APPLICATION BRIEF

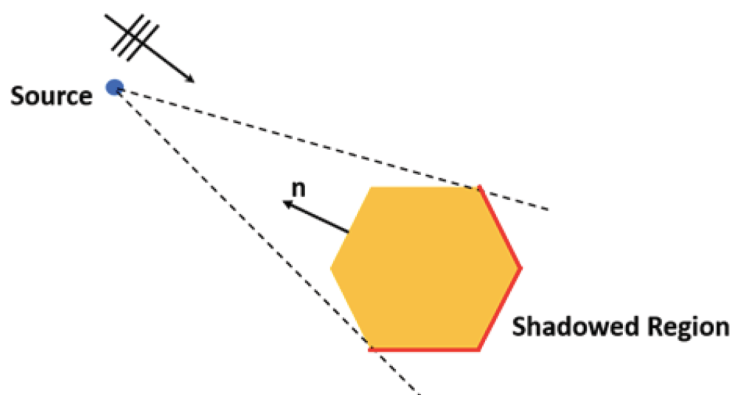
Ansys HFSS PO Hybrid Region

The design of electrically large systems poses many challenges. Electromagnetic simulations can relatively quickly assess options and trade-offs before any physical testing. Ansys HFSS offers 3D simulation technology for accurate and fast modeling of electrically large designs. HFSS-IE (3D method of moments) and physical optics (PO) solvers were introduced as an efficient alternative to finite element method (FEM) solver for metallic electrically large structures. Introduced in R14, hybrid solver combines FEM and IE techniques, leveraging the strength of both methods for accurate and efficient simulations. This paper shows applications for a new R17 feature, Hybrid Regions. The PO region is a fast alternative to the IE region for simulation of the smooth conducting or dielectric structures that are electrically very large. Three applications are discussed: horn fed reflector, reflector with radome and Cassegrain reflector. Each application leverages expanded hybrid solver enabled in new release for accurate and efficient simulation. These applications use hybrid regions: horn fed reflector modeled with FE-BI and PO hybrid regions; reflector with radome modeled with FE-BI, metallic PO and dielectric PO regions; and Cassegrain reflector modeled with FE-BI, IE and PO regions. FE-BI regions are FEM domains surrounded by a boundary that uses integral equation (HFSS-IE) formulation to truncate an open space. IE regions are objects or sheets solved with HFSS-IE solver. PO regions are dielectric objects and perfectly conducting objects or sheets solved with physical optics formulation.

PO Hybrid Regions

HFSS models are growing in complexity and fidelity as compute resources become more readily available. For example, HFSS is being used to model installed antenna performance, including things like feeding networks and reflector systems, rather than simply modeling the antenna in free space. Managing these multi-part models can become very complex if not impossible, especially when the engineer who is modeling the full system is not the one necessarily designing each individual part. 3D components facilitate the design process by providing an infrastructure to efficiently manage complex models and freely share parts among collaborators, customers and/or vendors.

The PO solver provides first-order scattering information and proves to be efficient approximation for metallic, smooth, locally flat structures. However, because PO is not a full wave solver, inappropriate use of the PO region may lead to an incorrect solution. For characteristics that are highly sensitive to effects only captured by a full wave solution, it is necessary to use HFSS-IE solver. The use of the PO region is optimal when the structure is locally flat, dimension of the structure is bigger than 10 wavelengths and the structure is located at least 10 wavelengths from the radiating source. When these conditions are met, a well-defined portion of the structure is visible to the radiating source. This region is called a lit region. The remaining region is termed a shadow region. In PO approximation, the currents on shadow regions are identically zero. One example perfectly suited for PO region workflow is horn fed reflector antenna at high frequency, where the antenna size is electrically large.



$$\mathbf{j} = 2\mathbf{n} \times \mathbf{H}^{inc} = \frac{2}{\eta}\mathbf{n} \times \mathbf{E}^{inc} \times \mathbf{n}$$ *Lit Region*

$$\mathbf{j} = 0$$ *Shadowed Region*

Figure 1. Lit and shadowed regions and applied current for geometry assigned as metallic PO regions.

