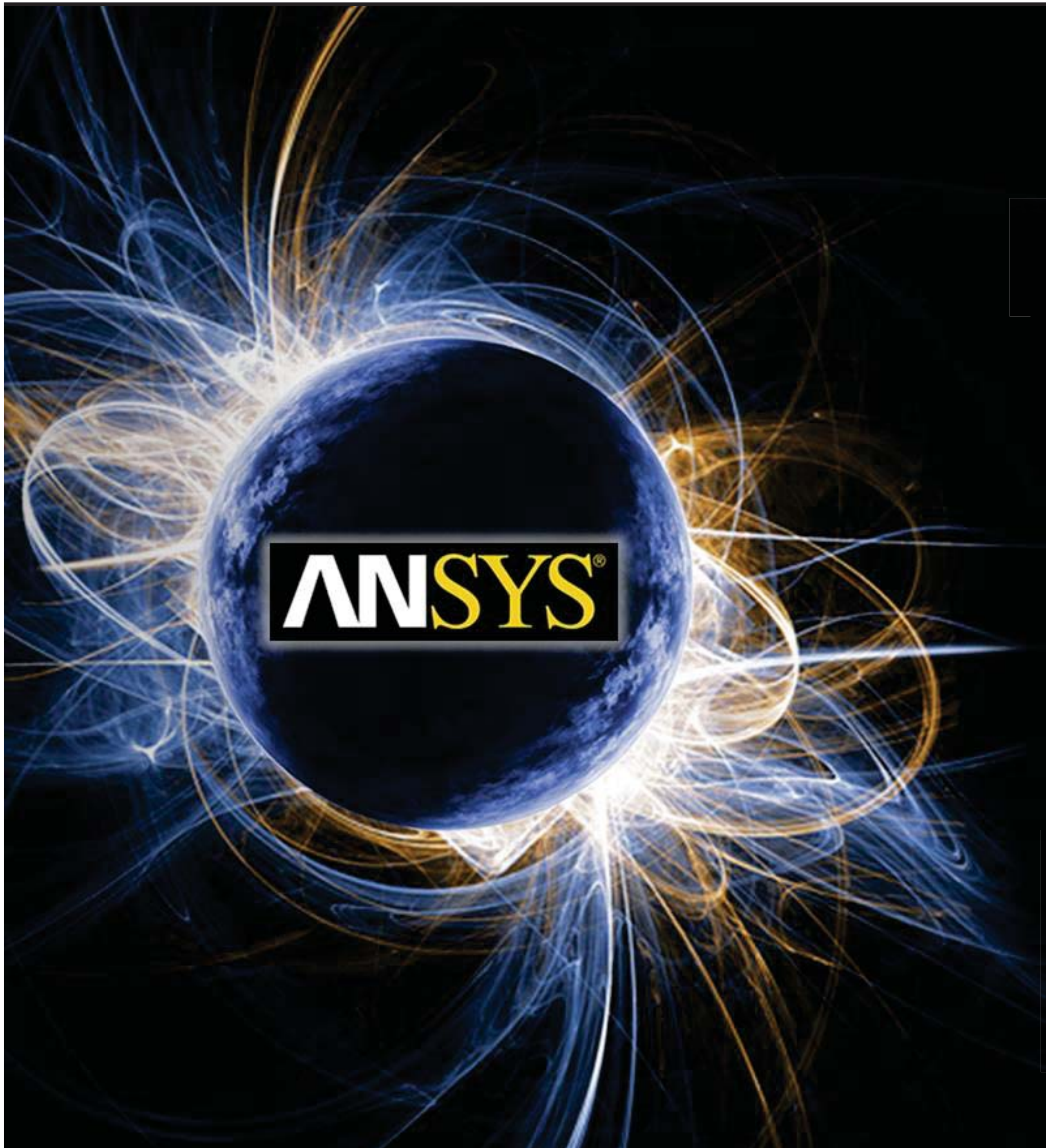
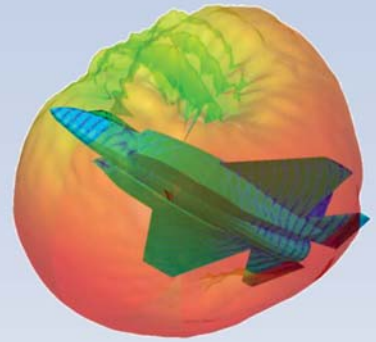


HFSS 12.0

Ansys

Comparison of HFSS 11 and HFSS 12 for JSF Antenna Model

- UHF blade antenna on Joint Strike Fighter
- Inherent improvements in runtime and RAM usage for this example
  - Model converges to desired accuracy in 50% of the time using 20% less RAM



JSF Antenna Model (8 CPUs)	Adaptive Passes to Reach $\Delta S = 0.02$	Tetrahedra	Runtime (min)	RAM (GB)
HFSS 11: 2nd order basis and iterative solver	6	162k	98	9.1
HFSS 12: 2nd order basis and iterative solver	6	119k	59	6.9
HFSS 12: mixed order basis and iterative solver	7	156k	47	7.6

(Option) DSO

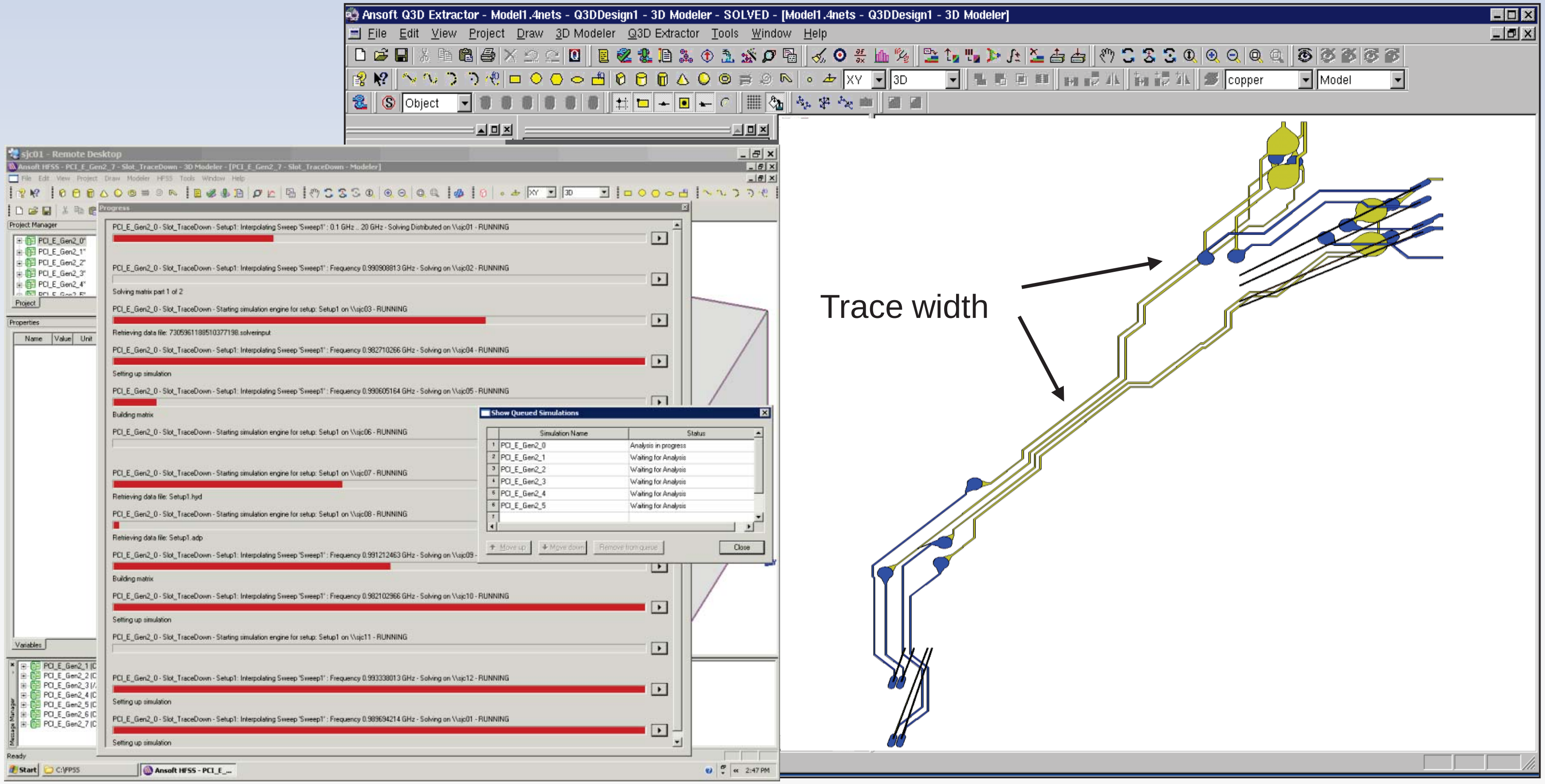
(Distributed Solve Option)

