Advanced RF Board Skills in ADS

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Application Engineer	

Outline

- Quick review of Momentum
- Lab1: Port Type Overview
- Lab2: Net Type Setup for Physical Model Simplified
- Lab3: Understand Mesh, Solver and Preprocessor
- Summary

Hot Keys – Schematic

Edit Commands

Following table lists the hot keys for the Edit menu options.

Menu Name	Default
Edit > Copy	Ctrl+C
Edit > Copy/Paste > Copy Using Reference	C
Edit > Cut	Ctrl+X
Edit > Delete	Del
Edit > End Command	Esc
Edit > Mirror About X	Shift+X
Edit > Mirror About Y	Shift+Y
Edit > Move > Move Component Text	F5
Edit > Move > Move Edge	
Edit > Move > Move Using Reference	M
Edit > Move > Move Wire Endpoint	Ctrl+Shift+M
Edit > Paste	Ctrl+V
Edit > Redo	Ctrl+Y
Edit > Rotate	Ctrl+R
Edit > Undo	Ctrl+Z

View Commands

Following table lists the hot keys for the View menu options.

Menu Name	Default
View > Clear Highlighting	F8
View > Command Quick Help	Shift+F1
View > Grid Display	Ctrl+G
View > Origin Crosshair	Shift+O
View > Pan View	Tab
View > Pop Out Of Hierarchy	B
View > Push Into Hierarchy	Shift+E
View > Restore Last View	Ctrl+L
View > View All	F
View > Zoom > Zoom Area	
View > Zoom > Zoom By Factor > Zoom In x2	+
View > Zoom > Zoom By Factor > Zoom Out x2	-
View > Zoom > Zoom To Selected	Z

Insert Commands

Following table lists the hot keys for the Insert menu options.

Menu Name	Default
Insert > Change Entry Layer To	Ctrl+Shift+C
Insert > Component > Component Library...	I
Insert > Measure...	Ctrl+M
Insert > Shape > Polygon	Shift+P
Insert > Shape > Rectangle	R
Insert > Shape > Undo Vertex	Backspace
Insert > Text	Ctrl+T
Insert > Wire	Ctrl+W

Window and Miscellaneous Cor

Following table lists the hot keys for the Window and Miscellaneous

Menu Name	Default
Window > Close	Ctrl+F4
Window > Layout	Ctrl+Shift+L
Window > Open Another Schematic Window	Ctrl+Shift+S
Help > Topics and Index	F1
Options > Snap Enabled	Ctrl+E
Select > Select All	Ctrl+A
Simulate > Simulate	F7

- Help > F1

Hot Keys – Data Display

File Command

Following table lists the File m

Menu Name	Default
File > New	Ctrl+N
File > Open...	Ctrl+O
File > Print...	Ctrl+P
File > Save	Ctrl+S

Edit Commands

Following table lists the Edit menu cor

Menu Name	Default
Edit > Copy	Ctrl+C
Edit > Cut	Ctrl+X
Edit > Delete	Del
Edit > End Command	Esc
Edit > Paste	Ctrl+V
Edit > Redo	Ctrl+Y
Edit > Select All	Ctrl+A
Edit > Undo	Ctrl+Z

View Commands

Following table lists the View menu command

Menu Name	Default
View > Grid Display	Ctrl+G
View > Restore Last View	Ctrl+L
View > View All	F
View > Zoom > Zoom Area	
View > Zoom > Zoom In x2	+
View > Zoom > Zoom Out x2	-

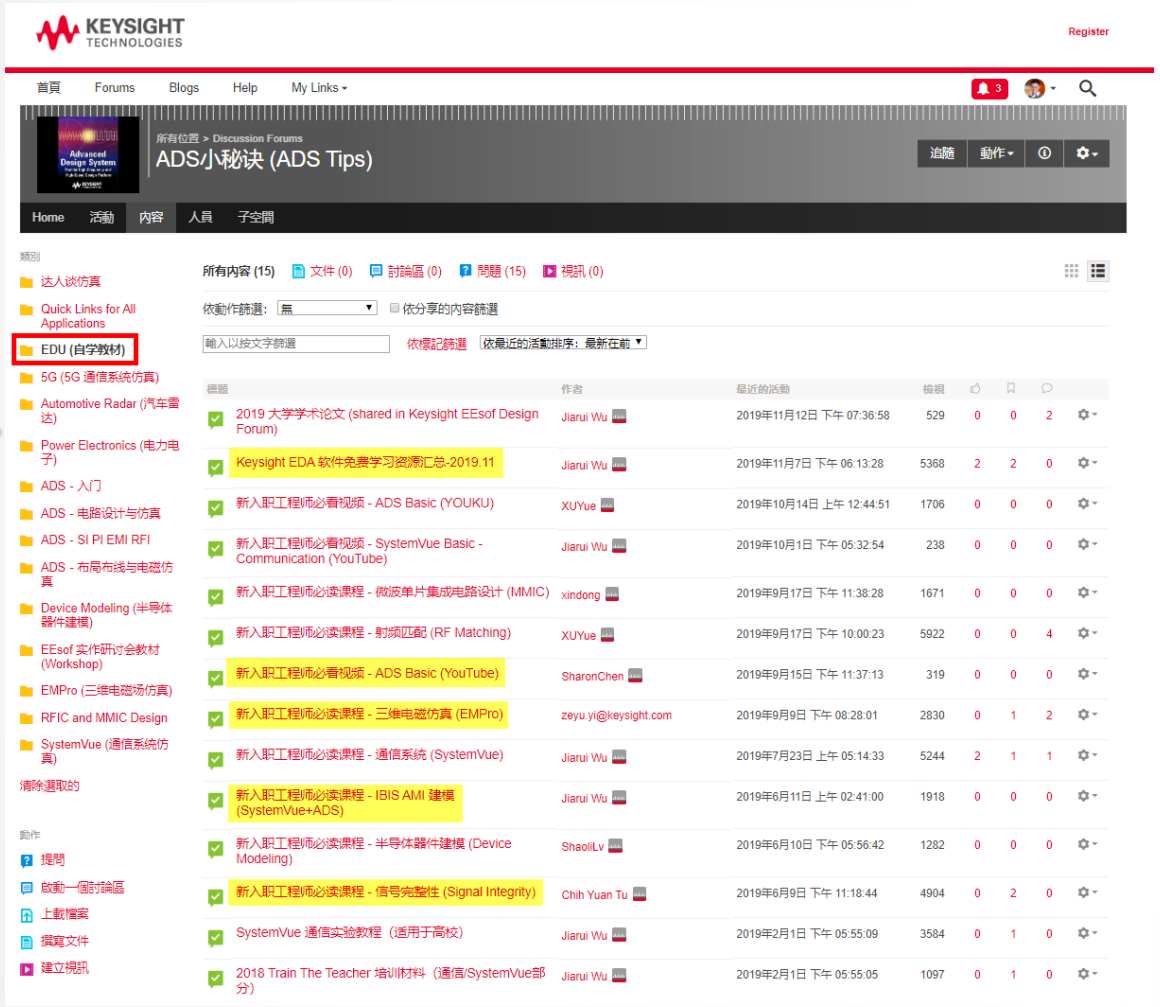
Miscellaneous Commands

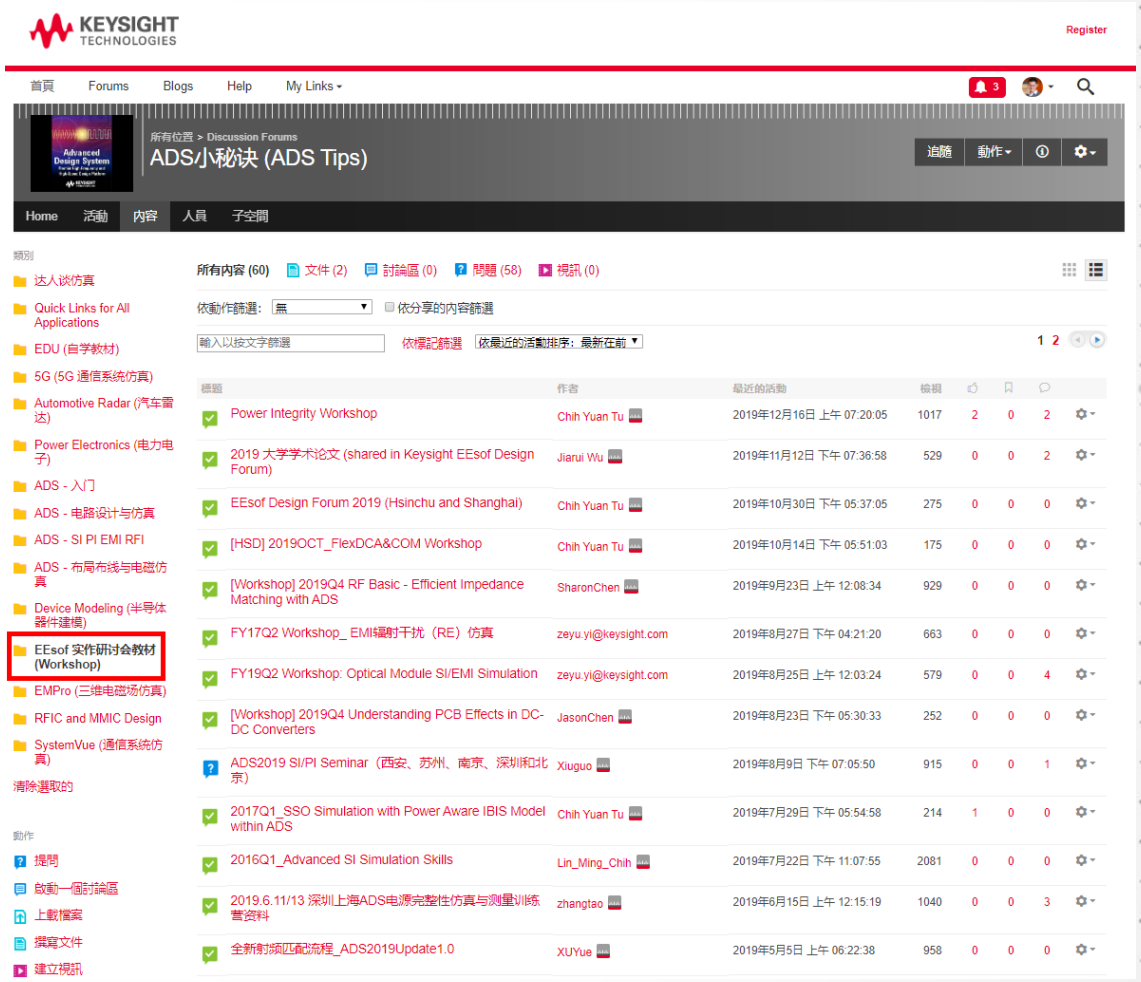
Following table lists the various other menu commands suc

Menu Name	Default
Help > Topics and Index	F1
Marker > New...	Ctrl+M
Options > Hide ADS Logo on all plots	Alt+L
Options > Snap Enabled	Ctrl+E
Window > Close	Ctrl+F4
Window > New	Ctrl+Shift+D

- Help > F1

ADS Tips Forum (ADS小秘訣) www.keysight.com/find/ADS_tips





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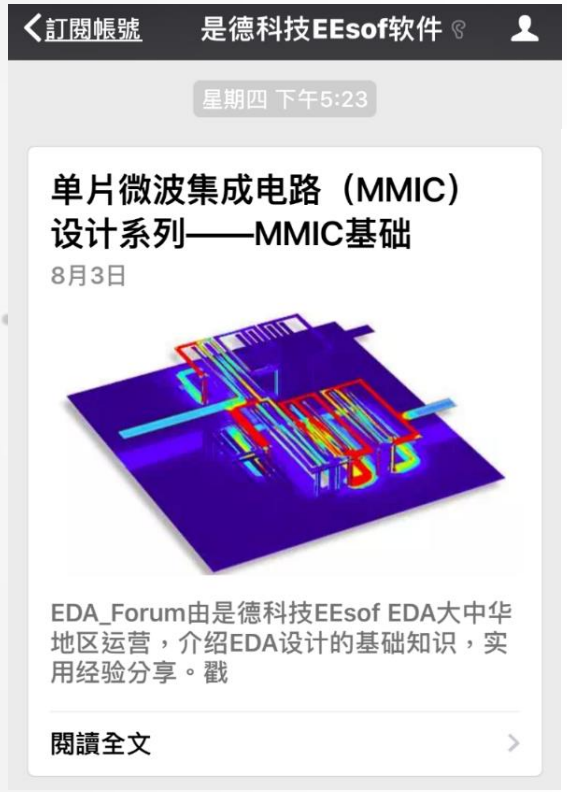

ID: EDA_Forum

信号完整性

1、分享信号完整性（SI）、电源完整性（PI）、电磁兼容性和微波射频方面的知识/行业信息及动态； 2、不定期举办线下/上公益活动； 3、帮助大家更好的学习和了解硬件、高速电路、微波射频电路、EMC和高速PCB的设计。 SIPIEMC

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ID: SI_PI_EMC

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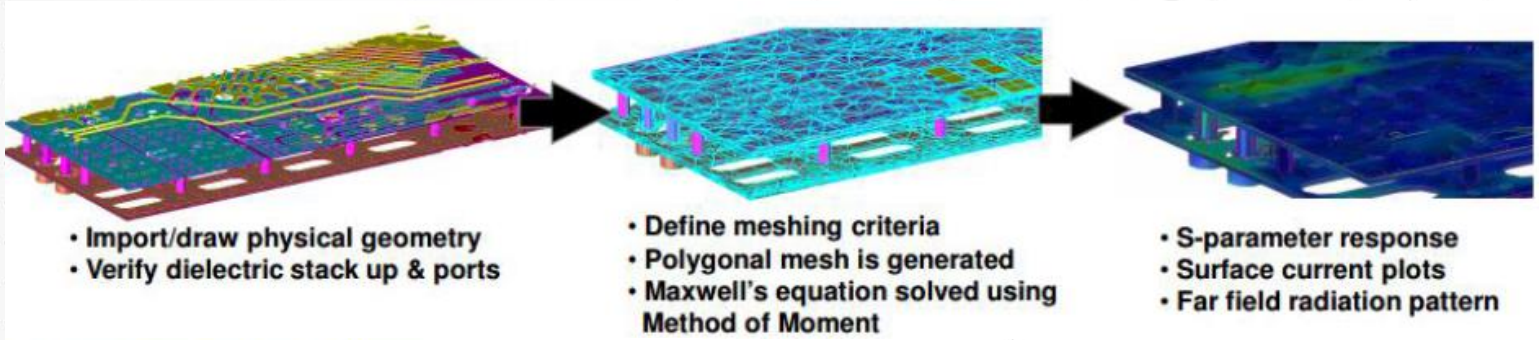
Momentum Overview

- Method of Moment (MoM) technology
- Accurate and efficient simulation of complex multilayer geometries



- Import/draw physical geometry
- Verify dielectric stack up & ports

- Define meshing criteria
- Polygonal mesh is generated
- Maxwell's equation solved using Method of Moment

- S-parameter response
- Surface current plots
- Far field radiation pattern

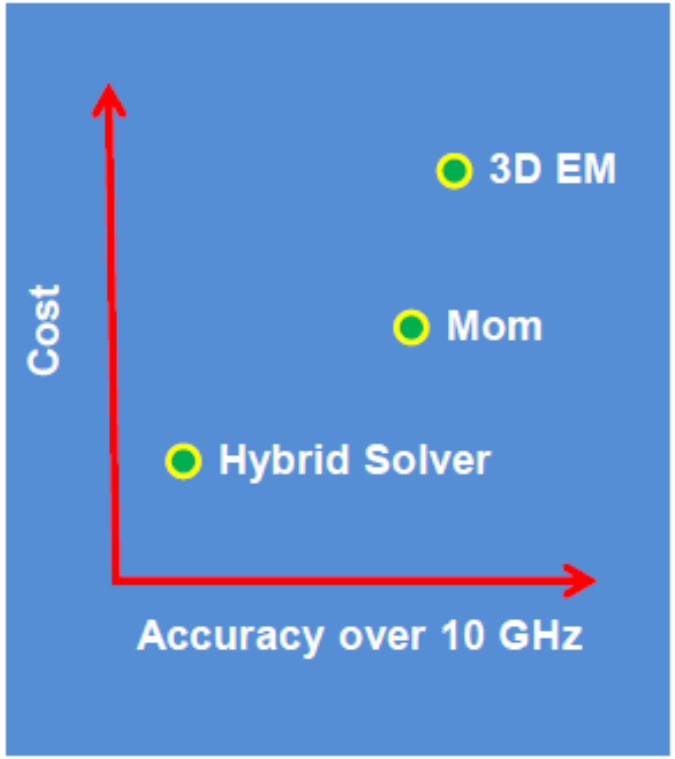
Advantages and Applications:

- Tightly integrated within ADS environment
- Design flow integration with ADS tools
- Solves complex 3D multilayer planar geometry
- Fast and efficient simulation
- Accurate from DC up to 100's of GHz
- Simulate large number of ports
- PCB, Packages

First version of Momentum simulator : Released in 1994

Benefit and Cost of MoM Technology

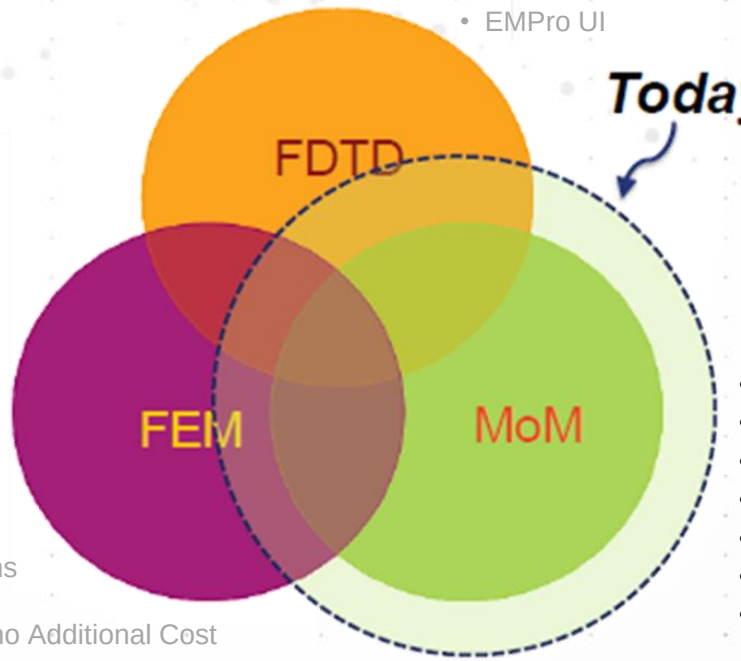
	Hybrid Solver	Mom	3D EM
Accuracy >10 GHz	Low	High	High
Learning	Easy	Normal	Hard
Usability	Easy	Normal	Normal
Flexibility	Low	Medium	High
Speed	Fast	Medium	Slow
Memory Required	Low	Medium	High
Price	Medium	Medium	High