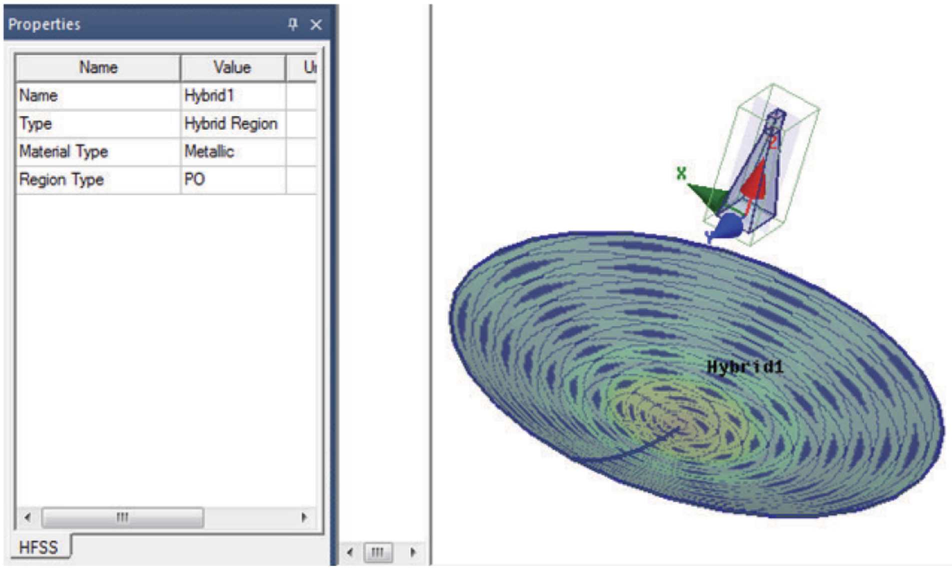


Figure 2. Reflector assigned as hybrid metallic PO region.

Horn-Fed Reflector Antenna

An electrically large reflector of 22 wavelengths in diameter is fed with a rectangular horn. To model the system using a hybrid solution with the reflector solved as a PO region, all geometry objects are placed in HFSS design. The horn geometry is surrounded by an air box named RadiatingSurface. The faces of this object are assigned as hybrid FE-BI region, the assignment corresponds to radiation FE-BI boundary in previous versions of Ansys HFSS. To assign, select the air volume surrounding FEM part of a design, and use menu item HFSS > HYBRID > ASSIGN HYBRID > FE-BI. The reflector is modeled as a 2D sheet object with PerfE boundary condition assigned. This sheet object is modeled as a hybrid metallic PO region. To assign, select the reflector and use menu item HFSS > HYBRID > ASSIGN HYBRID > PO REGION. The dialogue for the hybrid region opens, showing the default name and type selection as PO region. Since a user may decide to change an assignment to the IE region, the dialogue shows these types as radio button selections.

All hybrid regions are listed under the hybrid regions entry in the project manager.

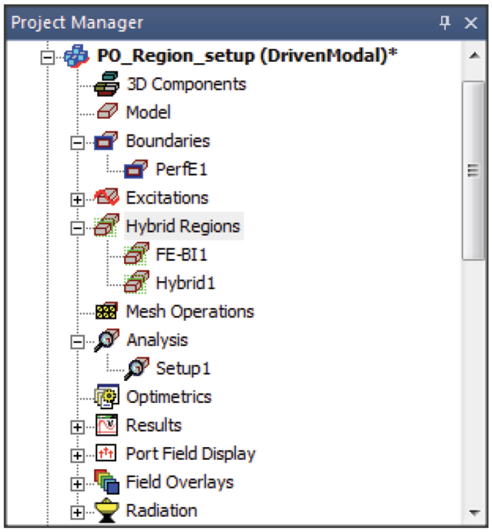


Figure 3. Project manager window lists hybrid regions of all types including FE-BI.

After the solution has completed, standard result reports like field plots, S-parameters and far field characteristics are available.

