PBOND1 to PBOND99 in the PBOND_lib (Philips-TU Delft Bondwires Model)

Symbol

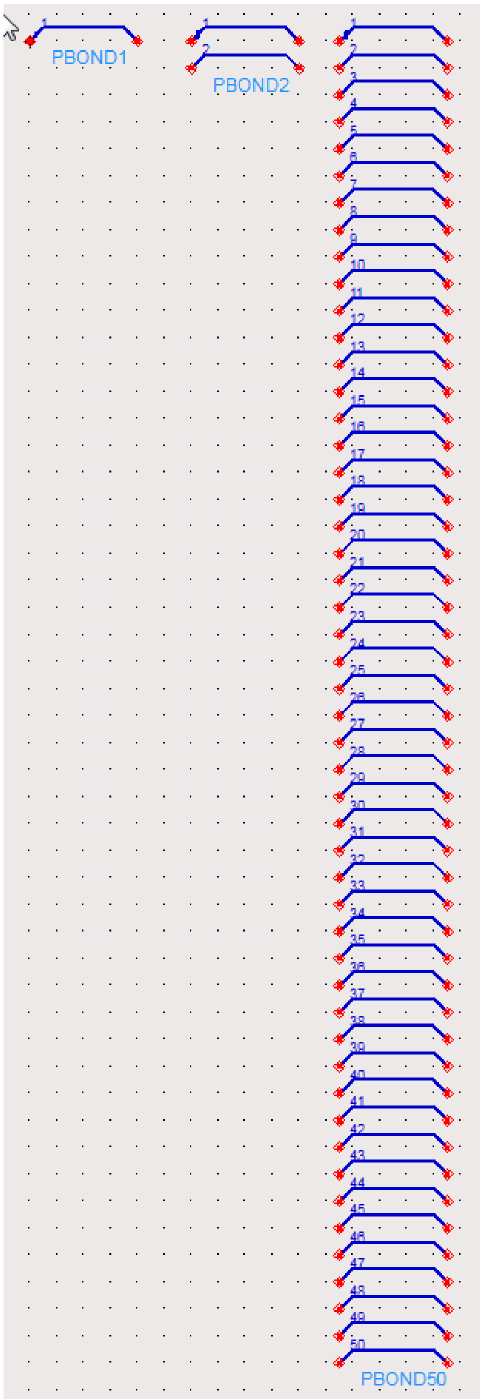

Figure 1Example symbols with 1,2 and 50 bonding wires.

Parameters

Name	Description	Units	Default
Radw	Radius of the bondwires	um	12.5
Cond	Conductivity of the bondwires	S	1.3e7
View	(ADS Layout option) Determines top or side view, with the option to make segments visible or not	None	side
Draw_Layer	(for Layout) Layer onto which the bondwires are drawn	None	bond:drawing
Annotate_Layer	(for Layout) Layer onto which the bondwires id numbers are drawn	None	text:drawing
Default_For_Wires	Defines the range of wires to apply the default modifications to: “*” = all wires; range 1,2,5::9,15::2::19 is wires 1,2,5,6,7,8,9,15,17,19	None	“*”
Default_Shape	Shape to use on all wires selected range	None	Shape1
Default_Layer1	(for Layout) Default layer for pin 1 of bond wires in range	None	cond:drawing
Default_Layer2	(for Layout) Default layer for pin 2 of bond wires in range	None	cond:drawing
Default_Length	Default wire length to apply to range of wires	um	0
Default_Xoffset	Default X offset to apply to range of wires	um	0
Default_Yoffset	Default Y offset to apply to range of wires	um	0
Default_Zoffset	Default Z offset to apply to range of wires	um	0
Default_Angle	Default Angle to apply to range of wires	deg	0
SepX	Separation, incrementally added to each X offset	um	0
SepY	Separation, incrementally added to each Y offset	um	0
Zoffset	Base offset to add to all Z offsets	um	0
SepAngle	Additional Angle change added incrementally to each wire angle	deg	0
W#_Shape	Shape reference (quoted string) for wire #	um	Shape1
W#_Layer1	Actual layer of pin 1 of wire #	None	cond:drawing
W#_Layer2	Actual layer of pin 2 of wire #	None	cond:drawing

W#_Length	Update of length is the 2D distance from pin 1 to pin 2 of wire #. The last wire segment will stretch only if Length > Shape Length otherwise Shape Length is used	um	0
W#_Xoffset	X offset added to all wires from nr #	um	0
W#_Yoffset	Y offset added to all wires from nr #	um	0
W#_Zoffset	Z offset added to all wires from nr #	um	0
W#_Angle	Rotation angle added to all wires from # with respect to start pins of wires (odd numbered connections)	deg	0
(W#_[XYZ][1-6])	18 hidden non-editable parameters used to pass the profile information for each wire to the model	um	Shape1_X1.. Shape1_Z6
Note1: The block W#_Shape...W#_Angle is repeated for each individual wire.			
Note3: The block Default_... are enhanced parameter edit fields which are only used to update the respective settings of the wires in the range defined by Defaults_For_Wires. These parameters are not netlisted and not used in artwork generation.			
Note2: W#_[XYZ]offset and W#_Angle are different from BONDW behavior. In the PBOND components these are all cumulative offsets starting from wire #.			

