Designing Horn Antenna utilizing FEM Symmetry Boundary Conditions

If a structure has any symmetry (E or M i.e. Electric or Magnetic), the structure’s physical size can be reduced symmetric plane boundary condition can be applied. Symmetric plane will take care of other half where symmetry is defined. This way the size of the problem subjected to simulation is reduced to half or lesser which now can be simulated in less amount of memory and lesser time. If a structure has both kind of symmetry (like rectangular waveguide) then it can be reduced to quarter, thus giving further advantage on memory and time.

Structure shown here is a Horn Antenna which is quite obviously symmetric in E-plane as well as H-plane so to characterize Horn Antenna performance we only need to simulate Quarter of an Antenna which will result in good amount of memory and simulation time.

**Step1: Building Horn Antenna Geometry for Symmetric Boundary Conditions**

Our overall dimension for 7.56 GHz Horn Antenna is having radiating aperture dimension of 184.6mm by 145.5mm with a tapered section of 339.8mm. Feed is WR90 waveguide with input aperture cross section of 22.86mm by 10.16mm.

a. To build the feed geometry click on Box icon and in the editor go to Specify Orientation tab and define the preset axis as XZ.

b. From the Edit Box tab, enter box dimensions as below:
   a. Width = 40 mm
   b. Depth = 11.43 mm (half of full depth)
   c. Length = 5.08 mm (half of full length)
   d. Modify the Box name as WG90

c. Go to Create->Geometry->Sheet Body and from Specify Orientation Tab, set the Z Origin to 339.8 mm

d. Go to Edit Profile and click somewhere in the GUI of the model.

e. Select Rectangle icon and press tab button to enter coordinates as below:
   a. $U' = 5.715$ mm
   b. $V' = 5.08$ mm

f. Press Tab again to enter parameters as below: (these as per bottom right side of the Horn which makes up for the quarter dimension of overall horn antenna)
   a. Width = -92.3 mm
   b. Height = -72.75 mm
   c. Enter Sheet name as Horn Aperture
   d. Press OK.
g. Rotate the Horn so that it appears as shown in next graphics. This shall enable us to pick WG90 face and Aperture face for using the Loft command to create tapered section of the horn

h. Select WG90, right click and select Modify->Loft Faces
i. In the next step select the front face of WG90 and HornAperture and go to Specify Loft tab. You can try modifying the slider for Smoothness factor to create tapered section with curvature....return to Smoothness factor of 0 for both the faces.
j. Select Add Loft As: WG90 Add On so that united Horn can be available for our simulations. Click Done to see Horn geometry as shown below
From the Project Tree on the left hand side, go to Definitions->Materials->Select from Default Material Library, select Cu material and click Add.

Drag and Drop Cu to WG90 and see the color change to RED indicating the Cu material is assigned to the Horn Antenna section.

Right click on the HornAperture and go to Gridding/Meshing and click on Include in Mesh to uncheck this option. This action shall ensure that we don’t include this Sheet body in our simulations. Check that Horn Aperture font becomes Italic and it is shown as *HornAperture*

Right click on Horn Aperture and select **Set Invisible**

Select Horn Geometry in GUI and select **Modify->Remove Faces** and select the Aperture face and click Done.

Save the project as HornAntenna_with_Symmetry.ep
Step2: Specifying Symmetric Boundary Conditions for Horn Antenna

a. Double click on Boundary Conditions option in the project tree and define following Boundary Conditions:

![Boundary Conditions Editor](image)

b. Double click on FEM Padding option and specify following padding for FEM simulations

![FEM Padding Editor](image)
c. Right click on the Horn Geometry in GUI and select Modify->Remove Faces. Select face on +Y side and then by pressing CTRL key select +X side. These faces are the 2 horizontal ones and opposite of the Horn Flare in both the directions where we shall apply the Symmetric Boundary conditions.

d. Once finished the Horn geometry will be shown as below

![Horn Geometry Image]

