Virtual High Intensity Radiated Field (HIRF) Testing

3DEXPERIENCE®

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Motivation I

- **New A/C concepts** (fly-by-wire, all electric aircraft, …)
- **Increasing …**
  - A/C number of functions performed by electronic systems
  - Susceptibility of A/C to EM environments (HIRF, Lightning, ESD, NEMP, HPM)
- **Increasing …**
  - A/C safety requirements
  - A/C development time & cost
  - A/C testing time & cost to comply with certification requirements

Motivation II

- **Computational electromagnetics (CEM) to …**
  - Support, improve & reduce A/C testing
  - Determine the EM environments of A/C electronic systems
  - Be used for design, upgrade & design certification / qualification of A/C
- **Virtual EMC test methodology for large multiscale problems …**
  - In Dassault Systemes SIMULIA CST Studio Suite®
  - Applied to Evektor's EV-55 Outback plane in a HIRF environment

Outline

- ▶HIRF
- ▶Virtual EMC / HIRF test
- ▶Aircraft application
- ▶Summary

HIRF I

High-intensity / high energy radiated fields (HIRF / HERF)

- **Severe external EM environment** due to high power RF sources
  - TV & Radio
  - Radar
  - Satellite communication with ground systems, ships or aircrafts
- **Impact** (threats inside fuselage)
  - Induced currents in A/C cables
  - EM field penetration into A/C fuselage

Source: Maria Lindback, Optimisation of aircraft transfer function measurements, M.Sc. Thesis, Lund University, in coop. with Airbus France, 2004

HIRF II

Frequency division of HIRF

Low frequency band

10kHz — 50MHz

- A/C acts as antenna
- Induced currents in A/C cables
- A/C electronics pot. affected by excessive current levels

Medium frequency band

30MHz — 400MHz

- Induced currents in A/C cables
- EM Field penetration into A/C fuselage
- A/C electronics pot. affected by excessive current and EM field levels inside fuselage

High frequency band

100MHz — 18/40GHz

- EM Field penetration into A/C fuselage
- A/C electronics pot. affected by excessive EM field levels inside fuselage

Source: Maria Lindback, Optimisation of aircraft transfer function measurements, M.Sc. Thesis, Lund University, in coop. with Airbus France, 2004

HIRF III

HIRF test objective

- To determine transfer functions
- Transfer function is
  - Induced currents/penetrated EM field in A/C over external EM field
    - 10kHz — 400MHz: 20 log $|I/E_{ext}|$ in dBA(V/m)
    - 100MHz — 18/40GHz: 20 log $|E_{int}/E_{ext}|$ in dB
- Impact of an external HIRF EM field to A/C electronics from:

  Transfer function + external HIRF EM field

Source: Maria Lindback, Optimisation of aircraft transfer function measurements, M.Sc. Thesis, Lund University, in coop. with Airbus France, 2004

Virtual EMC / HIRF Test I

Objective

- ▷ To support, improve & reduce A/C HIRF testing
- ▷ To determine the EM environments of A/C electronic systems
- ▶ To determine transfer functions by computational electromagnetics
- ▶ To support the R&D in Europe related to A/C EMC
- ▶ CST partnered in the European research project High Intensity Radiated Field Synthetic Environment (2007-2013)

The presented work has received funding from the European community's 7th framework program. (FP7/2007-2013) under grant agreement no 205294 (HIRF SE project).

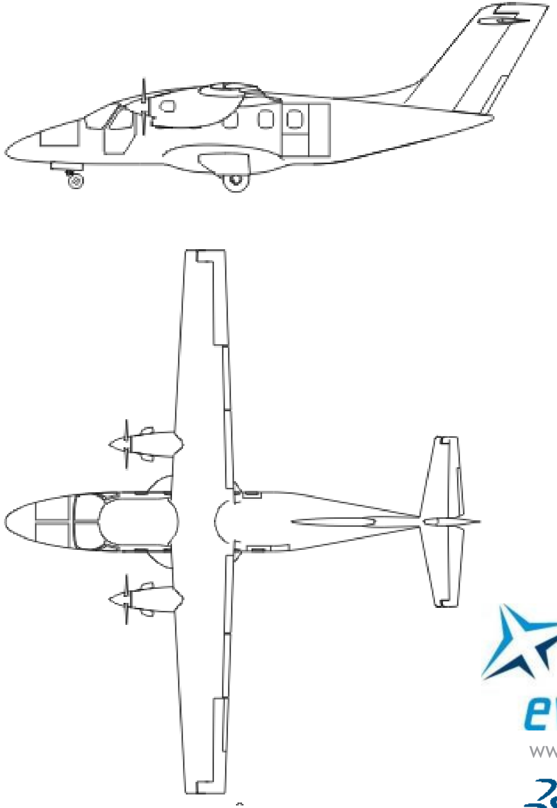
Virtual EMC / HIRF Test II

- **Pre-Processing**
  - CAD import & healing
  - Model setup & mesh generation
- **EM Simulation**
  - TD-HPC-Simulation
  - FD-HPC-Simulation
- **Post-Processing**
  - 2D / 3D field processing
  - Voltages & currents

→ **Transfer functions**

Physical aircraft

Source: www.evektor.cz



EV-55 Outback (twin turboprop)