The same geometry was solved with the reflector assigned as an IE region. We can see that the radiation patterns are almost identical and differ only for back lobes, while the PO region option significantly saves computational resources.

Note that PO regions may be used together with other useful features like 3D components. For parametric sweeps that vary the distance between assembled 3D components, it is possible to preserve and reuse the component-level meshes between these variations. For example, if a horn and a reflector are defined as 3D components with enabled “Do Mesh assembly” option, one can do a placement study running the parametric sweep over the distance between the horn and the antenna, recycling the mesh to speed up the parametric sweep simulations.

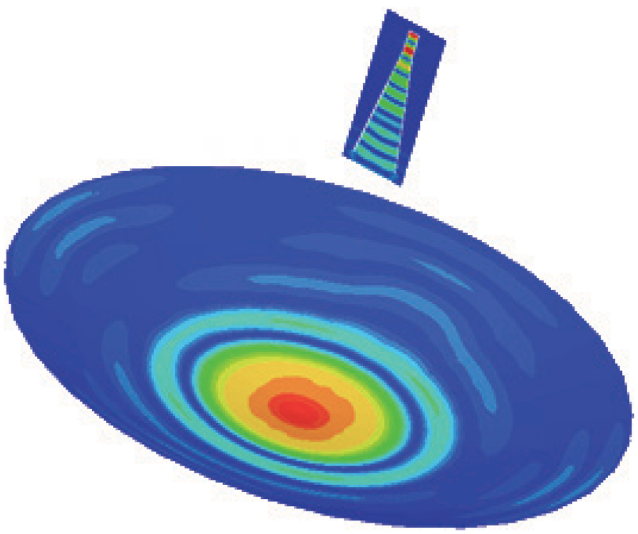
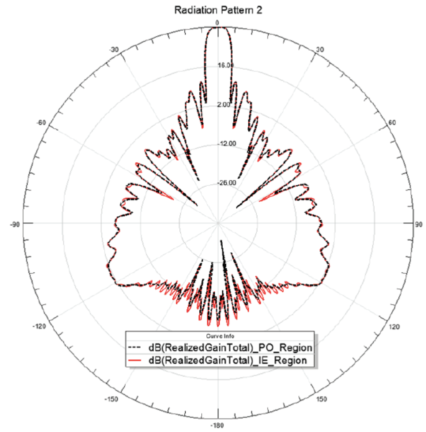


Figure 4. E-field plots in FE-BI region and J-field plot on PO region.

Project “Reflector_antenna_PO_Region” contains the designs for simulations described above. Note several limitations of the PO region option. First, every conducting material of the metallic PO region will be treated as perfect conductor, and every surface will be treated as PerfE boundary condition disregarding actually assigned materials and boundary conditions. The warning message will be issued if the PO region is assigned on a metal object or a boundary condition that is not a perfect electric conductor. Assigning the PO region to a dielectric object automatically turns this hybrid region to a dielectric PO region. Second, if there are multiple sources modeled with multiple disjoint FE-BI boundaries that makes it hard to accurately define the shadow region, the PO region solver does not provide reliable results. Furthermore, the solver will report an error message when it detects that a shadow region due to each FE-BI region does not mostly overlap.



Reflector assigned as	RAM 1st pass	Time (1 core used) Mesh + 1st pass
IE Region	2.49GB	10 min 31sec
PO Region	1GB	1 min 27 sec

Figure 5. Comparison of the designs that use IE region and PO region options to model a reflector: Radiation pattern and computational resources required for each design.

