HyperLynx 3D EM Designer AGIF Manual

Automatic Geometry to HyperLynx 3D EM Flow

Release 15.2

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This user manual is intended to cover every detail of the HyperLynx 3D EM AGIF module from EM model setup to simulation result analysis. The major topics include:

- ✓ How to use advanced parameter settings on AGIF?
- ✓ How to get correct EM models with efficient simulations and high accuracy?
- ✓ How to set the simulation parameters?
- ✓ How to import GDSII designs into AGIF and build EM models?
- ✓ How to run batch simulations based on one .i2i template file for multiple GDSII designs?
- ✓ What are *Layer Self Operations*, *Boolean Operations* as well as *Layer Mutual Operations*, and how to use these operations?

Cadence Allegro Package Designer (APD) users are recommended to start with the two AGIF quick start guides, i.e. *Quick_Start_Guide_wire_bonds.pdf* and *Quick_Start_Guide_flip_chip.pdf* before reading this manual in order to get familiar with the *APD/SiP* to *AGIF* flow; while *Cadence Virtuoso* users are recommended to pay more attention on the GDSII handling part in this manual.

Several typical structures, including stack-die as well as multi-die with bond wires, will be discussed in this manual in order to provide more detailed information on AGIF usage. In addition, several typical spiral inductor designs are provided for explaining how an .i2i template file is used for multiple designs with an identical layer stackup.

Besides the above contents, some useful utilities on AGIF will also be discussed, including GDSII conversion, result display etc.

Chapter 1 Introduction

IE3D full-wave simulator has been well known for its fast speed, accurate simulation results as well as less RAM consumption since its inception in 1992. It has been used for solving a wide range of problems from component level structures, such as antennas, RF filters, hybrids etc. to system level designs, such as signal integrity, package, MMIC/RFIC. In conjunction with other useful utilities included in IE3D EM Design System, IE3D has been also used for solving RF/Microwave circuitries, optimizing prototype designs, parameterizing geometries for real-time tuning etc. Many designers and researchers have been using IE3D for prototyping, simulation benchmarking as well as design verification.

Starting from v15.2, IE3D has been rebranded to *HyperLynx 3D EM Designer* as a part of HyperLynx product line. All the aforementioned features with IE3D have been seamlessly inherited to the new *HyperLynx 3D EM Designer* with additional advanced functionalities, such as the support of .cc file format of Mentor Graphics, a new architecture for distributed simulations and more.

With fast development of IC industry and modern semiconductor technologies, many IC/Package designers are facing with adverse electromagnetic effects incurred by higher data transfer rate, long signal transmission distance and higher device density on a circuit board, such as ringing, cross-talk, ground bounce and power noise. These effects can degrade the electrical signal to the point where errors occur, and the system or device may fail. It has been a great challenge for signal integrity engineers to analyze and mitigate these impairments. At gigahertz data transfer rate, these effects will be more prominent. Therefore a full-wave EM simulation tool that is able to address these effects appears to be more and more indispensible. Ideally the tool should be of:

1. Fast simulation speed in order to have shorter design turnaround
2. High capacity that can take in the whole system designs
3. High accuracy which is always a key point for a simulator
4. Direct link to popular CAD layout tools, such as *Mentor Graphics Expedition, Cadence Allegro Package Designer*, and *Cadence Virtuoso* etc.
5. Abilities of modeling and solving 3D objects, especially 3D metal structures, such as vias, non-uniform transmission lines, typical package structures, etc…
6. Minimum effort to obtain correct EM models
7. Capabilities of modifying created EM models for testing and verification purposes

AGIF was designed and release first in 2005 to meet the above requirements and other industrial needs, it has been adopted and used by many world renowned companies so far.

The new 15.2 release contains some attractive features compared to 15.1 release:

- ✓ Interface to Mentor Graphics Expedition/BoardSim (available on Windows OS only)

- ✓ New distributed simulation architecture and simulation monitoring module for LSF/SunGrid platforms support
- ✓ A better .geo file viewer
- ✓ Improved bond wire handling capabilities that support both Mentor Graphics Expedition and Cadence APD bond wire definition
- ✓ Less parameter settings by integrating many of them in the automated process
- ✓ More optimized default parameter value settings for less user interactions

Primarily AGIF can handle the following tasks:

1. Mentor Graphics Expedition/BoardSim to EM model flow
2. Cadence APD (.mcm)/Cadence SiP(.sip) to EM model flow
3. Cadence Virtuoso to EM model flow
4. GDSII to EM model flow
5. Batch Simulation for multiple GDSII designs that are based on one layer stackup

The following chapters are organized in the order of task list shown in the AGIF user interface. Detailed explanation on parameter settings will be given, and the How-Tos listed on the first page will also be discussed.

Chapter 2 Mentor Graphics Expedition/BoardSim to HyperLynx 3D EM Flow

One of the major improvements in *HyperLynx 3D EM* v15.2 is its new link with Mentor Graphics *HyperLynx BoardSim* and *Expedition*. *BoardSim* and *Expedition* users are now able to export their board designs to a .ccz (or .cc, .cce) file, and then load the .ccz file into AGIF for EM analysis. After obtaining the S-parameters from *HyperLynx 3D EM* simulation, users have flexibility to plug the S-parameter file in other circuit simulators, such as *HyperLynx SI* for time-domain or frequency-domain analysis. Interested users may also refer to *HyperLynx* manual for more information.

In this Chapter, a sample .cc file is used to demonstrate how AGIF sets up EM model. The sample file is stored in .\SDD_HOME\IE3D\ie3d_si\CC_Flow\ folder. Users are also recommended to export sample .cc file from your own *Expedition* or *BoardSim* designs to test the flow.

First go to HyperLynx 3D EM Program Manager, as shown below:

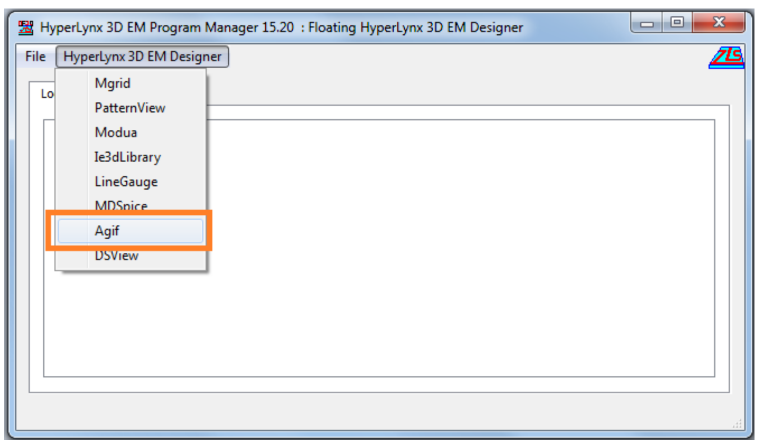


Fig 2-1 HyperLynx 3D EM Program Manager

Click on HyperLynx 3D EM Design, and then choose AGIF to bring up the AGIF task list:

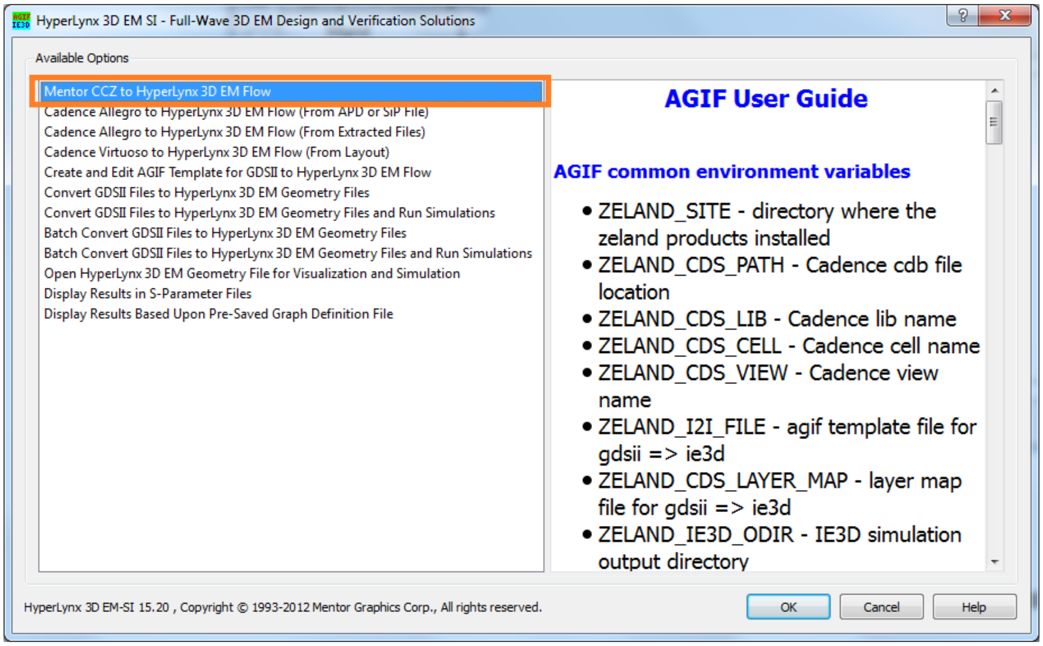


Fig 2-2 AGIF Task List

Select the first item in the list: *Mentor CCZ to HyperLynx 3D EM Flow*, users are prompted to select the design file, which could be in .cc, .ccz or .cce format:

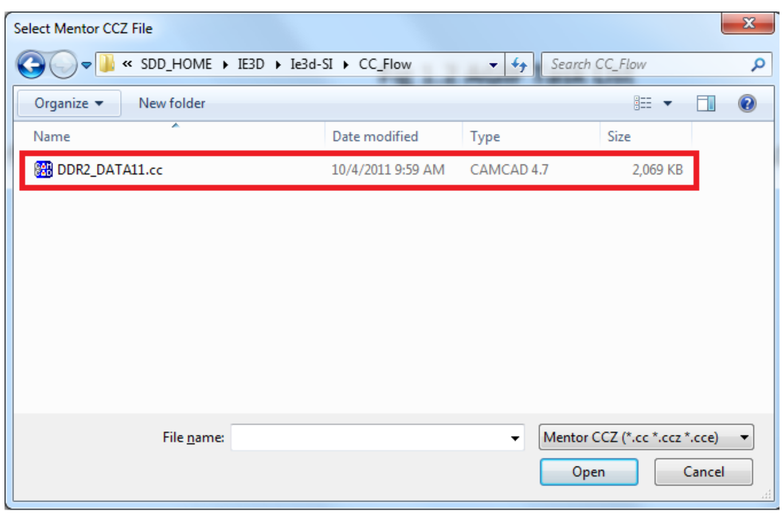


Fig 2-3 Select CC File

Navigate to the .\SDD_HOME\IE3D\ie3d_si\CC_Flow\ folder, and select *DDR2_DATA11.cc* file. Click on Open button to proceed. AGIF is now loading the design data:

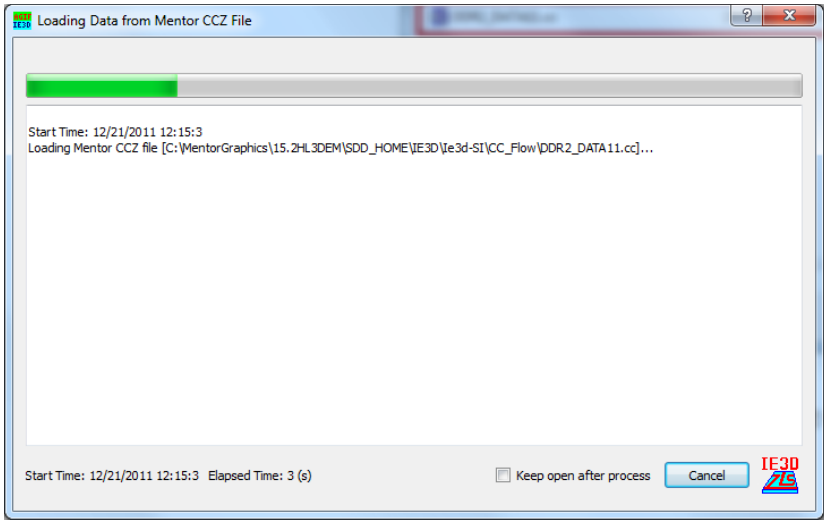


Fig 2-4 Loading Data

After the data is fully loaded, AGIF main menu will show up, as seen below:

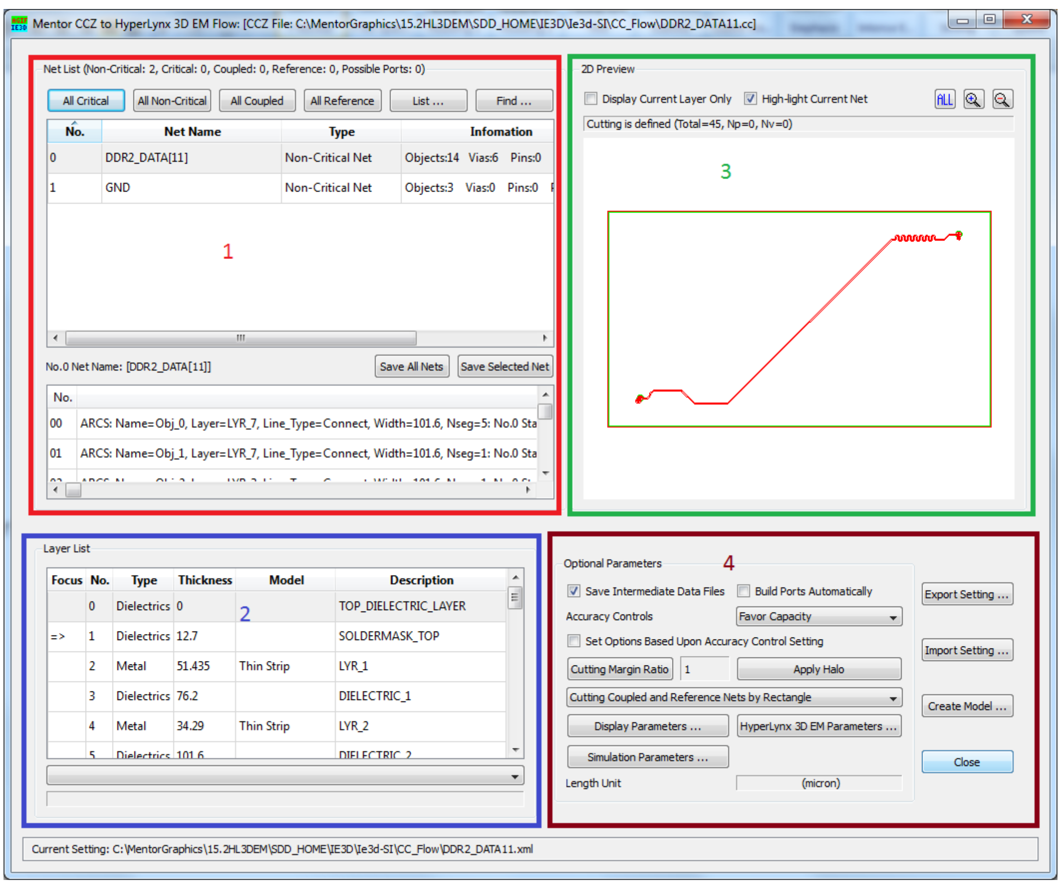


Fig 2-5 AGIF Main Menu

Basically the AGIF main menu contains four sections:

- Net-list
- Layer stackup
- Top view of the structure
- Optional parameters

The following explains the details on each section.

<u>Net-list</u>

This section shows all the nets imported from .cc database. The six buttons on the top are for setting net types:

Table 2-1 Functions of the Six Button in Net-list Area

Button	**Function**
All Critical	Define all the nets are critical nets. Critical nets will be included in the EM model, and ports will be attached to each critical net. There must be at least one critical net in order to create an EM model. This button is used when the whole structure need to be simulated.
All Non-Critical	Define all the nets are non-critical nets.
All Coupled	Define all nets are coupled nets. Coupled nets will also be included in the EM model, but no ports will be created for coupled nets. The main reason for including coupled nets is to observe the EM effects incurred by the coupled nets.
All Reference	Define all nets are reference nets. There must be at least on reference net defined in order to get correct EM model.
List ...	Click to see all the defined critical net(s), coupled net(s) and reference net(s).
Find ...	Click to search for a certain net by name. After finding the net, you may also use the button at the bottom to directly define its net type without going back to the main menu.

Below the function buttons is the list of the imported nets. User can click the combo box under *Type* column to set the type of each net:

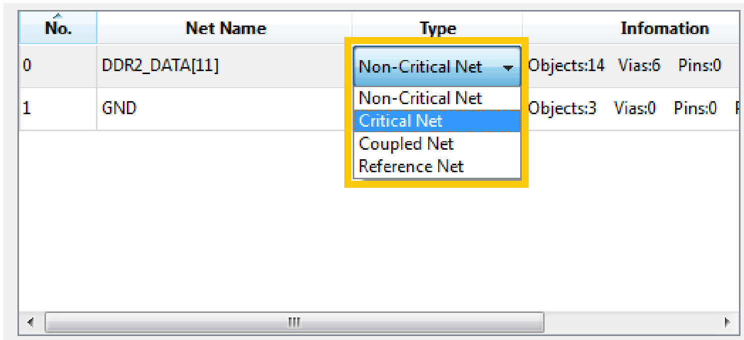


Fig. 2-6 Net List

User may also use the *Save All Nets/Save Selected Net* button to save nets in a text file for reference. The list below the net list is the information list of the highlighted net, which shows object information contained in the net:

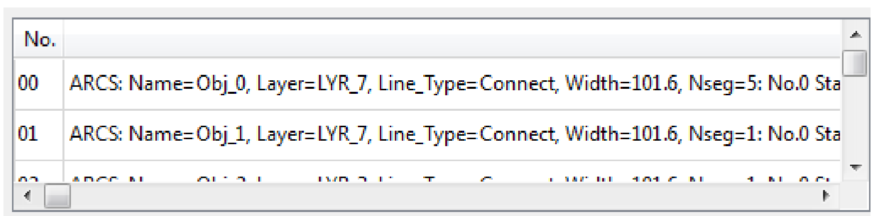


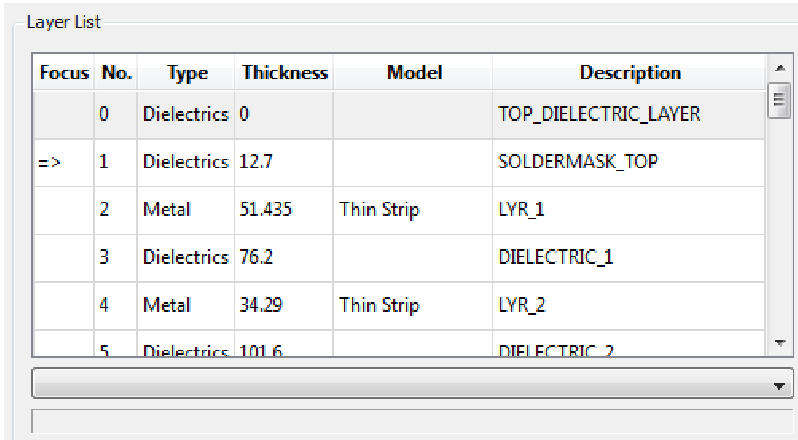
Fig. 2-7 Net Information

<u>Discussion:</u>

1. What nets should be defined as critical nets?
   Any nets that need to be included in the EM model, and S-parameters are desired, should be defined as critical nets.
2. Why must there be at least one reference net?
   An EM simulation should have a closed signal loop for each port. If there is no reference net, a critical net will not be able to form a closed signal loop, and the simulation results will be incorrect.
3. What is the difference between critical net and coupled net?
   The difference is there is no port attached to coupled net. However, the EM effects incurred by the coupled nets will be calculated by the program.

<u>Layer Stackup</u>

Fig. 2-8 shows the layer stackup region on AGIF main window:


Layer List

Focus	No.	Type	Thickness	Model	Description
	0	Dielectrics	0		TOP_DIELECTRIC_LAYER
=>	1	Dielectrics	12.7		SOLDERMASK_TOP
	2	Metal	51.435	Thin Strip	LYR_1
	3	Dielectrics	76.2		DIELECTRIC_1
	4	Metal	34.29	Thin Strip	LYR_2
	5	Dielectrics	101.6		DIELECTRIC_2

Fig. 2-8 Layer Stackup

Layer stackup data is also extracted from the .cc design file. User can define the *Model* type as well as the material parameters for each layer.

Table 2-2 shows the definition of each layer model type:

Table 2-2 Layer Model Definition

Layer Model Type	**Definition**
Wire Bond Group	The layer is defined as wire bond layer
Thin Strip	All the metal polygons on this layer do not have thickness
Thin Strip (2)	All the metal polygons on this layer do not have thickness, but the thickness of the metal will be added to the substrate
Thick	The thickness of the metal polygons will be applied to this layer
Void	The layer will be omitted in the EM model

To define the material parameters, simply double click one layer, either metal or substrate layer, to bring up the material parameter window:

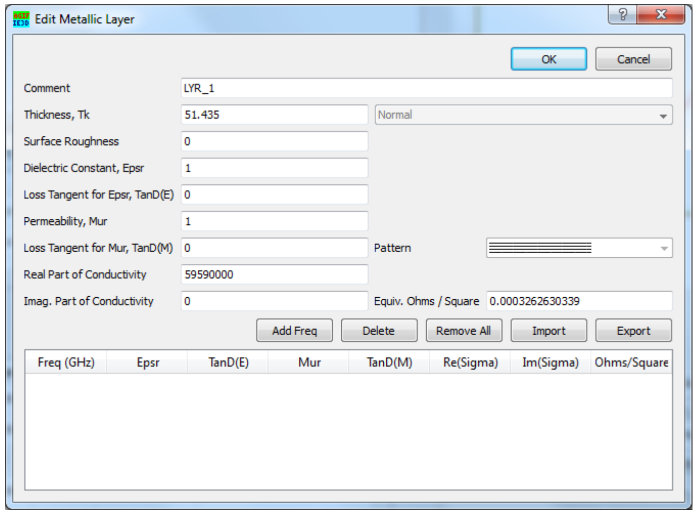


Fig. 2-9(a) Metal Material Parameters

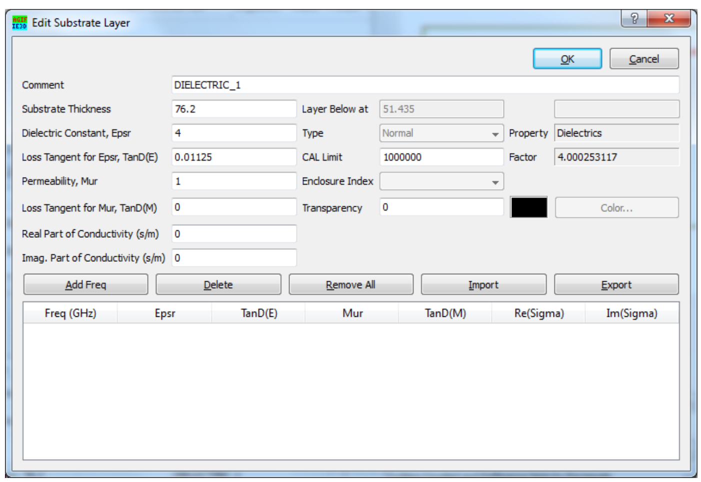


Fig. 2-9(b) Dielectric Material Parameters

As can be seen in the above pictures, besides the regular metal/dielectric material parameters, the frequency-dependent materials can also be defined in the lower part of the material parameter window. User can also prepare a text/excel file for the frequency-dependent materials, and use *Import* button to import the material information directly into the layer parameter settings. All the metal/dielectric material parameters are intuitive. If you have any questions to the definitions of the material parameters, please refer to *HyperLynx 3D EM User's Manual* for more details.

It is recommended for users to check the material parameters for each layer before creating the EM model in order to make sure all the parameter data are correct, and the layer model type is set correctly.

Discussion:

1. Why do I need to worry about layer stackup?

Sometimes there might be some mistakes and errors in the original design. Some designers might also add some useless layers in the design that should not be included in the EM model. Also there might be errors in the material parameters that should be corrected when doing layer stackup checkup.

2. Can I add new layers in the layer stackup?
   No. The layer stack up information is obtained from the original design, and user can not add/delete layer(s) on AGIF main menu. If it is necessary to add/delete layers, user can do it on *HyperLynx 3D EM MGrid* after creating EM model.

<u>Top View of the Structure</u>

The top view of the structure is shown on the top-right window on the AGIF main window:

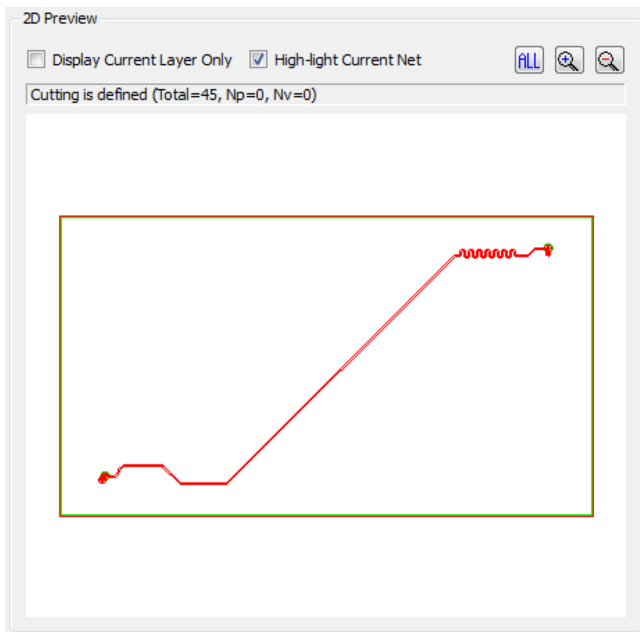


Fig. 2-10 Top View of the Structure

Though the top view window looks like quite intuitive, there are several functions that allow users visualizing the structure clearly:

1. Use ALL button to see the whole top view of the structure, use button to zoom in the view, and use button to zoom out the view
2. User can also mouse over the top view, and use the mouse scroll to zoom in/out the top view
3. All the reference nets and coupled nets are shown in blue color, while the critical nets are filled polygons. When a net is selected in the Netlist window, the color of the corresponding net will turn to red:

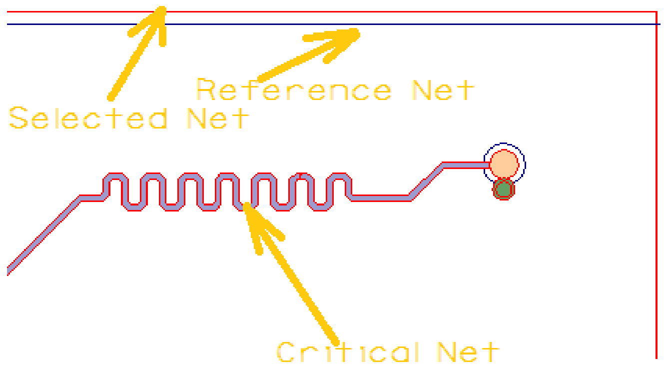


Fig. 2-11 Color-coded Net Types

4. User can also define the net type through top view window:
   a. Click any trace showing in the top view window, and a list of the nets at the click point will show up:

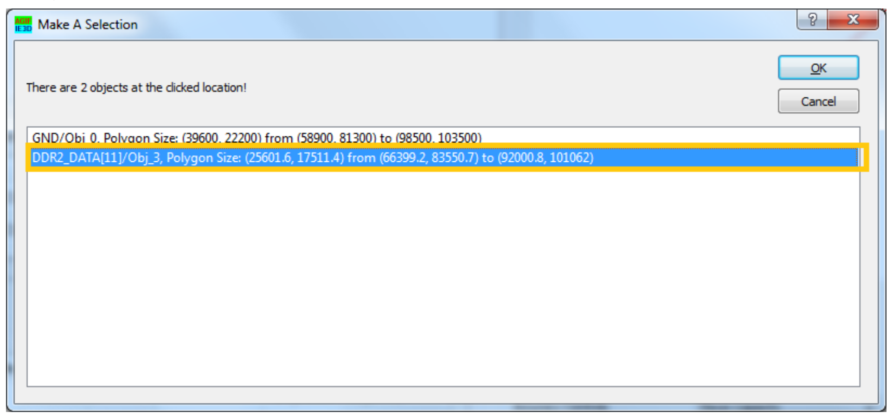


Fig. 2-12(a) Select a Net in the Top View Window

   b. Select the second net (DDR2_DATA(11)), and click OK:

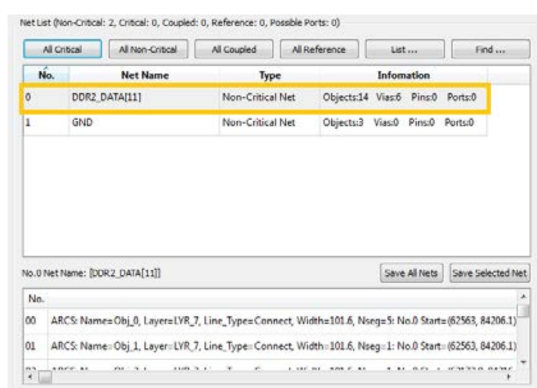


Fig. 2-12(b) The Selected Net

c. As can be seen in the Netlist window, the selected net has been automatically found and waiting for user defining its net type.

5. Showing the metal polygons on a certain layer. Sometimes it is desirable to show only the metal polygons on a certain layer. User can use ☑ Display Current Layer Only checkbox to show the polygons on a certain layer. For example, if you want to show the metal polygons on layer 7 (LYR_7):

   a. Simply select the LYR_7 layer in the layer stack up window:

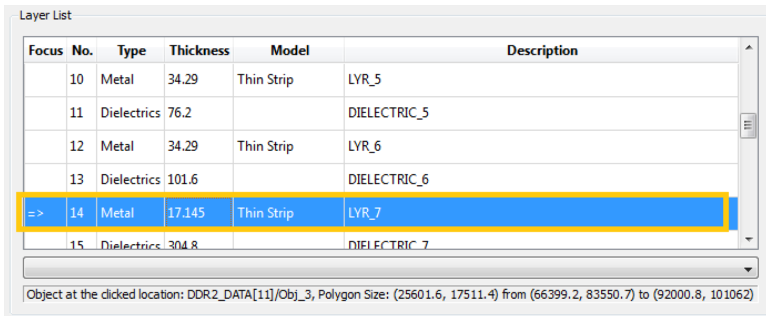


Fig. 2-13(a) Select a Layer in the Layer Stackup List

   b. Go to *Top View* window and make sure the *Display Current Layer Only* checkbox is enabled:

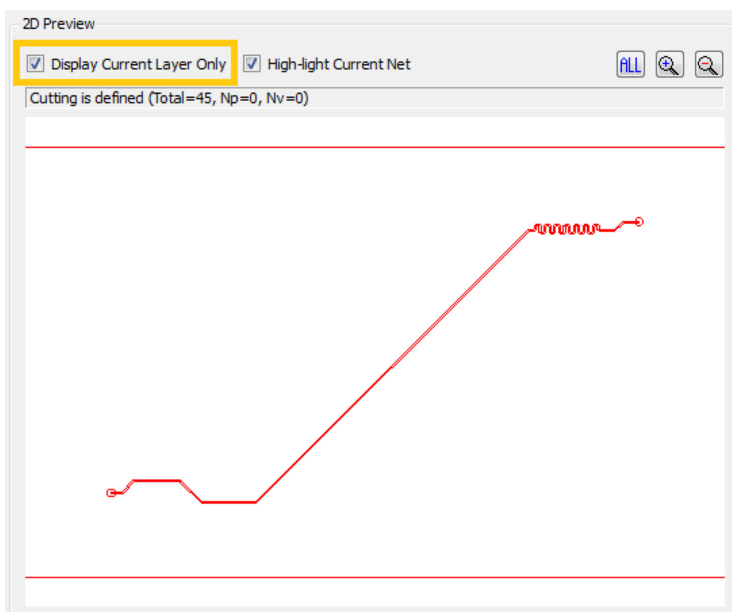


Fig. 2-13(b) Polygons on Layer 7

<u>Discussion:</u>

1. What is the red box shown in Fig. 2-10?

The red box defines the clip-out region for setting up the boundary of the EM model. More detailed information will be given in the HALO function section below.

