Simulation Techniques for Tablet and Mobile Phone Design

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Tablets in our daily lives

Tablets are very entertaining, stylish and powerful

- Shopping, reading, emailing, accessing social networks, gaming
- Schools, operating rooms, sports events

Pictures source: www.istockphoto.com
Problem
Predict the performance of a tablet design while meeting strict electrical standards and design specifications

Solution
Automated modeling and optimized analysis using ANSYS Electromagnetics tools allows for system simulation approach

Result
Detailed and accurate system simulation approach enables tablets to be put on market on time with reduced testing costs
Multi-Physics-Based Simulation
Electromagnetics, Thermal, Structural Mechanics, Fluid Dynamics
Virtual System Prototyping

- Layout
- 3D CAD
- Virtual Prototype
  - Electromagnetic Extraction
  - Mechanical and Thermal
- Vendor Specific Driver/Receiver Models
- Vendor Specific VRM Models
- Electronics
- Virtual System
- Virtual Compliance
Tablet Design Challenges

Designing the Tablet

- Touchscreen
- Tablet Case
- Packages
- Flex circuitry
- Antenna
- ESD
- EMI
Tablet Design Challenges

Designing the Tablet

• Touchscreen – Electromagnetic Analysis
• Tablet Case
• Packages
• Flex circuitry
• Antenna
• ESD
• EMI
HFSS: High Frequency Structure Simulator

Full-wave 3D electromagnetic field solver

- Computes electromagnetic behavior of electronics components and systems
- Extracts S-, Y-, and Z-parameters
- Provides 3D electromagnetic fields
- Common Applications:
  - RF/Microwave
  - Antennas
  - EMI
  - Signal Integrity
  - Bio-Medical
  - Consumer Electronics
Capacitive Touchscreen

No moving parts present

- Use a thin layer(s) of ITO (indium tin oxide) to sense the presence of a finger by capacitive coupling.
- Projected Capacitive Touch; PCT (or PCAP)
- Array of Capacitive sensors are mounted underneath glass
- Finger adds a measurable capacitive change in the touch sensor
- Change in sensor capacitance determines a position on the Array
- Change in Array Position determines motion and speed.
- Greater Control: Swiping and Pinching (Multi-Touch Operation)
- Non-Responsive to Stylus, Gloves, Other Objects...
Touchscreen Design Challenges

Model size, complexity and ....

- Voltage applied to the electrode array sets up E-field
- Each intersection represents a capacitor
- Finger on surface changes local E-field and reduces mutual capacitance
- Simulate “projected” and/or “mutual-capacitance”
- Include Skin and Proximity Effects
- Build detailed 3D model; include all objects and materials
Capacitive Touchscreen

Parameterized Example 10x10 electrodes model
The Mesh

- What is the Technology Behind the HFSS Field Solver?
  - Full Wave Volumetric Field Solver
  - Solution Method: 3D Finite Element Method (FEM)
  - Accuracy: There is no limit to the accuracy of the Finite Element Method
  - Mesh Type: Conformal
  - Mesh Element: Tetrahedron
  - Mesh Process: Automatic Adaptive

- The Key? The MESH

- Finite elements and adaptive meshing
  - Geometrically Conformal
  - Optimal: based on field behavior
  - Created automatically by the software

Recent Developments
Mixed Order Mesh Elements and Curvilinear Mesh Elements
Automatic and Robust Adaptive Meshing

Adaptive Mesh Refinement

- Automatically tunes the mesh to the electrical performance of the device. This ensures simulations are correct the first time.

Mesh Convergence

- Real-Time update of performance per adaptive solution
Capacitive Touchscreen

Accuracy of Electromagnetic solution

• Automated Meshing Refinement
Convergence criteria

• Based on change in Self or Mutual matrix capacitive terms
• Based on specific matrix value or user defined output variable

Solution Time (10x10 electrodes model)

• 2 hrs 45 min
• Supports all available cores
Focus on

- Area of contact
- Glass thickness
Receiver Signal

Non-contact

Electrode scanning change at contacted position

Proximity Effects (0.1mmGap)

Contact!
Tables Design Challenges

Designing the Tablet

• Touchscreen
• Tablet Case - Drop Test
• Packages
• Flex circuitry
• Antenna
• ESD
• EMI
Tablet Computer Case