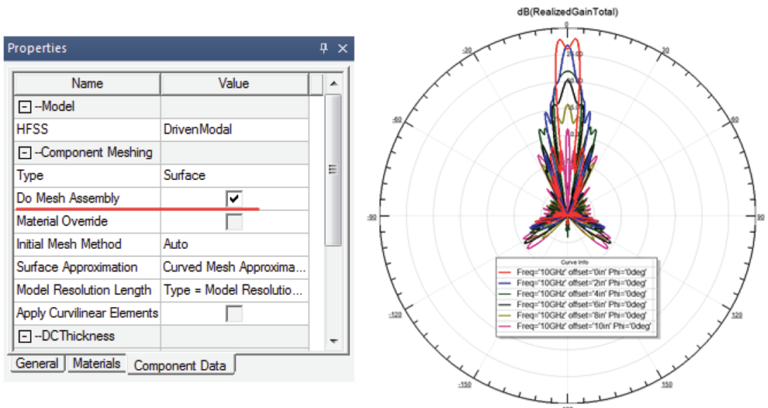


Figure 6. 3D Component data settings for mesh recycling and resulting radiation patterns for different distances between the horn and the reflector.

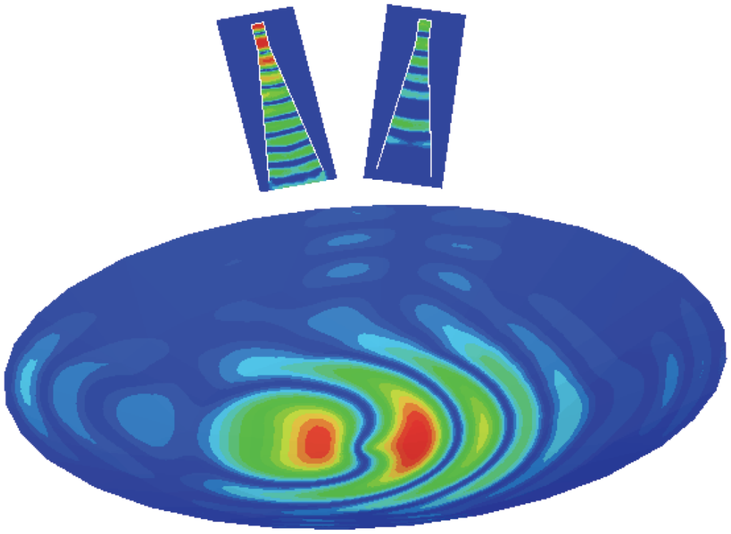
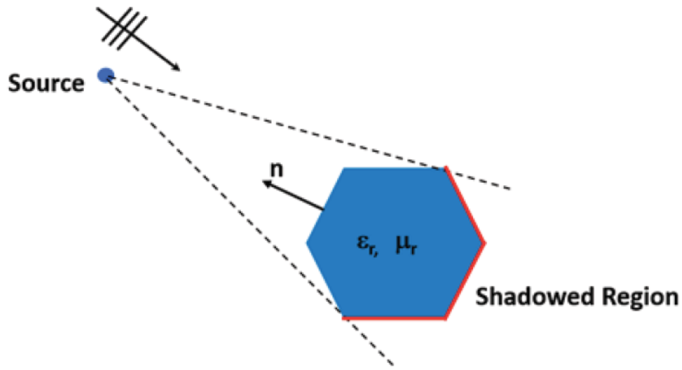


Figure 7. Example of two horns modeled with two disjoint FEBI boundaries. For this case, shadow regions for each FE-BI box are practically the same, making this design suitable for the PO region option. If it is hard to accurately define the shadow region, the PO region solver may not provide reliable results.

Dielectric PO Region: Antenna with Radome

A hybrid PO region may be assigned to dielectric object as well.



Lit Region

$$\mathbf{j} = (1-R)\mathbf{n}\times\mathbf{H}^{inc}$$
$$\mathbf{e} = (1+R)\mathbf{n}\times\mathbf{E}^{inc}\times\mathbf{n}$$

$$R = \frac{k_z^2 - k_{zs\_\mu}^2 - (k_z^2 - k_{zs\_\mu}^2)e^{-2jk_{zs}dd}}{(k_z + k_{zs\_\mu})^2 - (k_z - k_{zs\_\mu})^2 e^{-2jk_{zs}dd}}$$

$$T = \frac{4(k_z k_{zs\_\mu})e^{-jk_{zs}dd}}{(k_z + k_{zs\_\mu})^2 - (k_z - k_{zs\_\mu})^2 e^{-2jk_{zs}dd}}$$

