FEKO

Recent improvements and future roadmap

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Altair

New Features in FEKO 2017

January 2017

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FEKO 2017 Major Features

- FDTD parallelisation
- RL-GO improvements (since 14.0)
- 3D anisotropic material support
- MLFMM stabilisation (14.0.420)
- Extensions to the loft operator
- New mesh engine
- Improved windscreen visualisation
- 2D graph text and shapes
- Cartesian surface graph plot type (14.0.430)

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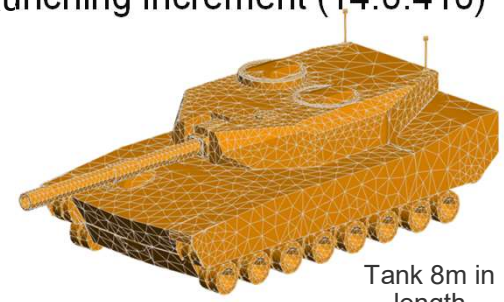
HyperWorks
FEKO 2017

- New version numbering adopted by HyperWorks: HyperWorks 14 to HyperWorks 2017

RL-GO Improvements

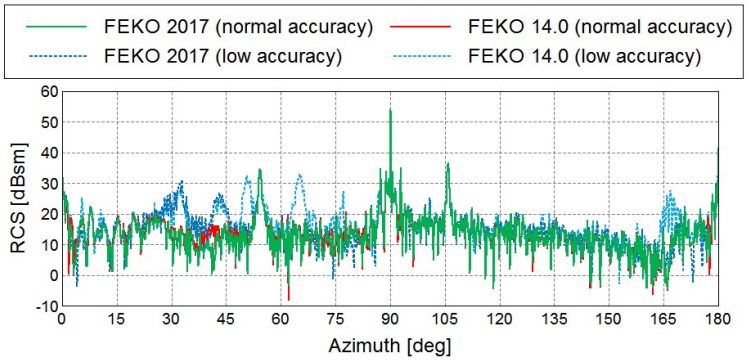
- Improved algorithm for automatically selecting the initial ray launching increment (14.0.410)
  - Often speeds up run time
  - Same or improved accuracy



Tank 8m in length

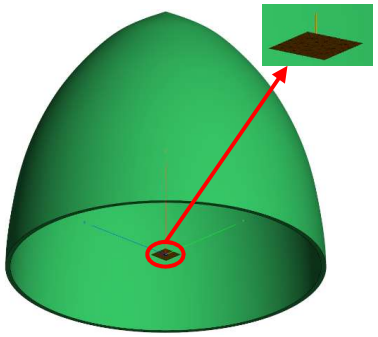
Version	Convergence accuracy	Memory (MByte)	Time per angle (s)	Total runtime
14.0	Low	49.36	0.87	10.2 minutes
14.0	Normal	49.36	38	**7.62 hours**
2017	Low	42.52	0.66	7.8 minutes
2017	Normal	42.52	31	**6.24 hours**

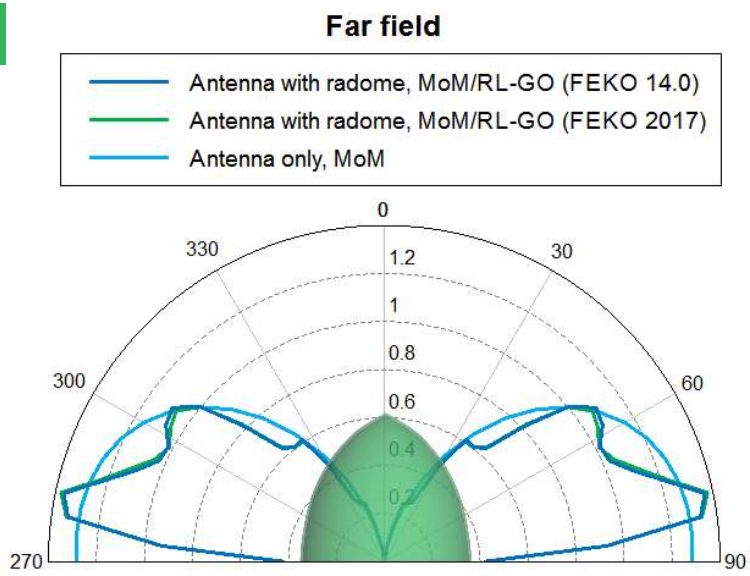
RCS of a tank at 10 GHz, horizontal plane



RL-GO Improvements

- Significantly less memory for uncoupled MoM/RL-GO examples with point sources and plane waves (14.0.420)
- Example
  - Monopole antenna (MoM)
  - Dielectric radome (RL-GO)
  - Frequency: 9.5GHz
  - 56 MoM basis functions
  - 2116 far field points
  - 5000 near field points