Balancing Time versus Resources DSO (Distributed Solve Option)

- **In the past, users had to make trade-off decisions about how much to simulate in a limited amount of time (eg, overnight)**
  - Multiple geometric variations
    - Pro: optimizes structure for best electrical performance
    - Con: requires more run-time
      - simulation time increases with # of variations
  - Solve for more frequency points
    - Pro: improves results accuracy
    - Con: requires more run-time
      - simulation time increases with # of freq. points

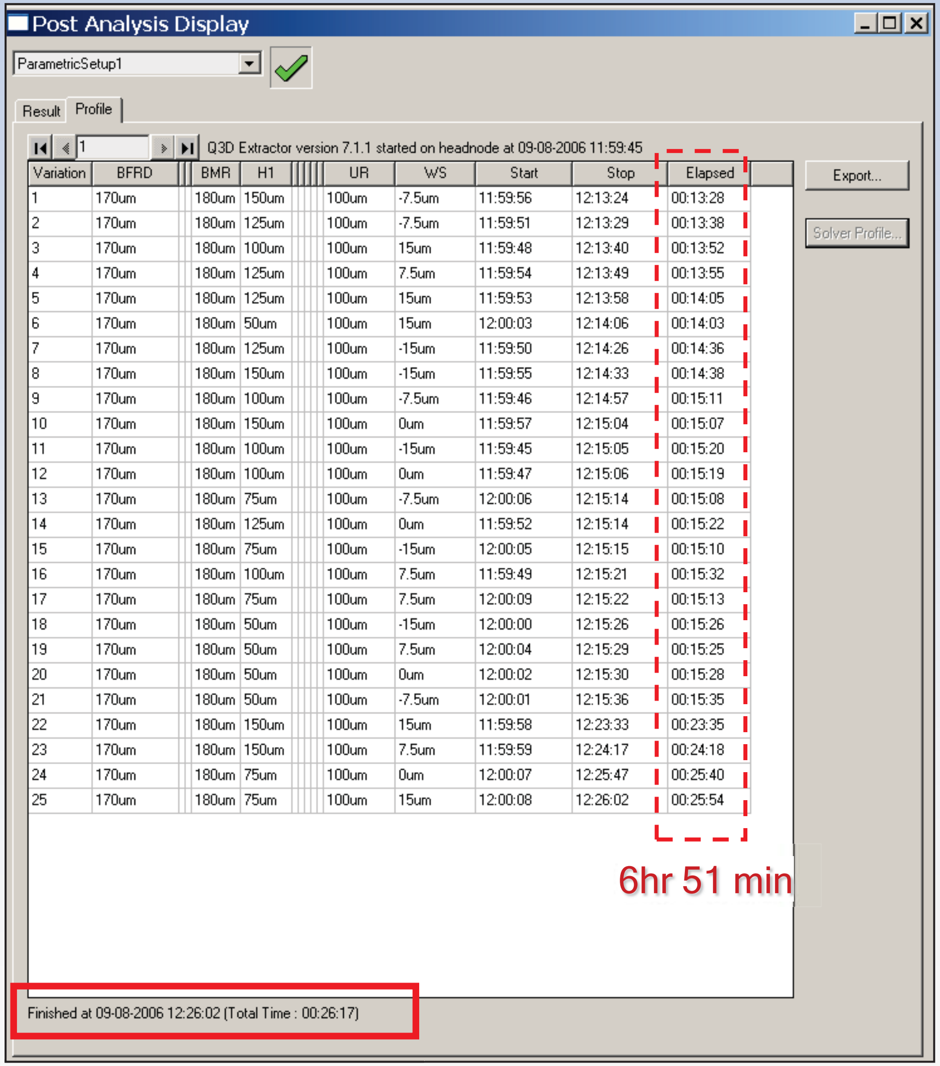
Reduce Simulation Run Times

- Trace width and spacing parameterization using Q3D
- Distributed Solve Option in action



Optimize Simulation Run Times

- **DSO Setup**
  - 25 Parametric Case
  - HeadNode: Dual-Dual-Core AMD 2.2GHz 16GB RAM
  - Nodes: 16 Dual Processor AMD 2.6GHz 8GB RAM
- **Nominal Case**
  - 6 hrs 51 min
- **DSO Solution Time**
  - 26 min !!!
- **Time Savings**
  - **15x speed up** !



Variation	BFRD	BMR	H1	UR	WS	Start	Stop	Elapsed
1	170um	180um	150um	100um	-7.5um	11:59:56	12:13:24	00:13:28
2	170um	180um	125um	100um	-7.5um	11:59:51	12:13:29	00:13:38
3	170um	180um	100um	100um	15um	11:59:48	12:13:40	00:13:52
4	170um	180um	125um	100um	7.5um	11:59:54	12:13:49	00:13:55
5	170um	180um	125um	100um	15um	11:59:53	12:13:58	00:14:05
6	170um	180um	50um	100um	15um	12:00:03	12:14:06	00:14:03
7	170um	180um	125um	100um	-15um	11:59:50	12:14:26	00:14:36
8	170um	180um	150um	100um	-15um	11:59:55	12:14:33	00:14:38
9	170um	180um	100um	100um	-7.5um	11:59:46	12:14:57	00:15:11
10	170um	180um	150um	100um	0um	11:59:57	12:15:04	00:15:07
11	170um	180um	100um	100um	-15um	11:59:45	12:15:05	00:15:20
12	170um	180um	100um	100um	0um	11:59:47	12:15:06	00:15:19
13	170um	180um	75um	100um	-7.5um	12:00:06	12:15:14	00:15:08
14	170um	180um	125um	100um	0um	11:59:52	12:15:14	00:15:22
15	170um	180um	75um	100um	-15um	12:00:05	12:15:15	00:15:10
16	170um	180um	100um	100um	7.5um	11:59:49	12:15:21	00:15:32
17	170um	180um	75um	100um	7.5um	12:00:09	12:15:22	00:15:13
18	170um	180um	50um	100um	-15um	12:00:00	12:15:26	00:15:26
19	170um	180um	50um	100um	7.5um	12:00:04	12:15:29	00:15:25
20	170um	180um	50um	100um	0um	12:00:02	12:15:30	00:15:28
21	170um	180um	50um	100um	-7.5um	12:00:01	12:15:36	00:15:35
22	170um	180um	150um	100um	15um	11:59:58	12:23:33	00:23:35
23	170um	180um	150um	100um	7.5um	11:59:59	12:24:17	00:24:18
24	170um	180um	75um	100um	0um	12:00:07	12:25:47	00:25:40
25	170um	180um	75um	100um	15um	12:00:08	12:26:02	00:25:54

Finished at 09-08-2006 12:26:02 (Total Time : 00:26:17)