EM Setup Are Different for Each Solver Technology

- FDTD (Finite Difference Time Domain)
- FEM (Finite Element Method)
- MoM (Method of Moment)

- Arbitrary 3D structures
- Time Domain
- Full Wave EM Simulations
- Handles much larger and complex problems
- Each port requires separate simulation
- GPU based hardware acceleration
- EMPro UI



- Arbitrary 3D structures
- Frequency Domain
- Full Wave EM Simulations
  Direct, Iterative Solvers
- Multiport Simulations at no Additional Cost
- High Q
- ADS or EMPro UI

- Restricted 3D Structures
- Frequency Domain
- Full-Wave and Quasi-Static Simulations
- Dense & Compressed Matrix Solvers
- Multiport Simulations at no Additional Cost
- High Q
- ADS UI

Outline

- Quick review of Momentum
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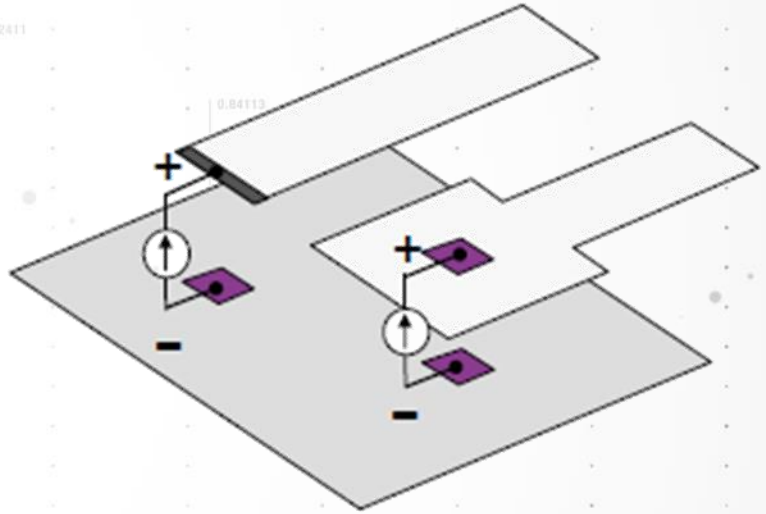
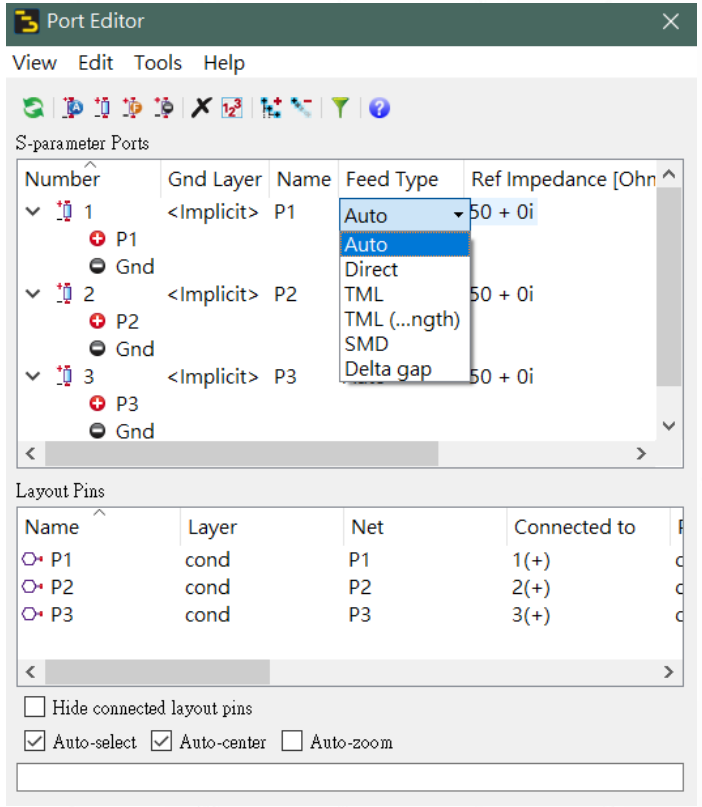
EM Ports in MoM Technology

- Consist of + and – terminals
- Placed where EM models connect to circuit components
- Compute voltages and currents from E&H field, and also S-parameters
- A lumped source is attached with a source impedance
  - No phase delay between + and –terminal
  - Must be electrically small (size < λ/10)
  - Otherwise it may result unphysical behaviors



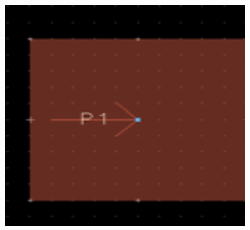
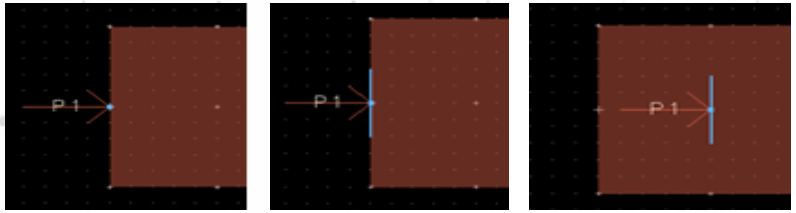
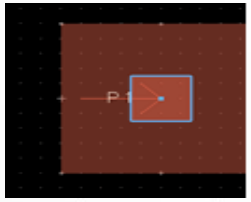
EM Port Calibration in MoM Technology

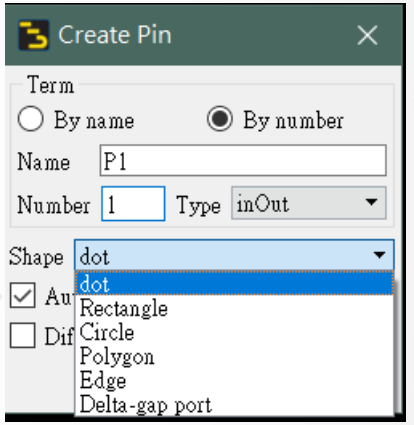
- Direct
- TML (**T**rans**m**ission **L**ine)
- TML (zero length)
- SMD (**S**urface **M**ount **D**evices)
- Delta gap



General Pin Types

- Correct Pins Allow for Correct Ports

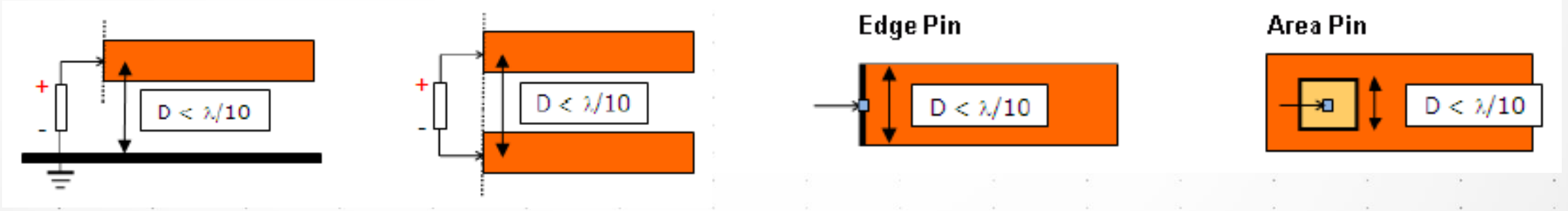
Point Pin		Pin placed anywhere within a geometry, but not on an edge.
Edge Pin		Pin placed on any geometry edge or any explicitly defined Edge Pin.
Area Pin		Explicitly defined Area Pin.



Excitation voltages can be limited in extent by using Edge/Area Pins

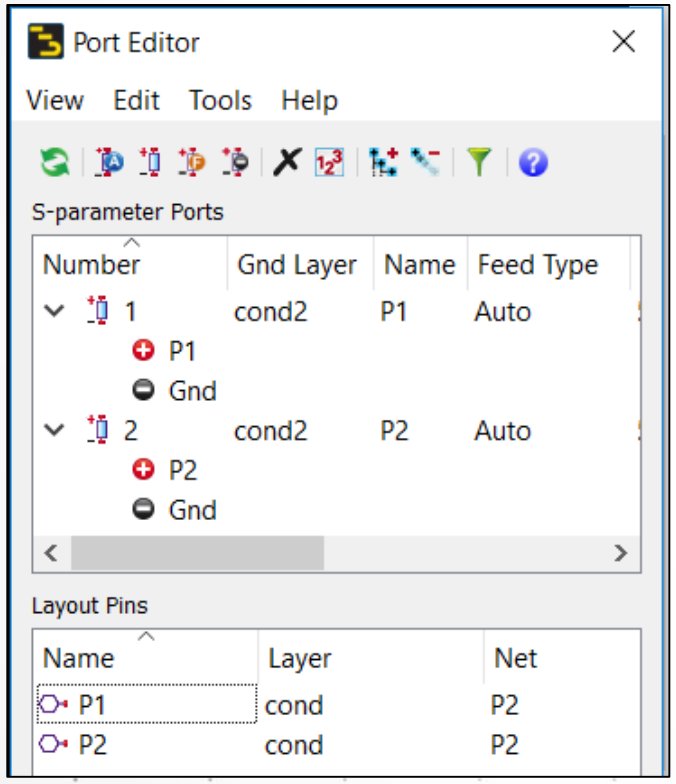
ADS Momentum Port Calibration/Feed Types

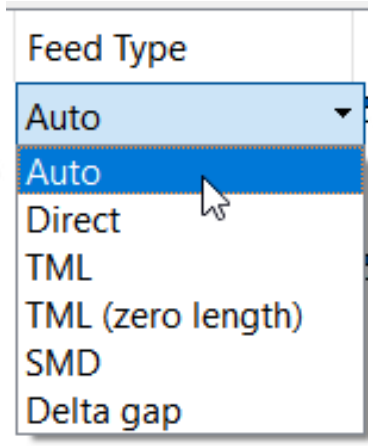
- MoM Ports placed on a metal EDGE will excite the entire edge with constant potential. Unless Edge Port is used to confine excitation. If the edge is >1/10 wavelength results can become non-physical.
- MoM Ports placed inside metal are point sources that will excite a mesh element around the port. Unless Area Port is used, area becomes constant potential.
- MoM Ports inject current with 0 deg phase shift (Lumped Source). If the physical difference between the + and – pins is > 1/10 wavelength results can become non-physical.
- MoM ports, being lumped sources will NOT couple to surrounding structures.
- Port Size restrictions:



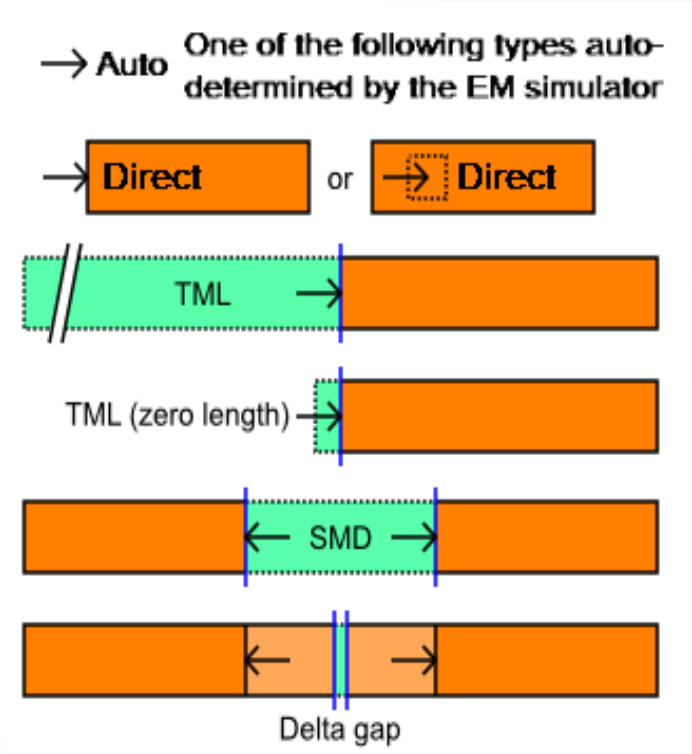
EM Ports Editor

- A Glimpse into Calibration/Feed Types





Hover over Feed Type for pop-up help graphic



Summary of EM Ports in ADS 2016

- “Old” Nomenclature for Calibration/Feed Type

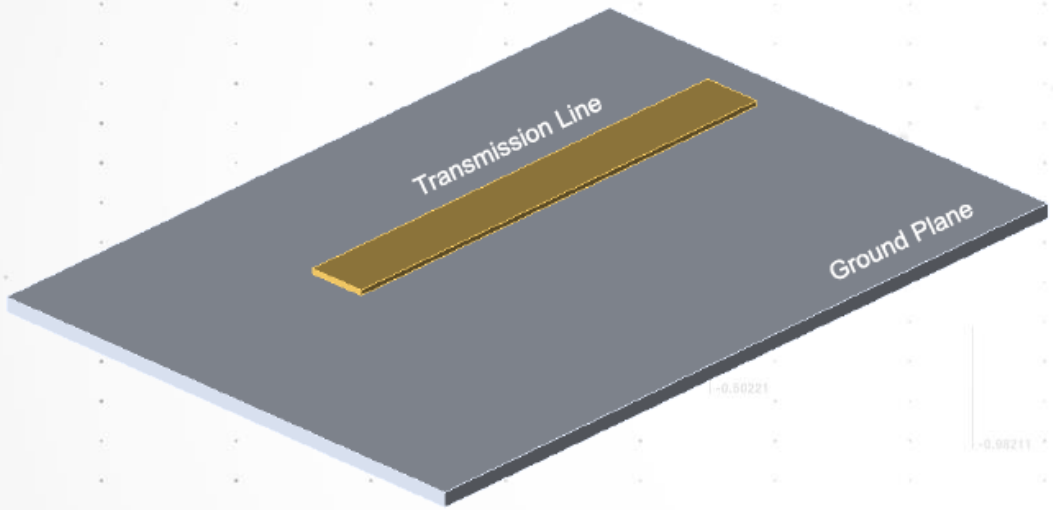
Calibration Type	Momentum
None	If none of the available calibration types is valid for the connecting component, specify “None”.
TML *(this is the default, changed @ sim time if not on outer edge)*	This calibration type assumes the structure is fed through a transmission line. It removes the open end effect and adds the mutual coupling induced by the feeding transmission line.
TML (zero length)	This calibration type removes the open end effect.
SMD	This calibration type removes the open end effect at port and adds the mutual coupling between the current flowing from the + to – pins and the rest of the circuit assuming the area between both pins would be filled with metal.
Delta Gap	This calibration type adds the effect of metal filled in the area between the + and – pins. A gap in the middle allows connecting the source.

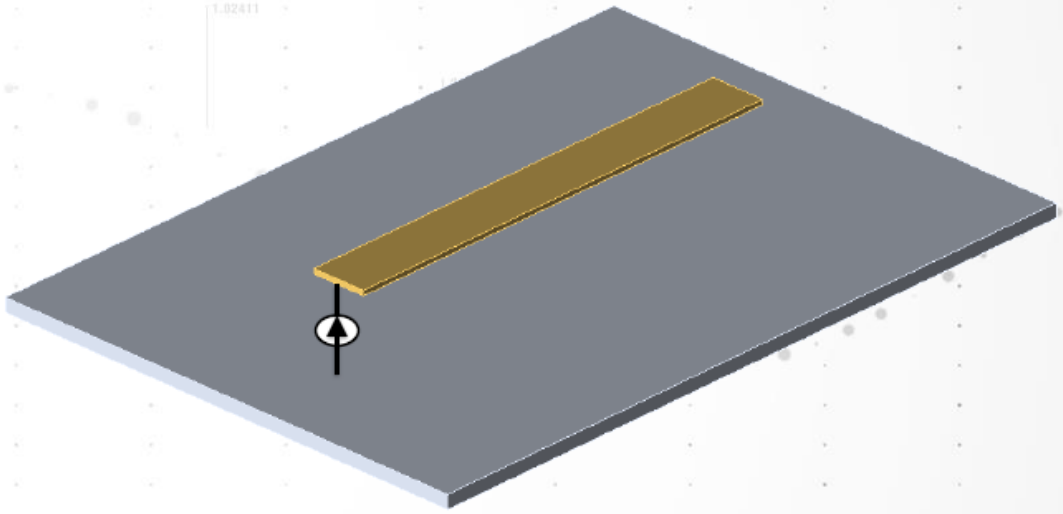
Summary of EM Ports in ADS 2017 & Newer

- New Nomenclature for Calibration/Feed Type

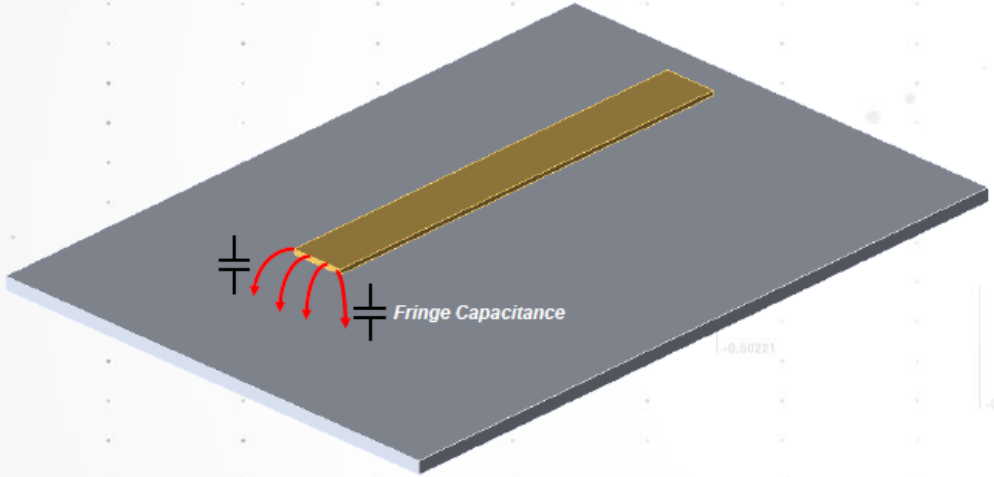
Feed Type	Momentum
Auto	This becomes Direct feed 99% of the time. Only TML if placed on outer edge of a slot plane geometry.
Direct	If none of the available calibration Feed types is valid for the connecting component, specify “Direct”.
TML	This calibration Feed type assumes the structure is fed through a transmission line. It removes the open end effect and adds the mutual coupling induced by the feeding transmission line.
TML (zero length)	This calibration Feed type removes the open end effect.
SMD	This calibration Feed type removes the open end effect at port and adds the mutual coupling between the current flowing from the + to – pins and the rest of the circuit assuming the area between both pins would be filled with metal.
Delta Gap	This calibration Feed type adds the effect of metal filled in the area between the + and – pins. A gap in the middle allows connecting the source.