Arrays of parallel bondwires PBondArray1 to PBondArray99 in the PBOND_lib (Philips-TU Delft Bondwires Model)

Symbol

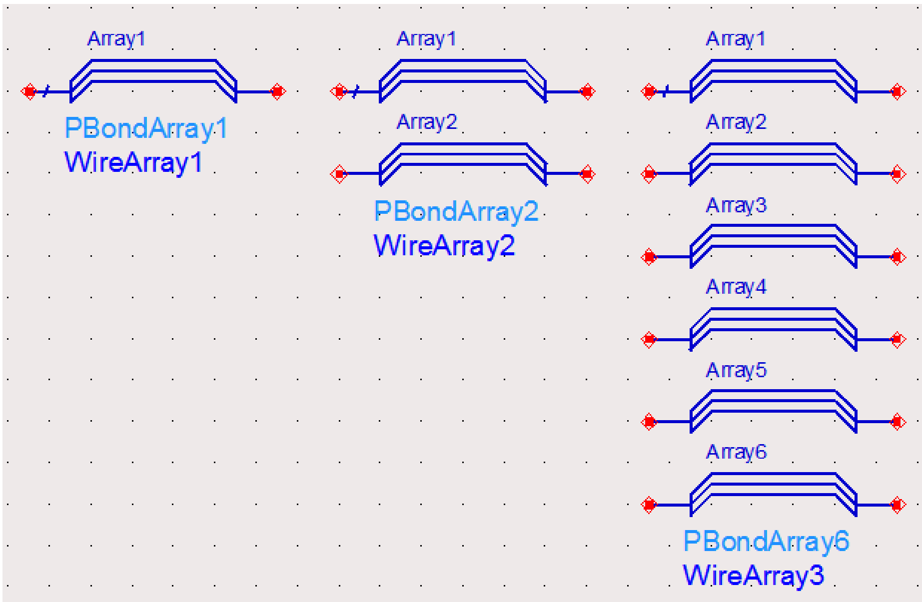

Figure 2Example symbols with 1,2 and 6 bonding wire arrays.

Parameters

Name	Description	Units	Default
(NrOfArrays)	(hidden) Number of arrays in component		
View	(ADS Layout option) Determines top or side view, with the option to make segments visible or not	None	side
Draw_Layer	(for Layout) Layer onto which the bondwires are drawn	None	bond:drawing
Annotate_Layer	(for Layout) Layer onto which the bondwire id numbers are drawn	None	text:drawing
Radw	Radius of the bondwires	um	12.5
Cond	Conductivity of the bondwires	S	1.3e7
(===Array # ===)	(non-edit) separator		
Array#_Xoffset	X offset added to all wires from array #	um	0

Array#_Yoffset	Y offset added to all wires from array #	um	0
Array#_Shape	Shape reference (quoted string) for entire array #	None	Shape1
Array#_N	Number of parallel wires in array	None	8
Array#_Spacing	Distance between wires in array #	mil	7
Array#_Layer1	Actual layer of pin 1 of array #	None	cond:drawing
Array#_Layer2	Actual layer of pin 2 of array #	None	cond:drawing
Array#_offsetZ	Z offset all wires in array #	um	0
Array#_Length	Update of length is the 2D distance from pin 1 to pin 2 of wire #. The last wire segment will stretch only if Length > Shape Length otherwise Shape Length is used	um	0
Array#_Pin1Xoffset	X offset added pin 1 off array nr #	um	0
Array#_Pin1Yoffset	Y offset added pin 1 off array nr #	um	0
Array#_Pin2Xoffset	X offset added pin 2 off array nr #	um	0
Array#_Pin2Yoffset	Y offset added pin 2 off array nr #	um	0
Array#_SpacingSeq	Sequencing string for std spacing above		“*”
Array#_AltSpacing1	Alternative spacing 1	um	0
Array#_AltSpacing1Seq	Sequencing string for spacing 1 above		“”
Array#_ AltSpacing2	Alternative spacing 2	um	0
Array#_AltSpacing2Seq	Sequencing string for spacing 2 above		“”
Array#_AltSpacing3	Alternative spacing 3	um	0
Array#_AltSpacing3Seq	Sequencing string for spacing3 above		“”
(ArrayW#_[XYZ][1-6])	18 hidden non-editable parameters used to pass the profile information for each array to the model	um	Shape1_X1.. Shape1_Z6

Note 1: The block ArrayW#_[XYZ][1-6] is repeated for each array

Note 2: Spacing<i>Seq strings have the format:

1) “*” apply for all positions 1 to N-1 between N wires of array i
2) “1,2,3” comma separated list of positions
3) “start::step::stop” at positions from start to stop with step; $ is last wire spacing; 1 is used if step is specification is missing i.e. 4::10
4) Comma separated combinations of above

Note 3: Spacing distances are added when several spacing sequences select location

Notes

1. The PBOND library in the Bondwire Utility design kit provides an alternative set of bondwire components similar to the BONDWn components available in the ADS ads_tlines library which allow parameterization inside ADS layout and schematic. This design kit can be found under $HPEESOF_DIR/ial/design_kit/BondwireUtility_DKit_x.x.zip. Installing the design kit will make these new components available for use in other workspaces.

2. The parameters of the components in the PBOND_lib generally do not allow direct optimization or tuning due to netlist and layout generation limitations but you can use an intermediate variable or parameters of the cell above these components to achieve the same goal.

3. The model is based on Koen Mouthaans model WIRECURVEDARRAY, which includes skin effects as well. The model calculates the effective inductance matrix of a set of mutually coupled bondwires as a function of the geometrical shape in space of the wires. The wire shapes must be linearized into 5 segments.

   To define the shape you must refer to a shape wire definition in your schematic hierarchy as provided by the BONDW_Shape or a BONDW_Usershape instances.