- Wing span = 16.10m
- Overall length = 14.21m
- Height = 5.13m

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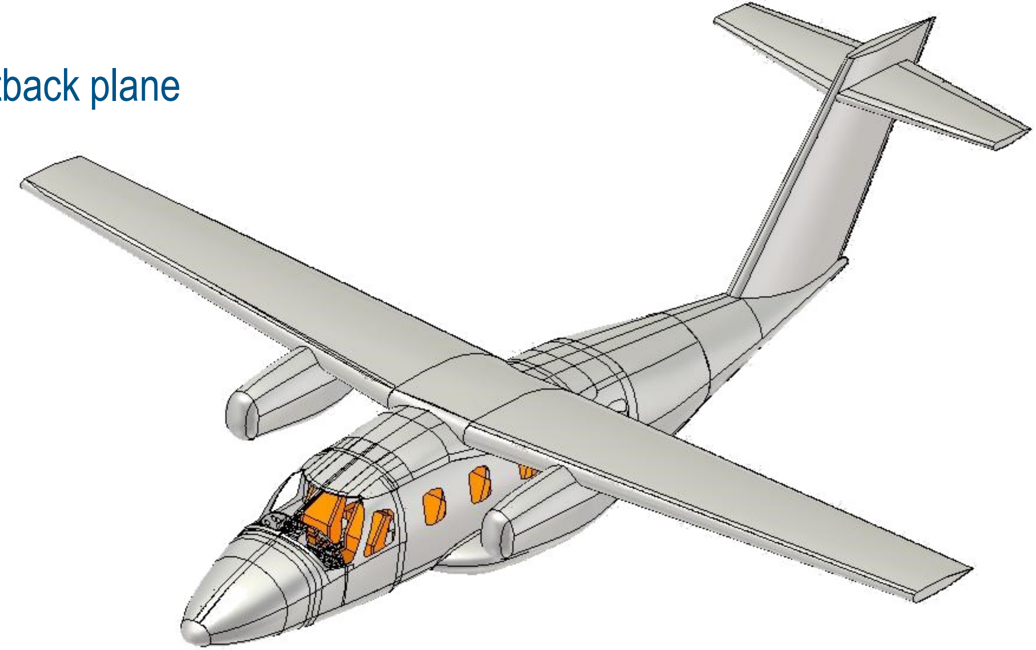
Virtual aircraft I

Morphed version of Evektor's EV-55 Outback plane

Used CAD tool: CATIA v.5.18

Aircraft parts:
- Fuselage
- Instrument panel
- Pilot and passenger seats
- Upholstery



Model exchange format: IGES
(other formats e.g. CATIA, STEP, … also possible)

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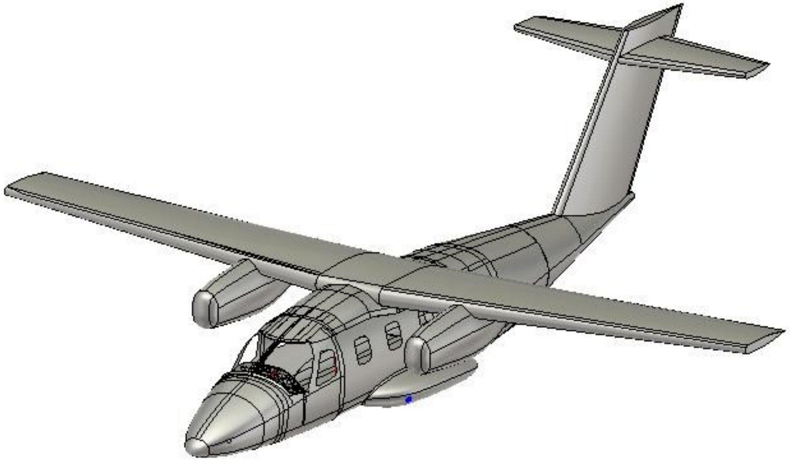
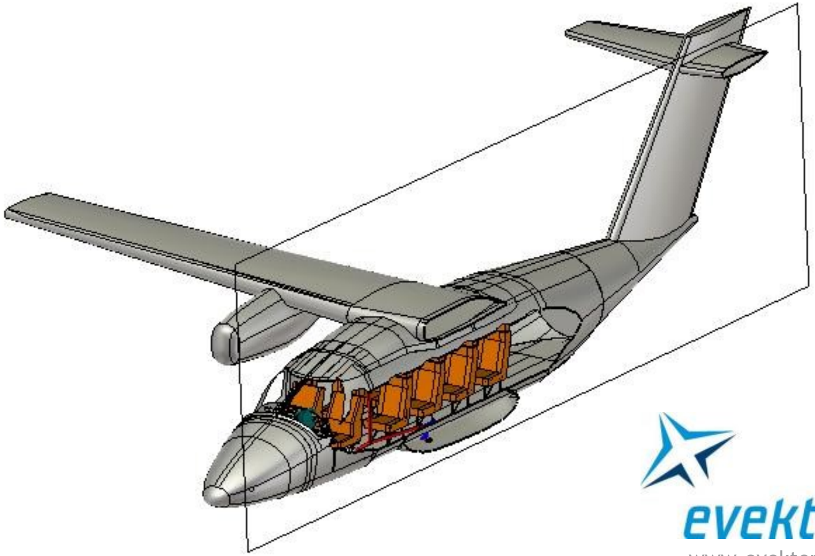
Virtual aircraft II

