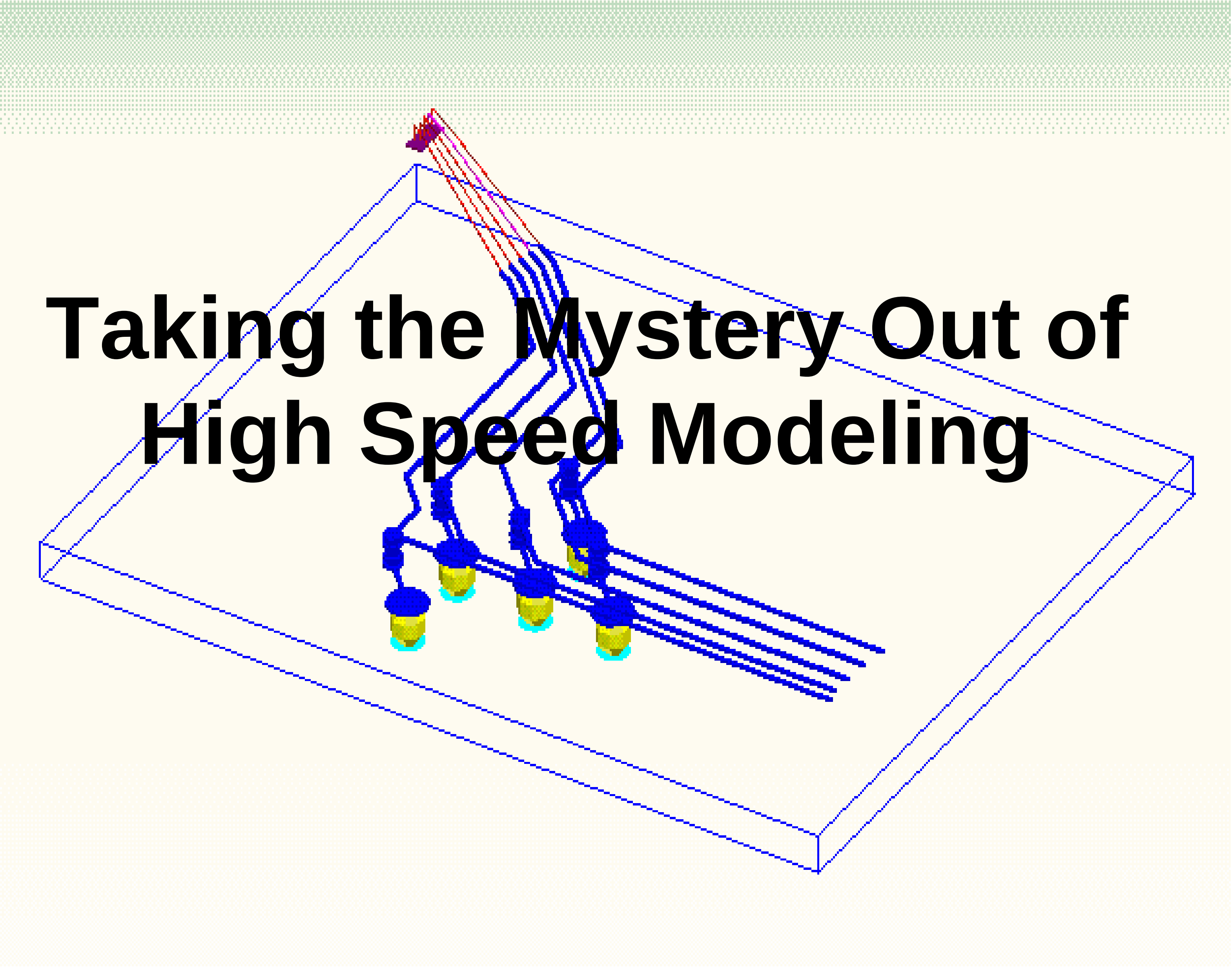
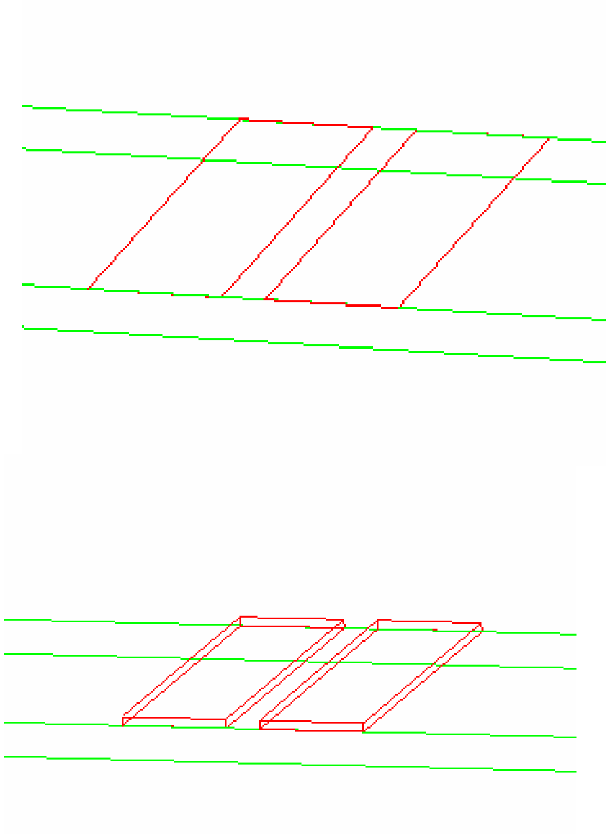
Taking the Mystery Out of High Speed Modeling



Boundary Setup

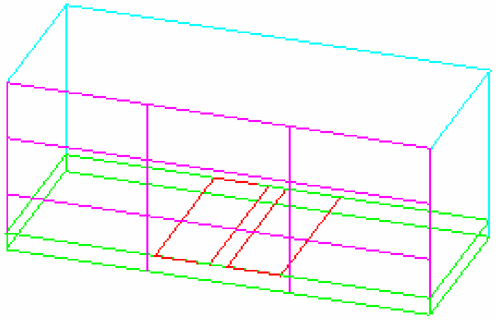


- 2D vs. 3D Metal
  - 3D metal properties are defined in the material setup
  - 2D metal properties are defined in the boundary setup
  - 2D metal definition is recommended if skin depth and edge coupling are not major concerns
- Perfect E vs. Finite Conductivity Boundary Definitions
  - HFSS uses less RAM and time to solve problems with perfect E metal definitions
    - Perfect E boundary consists of real matrices instead of complex ones
  - Add metal losses at the end of simulation for accurate loss calculation

Boundary Setup (cont.)

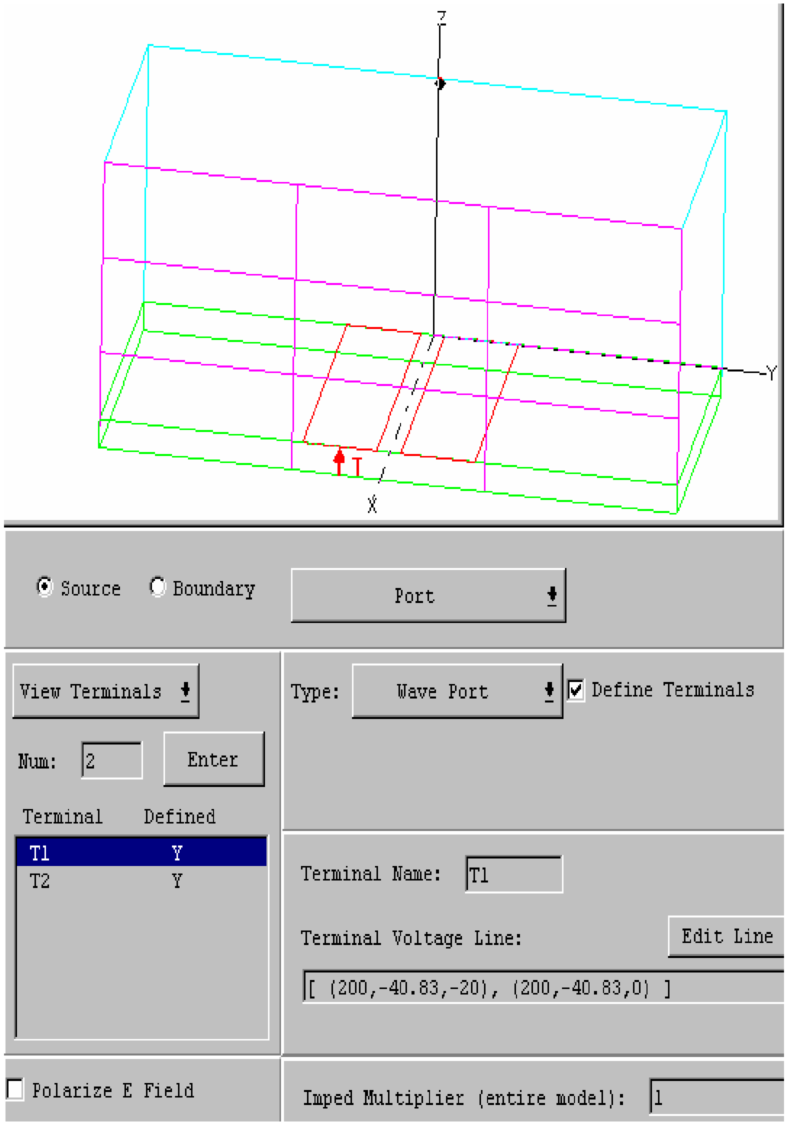
- Radiation Boundary vs. PML
  - Recommended spacing for radiation boundary is lamda/4 while for PML, it is lamda/6.
    - In general, PML boundaries can be placed closer to the structure
  - Depending on the angle of incidence, some reflections will exist for radiation boundaries
  - PML boundaries have zero reflections
  - Radiation boundaries is a boundary condition
    - Definition is the 2^{nd} order boundary condition that approximates free-space
  - PML is part of the solution space
    - Definition is a set of “fictitious” biaxial anisotropic material

Source Setup – Wave Port



- Traditional ports must be planar
- Traditional ports must have material properties of metal on one side of its surface
- Port size must be made large enough to include fringing fields
  - For microstrip lines with trace width w and dielectric height h
    - Recommended port height: between 6h to 10h
    - Recommended port width: for w >= h, 10w and for w<h, 5w
  - For stripline with trace width w and dielectric height h
    - Recommended port height: between top and bottom ground planes
    - Recommended port width: for w >= h, 8w and for w<h, 5w
- For use in time domain simulations, a terminal-based description in terms of voltages and currents is more useful than the traditional modal S-matrix

Source Setup – Wave Port (cont.)



● Source ○ Boundary

Type: Wave Port ☑ Define Terminals

Num: 2

Terminal	Defined
T1	Y
T2	Y

Terminal Name: T1

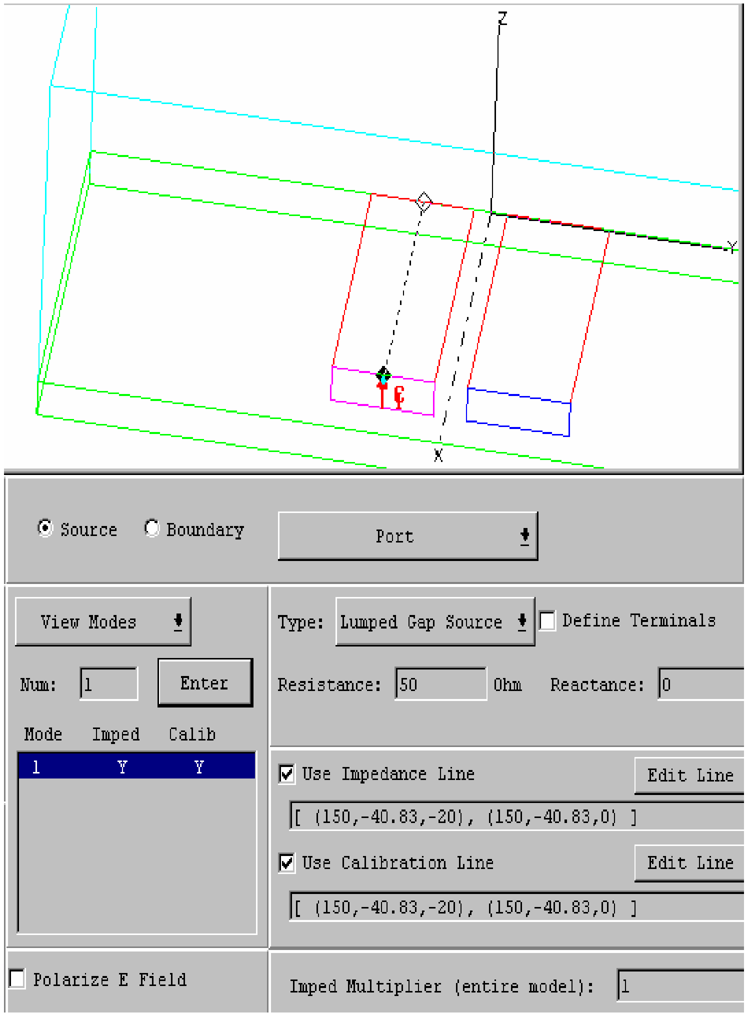
Terminal Voltage Line: [(200,-40.83,-20), (200,-40.83,0)]

☐ Polarize E Field

Imped Multiplier (entire model): 1

- Terminal lines must be created to define port voltages
- The number of terminals on each port must equal the number of modes for the port
- For multi-conductor transmission line ports, define one mode per conductor
- The maximum number of modes per port is 25
- The maximum number of ports allowed is 100

Source Setup – Lumped Gap Port



● Source ○ Boundary

Port

Type: Lumped Gap Source ☐ Define Terminals

Num: 1

Resistance: 50 Ohm Reactance: 0

Mode	Imped	Calib
1	Y	Y

☑ Use Impedance Line

[(150,-40.83,-20), (150,-40.83,0)]

☑ Use Calibration Line

[(150,-40.83,-20), (150,-40.83,0)]

☐ Polarize E Field

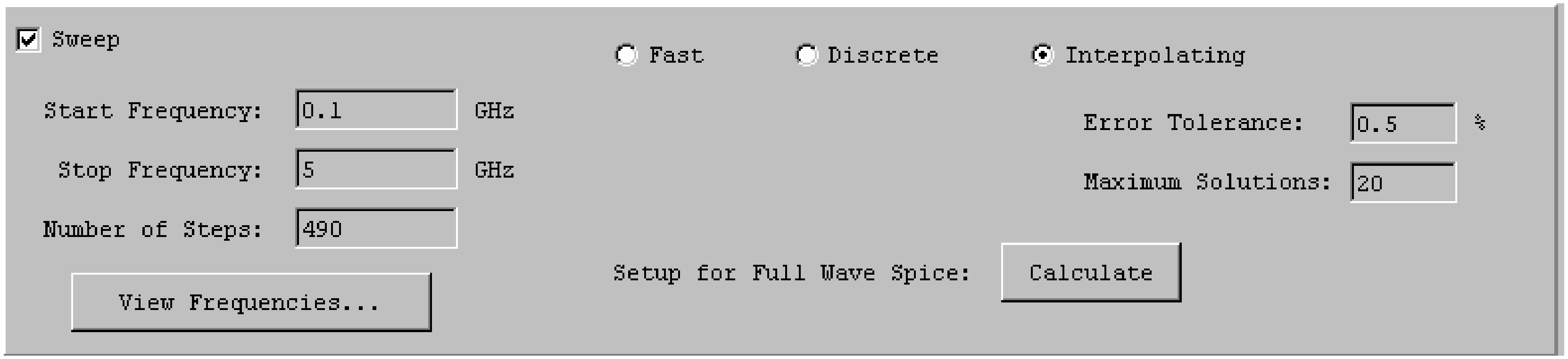
Imped Multiplier (entire model): 1

- Lumped gap ports must be planar
- Unlike traditional wave ports, gap ports can be defined internal to a structure and do require a metal surface as boundary
- Lumped gap ports need not be as big as the traditional wave ports
- A calibration and impedance line must be defined for a gap port
- The complex impedance must be non-zero and the resistance must be non-negative
  - The user defined complex impedance is used as reference impedance for the S matrix
- Only one terminal should be assigned to each gap port since only one port mode is allowed for each lumped gap port

Solution Setup

- Set the adaptive frequency to .5 ($1/t_{rise}$) and set your S matrix convergence to the desired level. (Do not run a frequency sweep just yet)
- When a convergence to the criteria in the step above is done, set the adaptive frequency to ($1/t_{rise}$) and set the number of passes to 3 and run the solver again
- Now you can run a frequency sweep
  - For full wave spice results, make sure you select an “interpolative” sweep
  - Use the calculator available to find the required frequency setting for your sweep
    - The frequency settings will depend on the signature of the time domain signals for your application
- Make sure you select the “Current” Mesh as your starting Mesh

Difference between Sweep Options



☑ Sweep

○ Fast ○ Discrete ● Interpolating

Start Frequency: 0.1 GHz

Stop Frequency: 5 GHz

Number of Steps: 490

Error Tolerance: 0.5 %

Maximum Solutions: 20

Setup for Full Wave Spice:

- Fast Frequency sweep solves for all the poles and zeros of the transfer function
  - For a well behaved structure, much time and resources are wasted
  - Poor error indicator
- Discrete Frequency is based on the current mesh and resolved for each frequency in the band that the user specified, this can take a long time for a large number of frequency steps
  - If you reduce the number of steps, you lose solution information
- Interpolative Frequency is based on interpolated results matched to error tolerances
  - For well behaved structures, interpolation between frequency points results in a fast solution
  - Better suited for very wide frequency bands

Mesh Options

- For structures with metal thickness because of skin depth concerns, seeding can be used to assist the mesher
    - For 3D metals, be sure to set the “Solve Inside” button in the material setup
    - Under Define Seed Operations, select all the 3D metals and seed the object face by skin depth
        - The relative Permeability, conductivity, and frequency information is required to use the internal skin depth calculator supplied within HFSS
- For structures with strongly coupled fields between signals line, virtual objects can be created to improve the mesh
    - Seeding can also be applied to these virtual objects to arrive at a more accurate solution faster

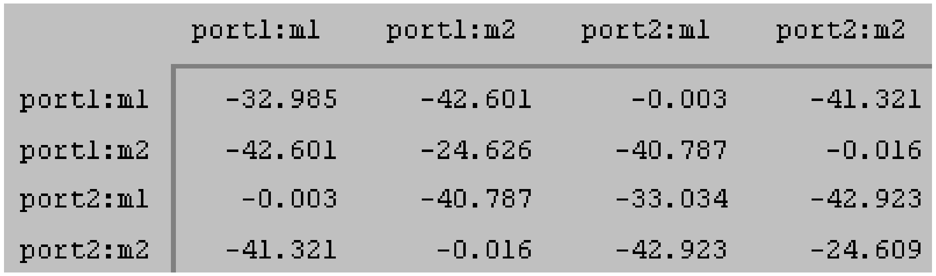
Mesh Options (cont.)

- Further mesh refinement can be added even after the problem has been solved if the mesh between highly coupled signals is not dense enough
  - In this case, define a manual mesh for the structure by performing a mesh refinement on the desired objects
- Another thing that can be done to improve the mesh is the addition of virtual objects in the model
  - Virtual objects are smaller objects within large dielectric material objects to help improve the quality of the mesh

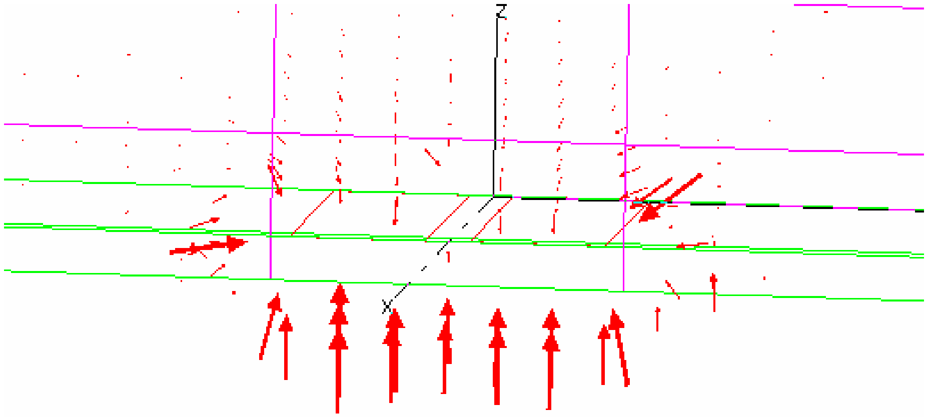
Differential Pair Setup

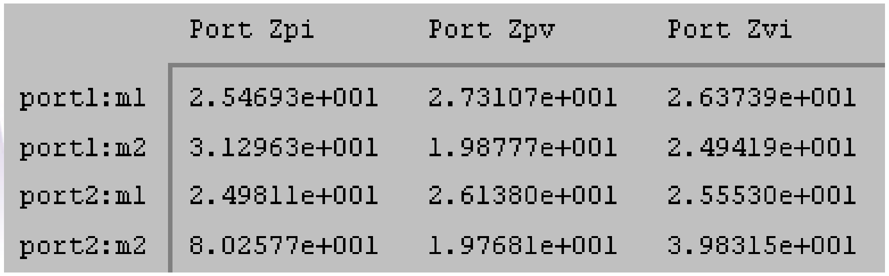
- Results based on differential excitation can be seen in HFSS before export into Spice by setting up differential pairs for a multiple transmission lines for a port
- A minimum of two transmission lines are required on a single port for differential setup
- A differential pair represents two circuits, one with positive excitation and the other with negative excitation on the port
- Differential pairs can be setup before a solve or after one by invoking “Setup Executive Parameters” in the Executive Commands
- A comparison of noise rejection to the conventional “single-ended” signal can be done by changing the terminal impedance of the differential pair to its best reference impedance

Post Processing
(Modal Matrix)



	port1:m1	port1:m2	port2:m1	port2:m2
port1:m1	-32.985	-42.601	-0.003	-41.321
port1:m2	-42.601	-24.626	-40.787	-0.016
port2:m1	-0.003	-40.787	-33.034	-42.923
port2:m2	-41.321	-0.016	-42.923	-24.609

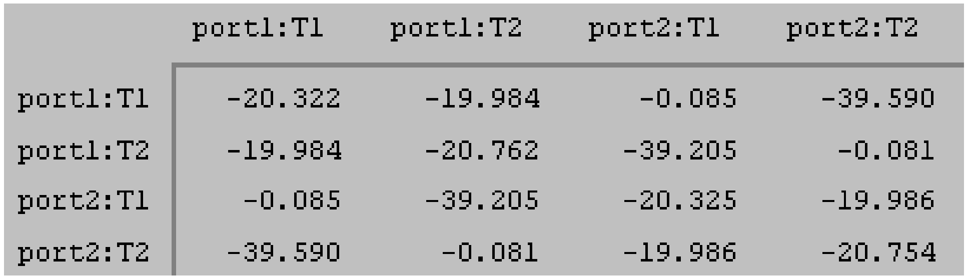




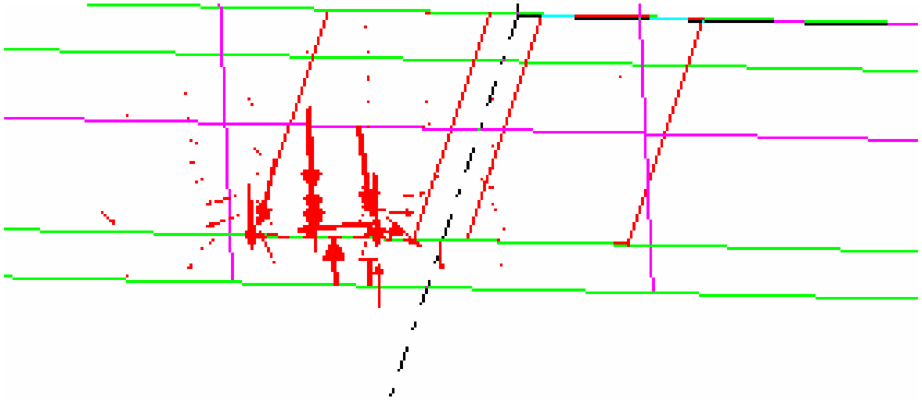
	Port Zpi	Port Zpv	Port Zvi
port1:m1	2.54693e+001	2.73107e+001	2.63739e+001
port1:m2	3.12963e+001	1.98777e+001	2.49419e+001
port2:m1	2.49811e+001	2.61380e+001	2.55530e+001
port2:m2	8.02577e+001	1.97681e+001	3.98315e+001

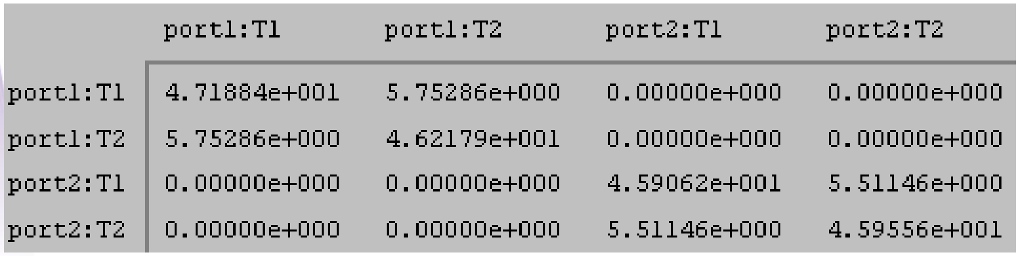
- S Matrix Results with in dB at 5 GHz
- No Terminal line, Port fields results
- Port Impedance Matrix at 5 GHz

Post Processing (Terminal Matrix)



	port1:T1	port1:T2	port2:T1	port2:T2
port1:T1	-20.322	-19.984	-0.085	-39.590
port1:T2	-19.984	-20.762	-39.205	-0.081
port2:T1	-0.085	-39.205	-20.325	-19.986
port2:T2	-39.590	-0.081	-19.986	-20.754

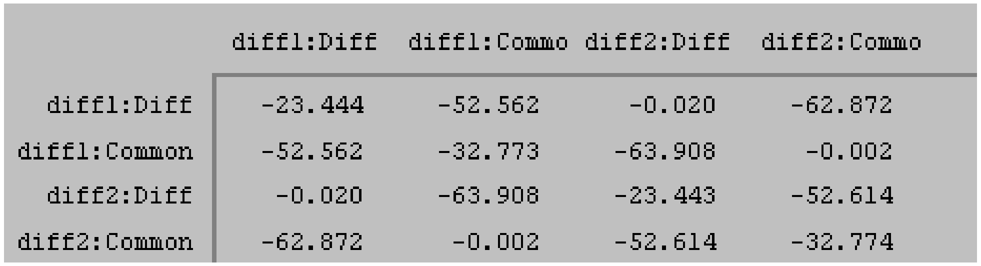




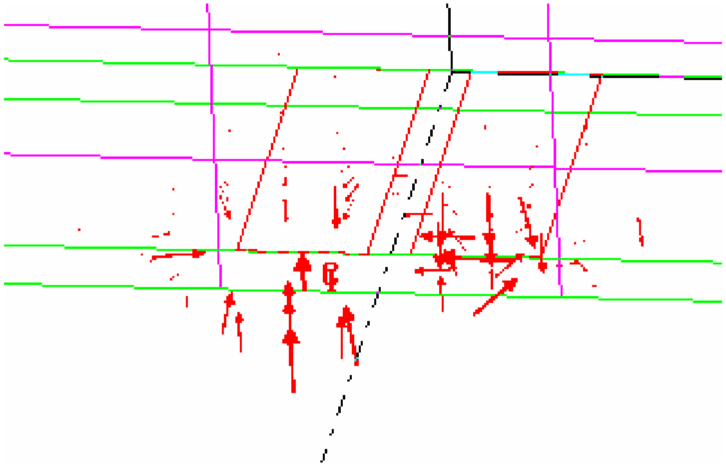
	port1:T1	port1:T2	port2:T1	port2:T2
port1:T1	4.71884e+001	5.75286e+000	0.00000e+000	0.00000e+000
port1:T2	5.75286e+000	4.62179e+001	0.00000e+000	0.00000e+000
port2:T1	0.00000e+000	0.00000e+000	4.59062e+001	5.51146e+000
port2:T2	0.00000e+000	0.00000e+000	5.51146e+000	4.59556e+001

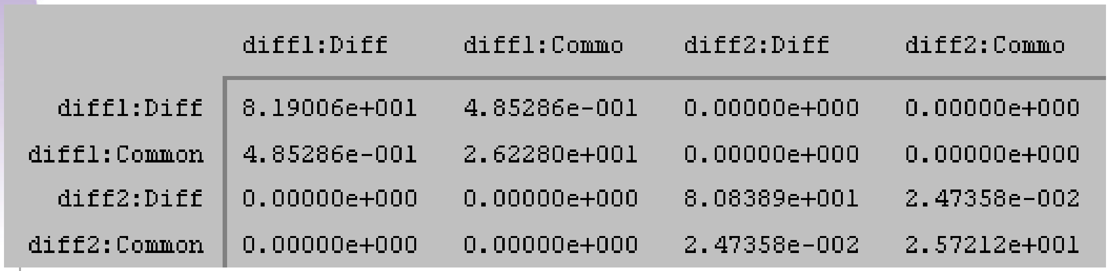
- S Matrix Results with in dB at 5 GHz
- With Terminal line, Port fields results for terminal 1
- Port Impedance Matrix at 5 GHz

Post Processing (Differential Matrix)



	diff1:Diff	diff1:Commo	diff2:Diff	diff2:Commo
diff1:Diff	-23.444	-52.562	-0.020	-62.872
diff1:Common	-52.562	-32.773	-63.908	-0.002
diff2:Diff	-0.020	-63.908	-23.443	-52.614
diff2:Common	-62.872	-0.002	-52.614	-32.774

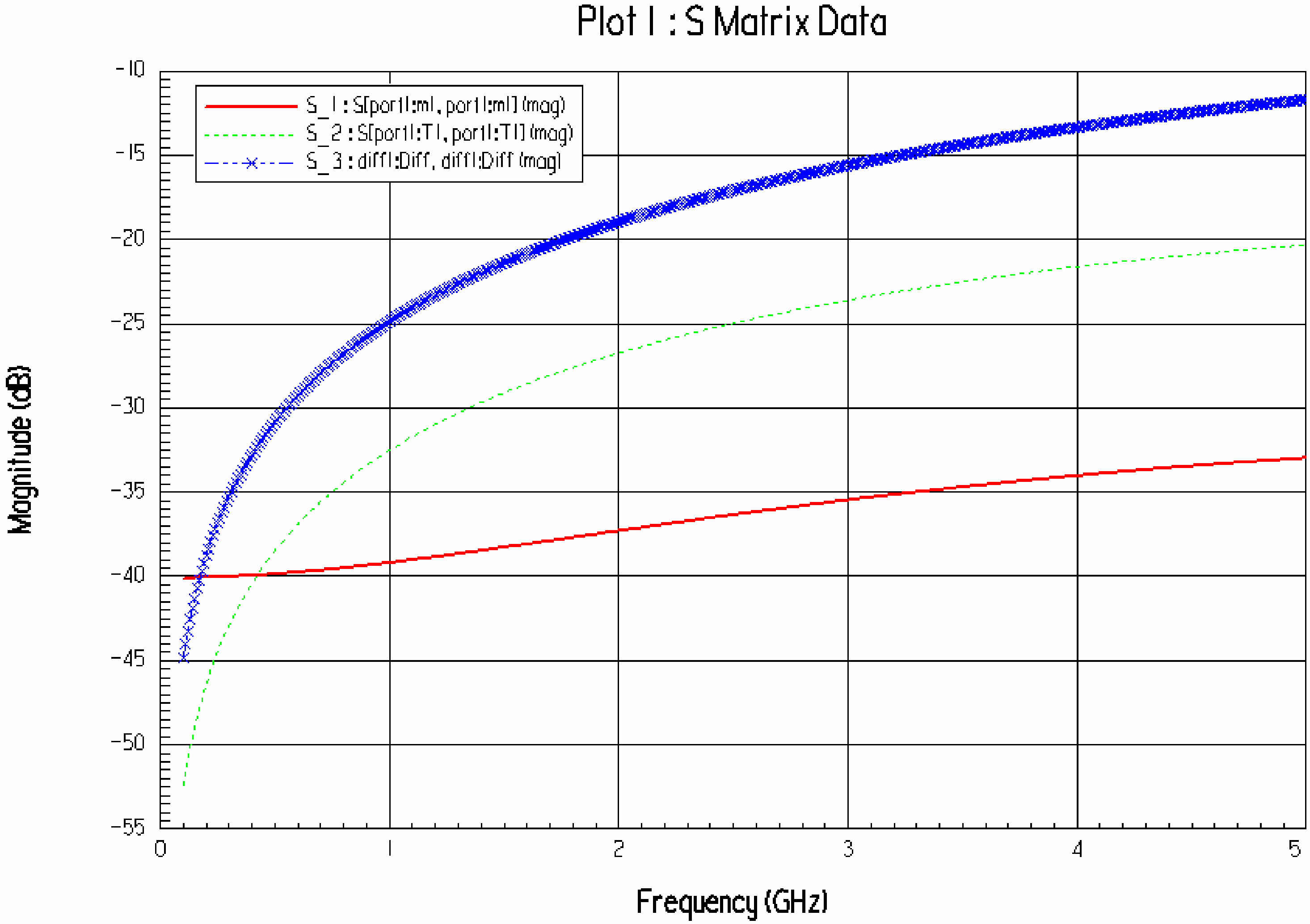




	diff1:Diff	diff1:Commo	diff2:Diff	diff2:Commo
diff1:Diff	8.19006e+001	4.85286e-001	0.00000e+000	0.00000e+000
diff1:Common	4.85286e-001	2.62280e+001	0.00000e+000	0.00000e+000
diff2:Diff	0.00000e+000	0.00000e+000	8.08389e+001	2.47358e-002
diff2:Common	0.00000e+000	0.00000e+000	2.47358e-002	2.57212e+001

- S Matrix Results with in dB at 5 GHz
- Differential Excitation, Port fields results
- Port Impedance Matrix at 5 GHz

Setting the Correct Impedance for Renormalization for the Differential Matrix (1)



high performance EDA

Setting the Correct Impedance for Renormalization for the Differential Matrix (2)

- After an interpolative sweep, use the post processed matrix data to calculate the impedance matrix
  - Make sure that all the differential pairs defined are selected and that the reference impedance for all the terminals are set to: Real: 50 ohms, Imag: 0 ohms
  - Look at the terminal Zo for the matrix you just calculated in the previous step
    - Look at the values of the matrix at a frequency in the sweep (recommendation: either the adaptive frequency or the highest frequency)
  - Use only the diagonal elements
    - Use the diff diff terminal Zo as the reference impedance for normalization for terminal 1
    - Use the common common terminal Zo as the reference impedance for normalization for terminal 2
  - Re-compute the terminal matrix for the differential pairs using the impedance found in the previous step

Setting the Correct Impedance for Renormalization for the Differential Matrix (3)