4. **Important:** Some examples of symbols are provided in the PBOND_lib design kit's component library palette (N=1,2,…,10,20) for PBOND components and N=1,2,…5 for the PBondArray components. Other PBONDxx components up to N=99 are also available in this PBOND_lib library but PBOND11 through PBOND19 and PBOND21 through PBOND99 are not presented in the component palette or library browser. The same is true for PBondArray6 through PBondArray20. These components can be accessed by typing their name in the component history field or dragging them onto the schematic or layout page from the library browser.

   To use these components in a Schematic window, type the exact name (such as PBOND12) in the Component History field above the design area; press Enter; move the cursor to the design area and place the component.

   Since the model inside the simulator works with any number of bondwires, or bondwire arrays, this ADS design kit also gives users the capability to create larger number of bondwire components with their symbols. The component definitions and symbol from any N>99 for PBONDn and N>20 for PBondArray can be generated using the ADS Command Line.

   The advised approach is to extend the PBOND_lib in the design kit with the additional components as it provides the ael support functionality for these components in the correct vocabulary.

   i) Create a new workspace with no design kits included
   ii) From the ADS Main Window Menu open **Design Kits → Manage Libraries**

iii) With the **Add Library Definition File** browse for the directory of the bondwire utility design kit and select the <path_to_BondwireUtility_DKit_x.x>/lib_foredit.defs file.
iv) Adds the PBOND_lib in edit mode to your workspace.
v) **Tools→Command Line** from the ADS Main window.
   (1) For a PBONDn component type generate_pbond_component(N,"PBOND_lib") where N is the number of bondwires and the PBOND library. A cell called PBOND<N> with the component definition and all the required symbol information will be created in the library when it is accessible from your workspaces that use the PBOND design kit.
   (2) For a PBondArrayn component type pbondArrayCreate_generate_component(N, "PBOND_lib") where N is the number of parallel bondwire arrays.
vi) Close and delete this workspace as it is not adviced to use these components in editable mode.

5. **Introduction to Bondwire Components**
   The bondwire model is a physics-based model, calculating the self inductances and mutual inductances (the inductance matrix) of coupled bondwires. For the calculation of these inductances, Neumann's inductance equation is used in combination with the concept of partial inductances [1], [2]. The method of images is used to account for a perfectly conducting groundplane [6]. The DC- and AC-resistance of each wire are included in the model using a zero order approximation.

6. **Bondwire Features and Restrictions**
   Calculation of the self- and mutual inductance of coupled bondwires using Neumann's inductance equation.
   - Each bondwire is represented by five straight segments.
   - Cartesian (*x,y,z)* coordinates for begin\- and end-points of the segments are entered.
   - Wires may not touch or intersect.
   - A perfectly conducting groundplane is assumed at z=0.
   - Capacitive coupling between bondwires is not accounted for.
   - Capacitive coupling to ground is not accounted for.
   - Loss, due to radiation is not considered.
   - A change in the current distribution due to the proximity of other wires (*proximity effect*) is not included.
   - DC losses, due to the finite conductivity of the wires is included.
   - AC losses, due to the skin effect, are accounted for in a zero-th order approximation.

7. When using any of the PBOND1 to PBOND99 components with the BONDW_Shape component, some parameter settings for the bondwire shape may be out of range. Depending on parameter settings, an error may result stating, for example, that the length of segment 1 of wire 1 is less than two times the wire's radius. To avoid this condition, use the BONDW_Usershape instead of the BONDW_Shape. The BONDW_Usershape enables you to define the same bondwire shape as the BONDW_Shape and ensure it is not smaller than twice the wire's radius.

8. **Input Parameters of the Model**
In modelling the bondwires, each bondwire is represented by five straight segments. This is illustrated in the following figure, where the SEM photo of a bondwire is shown: on the left two coupled bondwires are shown; on the right, five segments representing the bondwire are shown.
The bondwire model requires the following input parameters:
   - radius of the wires (meters)
   - conductivity of the wires (Siemens/meter)
   - view top, side, top (full), side (full)
   - layer (cond, cond2, resi, diel, diel2. bond, symbol, text, leads, packages)
   - begin point, intermediate points and endpoint of the segments in Cartesian coordinates (meters).

A perfectly conducting groundplane at z=0 is assumed. The presence of this groundplane normally reduces the inductance compared to the case of wires without such a groundplane.

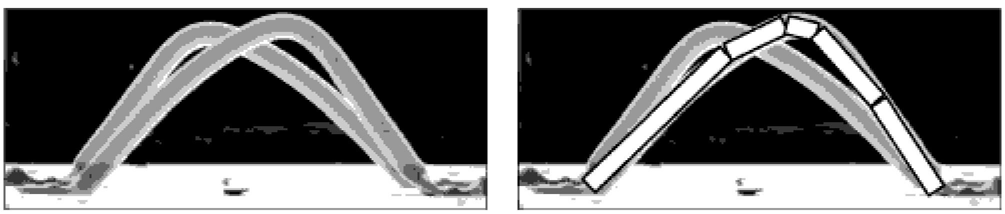

Figure 3 Piecewise Approximation of Bondwires on the right, wire is approximated by straight segments

9. **Example Instance**
The instance for three wires is shown in Figure 4. The symbol PBOND3 defines the number of bondwires and their relative positions.