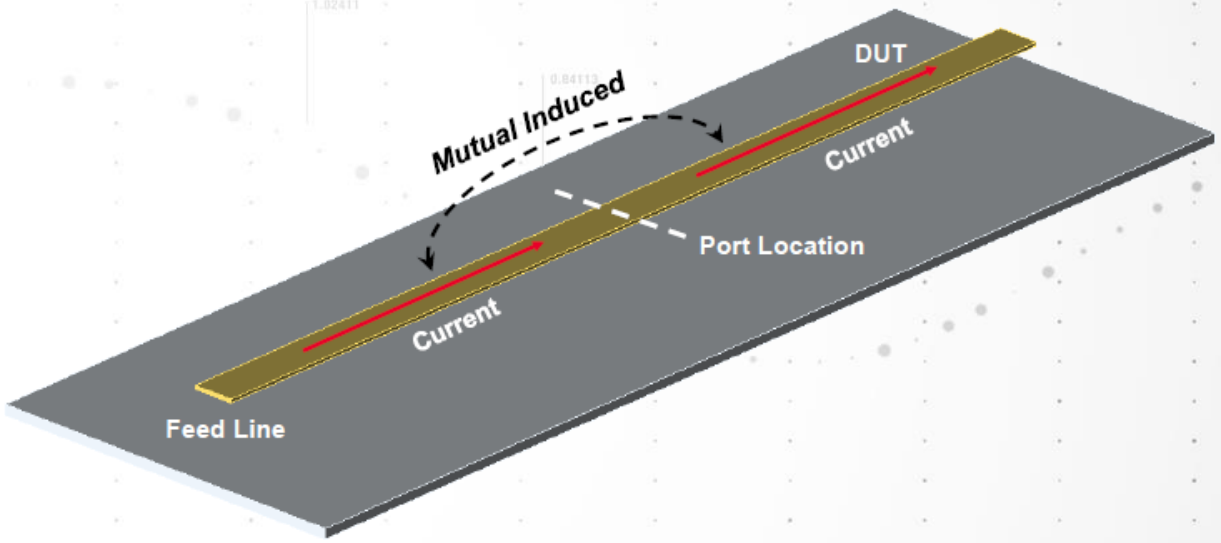
TML Feed Type (1/5)



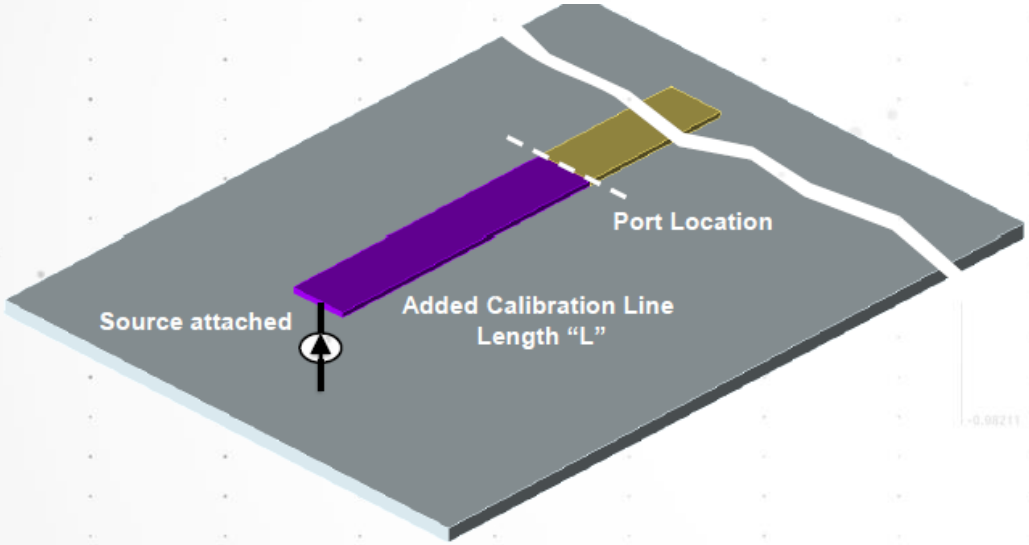


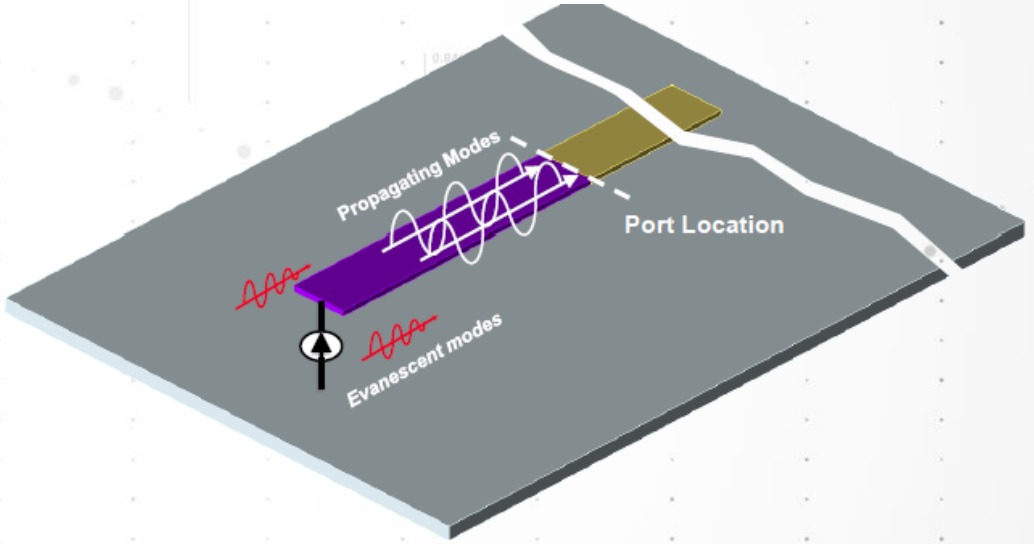
TML Feed Type (2/5)



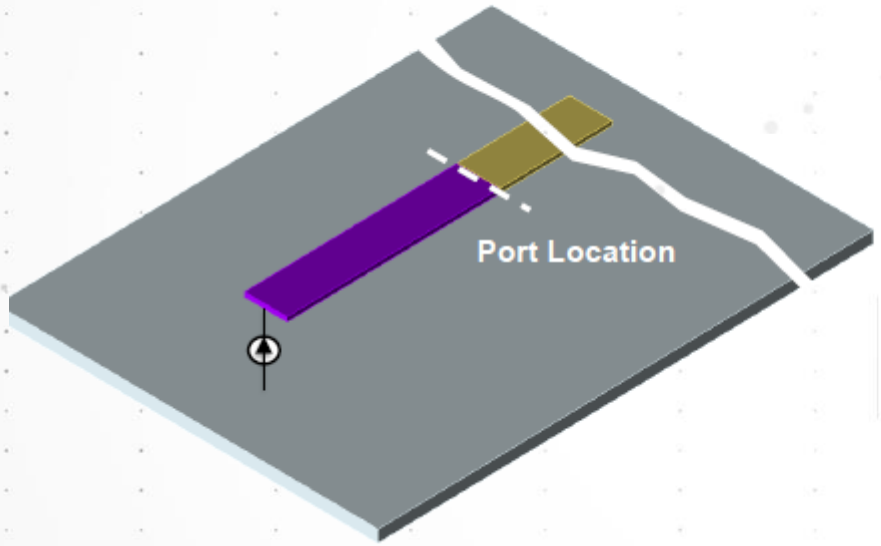


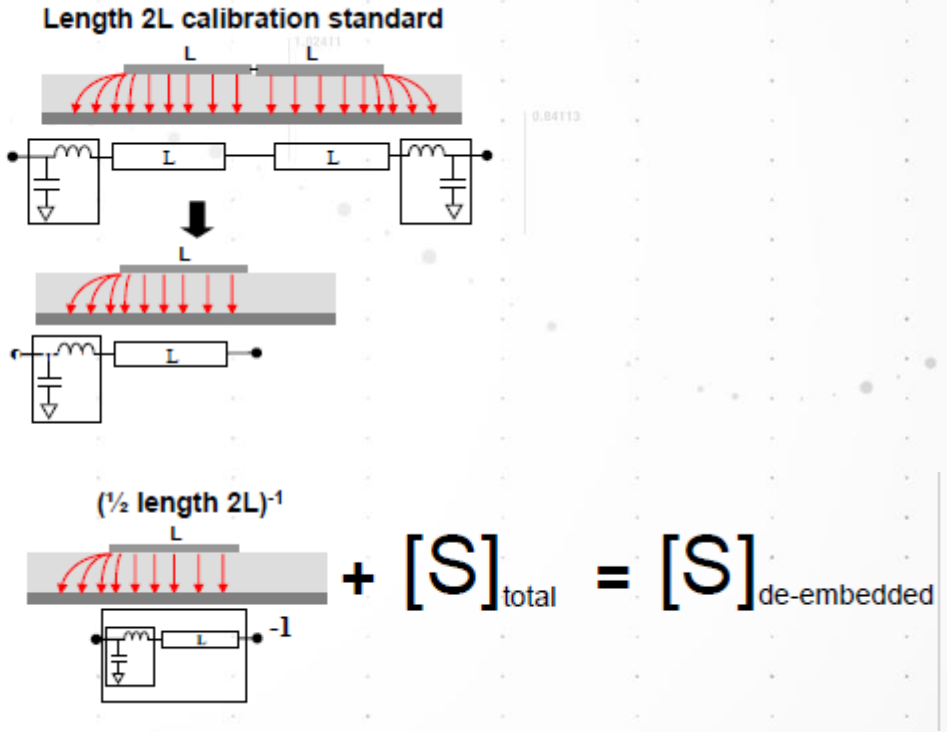
TML Feed Type (3/5)



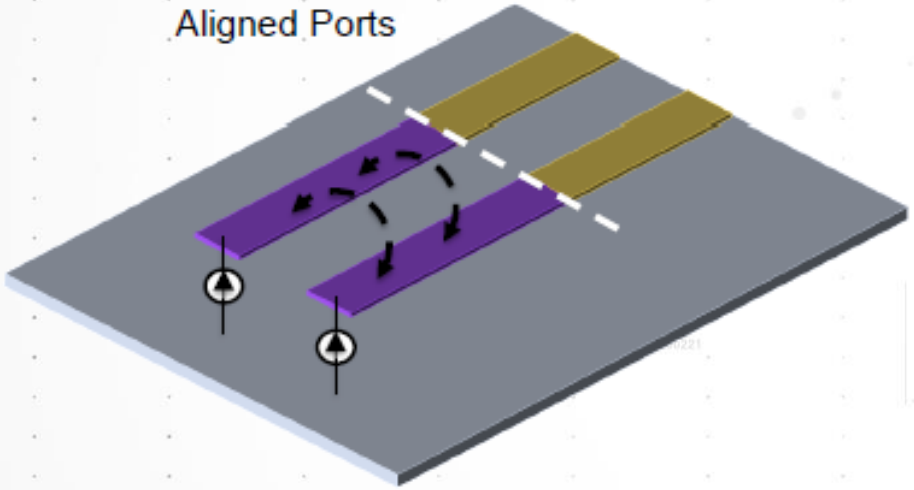


TML Feed Type (4/5)

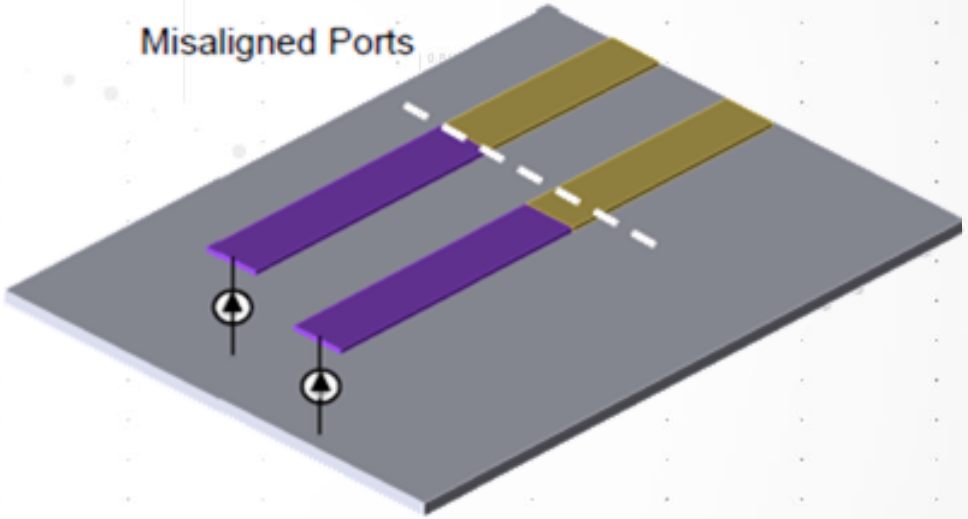




TML Feed Type (5/5)

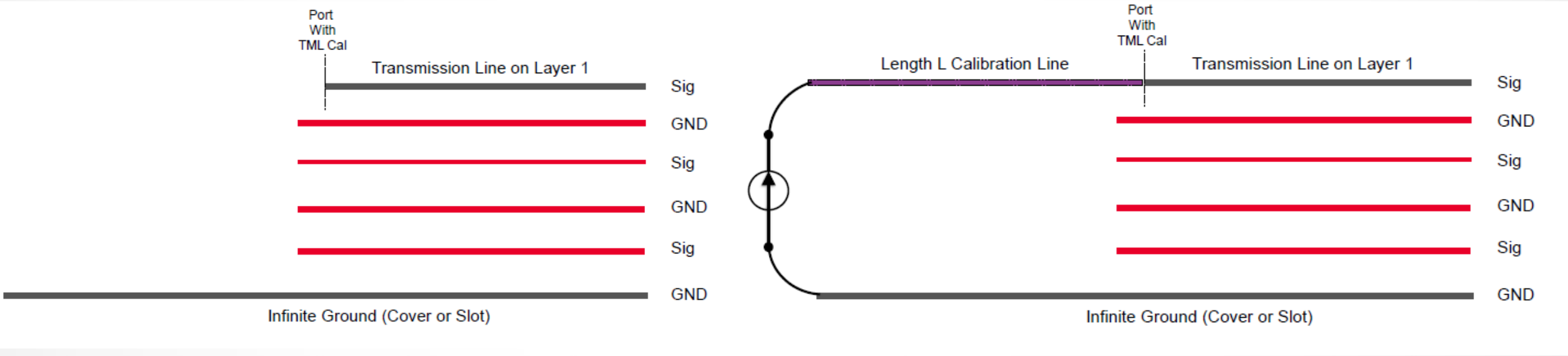


Mutual coupling between the feed lines will be removed after TML calibration

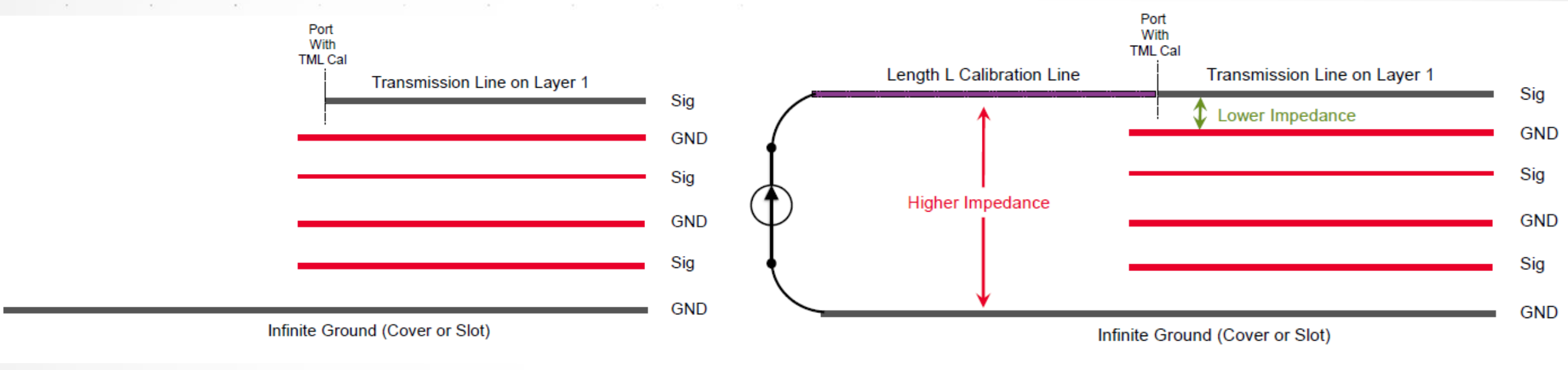


Mutual coupling between the feed lines **will be turned off** during TML calibration