Investigated Geometries

Full-EV55 without Seats Geometry



Full-EV55 with Seats Geometry



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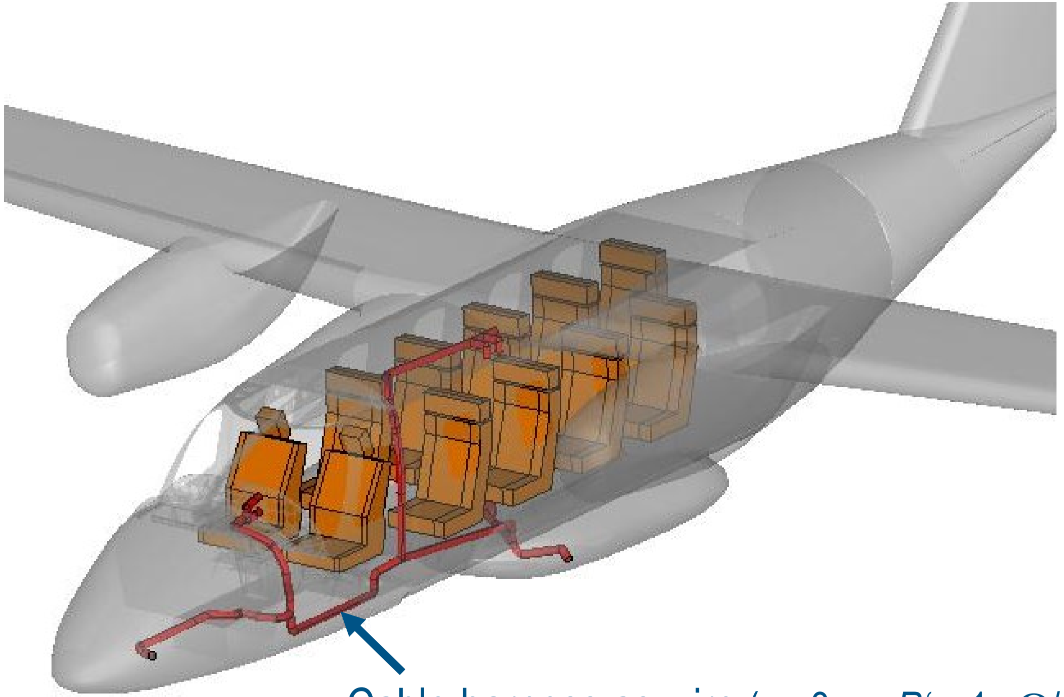
Virtual aircraft III

Wiring



Cable harness as wire (r = 3cm, R' = 1mΩ/m)

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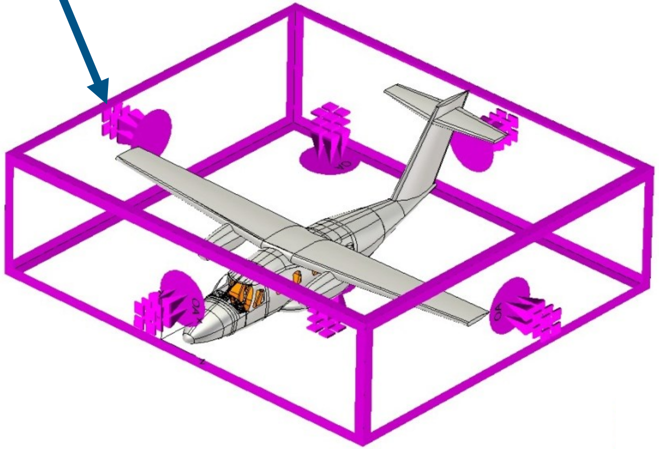
Pre-Processing I

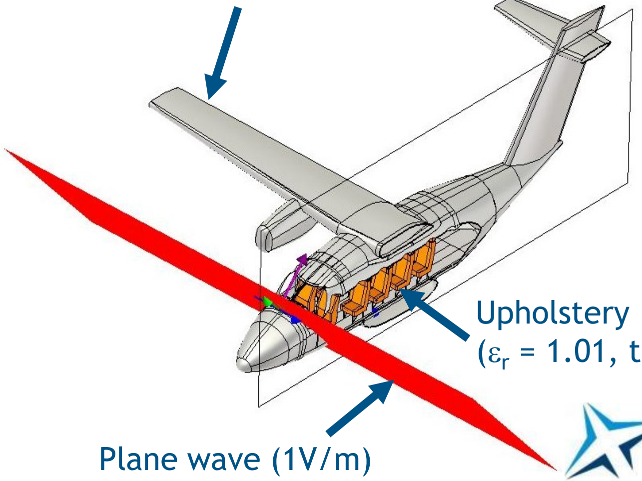
Model setup I

- Material properties
- RF sources (plane wave, field sources, …)
- Boundary conditions (0PEN, PEC, …)
- Frequency range: up to 1 GHz

Open boundary (free space)



PEC (fuselage, instrument panel, seat frames)



Upholstery (ε_r = 1.01, tan $\delta = 0.0001$)

Plane wave (1V/m)

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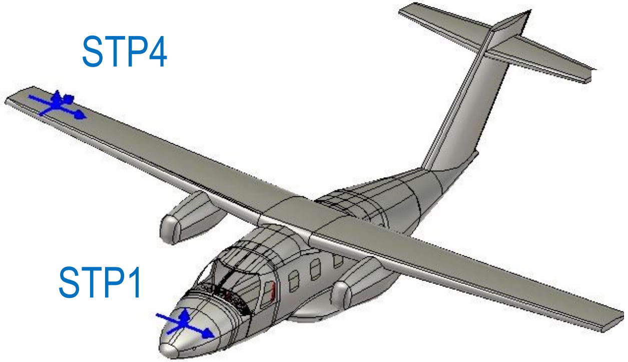
Pre-Processing II

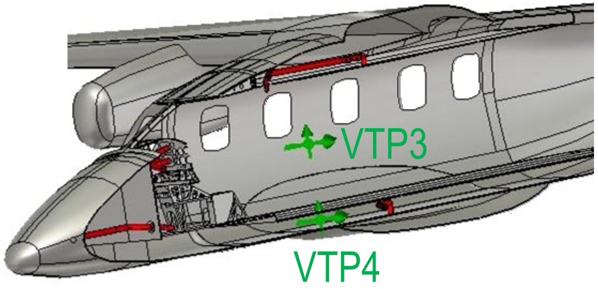
Model setup II

For Post-Processing

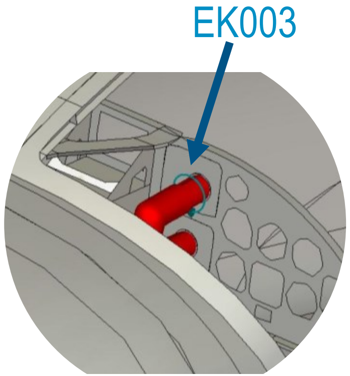
- Field monitors (*E* and *H* fields, surface currents, …)
- Broadband current and voltage monitors
- Broadband *E* field and *H* fie



