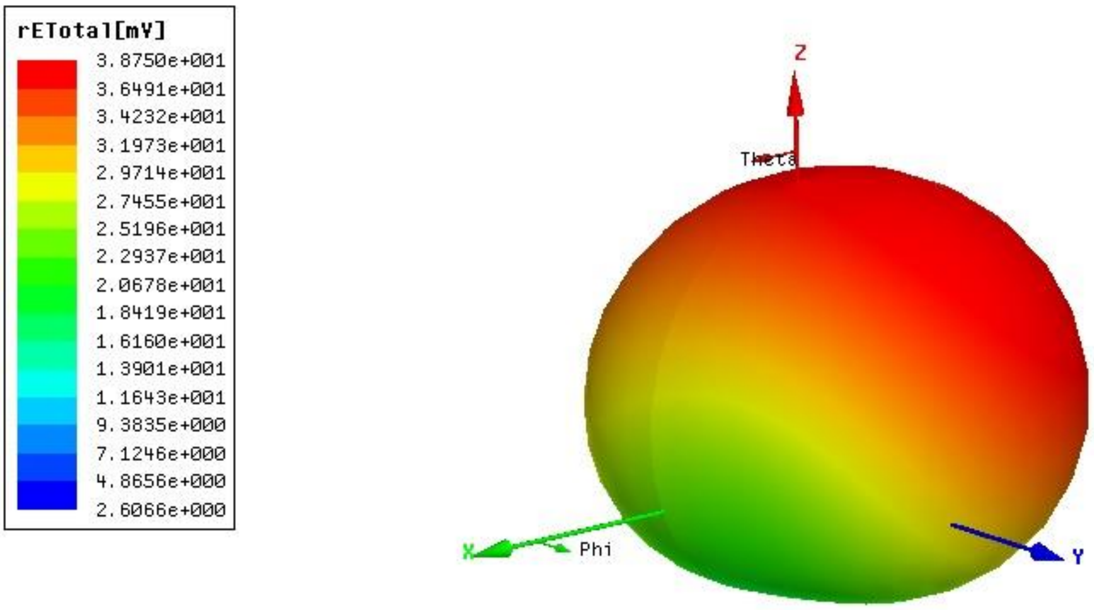


Ansoft HFSS - 25by25mm - HFSSDesign1 - XY Plot 1 - SOLVED - [25by25mm - HFSSDesign1 - XY Plot 1]
XY Plot 1
HFSSDesign1
dB(St(wave_port_T1,wave_port_T1))
Freq [MHz]
Curve Info
dB(St(wave_port_T1,wave_port_T1))
Setup1 : Sweep
Name X Y
m1 866.0000 -42.9328
m2 856.0000 -10.0298
m3 876.0000 -9.9079