6hr 51 min

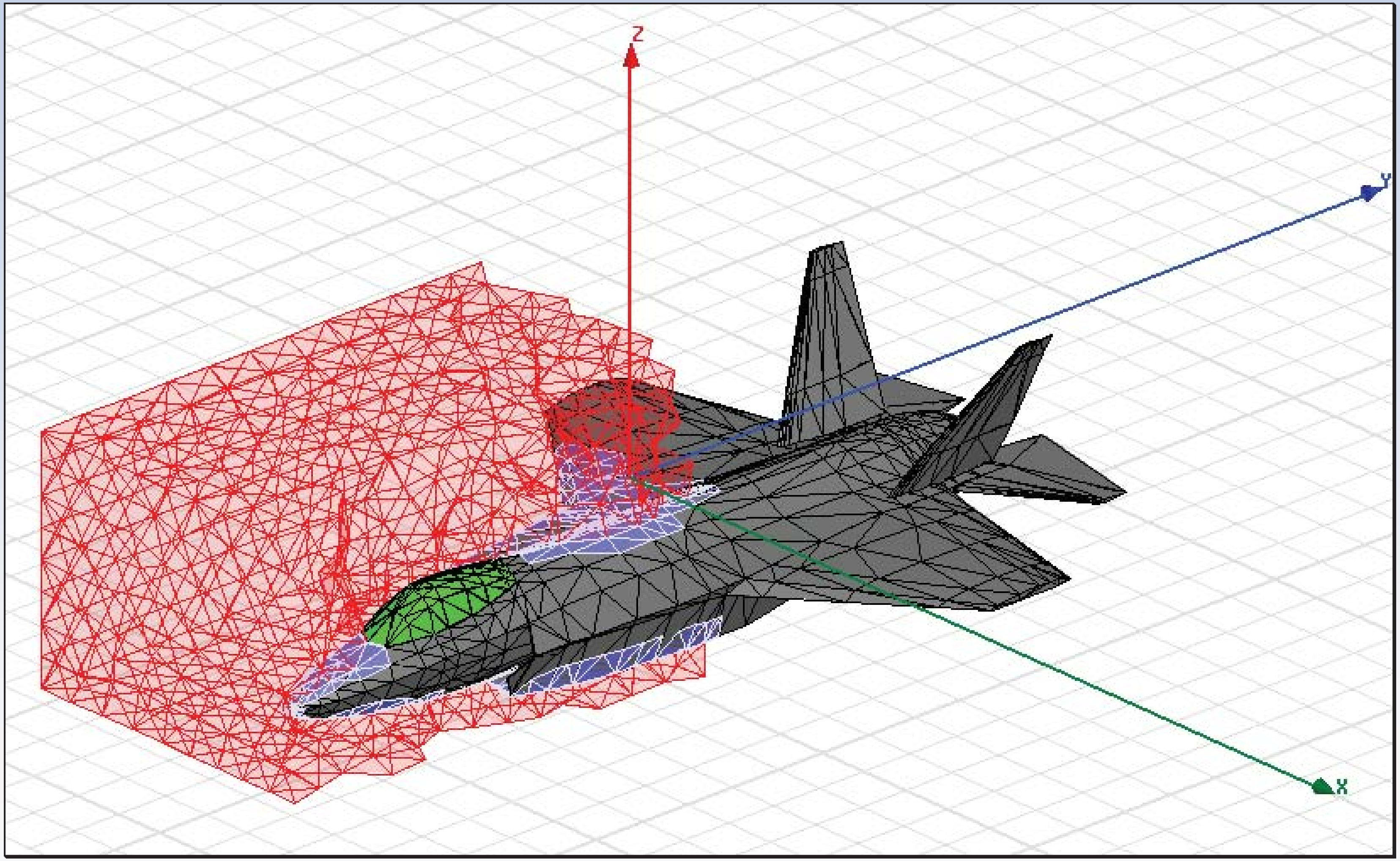
DSO Solution Time

(Option) DDM
(Domain Decomposition Solver)

Review DDM Technique

- **DDM subdivides a mesh into smaller mesh "*sub-domains"* that are solved in parallel.**
  - A "master" node iteratively solves for total solution
  - Subdivision into domains is automated
    - **Easy to use!!!**
- **The user defines a set of N available compute nodes to be used for a DDM solution**
  - n=1 is the "master" node, single core
  - n=2 to N are the sub-domain nodes solved with direct solver

Example of Domain Mesh

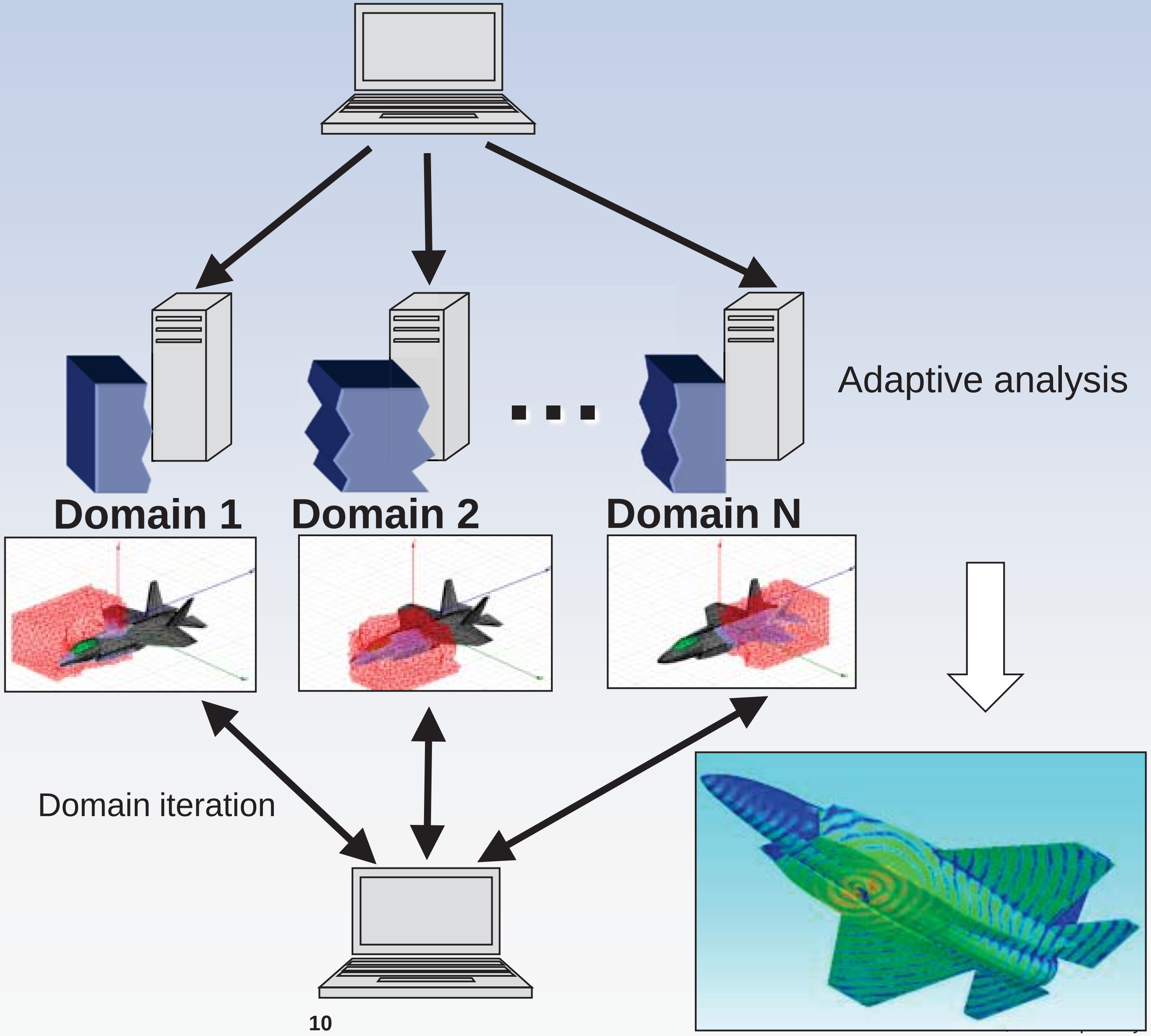


Domain Decomposition Process

Mesh partition

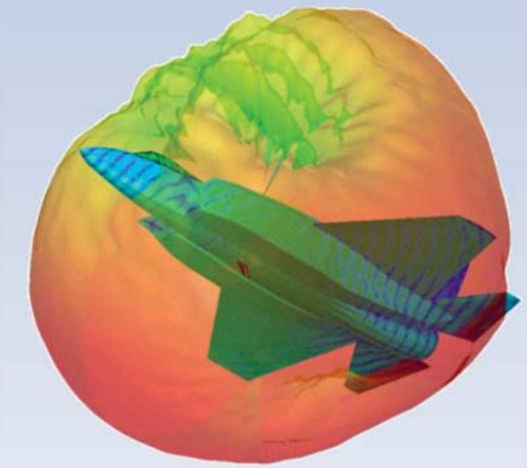
Mesh assembly/solve

Domain iteration



Antenna Example for Domain Decomposition Solver

- UFH blade antenna on F-35 JSF
  - 350 MHz solution frequency
- Demonstrates savings in computational time and RAM



	Direct Solver (1 CPU)	Iterative Solver (1 CPU)	Domain Solver (15 domains)
Total Memory	33 GB	12 GB	20 GB
Average Memory	33 GB	12 GB	1.35 GB
Final Adaptive Pass Time	6hr 27min	1hr 20min	22 min

HFSS 12 New Significant Capabilities

HFSS 12 Includes Fundamentally Different 3D Mesher

ANSYS

HFSS 11
(bottom up algorithm)

Surface Mesh → Volume Mesh

- model
- Geometric healing or repair (if model has defects)
- Surface mesh generation (union, stitching)
- Volume mesh generation

- Generally requires water-tight, clean geometric model
- Mesh quality depends on ACIS faceting triangulation quality
- Geometry flaws can cause stitching failure
- Less control on mesh quality
- Localized jump from small to large elements is possible

HFSS 12
(top down algorithm)

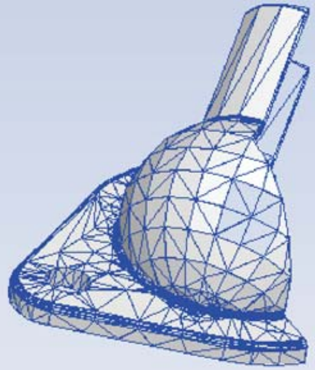
Volume Mesh → Surface Mesh

- model
- Volume mesh generation
- Mesh adaptation (if needed)
- Conformal surface mesh generation
- Mesh coarsening

