# ANTENNA DESIGN GUIDE

# (A TUTORIAL HANDBOOK)



# MUBARAK SANI M ELLIS, PhD

Antenna Group

(https://antennagroupknust.com/) Department of Telecommunication Engineering Kwame Nkrumah University of Science and Technology Kumasi-Ghana

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# SECTION 1: DUAL BAND MIMO PIFA ANTENNA

Prepared by: Kobina Ackon Annan & Sean Donkor (Telecom Eng. 2021)

# **INTRODUCTION**

ANSYS HFSS is a 3D electromagnetic (EM) simulation software for designing and simulating high frequency electronic products such as antennas, antenna arrays, RF or microwave components, high speed interconnects, filters, connectors, IC packages a printed circuit board. Engineers worldwide use ANSYS HFSS software to design high frequency, high speed electronics found in communication systems, satellites and IoT products.

This book introduces the structure and design of a dual band MIMO PIFA antenna for Bluetooth and WIFI application in laptops operating at 2400/5000 for Wi-Fi and 2450 for Bluetooth. This guide will typically walk you through the steps to build the geometry, setup the solution, run the analysis, and evaluate the results by generating plots using ANSYS HFSS 2020.

By following the steps in this guide you will learn how to perform the following tasks in HFSS:

- 1. Draw the geometric models.
- 2. Add the boundaries and excitation.
- 3. Specify solution setting for the design.
- 4. Run HFSS transient simulation.
- 5. Create plots for the results.

# For basic design tutorials using HFSS:

https://www.youtube.com/playlist?list=PLdIVd39LNkpSaTzAFCS\_jh3sV3Gc21mNg

# 1. STARTING HFSS

To be able to start the project you would have to first start or launch the software.

- Launching ANSYS Electronics Desktop 2015
  - a. Select Programs > ANSYS Electromagnetics > ANSYS EM Suite 2020 R1
  - b. Select ANSYS Electronics Desktop 2020 R1



# 2. <u>CREATING THE PROJECT</u>

- > To begin working with geometrics you need to insert an HFSS design.
  - a. From the toolbar, double click on the HFSS icon to open an HFSS project.



# 3. WORKING WITH THE GEOMETRICS

On the left side of the HFSS window, right click on **Project** from the Project Manager pane.



a. Select **Save As** from the pop up.

# b. Enter the File name as **DUAL BAND MIMO PIFA ANTENNA**



Title Bar	Menu Bar N	Ribbon Tabs	History Tree	Modeler Window
ANSYS Electronics	Desktop 2010 R3 - wg_comb Project Draw Modeler	oiner - HFSSI esign1 - 3D Modeler - HFSS Tools Window Help	SOLVED [wg_combiner - HFSSDesign1 - M	deler] – – ×
↓     Cut     ✓)       ↓     Cupy     ♥       Save     ♠     Paste	Undo Redo Delete Report * Variables	Modify Report Modal St. Data Re	lution port Report → Data	ions utions ons
Desktop View	Draw Model Sim	Results Automatic	on	Ø <u>N</u>
Project Manager	n L (DrivenModal)* nents nents	A Model     A Solids     Gevenum     Gevenum	e Field [V/m] 12296.4131 11476.6533 10656.8936 9837.1338 9017.3740	

# 4. DRAW THE GEOMETRIC MODELS

# **\*** Creating the Radiating Patch.

- From the *Draw* Ribbon Tab, select the rectangle tool
- > In the *Modeler Window*, click and drag from the origin to draw the rectangle.



4

- From the *History Tree*, right click on the **CreateRectangle** to change the dimensions and position of the rectangle.
  Properties DUAL BAND MIMO PIEA ANTENNA HESSDesign1 Modeler
  - Position: **0**, **0**, **0 mm**
  - Axis: Z
  - Xsize: **36 mm**
  - Ysize: **3 mm**
- > Select Apply
- > Select OK

Name         Value         One         Description           Coordinate Sys         Global		Value	Unit	Evaluated Value	Description	1	
Coordnate Sys     Global       Poation     0.0.0     mm       Vas     Z       XSize     30     mm       3     mm     30mm	Command	CreateBec	Onix	Evaluated value	Description		
Position         0,0,0         mm         0mm,0mm           Avis         Z             Avis         30         mm         30mm           YSize         3         mm         3mm	Coordinate Svs.	Global				-	
AxisZImage: Constraint of the second s	Position	0.0.0	mm	Omm , Omm , Omm		-	
XSize         30         mm         30mm           YSize         3         mm         3mm	Axis	Z				-	
YSize 3 mm 3mm	XSize	30	mm	30mm		-	
	YSize	3	mm	3mm		-	

- From the *History Tree*, right click on the **Rectangle1** to change its properties.
  - Name: **Patch**
  - Material: Copper
  - Colour: Blue
  - Transparency: **0.6**
- > Select Apply
- > Select OK

Name	Value	Unit	Evaluated Value	Description	Bead-only	
Name	patch	OTIL	Evaluated value	Description	The durbinity	
Material	"vacuum"		"vacuum"			
Solve Inside						
Orientation	Global					
Model	~					
Group	Model					
Display Wirefra						
Material Appea						
Color						
Transparent	0.6					

# 5. <u>CREATING THE SLOTS.</u>

- From the *Draw* Ribbon Tab, select the **Rectangle** tool.
- > In the *Modeler Window*, click and drag to draw the rectangle.
- From the *History Tree*, right click on the CreateRectangle to change the dimensions and position of the rectangle.
  - Position: **27.1**,**2**,**0** mm
  - Axis: Z
  - Xsize: -12.51 mm
  - Ysize: 0.1 mm

- Select Apply Select OK
- > Draw another rectangle
- From the *History Tree*, right click on the **CreateRectangle** to change the dimensions and position of the rectangle.
  - Position: 27 ,0 ,0 mm
  - Axis: Z
  - Xsize: 0.1 mm
  - Ysize: 2 mm
- > Select Apply
- Select **OK**
- Select the **patch** and **two rectangles** together
- Select **Subtract** from the Ribbon Tab.
- Move Patch under Blank Parts

Clone tool objects before operation

Cancel

0K

- Move Rectangle1 and Rectangle2 under Tool Parts.
- Select OK.
- Select **Rectangle1** > Select **Thicken Sheet** > Set the value to **0.05 mm**.

and					
Name	Value	Unit	Evaluated Value	Description	
Command	CreateRec				
Coordinate Sys.	Global				
Position	0, 0, 27	mm	27mm , 0mm , 0		
Axis	Z				
XSize	0.1	mm	0.1mm		
YSize	2	mm	2mm		
					E Change Likelyters

Properties: lap\_try\_9.5 - HFSSDesign1 - Modeler × Command 3D Modeler - [DUAL BAND MIMO PIFA ANTENNA - HFSSDesign1 - Modeler] Name Value Unit Evaluated Value mmand CreateRec Coordinate Sys... Global 00 🛅 🕐 🖦 📑 🖾 👌 - 🕹 -Eit All 🗊 🛆 🗄 🔲 🗩 🔪 🕲 🕲 In Meas 27.1 .2 .0 mm Position 27.1mm , 2mm L Fit Selected 🔒 🕒 🗩 🕖 🕖 ガ 🏹 🍾 ガ 🕂 🛃 🔛 👰 → ↓
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 ↓ Axis 🚥 Ruler 7 -12.51 -12.51mm 2 XSize mm ١., 1 1 1 Units Subtract Subtract objects Show Hidden ОК Cancel 🙇 ANSYS Electronics Desktop 2020 R1 - DUAL BAND MIMO PIFA ANTENNA - HFSSDesign1 - 3D Modeler - [DUAL BAND MIMO PIFA ANTENNA - HFSSDesign1 - Modeler] and and back to the Project Draw Modeler HESS Tools Window Help The Edit Vew Project Draw Modeler HESS Tools Window Help Save Baste × Dolete Save Baste × Dolete EDT Subtract Х Blank Parts Tool Parts Desktop View Draw Mode ults Aut patch Rectangle1 roject Manager 👻 🕂 🛪 🗐 🚯 Model Rectangle2 Z Solida 📳 DUAL BAND MIMO PIFA ANTENNA -HFSSDesign1 (Drive B 3D Components Model lal)' Patch CreateRec CoverLine Subtract

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 Optimetrics
 Results 🗄 🔮 S Parameter Plot 1 . dB(S(2,2))

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Field Overlay:

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 Rectar
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Rox1 Box1
 Box2
 Box2
 Gylinder1
 Ground
 Ground
 Short

Gircle1 Coordinate Systems

- Sheets - Wave Port

ThickenSl

6

# 6. <u>CREATING THE SHORTING PLATE.</u>

- ▶ From the *Draw* Ribbon Tab, select the rectangle tool
- > In the *Modeler Window*, click and drag from the origin to draw the rectangle.