Magnetic field probe on fuselage skin



Electric field probe in fuselage

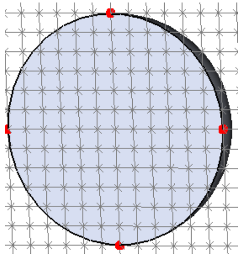


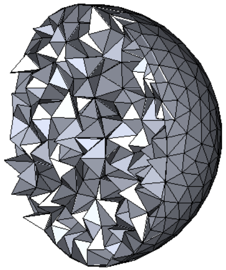
Current monitor on wiring

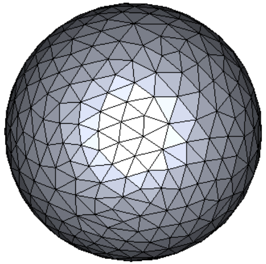
Pre-Processing III

Mesh generation (i)

- Mesh type is dependent on numerical algorithm (FIT, FEM, IE)







Structured Mesh

Hexahedral Mesh

- Transient simulations
- Less common: Frequency domain simulations

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Un-Structured Meshes

Tetrahedral Mesh

- Frequency domain simulations (general purpose 3D F-solver)

F

Surface Mesh

- Integral equation methods

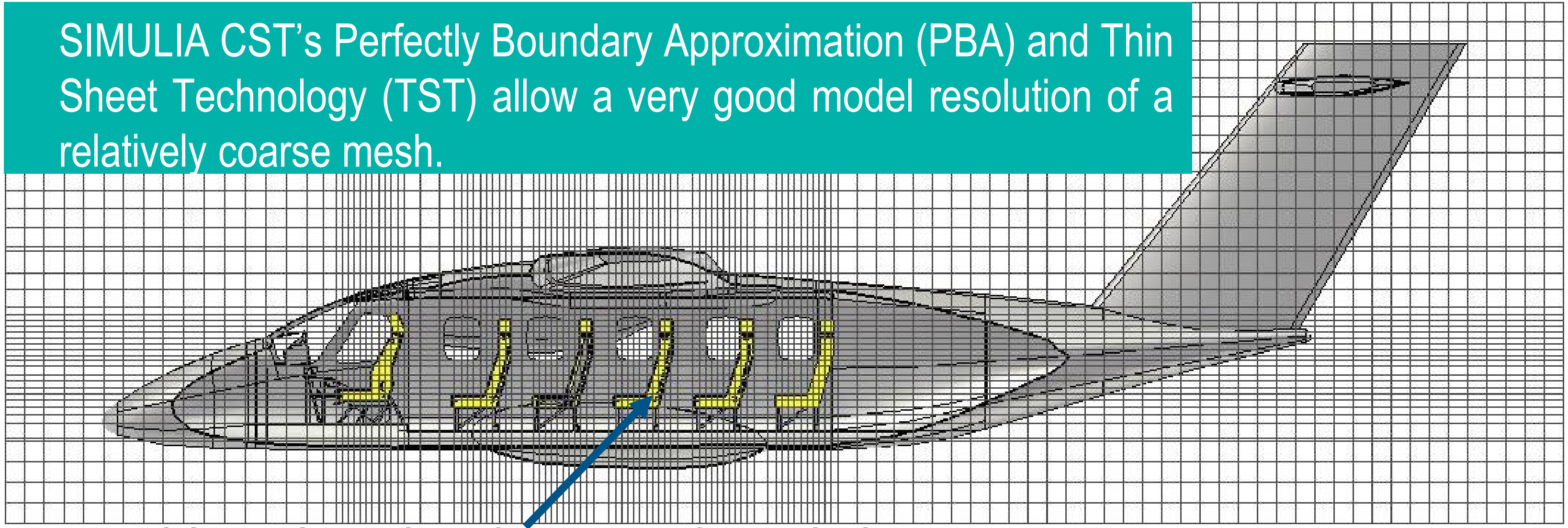
I

Pre-Processing IV

Mesh generation (ii) — PBA mesh

Hexahedral PBA mesh @ 150 MHz (min. 10 lines per wavelength)

SIMULIA CST's Perfectly Boundary Approximation (PBA) and Thin Sheet Technology (TST) allow a very good model resolution of a relatively coarse mesh.

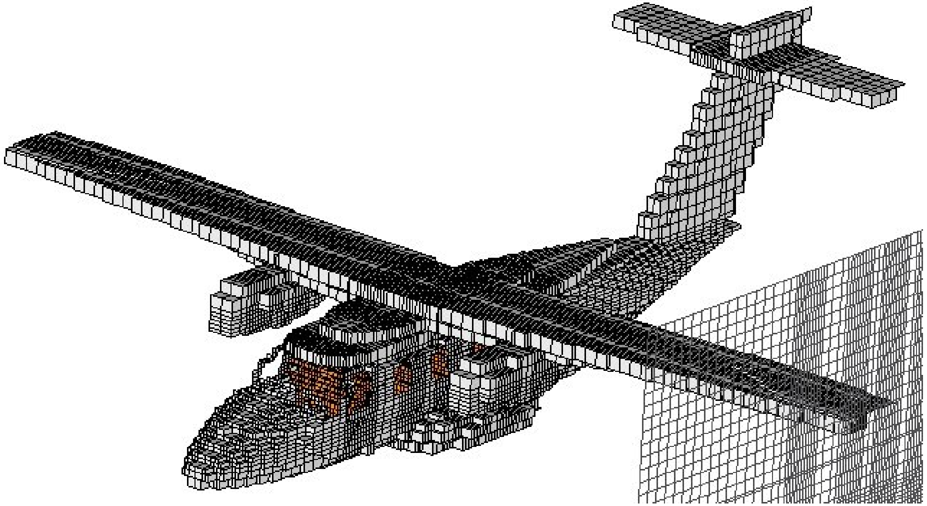


Material based mesh refinement for upholstery

Pre-Processing V

Mesh generation (iii) — Staircase mesh

Hexahedral staircase mesh @ 150 MHz (min. 10 lines per wavelength)