Optional Parameters

This section contains all the parameters users can control in order to create right EM model. Basically there are seven groups of parameters:

- ✓ Default parameter control
- ✓ HALO control
- ✓ Parameter settings import/export
- ✓ Top view display control
- ✓ EM model parameter control
- ✓ Simulation parameters

Default parameter control

Fig. 2-14 shows the default parameters control area:

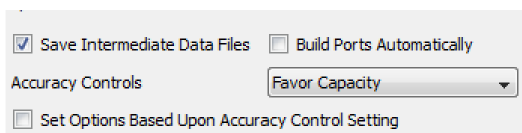


Fig. 2-14 Default Parameter Control

The default parameter control contains the following parameters:

1. Whether the intermediate files are saved automatically. Some intermediate files will be automatically created during the process of building EM model, such as parameter setting file, AGIF log etc. If the *Save Intermediate Data Files* is checked, all these files will be saved in the project directory.
2. Whether all the ports are built automatically. For PCBs, we recommend users to build ports in MGrid rather than using the *Build Ports Automatically* option. The reason is that usually there are several ground/power planes on a PCB design that could serve as reference plane for setting up ports. Multiple ground/power planes result in a certain ambiguity on building ports considering there are different simulation needs that could use different reference planes. Therefore we recommend users to set up ports according to *HyperLynx 3D EM User Manual* to prevent from any undesired port setups.
3. Accuracy control. This option provides users an option for defining the accuracy of the model. There are three options available in the combo box: *Favor Capacity*, *Favor Neither* as well as *Favor Accuracy*. In order to enable the accuracy control, the *Set Options Based Upon Accuracy*

Control Setting checkbox must be enabled. Once one of the options is chosen, some of the parameters in the HyperLynx 3D EM Parameters window will be turned off. Click the HyperLynx 3D EM Parameters button to see these turned-off parameters:

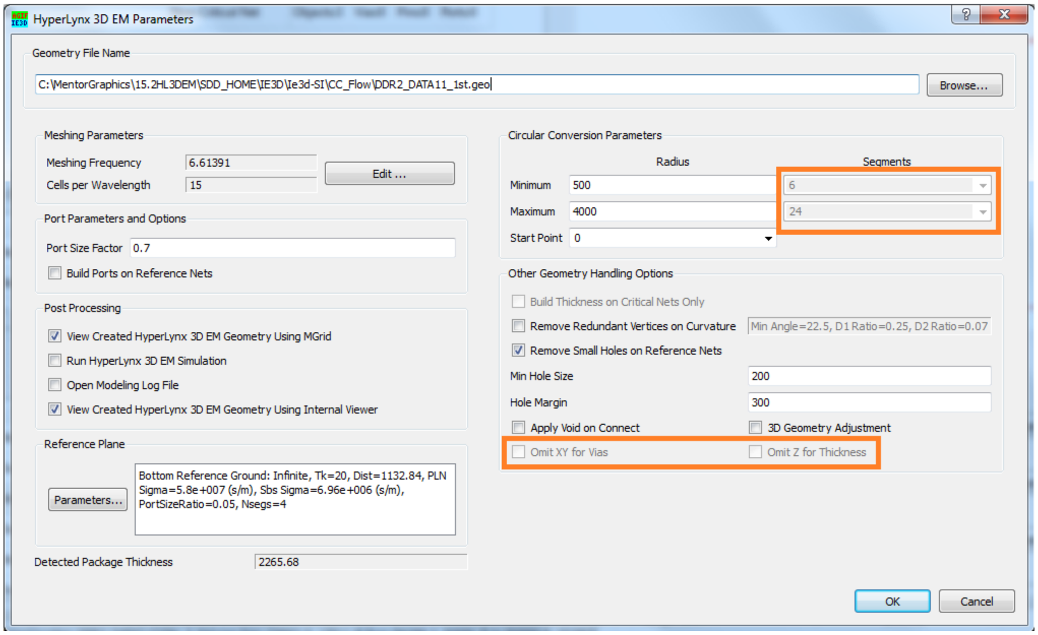


Fig. 2-15 Turned off Parameters

As can be seen, the circular shape definition will be handled by the program itself based on which option was chosen in the accuracy control combo box. The meaning of these turned-off parameters will be discussed in the *HyperLynx 3D EM Parameters* section.

<u>HALO control</u>

Fig. 2-16 shows the HALO control section:

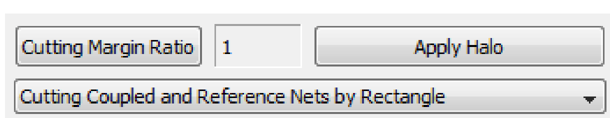


Fig. 2-16 HALO Control

AGIF provides two types of control for defining the clip-out region: rectangular region and HALO region. User can use the combo box shown in Fig. 2-16 to choose either rectangular or HALO region. If HALO is opted, click *Apply Halo* button to see the actual boundary of the EM model to be created, as shown in the following picture:

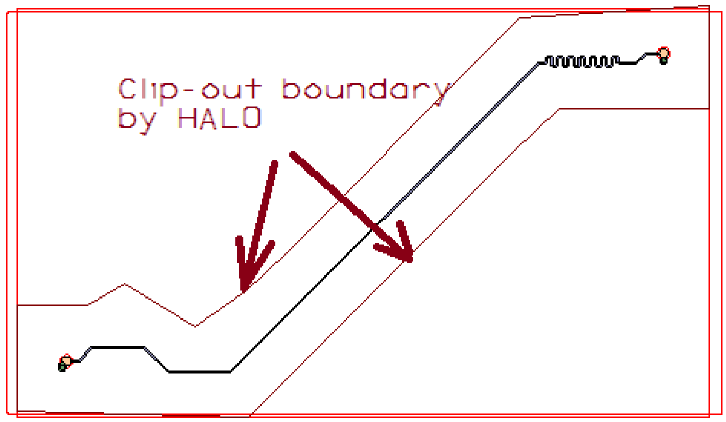


Fig. 2-17 Clip-out Region Defined by HALO

The *Cutting Margin Ratio* button is used for defining the size of the HALO region. The ratio is determined by the thickness of the board. User may use other values to see how the ratio affects the HALO region.

The last option in the combo box is *Using HALO to Define and Cut Coupled Nets*. If this option is applied, the program will automatically define the nets adjacent to the critical nets as coupled nets

Discussion:

1. Why do I need rectangular region with HALO available?
   In order to get the most effective EM model, cutting the clip-out region by using HALO does saves computer resources for EM simulation. However, in some special cases, for example, there are many bends on the traces, or the critical nets are closely surrounded by many other traces, or there is no much difference between HALO region and rectangular region, rectangular region is preferred.
2. What HALO ratio value should I use for my design?
   Generally speaking, the HALO region should be large enough to enclose all the possible EM effects incurred by critical nets, surrounding coupled nets as well as reference nets. The actual HALO margin value is highly dependent on the geometry itself. Typical values are from 0.25 to 2. Smaller margin value means smaller problem size, less simulation time and less RAM consumption, but sometimes it could yield inaccurate simulation results due to small HALO margin. Therefore there is a tradeoff between accuracy and capacity with different HALO margin value. Our experience is that, smaller value can be used if all the critical nets do not have many bends and there are not too many other traces around the critical nets; while larger value or rectangular region should be used for bended traces and crowded traces.

Parameter settings import/export

The [Export Setting ...] and [Import Setting ...] buttons can be used to either save the current parameter settings or import an existing parameter setting file into AGIF.

Click [Export Setting ...] button, and the program will prompt you to save the current parameter settings into a .xml file:

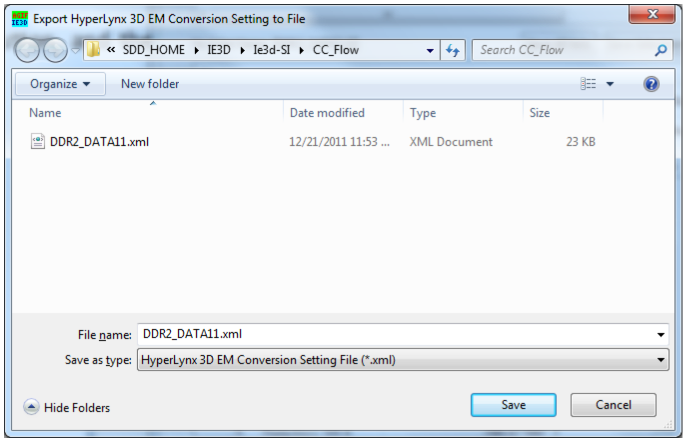


Fig. 2-18 Export Parameter Settings to a .xml File

Click *Save* button to save the current parameter settings in the project directory. If a .xml parameter setting file already exists, click the [Import Setting ...] button to import the setting file:

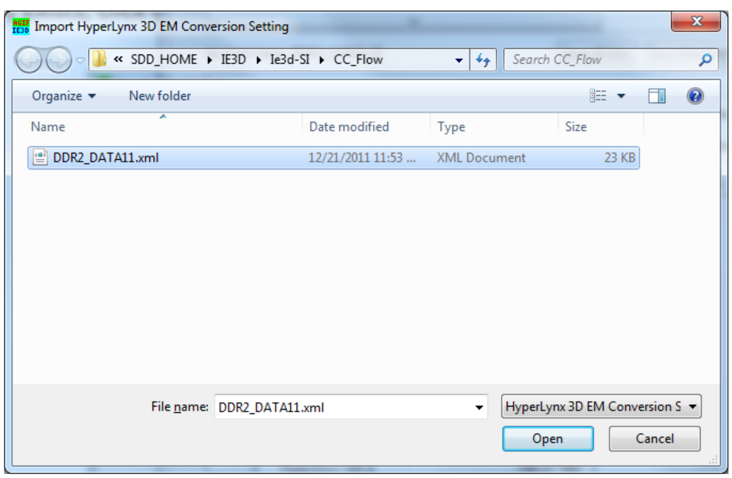


Fig. 2-19 Import Existing Parameter File

Please note the program will automatically search for the available parameter setting file in the project directory when importing .cc design into AGIF to facilitate the parameter settings. It is also recommended to save the parameter settings for future use.

Top view display control

The 

button controls how the circular shapes in the design are represented in the 2D top view window. Click this button to bring up the following parameter window:

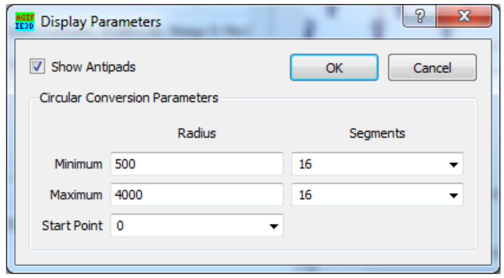


Fig. 2-20 Display Parameters

Users can use *Show Antipads* checkbox to turn on/off antipads in the top view. Users can also change the circular shapes in the top view by changing the *Circular Conversion Parameters*. The actual number of segments used for representing the circular shapes is determined by the following equation:

$$\text{Segments} = \text{Round}[N_{min} + (N_{max}-N_{min})/(R_{max}-R_{min})*(R-R_{min})]$$

in which N_{min} is segments used for minimum radius, N_{max} is segments for maximum radius; R_{min} is the minimum radius in the design, and R_{max} is the maximum radius in the design. For example, if the parameters are set to those shown in the following picture:

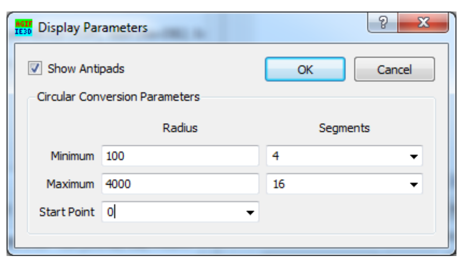


Fig. 2-21 New Parameters for Circular Shapes

Zoom in a certain area on the top view, and the circular shapes in the top view will be something like the following picture:

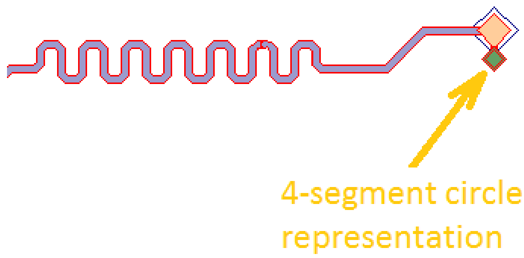


Fig. 2-22 Circular Shapes with New Display Parameters

The *Start Point* determines at what angle the circular shapes is drawn. If 0.5 is chosen, the circular shapes will rotate by an angle corresponding to half a segment.

Note that the display parameters discussed here only control the top view on the AGIF interface. They do not affect how the circular shapes are represented in the EM model.

<u>EM model parameter control</u>

Click the [HyperLynx 3D EM Parameters ...] button to see the HyperLynx 3D EM geometry control window as shown below:

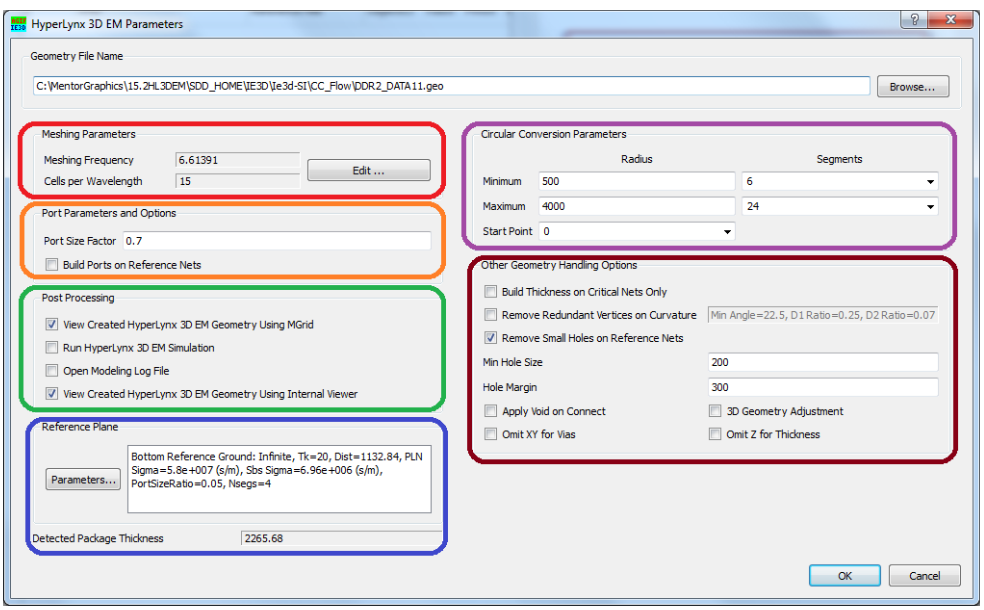
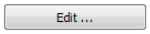


Fig. 2-23 HyperLynx 3D EM Parameters

Basically the HyperLynx 3D EM Parameters contain the following groups:

1. Meshing Parameters: This part defines how the created EM model will be meshed. Click the 

button to change the meshing parameters. These parameters will be discussed in the *Simulation Parameters* later.

2. Port Parameters: This part defines the size (gap length) of the port. The value shown in the edit box is the ratio between the gap length to the length from ground to the pin. Normally a vertical localized port with circular shape is added to each pin, and the gap length of the port should be smaller than the height of the pin. As a result, the *Port Size Factor* should be less than 1. The nominal default value is 0.7. Please tweak this number if the EM model is failed to be created due to the port settings.
If the *Build Ports on Reference Nets* is checked, the program automatically builds only one port for one chip BGA instead of building one port for each element in the BGA.

3. Post Processing: This part specifies what the program will do after the EM model is created. Users have options to view the EM model in the built-in viewer or MGrid, run simulation or take a look at the log file.

4. Reference Plane: an infinite ground plane is automatically added to the EM structure in order to ground all the ports. For some structures, such as structures with bond wires, an additional finite ground plane is needed to ground the bond wires. Some options for defining the top finite ground plane are available by clicking the *Parameters* button.

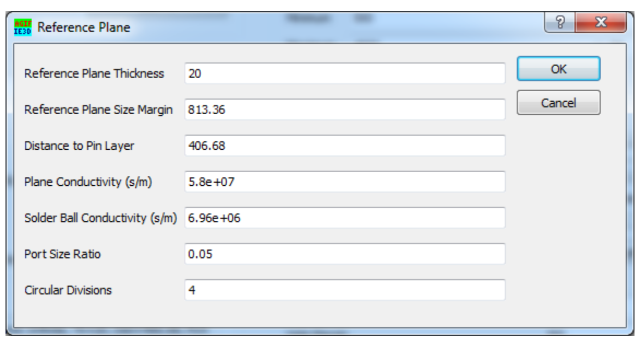


Fig. 2-24 Reference Plane Parameters

Reference Plane Thickness: defines the thickness of the reference.
Reference Plane Size Margin: defines the size of the reference. Normally the package thickness is used for the size margin.
Distance to Pin Layer: defines the height of the top reference plane from the pin layer.
Plane Conductivity: the conductivity of the top ground plane.
Solder Ball Conductivity: defines the conductivity of the solder balls or bumps.
Port Size Ratio: defines the ports size by using the ratio between the gap size to the pin height ratio.

Circular Division: defines how many number of segments used for the finite ground plane.

Normally the default values are good enough for setting up the top finite ground plane correctly. However, for PCBs, it is better to build ports manually in MGrid to avoid problems to ports.

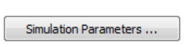
5. Circular Conversion Parameters: This part defines how to represent the circular shapes in the EM model. Obviously more segments used for the circular shapes, more accurate representation of the circular shapes can be obtained. However, more segments also mean more mesh cells and more computation effort for simulation. Normally 6-segment for circular shapes is good enough. Users may also use the method shown in the *Top view display control* section to use different number of segments for different sizes of the circular shapes.

6. Other Geometry Handling Options: This part contains some optional parameter to better control the EM model:

   Build Thickness on Critical Nets Only: If enabled, metal thickness will only be applied to critical nets. Thickness on reference planes and coupled nets will be neglected. Enabling this option will greatly reduce computation effort without losing accuracy on critical nets.
   Remove Redundant Vertices on Curvatures: If enabled, the redundant vertices will be automatically removed. Please use the default parameters to let program determine the redundant vertices.
   Remove Small Holes on Reference Nets: if enabled, the holes smaller than the specified Min Hole Size will be removed from the EM model.
   Apply Void on Connect: Connect is an object type in Cadence .mcm/.sip designs. Check to enable the Void Boolean operations on Connect objects. It does not affect .cc designs. Sometimes it is not desirable though.
   3D Geometry Adjustment: If enabled, the connectivity will be automatically checked when a 3D polygon crosses a 2D polygon.
   Omit XY for Vias: this parameters is obsolete.
   Omit Z for Thickness: this parameters is obsolete.

It is recommended to use the default values for all the optional parameters to get correct EM model.

Simulation parameters

Click the 

button to set up the parameters for EM simulations. Please note all these parameters can be re-defined on MGrid or the built-in viewer after the EM model is created:

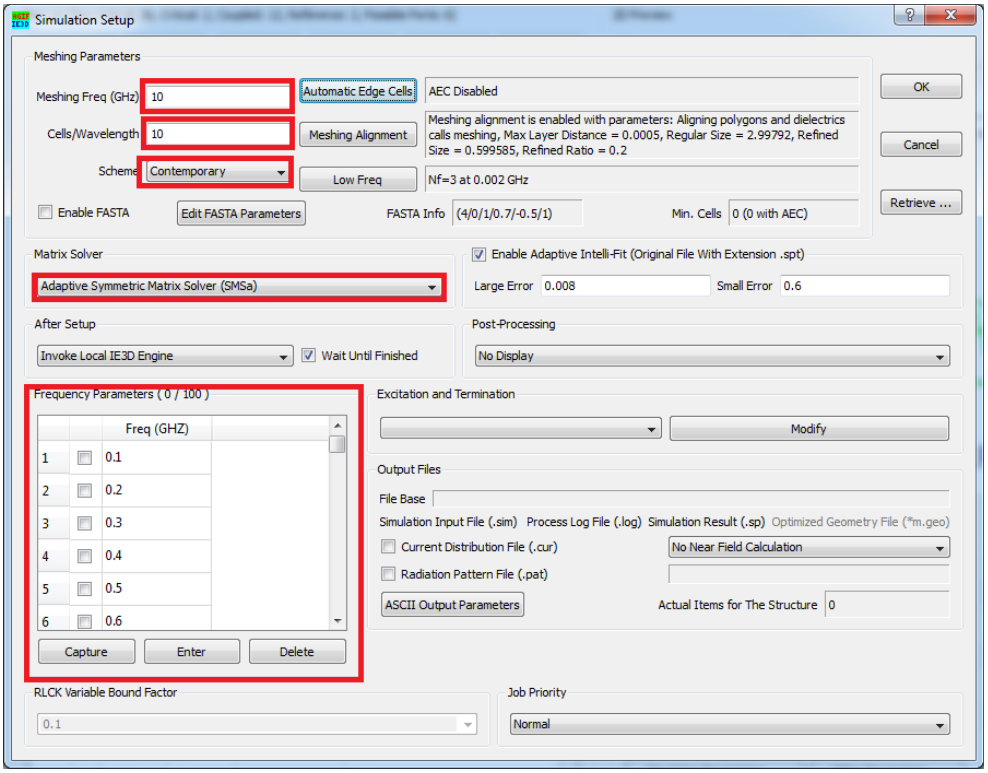


Fig. 2-25 Simulation Parameters

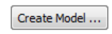
Though there are many parameters on the simulation set up windows, only those in the red box are important for simulating package structures. Specifying these parameters is quite easy and intuitive. Please refer to *HyperLynx 3D EM User's Manual* for details of other parameters if interested.

Click OK button to start EM simulations. After the simulation is done, you can view the simulation results in MGrid. Again users are recommended to take a look at the two *AGIF Quick Start Guides* to know how to run the EM simulations and view the results.

<u>Discussion:</u>

1. What is Meshing Frequency?
   Meshing frequency is one of the parameters for generating mesh on the structure. Usually this frequency is the highest frequency of the frequency range of interest. Higher meshing frequency can be specified if the mesh density is too coarse on the structure.
2. What is Cell/Wavelength?
   It is the other parameters for mesh generation. The larger the value is, more cells will be applied to the geometry. Normally 10 to 15 is good enough for most structures.
3. Which meshing scheme shall I use?
   Classic is more robust and stable, while *Contemporary* is more efficient that usually generates less cells than *Classic*. *Contemporary* is recommended for efficient simulations.

4. Which solver shall I use?
   The default solver (SMSa) is recommended for most applications. FMS and GEM are designed for some special applications. Interested users can refer to *HyperLynx 3D EM User's Manual* for more details.
5. How do I determine the frequency range?
   The frequency range here is quite different from that in circuit/digital designs. It is not the data transfer rate (DTR), which is typically used in digital designs, but the frequency range in spectrum. For high DTR, say in GHz range, the highest frequency for EM simulation should be higher, say 10GHz or even higher. For low DTR, the highest frequency could be down to 5GHz, or even lower.

After all the parameters have been set to correct values/settings, click the 

button to create the EM model for EM simulation.

To summarize the .cc to HyperLynx 3D EM flow for creating correct EM models, some main points are listed below:

1. Define net types correctly.
2. Check layer stackup and material parameters.
3. Define geometry handling parameters and simulation parameters correctly.
4. Create EM model and launch EM simulations.
5. Feed the simulated S-parameters model into other SI/PI tools for time-domain analysis.

Chapter 3 Cadence Allegro to HyperLynx 3D EM Designer Flow

In the AGIF Quick Start Guide, we have shown how to create EM models from Cadence APD database. Two single-die examples have been simulated and discussed. If you have used AGIF 15.1, you may already find that the user interface of 15.2 is a lot easier and more intuitive when creating EM models.

AGIF 15.2 supports multi-die structures since this type of structures have been more and more popular and widely used in order to have a smaller package design, reduce design and fabrication cost as well as add more functionalities. Fig. 3-1 shows a sample package structure with two dies:

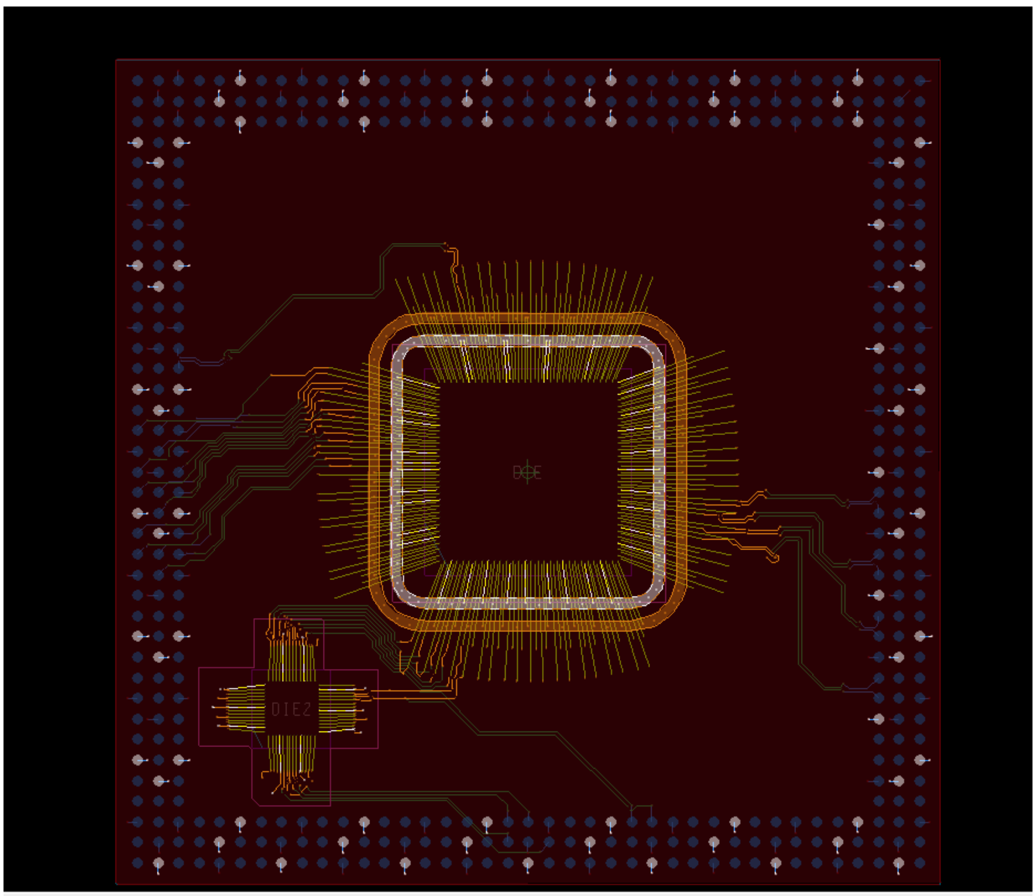


Fig. 3-1 A Sample Multi-die Structure

As described in the *Quick Start Guide for Stacked Die Packages*, users can import the above design to AGIF using the option of Cadence Allegro to HyperLynx 3D EM Flow. The imported structure is shown below:

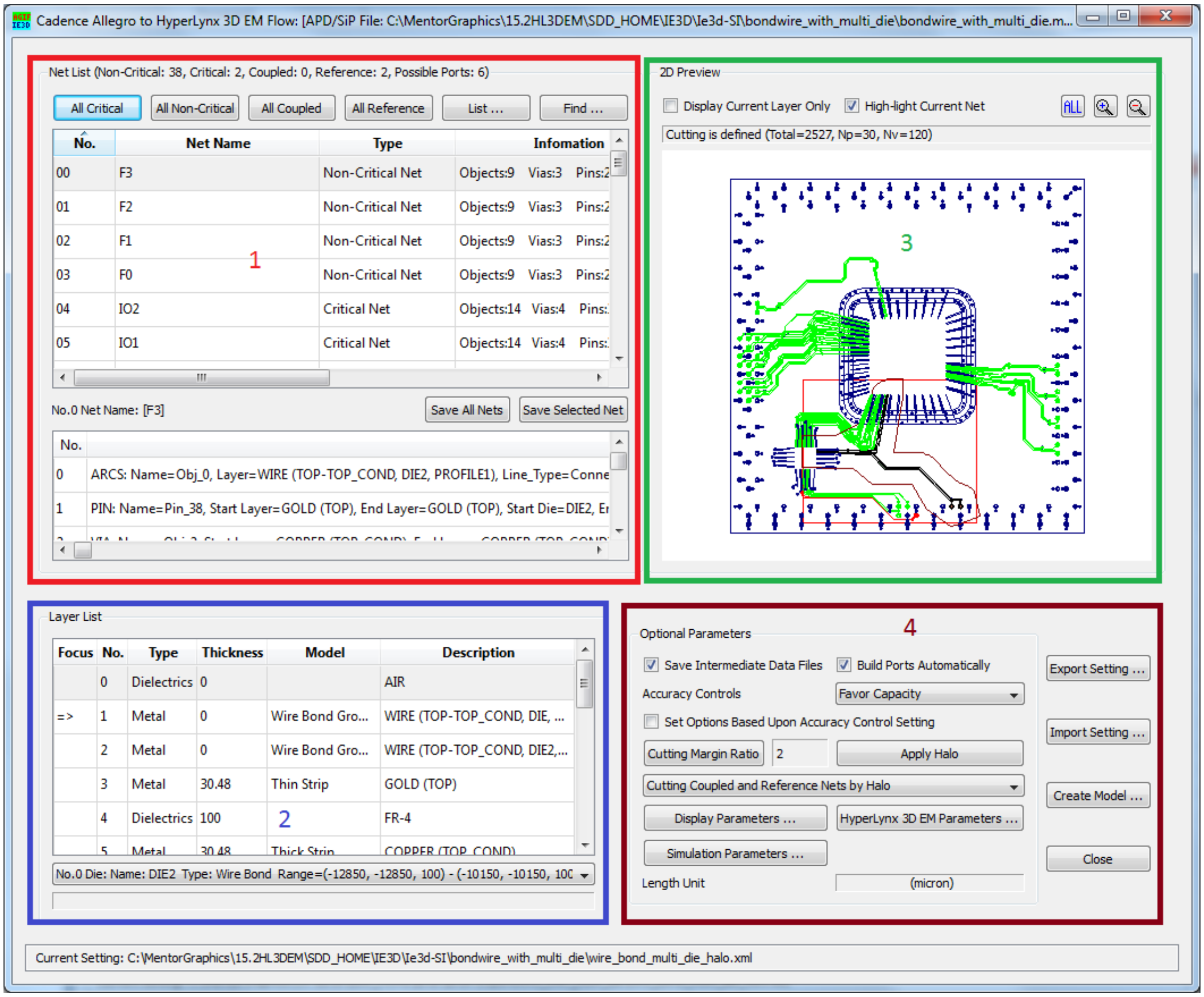


Fig. 3-2 AGIF Main Menu

Basically the AGIF main menu contains four sections:

- Net-list
- Layer stackup
- Top view of the structure
- Optional parameters

The following paragraphs show the details on each section:

Net-list

This section shows all the imported nets imported from Cadence APD database. The six buttons on the top are for setting net types:

Table 3-1 Functions of the Six Button in Net-list Area

Button	Function
All Critical	Define all the nets are critical nets. Critical nets will be included in the EM model, and ports will be attached to each critical net. There must be at least one critical net in order to create an EM model. This button is used when the whole structure need to be simulated.
All Non-Critical	Define all the nets are non-critical nets.
All Coupled	Define all nets are coupled nets. Coupled nets will also be included in the EM model, but no ports will be created for coupled nets. The main reason for including coupled nets is to observe the EM effects incurred by the coupled nets.
All Reference	Define all nets are reference nets. There must be at least on reference net defined in order to get correct EM model.
List ...	Click to see all the defined critical net(s), coupled net(s) and reference net(s).
Find ...	Click to search for a certain net by name. After finding the net, you may also use the button at the bottom to directly define its net type without going back to the main menu.

Below the function buttons is the list of the imported nets. User can click the combo box under *Type* column to design the type of each layer:

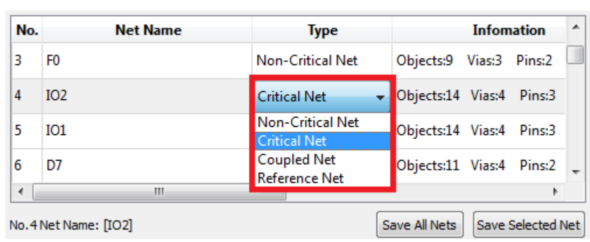


Fig. 3-3 Net List

User may also use the *Save All Nets/Save Selected Net* button to save nets in a text file for reference. The list below the net list is information list of the highlighted net, which shows object information contained in the net:

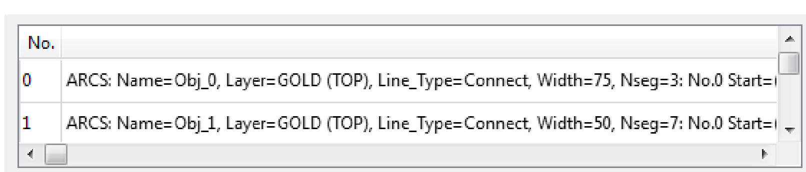


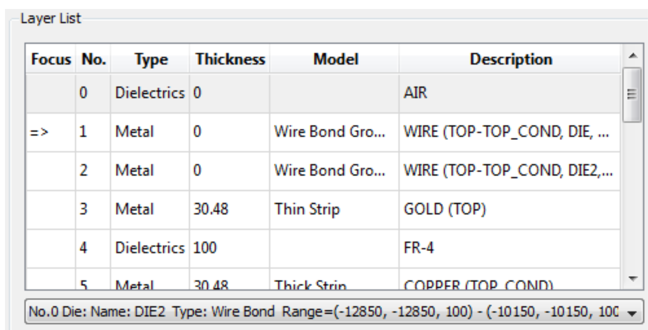
Fig. 3-4 Net Information

Discussion:

4. What nets should be defined as critical nets?
   Any nets that need to be included in the EM model, and S-parameters are desired, should be defined as critical nets.
5. Why must there be at least one reference net?
   An EM simulation should have a closed signal loop for each port. If there is no reference net, a critical net will not form a closed signal loop, and the simulation results will be incorrect.
6. What is the difference between critical net and coupled net?
   The difference is there is no port attached to coupled nets. However, the EM effects incurred by the coupled nets will be calculated by the program.