Shadowed Region

$$\mathbf{j} = -T\mathbf{n}\times\mathbf{H}^{inc}$$
$$\mathbf{e} = -T\mathbf{n}\times\mathbf{E}^{inc}\times\mathbf{n}$$

$$k_z = k_0,\quad k_{zs} = k_z\sqrt{\varepsilon_r\mu_r},\quad k_{zs\_\mu} = k_{zs}/\mu_r$$

Figure 8. Lit and shadowed regions and applied fields for geometry assigned as dielectric PO regions.

Application Example for Dielectric PO Region: Antenna with Radome

The dielectric PO region option is well suited for simulating antennas covered with radomes. To model the system using the dielectric PO region, all geometry objects are placed in a single HFSS design. Horn geometry is surrounded by the air box that is assigned as a hybrid FE-BI region. The radome geometry should be a standalone 3D object assigned with dielectric material. This object is also assigned as a hybrid dielectric PO region. To assign, select the radome and use the menu item HFSS > HYBRID > ASSIGN HYBRID > PO REGION. The dielectric PO region should not touch any other model geometry. This option may be used in the same design together with other hybrid regions. Below is the example of reflector with the flat FR4 radome between the reflector and the horn.

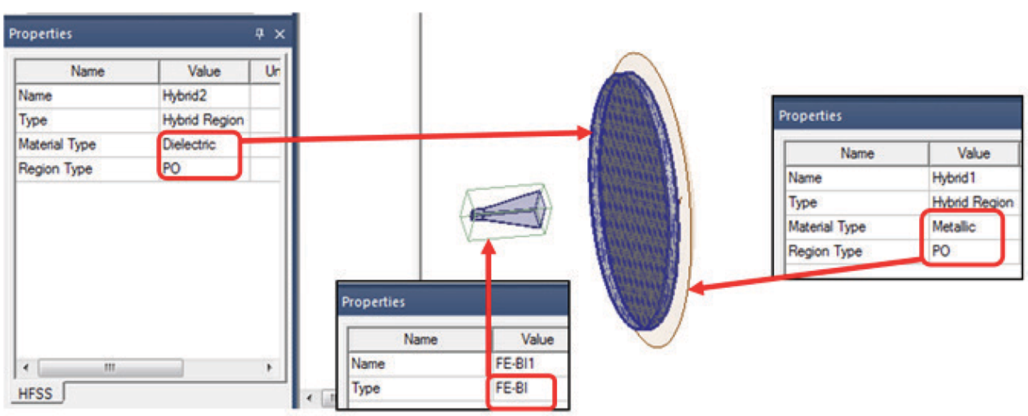


Figure 9. Three hybrid regions are assigned: FE-BI for air box around horn, metallic PO for PerfE reflector and Dielectric PO for FR4 radome.

Note some limitations for a dielectric PO region: no boundary condition may be assigned on the surface of a dielectric PO region; dielectric PO region cannot touch any other metallic IE or PO regions. However, several touching dielectrics like layers of the radome may be assigned as one hybrid dielectric PO region.

