EMPro Solving Challenges of 3D EM Designs

The Power Of Integration

Agilent EEsof EDA
Agilent EEsol EDA EM Product Vision

Provide the industry’s most complete selection of EM simulation technologies (MoM, FEM and FDTD) closely integrated in a consistent design flow and suited to our customer’s applications.
Three Most Popular EM Simulation Technologies

Method of Moments (Momentum G2 in ADS 2009) – LTCC, Multilayer…

Finite Element Method (EMDS G2 in ADS 2009) – Packages, Bondwires…

Finite Difference Time Domain (EMPro 2008) – Antennas, SI…
What is EMPro

Industry’s Latest 3DEM Design Platform

• Most modern architecture
• Interactive, Intuitive, Efficient, 3DEM design Environment
• Windows & Linux

Fastest, Highest Capacity

• Full Wave 3D EM FDTD/FEM Simulation Technology
• Up to 40x faster than traditional technology

Integrates with ADS

• Parameterize 3D EM components for co-simulation & optimization in ADS
• Transfer ADS Layouts to EMPro for additional 3D-EM simulation
• Access 3DEM without leaving your favorite RF-MW design environment
Advanced Design System: The HF/Hi-Speed Co-Design Platform

“A major restriction in the adoption of full 3D electromagnetic simulation by designers is the overhead in learning how to draw and setup the simulator…integrating 3D EM into the familiar interface enables the next wave of electromagnetic simulations to be adopted by design engineers.”
Typical Simulation Flow Without Integrated 3D EM

START

1. ADS Layout
2. Export GDS file (Simplified, octagonal vias)
3. Import GDS file into other 3rd party EM tools
4. Assign material information
5. Small geometry modifications for tool compliance
6. Export port locations to a .MSK file
7. Auto-generate Ports (Only when needed)
8. Run a custom program to obtain a script file to auto-generate ports in other 3rd party EM tools
9. Run EM simulation and obtain .sNp file
10. Run ADS to simulate .sNp with certain passives together (Reduced s-parameter file!)
11. Run ADS again to include the rest of the passives and active devices, evaluate performance

END

REPEAT

Tech file

Layer location Thickness

5 min.

10 min.

20 min.

10 min.

Hours of Simulation

20 min.

5 min.
Integrated 3D EM in Flow Saves Cycle Time!

Integrated EM flow removes:

- Unnecessary layout data conversion
- Redundant Import/Export process
- Custom tool development such as port generation utility
- Maintenance of two tech files for two design tools

Integrated Design Flow

START

ADS Layout

EM simulation

ADS simulation (layout component) with certain passives together (reduced s-parameter)

Run ADS again to include the rest of the passives and active devices, evaluate performance

END

REPEAT
Application Examples: Solder/Wafer Bumps

- Flip-chip, CSP, WLP (solder/wafer bumps)
- QFN packages
- RF Module/LTCC
Solder/Wafer Bumps Example

Why use 3D EM?

Solder/Wafer Bumps are very typical interconnect technology for Flip-Chip, CSP, and WLP applications.

3D full wave EM simulations are required to characterize bumps due to the 3D shape.
Solder/Wafer Bumps Example

3D View in ADS

Flip Chip

PCB

Solder bumps from 3D component design kit in ADS
Solder/Wafer Bumps Example

Simulated Isolation Performance between Bumps

Isolation Characteristic

Simulation Time: Only 5 min 25s on quad-core processor!
Solder/Wafer Bumps Example

3D Meshes and Post Processing

Wire Mesh

Volume Mesh

3D Meshes

Multiple E field plot

E field plot

Part 2
Solder/Wafer Bumps Example

3D EM Design Flow with 3D Components in ADS

- Integrated 3D EM design flow saves cycle time and increases first pass design success
- Allows designers to quickly draw 3D components such as solder bumps and co-design/optimize them with other schematic components
3D Design Kit Components: ADS

Insert into Layout from:
- Library
- Palette
Types of Standard 3D Design Kit Components

1. Each component has a 2D model (footprint) for ADS layout, and a full 3D model for 3D Preview and EMDS simulation.

2. Both 2D and 3D models are parameterized.

3. Layout components only: no schematic components
   - Basic : Block; SolderBall, Cylinder
   - Span : basic objects that span a substrate layer
   - Arrays : NxM arrays of basic objects
   - Span arrays : NxM arrays of span objects
   - Array outlines : 2(N-1)+2(M-1) basic objects, forming the outline of an array
   - Span array outline : 2(N-1)+2(M-1) span objects, forming the outline of an array
An example of Component Parameters: SolderBall

- **minRadius**
- **maxRadius**
- **height**
- **arcResolution=30**
- **arcResolution=45**

**Parameters**:
- **Instance Name**: SolderBall1
- **arcResolution**: 30
- **division**: 3
- **height**: 10 mil
- **material**: Cu
- **maxRadius**: 12.5 mil
- **minRadius**: 10 mil

**Description**: Arc resolution for the circular cross-section of the solder ball.
Component Parameters: Materials

‘material’ is a property defined in EMPro, and stored in the XML model file for the 3D component.

<table>
<thead>
<tr>
<th>Parameter Entry Mode</th>
<th>Parameter Entry Mode</th>
<th>Parameter Entry Mode</th>
<th>Parameter Entry Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arlon_AR1000</td>
<td>Arlon_DiClad880</td>
<td>Epoxy/Quartz</td>
<td>Isola_GigVer210</td>
</tr>
<tr>
<td>70-30 brass</td>
<td>Arlon_AR320</td>
<td>Arlon_DiClad933</td>
<td>FR-4</td>
</tr>
<tr>
<td>ABS</td>
<td>Arlon_AR350</td>
<td>Arlon_Intermcd</td>
<td>FR-5</td>
</tr>
<tr>
<td>Ag</td>
<td>Arlon_AR450</td>
<td>Arlon_IsolClad1791</td>
<td>Fluorooelastomer Rain Erosion</td>
</tr>
<tr>
<td>Alumina</td>
<td>Arlon_AR600</td>
<td>Arlon_LNB</td>
<td>GE_Getsk</td>
</tr>
<tr>
<td>Arlon_CSFFR</td>
<td>Arlon_CLTE</td>
<td>Au</td>
<td>GIL_GML1000</td>
</tr>
<tr>
<td>Arlon_255N</td>
<td>Arlon_CuClad217UX</td>
<td>Bismaleimide/Quartz</td>
<td>GIL_MC3</td>
</tr>
<tr>
<td>Arlon_AD270N</td>
<td>Arlon_CuClad233UX</td>
<td>CPS</td>
<td>GIL_MC5</td>
</tr>
<tr>
<td>Arlon_AD300N</td>
<td>Arlon_CuClad250DG</td>
<td>CPS/Fiberglass</td>
<td>GaAs</td>
</tr>
<tr>
<td>Arlon_AD320N</td>
<td>Arlon_CuClad250DGX</td>
<td>CPS/Quartz</td>
<td>HDPE</td>
</tr>
<tr>
<td>Arlon_AD350N</td>
<td>Arlon_DiClad522</td>
<td>Cu</td>
<td>In</td>
</tr>
<tr>
<td>Arlon_AD360N</td>
<td>Arlon_DiClad527</td>
<td>Cyanate Ester/Quartz</td>
<td>Isola_Durav-E-Cu</td>
</tr>
<tr>
<td></td>
<td>Arlon_DiClad670</td>
<td>Epoxy/E Fiberglass</td>
<td>Isola_FK408</td>
</tr>
<tr>
<td></td>
<td>Arlon_DiClad880</td>
<td>Epoxy/Quartz</td>
<td>Isola_GigVer210</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter Entry Mode</th>
<th>Parameter Entry Mode</th>
<th>Parameter Entry Mode</th>
<th>Parameter Entry Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neltec_MX0300</td>
<td>PTFE/Fiberglass</td>
<td>Rogers_RO3010</td>
<td>Teflon</td>
</tr>
<tr>
<td>Isola_GigaVer110</td>
<td>Neltec_MX0300</td>
<td>PTFE/Quartz</td>
<td>Rogers_RO3210</td>
</tr>
<tr>
<td>Matsushita_Megtron</td>
<td>Neltec_MX0301</td>
<td>Polycarbonate</td>
<td>Rogers_RO4003</td>
</tr>
<tr>
<td>Neltec_MX0243</td>
<td>Neltec_MX0318</td>
<td>Polyester/E Fiberglass</td>
<td>Rogers_RO4350</td>
</tr>
<tr>
<td>Neltec_MX0245</td>
<td>Neltec_MX0326</td>
<td>Polymide</td>
<td>Rogers_RT_Duroid5870</td>
</tr>
<tr>
<td>Neltec_MX0246</td>
<td>Nylon</td>
<td>Polymide/Quartz</td>
<td>Rogers_RT_Duroid5880</td>
</tr>
<tr>
<td>Neltec_MX0250</td>
<td>PEC</td>
<td>Polymide/E Fiberglass</td>
<td>Rogers_RT_Duroid5881</td>
</tr>
<tr>
<td>Neltec_MX0254</td>
<td>PEEK</td>
<td>Polyoxefin</td>
<td>Rogers_RT_Duroid6002</td>
</tr>
<tr>
<td>Neltec_MX0260</td>
<td>PEI</td>
<td>Polystyrene</td>
<td>Rogers_RT_Duroid6006</td>
</tr>
<tr>
<td>Neltec_MX0270</td>
<td>PES</td>
<td>Polyurethane Rain Erosion</td>
<td>Rogers_RT_Duroid6010</td>
</tr>
<tr>
<td>Neltec_MX0290</td>
<td>PMMA</td>
<td>Rogers_RO3003</td>
<td>Silicon</td>
</tr>
<tr>
<td>Neltec_MX0294</td>
<td>PPO</td>
<td>Rogers_RO3003</td>
<td>Silicon nitride</td>
</tr>
<tr>
<td>Neltec_MX0294</td>
<td>PTFE</td>
<td>Rogers_RO3006</td>
<td>Typical solder</td>
</tr>
<tr>
<td>Neltec_MX0300</td>
<td>PTFE/Ceramic</td>
<td>Rogers_RO3010</td>
<td></td>
</tr>
</tbody>
</table>

Agilent Technologies
August 4, 2009
Application Examples: QFN Package

Typical QFN packages

Source: Freescale

RFMD

Skyworks
QFN Package Example

3x3 [mm] 16 Pin QFN Package

Top metal – 0.1 mm thick

Plastic encasement

0.2 mm thick

Bottom metal – 0.1 mm thick
QFN Package Example

*EMDS G2 simulation with typical interconnect scheme*

- PCB Vias from QFN to ground
- Microstrip Line on ThinFilm Substrate
- Chip
- Board Microstrip Feed
- Double Bonding Wires

Good Up to 15GHz!
QFN Package Example

*Improving Package Performance With EMDS G2*

1. Increase the width of input/output transmission lines to make 50-Ohm impedance – Very simple to do in EMDS G2!

2. Use two lead frames instead of single to minimize the transitional impedance profile and split the double bonding to the two lead frames
QFN Package Example

*Improved Package Performance With EMDS G2*

![Graph showing dB(S11) and dB(S21) with frequency (GHz) on the x-axis and dB on the y-axis. The graph compares the performance of different design options. The colors and lines represent different design stages.*
Application Examples: Laminate/LTCC/Module

Typical Test Configuration

Laminate/LTCC/Module components are typically assembled and measured on PCB. 3D full wave EM simulations are required for the best simulation accuracy, that can be directly compared to the measured data.

- Dielectric brick simulation capability
- Accurate analysis of parasitics due to dielectric substrate change
Laminate/LTCC/Module Component Example

LTCC L/C Balun Design Process

Transmission Line Balun

L/C Balun

Final Design

AMC Design
Laminate/LTCC/Module Component Example

3D View for 3D EM Simulations (includes dielectric bricks)
Laminate/LTCC/Module Component Example

Simulation Results

**Simulation Time:**
Total Elapsed Time = 01:30:04
on quad-core processor!
Application Examples: C-Band Linear Antenna Array Example
Possible Effects of Radome on Antenna

- Change in S Parameter
- Change in Radiation pattern
- Gain Reduction

This kind of analysis is normally avoided because of

1) Modeling Radome structures in 3D are not easy:
   • In EMPro Modeling 3D Geometries are easy
   • Robust CAD import allows to bring any complicated structure within EMPro and develop Kit

2) Even if one gets success in drawing geometry then making a planar antenna along feed network is not easy in 3D drawing environment
   • EMPro Kit in ADS gives an option utilizing best of 3D Environment and 2D layout environment together
   • Optimization capability of ADS can be used to tune the Performance
Design Flow

Step 1
Radome Structure in EMPro

3D EM Component Kit

Step 2
Antenna in ADS along with Radome

Lab2-Radome

August 4, 2009
Step1: Creating Radome Structure in EMPro

1. Start EMPro
2. Select Geometry Tools and Choose Create> Extrude
Step2: Create 3D Design Kit

- Foot Print is displaced by 30 mm wrt ARC_OU
- Move ARC_OU (Right Click Specify Orientation > Advance mode > V’=30mm in Translations) by 30 mm
- ARC_OU will align with footprint
• Drag and Drop ARC_OU to MY3D Component

• Export the Kit to EMProRadome_DesignKit.zip
Step 3: Using the Radome 3D Comp in ADS

• Install the EMPro Kit in ADS

• Place the Radome Library Component on the Antenna Structure and align it so that Antenna Lies in the middle of radome
• Antenna with Radome in ADS Layout and 3D Preview
Simulation Results

S Parameter

Without Radome

With Radome
Radiation Pattern
Rectangular Plot (freq=5.116 GHz)

Without Radome
Gain=13.50 dB

With Radome
Gain=12.46 dB

Dip at theta=0deg for phi=0deg cut
Side lobe Rise
Radiation Pattern
Polar Plot (freq=5.116 GHz)

Without Radome

With Radome

Increased Power in Back Lobe
Application Example: SATA Connector

SATA Connector Details

- Housing Material - LCP, Er- 2.9
- Ground Pin: Pin-1, Pin-4, Pin-7
- Differential Ports (Transmit): Pin-2, Pin-3, Pin-5, Pin-6
- Differential Ports (Receive)
SATA Connector Example

EMPro Simulation Steps

1. SAT File import in EMPro
2. Assign Materials
3. Define Mesh
SATA Connector Example

Defining EMPro Ports and Excitation Source

4 Ports

Port-1 Port-2 Port-4 Port-6 Port-8

GND Voltage Source Tx/Rx Pin

5 EMPro Simulation

Simulate and view the result in EMPro
SATA Connector Example

EMPro Simulation Results (Return Loss, Insertion Loss)
SATA Connector Example

EMPro Simulation Results (Isolation of Adjacent Pins)
SATA Connector Example

**EMPro 3D EM Model Link in ADS using Design Kits**

1. **Generate ADS Design Kit (EMPro)**
2. **Install design kit in ADS**
3. **Select EMPro simulated Connector from ADS component Library**

---

**ADS Design Kits**
- Automatically generate design kit
- Generate Design Kit...

**EMPro 3D EM Model Link in ADS using Design Kits**

**Agilent Technologies**
August 4, 2009
SATA Connector Example
SI Analysis (co-simulating SATA Connector with channel)

High Speed Multi-pin SATA Connector (3D EM = EMPro)

Board traces (Planar EM = Momentum)

S-Parameter Simulation
Linear Frequency Sweep

S-PARAMETERS

SI Analysis

Agilent Technologies
August 4, 2009
Changing the playing field: Adding complete 3DEM to ADS Industry proven design flow

- **ADS Environment**
  - Momentum
    - Layout Pre-processing
    - Visualization
    - Nlog(N) Solver
    - Multithreading
    - Momentum *Turbo* Parallelization

- **EMDS G2**
  - 3D Models
  - New Mesher
  - Symmetry plane
  - Multi-threaded Solver
  - Unbeatable Price!

- **EMPro 2008**
  - Create 3D Models
  - Import/create Complex CAD
  - FDTD solver
  - Innovative Environment
  - Windows/Linux
## Application – Technology Matrix

<table>
<thead>
<tr>
<th>Application</th>
<th>Momentum G2</th>
<th>EMDS G2 (FEM)</th>
<th>EMPro 2008 (FDTD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFIC</td>
<td>Spirals, Capacitors, Interconnects (GoldenGate)</td>
<td>Wells, trenches, Under-Etching</td>
<td></td>
</tr>
<tr>
<td>SiP/LTCC</td>
<td>Package traces, vias, power/ground (Large)</td>
<td>3D components, Bond-wires, mixed technologies</td>
<td></td>
</tr>
<tr>
<td>SI / PI</td>
<td>Complex Board, Digital, board traces, vias, power/ground</td>
<td></td>
<td>Complex Connectors / EMC EMI</td>
</tr>
<tr>
<td>RF Board</td>
<td>EM-circuit cosim with active devices</td>
<td>Connectors, Shielding</td>
<td>Complex Connectors, Shielding</td>
</tr>
<tr>
<td>RF Packages</td>
<td></td>
<td></td>
<td>Cavities, Cavity filters Packages</td>
</tr>
<tr>
<td>Wireless</td>
<td>Planar, large antennas, EM-circuit cosim</td>
<td>EM-Circuit cosim, 3D components &amp; antennas</td>
<td>3D Antennas in complex environment, Wideband Human interaction, Compliance</td>
</tr>
<tr>
<td>A&amp;D</td>
<td>MMIC, Spirals, Capacitors, Interconnects</td>
<td>Waveguides in EMPro 2009</td>
<td>Large EM, RCS</td>
</tr>
</tbody>
</table>

**ADS Integrated**
Agilent EEsof EDA
*Leadership in High Frequency EDA*

- Over 25 years of high-frequency simulation leadership.
- Only company to integrate the 3 key EM simulation technologies within a circuit and system simulation flow.
- Best Price/Performance value of the integrated design framework.
- For more details about these products or to request an evaluation:
For more information about Agilent EEsol EDA, visit:
www.agilent.com/find/eesof

For more information on Agilent Technologies’ products, applications or services, please contact your local Agilent office. The complete list is available at:
www.agilent.com/find/contactus

Contact Agilent at:

**Americas**
- Canada (877) 894-4414
- Latin America 305 269 7500
- United States (800) 829-4444

**Asia Pacific**
- Australia 1 800 629 485
- China 800 810 0189
- Hong Kong 800 938 693
- India 1 800 112 929
- Japan 0120 (421) 345
- Korea 080 769 0800
- Malaysia 1 800 888 848
- Singapore 1 800 375 8100
- Taiwan 0800 047 866
- Thailand 1 800 226 008

**Europe & Middle East**
- Austria 01 36027 71571
- Belgium 32 (0) 2 404 93 40
- Denmark 45 70 13 1515
- Finland 358 (0) 10 855 2100
- France 0825 010 700*
  *0.125 €/minute
- Germany 07031 464 6333
- Ireland 1890 924 204
- Israel 972-3-9288-504/544
- Italy 39 02 92 60 8484
- Netherlands 31 (0) 20 547 2111
- Spain 34 (91) 631 3300
- Sweden 0200-88 22 55
- Switzerland 0800 80 53 53
- United Kingdom 44 (0) 118 9276201
- Other European Countries:
  www.agilent.com/find/contactus

Product specifications and descriptions in this document subject to change without notice.

© Agilent Technologies, Inc. 2009
Printed in USA, August 04, 2009