<u>Layer Stackup</u>

Fig. 3-5 shows the layer stackup region on AGIF main window:


Layer List

Focus	No.	Type	Thickness	Model	Description
	0	Dielectrics	0		AIR
=>	1	Metal	0	Wire Bond Gro...	WIRE (TOP-TOP_COND, DIE, ...
	2	Metal	0	Wire Bond Gro...	WIRE (TOP-TOP_COND, DIE2,...
	3	Metal	30.48	Thin Strip	GOLD (TOP)
	4	Dielectrics	100		FR-4
	5	Metal	30.48	Thick Strip	COPPER (TOP_COND)

No.0 Die: Name: DIE2 Type: Wire Bond Range=(-12850, -12850, 100) - (-10150, -10150, 10C

Fig. 3-5 Layer Stackup

Layer stackup data is also extracted from the Cadence database. User can define the *Model* type as well as the material parameters for each layer. The wire bond definition has been greatly improved: if one layer is associated with wire bond, the program can automatically assign it as wire bond type. Users do not have to consider defining it as *High Wire* or *Low Wire* as on 15.0.

Table 2-2 shows the definition of each layer model type:

Table 2-2 Layer Model Definition

Layer Model Type	**Definition**
Wire Bond Group	The layer is defined as wire bond layer
Thin Strip	All the metal polygons on this layer do not have thickness
Thin Strip (2)	All the metal polygons on this layer do not have thickness, but the thickness of the metal will be added to the substrate

Thick	The thickness of the metal polygons will be applied to this layer
Void	The layer will be omitted in the EM model

To define the material parameters, simply double click one layer, either metal or substrate layer, to bring up the material parameter window:

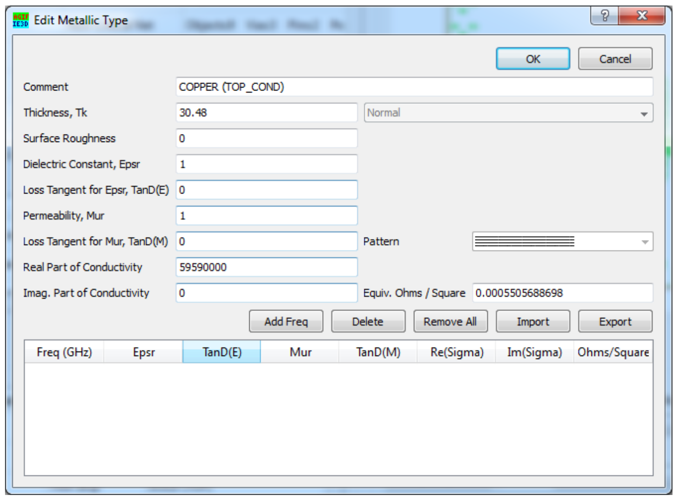


Fig. 3-6(a) Metal Material Parameters

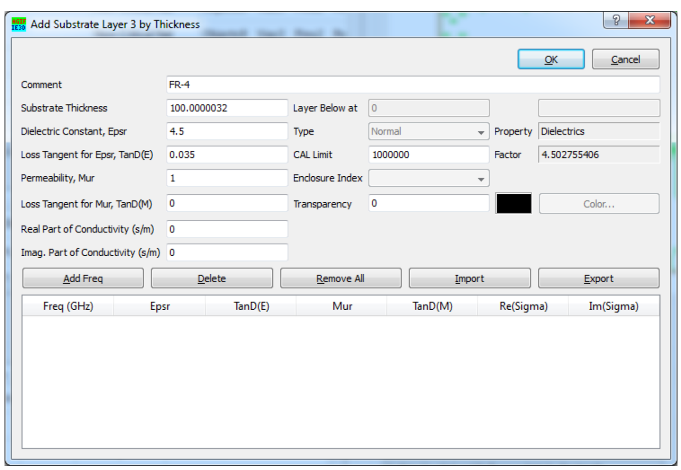


Fig. 3-6(b) Dielectric Material Parameters

As can be seen in the above pictures, besides the regular metal/dielectric material parameters, the frequency-dependent materials can also be defined in the lower part of the material parameter window. User can also prepare a text/excel file for the frequency-dependent materials, and use *Import* button to import the material information directly into the layer parameter settings. All the metal/dielectric material parameters are intuitive. If you have any questions to the definitions of the material parameters, please refer to *HyperLynx 3D EM User's Manual* for more details.

It is recommended for users to check the material parameters for each layer before creating the EM model in order to make sure all the parameter data are correct, and the layer model type is set correctly.

Discussion:

3. Why do I need to worry about layer stackup?
   Sometimes there might be some mistakes and errors in the original Cadence Allegro design. Some designers might also add some useless layers in the design that should not be included in the EM model. Also there might be errors in the material parameters that should be corrected when doing layer stackup checkup.
4. Can I add new layers in the layer stackup?
   No. The layer stack up information is obtained from the original design, and user can not add/delete layer(s) on AGIF main menu. If it is necessary to add/delete layers, user can do it on HyperLynx 3D EM MGrid after creating EM model.

Top View of the Structure

The top view of the structure is shown on the top-right window on the AGIF main window:

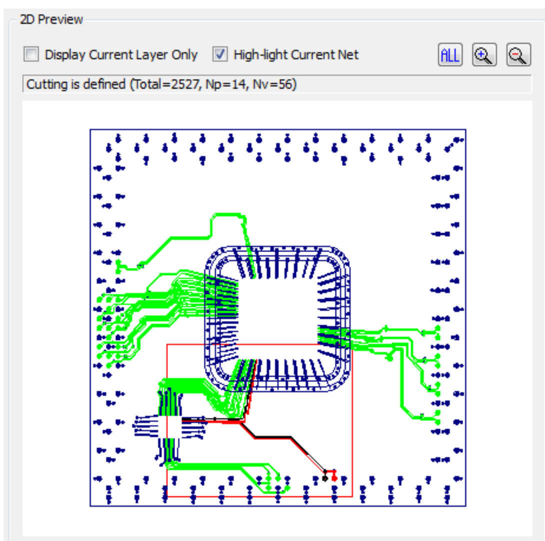


Fig. 3-7 Top View of the Structure

Though the top view window looks quite intuitive, there are several functions that allow users visualizing the structure clearly:

6. Use ALL button to see the whole top view of the structure, use button to zoom in the view, and use button to zoom out the view
7. User can also mouse over the top view, and use the mouse scroll to zoom in/out the top view
8. All the reference nets and coupled nets are shown in blue color, while the critical nets are filled polygons. When a net is selected in the Netlist window, the color of the corresponding net will turn to red:

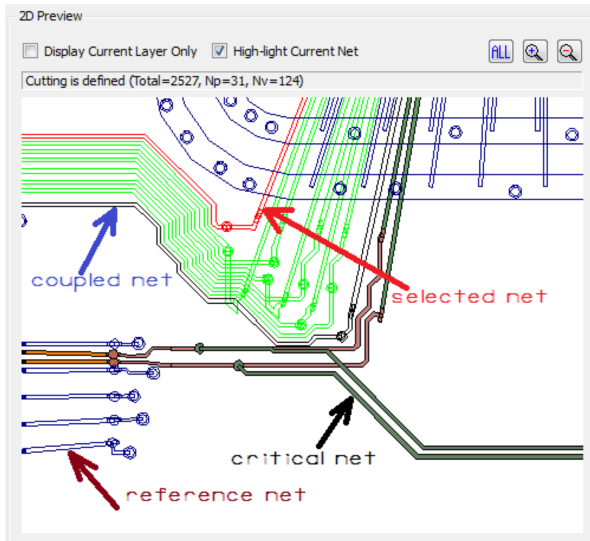


Fig. 3-8 Color-coded Net Types

9. Users can also define the net type through top view window:
   a. Click any trace showing in the top view window, and a list of the nets at the click point will show up:

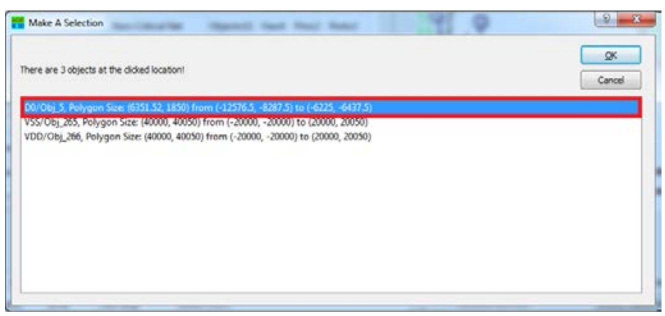


Fig. 3-9(a) Select a Net in the Top View Window

   b. Select the first net (D0), and click OK:

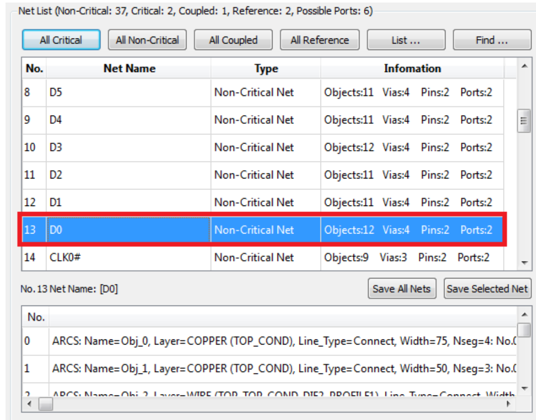


Fig. 3-9(b) The Selected Net

c. As can be seen in the Netlist window, the selected net (D0) has been automatically found and waiting for user defining its net type.

10. Showing the metal polygons on a certain layer. Sometimes it is desirable to show only the metal polygons on a certain layer. User can use ☑ Display Current Layer Only checkbox to show the polygons on a certain layer. For example, if you want to show the metal polygons on layer 5:

a. Simply select the layer 5 in the layer stack up window:

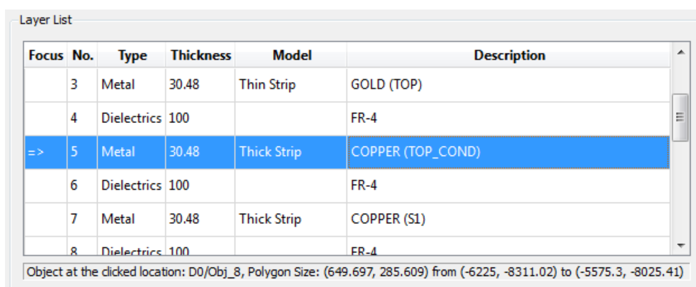


Fig. 3-10(a) Select a Layer in the Layer Stackup List

b. Go to *Top View* window and make sure the *Display Current Layer Only* checkbox is enabled:

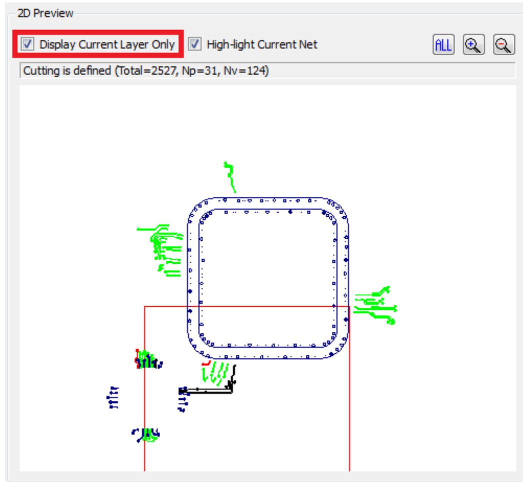


Fig. 3-10(b) Polygons on Layer 5

Discussion:

2. What is the red box shown in Fig. 3-7?
   The red box defines the clip-out region for setting up the boundary of the EM model. More detailed information will be given in the HALO function section below.

Optional Parameters

This section contains all the parameters users can control in order to create right EM model. Basically there are seven groups of parameters:

- ✓ Default parameter control
- ✓ HALO control
- ✓ Parameter settings import/export
- ✓ Top view display control
- ✓ EM model parameter control
- ✓ Simulation parameters
- ✓ Others

Default parameter control

Fig. 3-11 shows the default parameters control area:

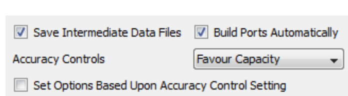


Fig. 3-11 Default Parameter Control

The default parameter control contains the following parameters:

4. Whether the intermediate files are saved automatically. The intermediate files refer to the extracted files created by Cadence EXTRACTA (see the *AGIF Quick Start Guide*). If the *Save Intermediate Data Files* is checked, all these files will be saved in the project directory.
5. Whether ports are built automatically, the *Build Ports Automatically* checkbox should be enabled. The program will attach a port to each pin in the critical net of the design and set up all the ports automatically. There are additional port settings in the HyperLynx 3D EM parameter control that will be discussed shortly.
6. Accuracy control. This option provides users an option for defining the accuracy of the model. There are three options available in the combo box: *Favor Capacity*, *Favor Neither* as well as *Favor Accuracy*. In order to enable the accuracy control, the *Set Options Based Upon Accuracy Control Setting* checkbox must be enabled. Once one of the options is chosen, some of the parameters in the HyperLynx 3D EM Parameters window will be turned off. Click the HyperLynx 3D EM Parameters button to see these turned-off parameters:

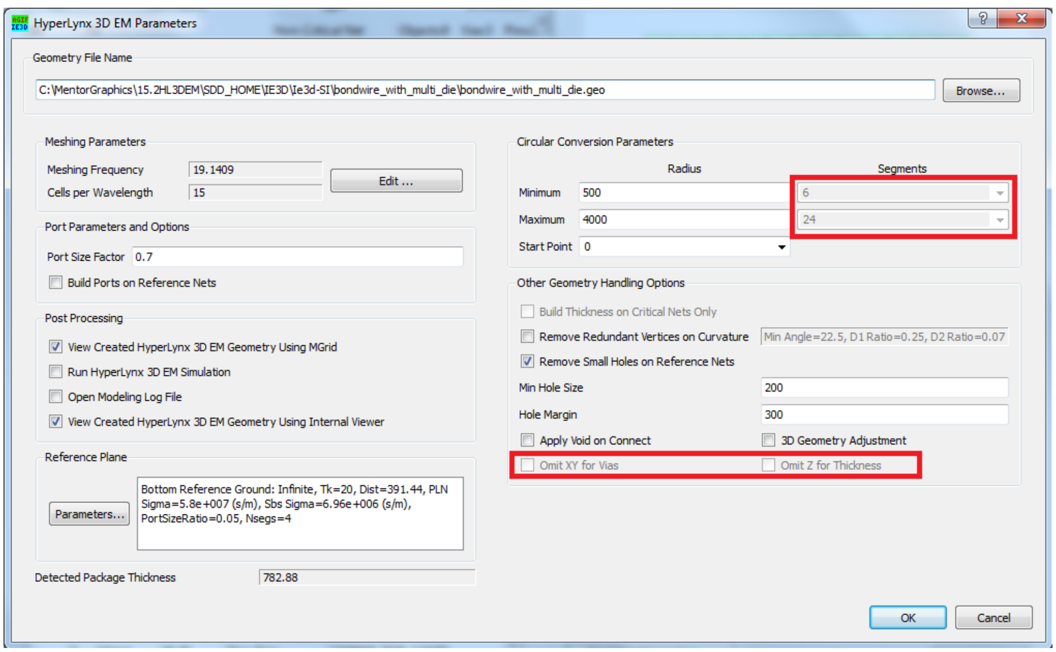


Fig. 3-12 Turned off Parameters

As can be seen, the circular shape definition will be handled by the program itself based on which option was chosen in the accuracy control combo box. The meaning of these turned-off parameters will be discussed in the HyperLynx 3D EM parameters section.

<u>HALO control</u>

Fig. 3-13 shows the HALO control section:

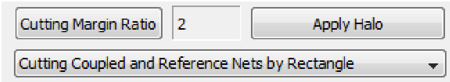


Fig. 3-13 HALO Control

AGIF provides two types of control for defining the clip-out region: rectangular region and HALO region. User can use the combo box shown in Fig. 3-13 to choose either rectangular or HALO region. If HALO is opted, click Apply Halo button to see the actual boundary of the EM model, as shown in the following picture:

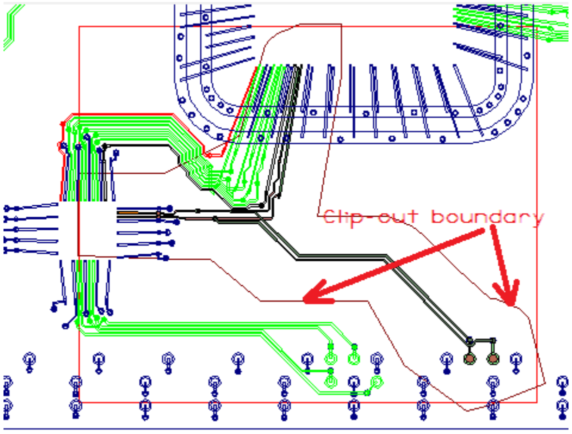


Fig. 3-14 Clip-out Region Defined by HALO

The *Cutting Margin Ratio* button is used for defining the size of the HALO or rectangular region. The ratio is determined by the thickness of the board. Users may use other values to see how the ratio affects the clip-out region.

The last option in the combo box is *Using HALO to Define and Cut Coupled Nets*. If this option is applied, the program will automatically define the nets adjacent to the critical nets as coupled nets, as shown in the following picture:

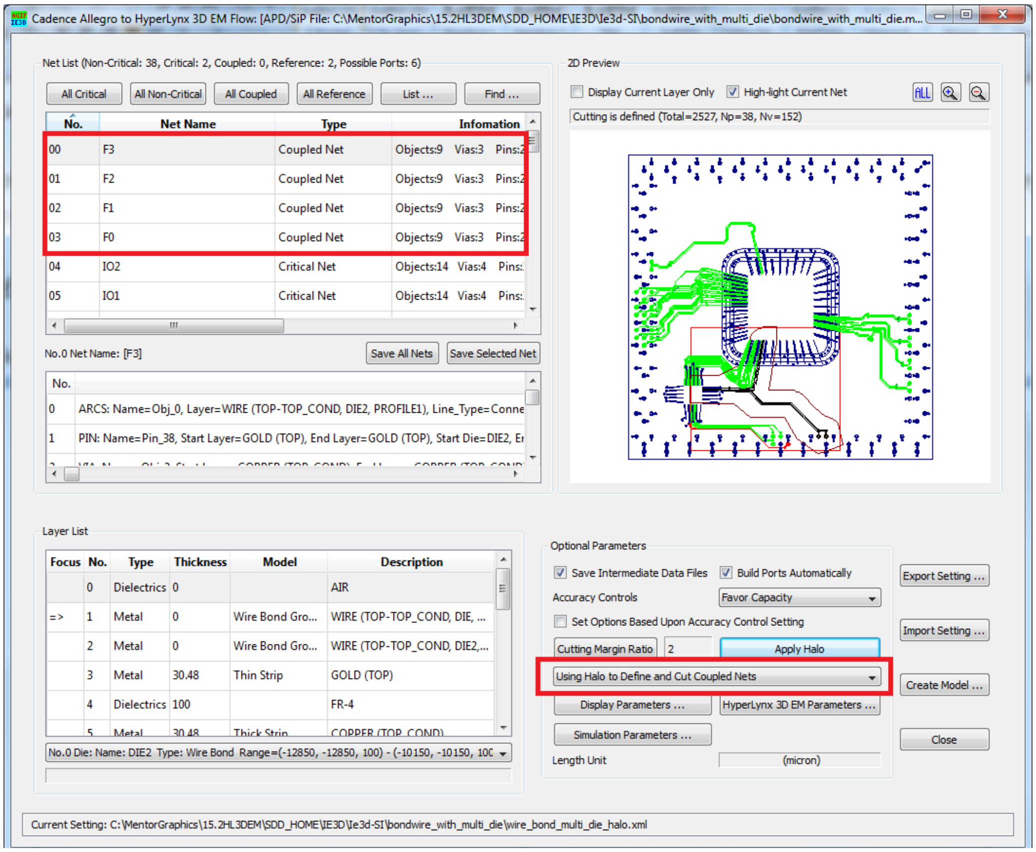


Fig. 3-15 Using HALO to Define and Cut Coupled Nets

Discussion:

3. Why do I need rectangular region with HALO available?
   In order to get the most effective EM model, cutting the clip-out region by using HALO does saves computer resources for EM simulation. However, in some special cases, for example, there are many bends on the traces, or the critical nets are closely surrounded by many other traces, or there is no much difference between HALO region and rectangular region, rectangular region is preferred.
4. What HALO ratio value should I use for my design?
   Generally speaking, the HALO region should be large enough to enclose all the possible EM effects incurred by critical nets, surrounding coupled nets as well as reference nets. The actual HALO margin value is highly dependent on the geometry itself. Typical values are from 0.25 to 2. Smaller margin value means smaller problem size, less simulation time and less RAM consumption, but sometimes it could yield inaccurate simulation results due to small HALO margin. Therefore there is a tradeoff between accuracy and capacity with different HALO margin value. Our experience is that, smaller value can be used if all the critical nets do not have many bends and there are not too many other traces around the critical nets; while larger value or rectangular region should be used for bended traces and crowded traces.

Parameter settings import/export

The Export Setting ... and Import Setting ... buttons can be used to either save the current parameter settings or import an existing parameter setting file into AGIF.

Click Export Setting ... button, and the program will prompt you to save the current parameter settings into a .xml file:

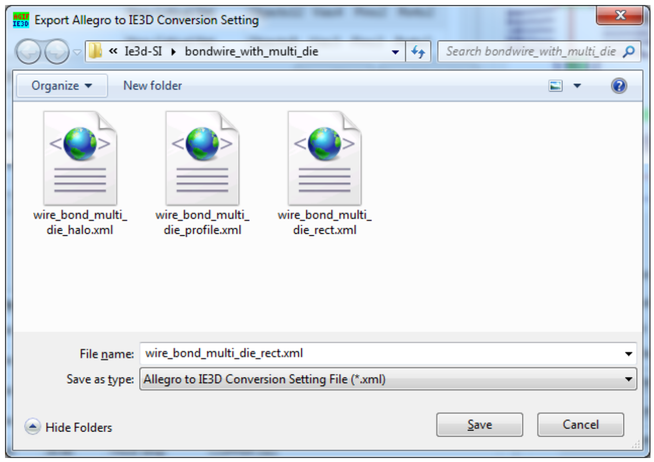


Fig. 3-16 Export Parameter Settings to a .xml File

Click *Save* button to save the current parameter settings in the project directory. If a .xml parameter setting file already exists, click the Import Setting ... button to import the setting file:

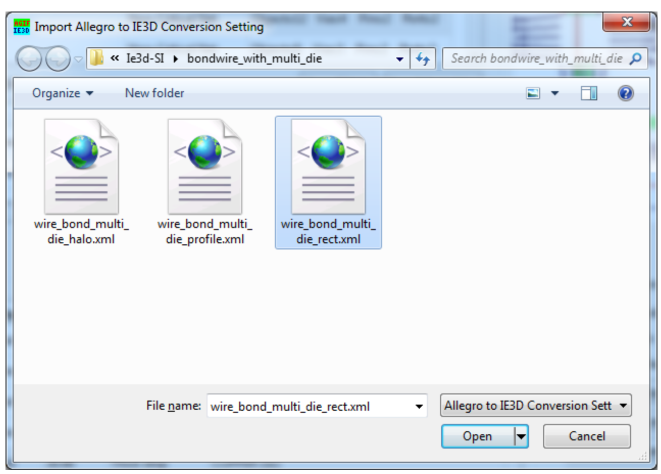


Fig. 3-17 Import Existing Parameter File

The program will automatically search for the available parameter setting file in the project directory when importing .mcm/.sip design into AGIF to facilitate the parameter settings. It is recommended to export the current parameter settings for future reference.

<u>Top view display control</u>

The 

button controls how the circular shapes in the design are represented in the 2D top view window. Click on this button to bring up the following parameter window:

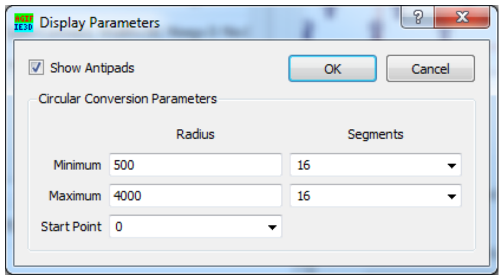


Fig. 3-18 Display Parameters

Users can use *Show Antipads* checkbox to turn on/off showing antipads in the top view. Users can also change the circular shapes in the top view by changing the *Circular Conversion Parameters*. The actual number of segments used for representing the circular shapes is determined by the following equation:

$$\text{Segments} = \text{Round}[N_{min} + (N_{max}-N_{min})/(R_{max}-R_{min})*(R-R_{min})]$$

in which N_{min} is segments used for minimum radius, N_{max} is segments for maximum radius; R_{min} is the minimum radius in the design, and R_{max} is the maximum radius in the design. For example, if the parameters are set to those shown in the following picture:

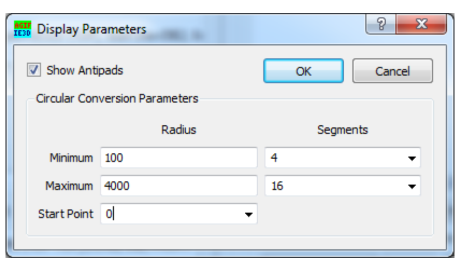


Fig. 3-19 New Parameters for Circular Shapes

Zoom in a certain area on the top view, and the circular shapes in the top view will be something like the following picture:

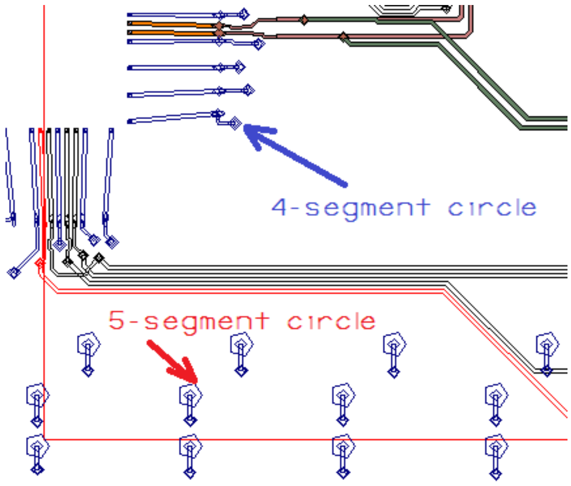
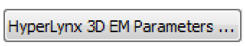


Fig. 2-20 Circular Shapes with New Display Parameters

The *Start Point* determines at what angle the circular shapes is drawn. If 0.5 is chosen, the circular shapes will rotate by an angle corresponding to half a segment.

Note that the display parameters discussed here only control the top view on the AGIF interface. They do not affect how the circular shapes are represented in the EM model.

<u>EM model parameter control</u>

Click on the  button to see the HyperLynx 3D EM geometry control window as shown below:

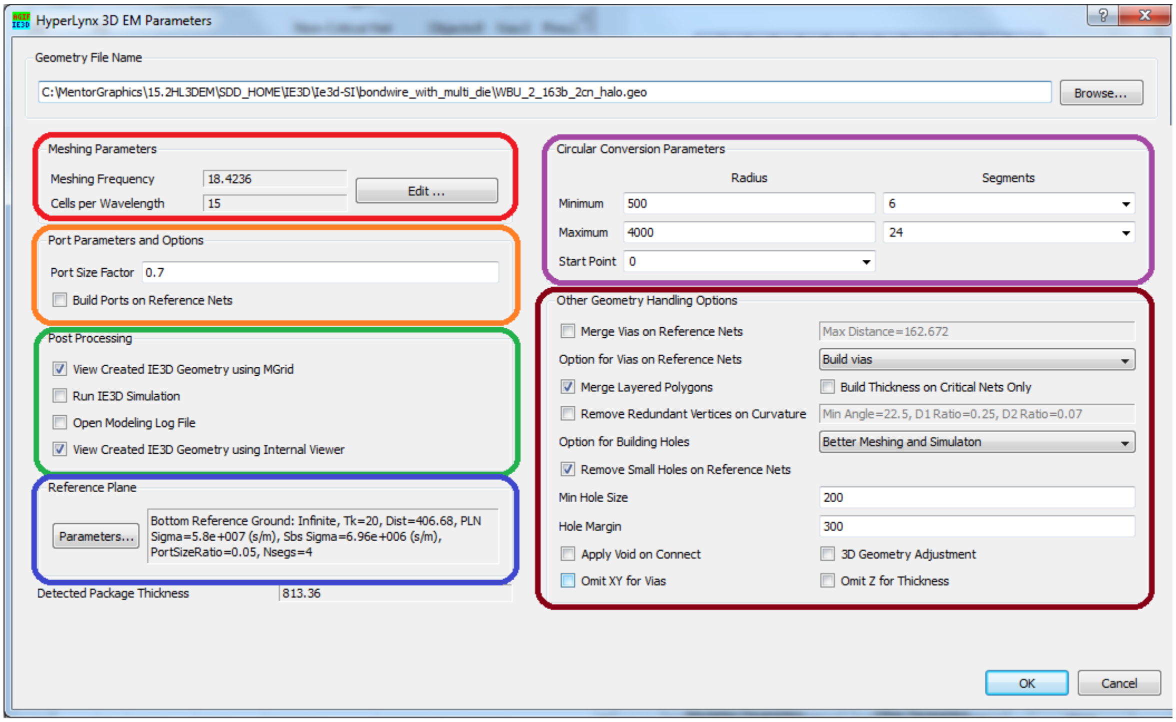
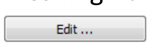


Fig. 3-21 HyperLynx 3D EM Parameters

Basically the HyperLynx 3D EM Parameters window contains the following groups:

1. Meshing Parameters: This part defines how the created EM model will be meshed. Click on the 

button to change the meshing parameters. These parameters will be discussed in the *Simulation Parameters* later.

2. Port Parameters: This part defines the size (gap length) of the port. The value shown in the edit box is the ratio between the gap length to the length from ground to the pin. Normally a vertical localized port with circular shape is added to each pin, and the gap length of the port should be smaller than the height of the pin. As a result, the *Port Size Factor* should be less than 1. The nominal default value is 0.7. Please tweak this factor if the EM model is failed to be created due to the port settings.
   If the *Build Ports on Reference Nets* is checked, the program automatically builds only one port for one chip BGA instead of building one port for each element in the BGA.

3. Post Processing: This part specifies what the program will do after the EM model is created. Users have options to view the EM model in the built-in viewer or MGrid, run simulation or take a look at the log file.

4. Reference Plane: an infinite ground plane is automatically added to the EM structure in order to terminate all the ports. For some structures, such as structures with bond wires, an additional

finite ground plane is needed to ground the bond wires. Some options for defining the top finite ground plane are available by clicking the *Parameters* button.

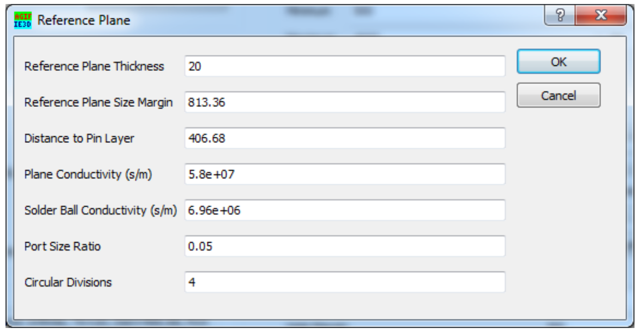


Fig. 3-22 Reference Plane Parameters

Reference Plane Thickness: defines the thickness of the reference.
Reference Plane Size Margin: defines the size of the reference. Normally the package thickness is used for the size margin.
Distance to Pin Layer: defines the height of the top reference plane from the pin layer.
Plane Conductivity: the conductivity of the top ground plane.
Solder Ball Conductivity: defines the conductivity of the solder balls or bumps.
Port Size Ratio: defines the ports size by using the ratio between the gap size to the pin height ratio.
Circular Division: defines how many number of segments used for the finite ground plane.

Normally the default values are good enough for setting up the top finite ground plane correctly.

5. Circular conversion parameters: This part defines how to represent the circular shapes in the EM model. Obviously more segments used for the circular shapes, more accurate representation of the circular shapes can be obtained. However, more segments also mean more mesh cells and more computation effort for simulation. Normally 6-segment for circular shapes is good enough. Users may also use the method shown in the *Top view display control* section to use different number of segments for different sizes of the circular shapes.

6. Other Geometry Handling Options: This part contains some optional parameter to better control the EM model:

   Build Thickness on Critical Nets Only: If enabled, metal thickness will only be applied to critical nets. Thickness on reference planes and coupled nets will be neglected. Enabling this option will greatly reduce computation effort without losing accuracy on critical nets.
   Remove Redundant Vertices on Curvatures: If enabled, the redundant vertices will be automatically removed. Please use the default parameters to let program determine the redundant vertices.

Remove Small Holes on Reference Nets: if enabled, the holes smaller than the specified Min Hole Size will be removed from the EM model.
Apply Void on Connect: Connect is an object type in .mcm/.sip designs. Check to enable the Void Boolean operations on Connect objects. Sometimes it is not desirable though.
3D Geometry Adjustment: If enabled, the connectivity will be automatically checked when a 3D polygon crosses a 2D polygon.
Omit XY for Vias: this parameters is obsolete.
Omit Z for Thickness: this parameters is obsolete.

It is recommended to use the default values for all the optional parameters to get correct EM model.