- From the *History Tree*, right click on CreateRectangle under Rectangle2 to change the dimensions and position of the rectangle.
  - Position: **0**, **0**, **-0.5 mm**
  - Axis: X
  - Ysize: 3 mm
  - Zsize: 0.5 mm
- > Select Apply
- > Select OK
- Select Rectangle2 > Select Thicken Sheet > Set the value to 0.05 mm

Name	Value	Unit	Evaluated Value	Description	
Command	CreateRec.				
Coordinate Sys.	Global				
Position	0.0.0	mm	0mm , 0mm , 0mm		
Axis	X				
YSize	3	mm	3mm		
ZSize	-0.5	mm	-0.5mm		

- > From the *History Tree*, right click on the **Rectangle2** to change its properties.
  - Name: Short
  - Material: Copper
  - Colour: **default**
  - Transparency: 0
- > Select Apply
- Select OK

Name	Value	Unit	Evaluated Value	Description	Read-only	
Name	short					
Material	"copper"		"copper"			
Solve Inside						
Orientation	Global					
Model	~					
Group	Model					
Display Wirefra						
Material Appea						
Color						
Transparent	0					
						Show Hidde

# 7. <u>CREATING THE FEEDING PORT.</u>

- From the *Draw* Ribbon Tab, select the circle tool.
- > In the *Modeler Window*, click and drag to draw the circle.



From the *History Tree*, right click on CreateCircle under Circle1 to change the dimensions and position of the circle.

• Position: **5**,**1**,-**5**.**3** mm

- Axis: Z
- Radius: 3 mm
- Number of Seg: 0
- > Select Apply
- > Select OK

Name	Value	Unit	Evaluated Value	Description			
Command	CreateCircle						
Coordinate Sys	Global				_		
Center Position	5 .15.3	mm	5mm , 1mm , -5		_		
Axis	Z						
Radius	3	mm	3mm		_		
Number of Seg	0		0				

#### 8. CREATING THE FEED LINE.

- From the *Draw* Ribbon Tab, select the cylinder tool.
- > In the *Modeler Window*, click and drag to draw the cylinder.



- From the *History Tree*, right click on CreateCylinder under Cylinder1 to change the dimensions and position of the cylinder.
  - Center Position: **5**, **1**, **-5.3 mm**
  - Axis: Z
  - Radius: **0.1 mm**
  - Height: **5.35 mm**
  - Number of Seg: 0
- > Select Apply
- > Select OK

	Name	Value	Unit	Evaluated Value	Description	
H	Command	CreateCyli				
H	Coordinate Sys	Global				
H	Center Position	5,1,-5.3	mm	5mm , 1mm , -5		
П	Axis	Z				
	Radius	0.1	mm	0.1mm		
	Height	5.35	mm	5.35mm		
	Number of Seg	0		0		

- From the *History Tree*, right click on the **Cylinder1** to change its properties.
  - Name: feed
  - Material: Copper
  - Colour: brown
  - Transparency: 0
- > Select Apply
- > Select OK



# 9. CREATING THE FEED LINE COVER.

- ▶ From the *Draw* Ribbon Tab select the Cylinder tool.
- > In the *Modeler Window*, click and drag to draw the circle.



- From the *History Tree*, right click on **CreateCylinder** under Cylinder2 to change the dimensions and position of the cylinder.
  - Center Position: **5**, **1**, **-5.3 mm**
  - Axis: Z
  - Radius: 1 mm
  - Height: **4.8 mm**
  - Number of Seg: 0
- > Select Apply
- > Select OK
- From the *History Tree*, right click on the **Cylinder2** to change its properties.
  - Name: Outer
  - Material: Teflon
  - Colour: **blue**
  - Transparency: 0.8
- > Select Apply
- Select OK

Command Creat Coordinate Sys Glob Center Position 5 .1 Axis Z Radius 1	eateCyli obal 1 ,-5.3 mm	5mm , 1mm , -5	_	
Coordinate Sys Glob Center Position 5 .1 Axis Z Radius 1	obal 15.3 mm	5mm , 1mm , -5		
Center Position 5.1 Axis Z Radius 1	1,-5.3 mm	5mm , 1mm , -5		
Axis Z Radius 1				
Radius 1				
	mm	1mm		
Height 4.8	8 mm	4.8mm		
Number of Seg 0		0		

Name	Value	Unit	Evaluated Value	Description	Read-only	
Name	Outer					
Material	"Teflon (tm)"		"Teflon (tm)"			
Solve Inside	<b>v</b>					
Orientation	Global					
Model	~					
Group	Model					
Display Wirefra						
Material Appea						
Color						
Transparent	0.8					
						Show Hidden

# 10. CREATING THE GROUND PLANE.

- From the *Draw* Ribbon Tab, select the rectangle tool.
- > In the *Modeler Window*, click and drag to draw the rectangle.



- From the *History Tree*, right click on Create Rectangle under Rectangle3 to change the dimensions and position of the rectangle.
  - Position: -10 ,-2 ,-0.5 mm
  - Axis: Z
  - Xsize: 210 mm
  - Ysize: **320 mm**
- Select Apply
- ➢ Select OK

Command         Create Rec           Coordinate Sys         Global           Postion         10.2.2.0.5           Avis         Z           XSize         210           YSize         320           mm         320mm		value	Unit	Evaluated Value	Description	
Coordinate Sys         Global           Postion         -10.2.05         mm           Avis         Z            XSize         210         mm           YSize         320         mm	Command	CreateRec				
Postion         -10,-2,05         mm         -10mm, -2mm,           Axis         Z             XSze         210         mm         210mm           YSize         320         mm         320mm	Coordinate	Sys Global				
Avis         Z         Image: Constraint of the second seco	Position	-1020.5	mm	-10mm , -2mm ,		
XSize         210         mm         210mm           YSize         320         mm         320mm	Axis	Z				
YSize 320 mm 320mm	XSize	210	mm	210mm		
	YSize	320	mm	320mm		
1						

- Select Rectangle3 > Select Thicken Sheet > Set the value to 0.05 mm
- From the *History Tree*, right click on the **Rectangle3** to change its properties.
  - Name: Ground
  - Material: **FR4 epoxy**
  - Transparency: **0.6**
  - Select Apply
  - Select OK



# 11. CREATING THE SUBSTRATE

- From the *Draw* Ribbon Tab, select the Box tool
- > In the *Modeler Window*, click and drag from any point to draw the box.



- From the *History Tree*, right click on **CreateBox** under Box1 to change the dimensions and position of the box.
  Properties: lap.try.9.5 - HFSSDesign1 - Modeler
  - Position: -10 ,-2 ,0 mm
  - Xsize: 210 mm
  - Ysize: **320 mm**
  - Zsize: -0.5 mm
- Select Apply
- ➢ Select OK

- Humo	Value	Unit	Evaluated Value	Description	
Command	CreateBox				
Coordinate Sys	Global				
Position	-102 .0	mm	-10mm , -2mm ,		
XSize	210	mm	210mm		
YSize	320	mm	320mm		
ZSize	-0.5	mm	-0.5mm		

- From the *History Tree*, right click on the **Box1** to change its properties.
  - Name: Substrate
  - Material: Air
  - Colour: blue
  - Transparency: **0.8**
- Select Apply
- ➢ Select OK

Name	0.1.1.1			
	Substrate			
Material	"air"	"air"		
Solve Inside	~			
Orientation	Global			
Model	~			
Group	Model			
Display Wirefra				
Material Appea				
Color				
Transparent	0.8			
Transparent	0.8			

# 12. MODELLING ANTENNA-2

In modelling antenna 2, there are two options;

- 1. Repeat the steps for creating the individual components but with different coordinates for their positions.
- 2. Copy and paste the individual components, thereafter, change the coordinates for their positions.