Drawbacks

- Poor spatial resolution
- Smaller mesh steps required
- Smaller time steps required
- Increase in CPU time
- Increase in memory requirement

EM Simulation I

Numerical Solvers

General purpose solver 3D-volume

Transient	▪ large problems ▪ broadband ▪ arbitrary time signals
Frequency Domain	▪ narrow band / single frequency ▪ small problems ▪ periodic structures with Floquet port modes

Special solver 3D-surface: large open metallic structures

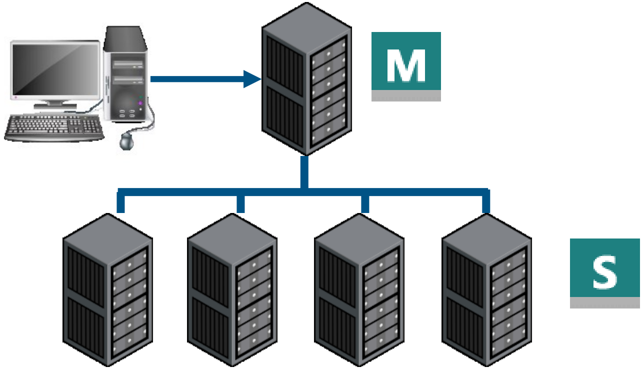
Integral Equation	▪ large structures ▪ dominated by metal

CST Studio Suite® Time Domain solver was used.

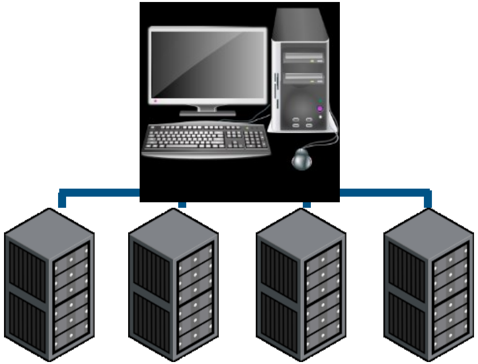
EM Simulation II

CPU Multithreading

GPU Computing



Distributed Computing



MPI Computing

Post-Processing I

Frequency division of HIRF

10kHz — 50MHz   30MHz — 400MHZ   100MHz — 18/40GHz

Induced currents

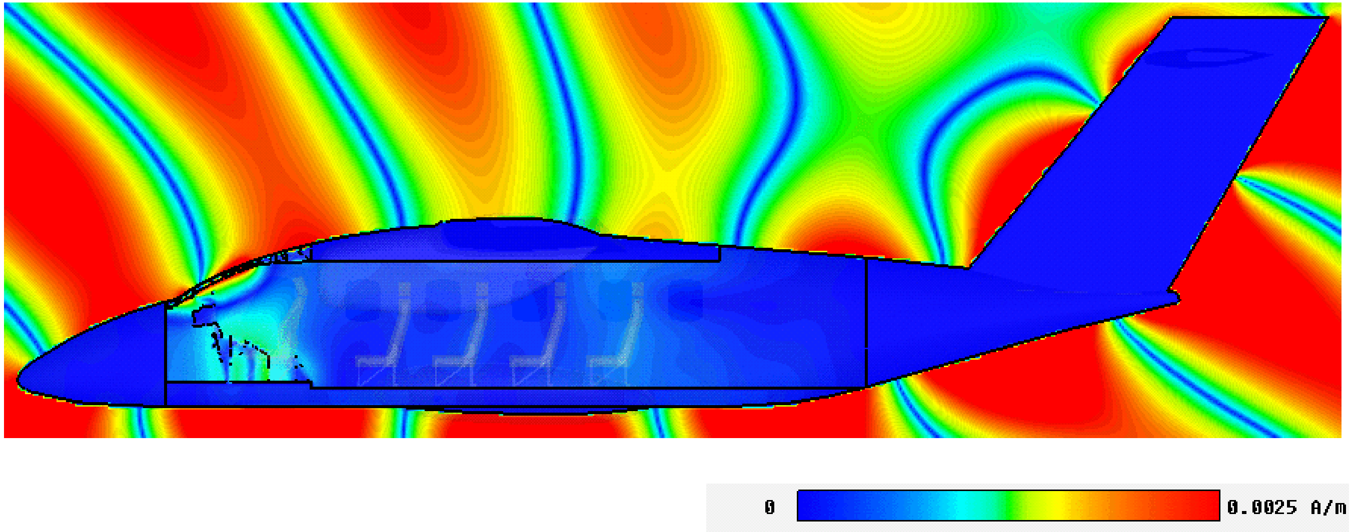
EM field penetration

Source: Maria Lindback, Optimisation of aircraft transfer function measurements, M.Sc. Thesis, Lund University, in coop. with Airbus France, 2004

Post-Processing II

▶ Magnetic field strength @ 70MHz (MF)

- Low EM field penetration into fuselage
- A/C electronics affected by excessive induced currents in A/C cables