Simulation Parameters

Click on the [Simulation Parameters ...] button to set up the parameters for EM simulations. Please note all these parameters can be re-defined on MGrid or the built-in viewer after the EM model is created:

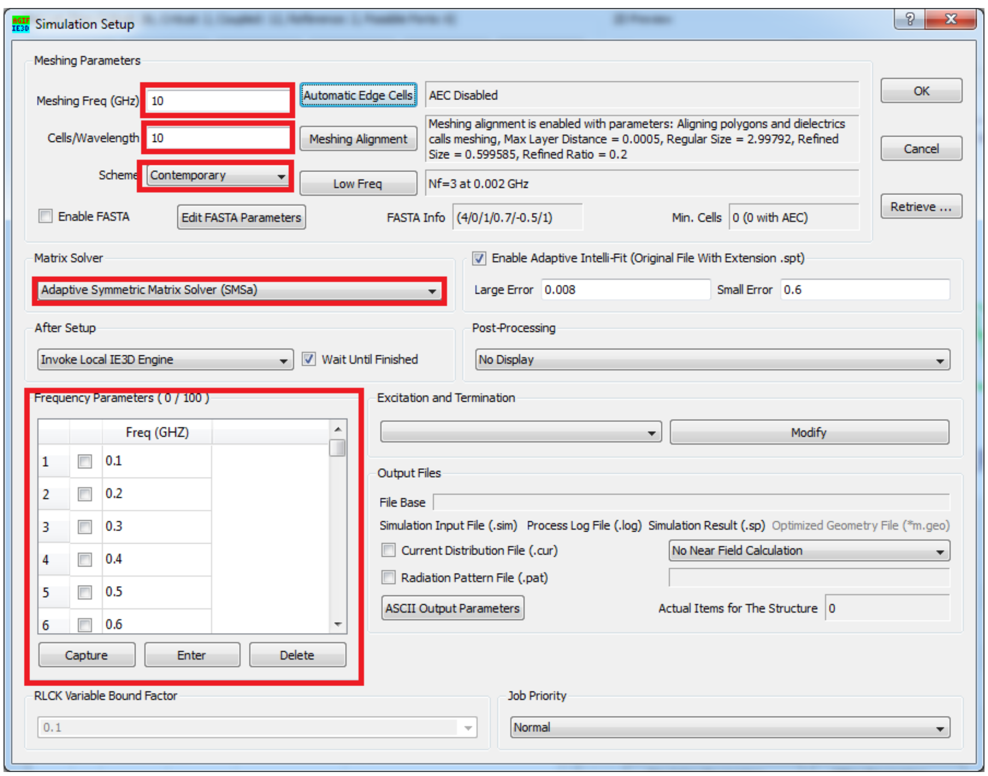


Fig. 3-23 Simulation Parameters

Though there are many parameters on the simulation set up windows, only those in the red box are important for simulating package structures. Specifying these parameters is quite easy and intuitive. Please refer to *HyperLynx 3D EM User's Manual* for details of other parameters if necessary.

Click on OK button to start EM simulations. After the simulation is done, you can view the simulation results in MGrid. Again users are recommended to take a look at the two *AGIF Quick Start Guides* to know how to run the EM simulations and view the results.

<u>Discussion:</u>

6. What is Meshing Frequency?
   Meshing frequency is one of the parameters for generating mesh on the structure. Usually this frequency is the highest frequency of the frequency range of interest. Higher meshing frequency can be specified if the mesh density is too coarse on the structure.
7. What is Cell/Wavelength?
   It is the other parameters for mesh generation. The larger the value is, more cells will be applied to the geometry. Normally 10 to 15 is good enough for most packages.
8. Which meshing scheme shall I use?
   Classic is more robust and stable, while *Contemporary* is more efficient that usually generate less cells than *Classic*. *Contemporary* is recommended for efficient simulations.
9. Which solver shall I use?
   The default solver (SMSa) is recommended for most applications. FMS and GEM are designed for some specific applications. Interested users can refer to *HyperLynx 3D EM User's Manual* for more details.
10. How do I determine the frequency range?
    The frequency range here is quite different from that in circuit/digital designs. It is not the data transfer rate (DTR), which is typically used in digital designs, but the frequency range in spectrum. However, the frequency range here has some indirect relationship which should be taken care of for more accurate SI/PI analysis. For high DTR, say in GHz range, the highest frequency for EM simulation should be higher, say 10GHz or even higher. For low DTR, the highest frequency could be down to 5GHz, or even lower.

After all the parameters have been set to correct values/settings, click on the Create Model ... button to create the EM model for simulations.

To summarize the Cadence Allegro to HyperLynx 3D EM flow for creating correct EM models, some main points are listed below:

1. Translate the Cadence design into AGIF.
2. Define net types correctly.
3. Check layer stackup and material parameters.
4. Define geometry handling parameters and simulation parameters correctly.
5. Create EM model and launch EM simulations.
6. Feed the simulated S-parameters model into other SI/PI tools for time-domain analysis.

Chapter 4 GDSII to HyperLynx 3D EM Flow

Cadence Virtuoso has been widely used for IC/RFIC applications. To address the electromagnetic effects on RFIC structures, HyperLynx 3D EM team developed a direct link with Cadence Virtuoso. Like Cadence Allegro Package Designer to HyperLynx 3D EM flow, users can also add an HyperLynx 3D EM menu item on Cadence Virtuoso Layout editor to directly call AGIF and do EM simulations. Interested users can refer to AGIF_integration_guide.pdf for more information on the link.

An alternative way to do EM simulations for the Cadence Virtuoso designs is to stream out the layout into a GDSII file (.gds), import the .gds file into AGIF and start EM simulations via AGIF. The following paragraphs describe how AGIF handles GDSII designs, how to do EM simulations and get EM simulation results. The main topics include:

- ✓ How to create .i2i template file
- ✓ How to link a .gds file to a .i2i file
- ✓ How to link multiple .gds files to a .i2i file
- ✓ How to create EM models for GDSII designs
- ✓ What is *Self Layer Operation*
- ✓ What is *Boolean Operations*
- ✓ What is *Mutual Layer Operations*
- ✓ How to do batch EM simulations for multiple GDSII designs based on the same .i2i file

Several GDSII examples will be shown in this chapter to demonstrate how to do the above tasks with AGIF. All these GDSII examples can be found in the .\SDD_HOME\IE3D\ie3d\agif\ folder. Users are recommended to try these examples to quickly get familiar with GDSII to HyperLynx 3D EM link.

<u>How to Create .i2i Template File and Link a GDSII Design</u>

The .i2i template file is pretty much like a .tech technology file which contains the location information of the associated .gds file(s), layer stackup information, simulation parameters, layer operations etc. If multiple .gds files share the same layer stackup and layer operations, these GDSII designs can share the same template file.

Go to AGIF task list and double click *Create and Edit AGIF Template for GDSII to HyperLynx 3D EM Flow*,

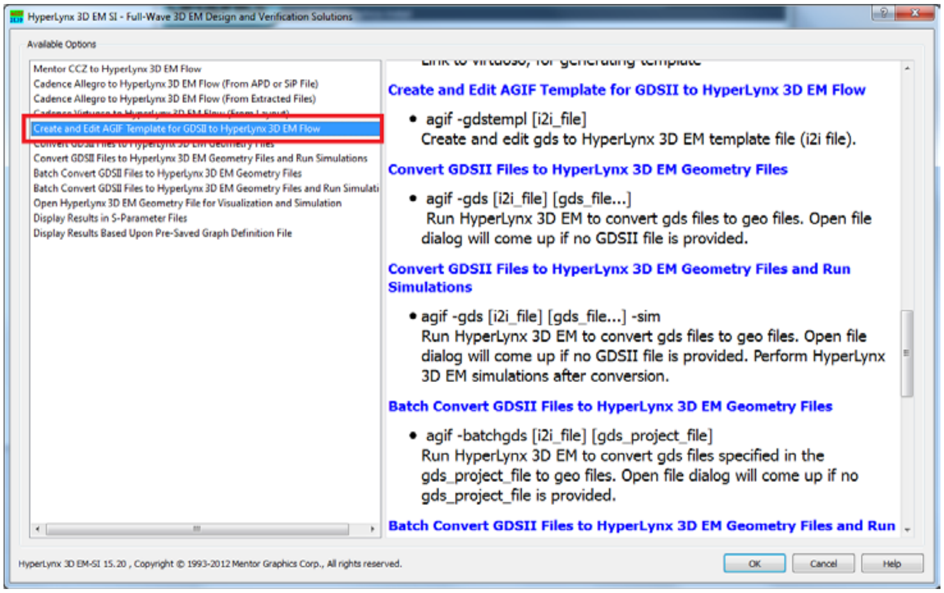


Fig. 4-1 AGIF Task List

The following *Automatic GDSII to HyperLynx Flow* main window will show up:

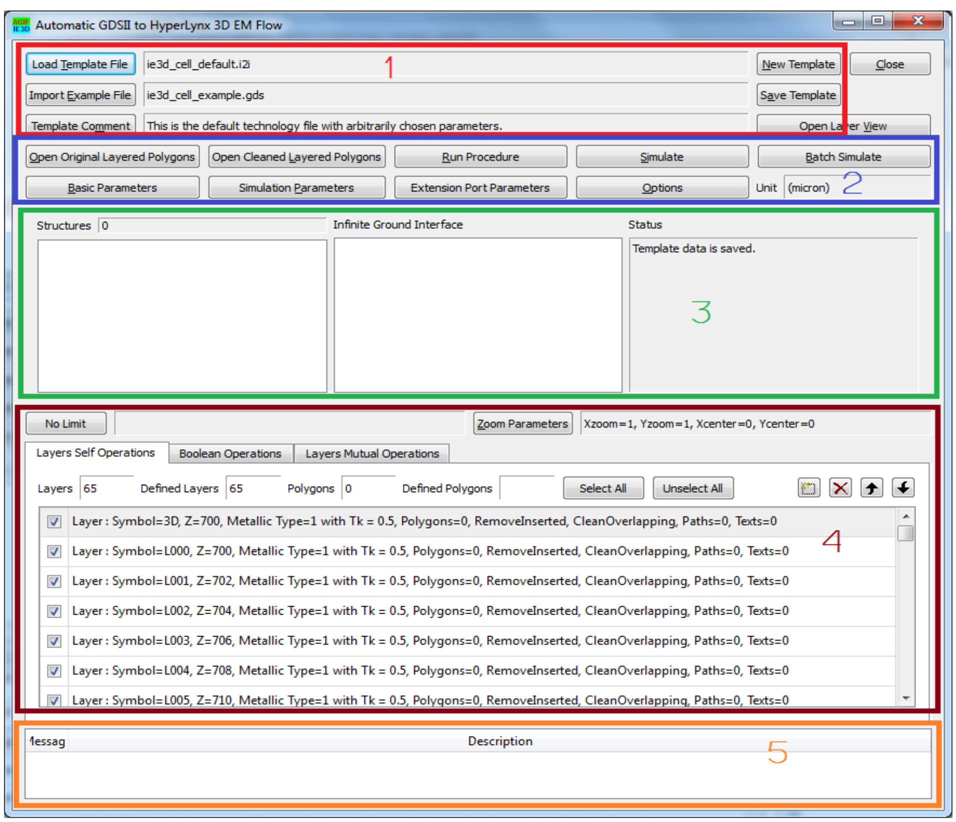
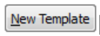


Fig. 4-2 Automatic GDSII to HyperLynx 3D EM Flow Main Window

Basically the main window can be divided into five regions:

1. Template and GDSII, which is for creating .i2i template and link a .gds file with the template file.
2. Function buttons, which are for creating EM models, viewing original designs, setting parameters, launch batch simulations etc.
3. Information and status on the GDSII design as well as the added infinite ground plane.
4. Layer list and layer operations. Users can do layer self operations, Boolean operations as well as mutual layer operations in this area.
5. Message window, which shows warnings and errors related to the EM model creation

Click on the 

button and select *Blank AGIF Template from Scratch*:

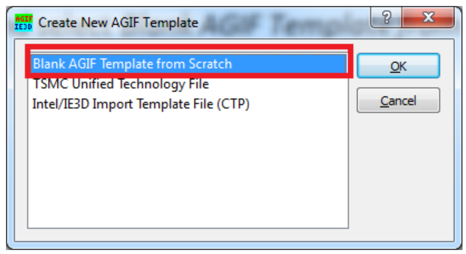


Fig. 4-3 Template File Selections

If you have a TSMC technology file (.tech, .tf) or layer mapping file (.map, .dat), please choose the second option; if you have an Intel CTP file, please choose the third option. Click *OK* to proceed, and you'll be prompted to save the new template file:

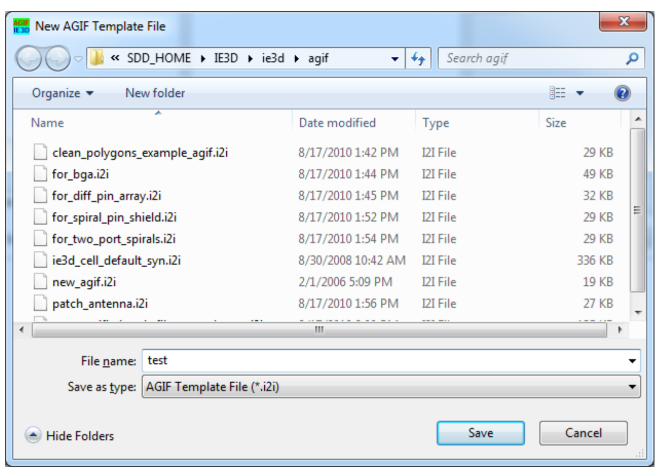


Fig. 4-4 Save the New Template File

Click the *Save* button, and a new window shows up asking for the .gds file that will be associated with the new template file. Navigate to .\SDD_HOME\IE3D\ie3d\agif\ folder, select bga_layers.gds, and click on *Open* button. The new template file has been created successfully with a .gds file associated:

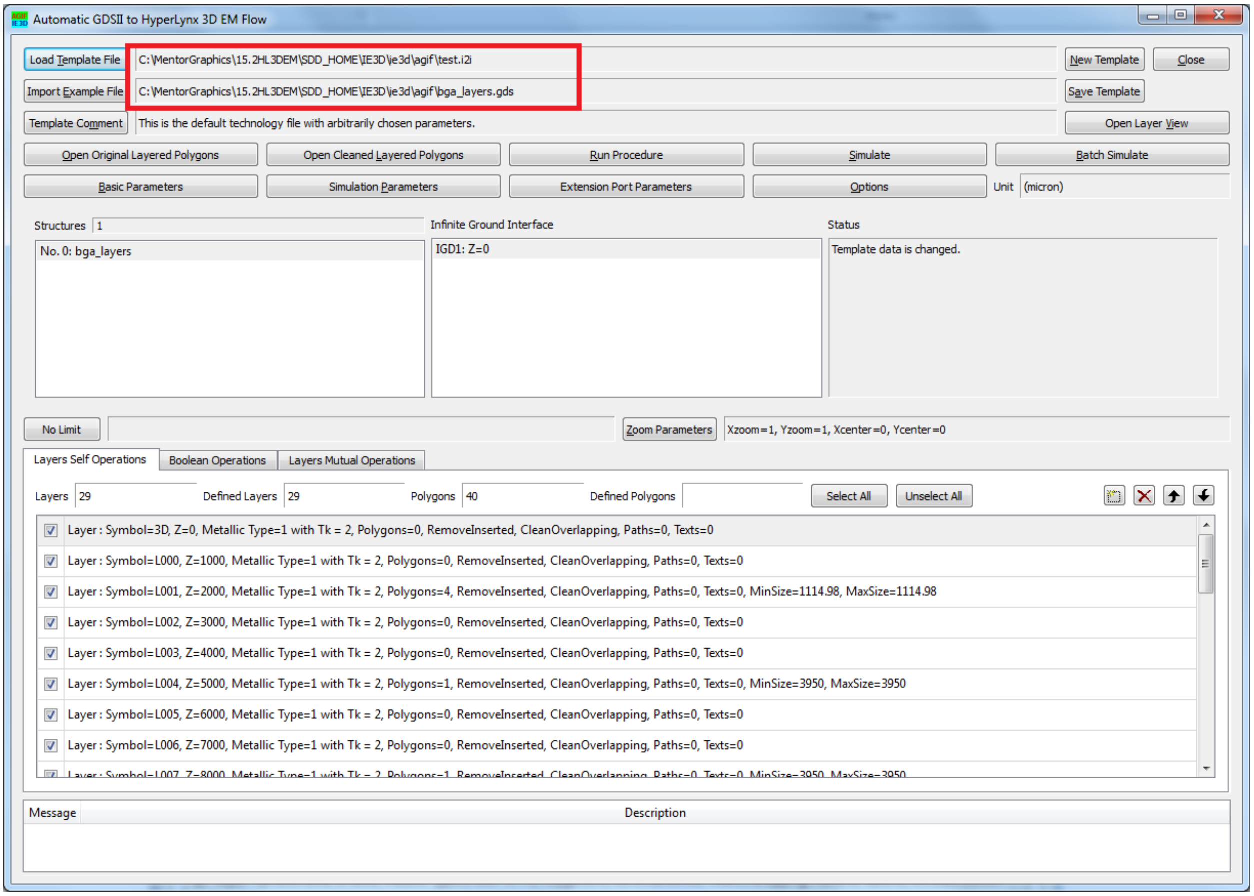


Fig. 4-5 Created Template File

Click on Save Template button to save the new template file. You may also open an existing .i2i file by clicking on Load Template File button. The previously associated .gds file stored in the .i2i file will also be automatically loaded in and shown after Import Example File button. You may also add some comments on the template file by clicking Template Comment button and enter some descriptions.

How to View the Imported GDSII Design

There are three buttons users can use to view the imported design:

1. Open Layer View button: View the polygons on each layer in 2D and 3D.

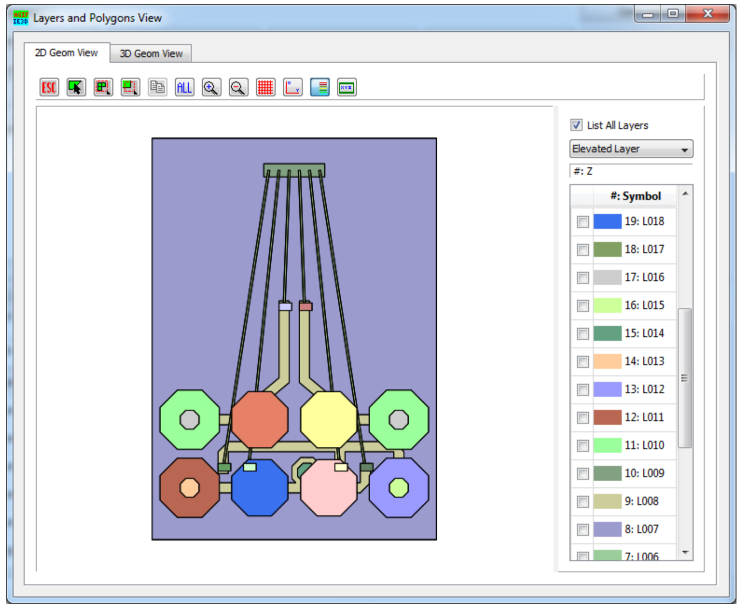


Fig. 4-6 Open Layer View

2. Open Original Layered Polygons button: Open HyperLynx 3D EM layout editor (MGrid) for the original imported polygons. They are the polygons before the *Zoom Parameters* are applied. User can see the polygons on both built-in viewer and MGrid in 2D and 3D. Some function buttons are also available on the top of the window.

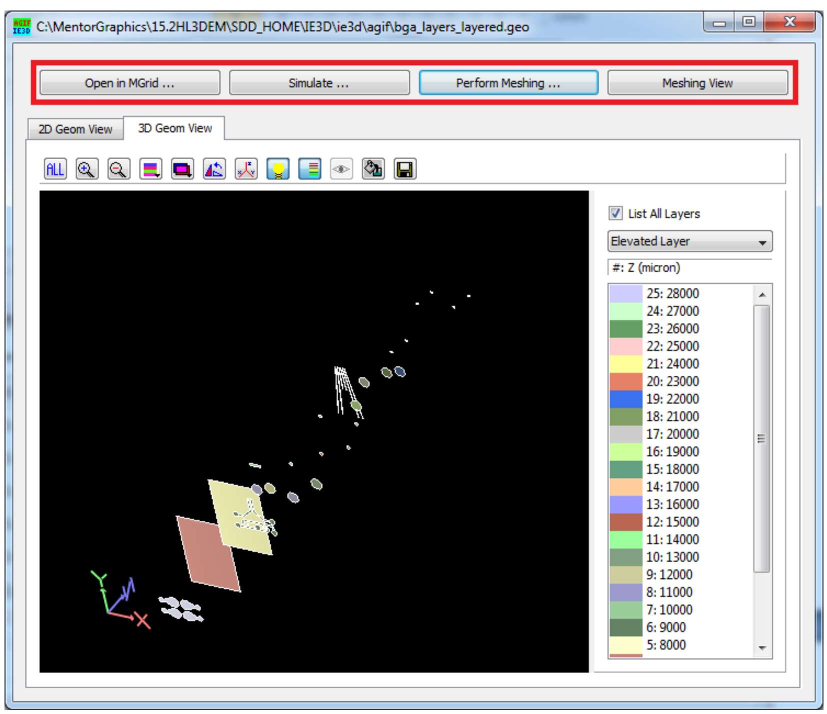


Fig. 4-7 Open Original Layered Polygons

3. Open Cleaned Layered Polygons button: Opens an MGrid window for the layered polygons after the *Zoom Parameters* and the *Self Layer Operations*.

The difference between these three views can not be shown before defining any self operations and zoom factors. You may open the *for_bga.i2i* template, and click these three buttons to see the difference.

Set up Basic Parameters

Click on the Basic Parameters button to set up the substrate layer stackup and define metal types:

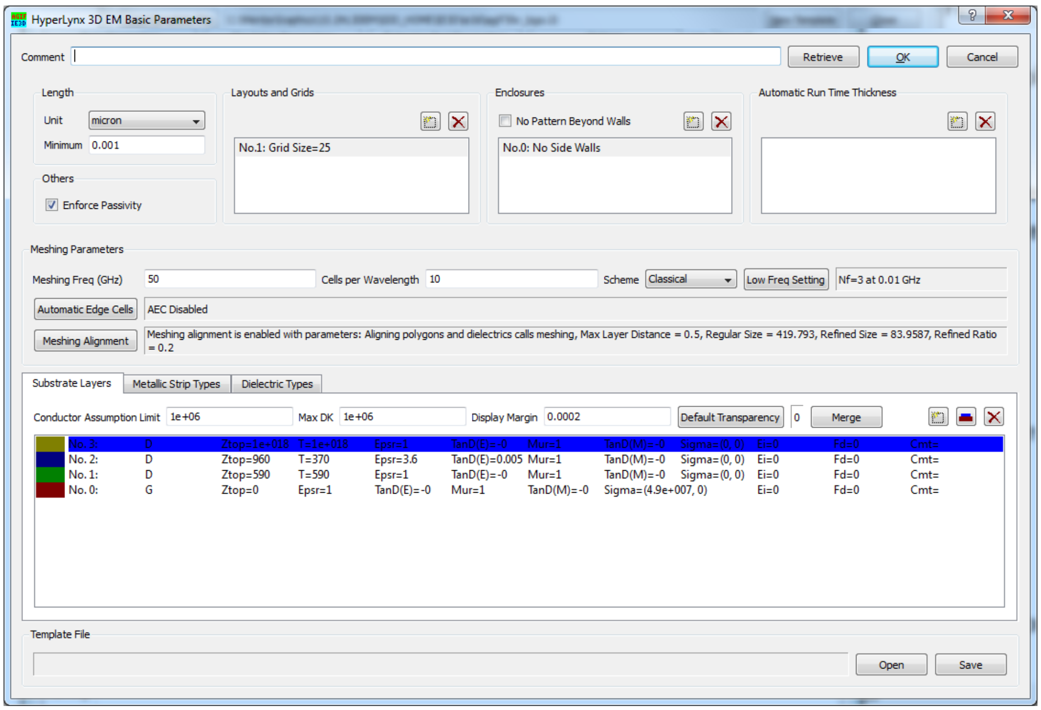


Fig. 4-8(a) Substrate Layer Stackup

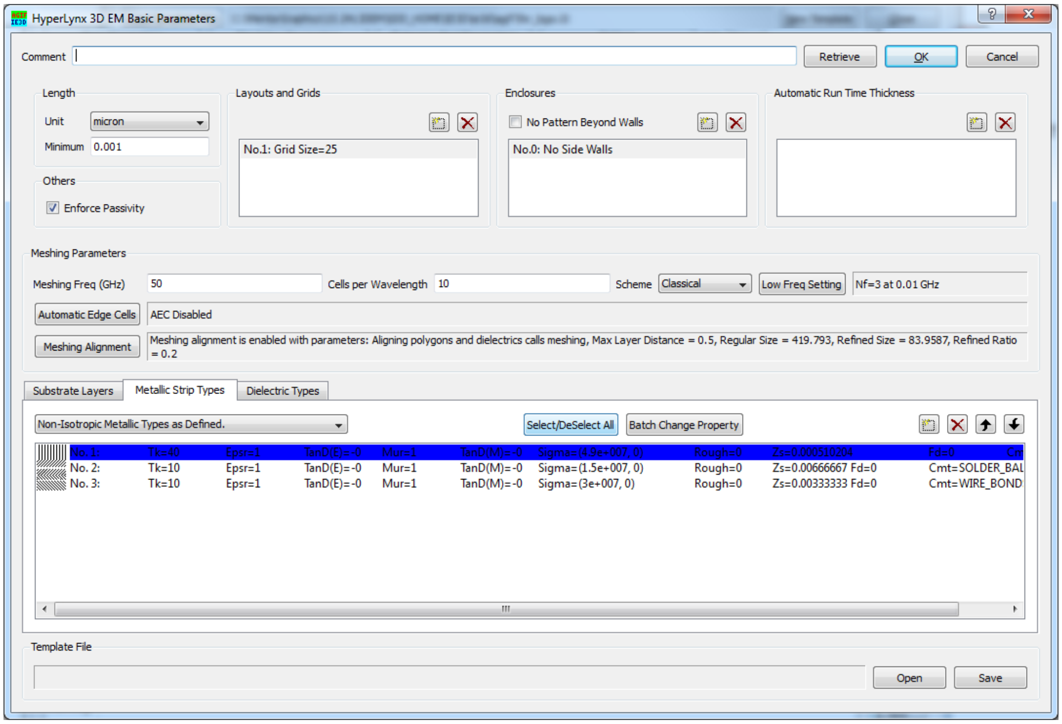


Fig. 4-8(b) Metal Types

Please refer to the *HyperLynx3D EM User's Manual* if you do not know how to set up the layer stackup or add metal types.

<u>Set up Simulation Parameters</u>

Click on the 

button for setting up the EM simulation parameters:

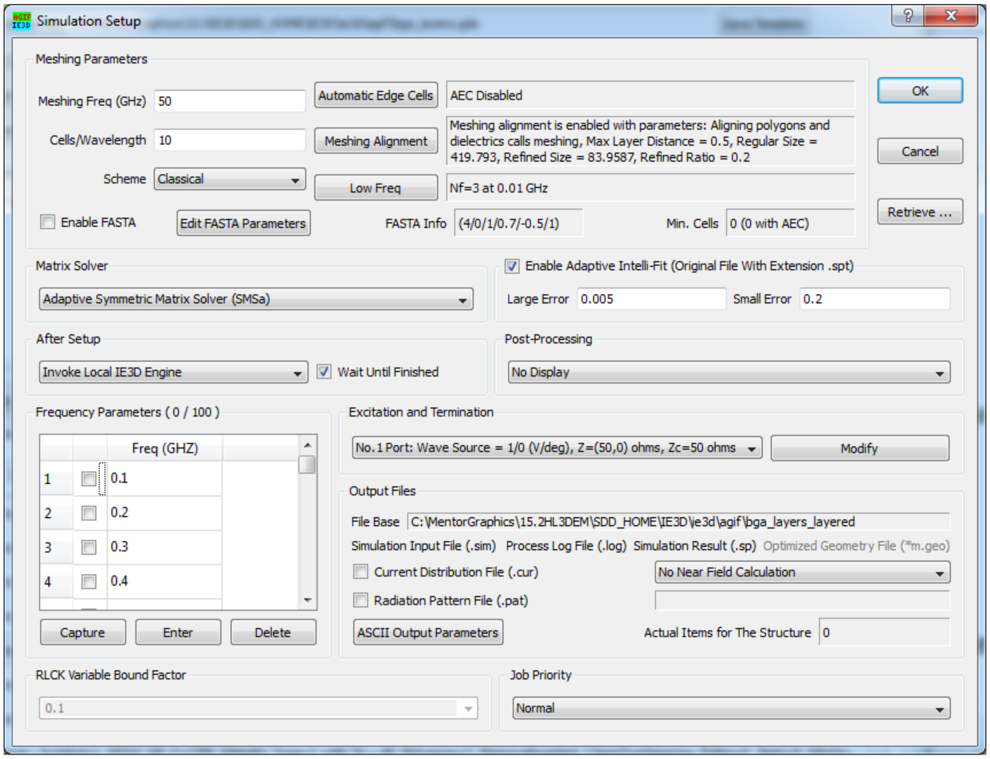


Fig. 4-9 Simulation Parameters

Please refer to *HyperLynx 3D EM User's Manual* if you do not know how to set the simulation parameters

<u>The Information and Status of the Current Template File</u>

The status and information of the current template file is shown in the information and status area:

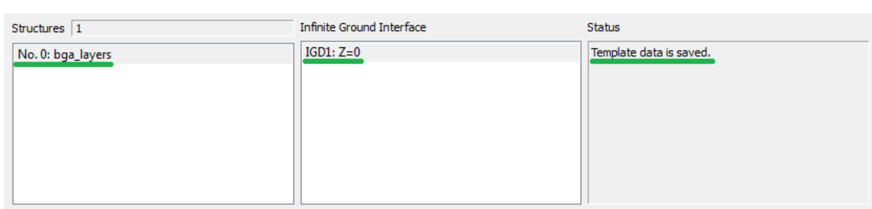


Fig. 4-10 Information and Status

It shows that currently there is one structure linked with the template file, and an infinite ground plane is added at Z=0. The template file has been saved.

<u>Layer Operations</u>

The bottom part on the AGIF window shows the layer stackup. Three operations are available for setting up the EM models of the GDSII design:

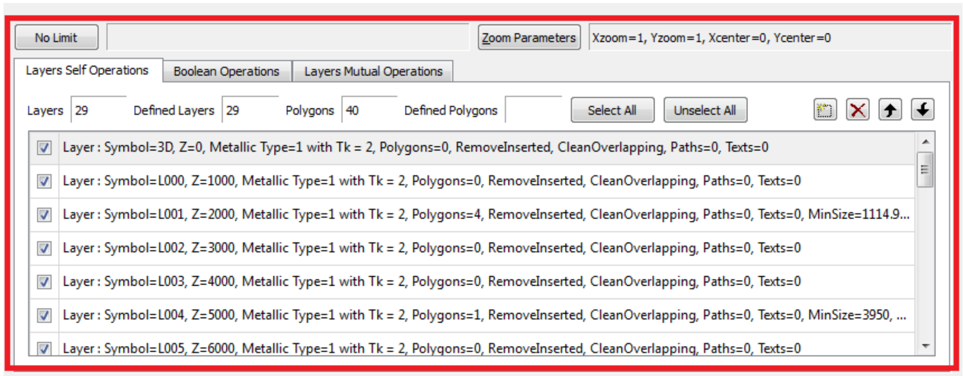


Fig. 4-11 Layer Stackup and Operations

As can be seen, all the layers in the .gds file are listed under the *Layer Self Operations* tab. By default, all the layers are selected for EM model setup. However, not all the layers are useful for creating EM model. Basically there are two types of layers in a GDSII design: one type is physical layer that contains real metal shapes; the other is purpose layer on which the polygons are used for creating some special objects, such as vias, solder balls and bond wires etc. For this BGA example, layer L001, L004, L007 ~ L009 are physical layers, which L010~L027 are purpose layers. Other layers should be unchecked as shown below:

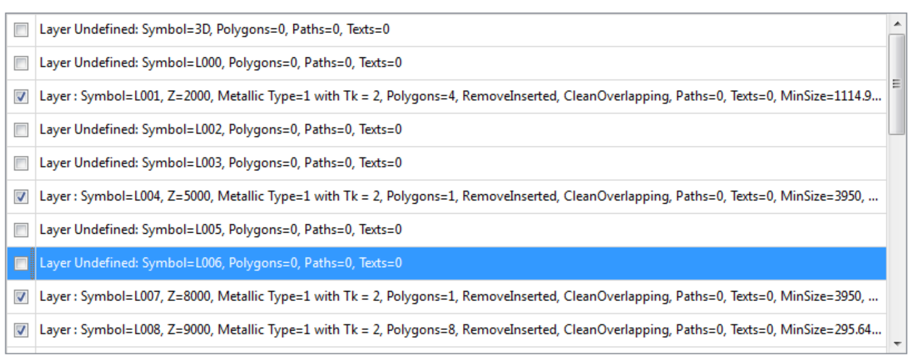
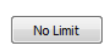


Fig. 4-12 Layers for Creating EM Model

If only a part of the GDSII design is desired to be simulated, click the 

button to define the boundaries in X and Y directions and crop the original design:

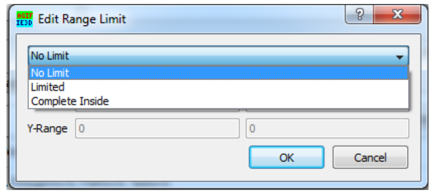
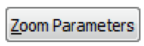


Fig. 4-13 Edit Range Limit

As can be seen, three options are available for defining the boundaries in X and Y directions:

1. No limit: the default choice which will enclose all the polygons in the design in the EM model
2. Limited: if selected, the boundary range in X and Y directions should be specified.
3. Complete inside: if selected, only the polygons that are completely inside the defined range are selected for creating EM model

You can also use the 

button to enlarge the imported polygons:

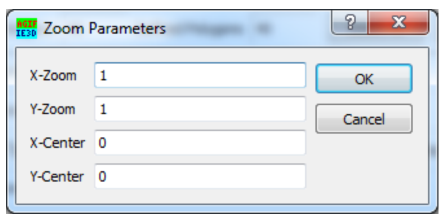


Fig. 4-14 Zoom Factor

Enter the zoom factors in either or both X and Y directions to zoom the polygons. You may also move the zoomed polygons to another location by specifying the zooming center.