# **Using Option 2**

#### **\*** Copy and Paste the components.

- > In the *History Tree*, select Patch, Short, Feed, Outer, Circle
- Press Ctrl + C to copy the selected components
- Single click inside the *Modeller Window*
- > Press Ctrl + V to paste the components

#### Change the coordinates of the components.

- Select the Create Rectangle under Patch1
- > Type the new coordinates for the *Position* as shown in the table below.
- > Repeat this step for the other pasted components using their new coordinates.

Component	Coordinates
Patch1	0, 313, 0 mm
Short1	0, 313, 0 mm
Feed1	5, 314, -5.3 mm
Outer1	5 , 314 , -5.3 mm
Circle1	5, 314, -5.3 mm

#### Creating Radiation Box

- From the *Draw* Ribbon Tab, select the Box tool
- > In the *Modeler Window*, click and drag from any point to draw the box.



- From the *History Tree*, right click on **CreateBox** under Box1 to change the dimensions and position of the box.

   Properties: lap.try\_95-HFSSDesign1-Modeler
  - Position:-100 ,-100 ,-5.3 mm
  - Xsize: **400 mm**
  - Ysize: **500 mm**
  - Zsize: 60 mm
- > Select Apply
- ➢ Select OK

Name	Value	Unit	Evaluated Value	Description		
Command	CreateBox					
Coordinate Sys	Global					
Position	01005.3	mm	-100mm , -100m			
XSize	400	mm	400mm			
YSize	500	mm	500mm			
ZSize	60	mm	60mm			

- From the *History Tree*, right click on the **Box1** to change its properties.
  - Name: RadBox
  - Material: Vacuum
  - Colour: green
  - Transparency: 0.9
- > Select Apply
- ➢ Select OK



# 13. ASSIGNING BOUNDARIES AND EXCITATIONS

#### **Radiation Boundary**

The purpose of using boundary conditions in HFSS is to define the behaviour of the electromagnetic. Field on the object interfaces and at the edges of a problem region. Defining boundary conditions reduces the electromagnetic or geometric complexity of the model.

- Create Boundary
- > Right click on **RadBox** inside the *History Tree*.
- Select Assign Boundary from the pop-up.
- Select Radiation.
- Select **Ok** from the pop-up.

Save 🖹 Paste 🗙 Delete	toom 😴 🖉 Or	rient -	) o 🔊	• L	2				<b>∖</b> ∗   <b>8</b> . ∗	Units
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Hybrid Regions		H-H-H-H	ALCON.			2-22	17	44		
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		HHHH	6FF				Æ	674		

	Expand All		KAL-FELFE
	Collapse All		Anisotropic Impedance
	Select	>	Aperture
	Edia	、	Coupled >
		1	Finite Conductivity
	Group	>	Half Space
	Create 3D Component		Impedance
	Replace with 3D Component		Layered Impedance
-	Assign Material		Linked Impedance
_		_	Lumped RLC
	View	`	Perfect E
	Properties		Perfect H
	Create Array		Radiation
	Create Open Region		Symmetry
	Update Open Region Padding		Fresnel (SBR+)
	Assign Boundary	>	PML Setup Wizard
	Assign Excitation	>	A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-
	Assign Hybrid	>	LAAAAA
	Assign Mesh Operation	>	AAAAA
	Plot Fields	>	
	Plot Mesh		150
	Plot VRT	>	

Radiation Boundary	×
Name: Rad1	
OK	Cancel

#### Wave Ports

Wave ports are used to excite transmission lines like microstrip, and hollow waveguides. A wave port represents the region through which electromagnetic energy enters or exits the solution space. In HFSS a wave port is treated as if it were a semi-infinitely long wave guide or transmission line of the exact same cross-section attached to them where it's excited. Wave ports yield S, Y, Z parameters, characteristic wave impedance and the propagation constant gamma. The S-parameters generated by a wave port are normalized to the matched loads and can also be normalized to any constant complex impedance.



#### Create Excitation

- Right click Circle inside the *History Tree*
- Select Assign Excitation from the pop-up
- Select Wave port
- Right click None from the pop-up
- Select New Line.
- In the *Modeller Window* draw a line from the centre of the circle to its circumference.
- > Ensure that the None has changed to **Defined**
- Click Next at the bottom of the pop-up.
- Select Finish.



C Hendiniaize opecinic modes	Wave Port : General	×
Deembed Settings Deembed Distance: 0 mm Positive distance will deembed the port into the model. Get Distance Graphically	Name:  Number of Modes:  Mode Integration Line Characteristic Impedance ( Defined Zpi	Zo)
< Back Finish Cancel	Mode Alignment and Polarity: © Set mode polarity using integration lines C Align modes using integration lines C Align modes analytically using coordinate system U Axis Line: Undefined Reverse V Direction Filter modes for reporter Use Defaults < Back Next >	Cancel

> Repeat the above steps for **Circle1** to create the wave port for *Antenna-2*.

# 14. SPECIFYING SOLUTION SETTINGS

### Performing Analysis Setup

- ▶ Right click on **HFSS** on the *Menu Bar*.
- Select Analysis Setup from the drop down menu.
- Select Add Solution Setup.
- Select Advanced.
- Select Multi-Frequencies under Adaptive Solutions
- Fill out the details as shown in the second image below



Driven Solution Setup		×	Driven Soluti	ion Setup				×
General Options Advanced Hybrid	Expression Cache   Derivatives   Defaults		General Op	otions Advanced	Hybrid Expres	sion Cache   Derivative	es Defaults	
Setup Name Setup 1 C Enabled C Adaptive Solutions	Solve Ports Only		Setup Nar Adaptive Solu	me Setup En-	abled 🗔 Single	Solve Ports Only	ncies C Broadband	
Solution Frequency:	Single C Multi-Frequencies C Broadband			Frequency	Unit	Max. Delta	Add	
Frequency	5 GHz 💌			2.4	GHz	0.02		
				2.45	GHz	0.02		
Maximum Number of Passes	6			5	GHz	0.02		
Maximum Delta S	0.02						Remove	
C Use Matrix Convergence	Set Magnitude and Phase						1	

- Select OK.
- > In the next pop-up window, select **Fast** under *Sweep Type*.
- > Under *Frequency Sweeps* change the following parameters:
  - Start: 0 GHz
  - End: **8 GHz**
- Select OK.

Edit F	rea	uency Sw	eep					×
Gen	arəl	ر م	1					
Gene		Defaults	1					
Sw	еер	Name:	Sweep				Enabled	
Sw	еер	Type:	Fast		-			
		.,,	, doc					
	Free	uency Sw	eeps [401 p	oints defined]				7
		Distr	ibution	Start	End			
	1	Linear Co	unt	0GHz	8GHz	Points	401	
		Add Aboy	/e	Add Below	Delete Se	lection	Preview	

### ✤ Inserting Far Fields

- ▶ Right click on **HFSS** on the *Menu Bar*.
- Select Radiation from the drop down menu.
- Select Insert Far Field Setup.
- > Select Infinite Sphere.



- Fill in the section under Phi with the following parameters.
  - Start: -180
  - Stop: 180
  - Step Size: 1
- ➢ Fill in the section under Theta with the following parameters.
  - Start: 0
  - Stop: 360
  - Step Size: 1
- ➢ Click OK.
- > Apply Design Settings.
- ▶ Right click on **HFSS** on the *Menu Bar*.
- Select **Design Settings** from the drop down menu.
- Select the Validations tab.
- > Check the box for **Skip Intersection Checks**.
- > Click **OK**.

# Perform Validations

- ▶ Right click on **HFSS** on the *Menu Bar*.
- Select Validation Check from the drop down
- ➤ menu.
- Ensure all Validation Checks have been completed.
- Click Close.