Figure 4 Instance of Bondwire Model for 3 Wires (PBOND3)

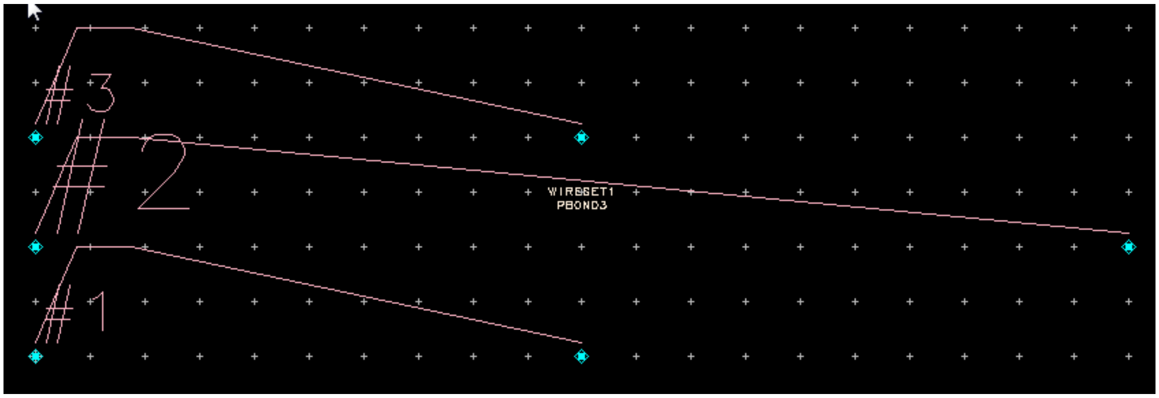

Figure 5 Layout representation of WIRESET1

In this example, the input parameters are as follows.

- Radw, radius of the wires (meters). If the diameter of a wire is 25 um, the value of Radw should be set to 12.5 um.
- Cond, conductivity of the wire (Siemens/meter). If the wires have a conductivity of 1.3 10E+7 S/m the value of Cond must be set to 1.3E7.
- View set to default side
- Draw_Layer set to the default bond:drawing
- Default_For_Wires is "*" so that any change to the other Default_<parameters> will be applied to all the wires.
- Default_<parameters> have default values and have not been used to edit the component.
- SepX = 0 is a constant separation in the x direction that is added incrementally to each wire.
- SepY = 100 um is a constant separation in the y direction, which is added incrementally to each wire. In the common case of parallel wires, this is the distance between wires.
- Zoffset = 0 is an offset added to each bondwire coordinates in the z-direction only used in circuit simulation. From layout only Layer settings are used to attach the wires on the correct mask positions.
- SepAngle = 0 is the angle increment added to each wires angle to allow flare out of the wires
- Wi_Shape = "Shape1" defines the shape instance. It can be BONDW_Shape or BONDW_Usershape.
- Wi_Layer1 = cond:drawing is the layer of pin 1 of this wire in the layout and the layer to which the bondwire will attach in the 3D view and EM simulations. This will override any z offset value specified to allow circuit simulation without layout.
- Wi_Layer2 = cond:drawing is the layer of pin 2 in layout.
- Wi_Length = 0 or 1000um the 0 settings will use the length defined by the Shape1 instance but W2_Length is larger than the profile length and the last segment is stretched until the new length is reached.
- Wi_Xoffset represents an offset added to each x coordinate of wire i (meters) and all following wires. You need to subtract the offset on wire i+1 if you want to apply the offset only to wire i.
- Wi_Yoffset represents an offset added to each y coordinate of wire i (meters) and all following wires.
- Wi_Zoffset represents an offset added to each z coordinate of wire i (meters) and all following wires.

- Wi_Angle represents the rotation around a z axis through the wire i reference point (x1,y1,z1), away from the x direction (degrees). Just like the offset values it is maintained for all following wires.

A perfectly conducting groundplane is assumed at the plane z=0.
By choosing the BONDW_Usershape (Shape1 symbol), each wire is divided into 5 segments and the Cartesian coordinates of the begin and endpoints must be entered.

Note: it is currently not possible for the circuit simulator to access the 3D/EM-substrate information which is why we still have z offset information in the model.

10. **What the Model Calculates**
The model calculates the self and mutual inductances of wires. Capacitive coupling between wires or capacitive coupling to ground is not included, nor is radiation loss included. The DC losses, due to the finite conductivity of the wires, are included. AC losses are included using zero-th order approximations for skin effect losses. The effect of proximity effects, when wires are located closely together, on the inductance and resistance is not included in the model. The model assumes a perfectly conducting ground plane at z=0. The presence of this groundplane normally reduces the inductance as compared to the case of wires without such a plane. Possible electromagnetic couplings between wires and other circuit elements are not accounted for. In conclusion, the model calculates the self- and mutual inductance of wires. DC losses are included and AC losses are approximately incorporated.
11. **Restrictions on Input**
The following illustrations demonstrate forbidden situations.
    - Wire segments must be fully located above the groundplane at z=0, as illustrated in Figure 6 Incorrect Application (on the left)Correct Application (on the right). To guarantee that the wire is fully located above the ground plane, add the wire radius in the BONDW_Shape component.

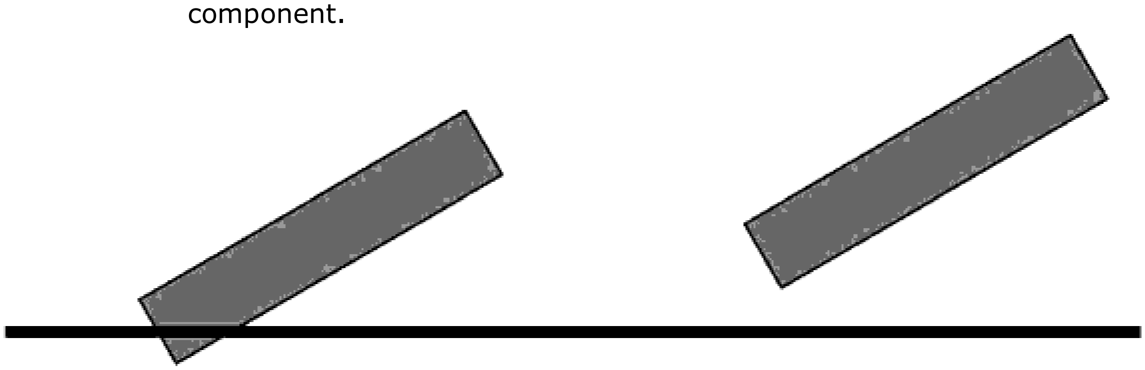

Figure 6 Incorrect Application (on the left)Correct Application (on the right)

- As shown in Figure 7, the angle between segments always must be greater than 90 degrees.