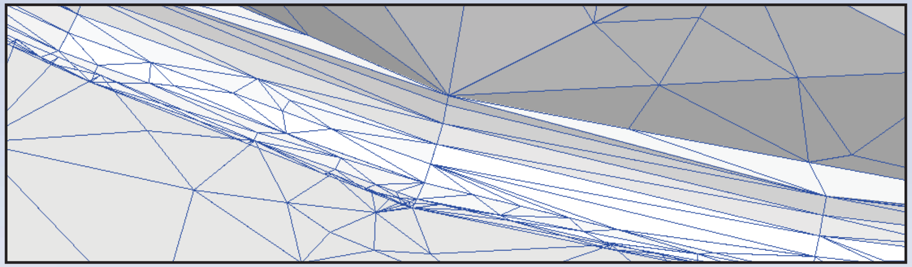
- Meshes higher percentage of models
- Mesh quality is ensured
- Automatic healing and repair
- More uniform mesh (gradual transition in element size)

Example Meshing Improvement

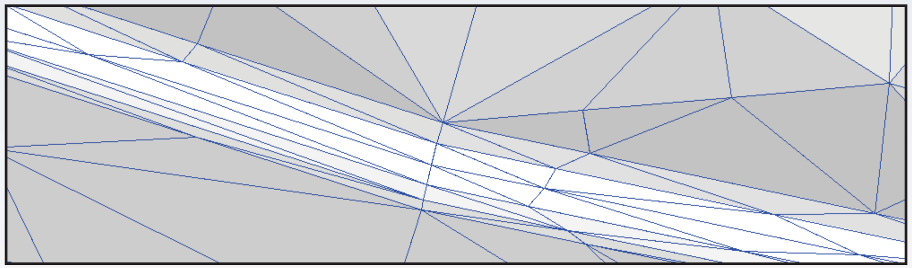
HFSS 11

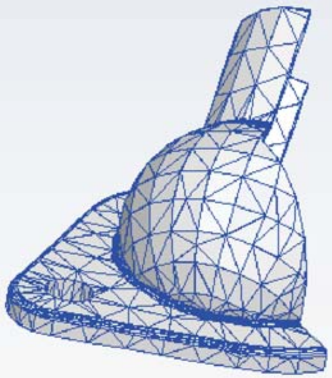


HFSS 11 mesher has difficulty with intersecting curves



HFSS 12 TAU mesher produces clean result

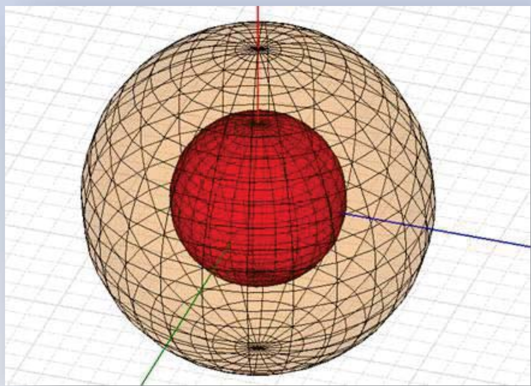




HFSS 12

Example Resonator with Concentric Spherical Dielectrics

- Curvilinear elements yield same accuracy as highly discretized rectilinear elements
  - Uses 88% fewer tetrahedra
  - Runs 16X faster



# Segments	f (GHz)
8	8.75
12	8.54
24	8.53
36	8.4
48	8.4
64	8.39
Curvilinear*	8.38

R_{in} = 1.75mm
R_{out} = 3.5mm
Dielectric:
ε_{in} = 90
ε_{out} = 10

Resonant frequency ~8.4 GHz

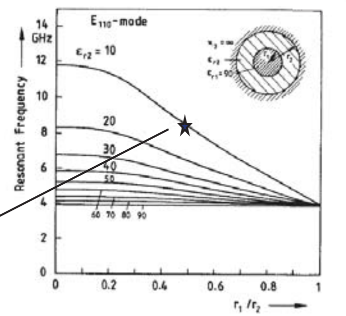


Fig.4a): Dependence of the resonant frequencies of a cavity resonator with two dielec- layers on the radius-ratio and with the

For ΔF = 0.1%	Mesh Elements	CPU Time
36 segments	53k	00:16:40
22.5° curvature	6.37k	00:00:55

*I Wolff, "A generalized description of the spherical three-layer resonator with an anisotropic dielectric material," *IEEE AP Symp,* June 1987, pp. 307-310

(Option) HFIE

(High Frequency Integral Equation Solver)

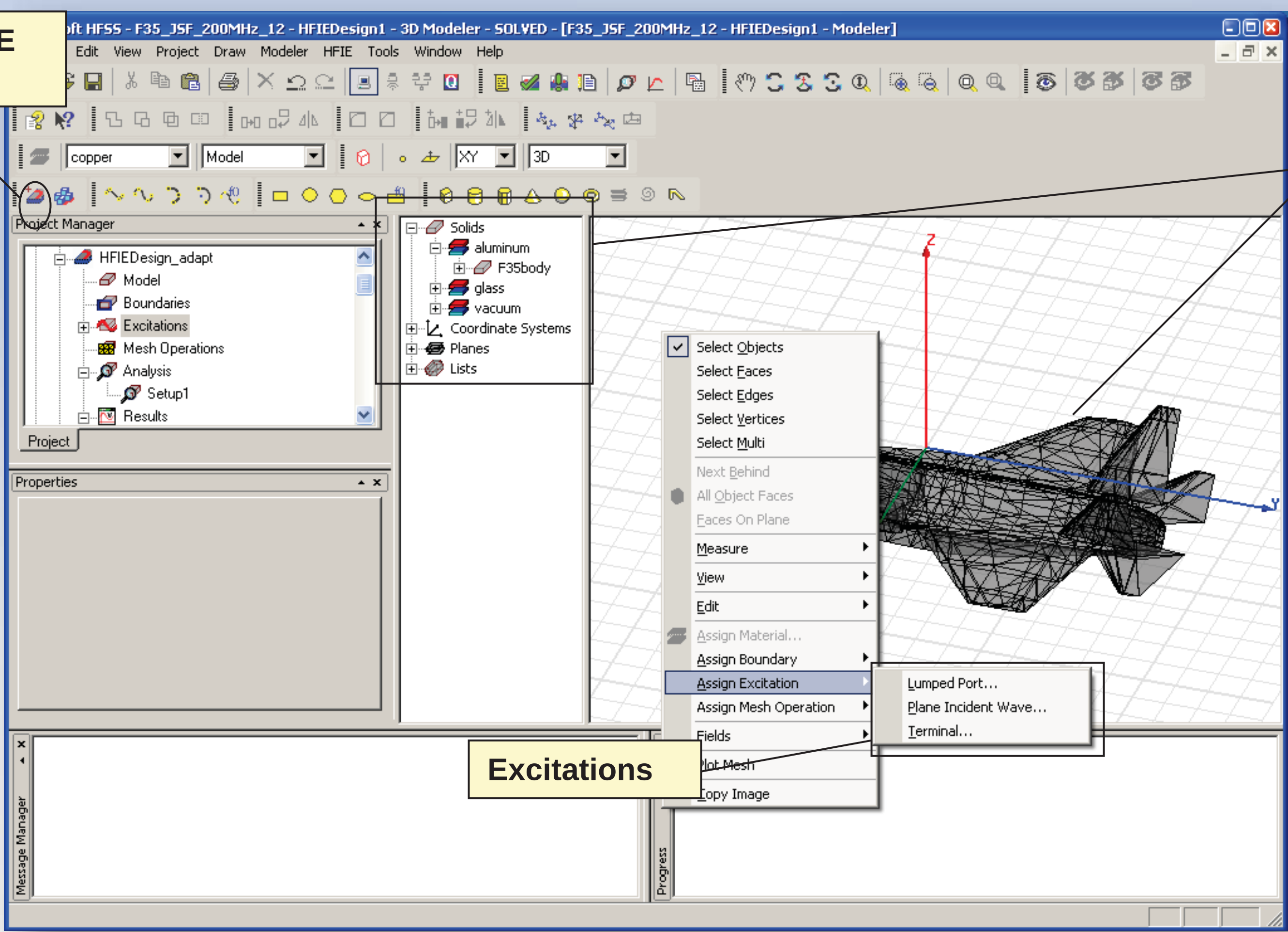
High Frequency Integral Equation Solver (HFIE)