Validation Check: DUAL BAND MIMO PIFA ANTENNA - HFS	SDesign1 X
HFSSDesign1	<ul> <li>Design Settings</li> <li>3D Model</li> <li>Boundaries and Excitations</li> </ul>
Validation Check completed.	Mesh Operations Analysis Setup
	<ul> <li>Optimetrics</li> </ul>
J	🖋 Radiation
Abort	

ite Sphere Coo	ordinate System	Radiation Surfac	e
Name	Infinite Sphere	1	
- Phi			
Start	-180	deg	-
Stop	180	deg	-
Step Size	. 1	deg	-
- Theta			
Start	0	deg	•
Stop	360	deg	•
Step Size	. 1	deg	•
Save As	Defaults	View Sweep Po	ints
	ОК	Cancel	Help

Infi

IFSS Design Settings			×
Set Material Override Validations	Lossy Dielectrics S Parameters	DC Extra Export S Para	apolation
Model			
Ignore Unclassified Ob	jects		
Skip Intersection Chec	ks		
Entry check Level . John	<u> </u>		
HFSS			
<ul> <li>Perform full validation:</li> </ul>	s with standard port validations		
C Perform full validation	s with extended port validations		
C Perform minimal valida	ations		
	Г	Save as default	
		ОК	Cancel

# 15. RUN HFSS TRANSIENT SIMULATION

#### Run Simulation

- Select **Simulation** on the *Ribbon Tab*.
- Click Analyze All.



# 16. PLOTTING THE RESULTS

- Plotting the S Parameters.
  - Click on **Results** on the *Ribbon Tab*.
  - Select Modal Solution Data Report.
  - Select the **2D** Graph on the menu.



- Select the following parameters in the pop-up menu
- Category: S Parameter
- > Quantity: S(1,1)
- ➢ Function: **dB**
- Click on New Report.

🔀 Report: lap_try_9.5 - HFSSDesign1 - S Pa	rameter Plot 4 - dB(S(1,1))	×
Context Solution: Setup1:Sweep	Trace Families Families Display Primary Sweep: Freq All All X: Ø Default Freq	
Update Report	Y: dB(S(1,1)); dB(S(2,2)) Category: Quantity: Variables SParameter Z Parameter Z Parameter Z Parameter Z Parameter Z Parameter VSWR Gamma Port 20 Lambda Epsilon Group Delay	Range Function: <pre>Function:</pre> <pre>Function: <pre>concept</pre> <pre>function: <pre>concept</pre> <pre>function: <pre>concept</pre> <pre>concept</pre> <pre>concept</pre> <pre>concept</pre> <pre>function</pre> <pre>func</pre></pre></pre></pre>
Output Variables Options	New Report Apply Trace Add Trace	Close



- ✤ Plotting the Radiation Pattern
  - Click on **Results** from the *Ribbon Tab*.
  - > Click on Far Fields Report.

ANSYS Electronics Desktop 202 File Edit View Project	20 R1 - lap_try_9.5 Draw Modeler	5 - HFSSDesign1 - 3D Mod HFSS Tools Windov	eler - SOLVED - [Iap_try_9.5 - HFSSDesi / Help	gn1 - Modeler)					- 0	j ×	×
↓     Cut     ♥     Undo       □     Copy     ♥     Redo       Save     ●     Paste     X     Delete     R	Open Output eport * Variables	C Delete All Reports	Modal Solution Data Report * Test Report	Far Fields Report Paran	Antenna U neters Report *	Jser Defined Report *	Browse Soli Browse Soli Clean Up Soli ta Mport Solu	utions plutions tions			
Desktop View Draw	Model Sin	nulation Results	Automation						Component Libraries	0	۸
Hyprid Regions - 27 Hybrid Regions - 27 Analysis - 29 Analysis - 29 Results	• + x c	Golids     Golids		2D	Stacked	Mag/Ang Polar	Data Table		Artennas	* *	
S Parameter Plot     S Pa	1 2 Fable 1	Formation (tm)     Formatio		3D	3D Polar	3D Spherical	2D Contour		⊕	7GHz_DT 4GHz_DT	71

- Select 3D Polar from the drop down menu.
- Select the following parameters in the pop-up menu
  - Sources: 1:1
  - Category: Gain
  - Quantity: GainTotal
  - Function: **dB**
- Click on New Report.

Context	Trace Families	
Solution: Setup1:LastAdaptive 💌	Primary Sweep: Phi 💽 All	
Geometry: Infinite Sphere 1	Secondary Sweep: Theta 💌 🗚	
Cumum [1.4	Phi: 🔽 Default Phi	
Sources: 1:1	Theta: 🔽 Default Theta	
	Mag: dB(GainTotal) Rang	e ion
	Category: Quantity: Function:	
	Variables A GainTotal Cum_integ	^
	Gain System Gain	ze
	Les (Gain)	7e



# **SECTION 2: HORN-FED REFLECTOR ANTENNA**

Prepared by: Kwakye Akosah Jeffrey & Emmanuel Frimpong (Telecom Eng. 2021)

# INTRODUCTION

Ansys HFSS is a 3D electromagnetic (EM) simulation software that can be used to design and simulate high-frequency electronic items including antennas, antenna arrays, RF or microwave components, high-speed interconnects, filters, connectors, IC packages, and printed circuit boards. Ansys HFSS software is used by engineers all over the world to develop high-frequency, high-speed electronics that can be found in communications networks, advanced driver assistance systems (ADAS), satellites, and internet-of-things (IoT) devices.

This document is intended to show you how to create, simulate, and analyze horn-fed reflector antenna system efficiently, using the ANSYS Electronics Desktop; HFSS and HFSS-IE Design Environments.

This example is intended to show you how to create, simulate, and analyze horn-fed reflector antenna system efficiently, using the ANSYS Electronics Desktop; HFSS and HFSS-IE Design Environments.

The design process is divided into 4 main parts namely;

- 1. Part 1: HFSS Design of horn antenna
- 2. **Part 2:** HFSS-IE design of reflector with excitation linking to HFSS design in part 1. Antenna solution using an Integral Equation and Physical Optics solution methods, both techniques are available within HFSS-IE.
- 3. **Part 3**: HFSS Hybrid design of a reflector + horn antenna
- 4. Part 4: Design simulations and results

# 1. LAUNCHING ANSYS ELECTRONICS DESKTOP

- Select Programs > ANSYS Electromagnetics > ANSYS Electromagnetics Suite 16.0
- Select ANSYS Electronics Desktop 2016.

# 2. <u>SETTING TOOL OPTIONS</u>

- Note: In order to follow the steps outlined in this example, verify that the following tool options are set:
- Select the menu item Tools > Options > HFSS Options...
   Click the General tab
- > Use Wizards for data input when creating new boundaries:  $\sqrt{Checked}$
- Duplicate boundaries/mesh operations with geometry: V Checked – Click the OK button
- Select the menu item Tools > Options > Modeler Options....
  Click the Operation tak
  - Click the Operation tab
- > Automatically cover closed polylines:  $\sqrt{\text{Checked}}$
- Select last command on object select: √
   Checked
  - Click the Drawing tab
- Edit properties of new primitives: Checked
  - Click the OK button



# PART 1 – HFSS: CREATING THE HORN ANTENNA

# \* Opening a New Project

In HFSS Desktop, click the / On the Standard toolbar, or select the menu item File > New.

# For basic design tutorials using HFSS:

https://www.youtube.com/playlist?list=PLdIVd39LNkpSaTzAFCS\_jh3sV3Gc21mNg

▶ From the Project menu, select Insert HFSS Design.