• Perform Drop test of Tablet PC from height of 4 feet onto a concrete floor at an angle of 45 degrees using ANSYS Explicit Dynamics

• The geometry of the Tablet PC was created from scratch using ANSYS DesignModeler

• Explicit Dynamics Simulation:
  – Impact tests, Drop Tests, Short duration high pressure loading tests...
  – Transient dynamic event simulation
  – Predicts Material deformations and failure
  – Predicts interactions between bodies and/or fluids
The geometry of the Table PC was created using ANSYS DesignModeler.
**Drop test**

- **Meshing:**
  - ANSYS Workbench meshing with Explicit Dynamics preference is used to create a mesh.
  - Hex dominant mesh is created to reduce the number of elements.
  - Total number of elements ~25,000

- **Analysis settings:**
  - Analysis is solved for 0.4mS.
  - Initial velocity of 4.9 m/sec is assigned to the Tablet.
  - The concrete floor is modeled as a rigid shell body with fixed constraints.
  - Automatic contact definition is used between all parts.
  - Parts that are in contact but may separate due to the drop test are assigned bonded contacts.
  - Bonded contacts are modeled as breakable based on stress criteria for debonding.
Drop Test Simulation Results

Equivalent Stress Contours Back Cover Off

Equivalent Stress Contours Front
Stress Modeling Analysis

Stress Modeling using ANSYS Mechanical includes:

- Joints to capture the kinematics
- Visco-elastic material
- Contact non-linearity
- Rigid flexible interaction
Tablets Design Challenges

Designing the Tablet

• Touchscreen
• Tablet Case
• Packages – Multiphysics; Electromagnetics and Thermal
• Flex circuitry
• Antenna
• ESD
• EMI
Mobile Device Component Packages

- BGA
- Flip-chip BGA
- SiP
- PoP
- CPU, Memory, Flash ...

Electrical and Thermal simulations
Multi-Physics Analysis
Electromagnetics, Steady State Thermal, Transient Thermal, Static Structural, Vibration...

RF Source/EM Losses

Imported Temperatures

Feedback: Material Properties, Deformation
Tablet packages

Design Challenges

• Signal Integrity
• Accurate SYZ and RLGC solution
• Dealing with multiple vendors/packages

Solution

• Automated merging capabilities
• Full-wave and Quasi-static solution

Courtesy of EEMS

Q3D Extractor and HFSS
Electromagnetics for Signal Integrity
Tablets Design Challenges

Designing the Tablet

• Touchscreen
• Tablet Case
• Packages
• Flex circuitry – Parameterized Electromagnetic Analysis
• Antenna
• ESD
• EMI
FLEX circuit analysis

Parameterized Transmission line model

- Accurate Zo analysis
- Trace spacing and offsets
- Solid vs. patterned ground

HFSS Transient
FLEX circuit analysis

Interconnect Transmission line model

- Trace Thickness and Width
- Trace to Ground Space
- Ground Shape (Solid vs. Meshed)
  - Reduce the Interference with High Speed signal Traces or noisy LCD surface
Design of Experiments

Flex Optimization analysis
- Impact of multiple variables on overall designs
- Goal driven optimization
Tablets Design Challenges

Designing the Tablet

• Touchscreen
• Tablet Case
• Packages
• Flex circuitry
• Antenna – Electromagnetic Analysis, Antenna DK, Hybrid Techniques
• ESD
• EMI
Tablet Antenna

Antenna Design Challenges

• Location, Beam Forming
• Antenna type
• Human Body Effect
  – Hand, Body
• Operation Environments
  – Metal Desk
  – Wooden Desk
  – Human lap
Antenna Design Kit
Antenna Design Challenges

- Location, Beam Forming
- Human Body Effect
  - Hand holding tablet at different locations
  - Close to antenna and away from antenna

Radiation Efficiency @2.4Ghz : 0.967907

Radiation Efficiency @2.4Ghz : 0.480466
Tablet Antenna

Antenna Design Challenges

• Operation Environments
  – Human Tissue
  – Metal Desk
  – Wooden Desk

Radiation Efficiency @2.4Ghz: 0.994337

Radiation Efficiency @2.4Ghz: 0.993303

Radiation Efficiency @2.4Ghz: 0.777207
Hybrid Solution for Antenna Placement Analysis Using IE-Regions