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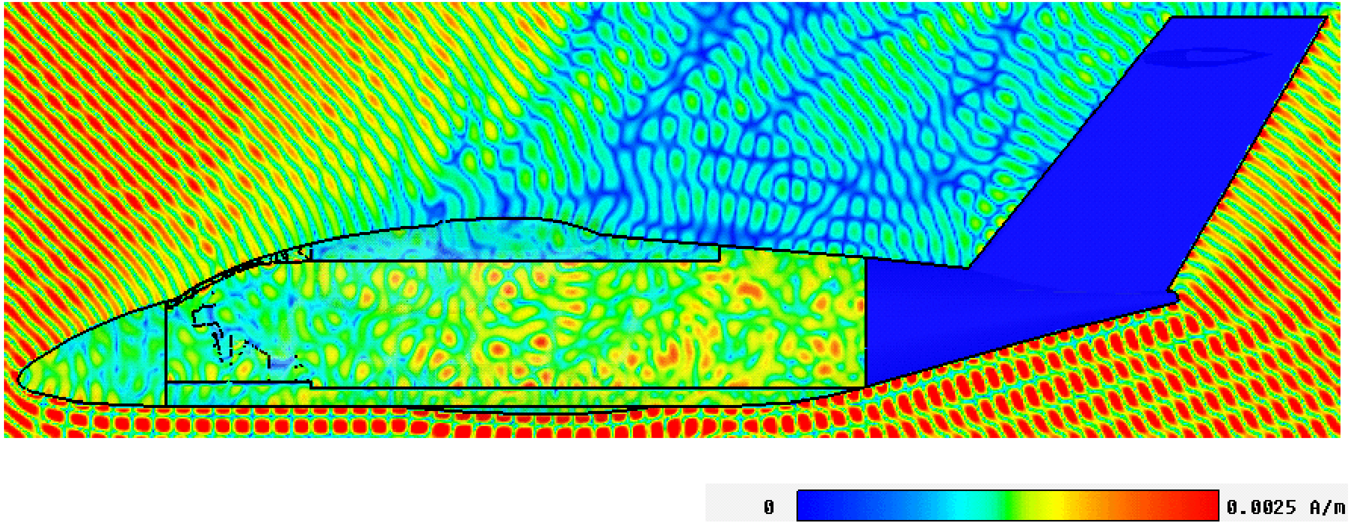
Post-Processing III

- **Magnetic field strength @ 1000MHz (HF)**
  - High EM field penetration into fuselage
  - A/C electronics affected by excessive EM field levels inside fuselage



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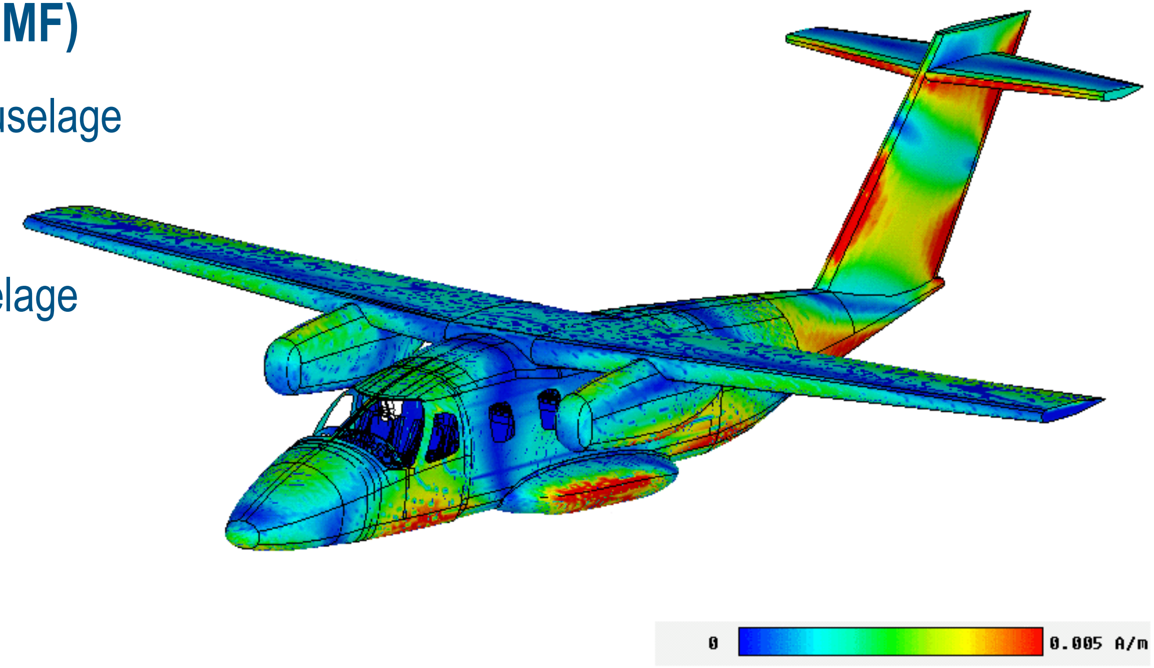
Post-Processing IV

▶ **Surface current @ 70MHz (MF)**

- Low EM field penetration into fuselage
- A/C acts as an antenna
- Strong surface currents on fuselage



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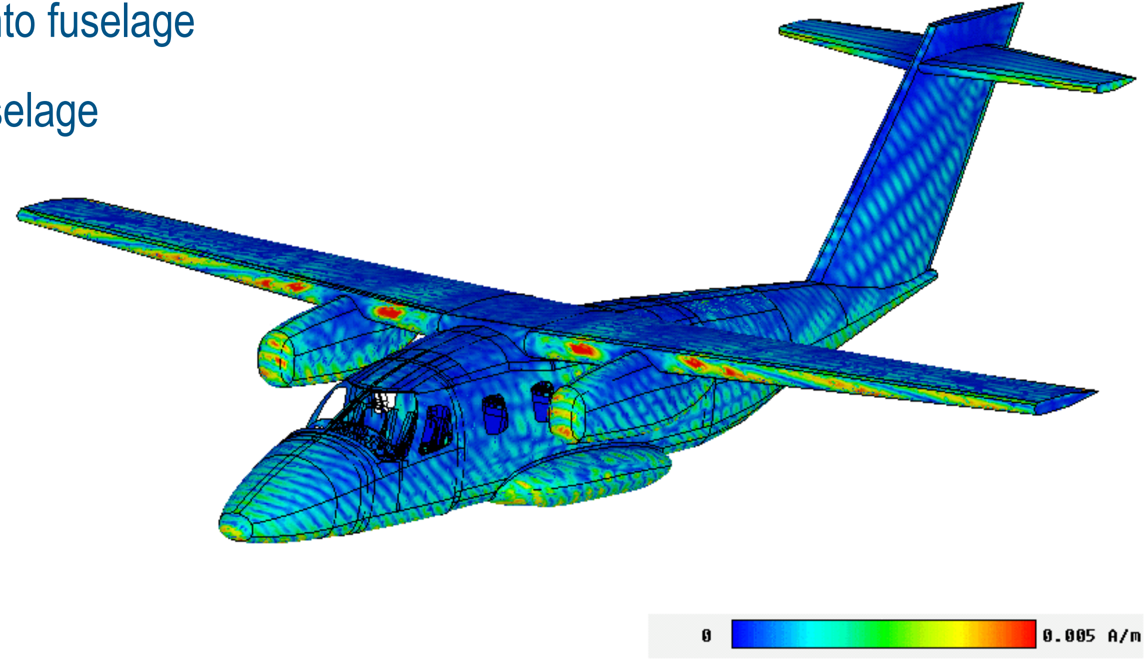
Post-Processing V

▶ **Surface current @ 1000MHz (HF)**

- High EM field penetration into fuselage
- Low surface currents on fuselage



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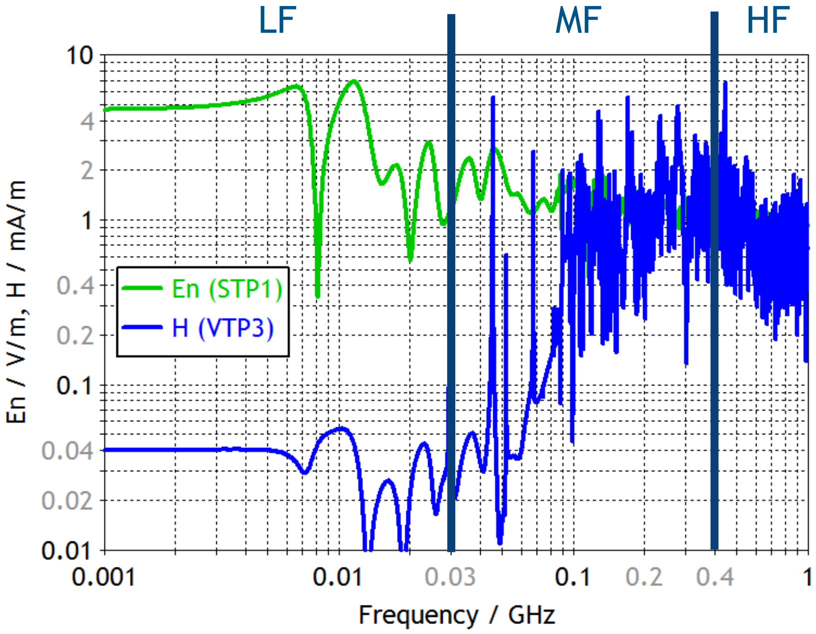
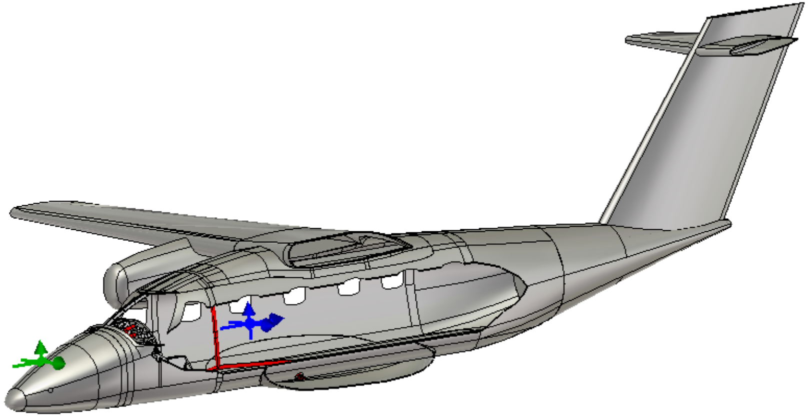
Post-Processing VI

EM fields @ field probes





Magnetic field probe in fuselage

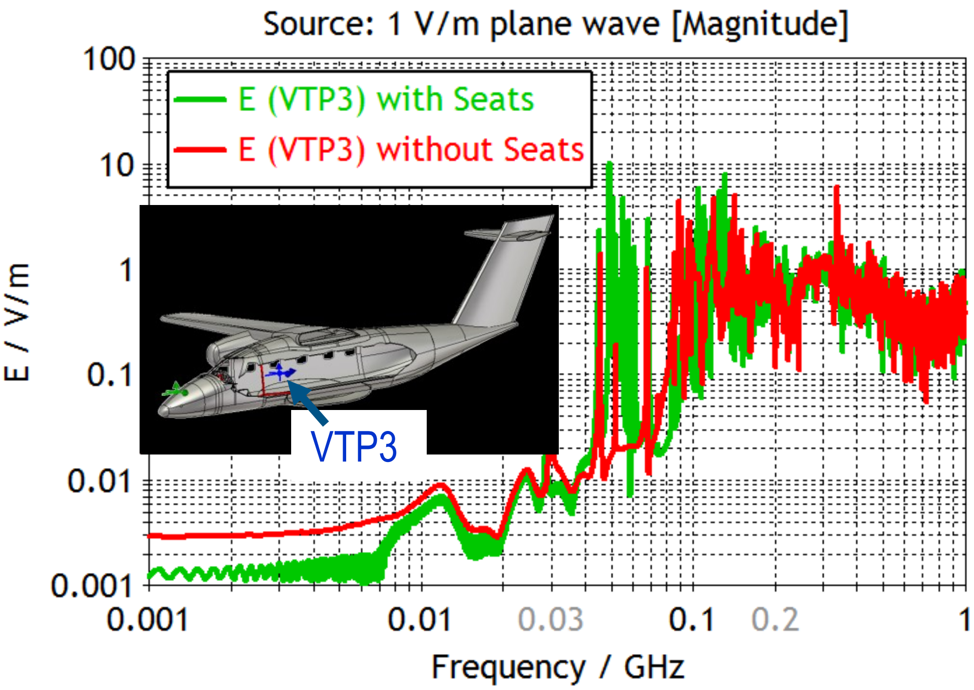
Electric field probe on fuselage skin

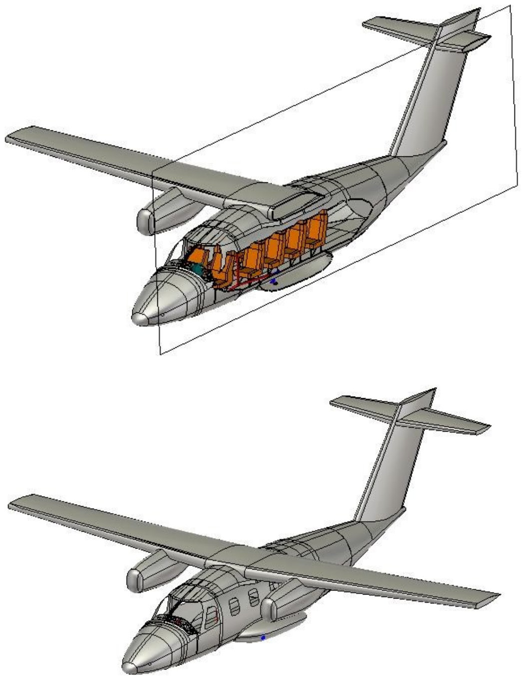
LF: Low field penetration

MF / HF: High field penetration

Post-Processing VII

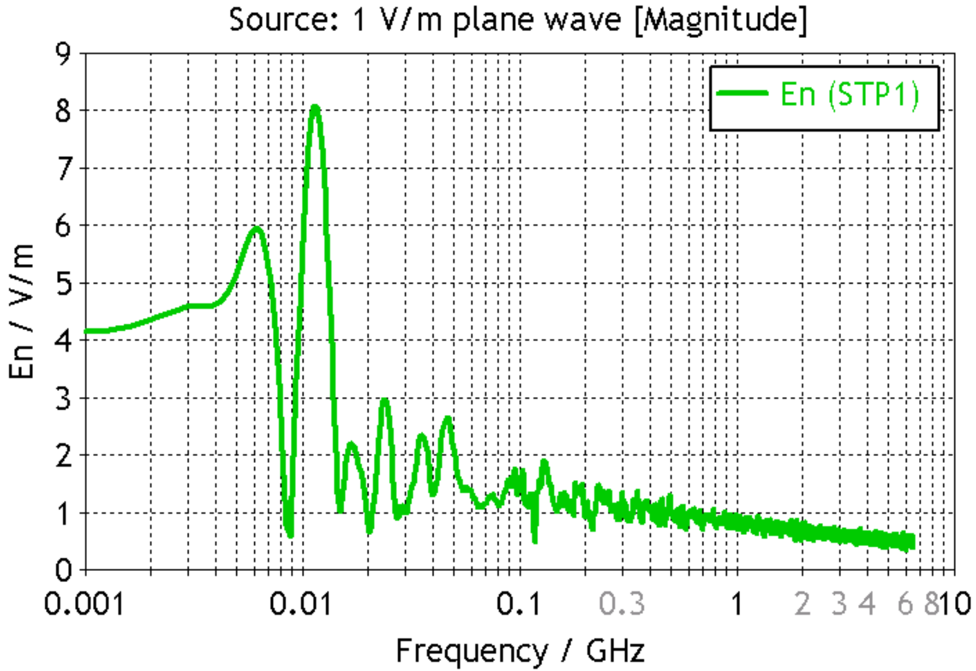
E-field @ field probe VTP3 inside fuselage

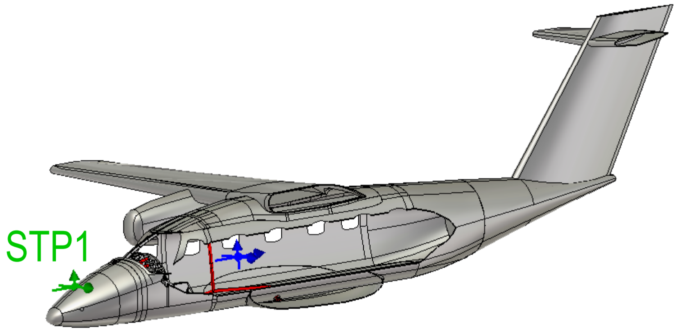




Post-Processing VIII

E-field probe result up to 6.5 GHz





# of mesh cells:	10.5 Billion
Degrees of freedom:	63 Billion
Dissipation of eneryg:	-40 dB
MPI:	131 nodes
Time of Simulation:	19.5 h

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Summary

Virtual EMC / HIRF tests in Dassault Systemes SIMULIA CST Studio Suite® support, improve & reduce A/C HIRF testing!

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