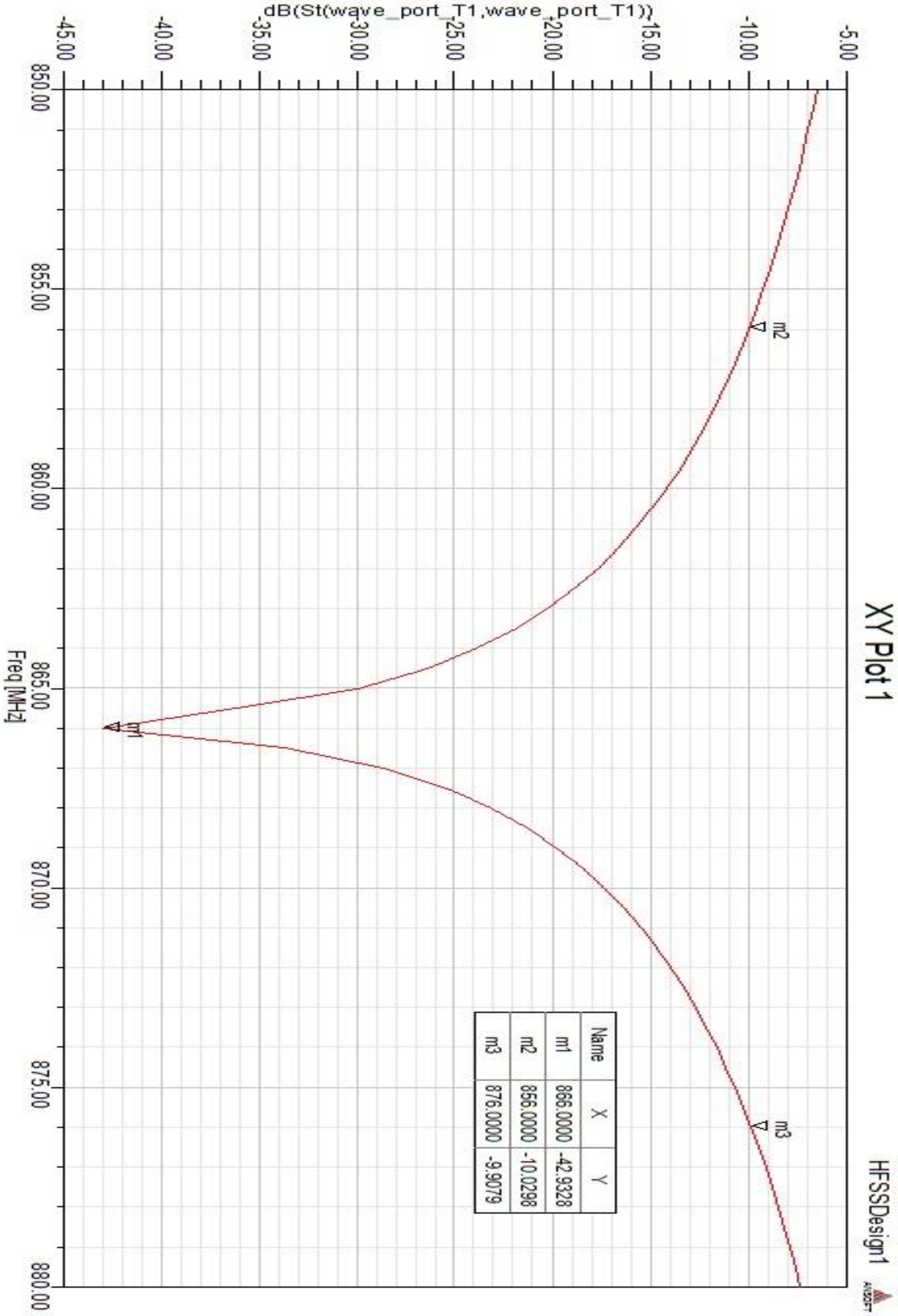
Chapter 5

Results and Discussions

3D Polar Plot:



S11 Plot:



XY Plot 1
HFSSDesign1
dB(St(wave_port_T1,wave_port_T1))
Freq [MHz]
-45.00
-40.00
-35.00
-30.00
-25.00
-20.00
-15.00
-10.00
-5.00
850.00
855.00
860.00
865.00
870.00
875.00
880.00
m1
m2
m3
Name | X | Y
m1 | 866.0000 | -42.9328
m2 | 856.0000 | -10.0298
m3 | 876.0000 | -9.9079

Change in Resonant Frequency With Respect to Change in Dielectric Constant of the Sample:

The Resonant frequency is measured by varying the permittivity of the sample. The observation obtained from the simulation in shown in table 5.1.