### ✤ Set Solution Type

- Select the menu item HFSS > Solution Type
  - Choose Driven Modal
  - Choose Network Analysis
  - Click the OK button

#### Set Model Units

- Select the menu item Modeler > Units
  - Select Units: in
  - Click the OK button
- Select The Menu Item Draw > 3D Component Library > Browse
  - Browse 3D Component Dialog
- Filename: Horn\_10GHz.a3dcomp
- Click the Open button
   Insert 3D Component Dialog
- ➢ FlareA: 2.65in
- ➢ FlareB: 1.95in
- ➢ Horn\_length: 5.2in
- Click the OK button
- $\succ$  To fit the view:
  - Select the menu item View > Fit All > Active View OR press the CTRL+D key

# 3. <u>CREATING THE AIRBOX</u>

- Select the menu item Draw > Region
   Padding Data: Pad all directions similarly
  - Direction: All
  - Padding type: Absolute Offset
  - Value: 0.3in



File Edit	View Proj	ect Tools Window Help	
0 🖨 🖬	X 🥵	Insert HFSS Design	
Rroject Manag	2 2 3 t4 14 14 14 14 10 10 10 10 10 10 10 10 10 10 10 10 10	Insert HFSS 3D Layout Design Insert HFSS-IE Design Insert Q3D Extractor Design Insert 2D Extractor Design Insert Circuit Design Insert Kaxwell 3D Design Insert Maxwell 2D Design Insert Maxwell Design Insert Maxwell Circuit Design	1
Properties		Insert Simplorer Design	
Name	Value	Insert Documentation File	
	*	Launch Savant Launch EMIT	
< Variables	_	Analyze All Submit Job	
Insert HFSS de	esign	Project Variables	

Set Model Units	×
Select units:	-
E Rescale to new units	
OK	Cancel

Name	Value	Units	Evaluated Value	Description	Т
FlareA	2.65	in	2.65in		
FlareB	1.95	in	1.95in		
Horn_length	5.2	in	5.2in		
WG_length	1	in	1in		
Wall_Thickness	0.05	in	0.05in		
а	0.9	in	0.9in		
b	0.4	in	0.4in		
arameters Image	Info				
arameters Image	<u>] Info</u>	ilobal	•		
arameters Image arget Coordinate odel is positioned su igned with specified	Linfo	ilobal e referer e system	▼ nce coordinate system i in the target design.	n the model is	

# 4. CREATE RADIATION BOUNDARY

- Select the menu item Edit > Select > By Name
  - Object Name: Region
  - Click the OK button
- Select the menu item HFSS > Boundaries
  - > Assign > Radiation...
  - Click the OK button

# 5. CREATE A RADIATION SETUP

➢ Select the menu item

# HFSS > Radiation > Insert Far Field Setup > Infinite Sphere

- Infinite Sphere Tab
- ➢ Name: 2D
- Phi: (Start: 0, Stop: 90, Step Size: 90)
- Theta: (Start: -180, Stop: 180, Step Size: 1)

- Click the OK button

# 6. CREATING AN ANALYSIS SETUP

Select the menu item HFSS>

# Analysis Setup > Add Solution Setup

- Click the General tab:
- ➢ Solution Frequency: 10 GHz
- Maximum Number of Passes: 6
- Maximum Delta S per Pass: 0.02
- Click the OK button





### 7. <u>SAVE PROJECT</u>

- Select the menu item File > Save As
  - Filename: Reflector
  - Click the Save button
- Source Design Analyze
- Select the menu item HFSS > Analyze All

#### PART 2: CREATING THE 3D MODEL

#### ✤ Create Reflector

- Select the menu item Draw > Equation Based Curve
  - $-X(_t): 0$
  - $Y(_t): (_t)*(1cm)$
  - $-Z(_t): (26.625-_t*_t/106.5)*(-1cm)$
  - Start\_t: 0
  - End\_t: 32
  - Number of Points: 0
  - Click the OK button
- Select the menu item Edit > Select All
- Select the menu item Draw > Sweep Around Axis
  - Sweep axis: Z
  - Angle of sweep: 360 deg
  - Draft angle: 0
  - Draft type: Round
  - Number of segments: 0
  - Click the OK button



Far Field Radiation S	phere Setup		×
Infinite Sphere Coor	dinate System	Radiation Surface	۱. <sub>-</sub>
Name	2D		
Phi			
Start	0	deg 🗨	3
Stop	90	deg 🗨	3
Step Size	90	deg 🗨	3
- Theta			
Start	<b>}180</b>	deg 🗨	]   [
Stop	180	deg 🗨	3
Step Size	1	deg 💌	]
Save As D	lefaults	View Sweep Point	S
	ОК	Cancel	Help

Equation	Based Curve	×
X(_t) =	0	
Y(_t) =		
Z(_t) =	(26.625t*_t/106.5)*(-1cm)	
Start_t:	0	
End_t:	32 💌	
Points:	0	
	0K Cancel	

#### 8. ASSIGN PEC

- Select the menu item Edit > Select All
- Select the menu item HFSS-IE > Boundaries > Assign > Perfect E - Click the OK button

# 9. CREATE LINKED EXCITATION

- Select the menu item HFSS-IE > Excitations > Assign > Incident Wave > Near Field Wave – General Data
- ➢ Name: Feed
- Vector Input Format: Cartesian
- Click the Next button
  - Near Field Wave options
- > Theta (rotation about the resultant X-axis): 180deg
- Click the Setup Link button
  - Product: HFSS
  - Source Project:  $\sqrt{}$  Use This Project
  - Source Design: HFSSDesign1
  - Source Solution: Setup1: Last Adaptive Simulate source design as needed:  $\sqrt{}$
  - Preserve source design solution:  $\sqrt{}$
  - Click the OK button

Setup Link			×
General Variable	Mapping		
Product	HFSS		
Source Project	✓ Use This Project		
	Save source path relative to:		
	C The project directory of selected product		
	This project		
	This Project* - Reflector		
Source Design:	HFSSDesign1		•
Source Solution:	Setup1:LastAdaptive		•
<ul> <li>✓ Simulate sour</li> <li>✓ Preserve sour</li> <li>Note: In extra</li> </ul>	ce design as needed rce design solution ctor mode, source project will be saved upon e	xit	
		ОК	Cancel

Driven Solution Setup	×
General Options Advanced Expression Cache Derivatives Defaults	
Setup Name: Setup 1	
✓ Enabled	
Solution Frequency: 10 GHz 💌	
- Adaptive Solutions	
Maximum Number of Passes: 6	
G Maximum Delta S 0.02	
C Use Makin Conversion	
Use Matrix Convergence	
Lise Defaults	
HPC and Analysis Options	
OK Can	cel

#### PART 3: HFSS HYBRID DESIGN OF A REFLECTOR + HORN ANTENNA

After the creation of the horn, we export it as a 3D component and save it on a desired location on our computer. Next, we design the parabolic reflector and save it as a separate component on any location on the computer. Finally, we include the two components to obtain our parabolic reflector antenna.

The horn is positioned such that its aperture is directly facing the inside surface of the parabolic reflector with the aim of collecting and recycling electromagnetic emissions. The coordinate system employed in this set up is the reflector focus coordinate system.

Next, a solution setup is added to the two components. After adding a solution set up, we do a frequency sweep for our design. This is where we indicate the frequency range in which our design should operate. We set the step size 0.05GHz.

	Driven Solution Setup
	General Options   Advanced   Expression Cache   Dervatives   Defaults           Setup Name:       Setup2         Iv Enabled       Solve Ports Only         Solution Frequency:       [10         Adaptive Solutions       GHz         Maximum Number of Passes:       6         (r) Maximum Deta S       0.02
Edit Frequency Sweep ×	C Use Matrix Convergence Set Magnitude and Phase
Sweep Name:       Sweep         Sweep Type:       Discrete         Frequency Sweeps [241 points defined]         Distribution       Start         End         1       Linear Step         4GHz       16GHz         Add Above       Add Below         Delete Selection       Preview	Use Defaults HPC and Analysis Options
3D Fields Save Options       Time Domain Calculation         Image: Save Fields (All Frequencies)       Time Domain Calculation         Image: Save radiated fields only       OK         OK       Cancel	OK Cancel

# 10. PART 4: 3D PATTERN RESULTS

- Create 3D Far Field Pattern for IE Solution
   Select the menu item HFSS-IE > Results > Create Far Fields Report > 3D Polar Plot
- Solution: IE\_Setup: LastAdaptive
- ➢ Geometry: 3D
- Primary Sweep: Phi
- Secondary Sweep: Theta
- Category: Directivity
- Quantity: DirTotal
- ➢ Function: dB
- Click the New Report button



NB: For results and discussion, refer to chapter 4 of our project report.