- **3D method of moments (MoM) solver**
- **Integrated into exiting HFSS interface and infrastructure as additional design type**
- **Optimal method for solving large “open” problems**
  - Radiating problems such as larger reflector antenna or radar cross section (RCS) of aircraft platform

HFIE: Interface

Insert HFIE Design

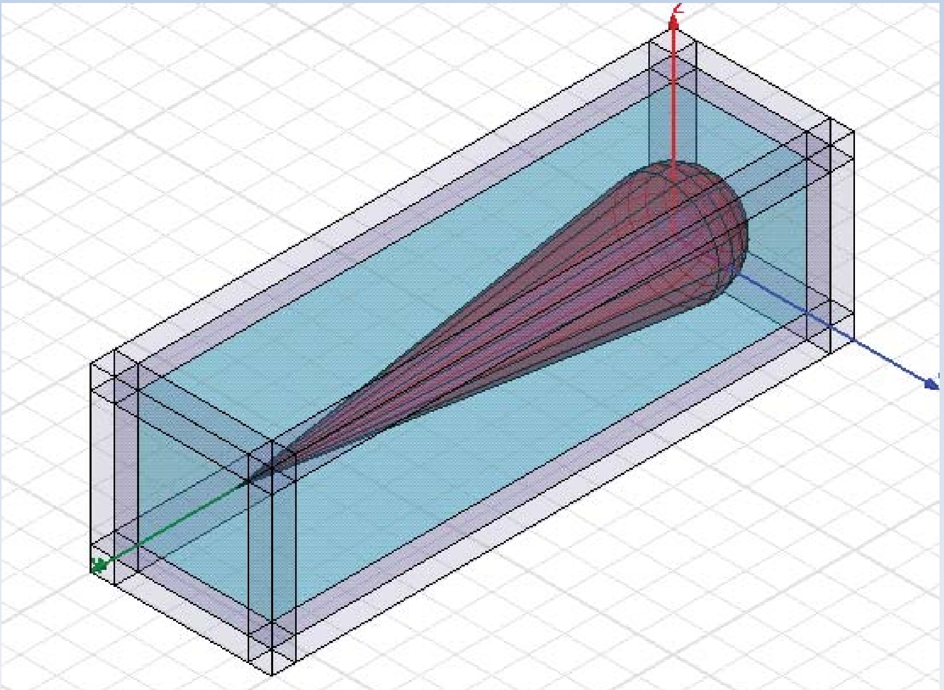
Same modeler and material setup



No air box needed

Excitations

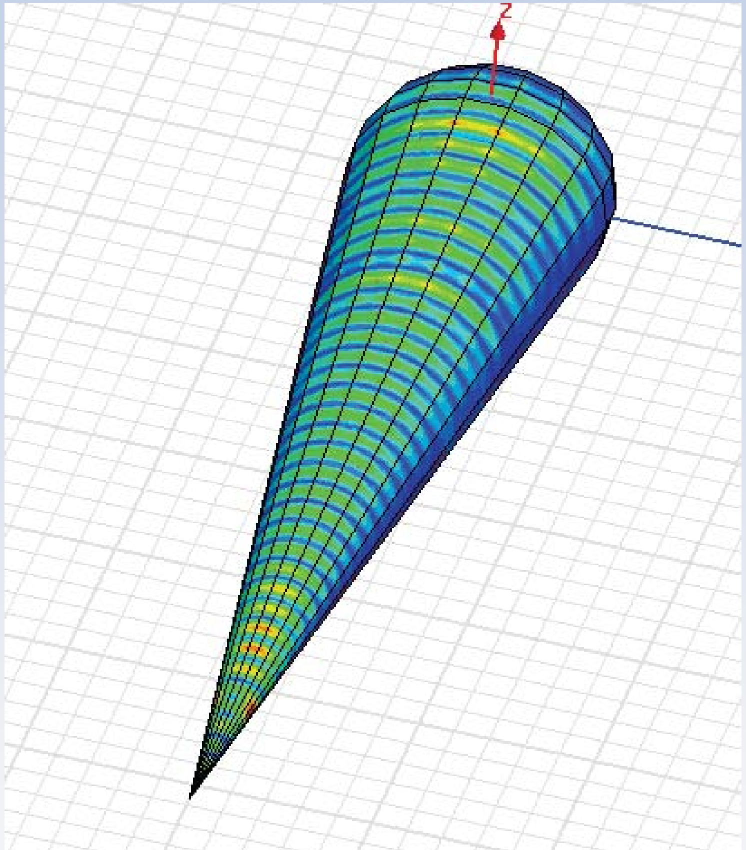
HFIE: Cone Sphere



RCS cone sphere at 9GHz.

Overall length 26.768” (≈20λ)

Incident directions for various φ at θ=90°. E_θ directed.

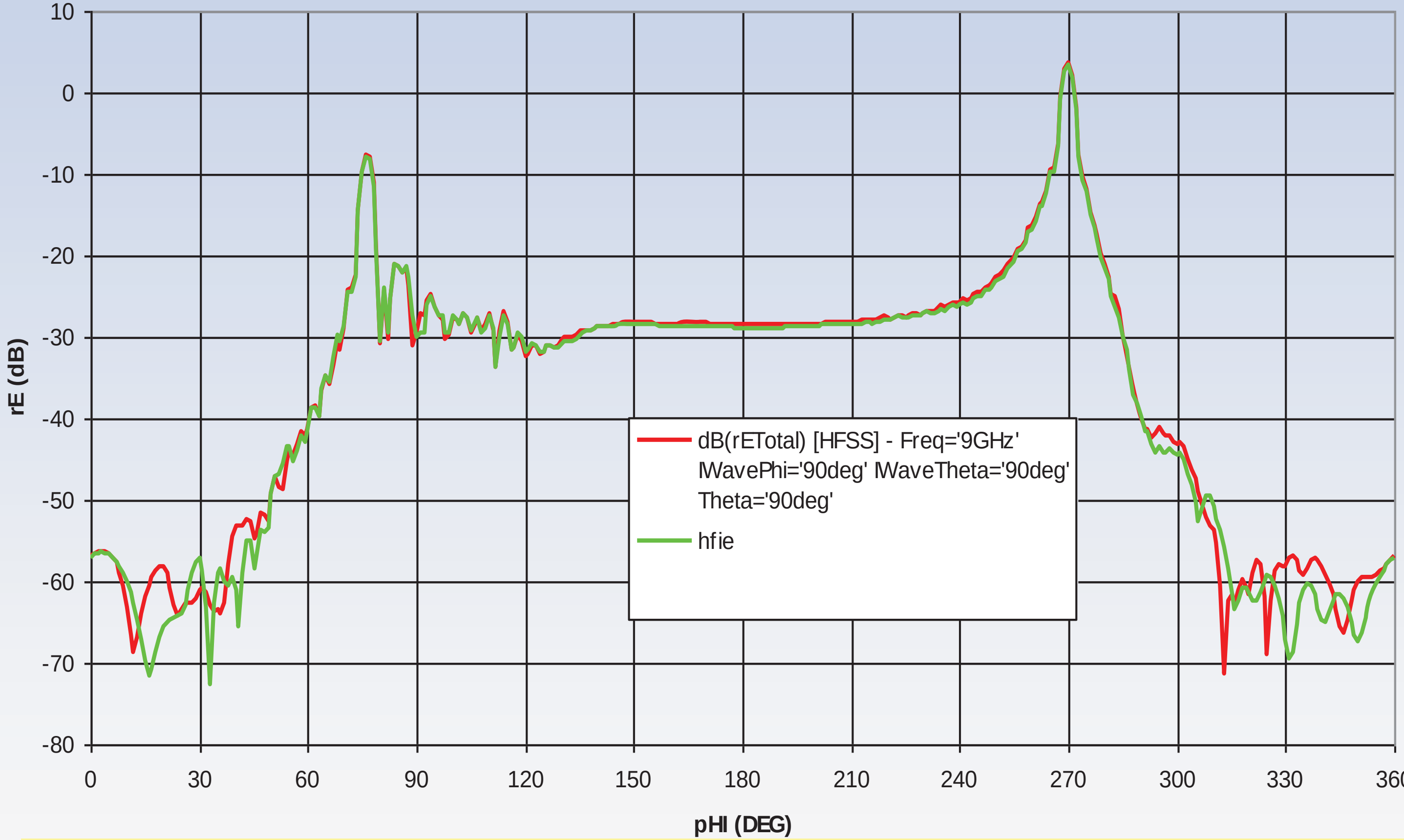


J_{HFIE} for inc. angles φ=0° and θ=90°

Data available from: A. Woo et al, “Benchmark Radar Targets for the Validation of computational electromagnetic programs,” *IEEE AP Mag.,* Feb., 1993, pp. 84-89

