Electromagnetic Simulation in EMC/EMI Design

Emissions, Susceptibility and Electromagnetic Environmental Effects (E3)
Since 2000, there have been several voluntary reports filed by pilots in the United States with the Aviation Safety Reporting System, administered by NASA. In 2007, one pilot recounted an instance when the navigational equipment on his Boeing 737 had failed after takeoff. A flight attendant told a passenger to turn off a hand-held GPS device and the problem on the flight deck went away.

“Due to the proliferation of wind farms and the increasing heights of the turbines there is a rising number of lightning-related incidents. While physical blade damage is the most expensive and disruptive caused by lightning, by far the most common is damage to the control system.”

Source: New York Times
41 medical devices were submitted to 3 EMI tests. A total of 34 EMI incidents were found; 22 were classified as hazardous including: total switch-off and change in rate of ventilators.

In a recent U.S. government test 4G wireless service caused interference to 75 percent of global-positioning system receivers examined. Due to better EMI filtering techniques cell phone GPS chips were unaffected.

Source: New York Times, Bloomberg, Forbes
The ability of an electrical system or device to work satisfactorily in its electromagnetic environment without influencing the surrounding devices (emissions), or being influenced by the surrounding equipment (susceptibility)

**Scope of EMC/EMI**

- **EMC**
  - Susceptibility
  - Environmental Effects (E3)
  - Emissions

**KHz**
- Switched Power, Lightning

**MHz**
- EMP, HIRF, Radio

**GHz**
- Digital electronics, RADAR
## Emissions Regulations

### Emissions Radiated and Conducted

<table>
<thead>
<tr>
<th>North America</th>
<th>CISPR</th>
<th>Europe</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCC Title 47 Part 18 - Part 15</td>
<td>11</td>
<td>EN 55011</td>
<td>Industrial, Scientific Automotive</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td></td>
<td>Broadcast Receivers</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>55013</td>
<td>House Appliances</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>55014</td>
<td>Electrical Lighting</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>55015</td>
<td>ITE</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>55022</td>
<td>Auto Components</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>55025</td>
<td></td>
</tr>
</tbody>
</table>

Not all the standards are shown in the table.
Emissions Problems

1. Slots in ground plane radiate onto cable, 2. DM to CM current conversion

Coupling between heat sink and connector bypasses signal path thru PCB

Coupling through vent in enclosure

EMC design involves minimizing the noise, absorbing the noise, containing the noise (shielding) and diverting/filtering the noise

Stray fields/couplings/radiation are critical in EMC/EMI! Often requires full system-level simulation

Image courtesy of Johnson Controls Inc.
Find Critical Structures on the PCB

CST BOARDCHECK

EMC Rule Checking provides a smooth, fast workflow from PCB design to EMC/EMI simulation.

The EMC Rule Check violation report allows you to focus on the most critical nets.

1. Deal with a new PCB layout
2. Analyze PCB in EMC rule checker
3. Decide which structures need simulation
4. Perform simulations and analyze results
5. Obtain EMC rules for layout engineers
Rule Checking and Violation Report

Critical Net Near I/O Net

Critical Net Near Edge of Reference Plane
Emissions Workflow: Cascading

Cascading applied if system can be decoupled

Import from CST BOARDCHECK  ➔  Compute transient CM voltage  ➔  Simulate radiation from cable
Partitioning of Model/USB Channel

Common Mode Noise
- 1.5 V without choke
- 80 mV with choke

Driver skew and imbalance in USB channel leads to CM noise
Radiated Emissions Prediction

Convolution of impulse response with periodic CM noise

3m emissions scan

Without CM choke
- 63 dBμV/m

With CM choke
- 34 dBμV/m
PCB to Cable Coupling

Transient co-simulation applied if system cannot be decoupled
Direct coupling from PCB to cable shield may cause emissions problem

Transmitted waveform (D+)

Received waveform (D+)

500 MHz pulse train analysis
Cable Radiation

CM current

Emissions from PCB and cable shield using a Gaussian pulse excitation (trends analysis)

Without CM choke

-2 dBV/m

With CM choke

21 dBV/m
Emissions Workflow: Near Field Source

Near field source enables stray field coupling to be modeled

Solve PCB in Detail and Export Near Fields

Compact seams and vents

Import Near Fields and Solve Full System Model
## Susceptibility Regulations

### Susceptibility Radiated and Conducted

<table>
<thead>
<tr>
<th>North America</th>
<th>IEC</th>
<th>Europe</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSI ESD 20:20</td>
<td>61000-4-2</td>
<td>EN 61000-4-2</td>
<td>ESD</td>
</tr>
<tr>
<td></td>
<td>61000-4-3</td>
<td>EN 61000-4-3</td>
<td>Radiated RF</td>
</tr>
<tr>
<td></td>
<td>61000-4-4</td>
<td>EN 61000-4-4</td>
<td>EFT</td>
</tr>
<tr>
<td></td>
<td>61000-4-5</td>
<td>EN 61000-4-5</td>
<td>Surge</td>
</tr>
<tr>
<td></td>
<td>61000-4-6</td>
<td>EN 61000-4-6</td>
<td>Conducted RF</td>
</tr>
<tr>
<td></td>
<td>61000-4-8</td>
<td>EN 61000-4-8</td>
<td>Magnetic fields</td>
</tr>
<tr>
<td></td>
<td>61000-4-11</td>
<td>EN 61000-4-11</td>
<td>Voltage Variations</td>
</tr>
</tbody>
</table>

Not all the standards are shown in the table
Susceptibility (Immunity⁻¹)

Electronic products have to work in electromagnetically harsh environments. Some of the noise levels are severe: ESD generates tens of thousands of Volts.