The button in Fig. 4-11 is for adding new layers in the imported GDSII design. However, it is not recommended to add layer here since no polygons would be able to be added on this new layer. The reason for adding this button is to generate .i2i file with a blank .gds design.

Layer Self Operations

Layer self operations include:

- If the polygons on a certain layer should be included in the EM model
- The name of the layer
- The metal type of the polygons and thickness on the layer
- The elevation of the layer in Z-direction
- Operations on the polygons

Double click the L004 layer in the list to bring up the following window:

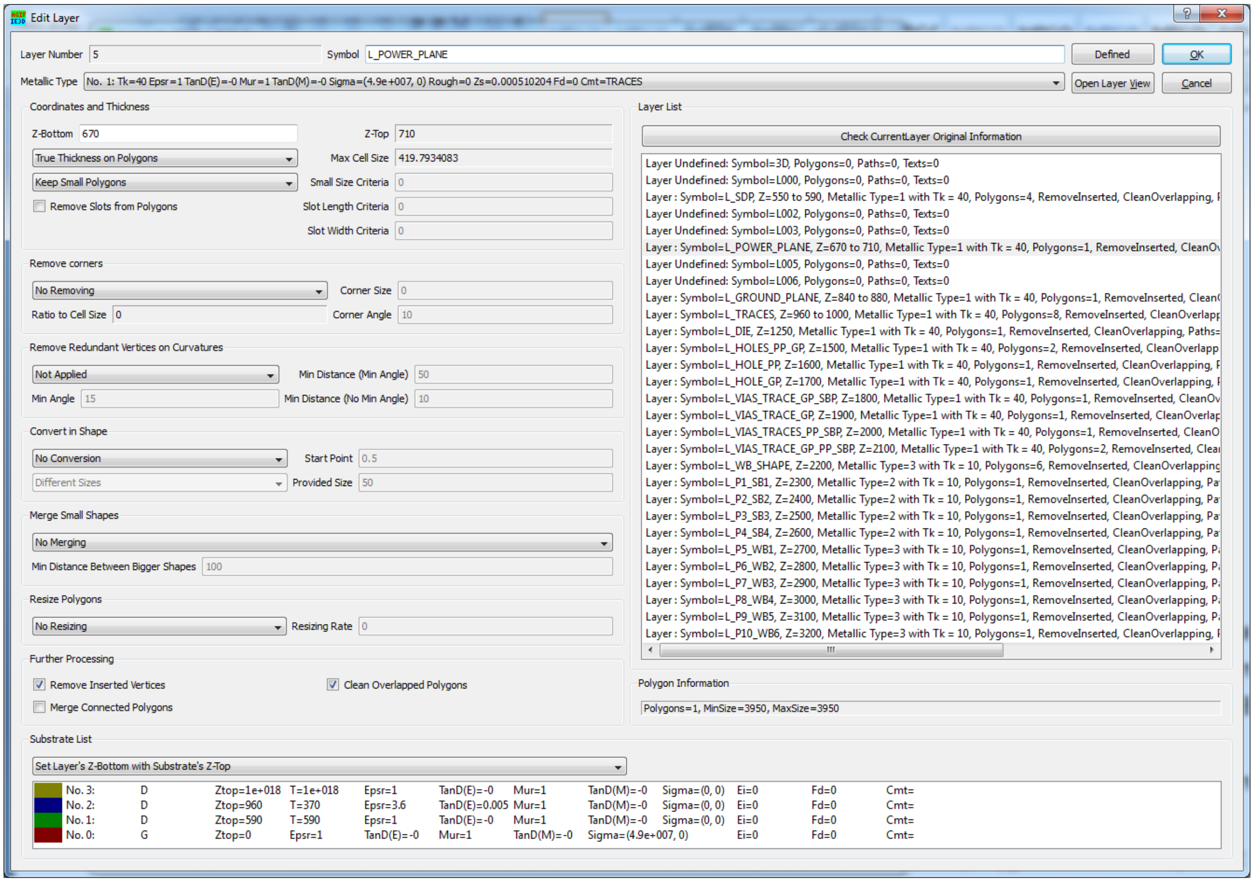


Fig. 4-15 Edit Layer

The Defined button is for check/uncheck the current layer. Click it to uncheck (undefined) and this layer will not be included in the EM model nor any layer operations.

Click the Open Layer View to take a look at all the polygons on each layer.

Symbol: In the *Symbol* edit box, give some meaningful name that describes the purpose of the layer, for example, *L_POWER_PLANE* for this layer which serves as power plane in the design. It is recommended to give a name to each selected layer to facilitate the later mutual layer operations or Boolean operations.

Metal Type: click the combo box to choose the metal type for the polygons on this layer.

Coordinates and Thickness: the Z-bottom and Z-top define how the polygons on this layer sit on the substrate. In conjunction with the options in *Substrate List* at the bottom of this window, users can define whether the polygons sit on the either top or bottom surface of the substrate as well the elevation of this layer.

Thickness on Polygons: after a certain metal type is assigned to the current layer, users have options to apply the true metal thickness or not to the polygons. Normally thickness should be applied to trace layer, while the power plane or ground plane do not need thickness in order to save computation effort. For this example, we still apply thickness to the power plane for demonstration purpose.

Keep or Remove Small Polygons: this option allows users to keep or remove small polygons. In many GDSII design, there are usually small polygons for description or fabrication purpose that are generally not needed in EM models. If *Remove Small Polygon* is selected, all the polygons smaller than the specified criteria will be remove. If *Remove Small Isolated Polygons* is selected, the program will only examine the isolated polygons for removal. The meaning of the criteria value is shown below:

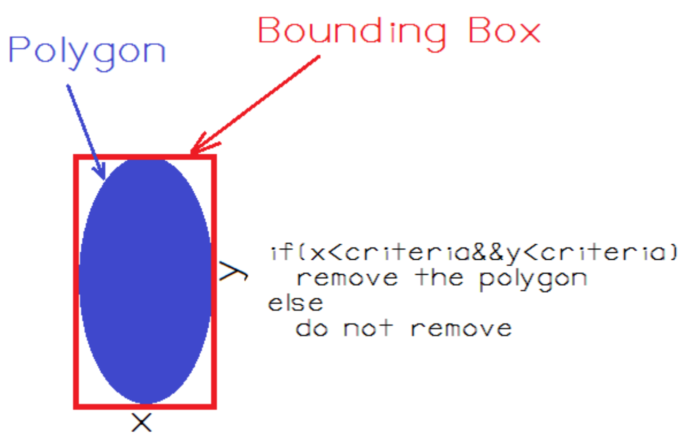
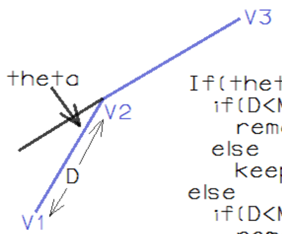


Fig. 4-16 Criteria for Removing Small Polygons

Remove Slots from Polygons: similar to *Remove Small Polygons*, slots can also be removed if they are smaller than the specified criteria.

Remove Corners: In manufacturing, we may have some small cut corners on each polygon. The small corners do not affect the performance of a circuit while it may affect the meshing significantly. Replacing the small cut corners by sharp angles may reduce the meshed cells significantly and improve the simulation efficiency. Corner size and angle can be specified for removal.

Remove Redundant Vertices on Curvatures: Try to reduce some extra vertices on a curvature. Normally, more vertices on a curved structure may describe the structure more precisely. However, for an EM simulation, it is not necessary to be extremely smooth. The extra vertices may cause the meshing program to create too many cells in a simulation and it will increase the simulation time significantly. We can use this command to reduce the redundant vertices on curvature so that we can improve simulation efficiency significantly while we will not lose accuracy. To remove redundant vertices, the *Min Angle* and/or *Min Distance* should be specified:




```
If(theta < Min Angle)
  if(D<Min Distance (Min Angle)|| D<Min Distance(No Min Angle))
    remove V2
  else
    keep V2
else
  if(D<Min Distance(No Min Angle))
    remove V2
  else
    keep V2
```

Fig. 3-17 Criteria for Removing Redundant Vertices

<u>Convert in Shape</u>: This feature allows us to convert some less regular shapes on a layer into more rectangular shapes. For example, we may have a group of polygons on a layer to describe the shapes of a group of vias. Each polygon can be slightly different after importing. Using the Convert in Shapes, we can convert them into regular shape of the same size.

<u>Merge Small Shapes</u>: instead of removing small polygons, users can use this option to merge small polygons into one large shape. In a semiconductor process, we may create vias between two layers by many tiny pins. Though these small pins can be simulated as they are, it is more efficient to model the many small pins as one single big via without losing accuracy. This feature allows us to merge many small shapes describing the pins into a larger one so that we can create vias more efficiently in a simulation. There are options for the merging. It is discussed later when we discuss *Mutual Layer Operation*.

<u>Resize Polygons</u>: This feature allows you to scale the polygons on a specific layer by a fixed ratio (percentage) or an offset (a real value).

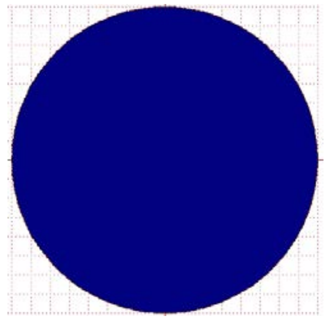
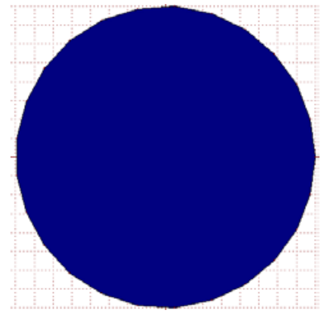
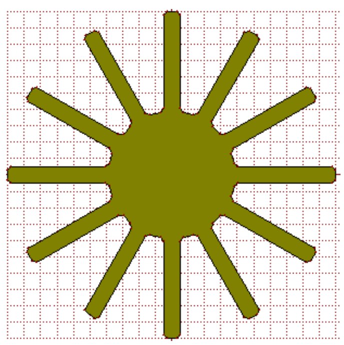
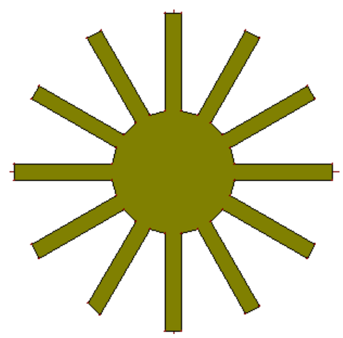
<u>Further Operations</u>: three more operations can be selected for optimal polygon representation: *Remove Inserted Vertices*, *Clean Overlapped Polygons* and *Merge Connected Polygons*.

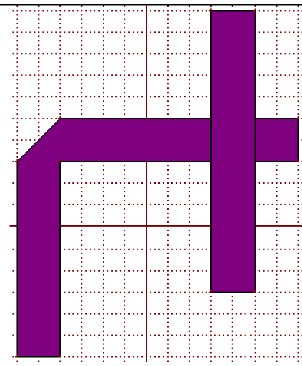
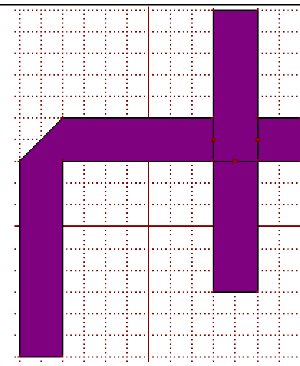
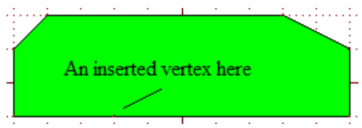
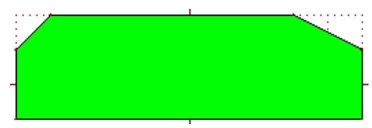
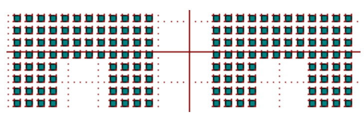
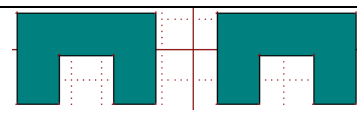
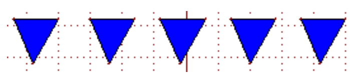
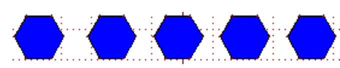
<u>Substrate List</u>: as aforementioned, the combo box provides different option for determining the relative positions of the polygons on the substrate.

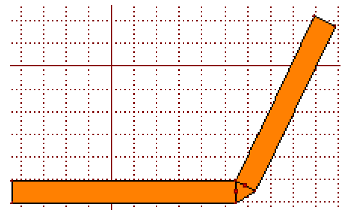
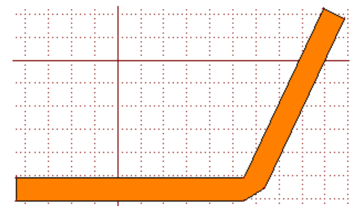
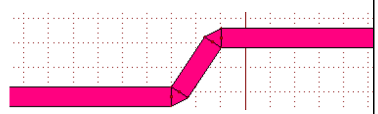
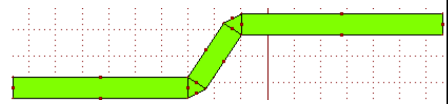
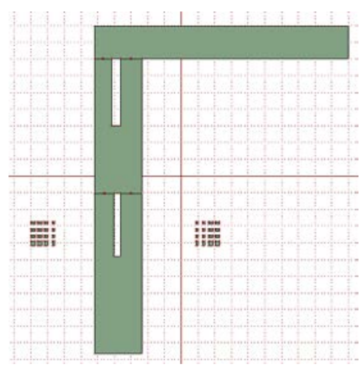
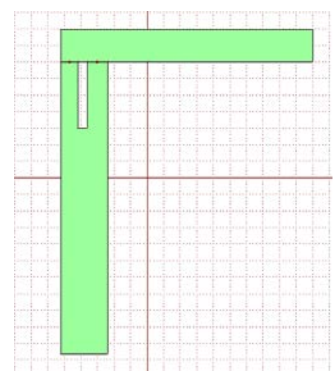
Continue to define the properties for each selected layers to complete the self layer operations. To better understand the self layer operations, you may open in the *clean_polygons_example_agif.i2i* file to get better idea on the self operations that are performed on each layer in the associated *clean_polygons_example_agif.gds* file as shown in the table below:

Table 4-1 The Layers and the Polygons on Them Before and After Cleaning

Cleaning	**Original Layered Polygons**	**Cleaned Polygons**

Remove Redundant Vertices on Curvature Symbol = "L_REMOVE_REDUNDANT" Min Angle = 15 Degrees Min Distance = 90 mils Min Distance (No Min Angle) = 18 mils Layer mapped to Z = 10 mills (Note: We will remove vertex B on curvature ABC if the outer angle is smaller than 15 degrees and the AB and BC are smaller than Min Distance. If either AB or BC is smaller than Min Distance (No Min Angle), we will also remove it).	 200 vertices on curvature	 Less than 30 vertices on curvature
Remove Corners Symbol="L_REMOVE_CORNERS" Corner Size = 20 mils Corner Angles = 5 Degrees Layer mapped to Z = 20 mils (Note: If a corner's cut size is less than 20 mils and the resulting angle is larger than 10 degrees, we will remove the cut for a sharp corner)	 There are cut corners at the finger tips and the roots	 The cuts are moved and the corners become sharp.

Remove Overlapped Polygons Symbol="L_REMOVE_OVERLAP" Layer Mapped to Z = 30 mils (Note: We suggest users to enable this option for every layer)	 Two polygons are overlapping and they are not connected on edges.	 The polygons are divided and connected on edges.
Remove Inserted Vertices Symbol = "L_REMOVE_INSERTED" Layer Mapped to Z = 40 mils (Note: We suggest users to enable this option for every layer.)	 An inserted vertex along a straight line	 The inserted vertex is removed.
Merge Small Shapes Symbol="L_MERGE_SMALL" Min Distance Between Bigger Shapes = 11 mils Layer Mapped to Z = 50 mils	 There are many small polygons on the layer (Note: The 11 mils come from the fact the distance between two small polygons is about 10 mils.)	 The small polygons are merged into two bigger ones. (Note: We should define the Min Distance to be slightly larger than the maximum distance between any two small polygons for the same group.)
Convert in Shape Symbol="L_CONVERT_SHAPE" Shapes Converted to 6-Sided Start Point = 0.5 Same Size as 1st One Layer Mapped to Z = 60 mils	 Five triangles (Note: This command is mainly for converting shapes for vias into regular shape.)	 Each triangle is converted into a 6-sided polygon. (Note: For small vias, we can use 4-8 side shapes to represent them accurately.)

Merge Connected Polygons Symbol=”L_MERGE_CONNECT” (Note: Normally, we do not merge connected polygons as long as they are in good shapes. Merging irregular shaped connected polygons may improve efficiency).		
Build Thickness Symbol=”L_BUILD_TK” (Note: Normally, we do not need to build true thickness unless the strip thickness is no longer small compared to width)	 The strip is on z = 80 mils	 The strip has 4 sides and the bottom side is on z = 80 mils and the top side is on z = 88 mils.
Remove Slots and Remove Small Polygons Symbol=”L_REMOVE_SLOTS” (Note: there are two slots in the bend, and only one of them will be removed by specifying the criteria in the layer property window. The small polygons are also removed by specifying *Small Size Criteria*)		

<u>Boolean Operations</u>

AGIF provides layer Boolean operations to facilitate 2D objects creation. The basic idea is to use the polygons on first layer to do Boolean operations, and the resultant polygons will be placed onto the third target layer.

Click the second tab from the left to see the *Boolean Operation* window as shown below:

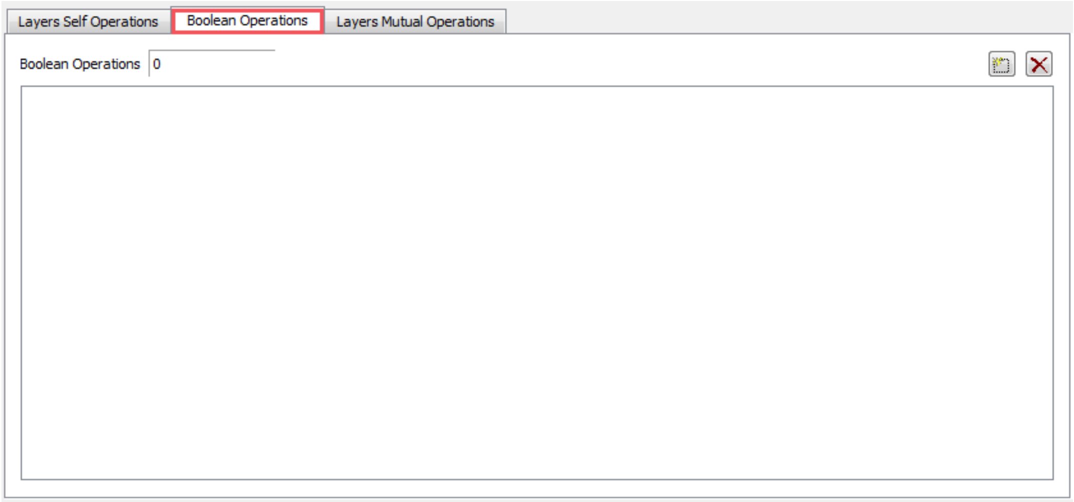


Fig. 4-18 Boolean Operation Window

Click  button to add new Boolean operation:

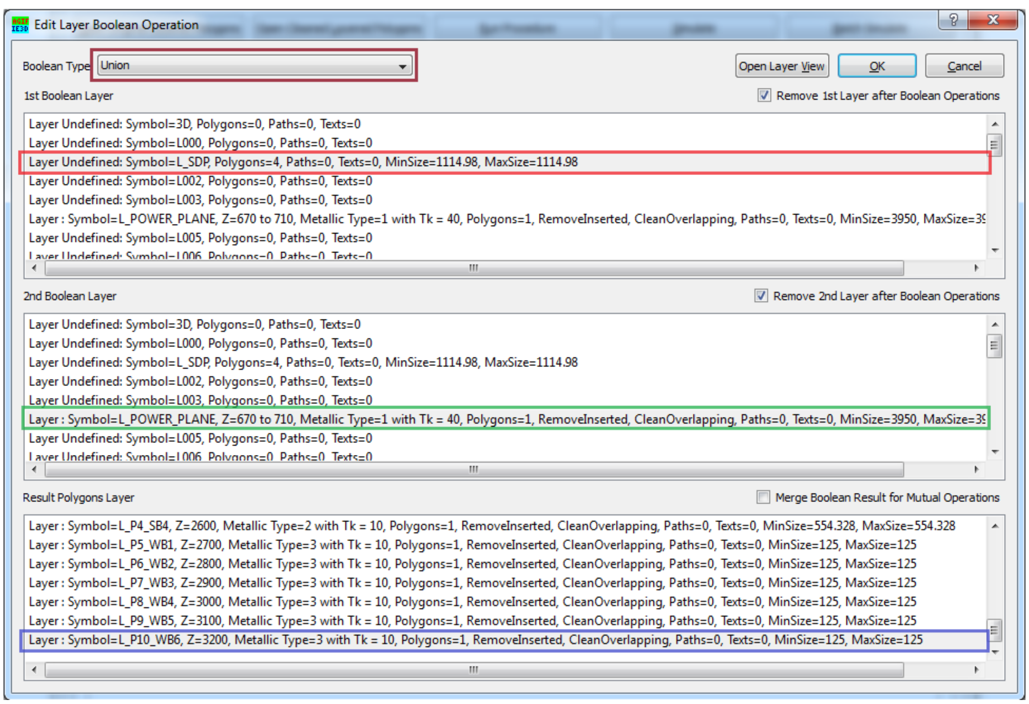


Fig. 4-19 Boolean Layer Operation

In the *Boolean Type* combo box, select the Boolean operation you want to conduct. Highlight the layer in the *1st Boolean Layer* list to define the first layer, and the layer in the *2nd Boolean Layer* list to define the second layer. Finally select the result layer in the *Result Polygons Layer* on which the resultant polygons will be placed. User have options to leave or remove the polygons on the first and second layers after the Boolean operation by enable/disable the checkbox at the top right corner of each list window. Click *OK* button to save the defined Boolean operation. If the resultant polygons are used for later mutual layer operations, the checkbox "*Merge Boolean Result for Mutual Operations*" should be enabled.

Since this example does not involve any Boolean operations, no Boolean operation is defined.

Mutual Layer Operations

Mutual Layer Operations provides a convenient way for creating both 2D and 3D objects. It also allows creating ports when creating 2D/3D objects. The basic idea is to use polygons on a purpose layer to create 2D/3D objects on one or multiple layers. Three typical 2D and 3D objects, i.e. voids, bond wires and vias, will be discussed in the following paragraphs.

Let's first take a look at the final structure we want to create, as shown in the following picture:

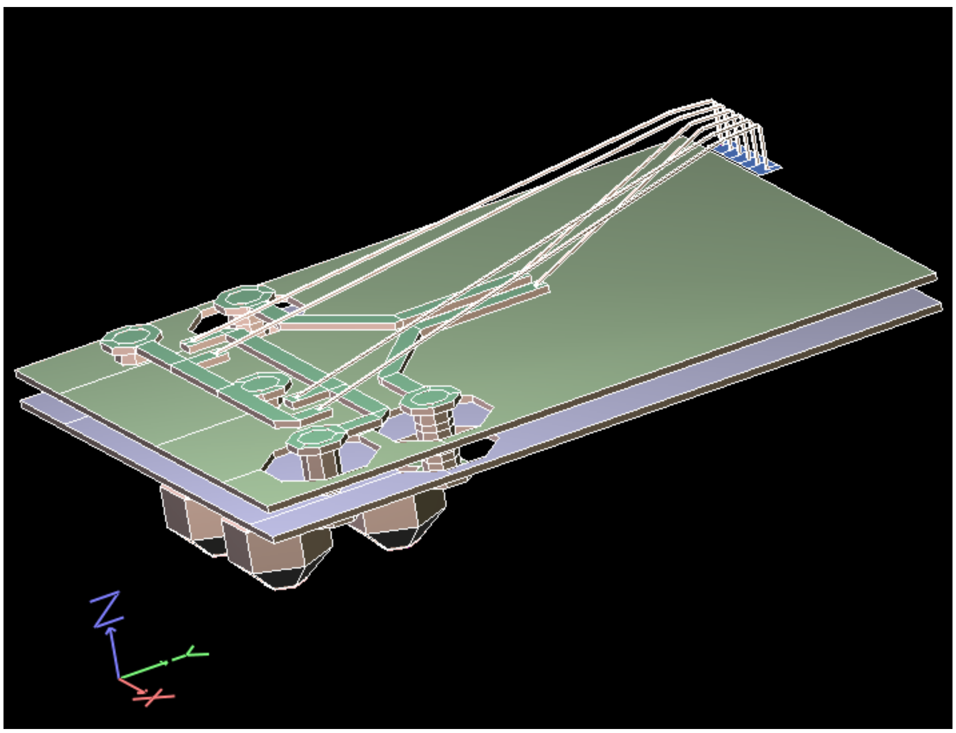


Fig. 4-20 The Final Structure to Be Created

As can be seen, there are three voids on both power and ground planes; four vias connect the trace layer to the bottom solder balls; and the ends of the each trace connect with die layer through bond wires. Therefore, we'll need to use polygons on purpose layers to create: voids, vias, solder balls as well as bond wires.

Click the *Layer Mutual Operations* tab as shown below:

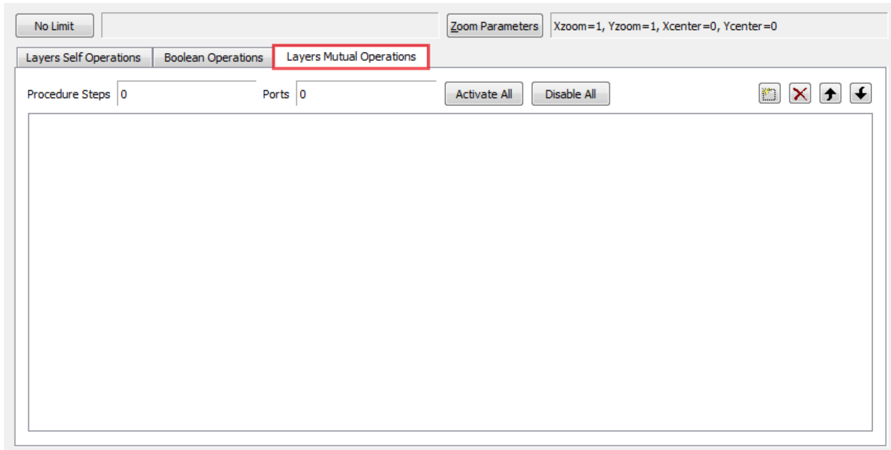


Fig. 4-21 Mutual Layer Operations

Create Voids

The L004 (L_POWER_PLANE) layer is the power plane, and the L007 (L_GROUND_PLANE) is the ground plane. In the original gds design, they are both represented as a 2D rectangular polygon in the layer polygon view. L010 (L_HOLES_PP_GP) is the purpose layer for creating the two holes on ground and power plane. L011 (L_HOLE_PP) is the purpose layer for creating the third hole on the power plane, and L012 (L_HOLE_GP) is the purpose layer for creating the third hole on the ground plane.

Click the button to add new mutual layer operations:

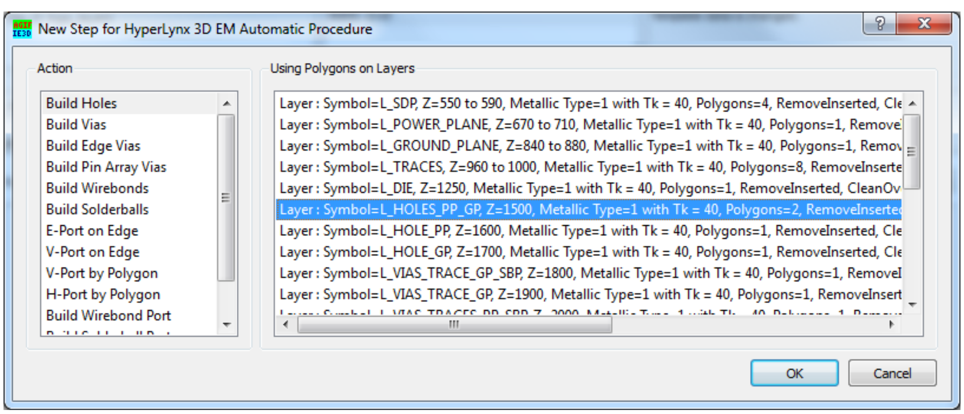


Fig. 4-22 New Layer Operations

As can be seen, all the available actions are listed in the *Action* column, select the first one, i.e. *Build Holes*, and then select the purpose layer (L_HOLES_PP_GP) in the layer list on the right. Click OK to proceed:

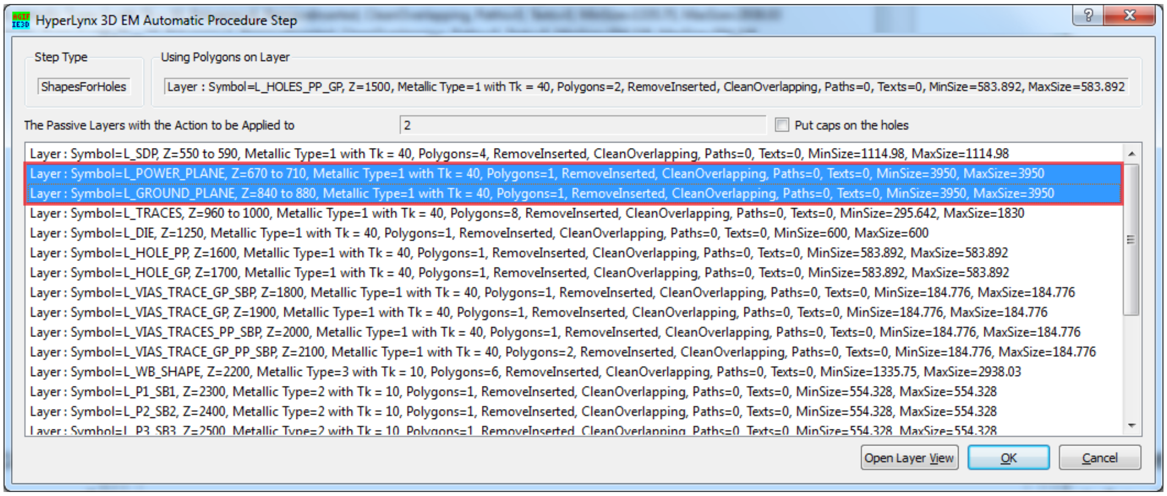


Fig. 4-23 Physical Layers for Mutual Layer Operation

Select the two physical layers (L_POWER_PLANE) and (L_GROUND_PLANE) where the mutual layer operation happens, and click *OK* to exit:

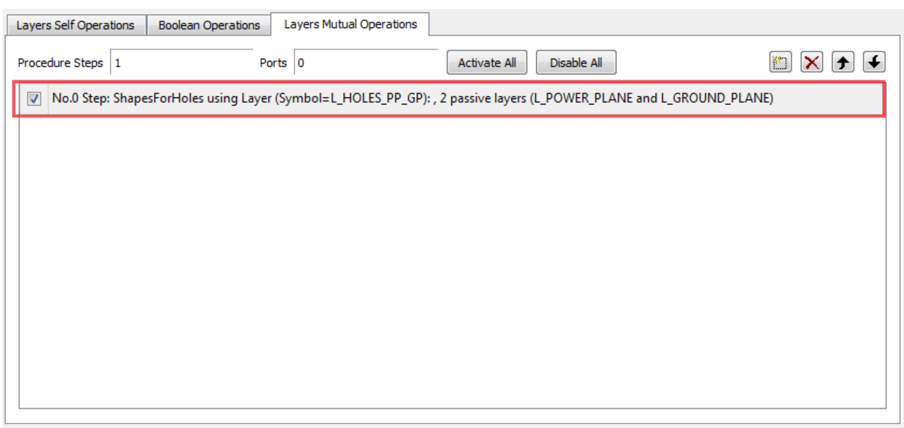


Fig. 4-24 Drill Holes on the Power and Ground Planes

The first mutual layer operation we just created has been added in the mutual layer operation list. Use the same method to create the third hole on both power and ground planes:

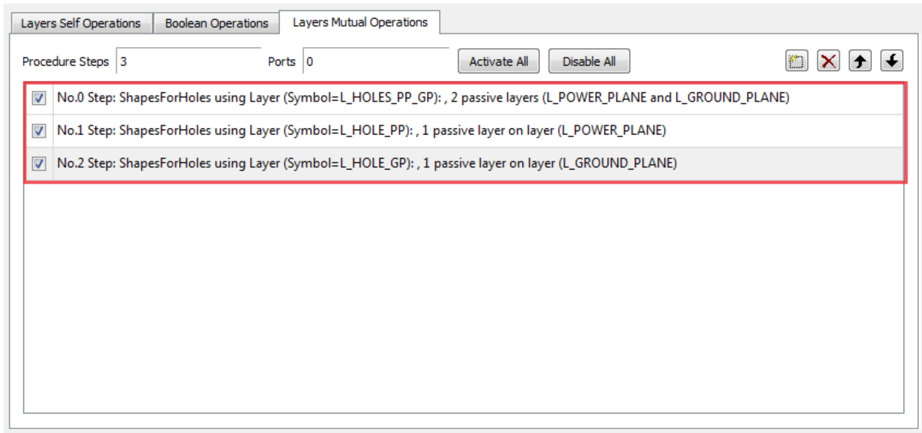


Fig. 4-25 Drill Holes on Power and Ground Planes

Create Vias

Now we are going to create the vias on the structure. The four purpose layers for creating the vias are: L013(L_VIA_TRACE_GP_SBP), L014(L_VIA_TRACE_GP), L015(L_VIA_TRACES_PP_SBP) and L016 (L_VIA_TRACE_GP_PP_SBP). Click the button to create a new mutual layer operation:

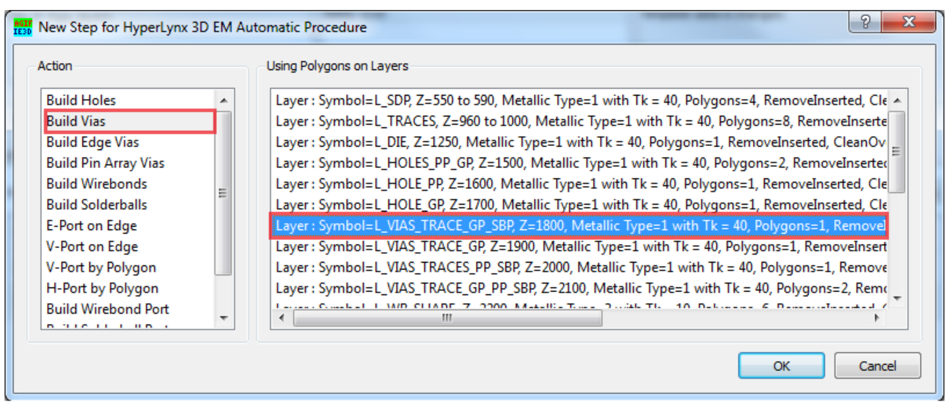


Fig. 4-26 Select Action and Layer

Select *Build Vias* option in the *Action* list, and select L_VIAS_TRACE_GP_SBP layer as the purpose layer. Click *OK* button to bring up the following window:

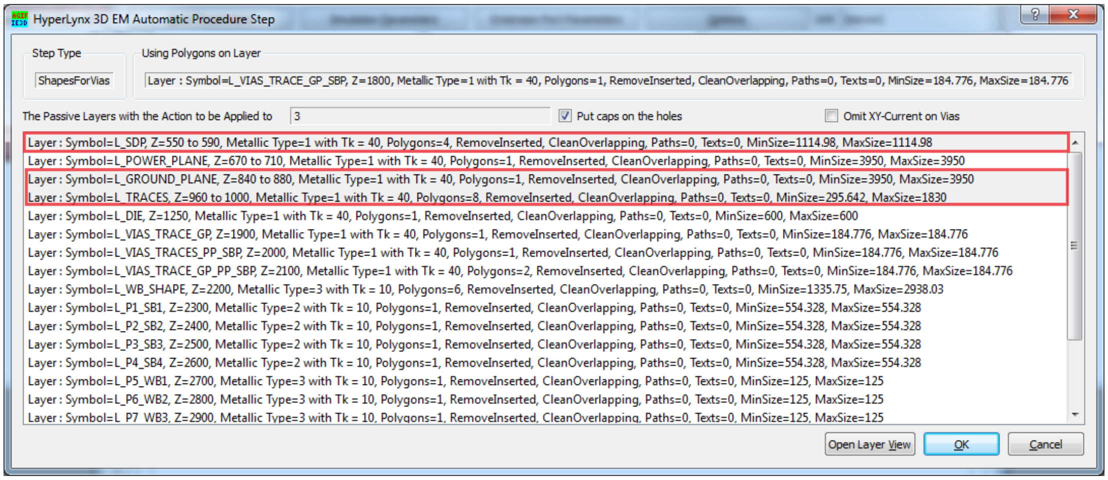


Fig. 4-27 Selected Physical Layers

Select L_GROUND_PLANE, L_SDP and L_TRACES layers, and click *OK*. Now the first via operation has been set up. You have option to put a cap on a via by enabling/disabling the *Put caps on the holes option*. Use the same method to set up other three via operations, as shown below:

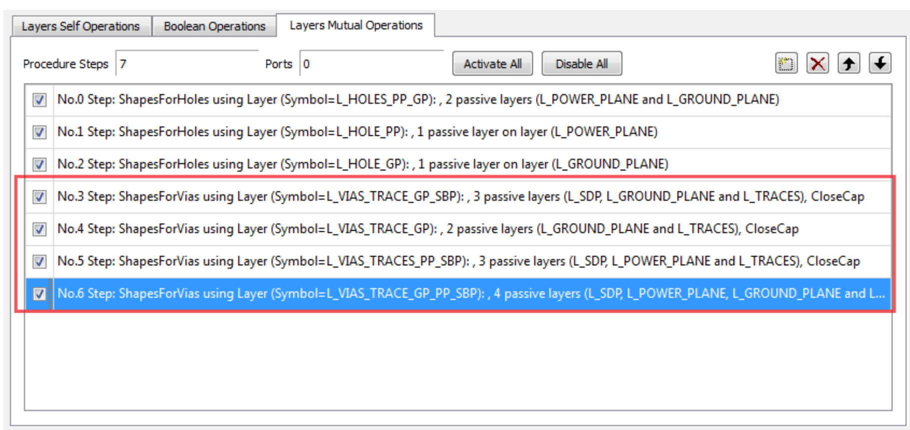


Fig. 4-28 Vias

As can be seen, giving a meaningful layer name will greatly save time for mutual layer operations.

Create Solder Balls

The solder balls are located between the bottom layer and the infinite ground plane, which has been automatically added when importing the GDSII design. Also there is a port between each solder ball and the infinite ground plane, which can also be automatically built when creating the solder ball. Click button to create a new mutual layer operation:

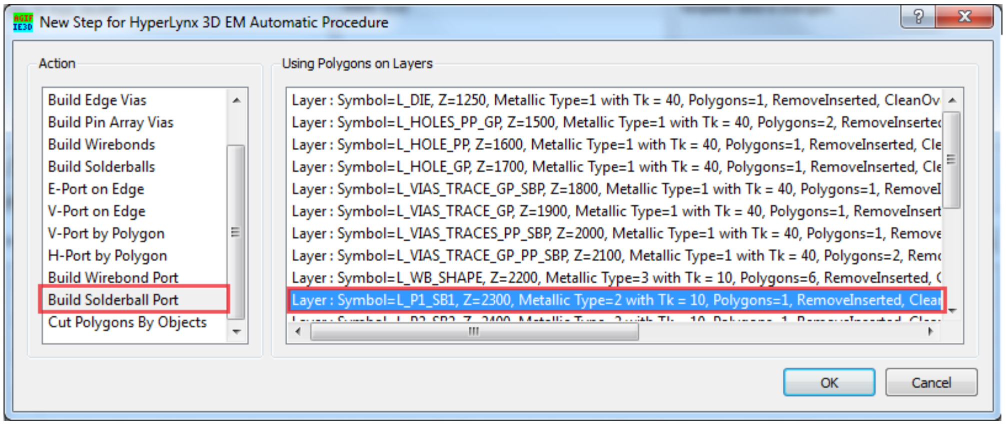


Fig. 4-29 Build Solder Ball

Select the *Build Solderball Port* in the *Action* list, and select L_P1_SB1 purpose layer, click *OK* to proceed to the next window:

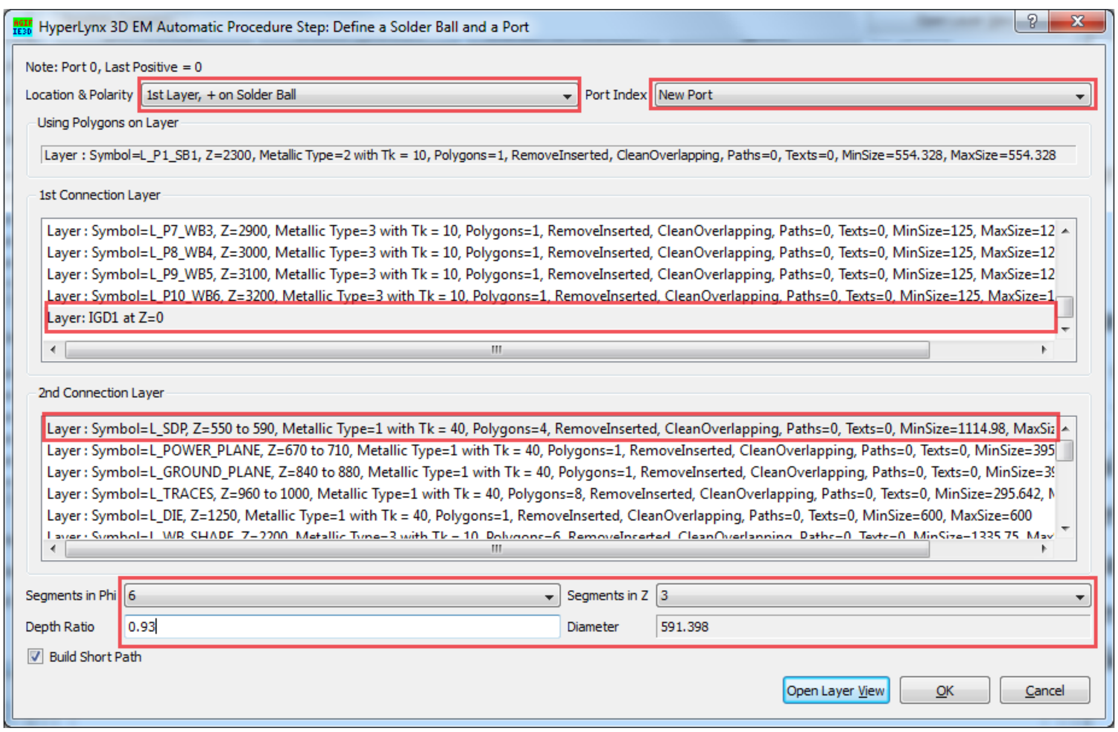


Fig. 4-30 Physical Layers for Solder Balls

The top left combo box defines the location and the polarity of the port:

1. 1st Layer, + on Solder ball: the port will be built between 1st layer defined in the *1st Connection Layer* and the solder ball. The positive electrode is on the solder ball, and the negative is on the 1st plane.

2. 1st Layer, + on 1st Layer: the port will be build between 1st layer and the solder ball. The positive electrode is on the 1st layer, while the negative electrode is on the solder ball.
3. 2nd Layer, + on Solder ball: the port will be built between 2nd layer defined in the *2nd Connection Layer* and the solder ball. The positive electrode is on the solder ball, and the negative is on the 2nd plane.
4. 2nd Layer, + on 2nd Layer: the port will be build between 2nd layer and the solder ball. The positive electrode is on the 2nd layer, while the negative electrode is on the solder ball.

Please be careful when defining the location and the polarity since the wrong location and/or polarity of the port could result in wrong simulation results.

The top right combo box is for defining the port index. If it's a new port, a new port index will be assigned. If the *Same Positive Port Index* is selected, the port index will be the same as the largest positive port index in the list. If the *Same Negative Port Index* is selected, the port index will be the same as the largest positive port index in the list with a negative sign.

Select the IGD1 at Z=0 to be the 1st layer, and L_SDP as the 2nd layer respectively. You have the option to control the shape of the solder balls shown at the bottom of the window: number of segments for representing the solder balls in X and Y directions, number of segments in Z directions. The *Depth Ratio* is to determine the size of the solder ball. The larger the ratio, the more the solder ball is like a ball. If you change the ratio, the *Diameter* of the solder ball also changes. Typically the default setting for controlling the shape and size of the solder ball is good enough. However, if the created solder balls have some serious problems, for example the solder ball is touching the adjacent ones, these settings can be used to adjust the shape/size of the solder balls. For this particular example, the depth ratio is 0.93, and the diameter is thus 591.398. Check the *Build Short Path* checkbox to build the most efficient port. Click *OK* to finish creating the solder ball with port.

Use the same method to build other three solder balls to complete solder ball creation:

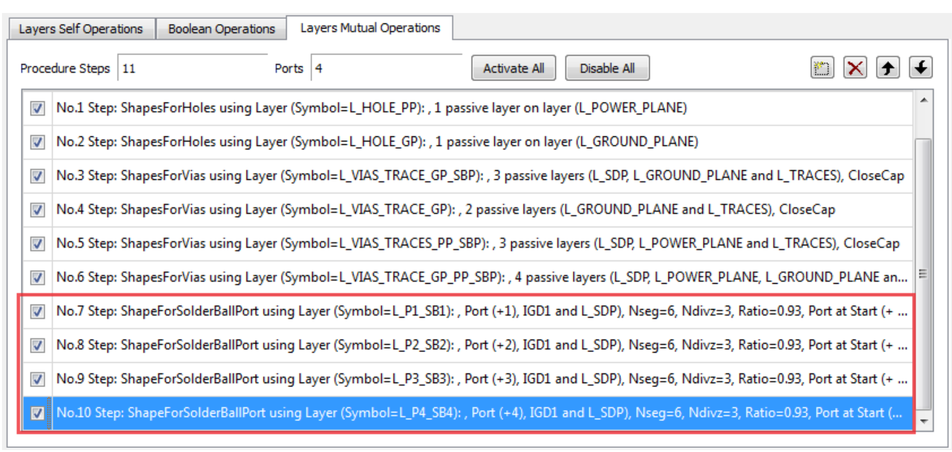


Fig. 4-31 Created Solder Balls

There is another similar operation in the *Action* list called *Build Solderballs* which only build solder ball without port attached.

Create Bond Wires

There are totally 6 bond wires on the design starting from the trace layer and land on the die layer. A port is between the end of the bond wire and the die layer. All these bond wires use the same purpose layer (L_WB_SHAPE), but the start and end locations are different. Similar to creating solder balls, you have options to create bond wires with or without ports by selecting different actions in the action list.

Click the button to create new mutual layer operation:

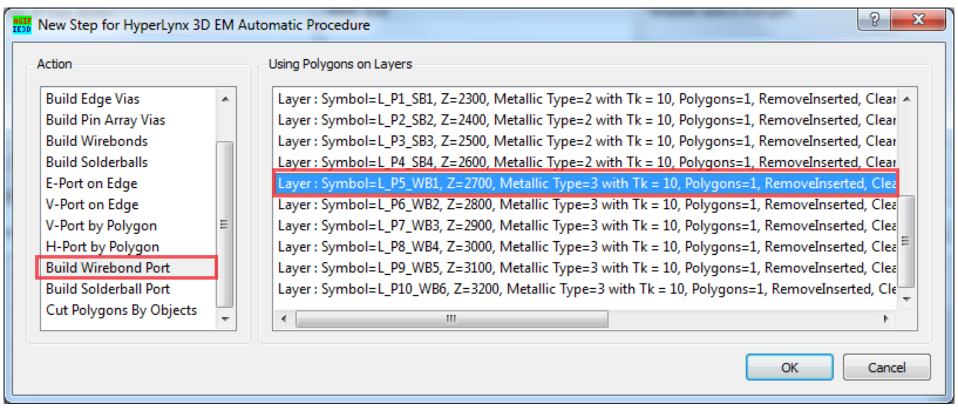


Fig. 4-32 Create Bond Wires

Select *Build Wirebond Port* in the *Action* list, and L_P5_WB1 as the purpose layer in the layer list. The polygon on the L_P5_WB1 defines the shape of the cross-section of the bond wire. Click *OK* to proceed:

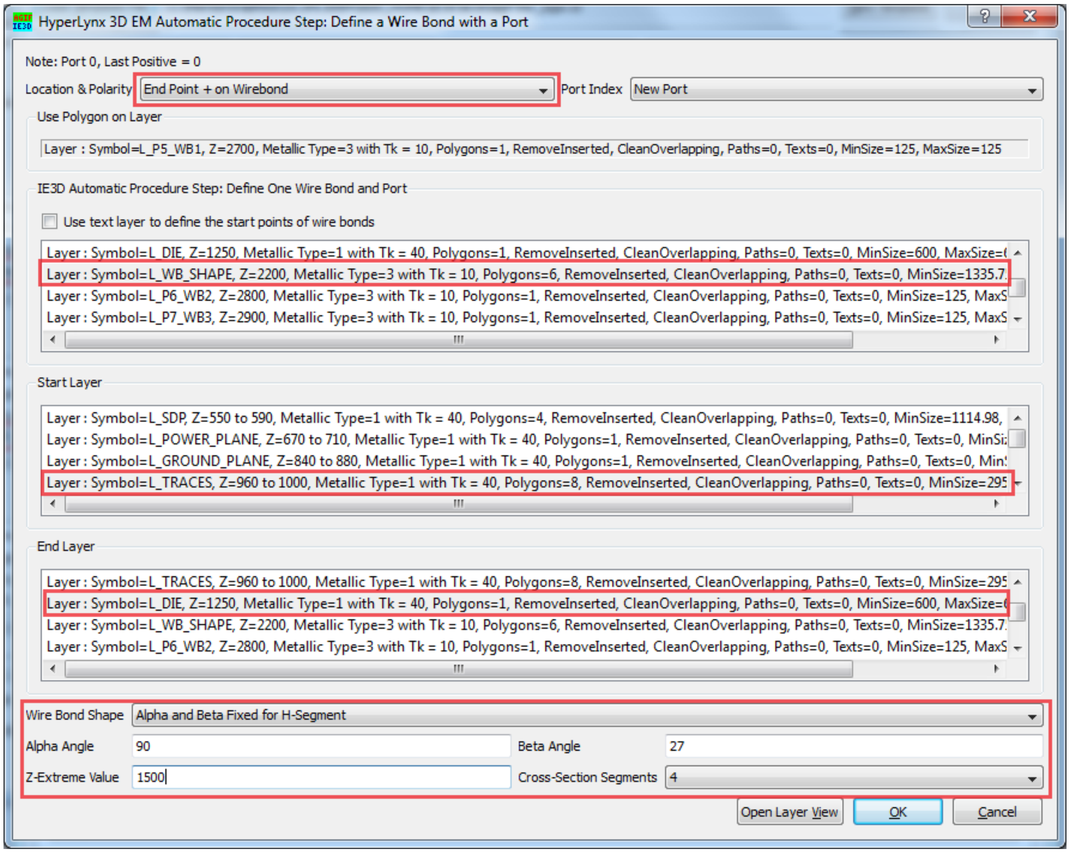


Fig. 4-33 Bond Wire Settings

The port settings are pretty much the same as that in solder ball port settings. The *Start Point* and *End Point* are determined by the selected *Start Layer* and End Layer below, and the positive electrode can be either on the bond wire or on the start/end layer. The port index could be either a new port index, same positive port index or same negative port index.

If the *Use text layer to define the start points of the wirebonds* is enabled, the program will automatically search the text object on the selected layer in the layer list box below, and find the position and port number (if available in the text object) for port definition. For this example, there is no text object for this purpose, and it should be unchecked. More detailed discussion on setting up ports will be given in the next sections. For this bond wire, we'll use L_WB_SHAPE as the shape of the bond wire to define the bond wire. Select the L_TRACES as the *Start Layer*, and L_DIE as the *End Layer* since the bond wire goes from the trace layer to the die layer.

The bottom part of this window provides some other parameter settings for bond wires. The bond wire contains three segments, and the Alpha and Beta angles are defined as shown in the picture below:

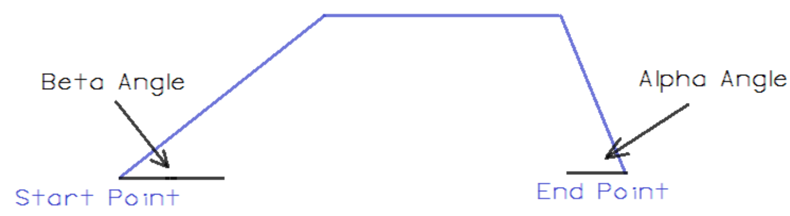


Fig. 4-34 Bond Wire Definition

Users can define the *Alpha* and *Beta* Angle to get different bond wire profiles. The *Z-Extreme Value* defines the maximum height of the bond wire, and the *Cross-section Segments* defines the shape of the cross-section of the bond wire.

Click *OK* to complete the bond wire definition. Take the same procedure to define other five bond wires, and the final Mutual Layer Operation List is shown below:

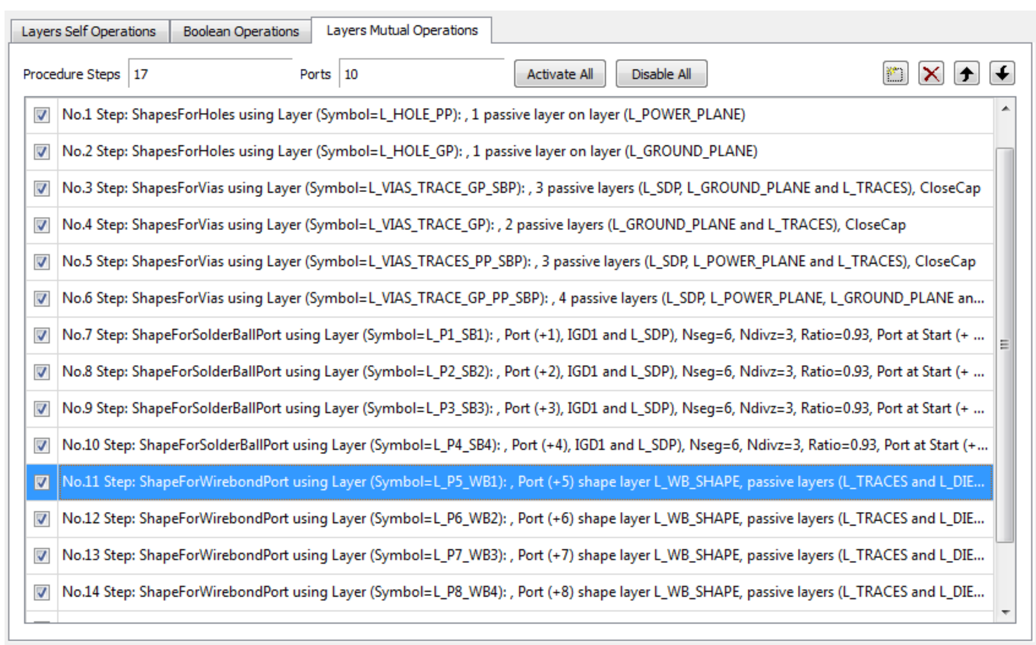


Fig. 4-35 Final Mutual Layer Operations

There are other actions in the action list for defining other types of objects, ports etc. The basic idea and operations are the same as described above: use polygons/text on the purpose layers to do operations on physical layers. User may try other options when necessary.

Create EM Model

After all the self and mutual layer operations are complete, click the 

button to create the EM model. After the whole procedure is complete, a message window will show up:

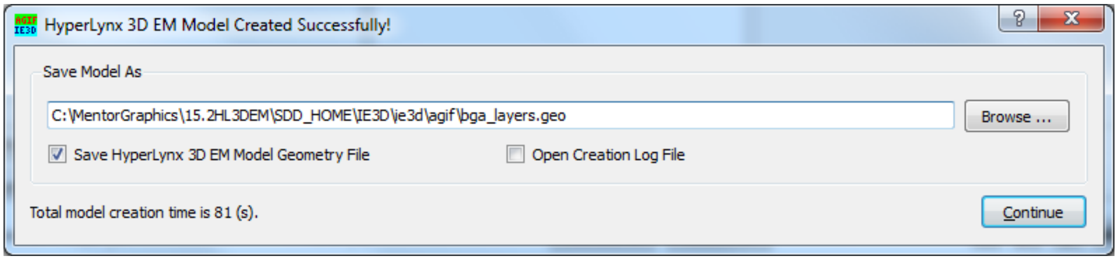


Fig. 4-36 Message Window

It tells you where the .geo file is saved, and the name of the .geo file. You can give another name for the .geo file if necessary. Click *Continue* button to proceed:

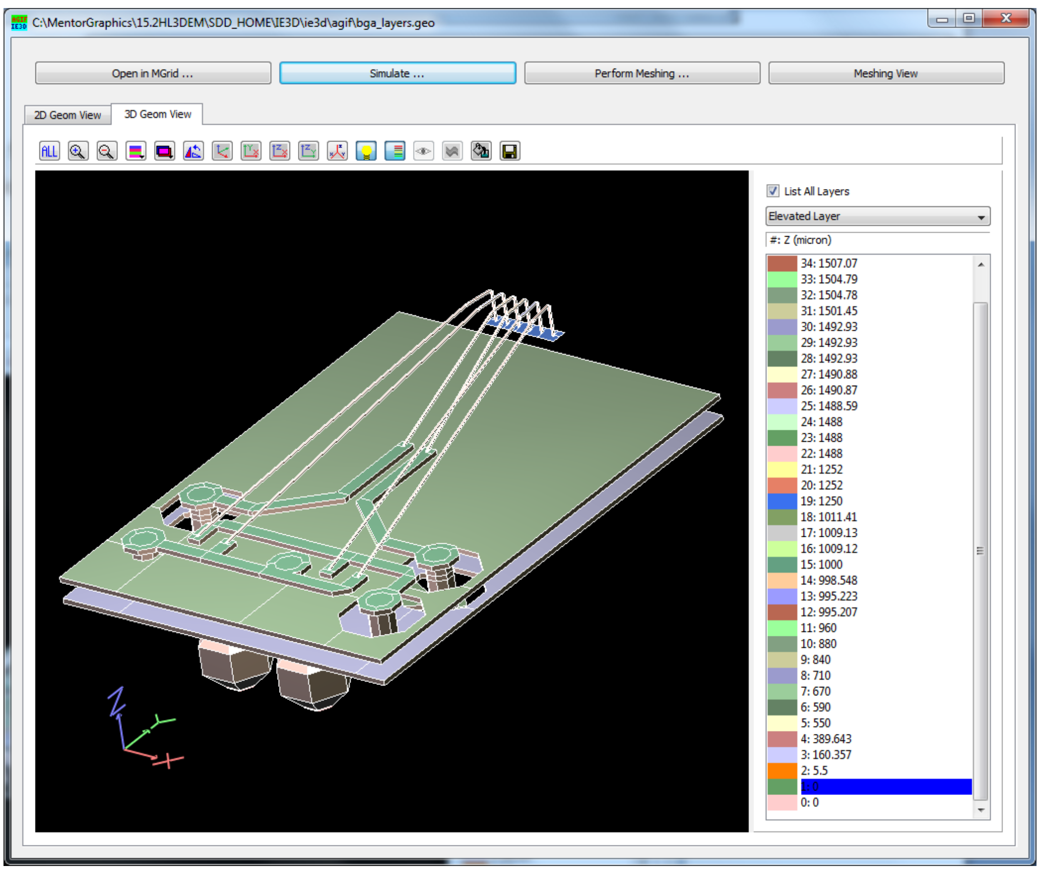
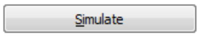


Fig. 4-37 EM Model

As can be seen, all the 2D and 3D objects have been correctly built. You can click function buttons on the top to simulate, mesh or open it in MGrid.
Back to the AGIF main menu, other function buttons are available for EM simulations:



button: click this button to start the simulation directly. After you click this button, AGIF will first run the model setup procedure, and then ask for some simulation settings as shown below:

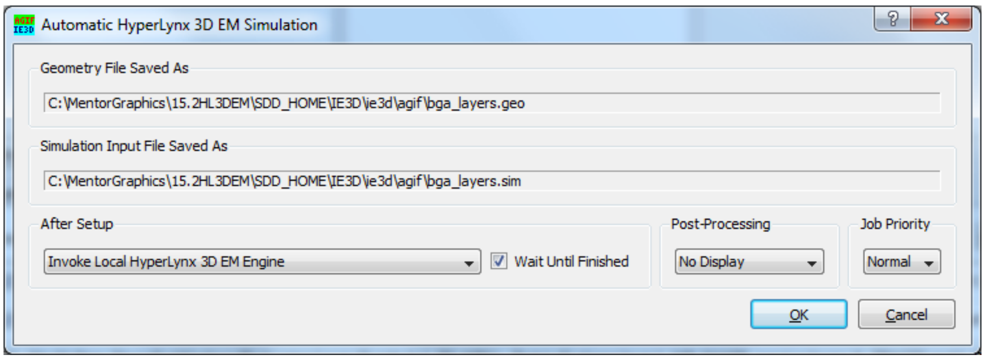
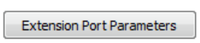
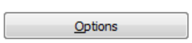


Fig. 4-38 Run Simulation

Click *OK* button to start the simulation directly. Note the created will not be automatically shown before starting the simulation. You can still manually open the saved .geo file to check the geometry of the created EM model.



button: use this button to set the parameters with *Extension Port*. You may refer to *HyperLynx 3D EM User's Manual* for more details on the definitions of these parameters.



button: some other optional parameters:

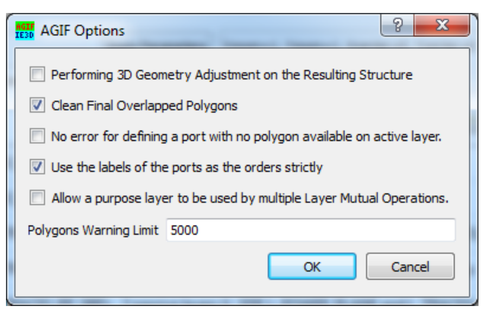
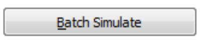


Fig. 4-39 Optional Parameters

- *Perform 3D geometry Adjustment on the Resulting Structure*: after the EM model is created, the program will automatically check the connectivity between 3D objects and 2D object to make sure the connections are right.

- *Clean Final Overlapped Polygons*: there might be overlapped polygons after the self/mutual layer operations that should be cleaned before setting up EM simulations.
- *No Error for Defining a Port with No Polygon Available on Active Layer*: no error message is shown if the program could not find polygons on the selected purpose layer. This option will allow users manually defining port in MGrid if AGIF fails to create ports.
- *Use the Labels of the Ports as the Orders Strictly*: this option is for port index. Usually the port label contains the port index.
- *Allow a Purpose Layer to be Used by Multiple Layer Mutual Operations*: normally a purpose layer is only used for creating one mutual layer operation. Enable this option to allow multiple use of a purpose layer for different mutual layer operations.
- *Polygon Warning Limit*: will give a warning message if the total polygons in the created EM model exceed this number.



button: this function will be discussed in the next chapter.