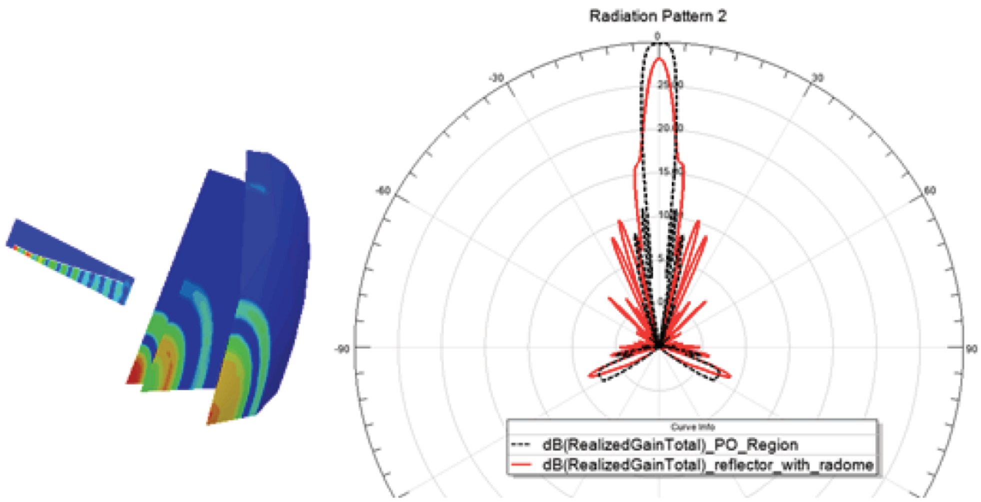
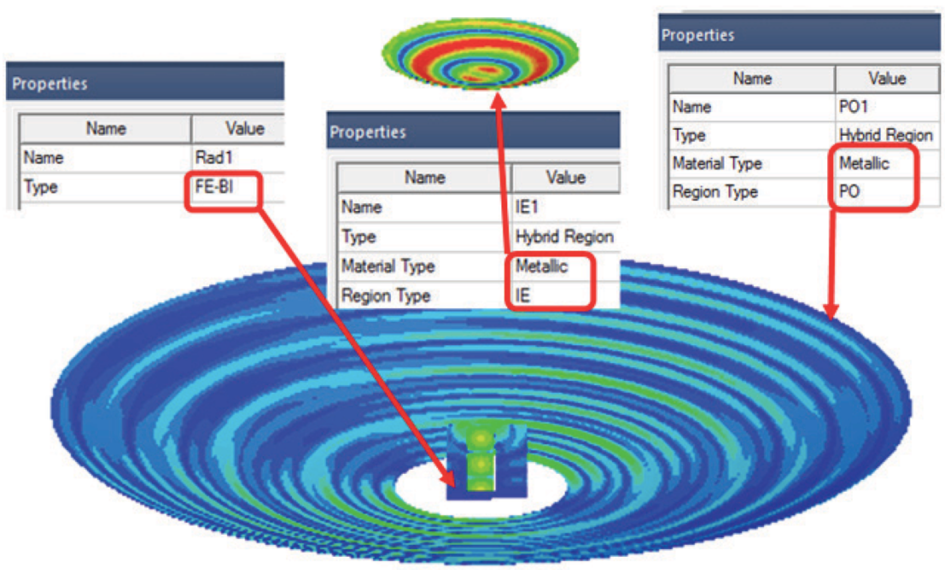


Figure 10. Solved fields for design with three hybrid regions, including, dielectric PO region for FR4 plate radome. Only a quarter of geometry is displayed for a field plot. In the Radiation Pattern plot, the black dotted line represents the far field of the reflector without radome, and the red line refers to the design with FR4 plate between the horn and the reflector.

/ Cassegrain Reflector: IE and PO Hybrid Regions in One Design

Hybrid PO regions may be combined with IE hybrid regions if desired. For applications like the Cassegrain reflector, there are 2 regions suitable for IE solver: a sub-reflector and a main reflector. A sub-reflector is usually not very large electrically but accuracy of the field solution on the sub-reflector is very important. A main reflector may be electrically very large and smooth making PO approximation justified for the main reflector. Below is the solved field for the Cassegrain system with a relatively small main reflector: The air box around the horn is assigned as a FE-BI region, the sub-reflector is assigned as a metallic IE region and the main reflector is assigned as a metallic PO region.



/ Summary

The PO region is a viable option for many electrically very large geometries. With an understanding of the limitations, users can generate accurate results using this very efficient method. Themetallic PO region is a fast alternative to the IE region for simulation of the smooth conducting structures that are electrically very large. Dielectric PO regions can be used for simulating standalone electrically large dielectric objects. PO regions may be flexibly combined with other hybrid regions and other Ansys HFSS features for efficient simulations of electrically very large systems.

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