Table 5.1 *Resonant Frequency Shift with Respect to Permittivity of Sample*

Permittivity of Milk Powder Sample (ε)	Resonant Frequency (MHz)	S11 (dB)
1.8	866.5	-37.19
1.9	**865.9**	**-43.58**
2.0	865.8	-39.86
2.1	864.7	-43.12
2.2	863.7	-48.65

Expected Outcome:

A rectangular microstrip patch antenna of,

- small size less than 5cm×5cm
- frequency within 865MHz to 867MHz
- Return Loss: Less than -10dB

Simulation Results:

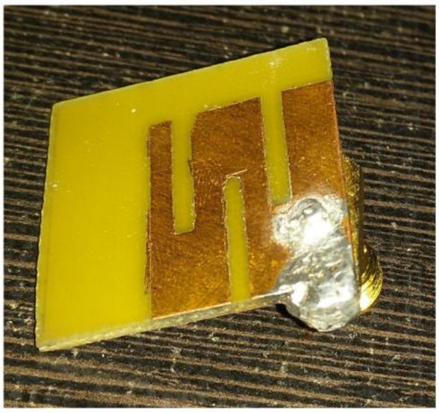
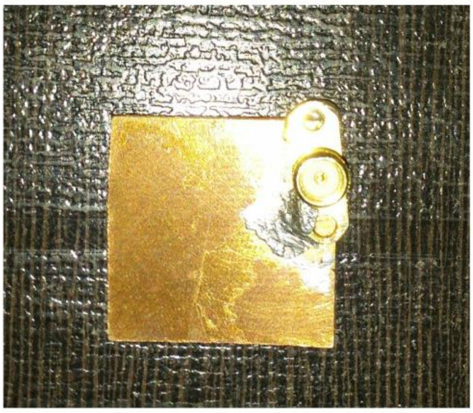
- Patch Length (L1) = 20mm
- Patch Width (L2) = 16mm
- Height (h) = 1.6mm
- Total Dimension = 25mm
- Dielectric Constant (εr) = 4.4

- Resonant Frequency (fr) = 865.9MHz
- The Resonant Frequency is inversely proportional to the permittivity of milk powder sample.

The results of the simulation is as per the expectation. The S11 plot which is the reflection coefficient shows a good plot. Its value at the resonant frequency goes up to -40dB which is good enough. The present project is concern with the result in the form of S11 plot whereas other parameter does not affect the aim of the project. The gain measured in simulation is very low but does not affect the aim of the project as the microstrip antenna is used as a sensor rather than for communication purpose. The reason for the less gain may be the miniaturization techniques used.

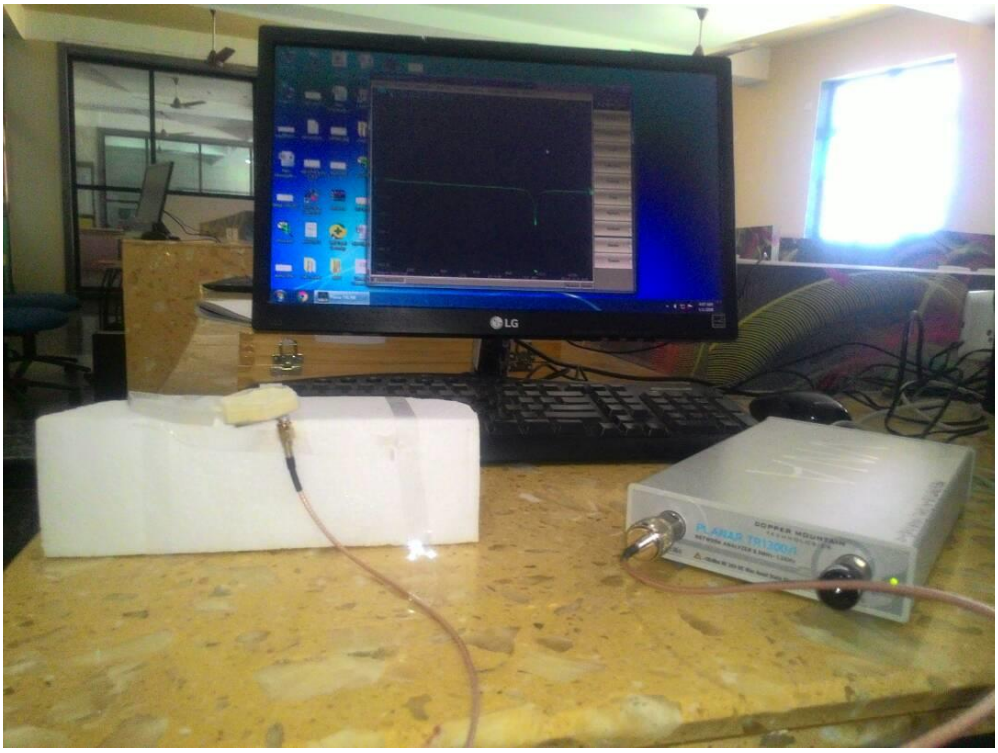
Practical Results:

Hardware

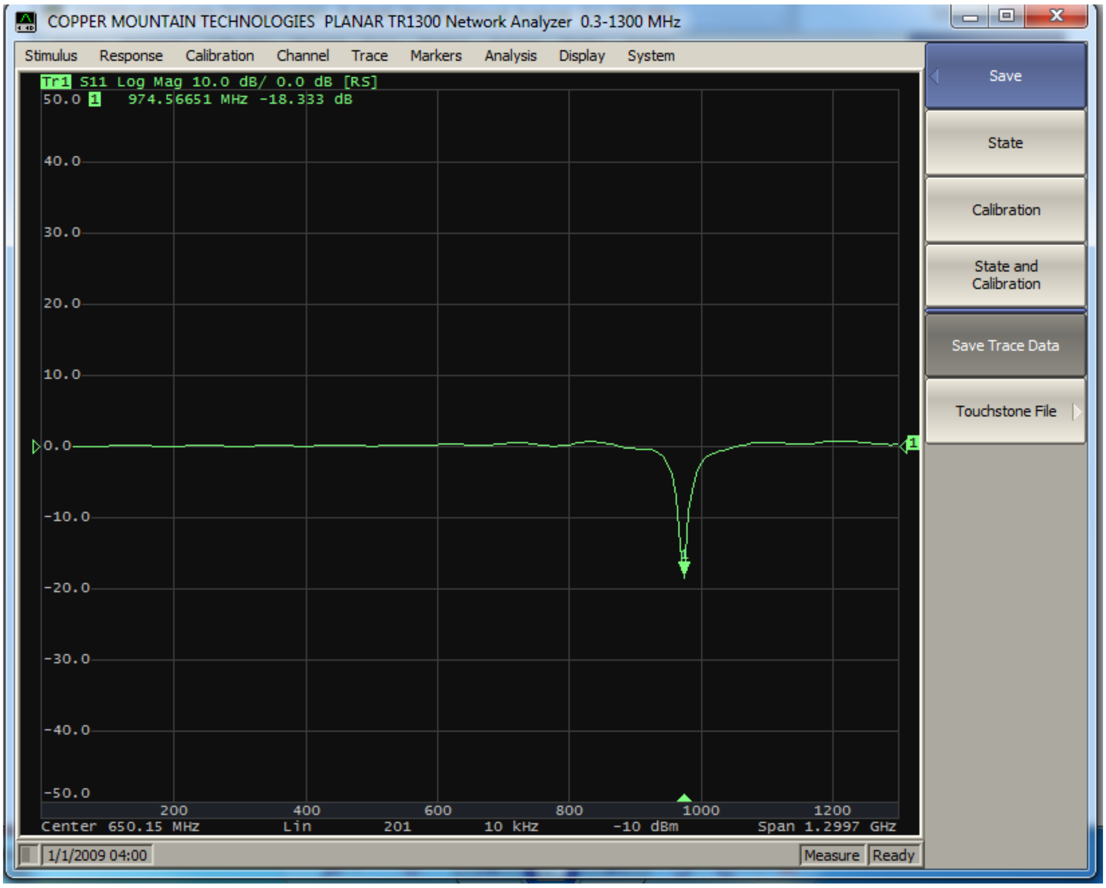



Microstrip Antenna Sensor with Container and Setup

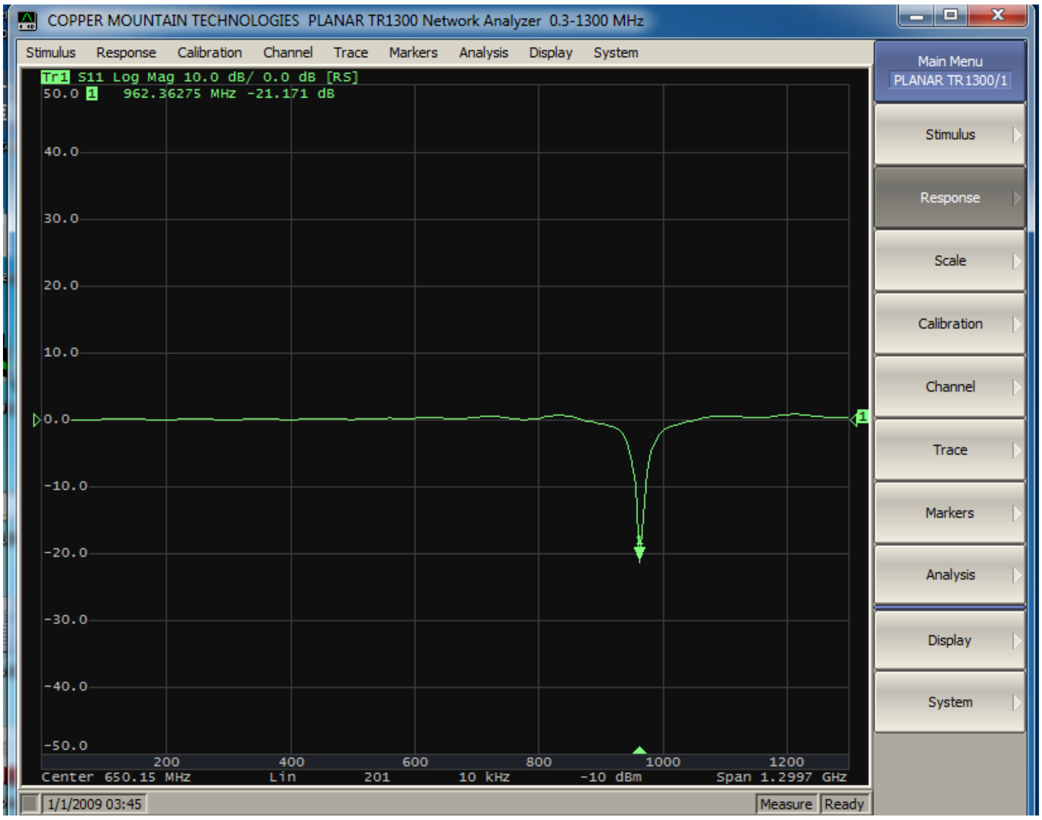

Testing of Samples



Output with container empty:



Output with Adulterated Milk Powder:



For the testing of the proposed project four samples are made and powder used for adulteration for that are talcum powder and wheat flour. The sample S1 is non-adulterated milk powder of 5g. Sample S2 is adulterated milk powder with milk powder 4.5g and talcum powder 0.5g. Sample S3 is adulterated milk powder with milk powder 4.5g and wheat flour 0.5g. Sample S4 is adulterated milk powder with milk powder 4.5g, talcum powder 0.5g and wheat flour 0.5g. The practical results obtained using VNA is shown in Table 5.2.