# SECTION 3: SPHERICAL PHANTOM DESIGN FOR SPECIFIC ABSORPTION RATE (SAR) SIMULATION

Prepared by: Philip Arthur (MPhil. Telecom Eng. 2021)

#### INTRODUCTION

With the increasing consumer demand for wireless devices, consumers and the media have become aware of and are concerned with the biological effects of long-term exposure to radio frequency radiation (RFR). To ensure public safety, the Federal Communication Commission (FCC) has developed safety standards that wireless devices are required to meet in order to be sold in the US (Similar guidelines exist in other countries). The quantity used to quantify the amount of energy absorbed is the Specific Absorption Rate or SAR [1]. The specific absorption rate which is defined as the amount of electromagnetic energy absorbed per-unit mass by the human body when using a wireless communication device and can be represented mathematically as:

$$SAR = \frac{\sigma \times E^2}{\rho} \tag{1}$$

Where  $\sigma$  is the conductivity of the body tissue (S/m), E expresses the RMS electric field intensity (V/m) and  $\rho$  denotes the mass density of the body tissue  $(Kg/m^3)$ . According to the IEEE C95.1-2005 standard for safety levels with respect to human exposure to RF energy, SAR limit is set to 1.6 W/kg and 2 W/kg over 1g and 10 g of contiguous tissue respectively by the FCC and International Commission on Non-Ionizing Radiation Protection (ICNIRP).

This example is intended to show you how to create, simulate, and analyze a simple phantom, which is commonly used to calibrate Specific Absorption Rate test equipment, using the Ansoft HFSS Design Environment.

For basic design tutorials using HFSS:

https://www.youtube.com/playlist?list=PLdIVd39LNkpSaTzAFCS\_jh3sV3Gc21mNg

#### 1. CREATE BOWL

- Select the menu item Draw > Sphere
- Using the coordinate entry fields, enter the sphere position
   X: 0.0, Y: 0.0, Z: 56.5, Press the Enter key
- Using the coordinate entry fields, enter the radius:
- **dX: 56.5**, dY: 0.0, dZ: 0.0, Press the Enter key
- Change name of Sphere1 to Bow1





utel			Sele	ect Definition									×		
			Ma	aterials Material Filters	1										
Na	me	Value		Saamh Paramatam											
Name		Bowl		Search by Name		Search Crite	ria		Librar	ies 🔽 Show Project de	finitions	Show	v all libraries		
Material		Edit	-			• by Name	•	C by Property	N R	iew / Edit Material					
Solve In	side	~				Relative P	ermittivity		1000	-					
Orientati	on	Global		Search		J. Control 1	Jan Markey		Mate	rial Name			_		
Model		~						1	My_	Bowl					
Group		Model			Name		Location	Origin							
Display	Wirefra		-	-			0.11		Pro	perties of the Material				View/Edit Material fo	or
Material	Appea		-	titanium			SysLibrary	Matenais		Name	Туре	Value	Units	Active Design	n
Color			-	tungsten			SysLibrary	Matenals		Relative Permittivity	Simple	4.6		C Active Projec	4
Transpa	rent	0		vacuum			Project	Matenals		Relative Permeability	Simple	1		- Adave Hope	
			-	vacuum			SysLibrary	Matenais		Bulk Conductivity	Simple	0	siemens/m	C All Properties	
				water_distilled			SysLibrary	Materials		Dielectric Loss Tangent	Simple	0		Physics:	
				water_tresh			SysLibrary	Matenais		Magnetic Loss Tangent	Simple	0		Electromagne	etic
				water_sea			SysLibrary	Matenais		Magnetic Saturation	Simple	0	tesla	Thermal	
				ZEONEX R5420 (th	n) DC 4		SysLibrary	Materials		Lande G Factor	Simple	2			
				ZEONEX R5420-LL	JS (tm)		SysLibrary	Matenais		Delta H	Simple	0	A_per_meter	Structural	
			-	zinc			SysLibrary	Matenais		Measured Frequency	Simple	9.4e+09	Hz		
			-	zirconium			SysLibrary	Matenais		Mass Density	Simple	0	kg/m^3	View/Edit Modifier fo	or
				<										Thermal Mod	ifiar
				View/Edit Materials		Add Material		Clone Material(s)							
			_		·									- Material Appearance	
														Use Material App	hearan
														Color	
										Notes				Transparency:	
									s	et Frequency Dependency	[C	alculate Pr	operties for: 🖉 👻	Validate Materia	al
												_	1		

# 2. <u>SET MATERIAL PROPERTIES (View/Edit Material Window)</u>

- Change material name to My\_Bowl
- ▶ For the Value of Relative Permittivity type: **4.6**
- Click the OK button

# 3. CREATE OFFSET COORDINATE SYSTEM

- Select the menu item 3D Modeler > Coordinate System > Create > Relative CS > Offset
- Using the coordinate entry fields, enter the origin
  - X: 0.0, Y: 0.0, **Z: 81.5**, Press the **Enter** key

🦳 Fillet	🔰 Surface 🔻	🕹 R	🖧 Relative CS 🔻 🕅 Measure 👻							
🖉 Chamfer	🗢 Sheet 🔹	4	Offset		uler	ХҮ				
	🔪 Edge 🔻	22	Rotated			3D				
		\$	Both							
		_								

Progress	X:	Y:	Z:	81.5	Absolut 💌	Cartesian 💌	mm



# 4. CREATE THE OPENING IN THE BOWL

- Right click Bowl > Edit > Boolean > Split
- ➢ Split Window:
  - Split Plane: **XY**
  - Keep Fragments: Negative Side
  - Click the **OK** button





# 5. CREATE BRAIN FLUID

- Set the working coordinate system (CS): Global or simply click on the Global CS
- Select the menu item Draw > Sphere
- Using the coordinate entry fields, enter the sphere position
  - X: 0.0, Y: 0.0, **Z: 56.5**, Press the **Enter** key
- ➤ Using the coordinate entry fields, enter the radius:
  - **dX: 51.5**, dY: 0.0, dZ: 0.0, Press the **Enter** key
- Change name Sphere1 to BrainFluid



.te				Salact	Definition										×	
	Name		Value	Jelect	et las com	1									-	
Nam	- Hume	Desis Duid	Value	Mate	nais   Material Filter	rs									1	
Mate	erial	Edit		S	earch Parameters -								<b>— •</b>			
Solv	e Inside		1	- S	earch by Name		Search Crite	ina	C. In: Presents	Librarie	S I	<ul> <li>Snow Project definitions</li> </ul>	J Sho	ow all librar	ies	
Orier	ntation	Global	1.				ve by Name	-	· by Floperty	perso	έĎΪ	View / Edit Material				
Mode	el	Citobal	2		Search		Relative P	ermittivity	~	[sys] A	Ма	terial Name				
Grou	n.	Model	1.							_	My	y BrainFluid			_	
Dieol	lav Winafra								1	Re						
Mate	erial Annea					Name		Location	Origin	Per	P	Properties of the Material				View/Edit Material for
Color	r		1		titanium			SysLibrary	Materials	1	İГ	Name	Type	Value	Units	Active Design
Trap	snarent		0		tungsten			SysLibrary	Materials	1		Relative Permittivity	Simple	42.9		-
	opurorit				vacuum			Project	Materials	1		Relative Permeability	Simple	1		C Active Project
					vacuum			SysLibrary	Materials	1		Bulk Conductivity	Simple	0.9	siemens/m	C All Properties
					water_distilled			SysLibrary	Materials	81		Dielectric Loss Tangent	Simple	0		Physics:
					water fresh			SvsLibrary	Materials	81		Magnetic Loss Tangent	Simple	0		Electromagnetic
					water sea			SvsLibrary	Materials	81		Magnetic Saturation	Simple	0	tesla	
					ZEONEX RS420	(tm)		SvsLibrarv	Materials	2.3		Lande G Factor	Simple	2		L Thermal
					ZEONEX RS420-	LDS (tm)		SvsLibrary	Materials	2.1		Delta H	Simple	0	A_per_meter	Structural
					zinc			SysLibrary	Materials	1		Measured Frequency	Simple	9.4e+09	Hz	
					zirconium			SysLibrary	Materials	1		Mass Density	Simple	0	kg/m^3	View/Edit Modifier for
					-											
																Thermal Modifier
				V	iew/Edit Materials		Add Material		Clone Material(s	)						
																Material Appearance
																Use Material Appearance
										_						Color
												Notes				Transparency:
												Set Frequency Dependency	. 16	alculate Pr	operties for	Validate Material
											-					
												Reset	ΠK		Cancel	