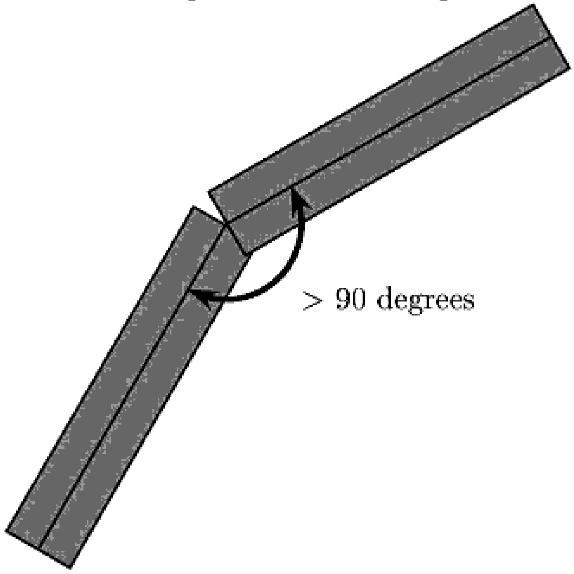

Figure 7 90-degree Angle Not Sufficient

- As shown in Figure 8 Non-adjacent Segments Touching,non-adjacent segments may not touch or intersect.

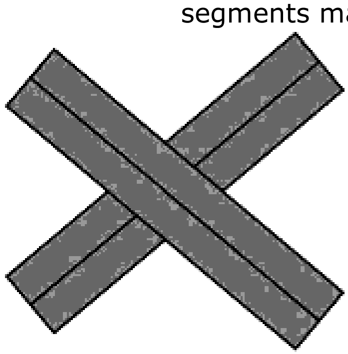

Figure 8 Non-adjacent Segments Touching

12. **Example With a Single Bondwire**

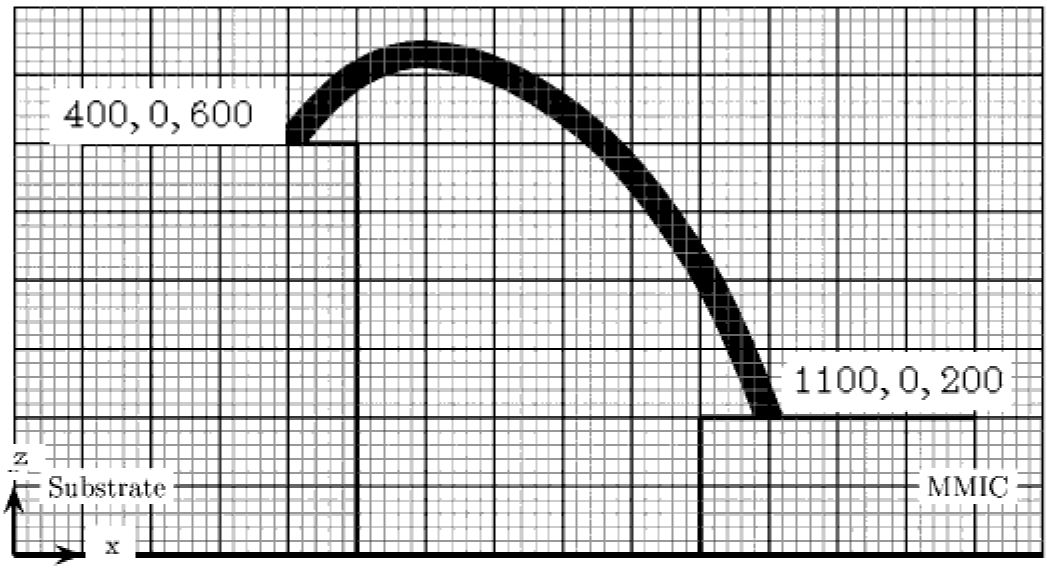

Figure 9 Example of a Bondwire Interconnecting a Substrate and a MMIC

For convenience, a grid with a major grid spacing of 100 um is also plotted. Using this grid, starting point, four intermediate points and end point are found as: (400,0,600), (500,0,700), (600,0,730), (800,0,650), (1000,0,420) and (1100,0,200) respectively (all in um). The radius of the wire is 20 um. The representation of this wire in ADS is shown in As a result of the simulation, the inductance is calculated as 0.730 nH.