Chapter 5 Advanced Topics on GDSII to HyperLynx 3D EM Flow

Batch Simulations

Many GDSII designs share the same layer stackup as well as fabrication process. For these designs, AGIF provides a convenient way to simulate these designs at once. Please note the requirements for batch simulating these designs:

1. Identical layer stackup
2. Same fabrication process, which means the same *Self Layer Operations*, *Boolean Operations* and *Layer Mutual Operations* in terms of AGIF

The following paragraphs describe how to set up batch simulations on AGIF for multiple GDSII designs. The example files are stored in .\SDD_HOME\IE3D\ie3d\agif\. The sample template file is *for_two_port_spirals.i2i*, and the .gds files to be associated with the template file are listed below:

- oct_spiral_layers.gds
- square_spiral_layers.gds
- circ_spiral_layers.gds
- rect_spiral_layers.gds

Open the .i2i file on AGIF main menu, and import the oct_spiral_layers.gds as shown below:

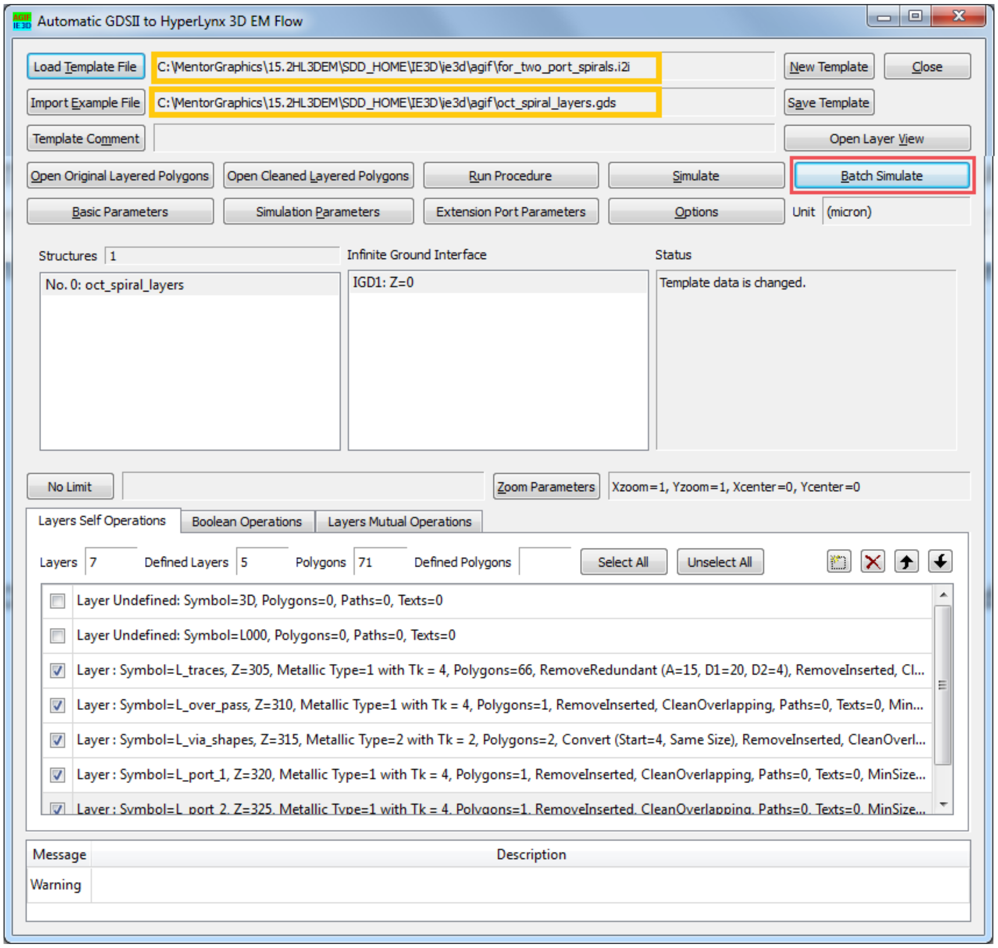


Fig. 5-1 Inductor Designs

The *Layer Mutual Operation* for the inductor design is shown below:

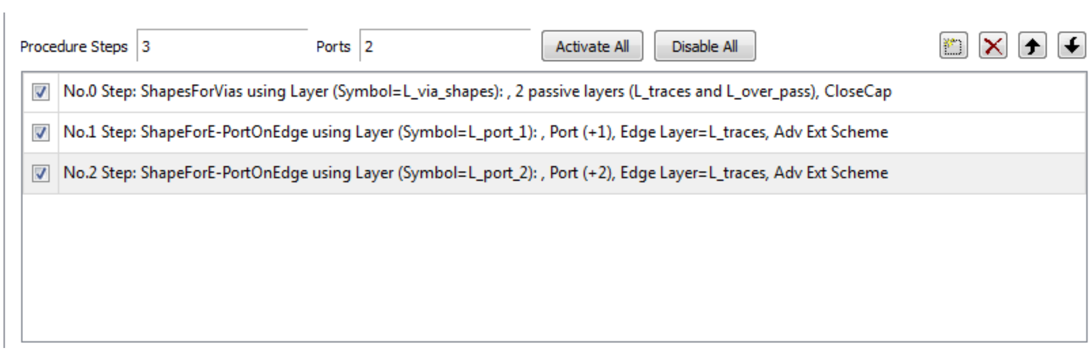
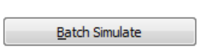


Fig. 5-2 Layer Mutual Operation for the Inductor Design

Click the 

button to load in more .gds designs:

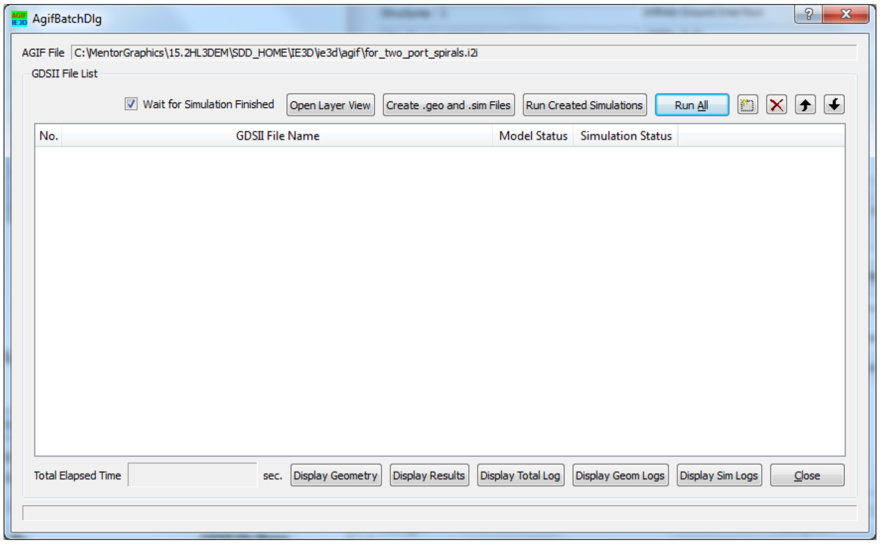


Fig. 5-3 Batch Simulations

Click the the button to select all the .gds files to add them in the list as shown below:

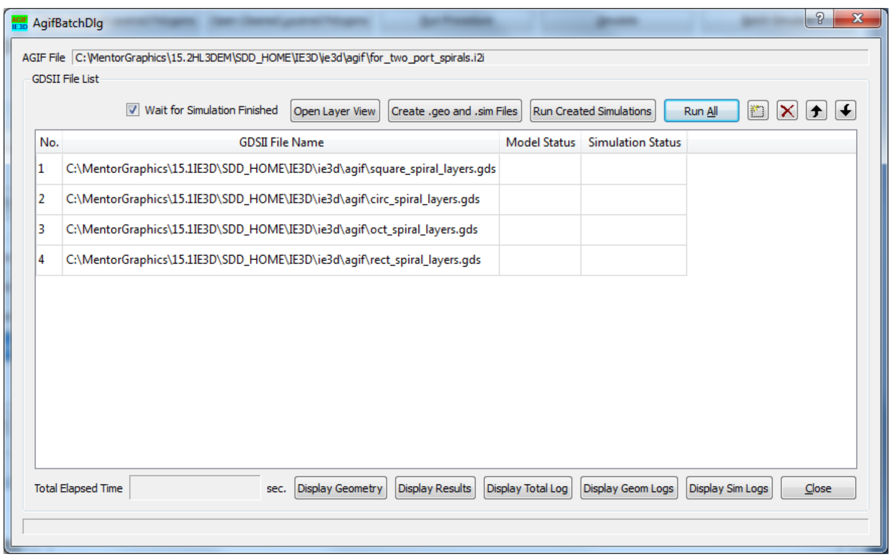


Fig. 5-4 GDSII Designs for Batch Simulations

Highlight each design and click the Open Layer View to take a look at the geometry respectively as shown below:

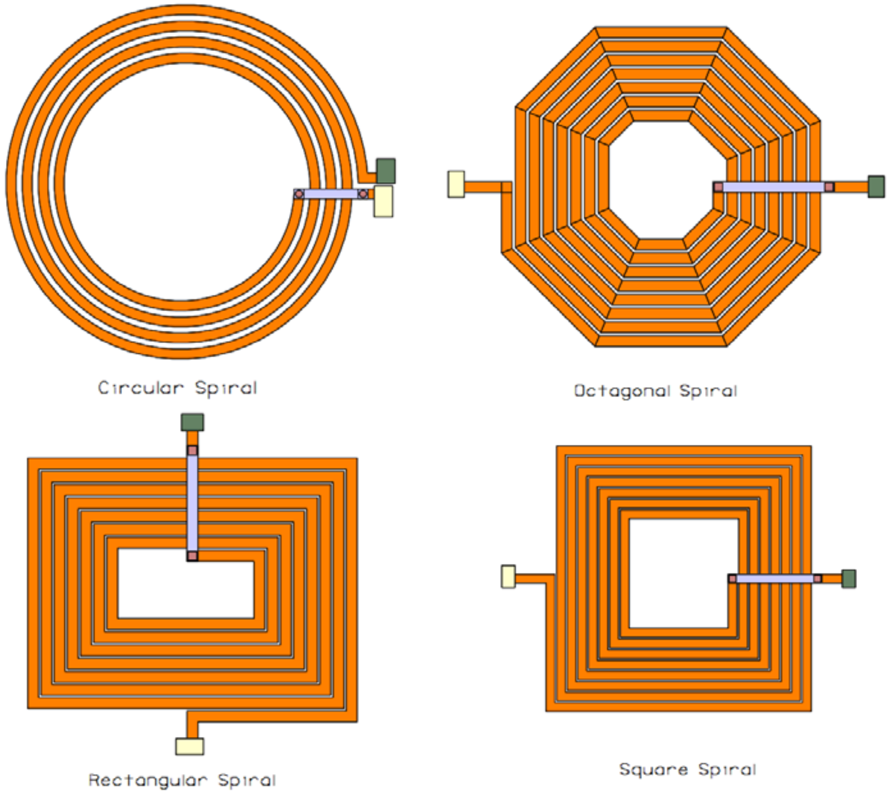


Fig. 5-5 Spiral Designs

Click the Create .geo and .sim Files button to create the EM model for each design. Highlight one of the designs in the list, and click Display Geometry to view the created EM model as shown below:

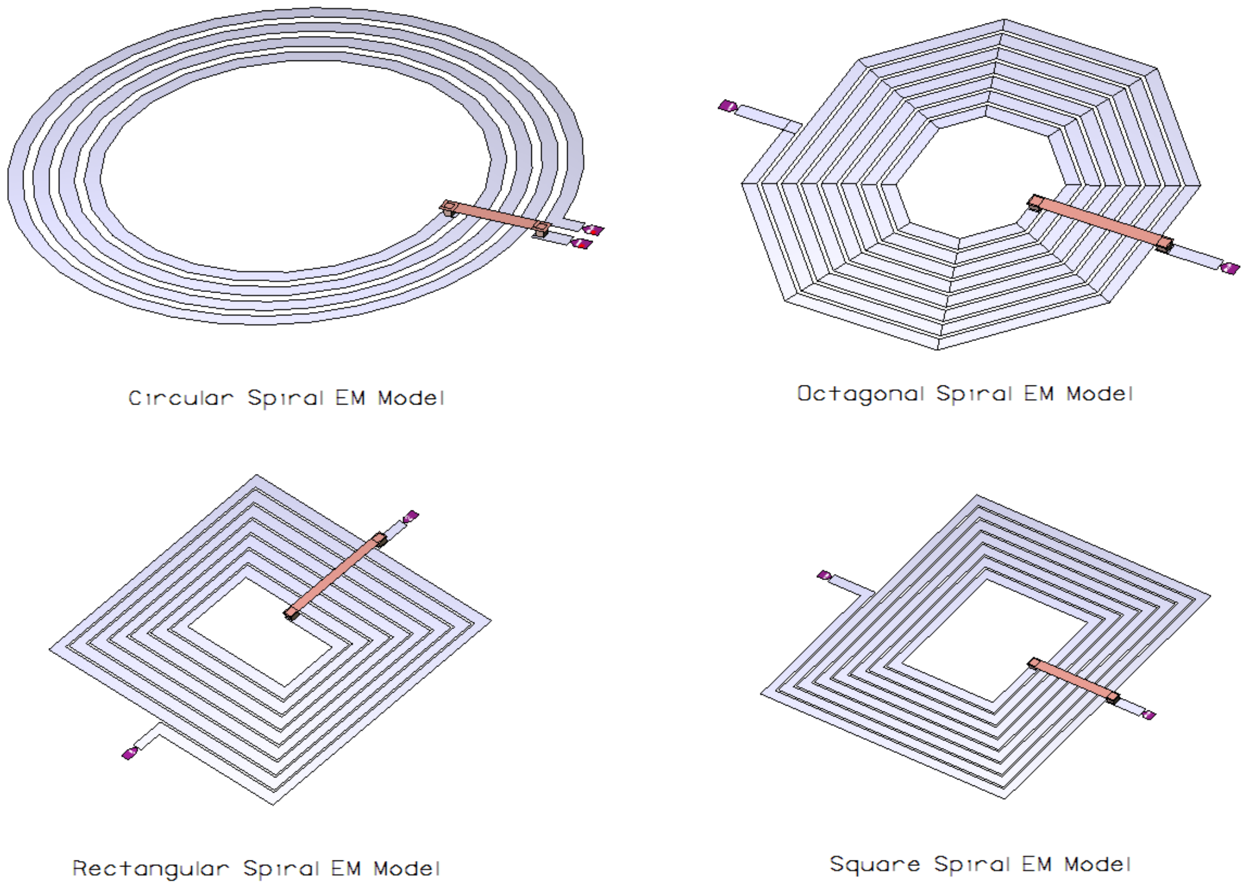


Fig. 5-6 Created EM Models

Now you can run the EM simulation by clicking Run Created Simulations button to simulate all the created EM models:

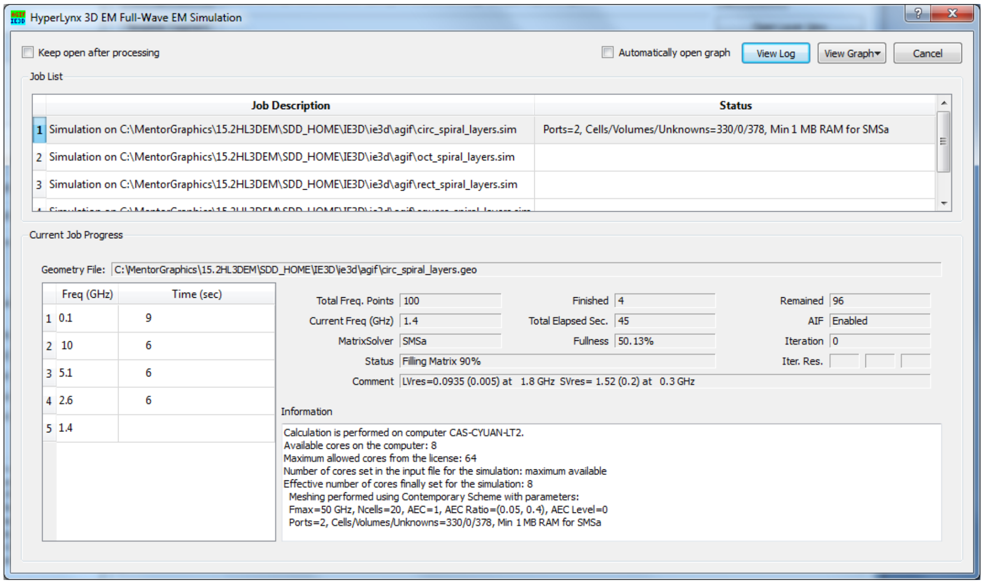


Fig. 5-7 Batch EM Simulations

The Run All button combines the functionalities of Create .geo and .sim Files and Run Created Simulations to set up EM simulation at one shot. After the simulation is done, click the Display Results button and select the parameters to display the simulation results. Use Display Total Log, Display Geom Logs or Display Sim Logs button to see different log files.

Users can also view the intermediate or final simulation by clicking the *View Graph* button on the *HyperLynx 3D EM Full-wave Simulation* window as shown below:

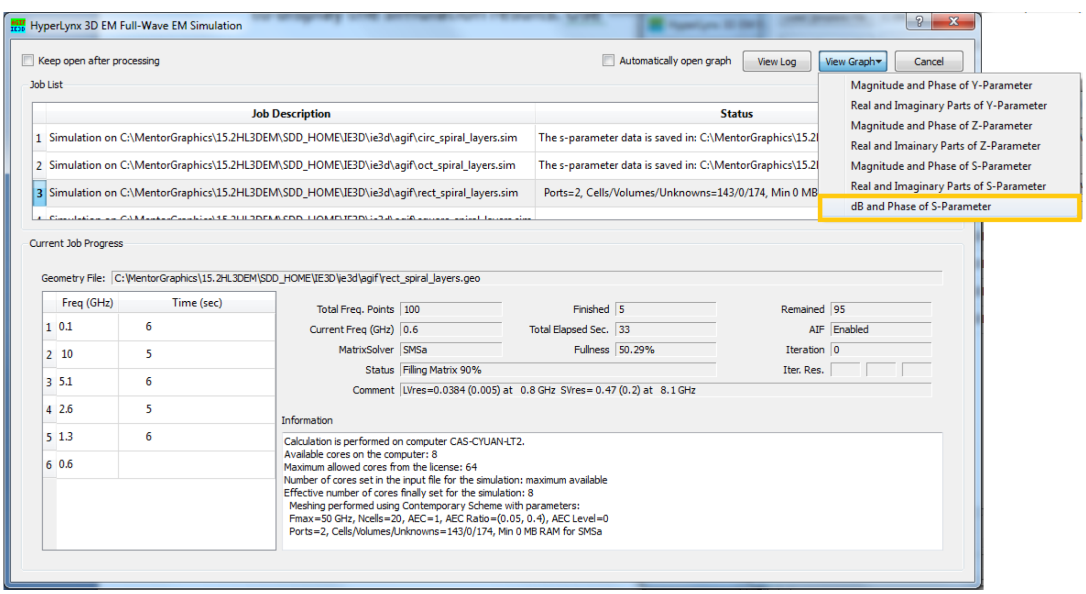


Fig. 5-8 View the Intermediate or Final Simulation Results

For example, click the *View Graph* button and select *dB and Phase of S-parameters* to take a look at the S-parameters:

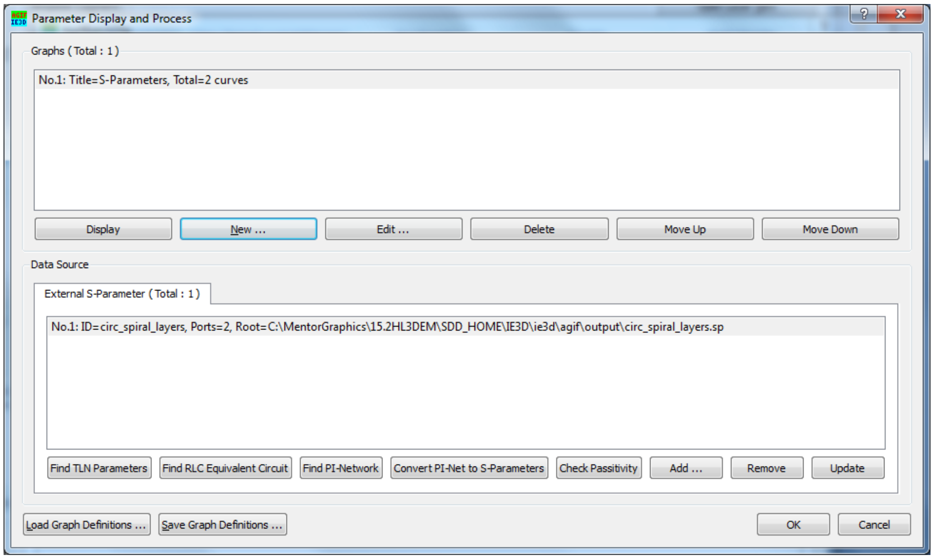
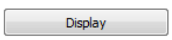


Fig. 5-9 Parameter Display and Process

Click 

button to display the S-parameters:

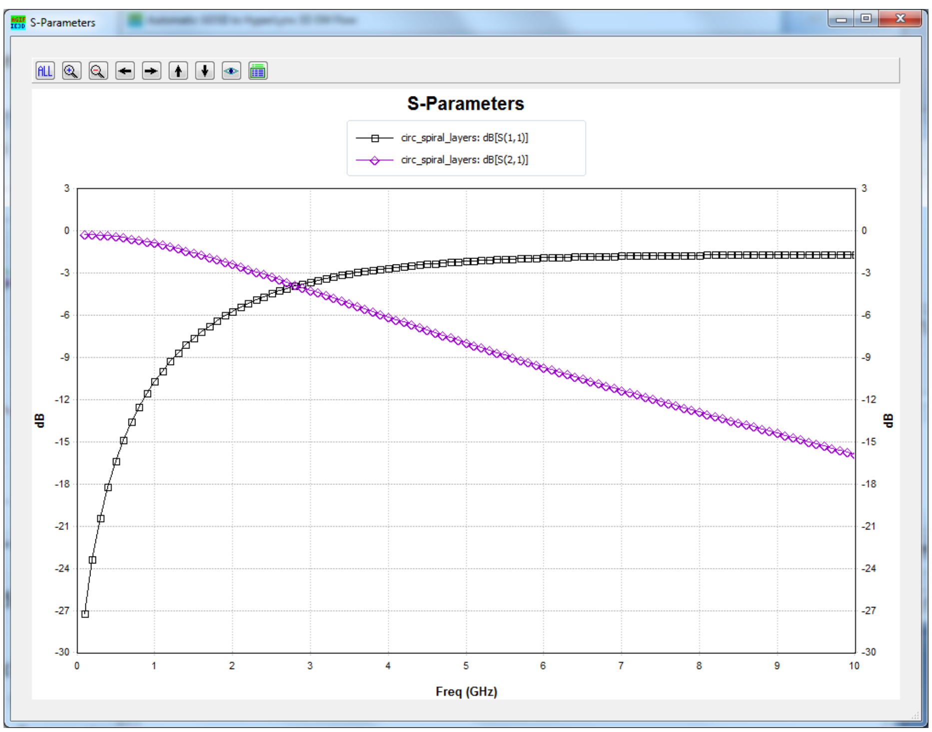


Fig. 5-10 S-parameters of the Circular Spiral

Use Edit ... button to choose which parameters to display. Users can also use the function buttons to display multiple S-parameter files, find transmission line parameters (Find TLN button), find RLC equivalent circuit model etc. on the *Parameter Display and Process* window. Users can also use Save Graph Definitions ... to save current graph definition into a .gdf file for future use. On the result display window (Fig. 4-10), use the button to show the data on the right-hand side panel, and use the button to set the graph parameters.

Build Ports with Polygons

Usually a GDSII design does not have a purpose layer that AGIF can use for setting up the ports. To make automatic port setup in AGIF, users have two options for setting up the port:

1. Use a polygon that covers the edge/polygon where the port is located in GDSII design.
2. Create text objects at the port locations. AGIF will automatically parse the text objects to set up the port as well as the port index.

To demonstrate how to set up the port with polygons, let's open the *for_two_port_spirals.i2i* file again, and click the Open Layer View:

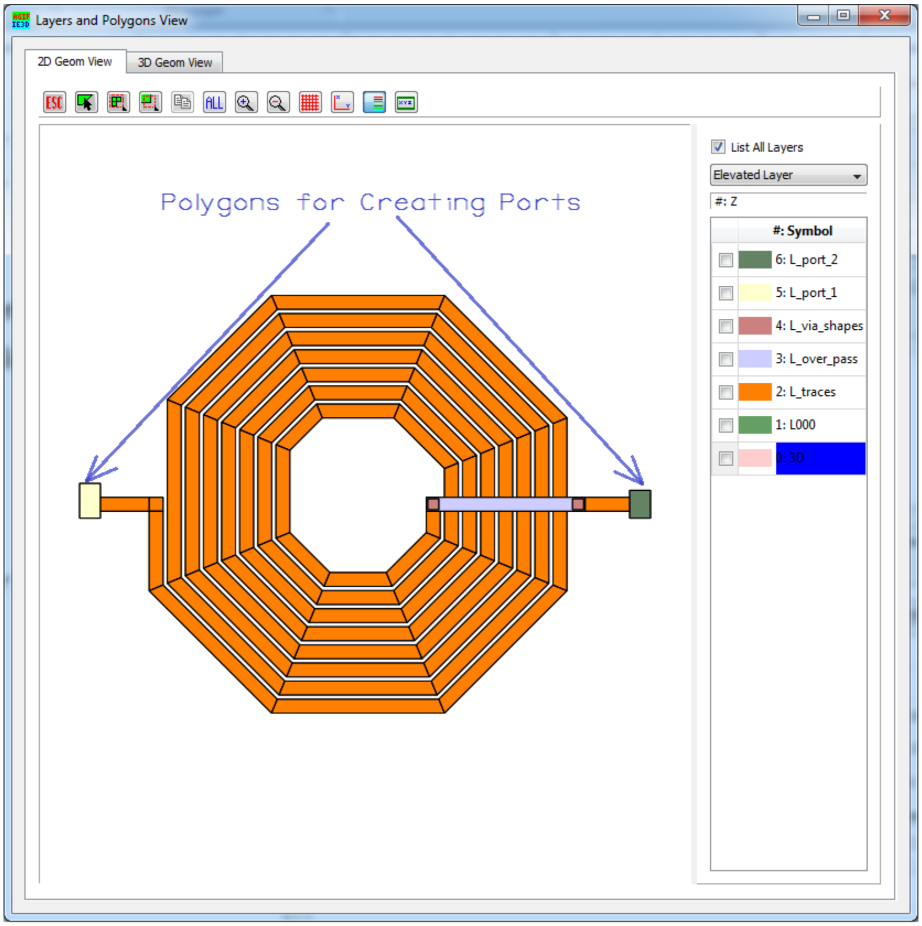


Fig. 5-11 Polygons for Creating the Ports

The two polygons that covers the two port locations are used for creating the ports. They are located on L_Port_1 and L_Port_2 layers respectively.

Click the *Layer Mutual Operations* tab and click button to bring up the new action window:

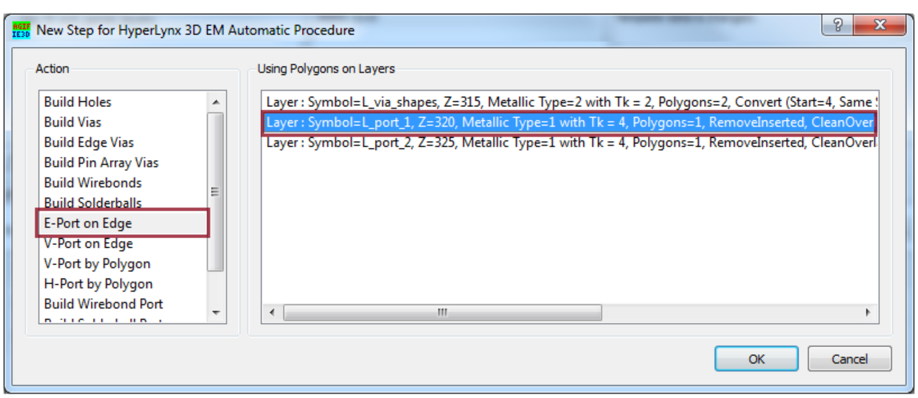


Fig. 5-12 Create Ports

Select *E-port on Edge* and *L_Port_1* respectively, and click OK:

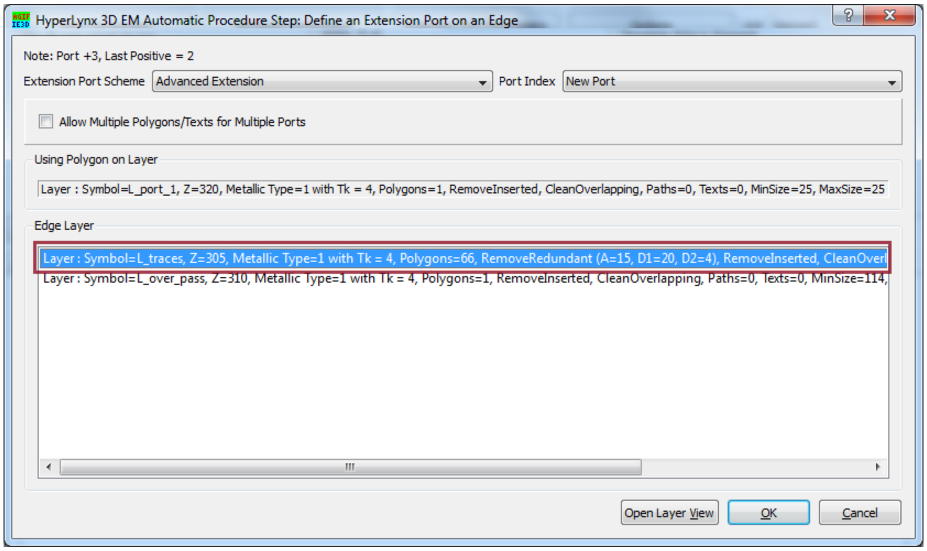
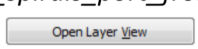


Fig. 5-13 Port Location

Select the *L_traces* layer where the ports are created. And click OK to exit. Run the procedure to create the EM model, and the ports are automatically created as shown in Fig. 5-6.

Therefore if possible, designers are recommended to put additional polygons indicating the port locations on your GDSII designs in order to use AGIF to create ports automatically.

<u>Build Ports with Text Objects</u>

An even more convenient method for setting up the ports is to use text objects. Open the *oct_spirals_port_from_text.i2i* file, and associate the *oct_spiral_layers_text_port.gds* file with it. Click the 

button:

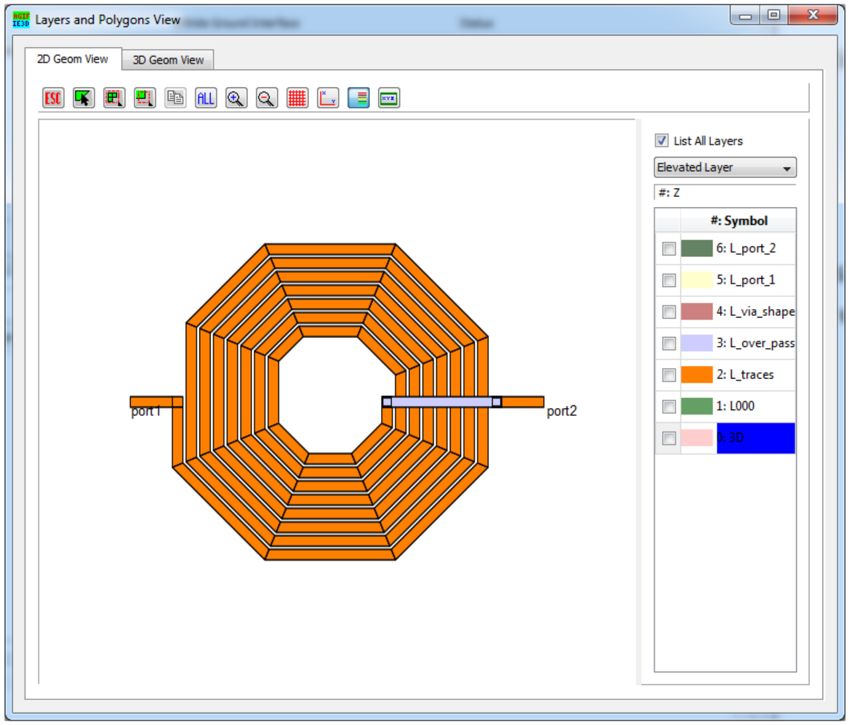


Fig. 5-14 Text Objects

As can be seen, there are two text objects on the L_port_1 layer, which will be used to create the two ports. The program will find the closest edge to the text objects as the port locations.

Click the button to add new action:

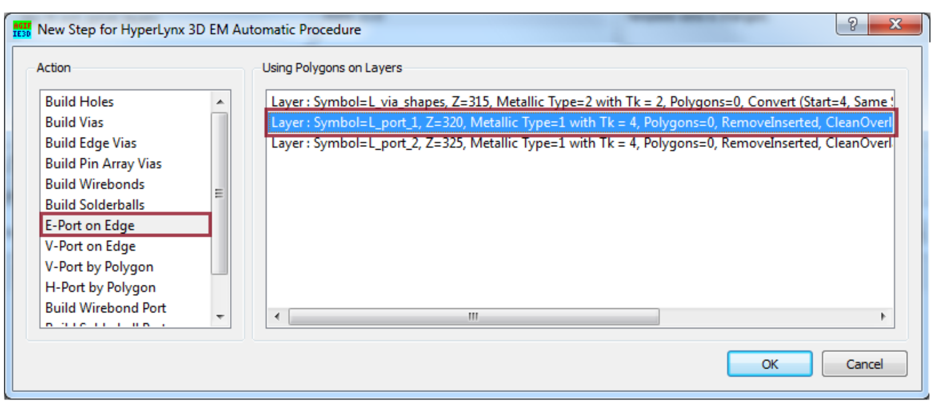


Fig. 5-15 Create Ports with Texts

Select *E-Port on Edge* and *L_port_1* respectively, and click OK:

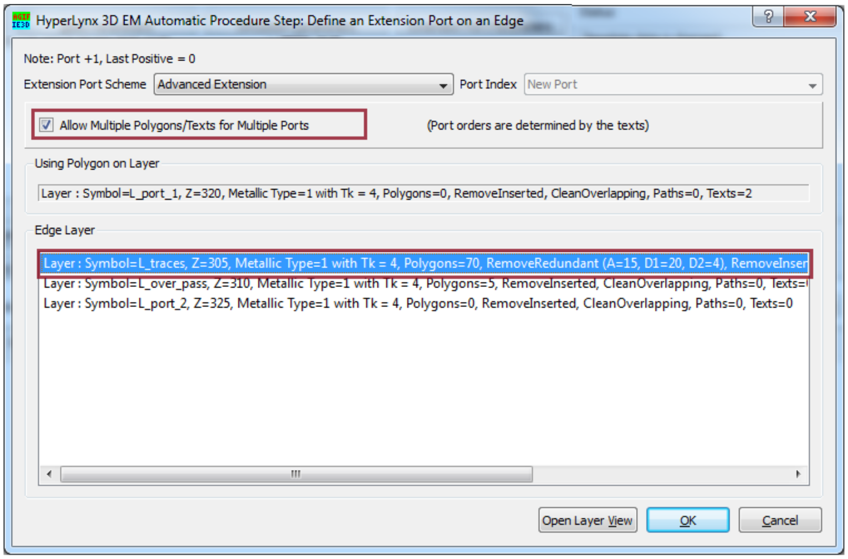
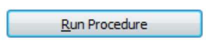


Fig. 5-16 Create Ports on Trace Layer

Enable the *All Multiple Polygons/Texts for Multiple Ports* checkbox since two text objects on this layer will be used for building two ports. Select the L-traces layer in the *Edge Layer* list where the ports will be created, and click OK to exit. Click on the 

button to create the EM model:

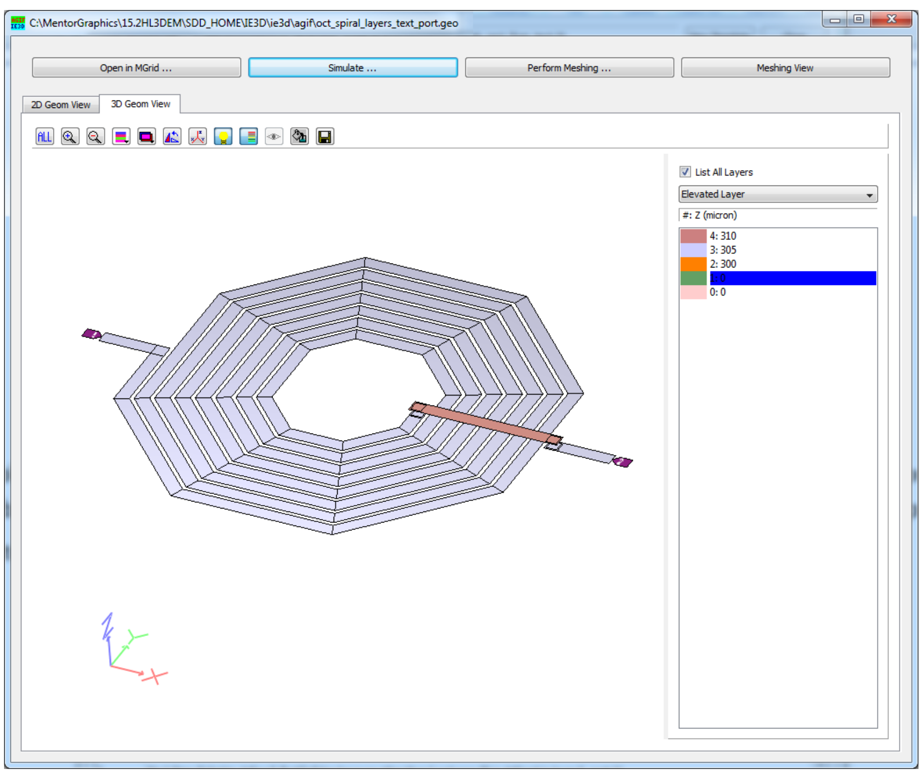


Fig. 5-17 Created EM Model

As can be seen, the ports on the EM model are successfully created by two text objects. In case it is not convenient to use polygons for creating ports, try to use the text objects for creating the ports.