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e. **Waveguide Port:**
   
   i. Right click on Circuit Components/Ports and select New Waveguide Port

   ![Waveguide Port Image]

   ii. In the pop up window, press Arrow button and select the face of the waveguide feed.
iii. Go to EditCrosssectionPage and uncheck the option “Auto extend to simulation domain boundaries

iv. In the Properties Tab, select Waveguide Port Definition as 1W Modal Power Feed

v. In the impedance Lines tab, click on the Arrow icon in Endpoint 1(-) and select the lower corner of the open edge and it should fill in the (X,Y,Z) coordinates as shown below

vi. Click on Arrow icon in Endpoint 2(+) and select the top corner point and it should fill in (X,Y,Z) coordinates as shown below.

vii. Click Done
Step 3: Simulating Horn Antenna

a. Click on Simulation Setup icon and enter the frequency range as shown below. We shall perform frequency sweep from 7 to 8 GHz and add a single point of 7.56GHz to see Antenna performance on this spot frequency.

b. Click on Mesh/Refinement Properties and define Consecutive passes of delta error required as 2 to ensure we have decent Mesh Convergence for antenna structure.
c. From the Solver Tab, change the solver type as Direct and click on Create & Queue simulation to start simulation of Horn Antenna.

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Total Elapsed Time = 0:06:25

d. It takes @500MB RAM and 6 mins to solve this structure on Win7-64bit Laptop which is much lesser than originally required memory for full structure simulation which is around 5GB RAM and 45mins of simulation time.
e. Go to Results tab and plot S11 response as shown below
Step 4: Post Processing and Antenna Radiation Pattern

We deliberately didn’t added Far Zone Sensor for Antenna Radiation pattern to illustrate that we can reuse the FEM simulation results to achieve better Mesh Convergence or to perform additional tasks in EMPro. Now let’s add sensors for our radiation pattern calculation etc.

a. Right click on Far Zone Sensors and select New Far Zone Sensor

b. Globe kind of outline will be displayed indicating 3D Radiation Pattern calculations. Go to Properties and define the sensor name as **3D Radiation Pattern**. Click Done.
c. Add a new far zone sensor as per above method and select “Use Single Phi Value” and leave it as 0°. Define the THETA sweep range from -30° to 30°, Increment = 0.1°. Go to Properties tab and give the name as PHI 0deg THETA -30 to 30 deg for this sensor. Click Done when finished.

d. Add another Far Zone Sensor and again click on “Use Single Phi Value” and provide Start Angle = 90°. Define Theta from -30° to 30°, Increment=0.1°. Go to Properties tab and give name PHI 90deg THETA -30 to 30deg for this sensor. Click Done when finished.
e. Click on FEM simulation setup and select previously run simulation from Simulation results to reuse as shown below.

f. Click on Create & Queue simulation and observe that last simulation result will be reused and only Far Field radiation pattern will be calculated.

g. Once finished, go to Results tab and select 3D Far Zone Sensor to plot the Gain of the Antenna. Set Centre point as following:
   a. X = 0 mm
   b. Y = 0 mm
   c. Z = 500 mm
h. Go to Results tab again and click on PHI 0deg THETA -30 to 30deg and select Gain to be plotted. Right click on the Gain and select Create Line Graph.

Choose parameters as shown below and click on View to see 2D cut of the Antenna Gain at 7.56GHz

![EMPro - Create Graph](image)

2D Far Field Cut at PHI = 0 deg
Similarly plot Gain pattern at PHI=90° as shown below

Field Distribution inside Horn Antenna

To plot field distribution inside Horn Antenna, go to Results tab and click on Advanced Visualization where display as below shall be available
Go to the Solution Setup and select desired frequency e.g. 7.56GHz. Go to Plot Properties and click on Animate Button and Click on Enable button in front of Y: 5.08 and X: 5.715. Once done orient the 3D view of Antenna for proper E-field distribution in Horn Antenna as shown below

***End of Lab Exercise***

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