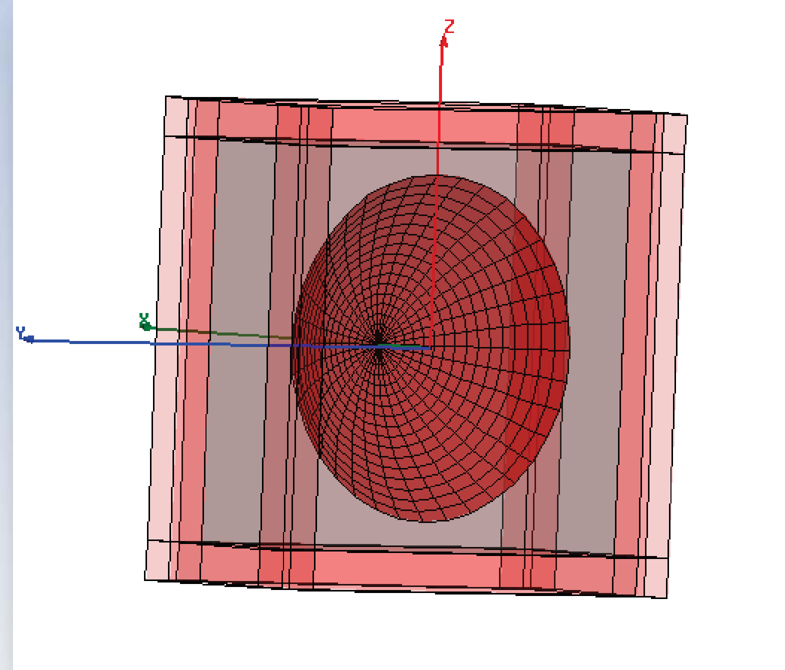
HFIE: Cone Sphere

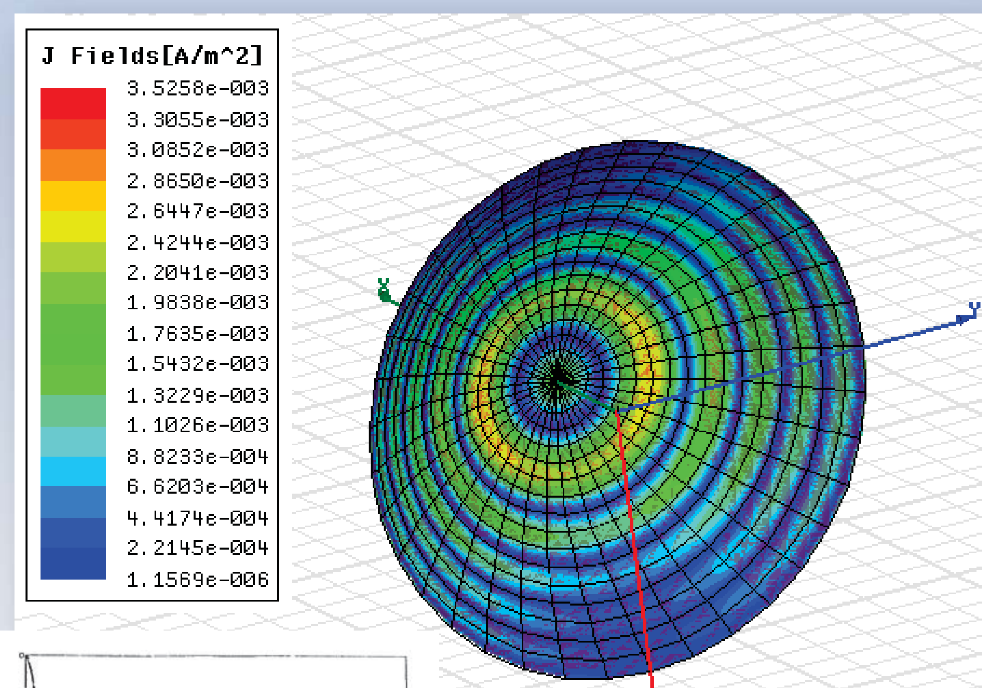
E^{scatt} for θ=90° with incident angles φ=θ=90°:



- **HFIE seeded ≈λ/7: 5:30 hours (w/30 incident angles) and used <2GB**
- **HFSS pass 2: 27.5GB 7 hours real time.**

HFIE: Reflector Antenna





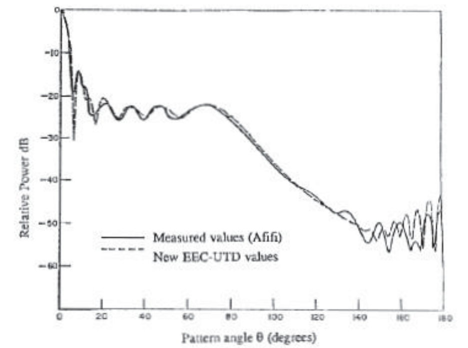


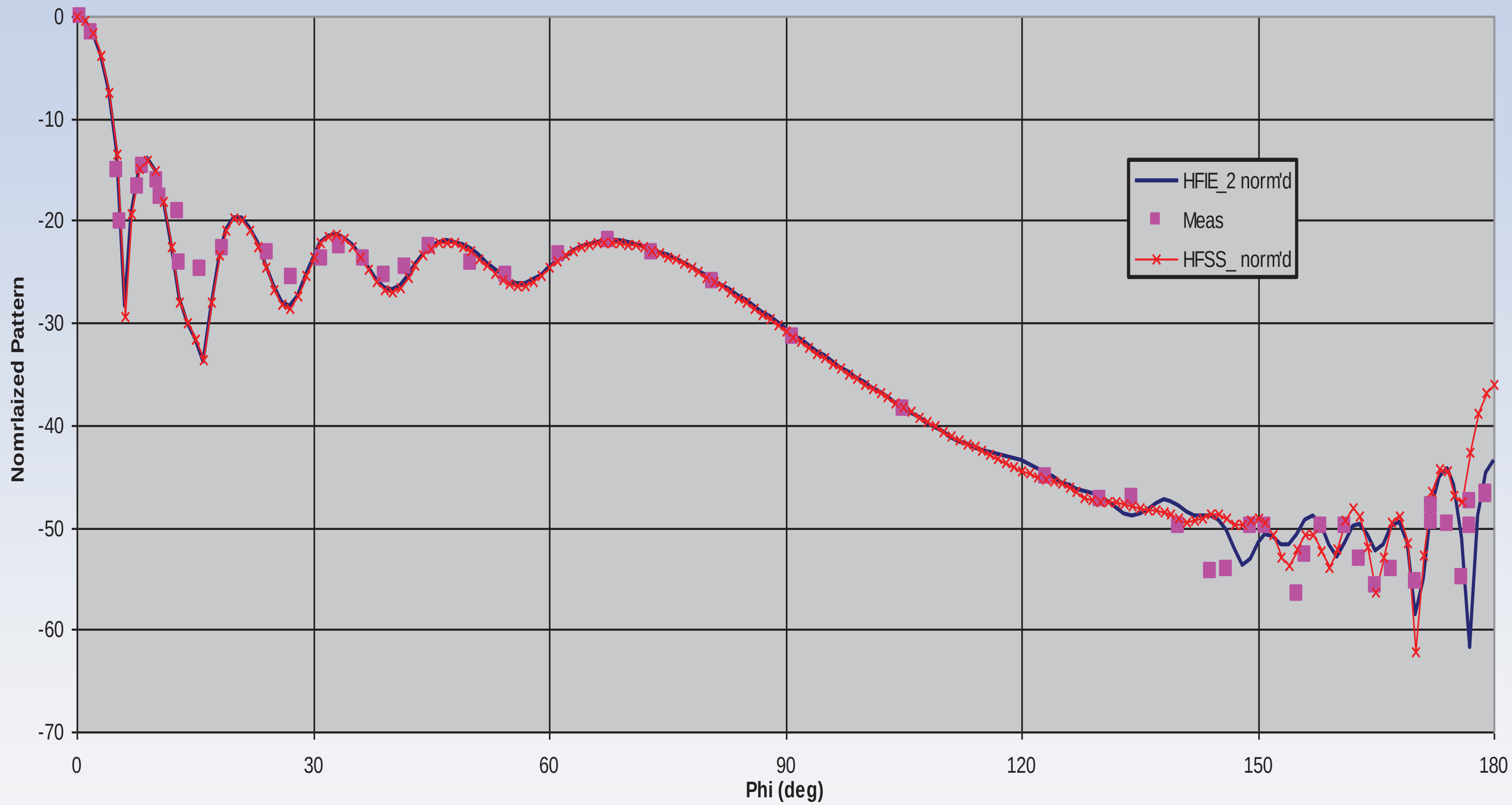
Figure 3. H-plane pattern of new EEC-UTD model versus measured values. Reflector illuminated by a short dipole feed; D = 10.65λ, F/D = 0.25.