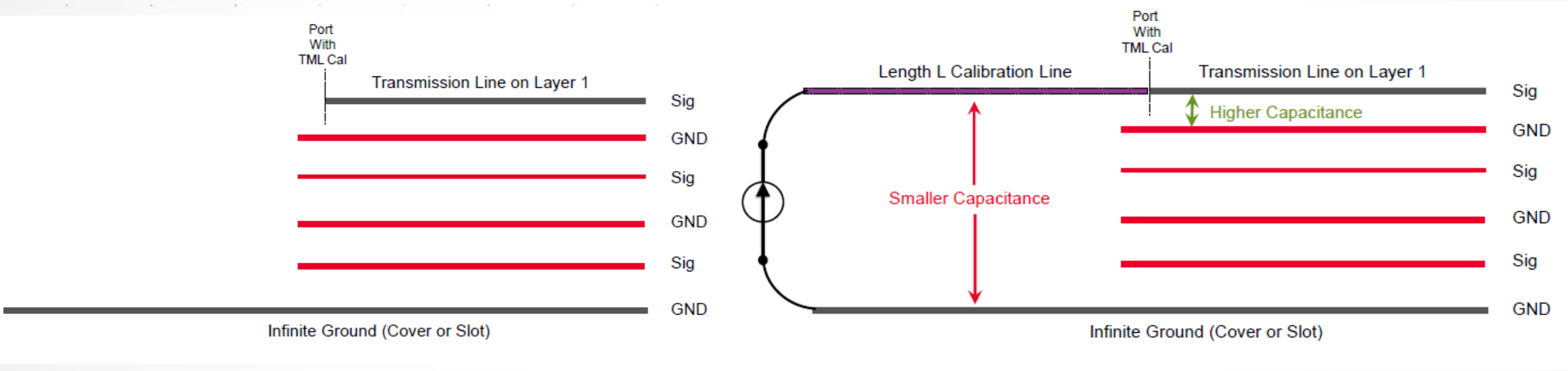
Incorrect Use of TML Feed Type



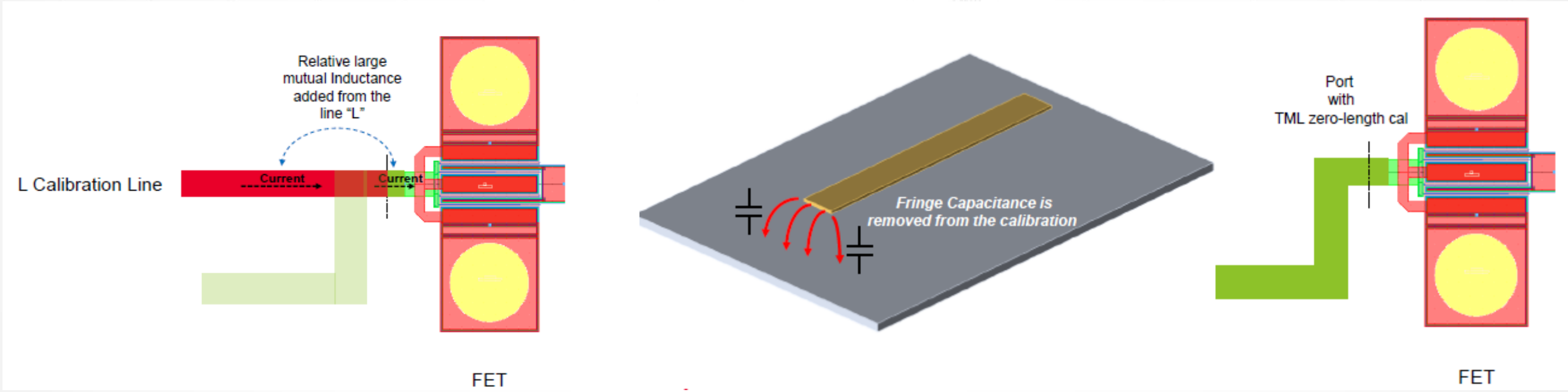
Incorrect Use of TML Feed Type



Incorrect Use of TML Feed Type

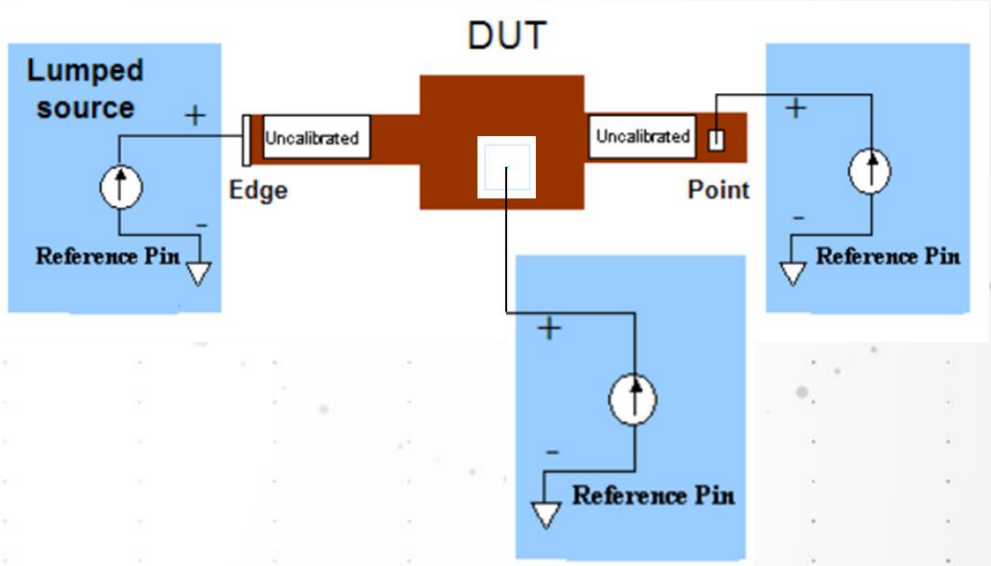


TML Zero-Length Feed Type

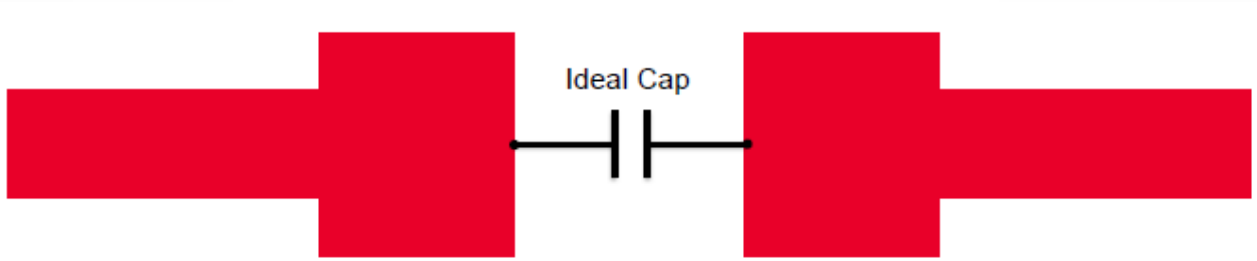


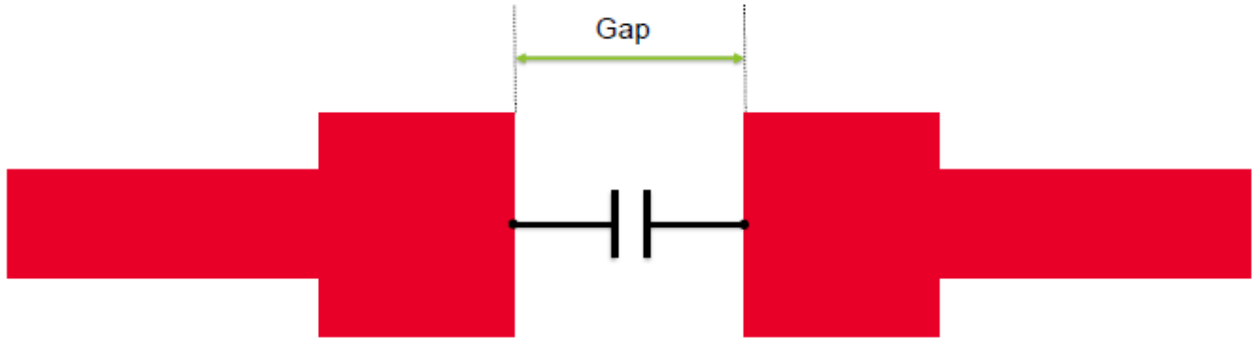
None Calibration - Direct Feed Type

- No port calibration but could be very versatile
- Ground reference can be anywhere
- Applies to point pins, edge pins and area pins
- Some guidelines
  - Port size must be electrically small (length < λ/10)
  - Ground reference should be on the true ground return path
  - A local open end effect is included in the DUT model. This is a result of the direct feed being applied to the edge port.

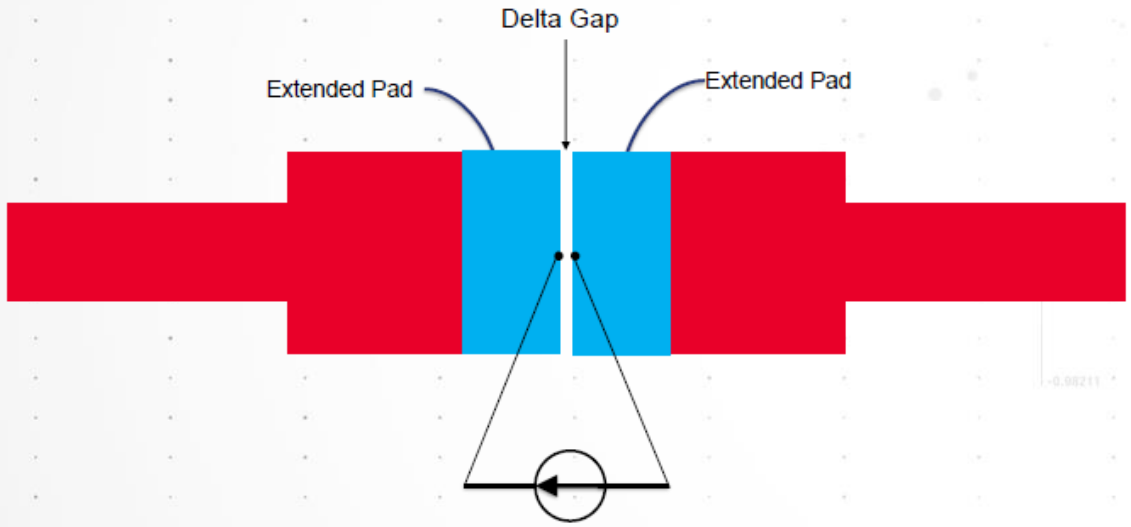


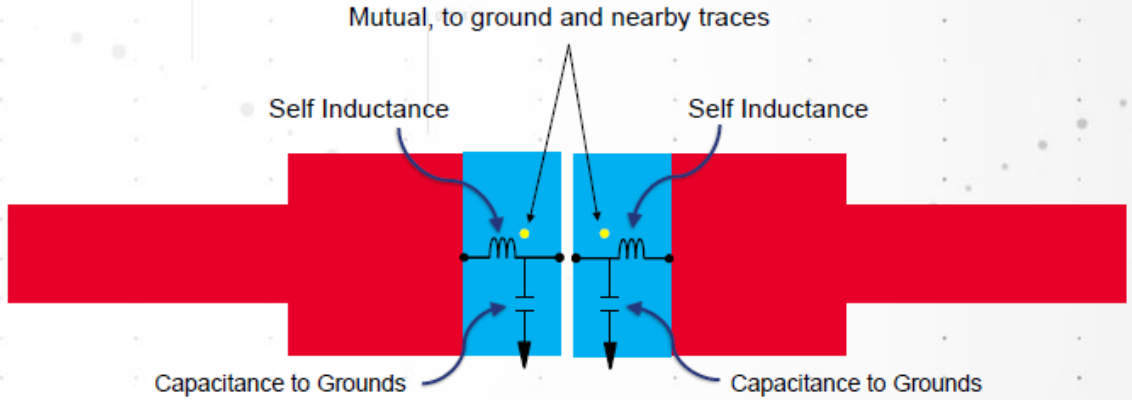
Delta-Gap Feed Type



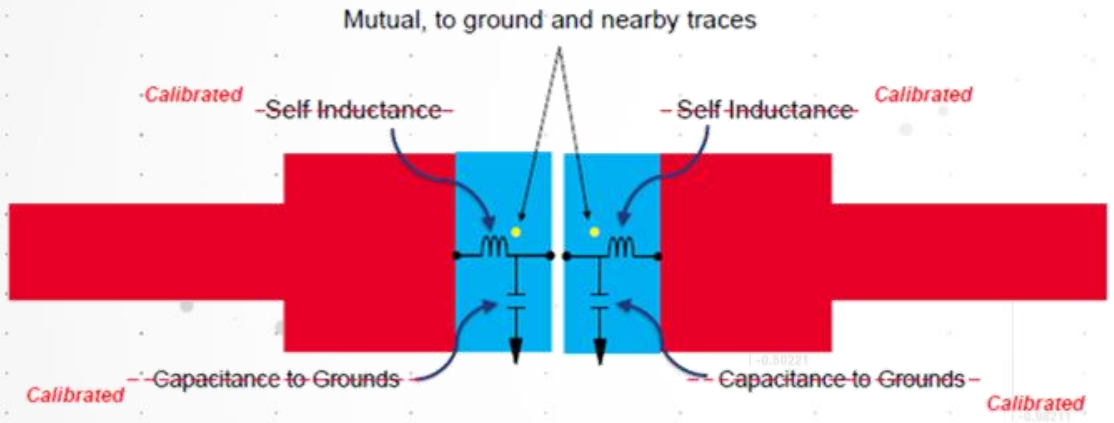


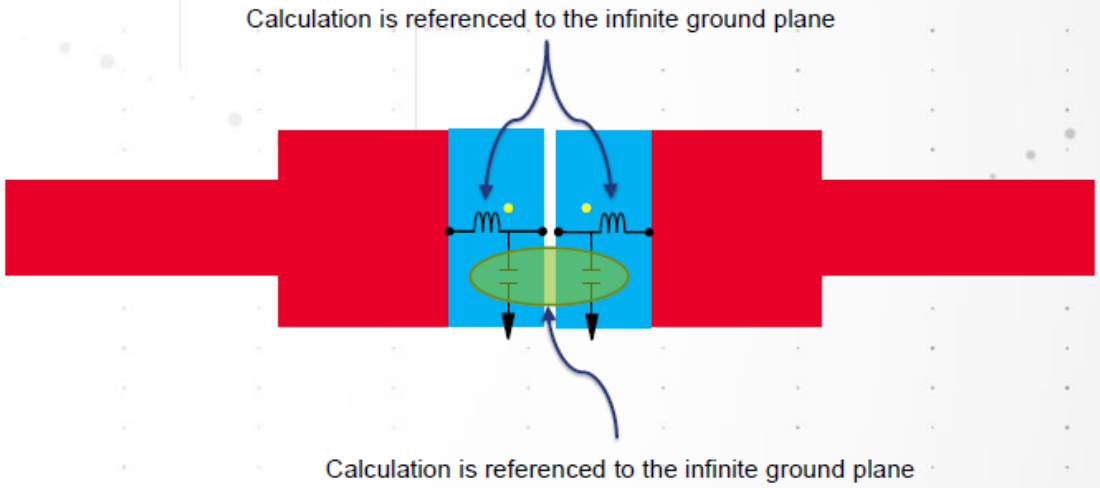
Delta-Gap Feed Type





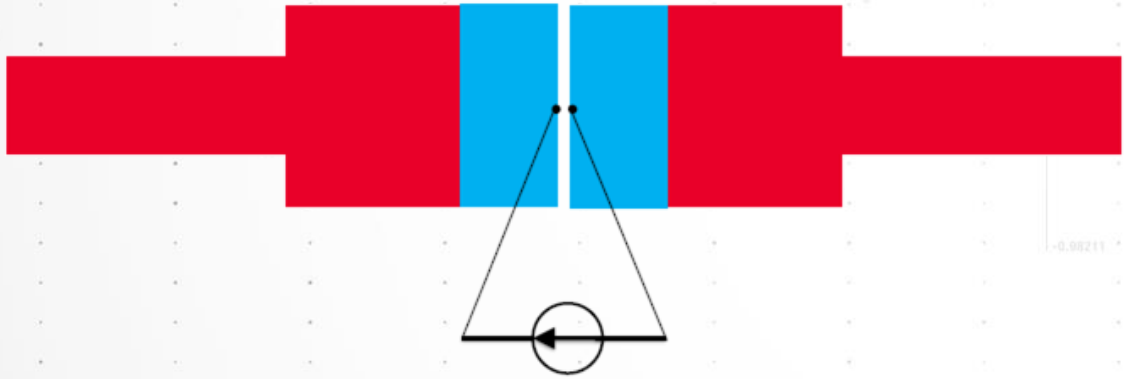
SMD Feed Type



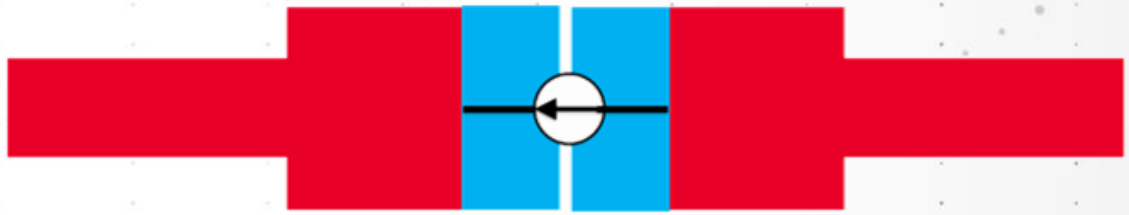


Both of Delta-gap and SMD Feed Type

- Only differential mode supported

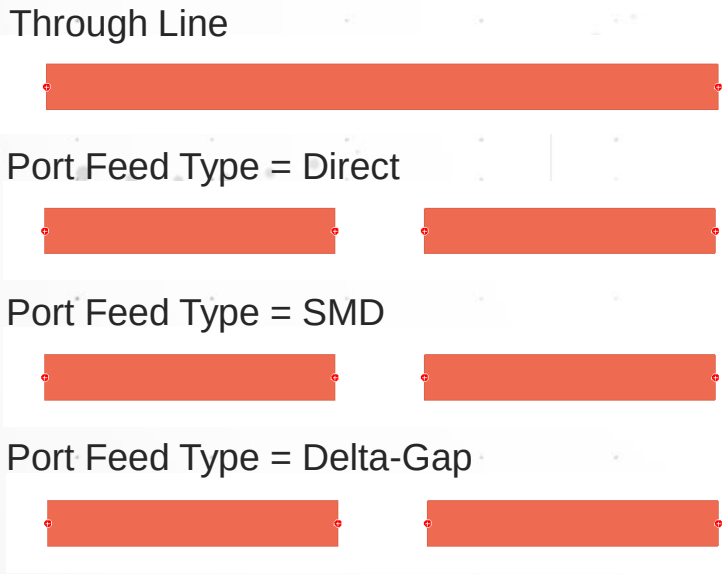


- Current flows straight through the added pads



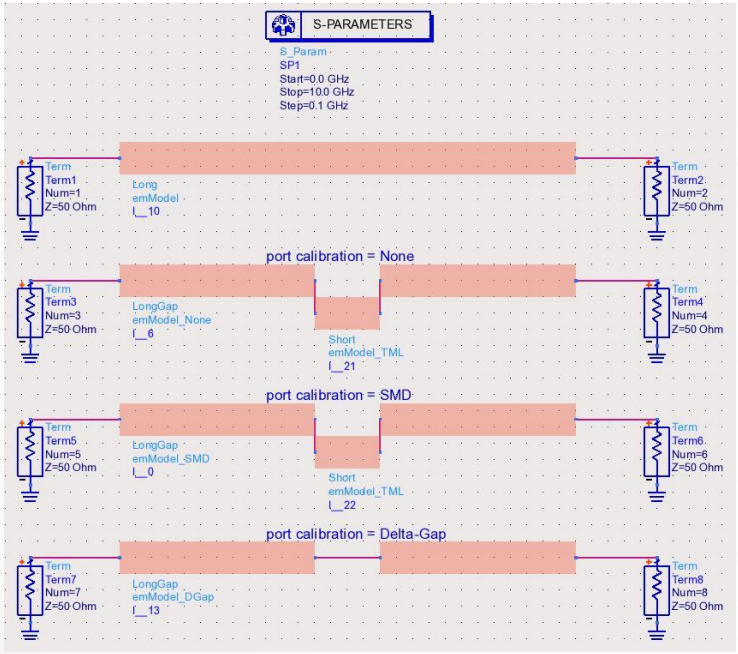
Lab1 – Port Calibration/Feed Types

- Long line with gap for SMD component
- Gap port calibration = DeltaGap|SMD|None(Direct)
- Gap shorted



Lab1 – Port Calibration/Feed Types

- Long line with gap for SMD component
- Gap port calibration = DeltaGap|SMD|None(Direct)
- Gap shorted with short line (TML calibration)