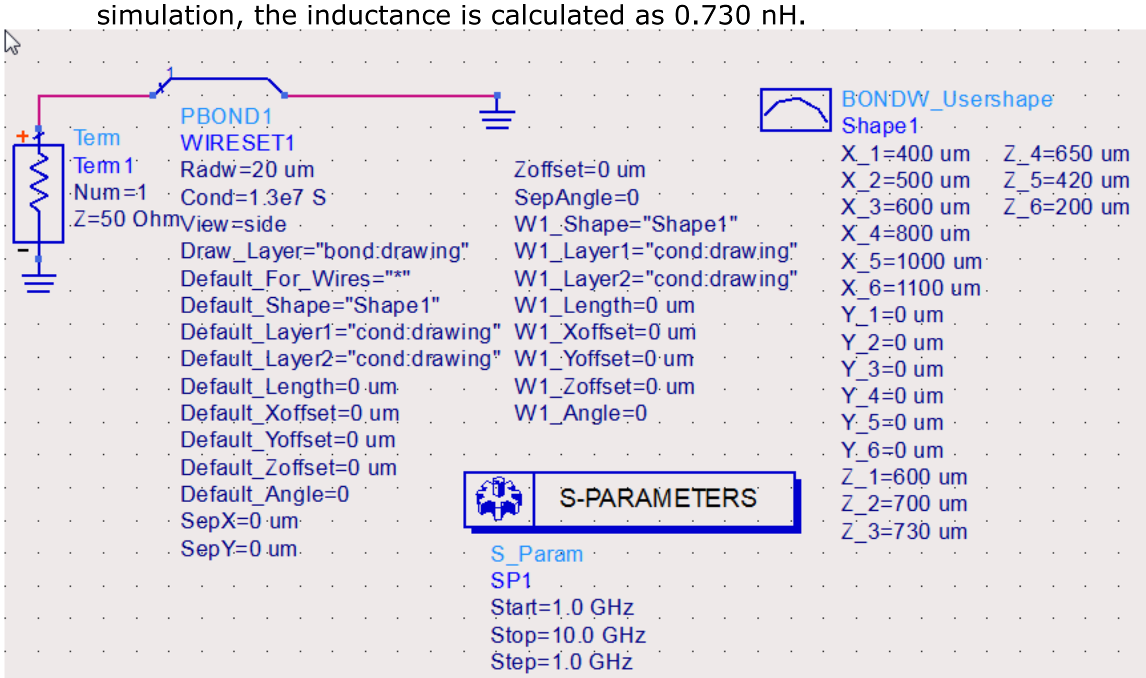

Figure 10 Example with a single PBOND bondwire in schematic

13. **Example With a 4 Bondwires**

Four bondwires are placed in parallel separated by 200 um as shown in Figure 11; each bondwire has the shape used in Figure 10. The inductance of the four parallel wires is calculated to be 278 pH. For simplicity, the four wires in this example are connected in parallel; with the model, it is easy to calculate mutual inductances in more complicated situations.

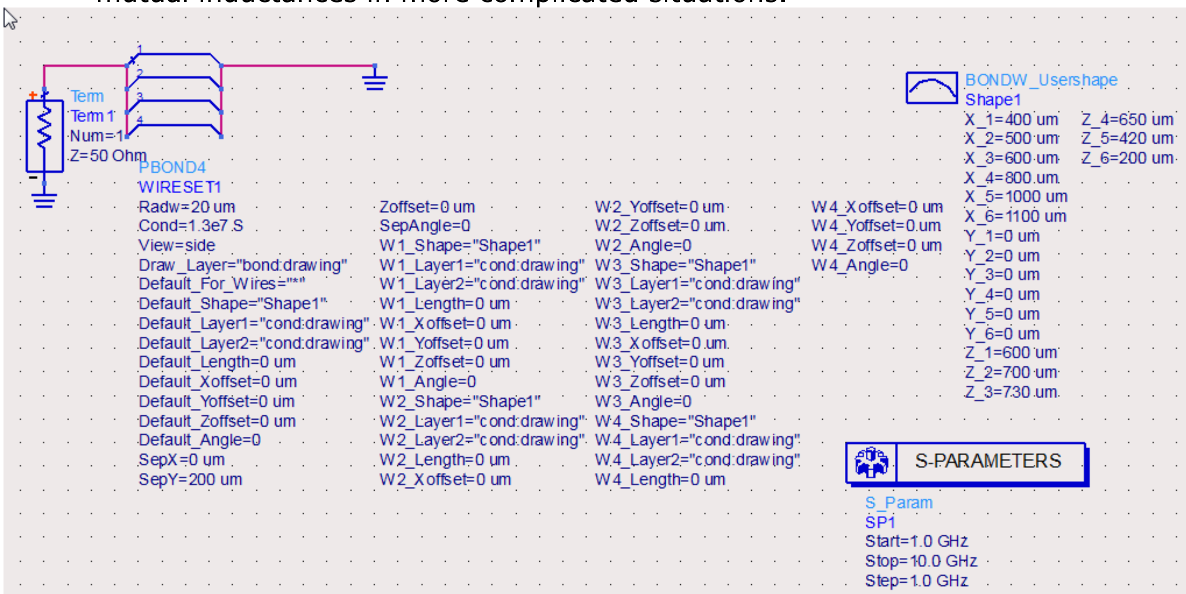

Figure 11 Example with 4 wires

14. **Neumann's Inductance Equation**
The bondwire model calculates the inductance matrix of coupled bondwires using Neumann's inductance equation. The principle of this equation for closed loops is illustrated in Figure 12. The mutual inductance Li,j between a closed loop Ci and a closed loop Cj is defined as the ratio between the flux through Cj, due to a current in Ci, and the current in Ci. The figure shows the definition of the mutual inductance between two current carrying loops as the ratio of the magnetic flux in contour Cj and the current in loop i.
In practice, however, bondwires are only part of a loop. To account for this effect, the concept of partial inductances is used [2]. This concept is illustrated in Figure 13. This figure illustrates that the model calculates the partial inductance between the bondwires, ignoring possible couplings between the wires and other circuit elements.