Simple single reflector excited by a dipole antenna. Diameter of reflector is 10.65λ.

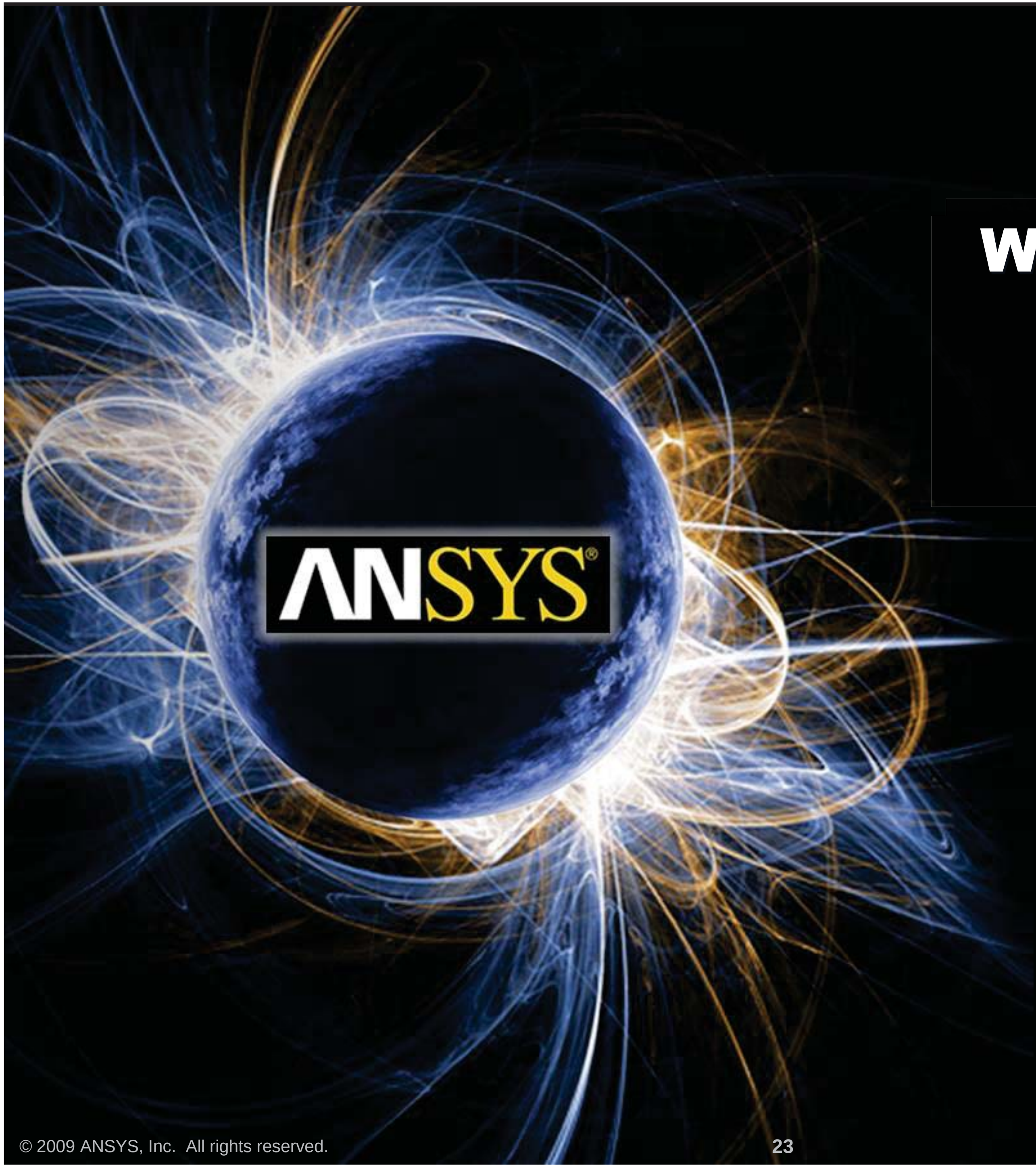
Measured radiation Patterns available from literature.*

* Data available from Lyerly, et al, “Equivalent edge current technique for accurate determination of reflector antenna patterns,” *IEEE AP Symp.*, 1993, pp. 254-7

HFIE: Reflector Antenna



HFIE seeded λ/10 and 1 pass: 24 min 1.6GB Ram
HFSS: 3hr, 30GB - last pass. Run 7 passes using iterative solver. Resulting ΔS = 0.12.



What's New in HFSS 13.0

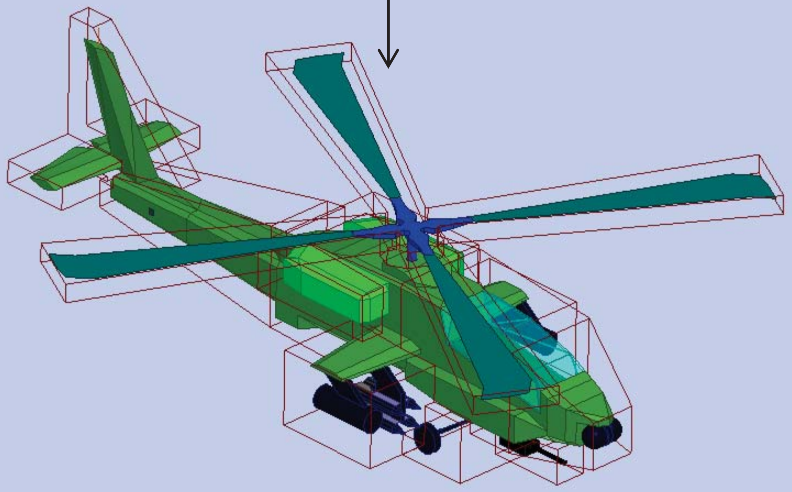
(Option) FEBI

(Finite Element – Boundary Integral)

Hybrid Finite Element-Integral Equation Method

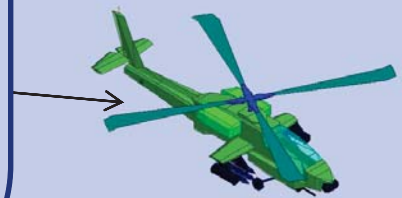
- **Finite Element Ba**
  - HFSS
  - Efficient handl
    material and g
  - Volume based
    solutions

Conformal radiation volume with Integral Equations



on Based Method

tion technique for
n and scattering
mesh and current

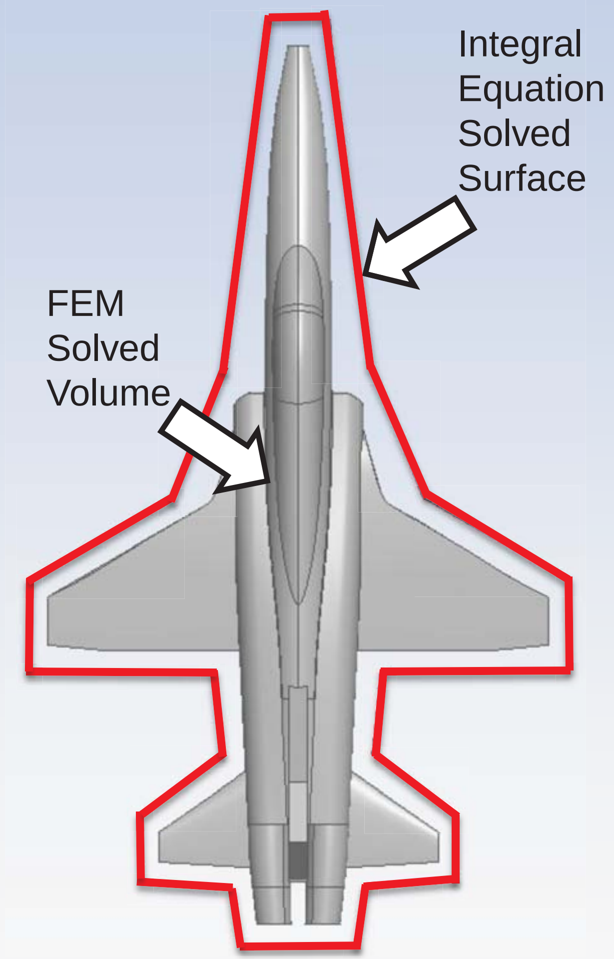


Finite Elements vs. Integral Equations

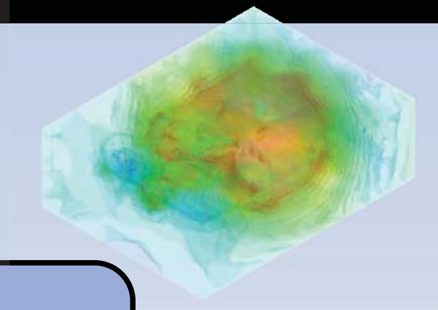
This Finite Element-Boundary Integral hybrid method leverages the advantages of both methods to achieve the most accurate and robust solution for radiating and scattering problems