# 6. SET MATERIAL PROPERTIES (View/Edit Material Window)

- > Change material name to My\_BrainFluid
- ▶ For the Value of Relative Permittivity type: **42.9**
- ▶ For the Value of Bulk Conductivity type: **0.9**
- Click the **OK** button



# 7. <u>CREATE THE SHELL OF THE BOWL</u>

- Select the objects: **Bowl**, **BrainFluid**
- > Clone tool objects before subtracting:  $\sqrt{}$  Checked
- Click the OK button

# 8. CREATE OFFSET COORDINATE SYSTEM

- Select the menu item 3D Modeler > Coordinate System > Create > Relative CS > Offset
- ➤ Using the coordinate entry fields, enter the origin
  - X: 0.0, Y: 0.0, Z: 69, Press the Enter key

Fillet	🔰 Surface 🔻	🖧 R	elative CS 🔻	🕅 Measure 🔻	∰ Gr
📶 Chamfer	🗢 Sheet 🔹	4	Offset	uler	ХҮ
	🔪 Edge 🔻	22	Rotated		3D
		2	Both		

# 9. <u>SET THE FLUID LEVEL</u>

- Right click BrainFluid > Edit > Boolean > Split
- > Split Window
  - Split Plane: XY
  - Keep Fragments: Negative Side
  - Click the **OK** button



Subtract			×						
Blank Parts Bowl	> <	Tool Parts BrainFluid							
Clone tool objects before operation									
ОК		Cancel							



# 10. CREATE AIR BOX

- Select the menu item Draw > Box
- Using the coordinate entry fields, enter the box position
   X: -150.0, Y: -150.0, Z: -150.0, Press the Enter key
- Using the coordinate entry fields, enter the opposite corner of the base rectangle:
  - **dX: 300.0, dY: 300.0, dZ: 300.0**, Press the Enter key
- Change name of Box1 to Airbox

# 1. CREATE RADIATION BOUNDARY

- Right click Airbox > Assign Boundary
   > Radiation
- Radiation Boundary Window:
  - Name: Rad1
  - Click the **OK** button





# SECTION 4: PIN DIODE MODELLING FOR ON/OFF SWITCHING IN RECONFIGURABLE ANTENNAS USING HFSS 2018

Prepared by: Philip Arthur (MPhil. Telecom Eng. 2021)

#### INTRODUCTION

Antenna reconfiguration has become an important feature in modern wireless communications such as MIMO systems, cognitive radio, 5G and satellite communication systems, IoT networks, and smartphones [4]. A reconfigurable antenna is capable of changing its performance characteristics (resonant frequency, radiation pattern, polarization, etc.) by mechanically or electrically modifying its architecture [5]. The basic goal of a reconfigurable antenna is to achieve more functionality with a single antenna element or an array.



Fig.1 PIN Diode (a) Basic structure [50] (b) Equivalent forward bias circuit (c) Equivalent reverse bias circuit.

The PIN diode is a simple technique of electronically modifying the functional properties of the antenna by the switching states of the diode. The PIN diode conducts current in one direction only and therefore determines the ON and OFF states respectively. When the diode is forward biased (ON state) the equivalent circuit is a combination of parasitic inductance L and a series resistance Rs as shown in Fig.4.0 (b). When a reverse-biased voltage is applied, the diode is known to operate in the OFF state with the equivalent circuit containing a large resistance (Rp) in shunt with a capacitor as shown in Fig.4.0 (c). This effect can be modeled as an RLC boundary in HFSS.

This example is intended to show you how to create, simulate, and analyze a PIN diode in a simple transmission line using the Ansoft HFSS Design Environment.

### For basic design tutorials using HFSS:

https://www.youtube.com/playlist?list=PLdIVd39LNkpSaTzAFCS\_jh3sV3Gc21mNg

# 1. CREATE DIELECTRIC SUBSTRATE

- Select the menu item Draw > Box
- Using the coordinate entry fields, enter the sphere position
  - X: -14.4, Y: -14.4, Z: 0, Press the Enter key
- Using the coordinate entry fields, enter the radius:
  - dX: 28.8, dY: 28.8, dZ: 1.6, Press the Enter key
- Change name of Box1 to Substrate



# 2. <u>SET MATERIAL PROPERTIES (View/Edit Material Window)</u>

- > Assign material: **FR-4 epoxy**
- Click the OK button

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		GILGI	11 1000 fm)	Svel ibrary	Materiale	3.12	1	0	
		GILGI	AL 1032 (m)	Svel ibrary	Materiale	3.72	1	0	
		GILGI	AL 2032 (m)	Svel ibrary	Materiale	3.2	1	0	
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								-	

# 3. CREATE GROUND PLANE

- Select the menu item Draw > Rectangle
- Using the coordinate entry fields, enter the sphere position
  - X: -14.4, Y: -14.4, Z: 0, Press the Enter key
- Using the coordinate entry fields, enter the radius:
  dX: 28.8, dY: 28.8, dZ: 0, Press the Enter key
- Change name of **Rectangle1** to **groundplane**

# 4. CREATE TRANSMISSION LINE

- Select the menu item Draw > Rectangle
- Using the coordinate entry fields, enter the sphere position
  - X: -14.4, Y: -1, Z: 1.6, Press the Enter key
- Using the coordinate entry fields, enter the radius:
  - dX: 28.8, dY: 2, dZ: 1.6, Press the Enter key
- Change name of Rectangle1 to TL

# 5. CREATE SLOT

- Select the menu item Draw > Rectangle
- Using the coordinate entry fields, enter the sphere position
   X: -1, Y: -1, Z: 1.6, Press the Enter key
- > Using the coordinate entry fields, enter the radius:
  - **dX: 2, dY: 2, dZ: 1.6**, Press the **Enter** key
- Change name of **Rectangle1** to **slot**

# 6. ASSIGN MATERIAL

- Select groundplane and TL
- Right click > Assign Boundary > Perfect E
- Click **OK** for PerfE1









# 7. <u>CREATE PORTS</u>

- Change drawing plan from default XY to YZ
- Select the menu item Draw > Rectangle
- Using the coordinate entry fields, enter the sphere position
  - X: -14.4, Y: -2, Z: 0, Press the Enter key
- Using the coordinate entry fields, enter the radius:
  - **dX: 0, dY: 2, dZ: 1.6**, Press the **Enter** key
- Change name of **Rectangle1** to **port1**
- Duplicate along line to create port2 (click and drag)

# 8. ASSIGN EXCITATION

- Right click port1 > Assign Excitation > Lumped port
- Draw integration line from bottom to top of port1
- Right click port2 > Assign Excitation > Lumped port
- > Draw integration line from bottom to top of **port2**











# 9. CREATE RLC BOUNDARY

- Change drawing plan from YZ to XY
- Select the menu item Draw > Rectangle
- ▶ Using the coordinate entry fields, enter the sphere position
  - X: -1, Y: -1, Z: 1.6, Press the Enter key
- ▶ Using the coordinate entry fields, enter the radius:
  - **dX: 0.5, dY: 2, dZ: 1.6**, Press the **Enter** key
- > Change name of **Rectangle1** to **C1** (Blocking capacitor 1)
- > Duplicate along line to create 3 other rectangles (click and drag) in the same slot.
- > Rename other ending rectangle as C2, middle 2 rectangles as L and R



#### 10. ASSIGN RLC BOUNDARY

- Right click C1 > Assign Boundary > Lumped RLC
- > Draw integration line in the chosen direction of the current flow.
- > Set C1 and C2 = 0.5uF (**ON** state)
- Right click L > Assign Boundary > Lumped RLC
- > Draw integration line in the chosen direction of the current flow (same direction as C1).
- > Set L = 0.4nH, R = 2  $\Omega$  (ON state)
  - For **OFF** state:
  - Set C1 and C2 = 32fF
  - Set L = 0.4nH, in parallel with R = > 15 k $\Omega$  (ON state)



Lumped RLC Boundary	×	
Name: LumpRLC5		
Parallel R, L, C Values		
Resistance: 0	ohm 💌	
Inductance: 0	nH 🔽	
✓ Capacitance: 0.5	pF 💌	
Current Flow Line: Undefined  Undefined New Line Use Defaults		X
ОК	Cancel	