Antenna performance modeled with placement in proximity to human head

- Cell phone platform and antenna with complex material properties and geometry are ideally modeled using FEM solution
- The uniform, high dielectric properties of the head are ideally modeled using IE solution

Hybrid Solution

- An internal dielectric IE Region can be applied to head geometry to reduce computational size and improve efficiency
- FEM solution is applied remaining volume

Human Head Material Properties:
\[ \varepsilon_r = 79, \sigma = 0.47 \text{ simems/m} \]
Hybrid Solution for Antenna Placement Analysis Using IE-Regions: Results

- **IE-Region Boundary Condition Applied**

### Results

<table>
<thead>
<tr>
<th>Solution Type</th>
<th>Total RAM (GB)</th>
<th>Elapsed Time (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEM Only</td>
<td>6.2</td>
<td>1</td>
</tr>
<tr>
<td>Hybrid Solution</td>
<td>3</td>
<td>0.5</td>
</tr>
</tbody>
</table>

#### Graphs

- **Return Loss Plot**
  - Cell Phone Only
  - FEM Only: Cell Phone + Head
  - Hybrid: Cell Phone + Head

- **Gain Plot (Phi = 90 deg)**

- **IE-Region Boundary Condition Applied**

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Hybrid FEM-IE Solution 1.8 GHz

FEM Only Solution 1.8 GHz
Hybrid Solution for Antenna Placement Analysis Using IE-Regions

Antenna performance modeled with placement in proximity to human head inside vehicle
- Cell phone platform and antenna with complex material properties and geometry are ideally modeled using FEM solution
- The uniform, high dielectric properties of the head are ideally modeled using IE solution
- The car is ideally modeled using IE-Region

Hybrid Solution Setup
- An internal dielectric IE-Region can be applied to head geometry to reduce computational size and improve efficiency
- An exterior metallic IE-Region is applied to car model
- FEM solution is applied remaining volume
Hybrid Solution for Antenna Placement Analysis Using IE-Regions: Results

<table>
<thead>
<tr>
<th>Solution Type</th>
<th>Total RAM (GB)</th>
<th>Elapsed Time (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEM w/ DDM</td>
<td>160G</td>
<td>8</td>
</tr>
<tr>
<td>Hybrid Solution</td>
<td>11</td>
<td>2.7</td>
</tr>
</tbody>
</table>
Tablets Design Challenges

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○ HFSS Transient Solver for Electromagnetic Modeling of ESD
○ Combined Circuit and Electromagnetic Modeling of ESD

ESD Gun and Metal Plate

ESD Gun Simulation Time length: 0 ns ~ 118 ns

HFSS Transient Solver for Electromagnetic Modeling of ESD
Combined Circuit and Electromagnetic Modeling of ESD

Courtesy of: HUWIN
### ESD Gun Simulation Results

<table>
<thead>
<tr>
<th>Applied Voltage (kV)</th>
<th>IEC 61000-4-2 (ESD Test)</th>
<th>Peak Current (A) Simulation Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>7.5</td>
<td>7.75</td>
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<tr>
<td>4</td>
<td>15</td>
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<td>5</td>
<td>18.75</td>
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<tr>
<td>6</td>
<td>22.5</td>
<td>23.25</td>
</tr>
</tbody>
</table>

#### Peak Current VS Applied Voltage

- **6kV**: Gray line
- **5kV**: Red line
- **4kV**: Black line
- **2kV**: Green line

Credit: Courtesy of HUWIN
ESD Gun on Tablets touch electrodes

ESD gun applied on 1 driver and 1 receiver full length electrode
ESD Gun effect on Tablets touch electrodes
ESD Gun current injected on touch electrodes
ESD represented by PWL data set
Tablets Design Challenges

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- EMI
Tablet EMI

EMI Design Challenges

- Entire PCB + Case
- Driver & Receiver
- Near field, Far field
- Immunity
Tablet EMI

EMI Design Results

- Near Field and Far Field Spectrum

Simulation vs. Measurement
Tablet Simulation Recap

Tablet Design Simulations

• Touchscreen – Electromagnetic Analysis
• Tablet Case – Drop Test
• Packages – Electromagnetic Analysis and Thermal Analysis
• Flex circuitry – Parametric Electromagnetic Analysis
• Antenna – Electromagnetic Analysis
• ESD - Transient EM Analysis and Circuit/System Analysis
• EMI – Electromagnetic Analysis