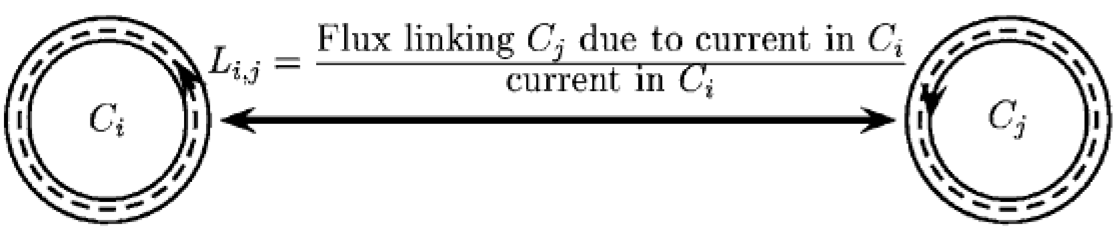

Figure 12 Definition of Mutual Inductance

Figure 13 shows Current carrying loops formed with network elements. On the left, closed loops are shown using elements such as a capacitor, a resistor and a voltage source. Each loop also has a bondwire. If only the mutual inductance between the wires is of interest, the concept of partial inductance is used [2] where for reasons of simplicity the mutual coupling between the wires and the remaining network elements is assumed negligible. In this case Neumann's inductance equation is not applied to the closed contours, but to the wires only.

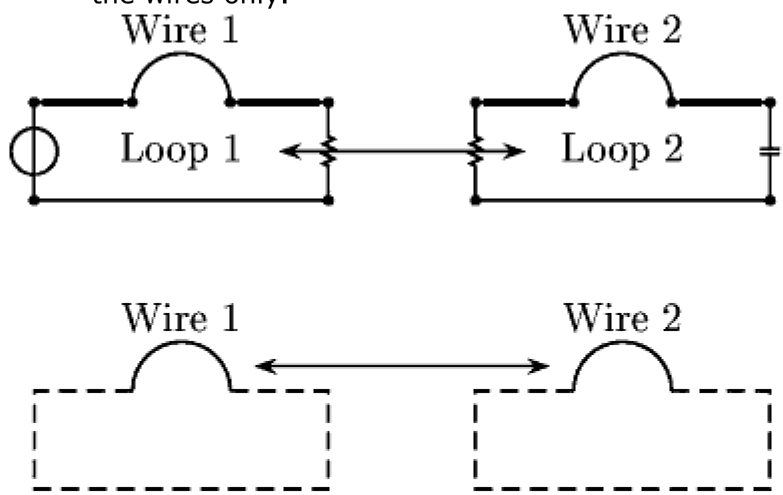

Figure 13 Loops Formed with Network Elements

Figure 14 shows modelling of bondwires in ADS. Inductive coupling is modelled by the inductance matrix L and resistive losses are modelled by a resistance matrix R.

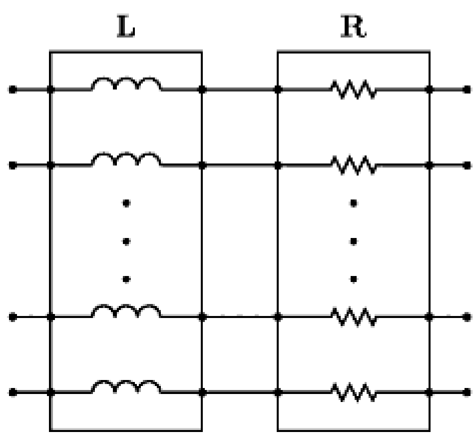

Figure 14 Modelling of Bondwires in ADS

15. **Background**
    The bondwire model calculates self and mutual inductances of coupled bondwires and puts the values into an inductance matrix L. In addition the model calculates the DC and AC resistances assuming uncoupled bondwires. Changes in the current distribution within a wire due to a nearby located

current carrying wire (proximity effect) are not accounted for. The DC and AC resistances are put into a resistance matrix R. The bondwire model is formed by placing the inductance matrix and the resistance matrix in series ([Modelling of Bondwires in ADS|BONDW1 to BONDW50 (Philips-TU Delft Bondwires Model)#1115825]).

16. **Specification Coordinate Segments for Bondwire Components**
This model calculates the real coordinate points xj(i),yj(i),zj(i) (j from 1 to 6) for the five wire segments of each bondwire i by using the corresponding reference coordinates Xj,Yj,Zj of the associated bondwire shape (e. g. the shape corresponding to the W i *Shape parameter of wire i*) and applying a rotation to it and two translations to them.