Lumped RLC Boundary	×
Name: LumpRLC5	
Parallel R, L, C Values	
Resistance: 0	ohm 💌
🗖 Inductance: 🛛 🗍	nH 💌
Capacitance: 0.5	pF 💌
Current Flow Line: Defined	
Use Defaults	
ОК	Cancel

E - Lum E - Lum E - Coordinate E - Lam E -	pped C1 C2	RLC Expand All Collapse All Select > Edit > Group > Create 3D Component Assign Material					
		View >> Properties Create Array Count Occurs Busines					2
		Create Open Region Update Open Region Padding					
		Assign Boundary >	4	Anisotropic Impedance		<b>N</b>	- 1
		Assign Excitation >	4	Aperture			
		Assign Hybrid >	F	Finite Conductivity			
		Assign Mesh Operation >	H	Half Space			
		Plot Fields >	1	Impedance			
		Plot Mesh	1	Linked Impedance			
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Lumped RLC Boundary	×
Name: LumpRLC5	
Parallel R, L, C Values	7
Resistance: 0 ohm 💌	
✓ Inductance: 0.4 nH <	
Capacitance: 0	
Current Flow Line: Defined	
Use Defaults	
OK. Cancel	

Lumped RLC Boundary	×
Name: LumpRLC5	
Parallel R, L, C Values	
Resistance: 2	ohm 💌
Inductance: 0	nH 💌
Capacitance: 0	pF 💌
Current Flow Line: Defined	•
Use Defaults	
ОК	Cancel



# 11. CREATE AIR BOX

- Select the menu item Draw > Box
- Using the coordinate entry fields, enter the box position
  - X: -50.0, Y: -50.0, Z: -50.0, Press the Enter key
- Using the coordinate entry fields, enter the opposite corner of the base rectangle:
  - **dX: 100.0, dY: 100.0, dZ: 100.0**, Press the Enter key
- Change name of Box1 to Airbox

# 12. CREATE RADIATION BOUNDARY

- Right click Airbox > Assign Boundary > Radiation
- Radiation Boundary Window:
- > Name: Rad1
- Click the OK button



### 13. SIMULATION (ANALYSIS) SET UP

- Right click Analysis > Add Solution Set up
- Driven Solution Set up window:
  - Set frequency = 2.4 GHz
  - Set Maximum Number of passes = 20
  - Maximum Delta S = 0.02
  - Click OK
- Right click on Setup1 > Add Frequency Sweep
- Edit frequency sweep window:
  - Set frequency sweep from 1GHz 5GHz
  - Click OK
  - Validate
  - Analyze





Driven Solution Setup	×
General Options Advanced Hybrid	Expression Cache   Derivatives   Defaults
Setup Name Setup 1	
. , .	Solve Ports Only
Adaptive Solutions	j Solve Forta only
Solution Frequency:	Single C Multi-Frequencies C Broadband
Frequency	
requency	
Maximum Number of Passes	20
• Maximum Delta S	0.02
C Use Matrix Convergence	Set Magnitude and Phase
	UPC and Arabaic Onlines
	HPC and Analysis Options
	OK Cancel



#### 14. PLOTTING RESULTS

- (When PIN diode is switched ON)
  - Right click on Results > Create Modal Solution Data Report > Rectangular Plot
  - In the New Report dialog box
    - Solution setup1: Sweep
    - Domain: Sweep
    - Primary Sweep: Frequency (All)
    - Category: **S Parameter**
    - Quantity: **S(1,1)**
    - Function: dB
    - Click New Report

ontext -		Trace Families Families Display	
olution:	Setup1:Sweep	Primary Sweep: Freq      All	
omain:	Sweep	X: V Default Freq	
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		Category: Quantity:	▼ Function:
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- Right click on TL > Plot Fields > E > Mag\_E
- Create Field Plot window : Click **Done**
- Right click on Mag\_E1 > Animate
- Set up Animation window: click **OK**





Create Field Plot	X	
Setup Animation	alculator	
Name: Animation2 Description:		
Swept Variable Design Point	) Surface	
Swept variable: Phase	E Field [Y/m] 3.1619E+894 2.9511E+894	
Start: Odeg	2.74032E404 2.5296E404 2.3186E404 2.3186E404	
Stop: 170deg	2.1808Fe94 1.6973E94 1.6865E994	
Steps: 17	nine 1. 1757E-94 1. 2650E-94 1. 2650E-94 8. 4942E-93 6. 3266E-93 2. 1112E-93 3. 5442E+98 3. 5442E+98	
OK Cancel		

# \* (When PIN diode is switched OFF)

- Set parallel combination of R and C from the Boundaries and simulate (analyze all) Refer to section 10.
- Right click on Results > Create Modal Solution Data Report > Rectangular Plot
- ➢ In the New Report dialog box
  - Solution setup1: Sweep
  - Domain: Sweep
  - Primary Sweep: Frequency (All)
  - Category: **S Parameter**
  - Quantity: **S**(1,1)
  - Function: **dB**
  - Click New Report
- Right click on TL > Plot Fields > E > Mag\_E
- Create Field Plot window : Click Done
- Right click on Mag\_E1 > Animate
- Set up Animation window: click **OK**





# SECTION 5: MODELLING BENDING FEATURES IN FLEXIBLE ANTENNAS USING CST 2019

Prepared by: Philip Arthur (MPhil. Telecom Eng. 2021)

#### INTRODUCTION

The demand for wearable electronics to establish wireless body area communication has been growing rapidly. This places unique requirements on some electronic devices to possess conformable features. The flexibility feature has some striking advantages over its fixed counterparts in wearable applications. Due to the random postures of the host body, poor performance effects may result from the operation of these devices. Several applications of bodyworn sensors in health monitoring, sports and entertainment, emergency services and the military present the demand for flexible antennas. Hence, the simulation and design techniques to address the conformable features and its effects in such systems is equally important.

This guide is intended to show you how to apply bending features to an already designed slotted planar monopole antenna using the Computer Simulation Technology (CST) EM tool. CST Studio Suite is a high-performance 3D EM analysis software package for designing, analyzing and optimizing electromagnetic (EM) components and systems [6].



Fig.1 Applications of Flexible antennas [8]-[11]

# 1. LAUNCHING CST

- Select Programs > CST Studio Suite 2019
- > Close quick introduction video window.

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Save As Save All Open	Project Template Create a project template with settings tailored to your application area.	Restore last session 1 Project(s)	
Close	Antenna - Planar_1	vivaldi_Ant.cst -== CnUsersiApelDesitopiDesingsivivaldi	
New and Recent	Flexible Antenna -M MW & RF & OPTICAL, Time Domain	On-Body_ant_PETsubst_switchPort.cst C:\Users\Ape\Desktop\Desings\CST	
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Click on Microwaves & RF/Optical > Antennas



# Click on > Planar (Patch, Slot, etc.) > Next

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> Change name of project



# 2. HIDING THE BOUNDING BOX

Go to > View > Uncheck Bounding Box

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File	Home	Modeling	Sim	ulation	Post-Processing	View			
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View	Сору	Export	Hide	Show	Bounding Box	Wire	Working	Dimension	l Rectangle
Options	View -	Image	-	•	Text and Labels $~$	Frame	Plane 👻	-	Selection -
Options	Exchange		Visibility			Drawing	Selection		

# 3. ANTENNA BENDING

- > Perform outward cylindrical bending along the *x*-axis (*u*-axis; local coordinate)
- Select component1 > Go to Bending Tools > Cylindrical Bending
- Cylindrical Bend Window:
  - Impact direction: Two sided
  - Bending Parameters: Select Angle = -90 or choice of angle
  - Preview; **OK**



Cylindrical Bend	×				
Impact direction Two sided One sided	OK Cancel				
Bending parameters <ul> <li>Angle: -90</li> </ul>	Preview				
O Radius: 10					
Length: 0	Transf. WCS Help				

# For basic bending and antenna modelling tutorials in CST:

https://www.youtube.com/watch?v=nnnr0ccXOmE

https://www.youtube.com/c/tensorbundle/videos

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