EMC requires that products are not susceptible to electromagnetic noise. In other words they must be immune or have immunity!

- Picture distorted when watching television
- ESD causes “fruit machine” to go into payout mode!
- Fast transients cause dentist chair to spin!
Susceptibility Coupling Paths

Failure criteria depends on the test

A  No degradation in performance, operates as intended at all times
B  Degradation allowed during the test, full performance must be restored following the test, without user intervention
C  Degradation allowed during the test, and after the test, provided that full performance can be restored automatically or by user intervention
Automotive EMI Simulation

Radiated Susceptibility Simulation
Antenna to Cable Coupling
Cable Harness Modeling
ESD Simulation of Mobile Phone

A combination of simulations and measurements allows to identify soft failures of mobile phones.

ESD to Enclosure with Cable Entry

Bi-Directional co-simulation between the 3D field, cable and circuit simulations allows the effect of cable entry to be considered.

External Cable Screen Bonded to Enclosure

External Cable Screen not Bonded to Enclosure
Detailed ESD Generator Model

The motivation for developing a detailed full 3D model of the generator is to correctly simulate the asymmetric fields generated by the discharge and their coupling to the system.

Full wave model for simulating Noiseken ESD Generator

Discharge current at gun tip

Induced voltage in semi-circular loop

Time animation confirms the asymmetric field distribution. This may affect the coupling to the system under test.
Hybrid Cable EMI

Programmable switch mode power supply driving an intelligent sensor with high speed RS485 communications

Interference between SMPS and RS485 circuit

Import measured screen transfer impedance
Cable Parameter Extraction

Analysis of mutual capacitance between Vpos and Vneg phase wires

- $C_{+, -} = 0.0021\text{pF/m}$
- $C_{+, -} = 0.0021\text{pF/m}$

CST EMS can be used to design cable cross section and extract parasitic values. CST CS uses an internal 2D field solver to extract parasitic values for TL analysis.
Interference Analysis

Cable/circuit co-simulation

CST CS used to investigate CM noise for different SMPS waveforms, cable lengths, cable screens and terminations

CM Current in RS485 line

Input SMPS PWM voltage
# E3 Regulations

## Electromagnetic Environmental Effects

<table>
<thead>
<tr>
<th>MIL-STD</th>
<th>ANSI</th>
<th>RTCA</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>461/4, 1757</td>
<td>C63.41</td>
<td>DO-160F</td>
<td>Lightning</td>
</tr>
<tr>
<td>461/4</td>
<td>C63.41</td>
<td>DO-160G</td>
<td>HIRF</td>
</tr>
<tr>
<td>461, 188-125-1</td>
<td>C63.14-1992</td>
<td>DO-160F</td>
<td>EMP</td>
</tr>
<tr>
<td>461/4</td>
<td>C95.1-1992</td>
<td>DO-160C</td>
<td>EMP</td>
</tr>
<tr>
<td>1686</td>
<td>ESD 20:20</td>
<td>DO-160D</td>
<td>RADHAZ</td>
</tr>
</tbody>
</table>

Not all the standards are shown in the table.
E3 Applications

Lightning
Direct or near lightning strikes can upset or damage electronic systems

HIRF
Aircraft must not be susceptible to high intensity radiated fields

EMP
Critical against electronic systems must be hardened against electromagnetic pulse

Threat levels can be extremely high: 200kA lightning strike, 50 kV/m EMP, 10kV/m HIRF radiation. Transient protection required to limit voltage and current levels. Semiconductors are vulnerable to damage by heat.

Lightning and EMP are transient effects, ideal for transient co-simulation. HIRF covers a wide band 10 KHz to 40 GHz - combination of solvers required.
Rotorcraft EMP Simulation

Important detail such as panel joints/seams and realistic cables can be modeled efficiently.

Multi-Layer Thin Panel
Direct Transient Solution

MIL-STD 464 Unclassified Waveform

Direct time-domain simulation of transient effects
EMP Protection Assessment

Real world cable modeling

Solid and braided screens can be added to cable model to investigate shielding

True transient co-simulation

Non-linear transient protection devices modeled by true transient co-simulation
Interference Analysis

Powerful workflows for antenna co-site and RADHAZ analysis

Near Field Source

Complete Solver technology for efficiency
Lightning Strike Simulation

Wind turbine lightning analysis
Conclusions

Efficient EMC simulation workflows
- CST BOARDCHECK identifies potential problem areas for 3D field simulation

Transient solver
- Direct time-domain analysis of transients such as ESD, EMP and lightning

Co-simulation
- MWS+CS+DS co-simulation enables coupling between fields, cables and circuits

Compact models
- Thin conducting panels, slots/gaps, joints/seams and ventilation panels

Realistic cables
- Bi-directional coupling between field solution and complex cable models