Chapter 6 Other Tasks on AGIF

Some other tasks are available on the AGIF task list to facilitate users for other types of jobs. Generally these tasks are supplementary to the major one described above with some minor improvements.

<u>Cadence Virtuoso to HyperLynx 3D EM Flow (From Layout)</u>

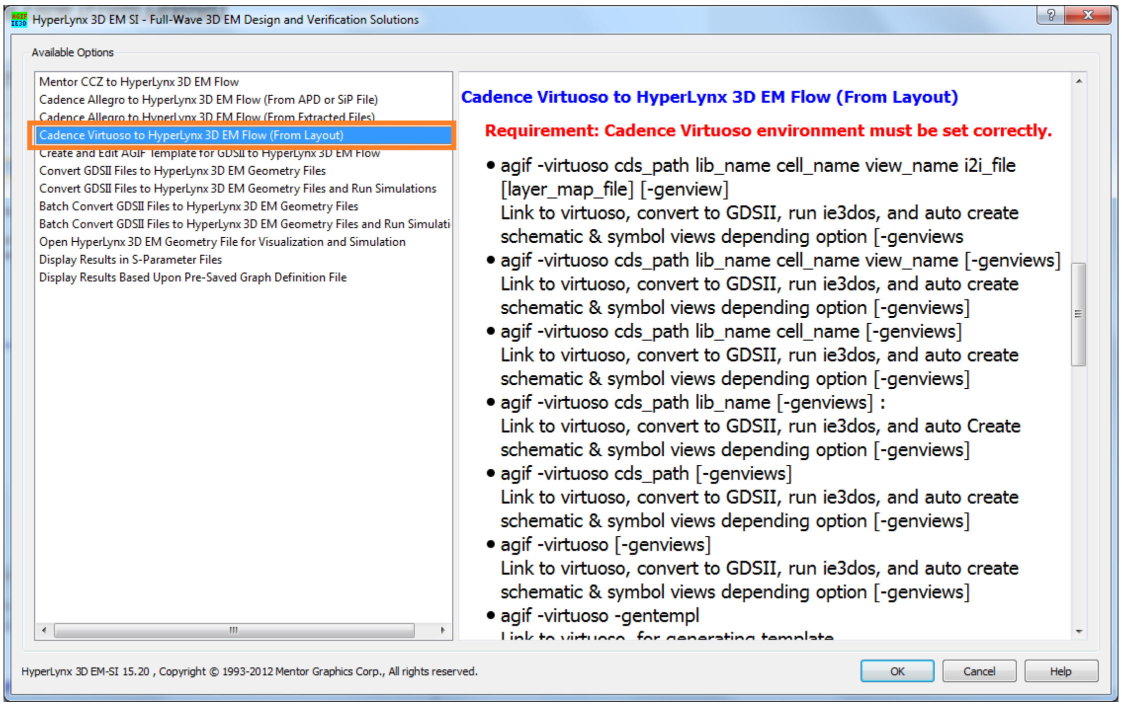


Fig. 6-1 AGIF Task List

If you already have the *Cadence Virtuoso* layout files, you can use this option to import those files into AGIF to obtain the EM model. Select this option and click OK:

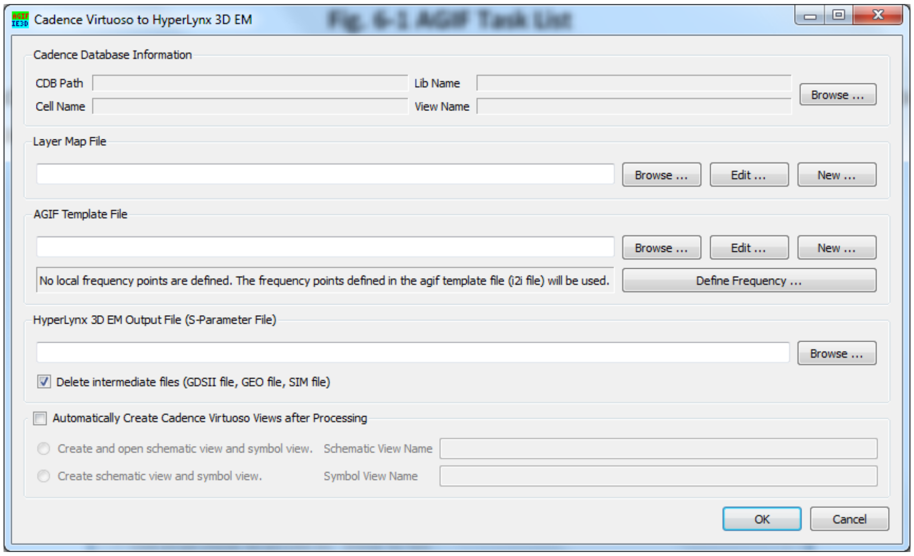
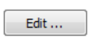


Fig. 6-2 Cadence Virtuoso to HyperLynx 3D EM Flow

As can be seen, the Cadence .cdb file, layer mapping file and a AGIF template file are required. Click the 

button to edit either layer mapping file or the template file. Click OK and follow the instructions to create the EM model. Users can also use the method described in the *AGIF_integration_guide.pdf* to run the flow directly from Cadence Virtuoso layout editor.

Convert GDSII Files to HyperLynx 3D EM Geometry Files

This utility provides a way to convert the GDSII designs (.gds) into HyperLynx 3D EM .geo files.

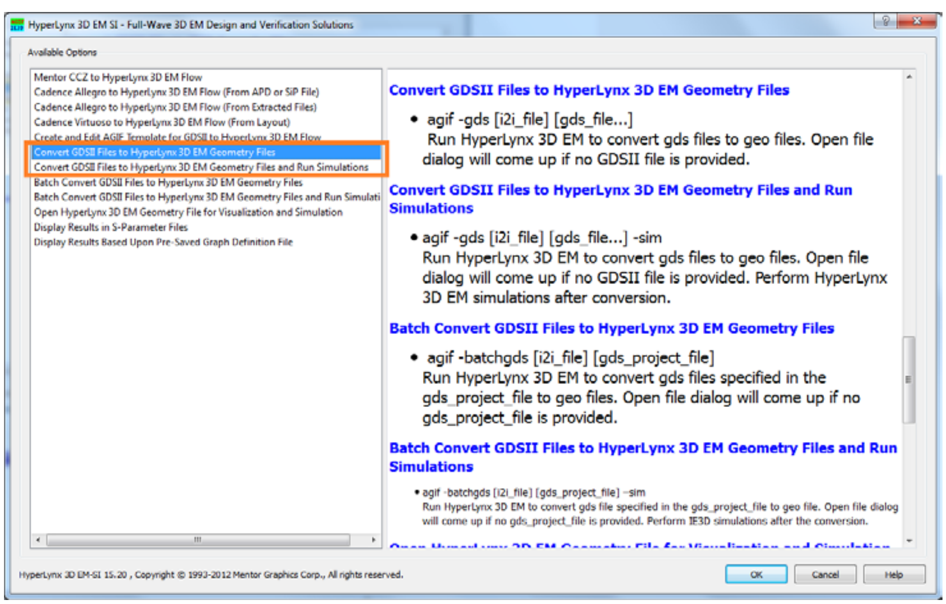


Fig. 6-3 Convert GDSII to HyperLynx 3D EM Files

Select this option and click OK to choose the template file:

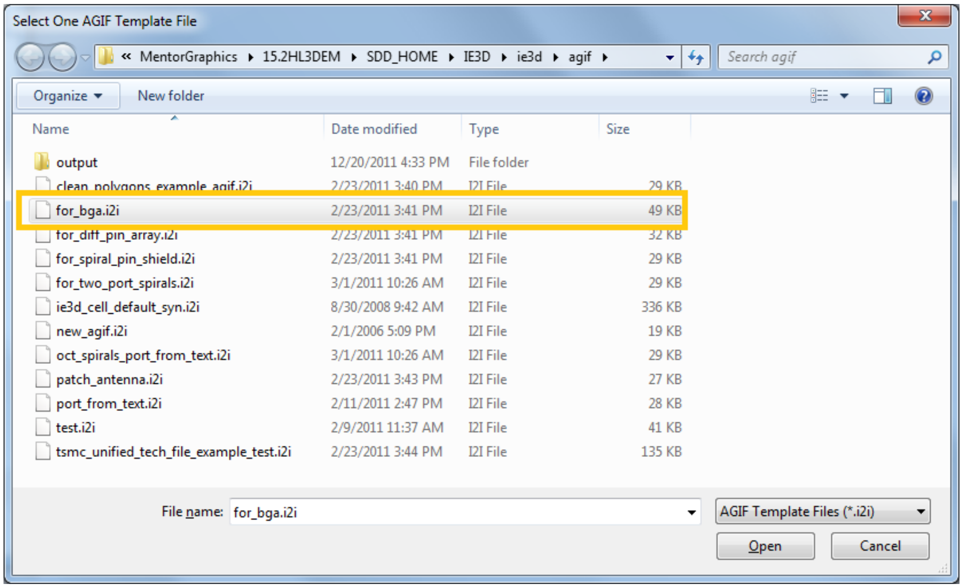


Fig. 6-4 Choose Template File

For example, let's select *for_bga.i2i* file, and click Open to select the bga_layers.gds file:

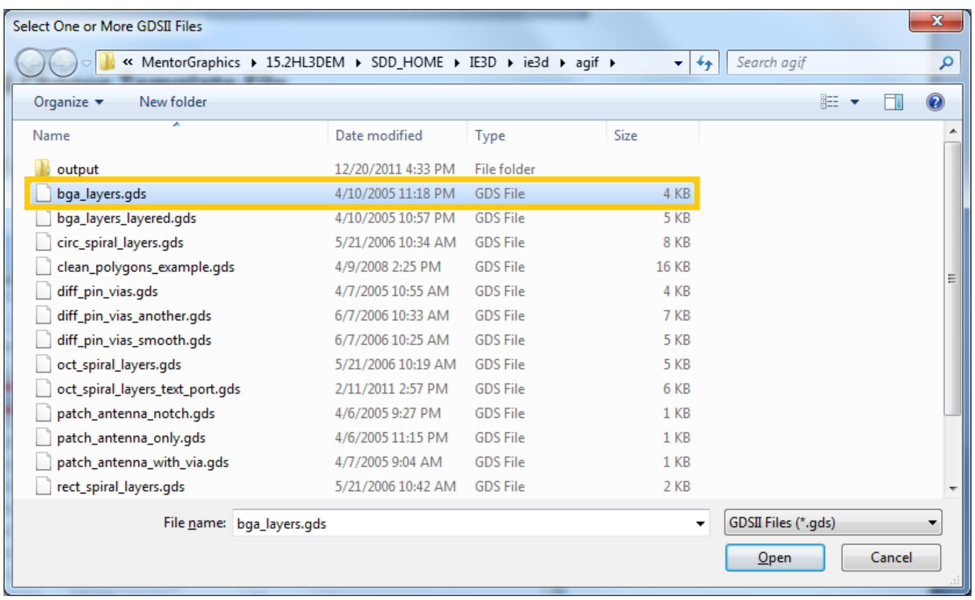


Fig. 6-5 Choose GDSII File

After clicking the Open button, the following window will pop up showing "Creating the EM Model":

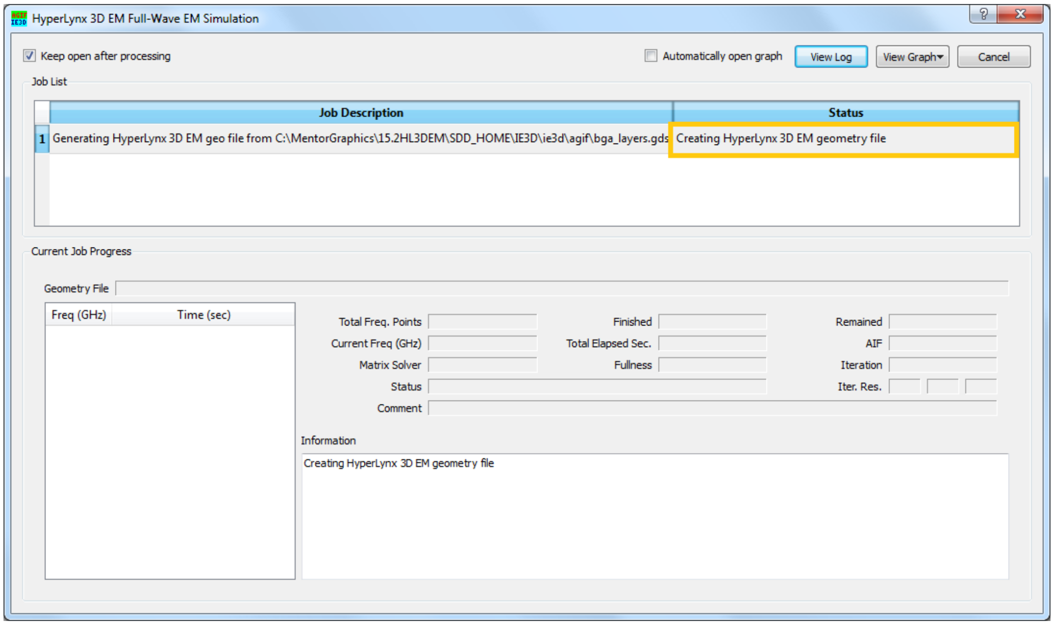


Fig. 6-6 Creating EM Model

After the model creation is complete, the .geo file can be found in the same directory where the .gds file is stored.

Though the EM model can be created through this option, it is recommended to use the entire GDSII to HyperLynx 3D EM flow to create the EM model to avoid any errors.

You may also run the simulation immediately after the EM model is created by selecting *Convert GDSII to HyperLynx 3D EM Geometry Files and Run Simulations* option on the AGIF task list.

Batch Convert GDSII Files to HyperLynx 3D EM Geometry Files

This utility can be used to batch convert the GDSII files to EM models. A text file should be first created stating the location of the .gds file(s) to be converted, as shown below:

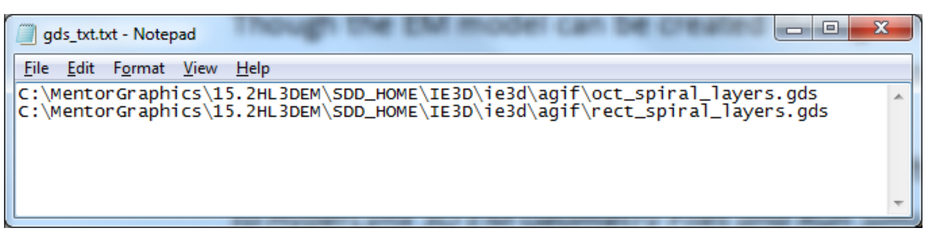


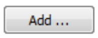
Fig. 6-7 Sample Text File For Batch GDS Conversion

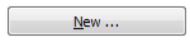
Also simulations can be run right after the conversion by choosing *Batch Convert GDSII Files to HyperLynx 3D EM Geometry Files and Run Simulations* option on AGIF task list.

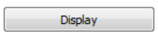
<u>Open HyperLynx 3D EM Geometry File for Visualization and Simulation</u>

Since there is no MGrid for Linux platform, Linux users can use this option to open the created EM model (.geo) file to view the EM model and run simulations.

<u>Display Results in S-parameter File</u>

This option is also primarily for Linux users to view the S-parameters. Select and click OK. Click the 

button to load in the .sp file. Click 

button to parameters to display, and click the 

button to view the results.

<u>Display Results Based Upon Pre-saved Graph Definition File</u>

If a .gdf (Graph Definition File) file is available, user can use the *Display Results Based Upon Pre-saved Graph Definition File* to display the results.

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4.3. Customer agrees to maintain Beta Code in confidence and shall restrict access to the Beta Code, including the methods and concepts utilized therein, solely to those employees and Customer location(s) authorized by Mentor Graphics to perform beta testing. Customer agrees that any written evaluations and all inventions, product improvements, modifications or developments that Mentor Graphics conceived or made during or subsequent to this Agreement, including those based partly or wholly on Customer's feedback, will be the exclusive property of Mentor Graphics. Mentor Graphics will have exclusive rights, title and interest in all such property. The provisions of this Subsection 4.3 shall survive termination of this Agreement.

5. **RESTRICTIONS ON USE.**

5.1. Customer may copy Software only as reasonably necessary to support the authorized use. Each copy must include all notices and legends embedded in Software and affixed to its medium and container as received from Mentor Graphics. All copies shall remain the property of Mentor Graphics or its licensors. Customer shall maintain a record of the number and primary location of all copies of Software, including copies merged with other software, and shall make those records available to Mentor Graphics upon request. Customer shall not make Products available in any form to any person other than Customer's employees and on-site contractors, excluding Mentor Graphics competitors, whose job performance requires access and who are under obligations of confidentiality. Customer shall take appropriate action to protect the confidentiality of Products and ensure that any person permitted access does not disclose or use it except as permitted by this Agreement. Customer shall give Mentor Graphics written notice of any unauthorized disclosure or use of the Products as soon as Customer learns or becomes aware of such unauthorized disclosure or use. Except as otherwise permitted for purposes of interoperability as specified by applicable and mandatory local law, Customer shall not reverse-assemble, reverse-compile, reverse-engineer or in any way derive any source code from Software. Log files, data files, rule files and script files generated by or for the Software (collectively "Files"), including without limitation files containing Standard Verification Rule Format ("SVRF") and Tcl Verification Format ("TVF") which are Mentor Graphics' proprietary syntaxes for expressing process rules, constitute or include confidential information of Mentor Graphics. Customer may share Files with third parties, excluding Mentor Graphics competitors, provided that the confidentiality of such Files is protected by written agreement at least as well as Customer protects other information of a similar nature or importance, but in any case with at least reasonable care. Customer may use Files containing SVRF or TVF only with Mentor Graphics products. Under no circumstances shall Customer use Software or Files or allow their use for the purpose of developing, enhancing or marketing any product that is in any way competitive with Software, or disclose to any third party the results of, or information pertaining to, any benchmark.

5.2. If any Software or portions thereof are provided in source code form, Customer will use the source code only to correct software errors and enhance or modify the Software for the authorized use. Customer shall not disclose or permit disclosure of source code, in whole or in part, including any of its methods or concepts, to anyone except Customer's employees or contractors, excluding Mentor Graphics competitors, with a need to know. Customer shall not copy or compile source code in any manner except to support this authorized use.

5.3. Customer may not assign this Agreement or the rights and duties under it, or relocate, sublicense or otherwise transfer the Products, whether by operation of law or otherwise ("Attempted Transfer"), without Mentor Graphics' prior written consent and payment of Mentor Graphics' then-current applicable relocation and/or transfer fees. Any Attempted Transfer without Mentor Graphics' prior written consent shall be a material breach of this Agreement and may, at Mentor Graphics' option, result in the immediate termination of the Agreement and/or the licenses granted under this Agreement. The terms of this Agreement, including without limitation the licensing and assignment provisions, shall be binding upon Customer's permitted successors in interest and assigns.

5.4. The provisions of this Section 5 shall survive the termination of this Agreement.

6. **SUPPORT SERVICES.** To the extent Customer purchases support services, Mentor Graphics will provide Customer updates and technical support for the Products, at the Customer site(s) for which support is purchased, in accordance with Mentor Graphics' then current End-User Support Terms located at http://supportnet.mentor.com/about/legal/.

7. **AUTOMATIC CHECK FOR UPDATES; PRIVACY.** Technological measures in Software may communicate with servers of Mentor Graphics or its contractors for the purpose of checking for and notifying the user of updates and to ensure that the Software in use is licensed in compliance with this Agreement. Mentor Graphics will not collect any personally identifiable data in this process and will not disclose any data collected to any third party without the prior written consent of Customer, except to Mentor Graphics' outside attorneys or as may be required by a court of competent jurisdiction.

8. **LIMITED WARRANTY.**

8.1. Mentor Graphics warrants that during the warranty period its standard, generally supported Products, when properly installed, will substantially conform to the functional specifications set forth in the applicable user manual. Mentor Graphics does not warrant that Products will meet Customer's requirements or that operation of Products will be uninterrupted or error free. The warranty period is 90 days starting on the 15th day after delivery or upon installation, whichever first occurs. Customer must notify Mentor Graphics in writing of any nonconformity within the warranty period. For the avoidance of doubt, this warranty applies only to the initial shipment of Software under an Order and does not renew or reset, for example, with the delivery of (a) Software updates or (b) authorization codes or alternate Software under a transaction involving Software re-mix. This warranty shall not be valid if Products have been subject to misuse, unauthorized modification or improper installation. MENTOR GRAPHICS' ENTIRE LIABILITY AND CUSTOMER'S EXCLUSIVE REMEDY SHALL BE, AT MENTOR GRAPHICS' OPTION, EITHER (A) REFUND OF THE PRICE PAID UPON RETURN OF THE PRODUCTS TO MENTOR GRAPHICS OR (B) MODIFICATION OR REPLACEMENT OF THE PRODUCTS THAT DO NOT MEET THIS LIMITED WARRANTY, PROVIDED CUSTOMER HAS

OTHERWISE COMPLIED WITH THIS AGREEMENT. MENTOR GRAPHICS MAKES NO WARRANTIES WITH RESPECT TO: (A) SERVICES; (B) PRODUCTS PROVIDED AT NO CHARGE; OR (C) BETA CODE; ALL OF WHICH ARE PROVIDED "AS IS."

8.2. THE WARRANTIES SET FORTH IN THIS SECTION 8 ARE EXCLUSIVE. NEITHER MENTOR GRAPHICS NOR ITS LICENSORS MAKE ANY OTHER WARRANTIES EXPRESS, IMPLIED OR STATUTORY, WITH RESPECT TO PRODUCTS PROVIDED UNDER THIS AGREEMENT. MENTOR GRAPHICS AND ITS LICENSORS SPECIFICALLY DISCLAIM ALL IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NON-INFRINGEMENT OF INTELLECTUAL PROPERTY.

9. **LIMITATION OF LIABILITY.** EXCEPT WHERE THIS EXCLUSION OR RESTRICTION OF LIABILITY WOULD BE VOID OR INEFFECTIVE UNDER APPLICABLE LAW, IN NO EVENT SHALL MENTOR GRAPHICS OR ITS LICENSORS BE LIABLE FOR INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES (INCLUDING LOST PROFITS OR SAVINGS) WHETHER BASED ON CONTRACT, TORT OR ANY OTHER LEGAL THEORY, EVEN IF MENTOR GRAPHICS OR ITS LICENSORS HAVE BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. IN NO EVENT SHALL MENTOR GRAPHICS' OR ITS LICENSORS' LIABILITY UNDER THIS AGREEMENT EXCEED THE AMOUNT RECEIVED FROM CUSTOMER FOR THE HARDWARE, SOFTWARE LICENSE OR SERVICE GIVING RISE TO THE CLAIM. IN THE CASE WHERE NO AMOUNT WAS PAID, MENTOR GRAPHICS AND ITS LICENSORS SHALL HAVE NO LIABILITY FOR ANY DAMAGES WHATSOEVER. THE PROVISIONS OF THIS SECTION 9 SHALL SURVIVE THE TERMINATION OF THIS AGREEMENT.

10. **HAZARDOUS APPLICATIONS.** CUSTOMER ACKNOWLEDGES IT IS SOLELY RESPONSIBLE FOR TESTING ITS PRODUCTS USED IN APPLICATIONS WHERE THE FAILURE OR INACCURACY OF ITS PRODUCTS MIGHT RESULT IN DEATH OR PERSONAL INJURY ("HAZARDOUS APPLICATIONS"). NEITHER MENTOR GRAPHICS NOR ITS LICENSORS SHALL BE LIABLE FOR ANY DAMAGES RESULTING FROM OR IN CONNECTION WITH THE USE OF MENTOR GRAPHICS PRODUCTS IN OR FOR HAZARDOUS APPLICATIONS. THE PROVISIONS OF THIS SECTION 10 SHALL SURVIVE THE TERMINATION OF THIS AGREEMENT.

11. **INDEMNIFICATION.** CUSTOMER AGREES TO INDEMNIFY AND HOLD HARMLESS MENTOR GRAPHICS AND ITS LICENSORS FROM ANY CLAIMS, LOSS, COST, DAMAGE, EXPENSE OR LIABILITY, INCLUDING ATTORNEYS' FEES, ARISING OUT OF OR IN CONNECTION WITH THE USE OF PRODUCTS AS DESCRIBED IN SECTION 10. THE PROVISIONS OF THIS SECTION 11 SHALL SURVIVE THE TERMINATION OF THIS AGREEMENT.

12. **INFRINGEMENT.**

12.1. Mentor Graphics will defend or settle, at its option and expense, any action brought against Customer in the United States, Canada, Japan, or member state of the European Union which alleges that any standard, generally supported Product acquired by Customer hereunder infringes a patent or copyright or misappropriates a trade secret in such jurisdiction. Mentor Graphics will pay costs and damages finally awarded against Customer that are attributable to the action. Customer understands and agrees that as conditions to Mentor Graphics' obligations under this section Customer must: (a) notify Mentor Graphics promptly in writing of the action; (b) provide Mentor Graphics all reasonable information and assistance to settle or defend the action; and (c) grant Mentor Graphics sole authority and control of the defense or settlement of the action.

12.2. If a claim is made under Subsection 12.1 Mentor Graphics may, at its option and expense, (a) replace or modify the Product so that it becomes noninfringing; (b) procure for Customer the right to continue using the Product; or (c) require the return of the Product and refund to Customer any purchase price or license fee paid, less a reasonable allowance for use.

12.3. Mentor Graphics has no liability to Customer if the action is based upon: (a) the combination of Software or hardware with any product not furnished by Mentor Graphics; (b) the modification of the Product other than by Mentor Graphics; (c) the use of other than a current unaltered release of Software; (d) the use of the Product as part of an infringing process; (e) a product that Customer makes, uses, or sells; (f) any Beta Code or Product provided at no charge; (g) any software provided by Mentor Graphics' licensors who do not provide such indemnification to Mentor Graphics' customers; or (h) infringement by Customer that is deemed willful. In the case of (h), Customer shall reimburse Mentor Graphics for its reasonable attorney fees and other costs related to the action.

12.4. THIS SECTION 12 IS SUBJECT TO SECTION 9 ABOVE AND STATES THE ENTIRE LIABILITY OF MENTOR GRAPHICS AND ITS LICENSORS FOR DEFENSE, SETTLEMENT AND DAMAGES, AND CUSTOMER'S SOLE AND EXCLUSIVE REMEDY, WITH RESPECT TO ANY ALLEGED PATENT OR COPYRIGHT INFRINGEMENT OR TRADE SECRET MISAPPROPRIATION BY ANY PRODUCT PROVIDED UNDER THIS AGREEMENT.

13. **TERMINATION AND EFFECT OF TERMINATION.** If a Software license was provided for limited term use, such license will automatically terminate at the end of the authorized term.

13.1. Mentor Graphics may terminate this Agreement and/or any license granted under this Agreement immediately upon written notice if Customer: (a) exceeds the scope of the license or otherwise fails to comply with the licensing or confidentiality provisions of this Agreement, or (b) becomes insolvent, files a bankruptcy petition, institutes proceedings for liquidation or winding up or enters into an agreement to assign its assets for the benefit of creditors. For any other material breach of any provision of this Agreement, Mentor Graphics may terminate this Agreement and/or any license granted under this Agreement upon 30 days written notice if Customer fails to cure the breach within the 30 day notice period. Termination of this Agreement or any license granted hereunder will not affect Customer's obligation to pay for Products shipped or licenses granted prior to the termination, which amounts shall be payable immediately upon the date of termination.

13.2. Upon termination of this Agreement, the rights and obligations of the parties shall cease except as expressly set forth in this Agreement. Upon termination, Customer shall ensure that all use of the affected Products ceases, and shall return hardware and either return to Mentor Graphics or destroy Software in Customer's possession, including all copies and documentation, and certify in writing to Mentor Graphics within ten business days of the termination date that Customer no longer possesses any of the affected Products or copies of Software in any form.

14. **EXPORT.** The Products provided hereunder are subject to regulation by local laws and United States government agencies, which prohibit export or diversion of certain products and information about the products to certain countries and certain persons. Customer agrees that it will not export Products in any manner without first obtaining all necessary approval from appropriate local and United States government agencies.

15. **U.S. GOVERNMENT LICENSE RIGHTS.** Software was developed entirely at private expense. All Software is commercial computer software within the meaning of the applicable acquisition regulations. Accordingly, pursuant to US FAR 48 CFR 12.212 and DFAR 48 CFR 227.7202, use, duplication and disclosure of the Software by or for the U.S. Government or a U.S. Government subcontractor is subject solely to the terms and conditions set forth in this Agreement, except for provisions which are contrary to applicable mandatory federal laws.

16. **THIRD PARTY BENEFICIARY.** Mentor Graphics Corporation, Mentor Graphics (Ireland) Limited, Microsoft Corporation and other licensors may be third party beneficiaries of this Agreement with the right to enforce the obligations set forth herein.

17. **REVIEW OF LICENSE USAGE.** Customer will monitor the access to and use of Software. With prior written notice and during Customer's normal business hours, Mentor Graphics may engage an internationally recognized accounting firm to review Customer's software monitoring system and records deemed relevant by the internationally recognized accounting firm to confirm Customer's compliance with the terms of this Agreement or U.S. or other local export laws. Such review may include FLEXlm or FLEXnet (or successor product) report log files that Customer shall capture and provide at Mentor Graphics' request. Customer shall make records available in electronic format and shall fully cooperate with data gathering to support the license review. Mentor Graphics shall bear the expense of any such review unless a material non-compliance is revealed. Mentor Graphics shall treat as confidential information all information gained as a result of any request or review and shall only use or disclose such information as required by law or to enforce its rights under this Agreement. The provisions of this Section 17 shall survive the termination of this Agreement.

18. **CONTROLLING LAW, JURISDICTION AND DISPUTE RESOLUTION.** The owners of certain Mentor Graphics intellectual property licensed under this Agreement are located in Ireland and the United States. To promote consistency around the world, disputes shall be resolved as follows: excluding conflict of laws rules, this Agreement shall be governed by and construed under the laws of the State of Oregon, USA, if Customer is located in North or South America, and the laws of Ireland if Customer is located outside of North or South America. All disputes arising out of or in relation to this Agreement shall be submitted to the exclusive jurisdiction of the courts of Portland, Oregon when the laws of Oregon apply, or Dublin, Ireland when the laws of Ireland apply. Notwithstanding the foregoing, all disputes in Asia arising out of or in relation to this Agreement shall be resolved by arbitration in

Singapore before a single arbitrator to be appointed by the chairman of the Singapore International Arbitration Centre ("SIAC") to be conducted in the English language, in accordance with the Arbitration Rules of the SIAC in effect at the time of the dispute, which rules are deemed to be incorporated by reference in this section. This section shall not restrict Mentor Graphics' right to bring an action against Customer in the jurisdiction where Customer's place of business is located. The United Nations Convention on Contracts for the International Sale of Goods does not apply to this Agreement.

19. **SEVERABILITY.** If any provision of this Agreement is held by a court of competent jurisdiction to be void, invalid, unenforceable or illegal, such provision shall be severed from this Agreement and the remaining provisions will remain in full force and effect.

20. **MISCELLANEOUS.** This Agreement contains the parties' entire understanding relating to its subject matter and supersedes all prior or contemporaneous agreements, including but not limited to any purchase order terms and conditions. Some Software may contain code distributed under a third party license agreement that may provide additional rights to Customer. Please see the applicable Software documentation for details. This Agreement may only be modified in writing by authorized representatives of the parties. Waiver of terms or excuse of breach must be in writing and shall not constitute subsequent consent, waiver or excuse.

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