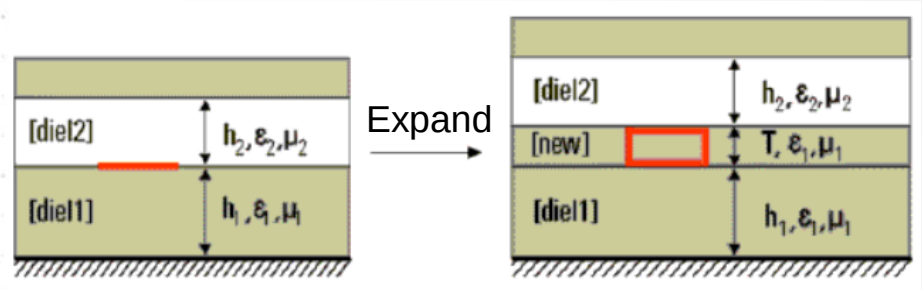


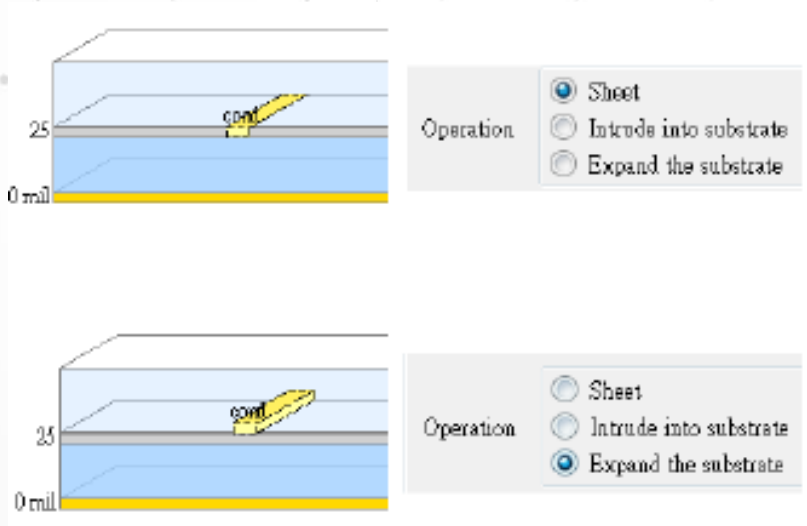
Outline

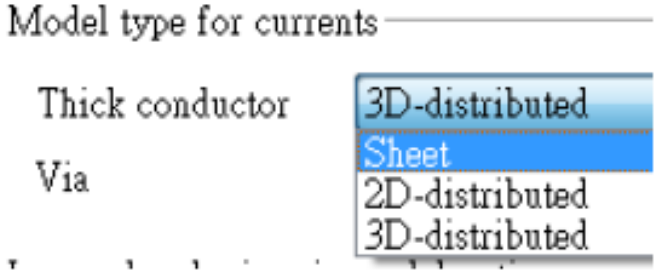
- Quick review of Momentum
- Lab1: Port Type Overview
- Lab2: Net Type Setup for Physical Model Simplified
- Lab3: Understand Mesh, Solver and Preprocessor
- Summary

Metal Model Types

- Sheet-Sheet
- Intrude/Expand-Sheet
- Intrude/Expand-2D distributed
- Intrude/Expand-3D distributed (Recommended)

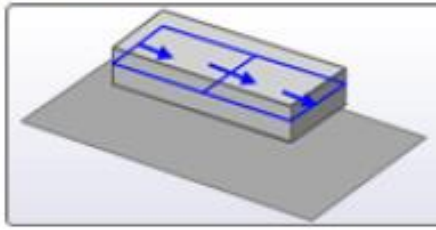






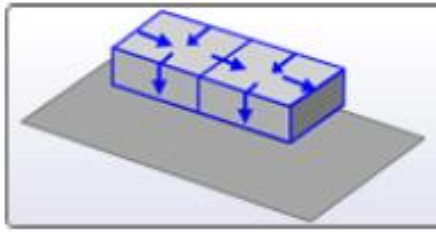
Thick Metal Model Types

Sheet



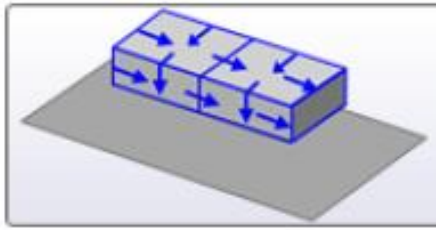
- Top and bottom currents collapsed
- No sidewall currents

2D distributed



- Top and bottom currents separate
- Vertical sidewall currents only

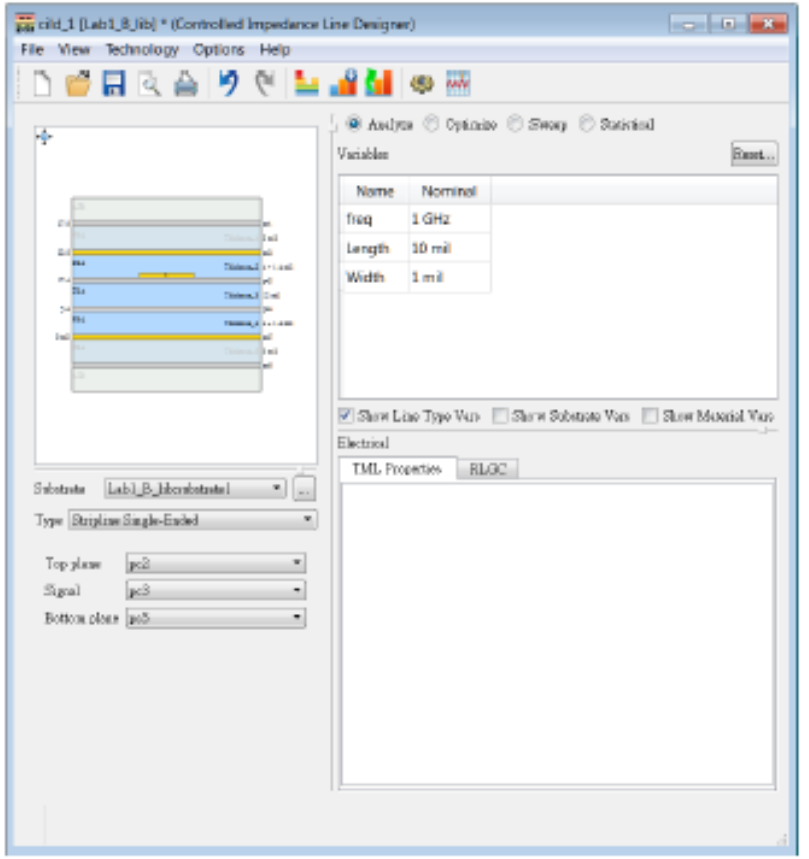
3D distributed(Recommended)



- Top, bottom and sidewall currents separate
- Any surface current

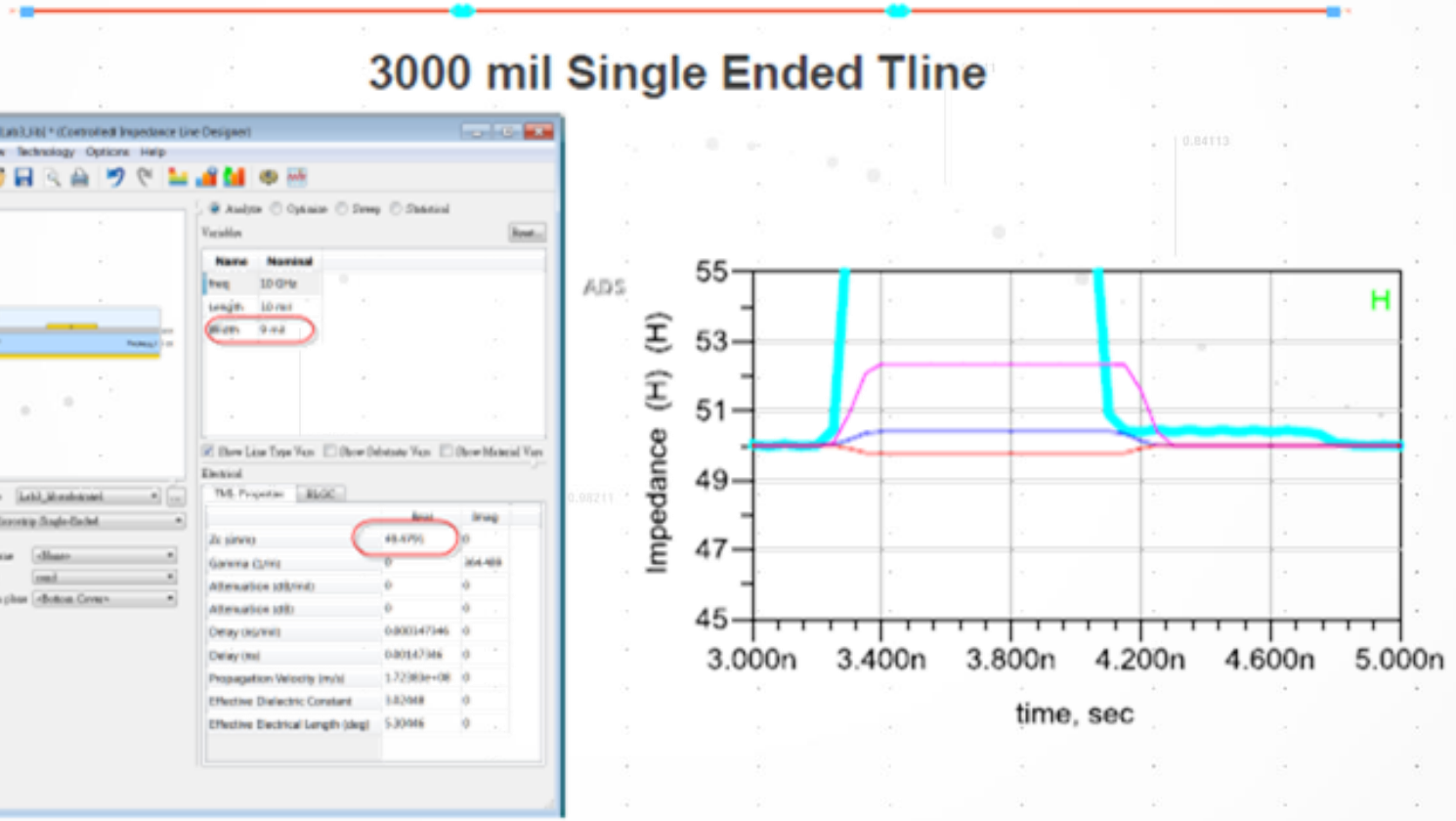
Controlled Impedance Line Designer (CILD)

- Impedance Calculation
- Width Calculation for specific impedance
- Support Strip, Microstrip, CPW, Single-Ended, Differential Pair Types
- Statistical Calculation
- Model Generation



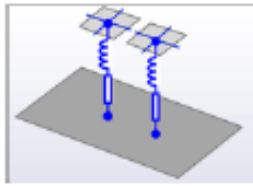
Check TDR of Metal Type

Accuracy: 3D+Edge > 3D > 2D >> Sheet



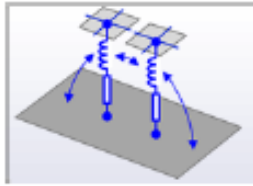
Via Modeling

Lumped (Recommended for Power/Ground vias)



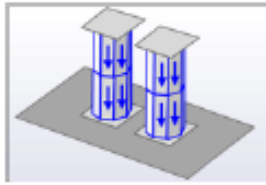
- DC resistance and skin effect
- Wire self inductance
- Meshless equivalent circuit

Wire



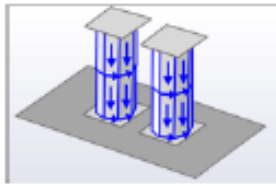
- DC resistance and skin effect
- Wire self inductance
- Mutual wire-wire and wire-infinite ground inductances
- Meshless equivalent circuit

2D-Distrubuted (Recommended for TLine vias)



- DC resistance and skin effect
- All self and mutual inductances and capacitances
- Vertical sidewall currents only

3D-Distrubuted

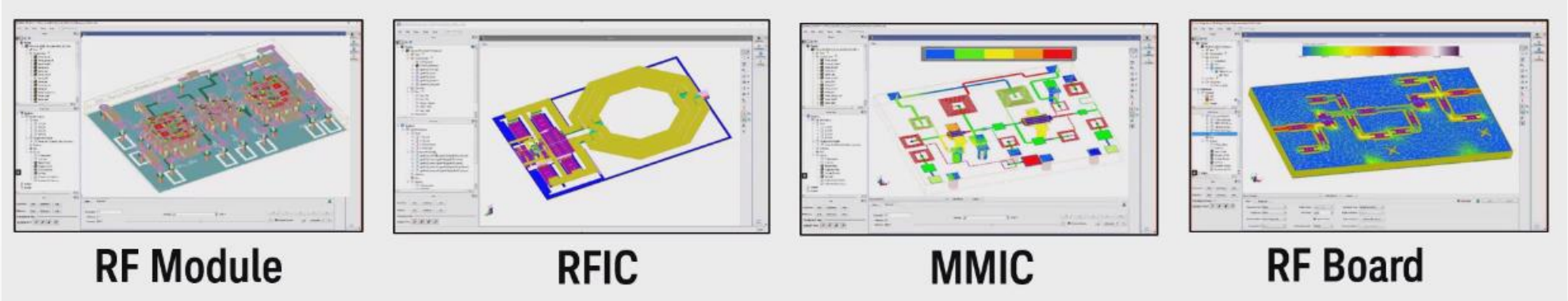


- DC resistance and skin effect
- All self and mutual inductances and capacitances
- Any surface current

RFPro Vision: EM for every RF circuit designer

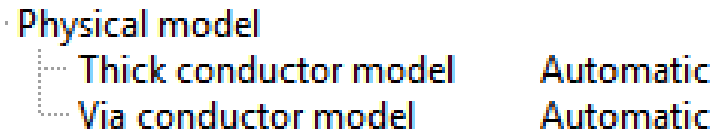
Allows users to focus on design rather than setting up EM

- Integration
  - ✓ **3D view**
  - ✓ Solution for RF PCB, RFIC, MMIC and RF Modules
  - ✓ Enhanced ADS MOM and FEM simulator performance
- Solver
  - ✓ **Automatic EM expert settings** guarantee confidence in EM results for novice and expert users
  - ✓ Fast & correct analysis setup for **EM-circuit co-simulation**
- Layout
  - ✓ No Cookie cutting
  - ✓ **No exporting**
  - ✓ No removing active devices and placing pins & ports
  - ✓ **No reconnecting schematics to s-parameter files**



RFPro Momentum: Automatic Mode for Vias/Thick Metals

- Thanks to RFPro platform, Momentum can now automatically apply different via/thick conductor models depending on the nets type : signals, grounds and power planes

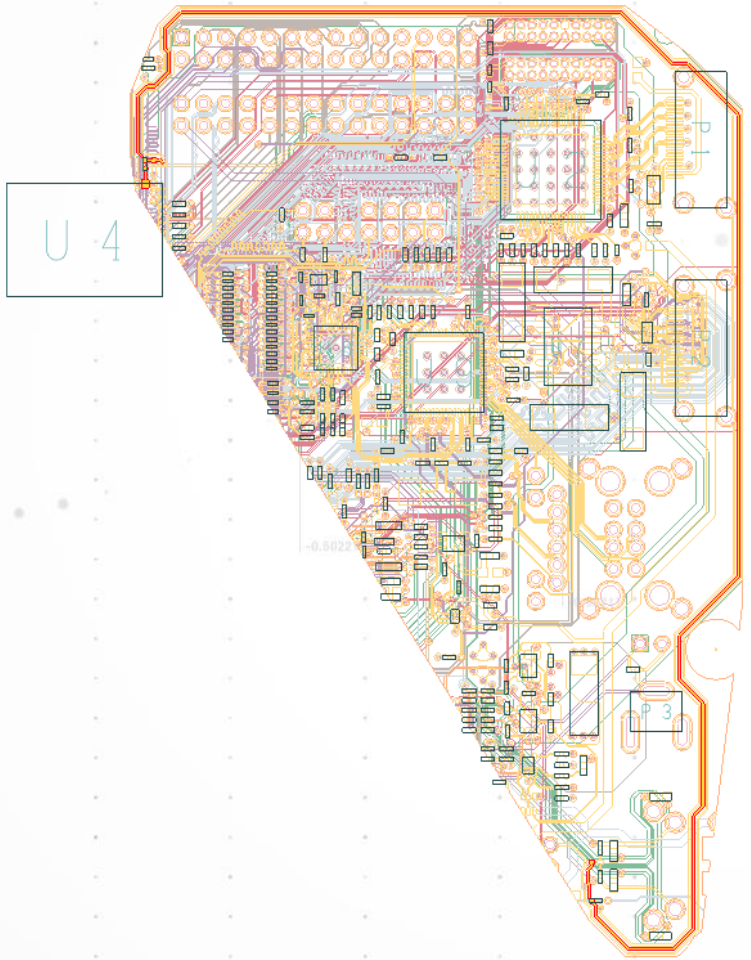


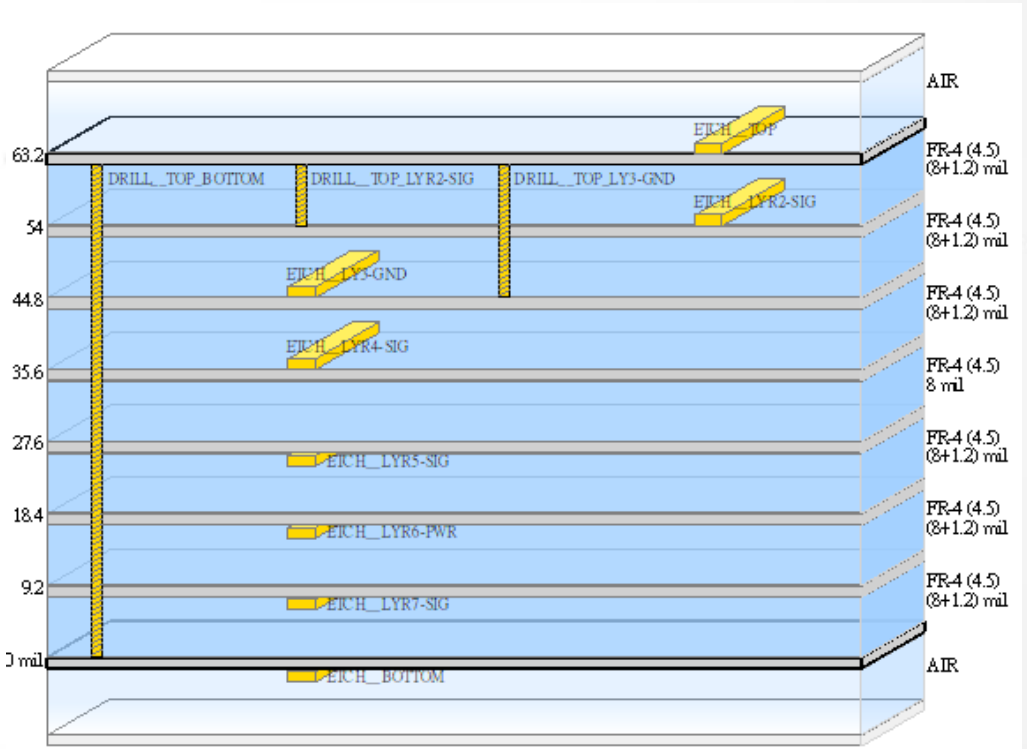
Example on a 60 GHz Wilkinson divider

	RFPro 2020	RFPro 2020U1
Matrix size	127500	4750
Runtime (MomRF)	> 10h	27mn

Lab2 - Net Type Setup for Physical Model Simplified

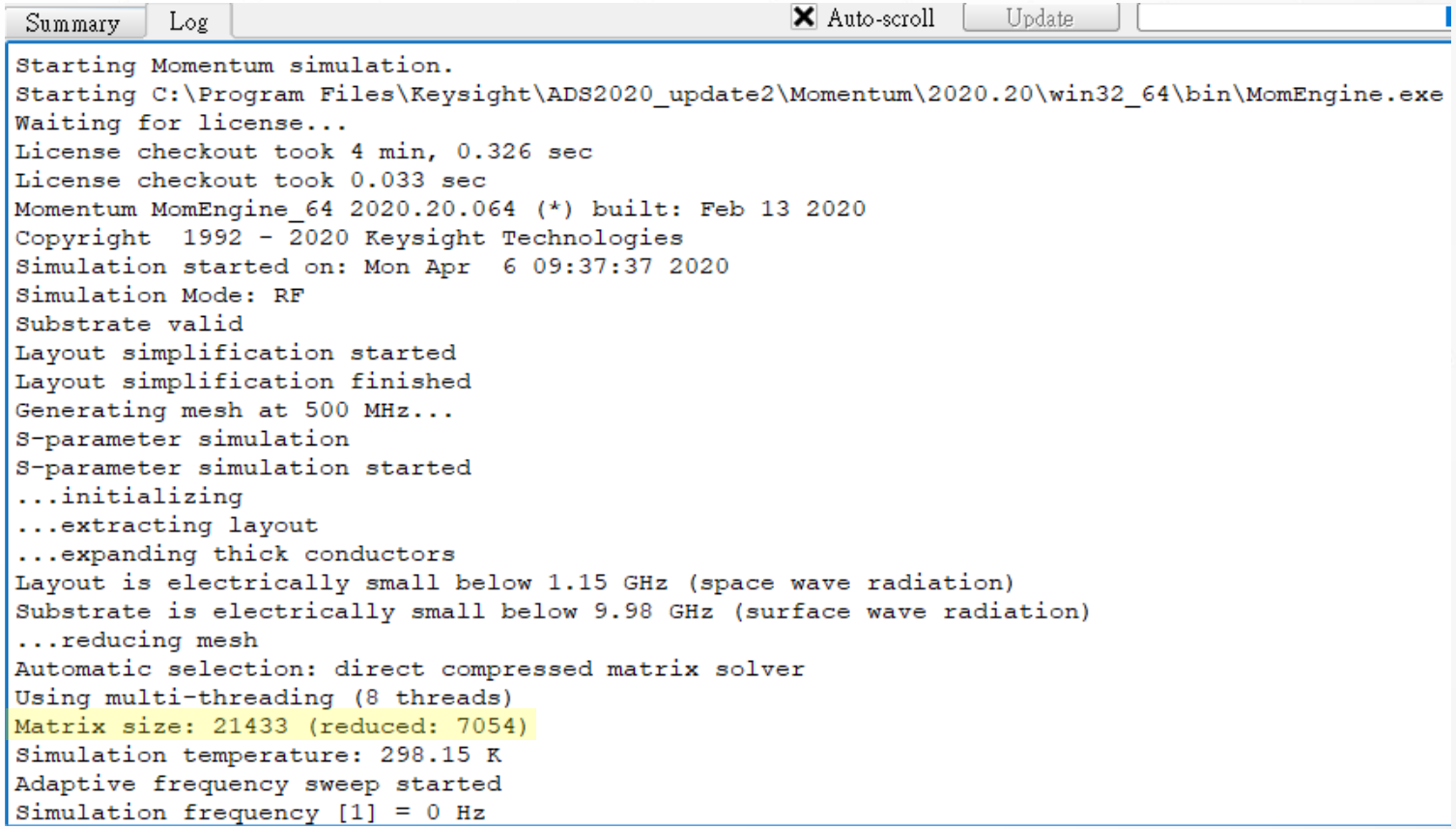
- Panda Board
- FM_ANT_RX
- FM_ANT_IN
- Frequency Range
  - 0~500 MHz





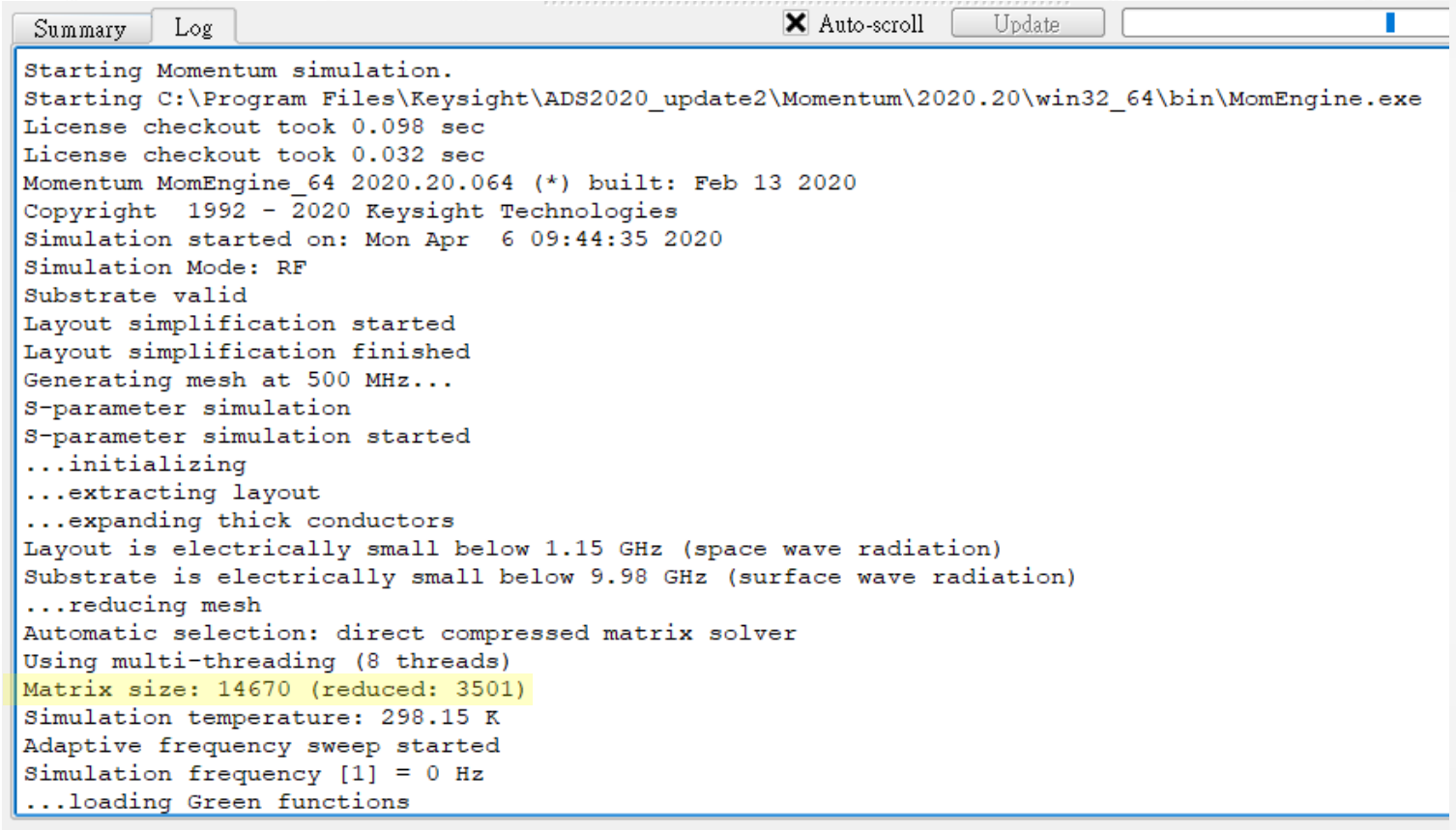
Simulation Result with Automatic Physical Model

- Thick Conductor Model
  - Automatic
- Via Conductor Model
  - Automatic



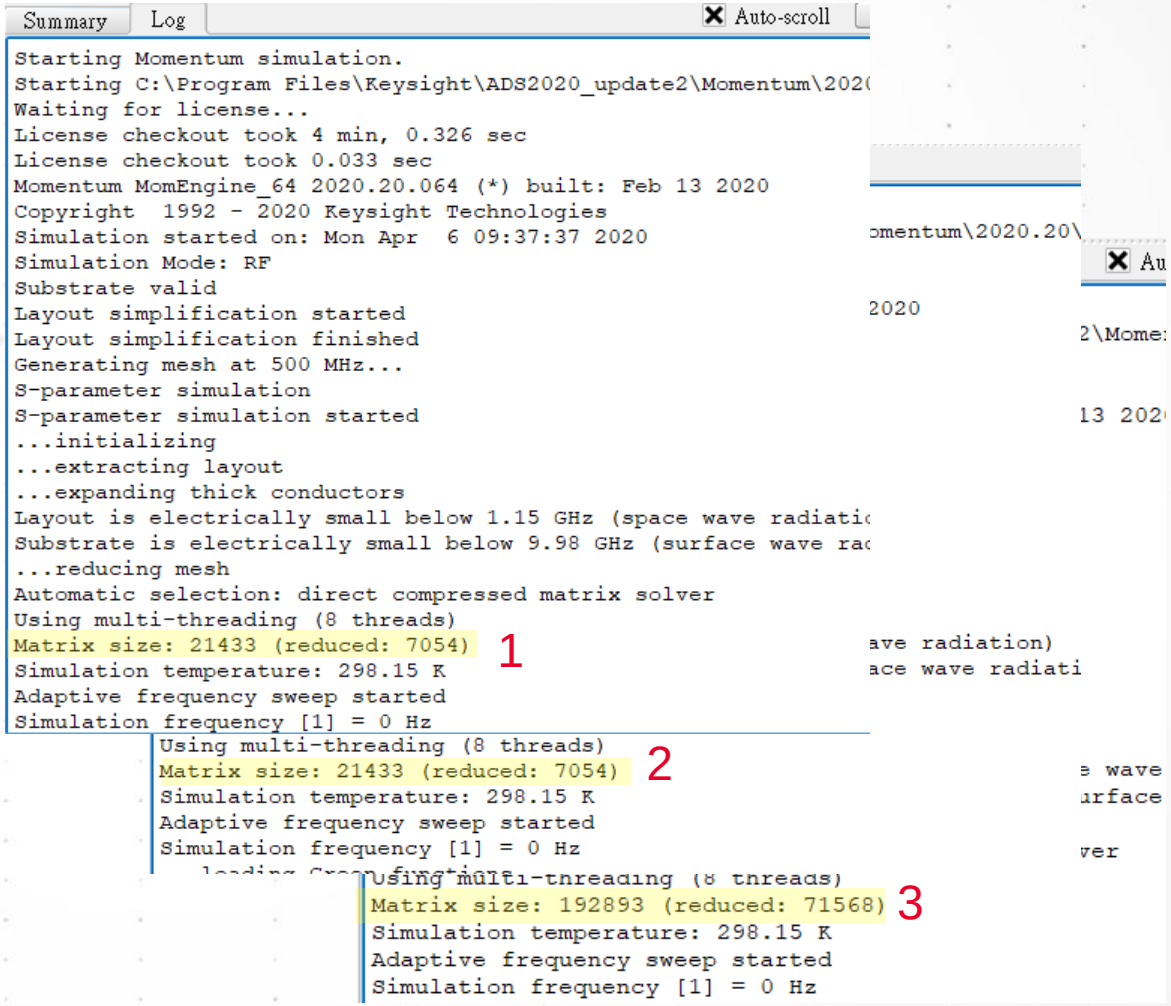
Simulation Result with Manuel Physical Model

- Thick Conductor Model
  - 3D
- Via Conductor Model
  - 2D



Simulation Result with Different Net Type

1. Set D_GND net type as GND
2. Set D_GND net type as PWR
3. Set D_GND net type as SIG



Outline

- Quick review of Momentum
- Lab1: Port Type Overview
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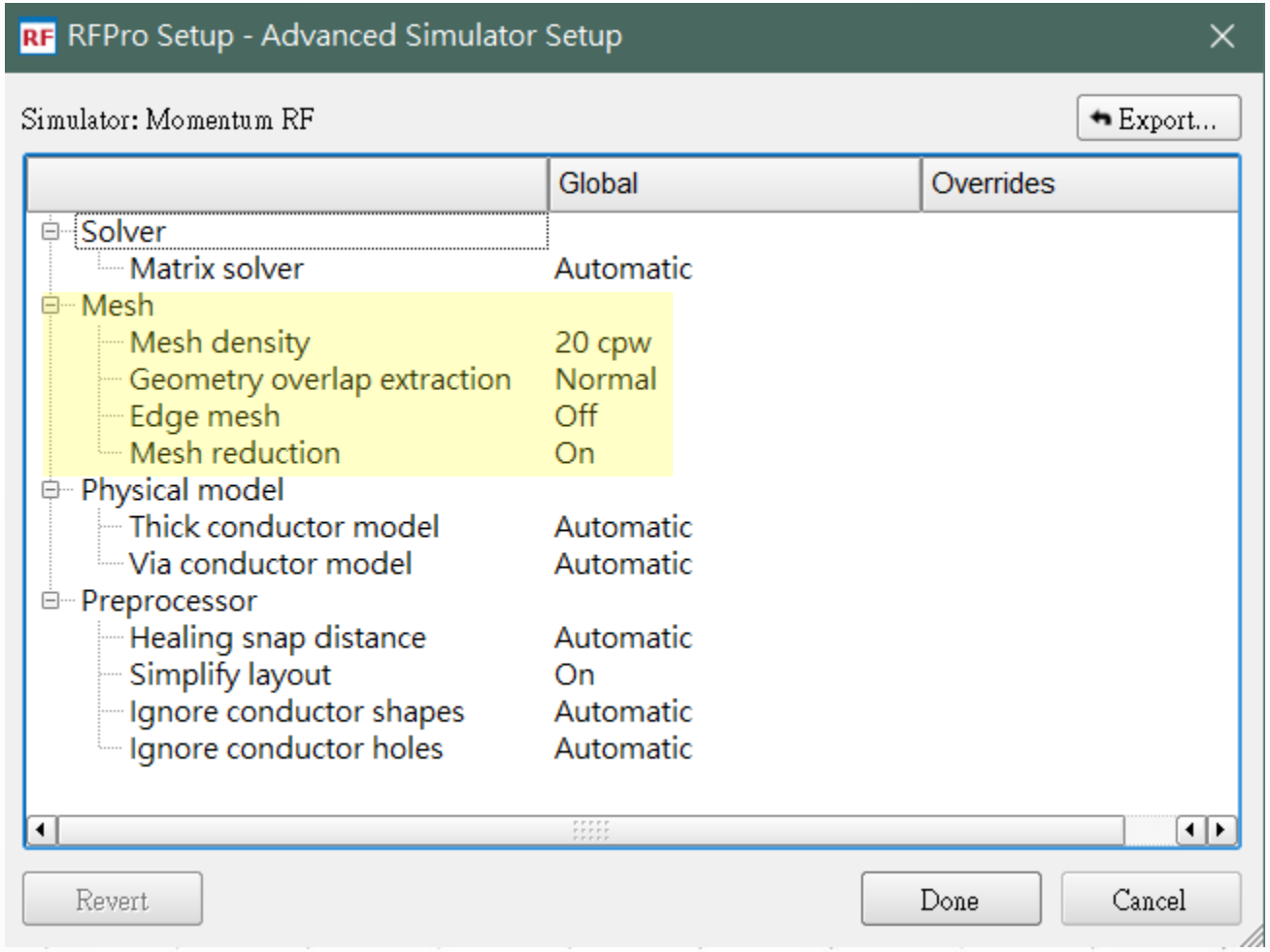
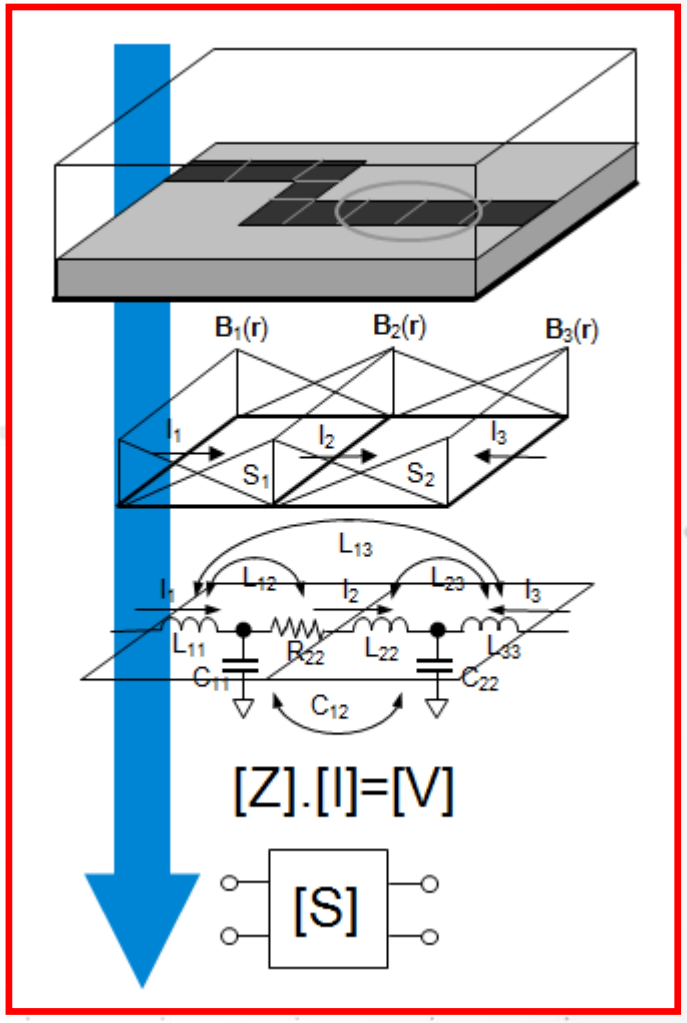
Mesh in RFPro



Momentum Mesh Generator

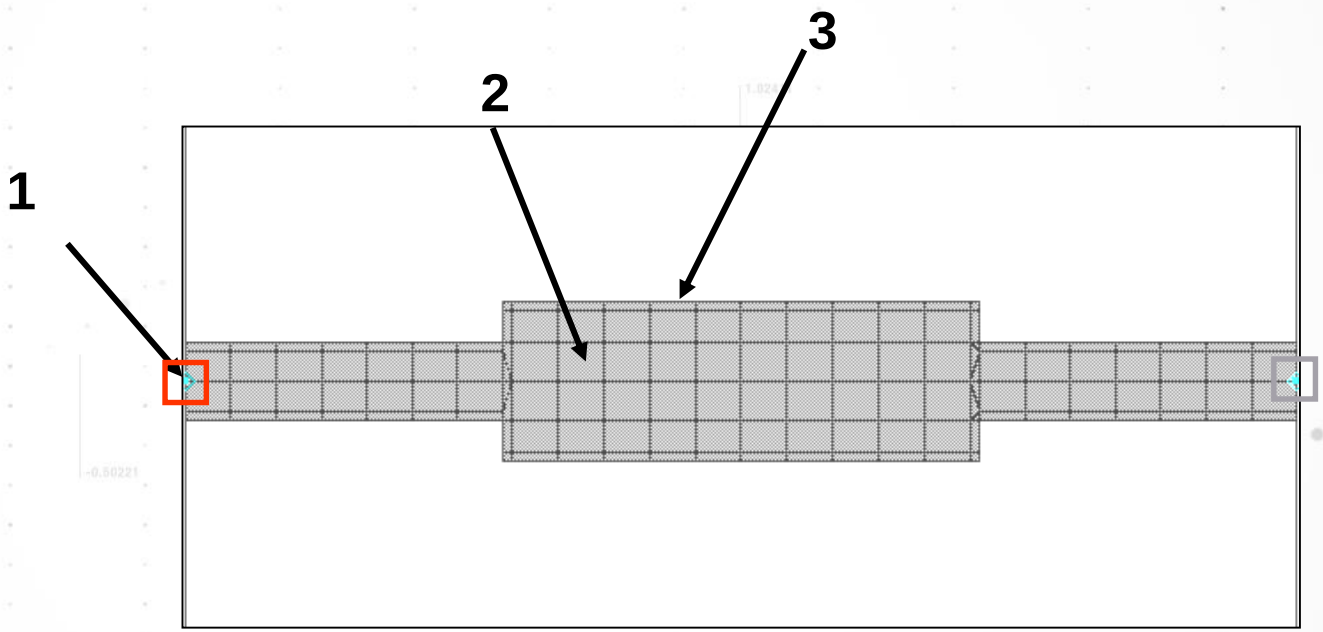
- Layout conforming meshes with quadrilateral, rectangular and triangular cells used to compute currents

- MoM problem can be mathematically thought of as a 3D equivalent circuit network with frequency-dependent R's, L's, and C's
- An impedance matrix is created and then solved that allows us to obtain the current amplitudes based on the excitations at the ports
- Create matrix = Matrix Load (quadruple integrals over surfaces of all cell pairs)



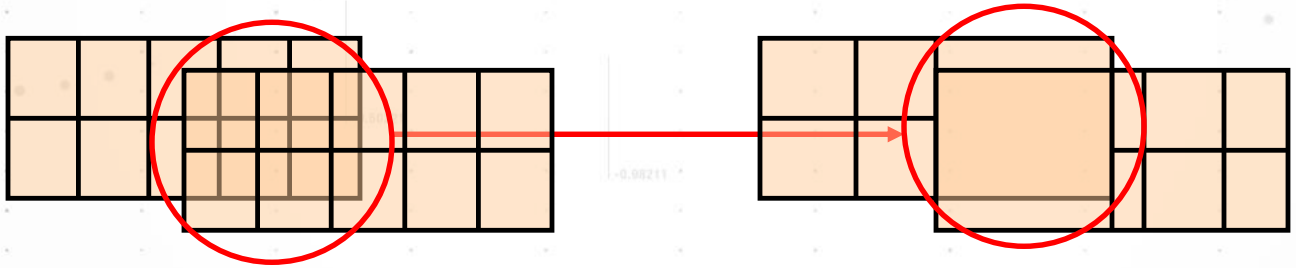
Edge Mesh

- 1 - Port
- 2 - Mesh
- 3 - Edge Mesh



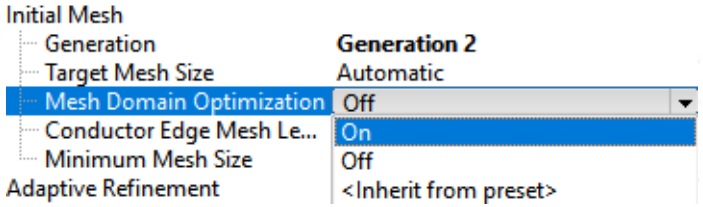
Geometry Overlap Extraction

- Thin Layer Overlap
- If two drawing layers are separated by a thin substrate layer and the mesh cells and object boundaries are not aligned correctly, the simulation data may be less accurate

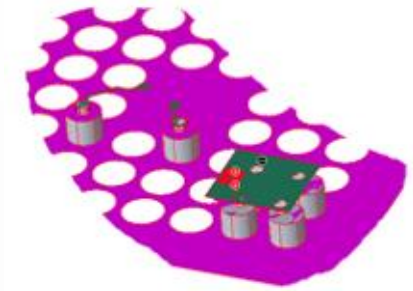


FEM Generation 2 : Mesh-domain optimization

Mesh-domain optimization in Momentum is coming soon.

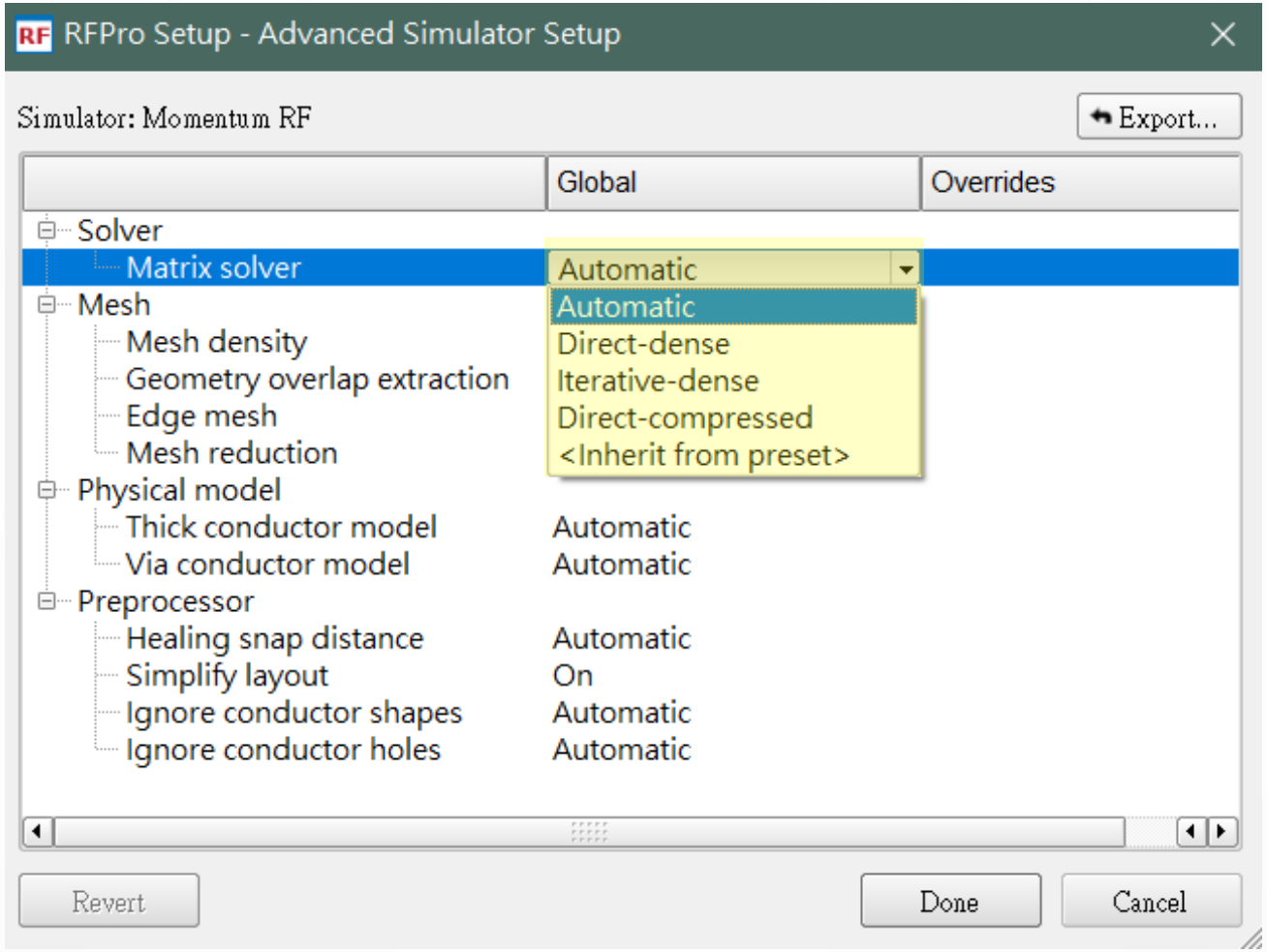


The mesher automatically optimizes the domain to suppress parts where the field is neglectable



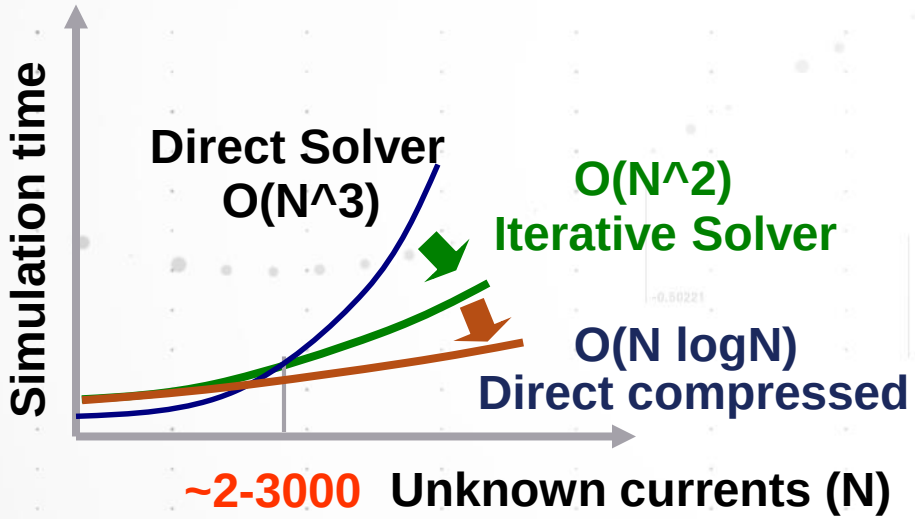
- In case of large ground or power planes, the simulation space might still be too large to be efficient
- ADS 2020 Update 1.0 Mesh Domain Optimization to reduce the simulation space with 2 constraints
  - Much more stable than a cookie cut
- Automatically adapts for several critical nets to be simulated in series
  - No need to multiply layout views for each cookie cut

Solver in RFPro



Solver in RFPro

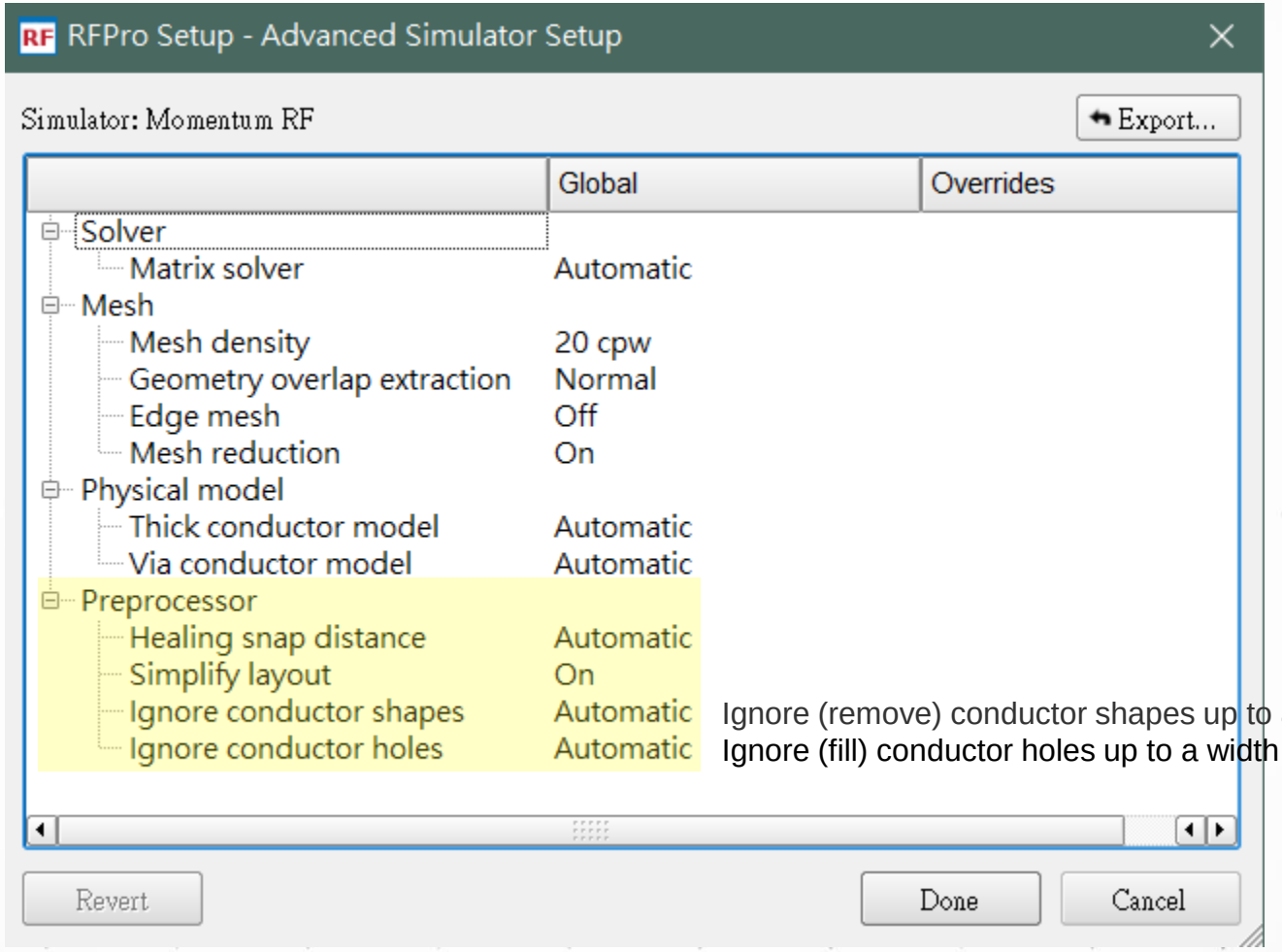
- MoM technology chooses automatically the best solver for your application



CPU time = A + B N + C N 2 + D N 3

where:
N = number of unknowns
The constant term **A** accounts for the simulation set up time.
The meshing of the structure is responsible for the linear term, **BN**.
The loading of the interaction matrix is responsible for the quadratic term and the solving of the matrix equation accounts for:
- Part of the quadratic term (when using the iterative solver)
- The cubic term (when using the direct solver)

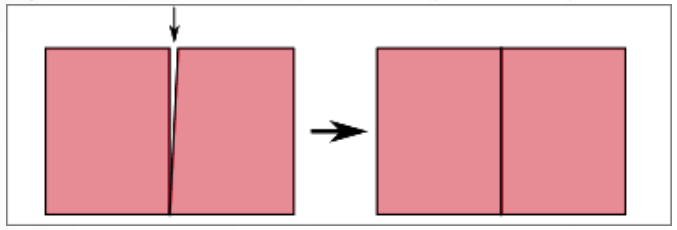
Preprocessor in RFPro



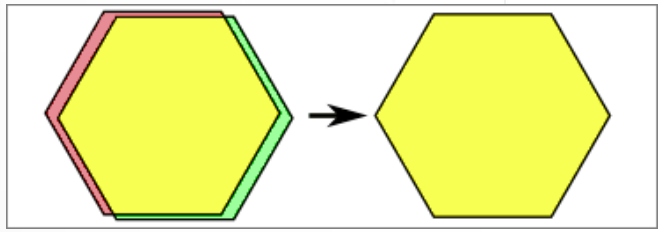
Ignore (remove) conductor shapes up to a width or height of 5 microns.
Ignore (fill) conductor holes up to a width or height of 5 microns.

Layout Healing

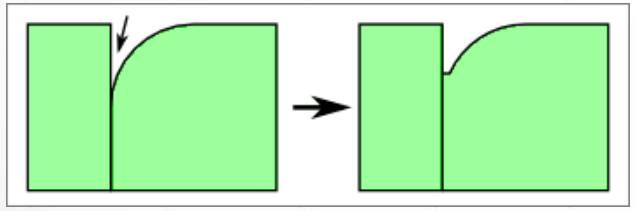
- Closes unintentional gaps between adjacent shapes



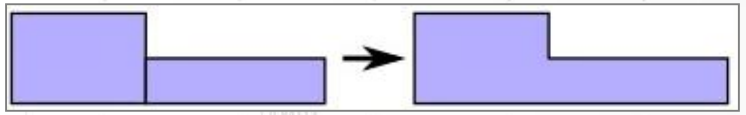
- Ensures that stacked vias have only one joint boundary



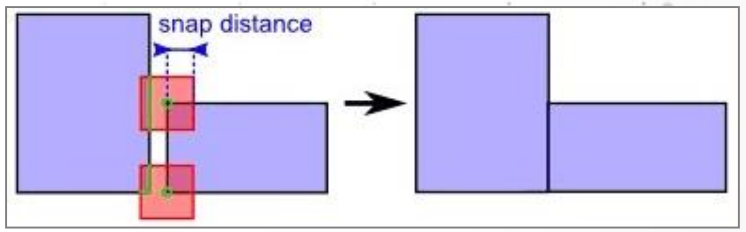
- Eliminates acute angles



- Merge

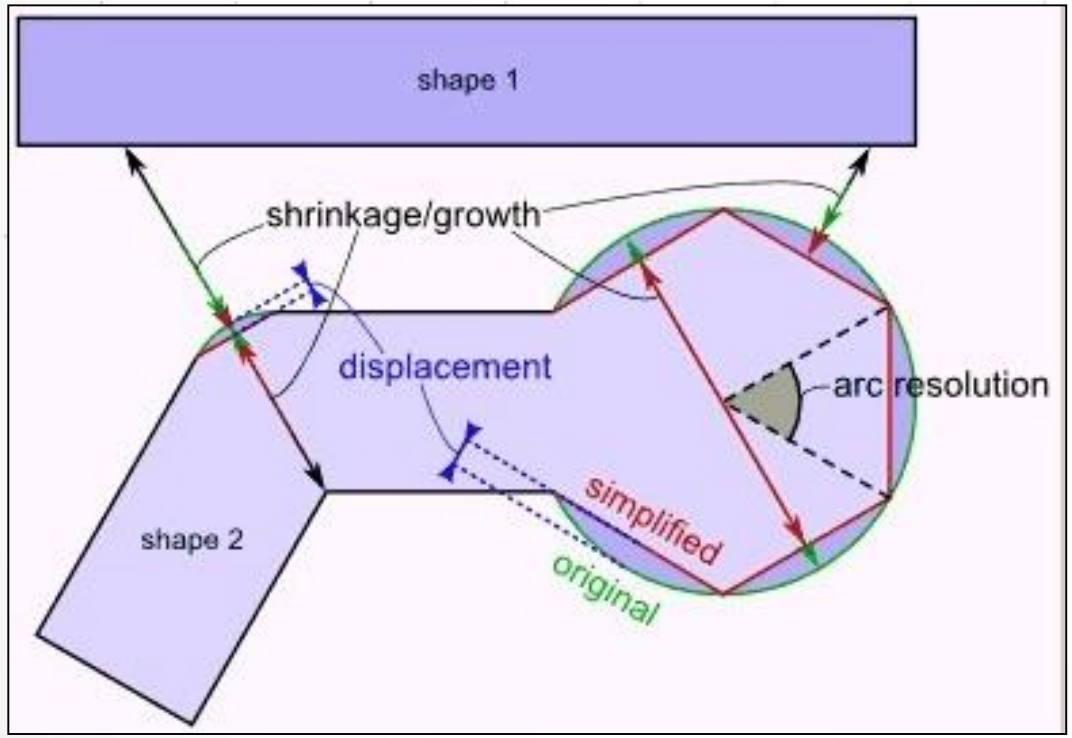


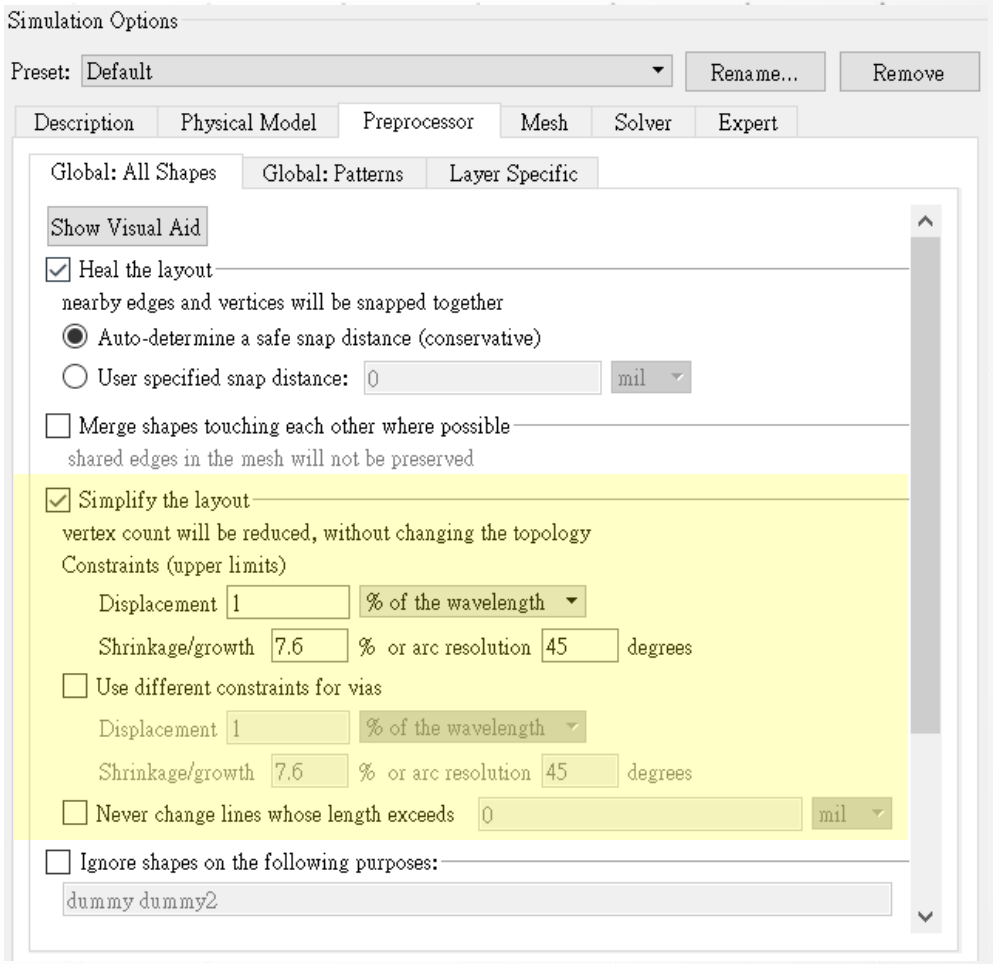
- Snap



Layout Simplification

- Layout simplification is required to reduce number of meshes without loss of accuracy





Guidance RFPro Setup for IC Design

Reasonable defaults for IC Designs:

- Mode: MomRF (switch to MomMW if status window indicates electrically large design)
- Ports: 'Auto'/'Direct' for most ports, TML only if intend design to be included in context with same transmission line widths at those port locations.
- Frequency plan: include DC in frequency plan
- Output Plan: only save currents if necessary for post-processing visualization (also uncheck 'Reduce to decrease size' in Model options if you do wish to visualize currents)
- Physical Model: 3D-distributed thick conductor model, 2D-distributed/Wire via model for most (3D Distributed for via in RF path)
- Preprocessor: displacement=0.1 um or auto, arc resolution = 5 degrees for arcs, 45 degrees for vias, use via merge options and/or metal fill options (when needed)
- Mesh: mesh density 200-1000 cells @ highest frequency, edge mesh (on for sheet conductors, off for thick conductors), thin layer overlap extraction (Normal for MIM caps, off otherwise), consider Layer Specific meshing if need finer/coarser mesh on specific layer(s)
- Solver: if using 'Auto-select' or 'Direct Compressed' ('Direct Dense' guarantees highest accuracy, at potential cost of more RAM and sim time)

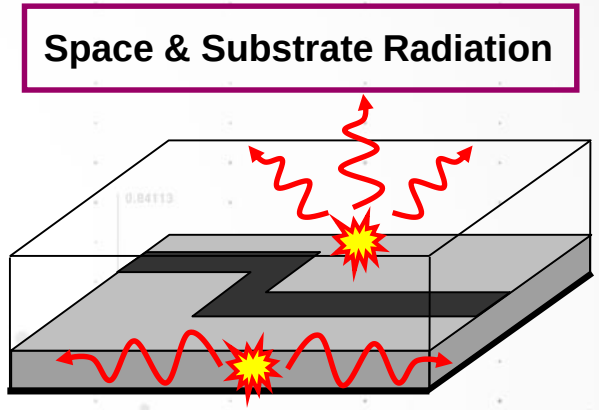
Guidance RFPro Setup for Laminate/PCB

Reasonable defaults for Laminate/PCB Designs:

- Mode: MomRF (switch to MomMW if status window indicates electrically large design)
- Ports: 'Auto'/'Direct' for most ports, TML only if intend design to be included in context with same transmission line widths at those port locations.
- Frequency plan: include DC in frequency plan
- Output Plan: only save currents if necessary for post-processing visualization (also uncheck 'Reduce to decrease size' in Model options if you do wish to visualize currents)
- Physical Model: 3D-distributed thick conductor model, 2D-distributed/Wire via model for most (3D Distributed for via in RF path)
- Preprocessor: displacement=1 um or auto, arc resolution = 5 degrees for arcs, 45 degrees for vias
- Mesh: mesh density 20-60 cells @ highest frequency, edge mesh (on for sheet conductors, off for thick conductors), thin layer overlap extraction off, consider Layer Specific meshing if need finer/coarser mesh on specific layer(s)
- Solver: if using 'Auto-select' or 'Direct Compressed' ('Direct Dense' guarantees highest accuracy, at potential cost of more RAM and sim time)

Momentum RF vs. Momentum Microwave

- Physical structures radiate into free space (spherical waves) and into substrates (cylindrical waves)
- Radiation for electrically small structures is very small
- MomRF mathematically eliminates radiation
- Computes quasi-static Green's functions at a low frequency
- High accuracy possible even at very high frequencies (100 GHz or more) – just depends on electrical size of structure
- Approximate frequency limits are reported in the log file

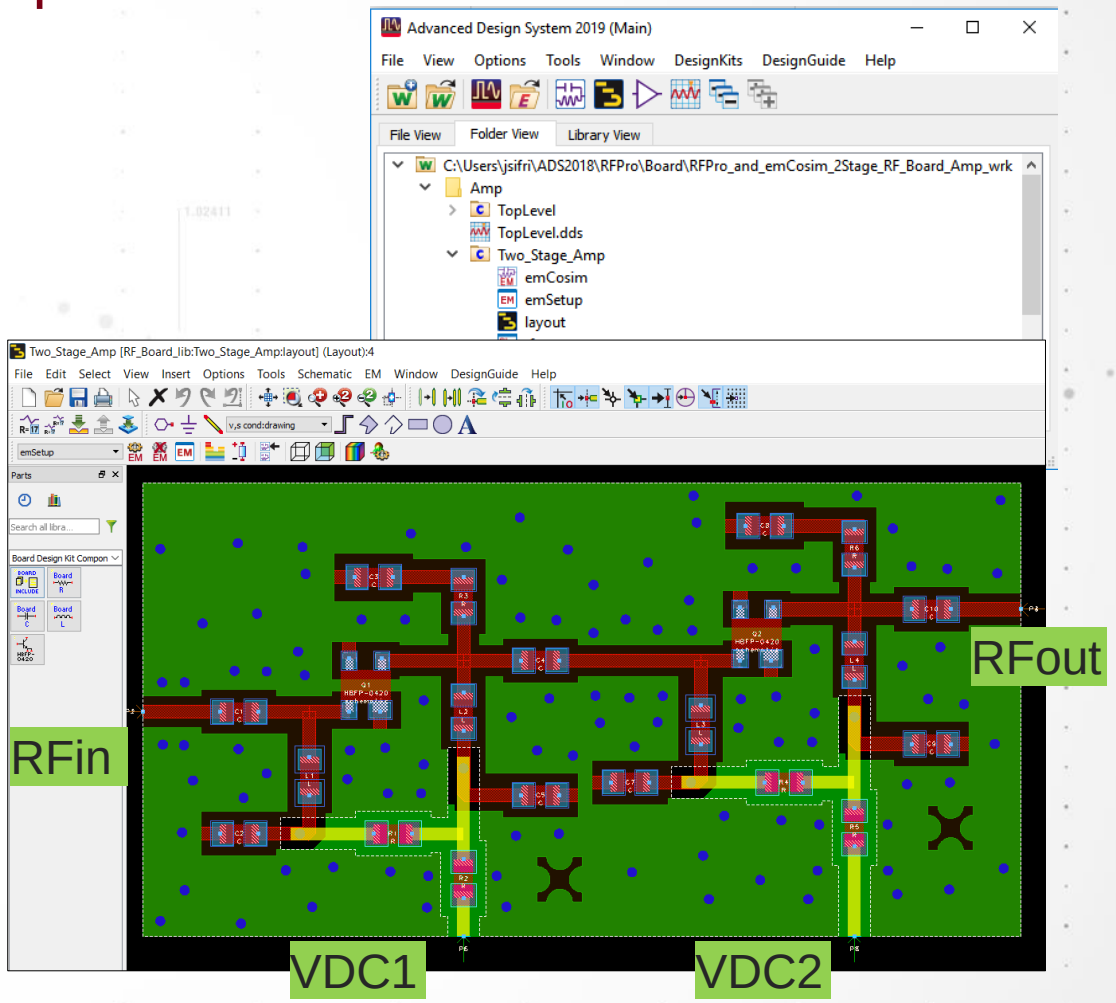



```
S-parameter simulation
S-parameter simulation started
...initializing
Layout is electrically small below 18.4 GHz (space wave radiation)
Substrate is electrically small below 8.05 GHz (surface wave radiation)
...extracting layout
Automatic selection: direct dense matrix solver
Using multi-threading (2 threads)
Adaptive frequency sweep started
Simulation frequency [1] = 0 Hz
```

Lab3 - RFPro EM-cosimulation

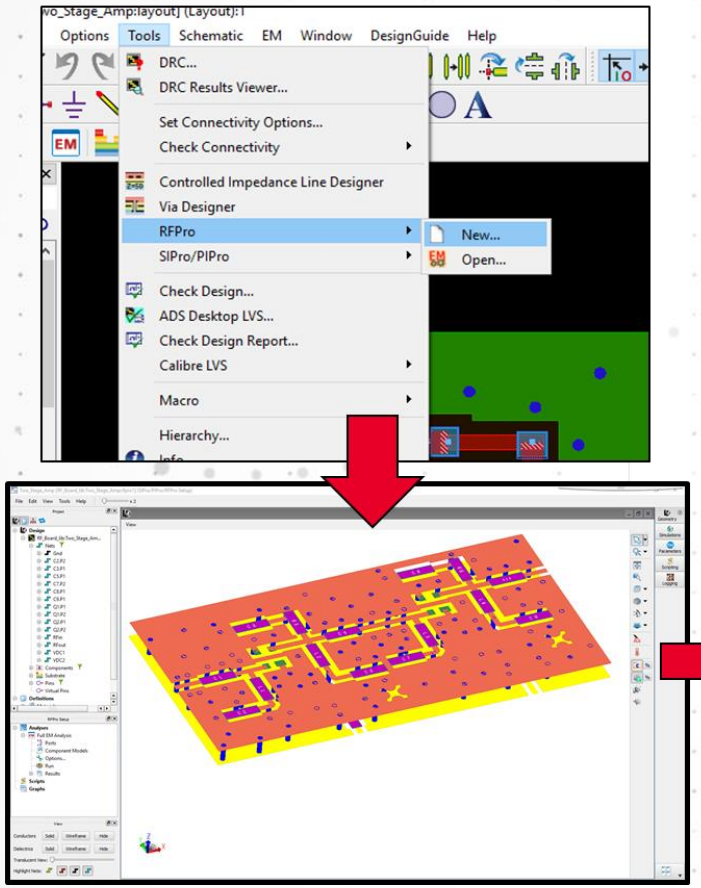
Two-Stage RF Board Amplifier with SMT Components

- A 2-stage LNA built on a 2-layer board.
- SMT components (transistors, capacitors, inductors, resistors) are from a board design kit, all have component models.
- Interconnect lines are Layout based and will be simulated with EM.
- There are 4 ports (8 pins)
  - 2 pins RFin (Signal, Gnd)
  - 2 pins RFout (Signal, Gnd)
  - 2 pins VDC1 (Power, Gnd)
  - 2 pins VDC2 (Power, Gnd)

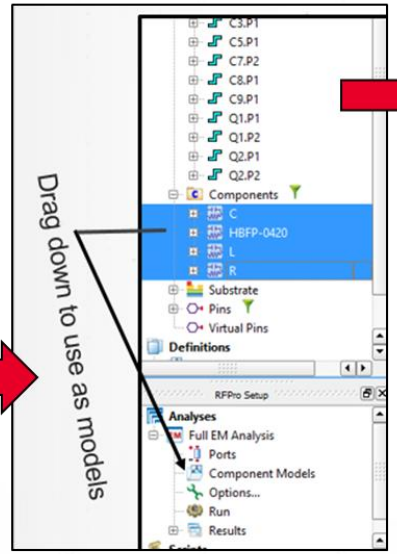


Three Main Steps to RFPro

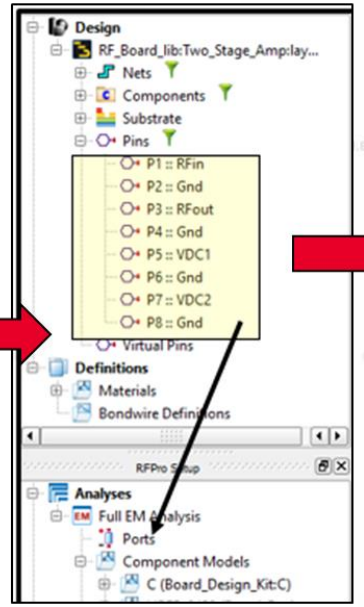
Start RFPro from Layout page



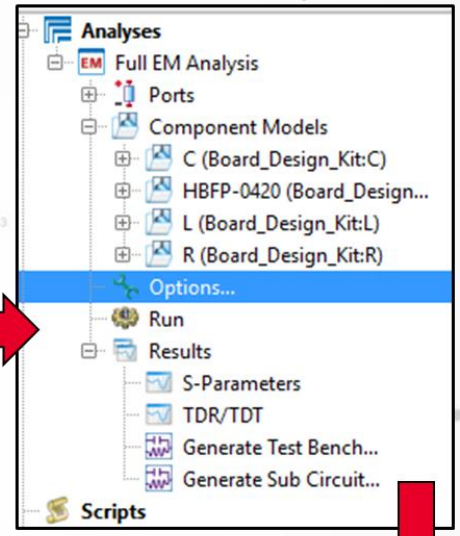
1- Drag down circuit model components into analysis section



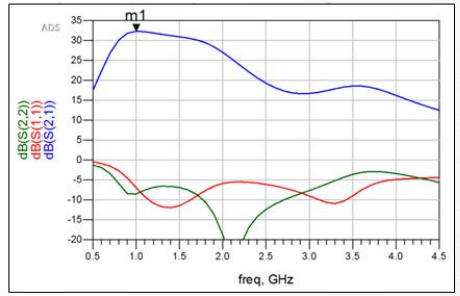
2- Drag down Pins into analysis section to form Ports



3- Setup the simulation frequency and EM Simulator in "Options"



Run simulation

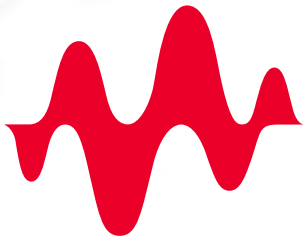


Outline

- Quick review of Momentum
- Lab1: Port Type Overview
- Lab2: Net Type Setup for Physical Model Simplified
- Lab3: Understand Mesh, Solver and Preprocessor
- Summary

Summary

- This Webinar help users to understand the port type (calibration type), physical model, mesh, solver and preprocessor setting of MoM technology (Momentum) in RFPro.
- There are different factors having to be taken into account when modeling. User have to understand the difference between condition to get accurate results. It is important to seek balance between cost and accuracy.
- ADS RFPro not only can do EM & Circuit co-simulation easily, but also check TDR/TDT impedance, near-field, far-field directly. It’s a useful tool for users to analyze simulation quality.



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