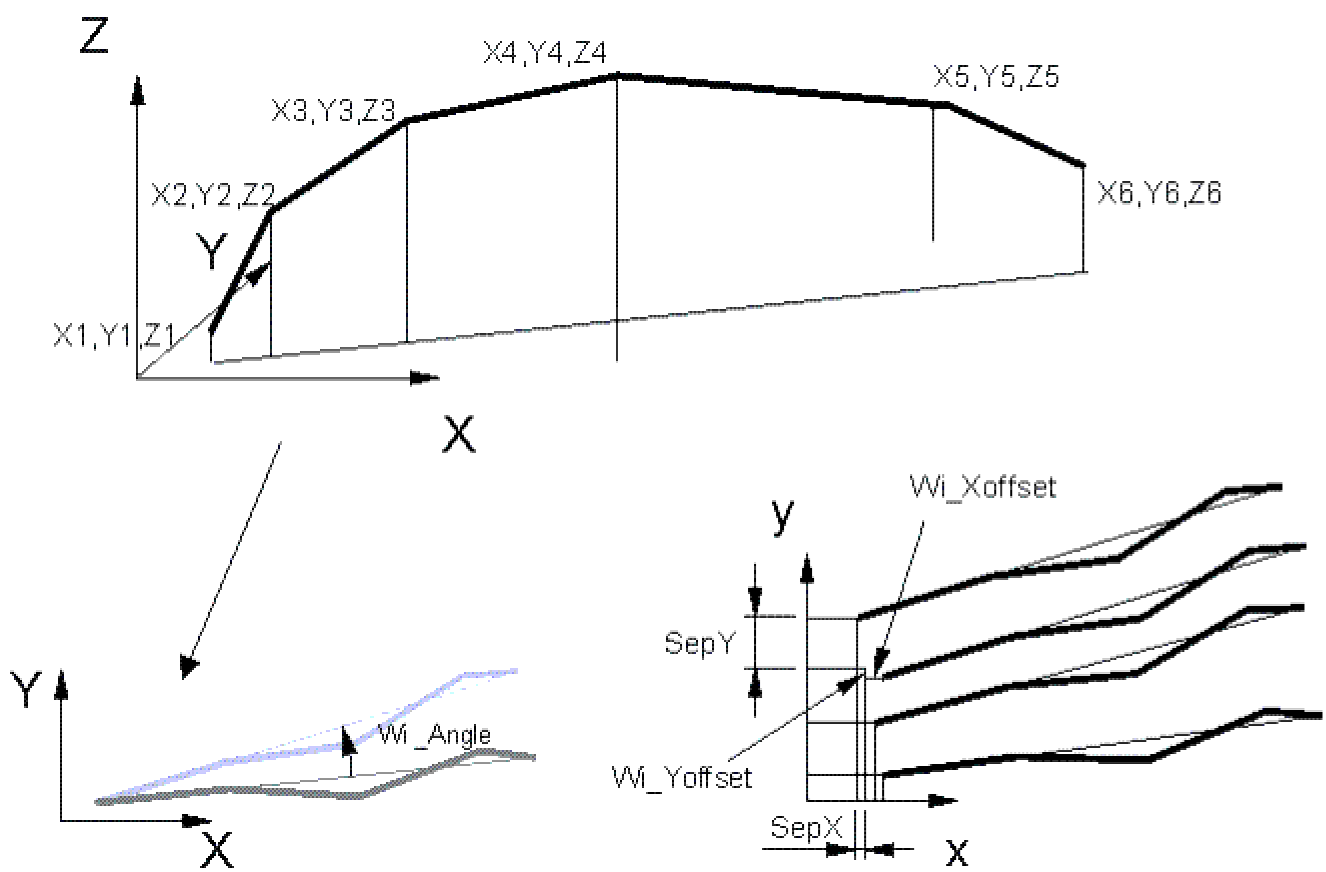

Figure 15 An Illustration of the Process of Rotation and Translation for the Top View of the Wire Above

The bondwire *i* reference shape is rotated over an angle of Wi_Angle degrees around a z axis through the "reference point" X1,Y1,Z1.
The first translation is over a distance ((i-1) SepX, (i-1) SepY, Zoffset) associated with the general step for multiple wires and general height setting defined for the entire PBOND# component.
The second translation is an individual perturbation of the x,y,z positions of each wires with respect to the general stepping above and is defined by the individual Wi_Xoffset,Wi_Xoffset,Wi_Zoffset parameters.

This is expressed by the following equations that are valid for all BONDWx components:
xj(i) = SepX*(i-1) + Wi_finalXoffset + X1 + (Xj - X1)*cos(Wi_finalAngle) - (Yj-Y1)*sin(Wi_finalAngle)
yj(i) = SepY*(i-1) + Wi_finalYoffset + Y1 + (Xj - X1)*sin(Wi_finalAngle) + (Yj-Y1)*cos(Wi_finalAngle)
zj(i) = Zoffset + Wi_finalZoffset + Zj

with Wi_final[XYZ]offset=$\sum_{1}^{i} Wi\_[XYZ]offset$
and Wi_finalAngle=$SepAngle * (i-1) + \sum_{1}^{i} Wi\_Angle$

17. **Generating 2D Mask Layout**
A layout representation can be generated through the ADS Schematic window. After setting up wire shapes and bondwire components, choose Layout > Generate/Update Layout to generate a 2D visualization of the bondwires.
You can select a top or side view of the wires, with or without detail of the wire segments. The default representation is a side view in simple line art. When you select the View options side(full) or top(full), a representation showing the 5 segments per bondwire which are used inside the simulator is shown. You can use these two full views in case of setup problems with the bondwire shape components.

A bondwire simulation typically fails with errors when unexpected forms are shown, shape instances are not reachable, or overlap occurs, in these detail views.

Tip: On the schematic, pin 1 is the upper left pin. The orientation of the pins in the layout is determined by the parameter value for SepY (or SepX) and XYoffset. For example, suppose SepX = 0 and SepY is negative, pin 2 in the layout will be below pin 1. Making SepY positive will move pin 2 above pin 1.

18. **Generating 3D/EM representation**
From the 2D Mask Layout a 3D assembly will be created when needed for 3D viewing and EM simulation. From the 2D layout only the pin positions in the (x,y, layer) coordinates of the wires will be used to derive the correct attachment for the 3D bond wire objects. The substrate as defined in the EM Setup (or the default substrate when no EM Setup exist) is used to translate the layer masks for the pins into the actual Z coordinates of the attachment positions of the wires in 3D space.
The wire profiles defined by the Shape components are reevaluated relative to the actual pin positions in 3D ignoring the component or profiles z based offsets.

19. **Further Information**
In the Ph.D. thesis of K. Mouthaan [5], the model and a comparison of the model with rigorous simulations and measurements, are described in detail. To obtain a copy of the dissertation, visit the internet site: *www.DevilsFoot.com* .

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