Finite Element – Boundary Integral: FEBI

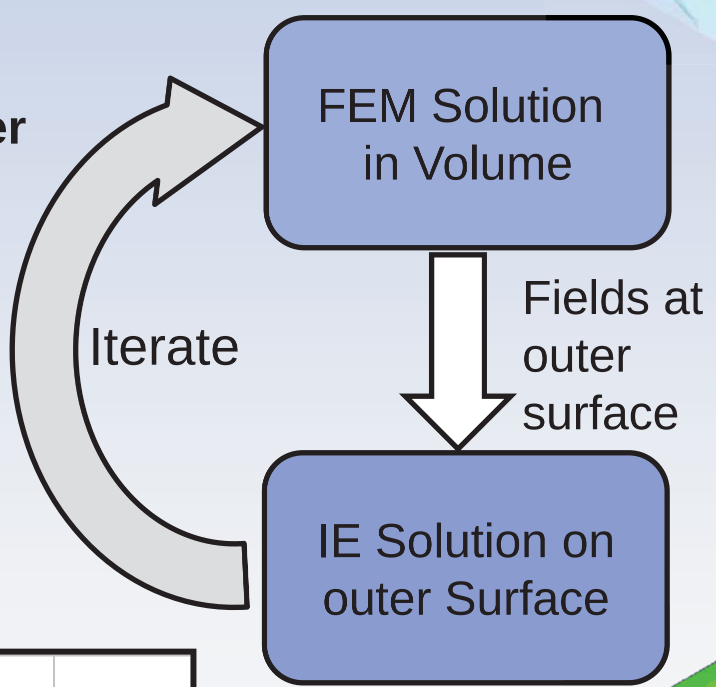
- **True solution to the open boundary condition**
  – Surface currents directly computed by IE solver
  – Very accurate far fields
- **No minimum distance from radiator**
  – Advantage over ABC
- **Reflection less boundary condition**
  – Ability to absorb incident fields is not dependent on the incident angle
- **Arbitrary shaped boundary**
  – Outward facing normal's can intersect
  – Can contain separated volumes
- **FE-BI does come with a computational cost**
  – Ability to create air box with smaller volume than ABC or PML can significantly offset this cost
  – Air volumes that much smaller than ABC/PML boundaries will be solvable in less RAM with FEBI



Finite Element Boundary Integral: Solution Process

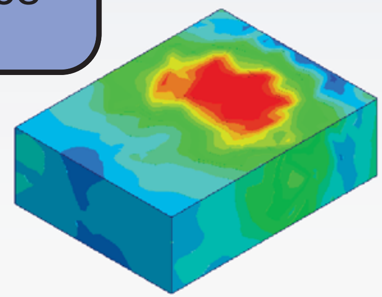


- **The FEM solution is applied to volume**
  - ABC boundary applied to outer surface
- **Integral Equation Solver computes surface currents on ABC**
- **Correction passed to the FEM solver where volume fields are corrected**
  - Iterated until converged



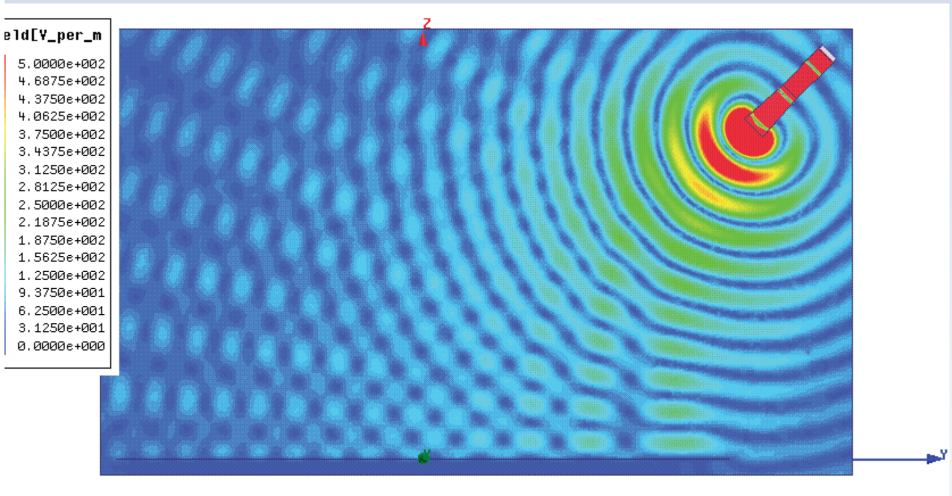
Example Profile

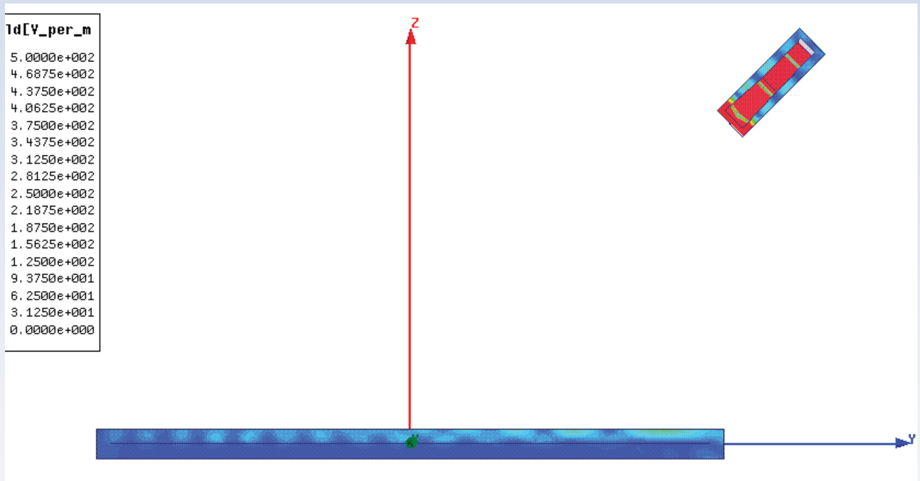
	Adaptive Pass 1			
FEM Domain →	Matrix Assembly/Solver MCS4	00:02:53	00:07:28	2.76 G
IE Domain →	Matrix Assembly/Solver DCS4, IE	00:01:25	00:03:47	4.77 G
Iteration Process →	Iterations	00:03:18	00:04:18	4.77 G



FEBI – Benchmark #2

Run with rectangular air box and PML and with separate closely spaced FEBI

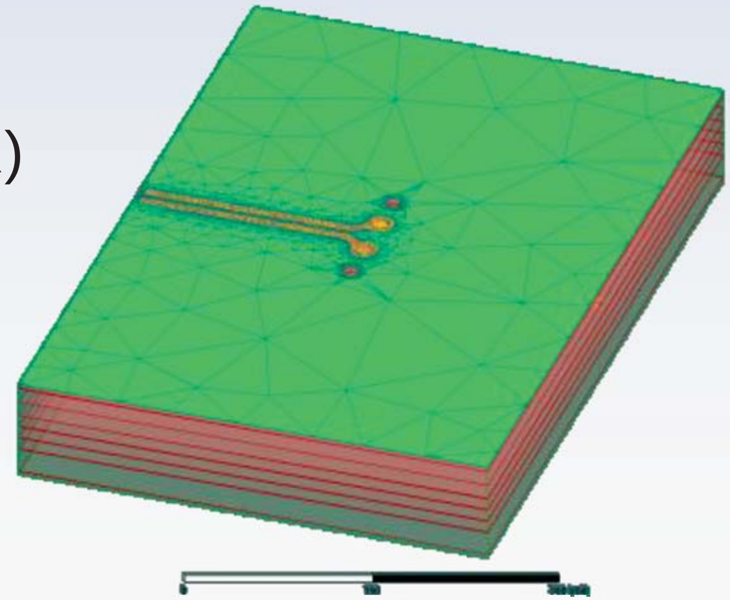




(Option)
HFSS - Transient

HFSS-Transient

- **Full-wave solution for solving transient design problems**
- **Based on Discontinuous Galerkin Method (DGTD)**
  - Applied to **unstructured**, finite element mesh
  - **Rigorous** and **accurate** solution to arbitrary geometries
- **Applications**
  - Pulsed Ground Penetrating Radar (GPR)
  - Lightning strike
  - Electrostatic discharge (ESD)
  - Time Domain Reflectometry (TDR)
  - Transient field visualization
  - Pulsed radar cross section (RCS)
  - EMI/EMC



Transient problems