Table 5.2 *Resonant Frequency Shift with Respect to samples*

Sample	Centre Frequency	Δf (MHz)	S11 (dB)
S1	968.46	-	-23.82
S2	962	6.46	-19.89
S3	962.36275	6.09725	-17.74
S4	960.32879	8.13121	-21.97

In table 5.2, the Δf is the frequency shift with respect to the resonant frequency of the non-adulterated milk powder (968.46 MHz). In practical performance frequency shift is observed when the milk powder is adulterated as shown in table 5.2.

The difference in the resonant frequency of simulation result and practical result are may be due to container material selected for practical was different. Another but important reason is the dimension of the shorting post is not perfect in implemented hardware as it is made by soldering patch to the ground.

Chapter 6

Conclusion

The adulteration in the milk powder can be detected by using microstrip antenna sensor. The non-adulterated milk powder sample make antenna to radiate at specific resonant frequency. If the milk powder sample is replaced by adulterated milk powder sample the resonant frequency of the antenna changes and from the shift in resonant frequency the milk powder sample is detected to be adulterated. Summarising the result and discussion,

1. The relation between the permittivity of the milk powder sample and the resonant frequency is inversely proportional to each other.
2. There is a shift in the resonant frequency of the microstrip antenna sensor when the non-adulterated milk powder sample is replace with adulterated milk powder sample.
3. The microstrip antenna sensor has resonant frequency of 865.9 MHz with S11 of about -43.58.
4. For every 0.1 rise in the permittivity of the sample a fall of 100 KHz to 1 MHz is observed.
5. The microstrip antenna sensor is made of detection purpose. Thus other parameters of antenna other than S11 plot does not the aim of the project.

In future scope, there are many further works can be done to add more features to the project. A database can be made of adulterated milk powder samples with the resonant frequency as the signature frequency. It is possible to make a microstrip antenna sensor which beyond detection can also determine the adulteration and the adulterant in the sample from its signature frequency. A complex algorithm and system can be made with the help of data base which can provide adulteration detail in the milk powder sample.

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(54) Title of the invention : DESIGN AND MODEL TO IDENTIFY MILK POWDER ADULTERATION USING MICROSTRIP ANTENNA.

(51) International classification	:G01N33/04, Â G01N21/27	(71)**Name of Applicant :** **1)MOMIN ADNAN ANIS** Address of Applicant :302, ZUBEDA PLAZA, OLD FISH MARKET, KALYAN(W)-421301, MAHARASHTRA, INDIA. Maharashtra India **2)RAHUL B. KHADASE** (72)**Name of Inventor :** **1)MOMIN ADNAN ANIS** **2)RAHUL B. KHADASE**
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Filing Date	:NA	

(57) Abstract :

The rectangular microstrip antenna sensor for identification of adulteration in milk powder comprising of a dielectric substrate and a ground plane at the bottom and a meandered radiating element at the top with the milk powder container assembly. The meandered radiating element is shorted to the ground plane with the rectangular shorting post. The radiating element is directly feed by using coaxial feeding technique. The milk powder container assembly has a cuboid shaped glass container in which the milk powder to be tested is poured. The non-adulterated milk powder makes the microstrip antenna to radiate at a specific resonant frequency. When the milk powder is adulterated its dielectric constant changes and the adulterated milk powder makes the microstrip antenna to radiate at some other resonant frequency. The microstrip antenna sensor shows a shift in its resonant frequency when the non-adulterated milk powder sample is replaced by the adulterated milk powder sample. The relative permittivity i.e. the dielectric constant of the milk powder sample and the resonant frequency of the antenna has inversely proportional relation. Thus the microstrip antenna sensor identifies whether the milk powder sample is adulterated or not adulterated from the shift in resonant frequency experienced by it.

No. of Pages : 10 No. of Claims : 6

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It is a matter of great privilege for me, to present this project on **“Design of Microstrip Antenna for Detection of Adulteration in Milk Powder”.** I have tried my best to collect all the information pertaining to it. It was indeed great experience for me.

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Momin Adnan Anis (14DET94)

Date: