Introduction To ANSYS EM Solutions

Fluid Dynamics  Structural Mechanics  Electromagnetics  Systems and Multiphysics
Agenda

- Electromagnetic product/industry overview
- Electromechanical product/industry overview
- Product Updates
Two Product Segments

Electronics (HF/SI) or “High Frequency”

Electromechanical (EM) or “Low Frequency”
Electronics Application Segments

Signal & Power Integrity

RF & Microwave

IC Design & Verification

Electromechanical Systems
Electronic Trends

Electronic Systems drive toward smaller, faster, higher power, higher complexity, and higher density.

- RF, digital, data conversion, and high-performance DSP on single platform
- Switching power supplies at high frequency

Consumer market driving unit growth.

- Increasing demand volatility
- Shorter product life cycles
- Extreme price sensitivity.

System EMI Predicts Display Anomaly
System SI Predicts Receiver Desensitization
Cornerstone: Rigorous, Physics Based Solution
Cornerstone: Automatic Adaptive Meshing for Accuracy
Cornerstone: Circuit + Electromagnetics

Dynamic Link

Simulated

Measured
Products for Electronics

Fluid Dynamics  Structural Mechanics  Electromagnetics  Systems and Multiphysics
HFSS: High Frequency Structure Simulator

Full-wave 3D electromagnetic field solver

- Computes electromagnetic behavior of high-frequency and high-speed components and systems
- Extracts S-, Y-, and Z-parameters
- Provides 3D electromagnetic fields

Simulation of RFIC in Package

Antenna on UAV
SIwave

Full-wave Printed Circuit Board and BGA IC Package Solver

• Unique Field Solver Based on *Finite Element Method* coupled with transmission lines

• Computes electrical behavior of high-frequency and high-speed PCBs and BGAs

• Extracts S-, Y-, and Z-parameters
Ansoft Designer

- Design Environment for System-Level Electronics
  - Design framework with schematic, layout, and post-processing
  - Links to EM field solvers and Circuit Simulation

Nexxim

- Advanced Circuit Simulator
  - Transient, Harmonic Balance, and Statistical
Signal Integrity

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Applications: Signaling Standards

Standard interfaces
- DDR3, PCI Express, HDMI, SATA, USB 3

Serial rates of 3 to 10 Gb/s point-to-point serial buses.

This requires reliable signal transmission across a host board or between daughter cards on a backplane at GHz speeds.
The Fundamental High Speed Challenge

We want to get digital 1’s and 0’s from transmitter to receiver. However, the channel over which this occurs is a low pass filter.
6 Gb/s SATA Interconnect: “Divide and Conquer” Solver Technology

Models courtesy of:

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Validation: Nexxim + QuickEye
EMI/EMC

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Network Camera System

Flexible Printed Circuit (FPC)

Flat Flexible Cable (FFC)

CCD

TILT Board

CPU Board

Video Board

Panasonic Electronic Devices
Panasonic Communications Co.
Molex Japan
Aki Nakatani, Ansoft Japan
EMI Measurements

EMI regulation limit
Simulation Methodology

HFSS connector models
Nexxim W-element

Video board
FPC
TILT board
FFC
CPU board
Reducing Differential Skew

1. Asymmetrical component pads removed
2. Differential vias re-arranged so signal will arrive at the same time.
3. EMI test passed
RF/Microwave
Typical spacecraft is host to numerous antennas

- Important to understand interactions between structures
- Avoid performance degradations

Added reflector antenna to spacecraft bus

- X-band data relay link
- Need to evaluate potential impact on helix array
- Antenna placement scenario
From Components to System

Antenna element design
• Distributed solve option
  – Remote Simulation Manager
• Analytical derivatives
  – Design sensitivities
  – SNLP optimization

Finite array design
• Multi-processing option
• Post-processing variables

Integration onto spacecraft
• 64-bit mesher
• Domain decomposition solver
Design Exploration: Critical Antenna Design Parameters

- Helix Pitch
- Helix Radius

Large solution space efficiently mapped using DSO

- **1 hr total time**

Acceptable ranges for design parameters easily determined
Space-based Multi-Physics

Electromagnetic

Thermal

Mechanical Stress and Strain
Ansoft Solutions for Electromechanical
Maxwell B Field Around Motor
Simplorer

Mechanic Source
Generator
400Hz Transformer
DC/DC Converter
Electrical Load: Communication Electronics
Mechanic Load: Actuator
Simplorer: Multiphysics Integration Framework

- Custom Model, C
- IcePak
- Simulation
- Fluent
- Maxwell
- Q3D
- ANSYS Mechanical
- Simulink
- Thermal Domain
- Electrical Domain
- Mechanical Domain
Hybrid Electric Vehicles
HEV: System Simulation

MULTIPHYSICS
HEV: Battery Thermal Management with ANSYS CFD

- Increase power capability, while avoiding hot spots that cause premature failure.
- Accurate circuit simulation for battery packs includes temperature dependencies.

\[
\begin{align*}
\frac{d}{dt} \left[ \frac{SOC}{V_1} \right] &= \begin{bmatrix} 0 & 0 \\ -1/R_s C_1 & -1/C_1 \end{bmatrix} \begin{bmatrix} SOC \\ V_1 \end{bmatrix} + \begin{bmatrix} 1/Q \\ -1/C_1 \end{bmatrix} I(t) \\
V(t) &= V_{OCV}(SOC) + V_1 - (R_s + R_{PTC}) I(t)
\end{align*}
\]
HEV: System Simulation with Simulorer

MULTIPHYSICS

Phase Transformation / Control Signal Generation by Space Vector Modulation

Phase Current
HEV MultiPhysics

STRUCTURAL MECHANICS

- Temperature
- Losses
- Mapped Losses
Electronics Solutions

HF/SI
- Extractors
  - HFSS
  - Q3D
  - SIwave
- System
  - Ansoft Designer

EM
- Extractor
  - RmXprt
  - Maxwell 2D/3D
- System
  - Simpler with Multiphysics Integration
Product Updates
High Frequency

Fluid Dynamics  Structural Mechanics  Electromagnetics  Systems and Multiphysics
Overview

• Advanced Integrated Solver Technologies
  – Finite Arrays with Domain Decomposition
  – Hybrid solving
    · FEBI
    · IE Regions
• Physical Optics Solver in HFSS-IE
• New Layout interface for HFSS: Solver on Demand in Designer
• Usability Enhancement
  – Radiated fields.....
  – 3D modeler improvements
• CAD Integration in Workbench
  – Improved Multiphysics flow
Advanced Solvers: Finite Arrays with DDM
Finite Arrays with Domain Decomposition

Efficient solution for repeating geometries (array) with domain decomposition technique (DDM)
A Review: Domain Decomposition

Distributed memory parallel solver technique

Distributes mesh sub-domains to network of processors

Significantly increases simulation capacity

Highly scalable to large numbers of processors

Automatic generation of domains by mesh partitioning

- **User friendly**
- **Load balance**

Hybrid iterative & direct solver

- **Multi-frontal direct solver for each sub-domain**
Finite Arrays

Solve large finite array designs

Efficient setup and solution

Define unit cell and array dimensions
• Efficient geometry creation and representation

Efficient Domain Decomposition solution
• Leverages repeating nature of array geometries

- Memory efficient
- Enabled with the HFSS HPC product
Example: Skewed Waveguide Array

- 16X16 (256 elements and excitations)
- Skewed Rectangular Waveguide (WR90) Array
  - 1.3M Matrix Size
- Using 8 cores
  - 3 hrs. solution time
  - 0.4GB Memory total
- Using 16 cores
Hybrid Solving: Finite Element-Boundary Integral

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Finite Element-Boundary Integral
Solving Larger Problems with Rigor

- Antenna Placement Study: UHF Antenna on Apache UH64 airframe
  - Finite Elements with DDM
  - Boundary Integral (3D Method of Moments)
  - Hybrid Finite Element-Boundary Integral (FE-BI)
Hybrid Solving: Finite Element-Boundary Integral

Apache helicopter
- UHF antenna placement study @ 900 MHz

Solution volume
- 1,250 m³
- 33,750 λ³

Solution Specs
- 72 engines
- Matrix size = 47M
- 6 adaptive passes
- 300 GB RAM
- 5 hr 30 min

Finite Elements with DDM
Hybrid Solving: Finite Element-Boundary Integral

Apache helicopter
• UHF antenna placement study @ 900 MHz

Solution surface
• 173 m²
• 1557 λ²

Solution Specs
• 12 core MP
• 680k unknowns
• 9 adaptive passes
• 83 GB RAM
• 5 hr 28 min

Boundary Integral, 3D MoM with HFSS-IE
Hybrid Solving: Finite Element-Boundary Integral

Apache helicopter
• UHF antenna placement study @ 900 MHz

FEM solution volume
• 69 m³
• 1863 \lambda^3

IE solution surface
• 236 m²
• 2124 \lambda^2

Solution Specs
• 12 cores total using DDM with MP
• Matrix Size = 2.9M
• 6 adaptive passes
• 21 GB RAM
• 1 hr 3 min

Compared to 72 core FEM solution
14X less memory
5.5 times faster
### Summary of FEBI performance

<table>
<thead>
<tr>
<th>Type</th>
<th>Time</th>
<th>Ratio</th>
<th>Memory</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEM + DDM</td>
<td>5hr 30min, 1</td>
<td></td>
<td>300GB, 1</td>
<td></td>
</tr>
<tr>
<td>IE</td>
<td>5hr 28min, 1</td>
<td></td>
<td>83GB, 3.6</td>
<td></td>
</tr>
<tr>
<td>FEBI</td>
<td>1hr 3min, 5.5</td>
<td></td>
<td>21 GB, 14.3</td>
<td></td>
</tr>
</tbody>
</table>
Hybrid Solving: IE Regions
FEBI and Physically Separate “Domains”

Reflector with multiple FEBI domains

• Conducting reflector and feed horn each surrounded by air with FEBI applied to surface of air volumes
  - Provides integral equation “link” between FEM domains

• But 3D MoM solution from integral equations could be applied directly to conducting surface only

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Memory Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 GHz</td>
<td>2GB</td>
</tr>
<tr>
<td>6 GHz</td>
<td>10GB</td>
</tr>
<tr>
<td>9GHz</td>
<td>30GB</td>
</tr>
</tbody>
</table>
HFSS Hybrid Solving – IE Regions

- **Parallelized**
  - IE regions solved in parallel.
  - Analogous to FEM domains
- **Rigorous**
  - Multiple reflection
- **Automated**
HFSS-IE PO

**Asymptotic solver for extremely large problems**

- In HFSS-IE
- Solves electrically huge problems
  - And provides first pass “quick solution” for IE
- Currents are approximated in illuminated regions
  - Set to zero in shadow regions
- No ray tracing or multiple “bounces”
Notice the *shadowing of the gun barrel on the tank* and the tank on the ground.
HFSS
Transient
Transient problems
Aircraft: Pulsed RCS
HFSS Transient

Introduced in HFSS 13.0

Discontinuous Galerkin Time Domain (DGTD)

• Finite element solution
  - Retains accuracy and reliability of adapted unstructured-mesh
• Supports higher order basis functions
  - Efficient for geometries with a wide range of geometric detail
• Local time stepping
  - Based on element size, order and material property mesh elements may advance in time with different time steps
HFSS Transient

Transient Network Analysis
• Separate Frequency and Time domain “Edit Source“ settings
• Specify delay of TDR to synchronize rise times
• Handling of partial S due to passive ports

Transient
• Scaling and delay of individual sources

General
• Support for general frequency dependent materials
Solver on Demand

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Designer RF with HFSS - Solver on Demand

HFSS - Solver on Demand

- Intuitive PCB design entry for HFSS
- Chips, packages, channels, modules, ...
- Designer layouts simulated with HFSS
  - Automated boundary and port setups
  - Finite dielectrics and ground supported
- Wave and Lumped Gap Port
  - Single ended and Differential
  - Vertical and Horizontal
Usability Enhancements
General Enhancements

• Save Radiated field data only
  – Reduced the amount of stored data

• Import list for Edit Sources
  – Can include parametric variables

• Network Installation for clusters
  – Improved reliability on Linux

~10X Reduction

New Registry Configurations

– Installation: Lowest precedence
  – Defaults applicable to all users

– Machine:
  – Defaults applicable to all users on a machine.

– User:
  – Machine-independent user specific default

– User and machine:
  – Highest precedence
  – Defaults specific to user + machine

~10X Reduction
CAD Integration on WB Improvements

- CAD integration in ANSYS Workbench provides direct link to 3rd party CAD tools
- Such as ProEngineer, Catia, SpaceClaim
- Added support for parametric analysis and distributed solving of CAD parameter
Ansoft to ANSYS Geometry Transfer

- Geometry and material assignment transfer from Ansoft to ANSYS
- Consume geometry from multiple upstream CAD sources
  - Source can be any of CAD, DesignModeler or Ansoft products
  - Further geometry edits are possible in ANSYS Design Modeler
- Creates User Defined Model (UDM) for each geometry input.
Signal-, Power-Integrity, & EMI Update

Steve Pytel, PhD. Signal Integrity Product Manager
Overview

- ANSYS ECAD Solutions
- HFSS for Signal Integrity
- SIwave Full BRD and PKG Solutions
- SI Circuit Simulation for IBIS-AMI and Memory
- Q3D Extractor 11.0 Updates
- General SI Updates for HFSS, Q3D Extractor, and DesignerSI
- TPA Enhancements
ANSYS ECAD Solutions

Fluid Dynamics  Structural Mechanics  Electromagnetics  Systems and Multiphysics
AnsoftLinks Translation Paths

- AnsoftLinks
  - Static ECAD Transfer (.anf)
    - TPA
    - Q3D
    - Slwave
    - HFSS
    - Designer
    - Icepak
    - Mechanical
  - Dynamic ECAD Transfer
    - AnsoftLinks with Extracta
      - Cadence
        - Virtuoso
        - SiP
        - APD
        - Allegro
    - Solver on Demand
      - HFSS
      - PlanarEM
      - Nexxim
      - HSPICE
ECAD Translation Updates

**Cadence**
- Allegro ü 16.0, 16.1, 16.2, 16.3 and 16.5
- APD ü 16.0, 16.1, 16.2, 16.3 and 16.5
- SiP Digital/RF ü 16.0, 16.1, 16.2, 16.3 and 16.5
- Virtuoso ü 4.46, 5.0, 5.0.32 and 6.x

**Mentor Graphics**
- Boardstation ü 8.x
- PADS ü PowerPCB v5.2a, v2005 and v2007

**Zuken**
- CR5000 ü 9.x and lower

**ODB++**
- Altium Designer ü R10
HFSS for Signal Integrity
ECAD & Field Solver Improvements
Solver on Demand: An ECAD Interface for HFSS

Problem Description:

1. Converting package and printed circuit board layout data to 3D mechanical CAD models creates a large amount of unnecessary overhead in the geometry database

2. A key capability needed for wide-spread use of HFSS as an extraction tool is to make it accessible to non-experts

Solution:

3. When HFSS is used for package and PCB extraction a 2D Electrical CAD layout editor is better suited for model creation and setup

4. The Designer Layout editor with Solver on Demand improves HFSS accessibility for non-expert engineers who need to use HFSS for package and PCB extraction
“HFSS for ECA"

Two Design Flows for Electrical Design:

• Mechanical CAD
  - Connectors, Waveguides
  - HFSS

• Electric CAD (layout)
  - PCBs, Packages, On-chip Passives
  - HFSS - Solver on Demand
“HFSS for ECAD”

Highly automated for in layout design environment
- Primitives = traces, pads, bondwires, vias
- Net name definition

Significantly reduce engineering time interacting with software

Lightweight interface for geometrically complex structures

Direct import of Cadence products using Cadence Extracta
- Allegro, APD, and SiP

Direct HFSS solve from within the Cadence environment
- Virtuoso, Allegro, APD, and SiP
HFSS within Cadence SPB & Virtuoso

- Dynamic ECAD Flow
- Create and Solve models with HFSS from within Cadence SPB
HFSS Setup & Solve in Virtuoso

Back annotation scheduled for final release
HFSS ECAD Layout Editor

- HFSS Solver Technology is embedded in Designer as “Solver on Demand”

2D+3D Layout view in one

Export 3D HFSS Model

Solve in Designer using HFSS
HFSS Solve for PKG merged to PCB

Lumped ports on package bumps

Wave Port at cutout boundary
Parameterized Differential Via
New in R14

- Parameterized padstacks
- Automated causal material
- Multi-frequency point adapting
- Integrated 2D/3D views
- Huray Surface Roughness
- Lumped Port De-embedding
- Trapezoidal Trace Cross-sections
- Automated Virtuoso HFSS
- Passivity Enforced Interpolation

- HFSS Solves from within Cadence
SIwave Full BRD and PKG Solutions

DDR3 and High Speed Serial Improvements
Memory and High Speed Serial improvements

Table Impedance MoM Calculator
- Ideal and non-ideal lumped parameters (i.e Zo)
- Nexxim and HSPICE RLC simulations

Via to Via Coupling
- Differential pair accuracy improvements

Solver Support for Arbitrary Antipad Cutouts
- Improvement in via modeling accuracy

SYZ Solver Improvements
- Guaranteed passive/causal SYZ solutions

64 bit GUI for Windows

Table Impedance Calculator
- Flight time plots
- Transient Simulations with Nexxim or HSPICE

PKG & PCB Automation
- Graphical selection

Pin Grouping Automation
- Multi-part select with group per part/net definitions

Improved Validation Checker
- Detection of pins belonging to multiple pin

Improved SYZ Storage Architecture
- 6x reduction in disk space for SYZ parameters

Improved ODB++ Support

Support for X2Y Low Inductance Capacitors
DDR3 Solutions: Signal Net Analyzer

- Displays $Z_0$, length, time delay, and reference layer
- All possible paths (from each pin to every other pin on net) are displayed
  - Sorted in descending order of path distance
- User can click on an individual path in the table
  - Variation in $Z_0$ is graphically displayed
  - Path is highlighted in SIwave's main layout window
- Ideal reference layer mode (default)
  - Traces on top & bottom metal layers are assumed to be microstrips
  - Interior traces are assumed to be striplines
- Non-ideal reference layer mode
  - Reference layer is explicitly calculated for each trace segment
  - Some traces may be floating (no suitable reference layer available)
Huray Surface Roughness &
Equipotential Pads for DCIR

Power Density Plot: Without Pad

Power Density Plot: With Pad

Current Density Plot: Without Pad

Current Density Plot: With Pad
SI Circuit Simulation for IBIS-AMI and Memory
Macro-modeling Functionality

New functionality for the SI market

Network Data Explorer
- State-space fitting
- Passivity enforcement
- Passivity checker
- S-parameter visualization
- S-matrix reduction
- Macro-model generation

Measured Data

Circuit Simulation
- Designer
- Simplorer
- Other

- State Space
- Simplorer
- Spectre
- HSPICE
- PSPICE

HFSS
Q3D
SIwave
Designer
Network Data Explorer

Graphic comparison showing the difference between the Z-Matrix entries for two different decoupling capacitor schemes.
Vendor Libraries

Design Engineers require accurate electrical models for components when designing circuits.

A key feature of the web based library support is ease of use. Library installation generally requires users to download files, uncompress them and place them in the correct location on a local drive.

Automated web based download from within Designer automates these steps, making it easy for users to keep their component libraries up to date.

Design Kits
- DDR3, PCIe 3.0, HDMI, SATA, SAS, ...
Vendor Libraries

Accessible from the menu via Tools > Download Component Libraries...

Filtering limits the number of components to be updated.
Automated IBIS-AMI Importing
High Speed Serial Design With IBIS-AMI

- **Automated IBIS-AMI Importing**
  - IBIS-AMI Specification Testing
    - Pass/Fail
    - Advanced
QuickEye Multi-core Speed Up

Linear speed improvement with multiple cores!

![Graph showing linear speed improvement with multiple cores](image)
Q3D Extractor 11.0

Fluid Dynamics  Structural Mechanics  Electromagnetics  Systems and Multiphysics
Touch Screen Accuracy Improvements

- Added the ability to converge on off diagonal terms with Touch Panel displays
Q3D – Magnetic Materials

Simulation Time

<table>
<thead>
<tr>
<th></th>
<th>Q3D AC</th>
<th>Q3D DC</th>
<th>Sweep</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 s</td>
<td>6 min 30 s</td>
<td>2 s</td>
</tr>
<tr>
<td>Maxwell</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3D</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>&lt; 7 min</td>
<td></td>
<td>50 min</td>
</tr>
<tr>
<td>Peak RAM</td>
<td>0.6 GB</td>
<td></td>
<td>5 GB</td>
</tr>
</tbody>
</table>

Electroplated Nickel has $\mu = 5$

Bulk Nickel has $\mu = 600$

Maxwell*

* Each additional frequency point takes ~ 15 minutes to solve with Maxwell.

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HFSS

Q3D

L(f)
Ansoft HPC Enhancements: Fixed Variables

Desktop supports fixed variables

- Solution database is NOT indexed by these variables
- User will not sweep them
- Any change to these variables invalidate existing solutions

Benefits

- Faster access to solution database
  - Faster post-processing
- Improved reporter-dialog response

- Via Wizard generated project with 746 variables
  - Only one variable, called Pad, is swept in a parametric setup
  - Turn off “Sweep” checkbox for all variables except Pad