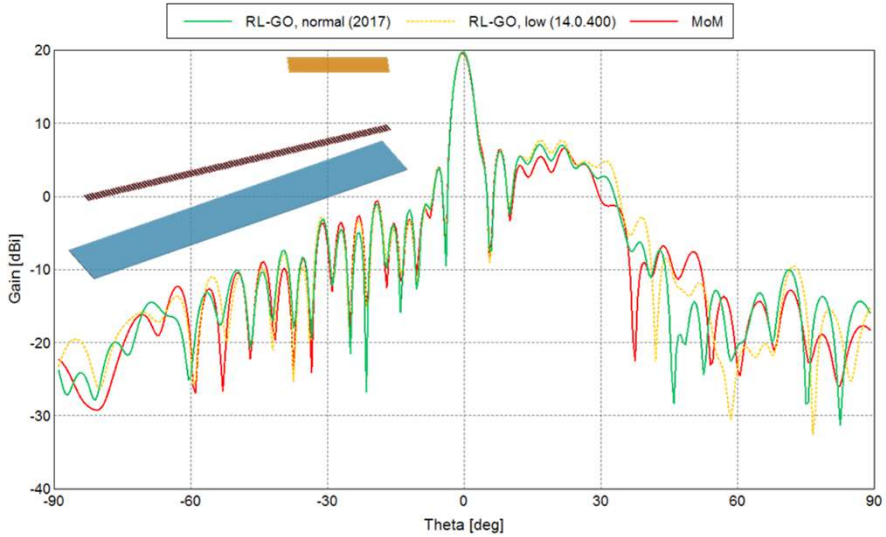


Version	Memory	Runtime (hours)
14.0	1.04 **GByte**	7.2
2017	20.46 **MByte**	5.4

RL-GO Improvements

- Near field aperture source transformation example
  - Near field aperture source with 812 samples transformed into 6 spherical mode sources

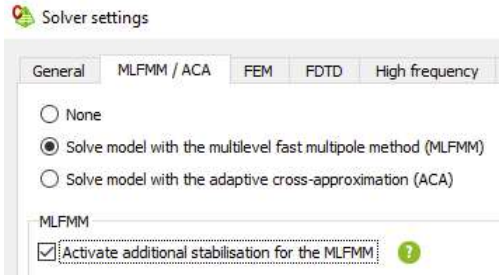
Solution	Memory	Runtime
14.0.400 RL-GO (**normal** accuracy)	Not enough memory (32 GByte machine)	-
14.0.400 RL-GO (**low** accuracy)	1.44 **GByte**	5.94 **hours**
2017 RL-GO (**normal** accuracy)	10.20 **MByte**	23.16 **minutes**
2017 MoM (with near field source)	2.66 **GByte**	19.62 **minutes**

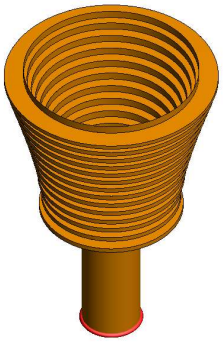


Result comparison between ray launching geometrical optics solutions since FEKO 14.0.400. The method of moments solution is shown as reference.

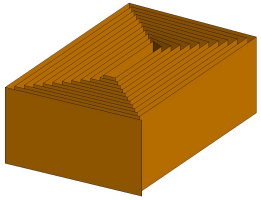
MLFMM Stabilisation

- Additional stabilisation option for the MLFMM (14.0.420)
- Addresses models with severe convergence problems
  - Large problems with intricate detail

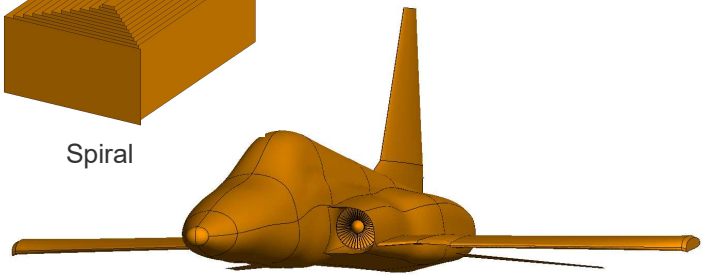




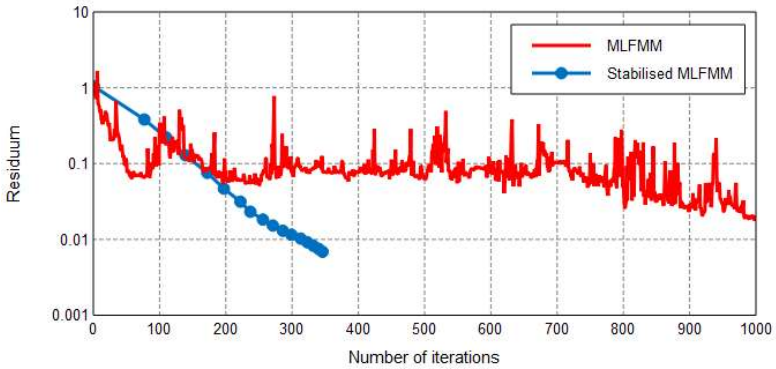
Corrugated waveguide horn



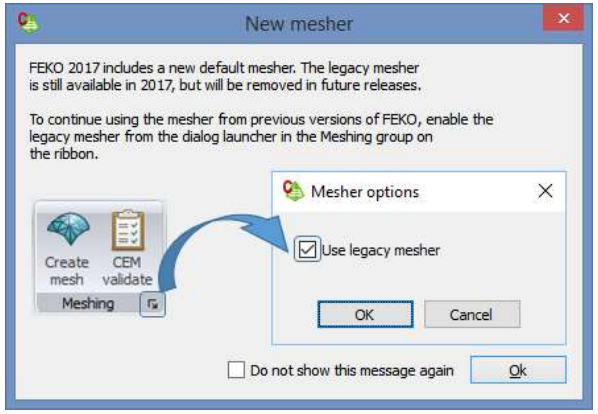
Spiral



Aircraft including engine inlets with fan blades



New Mesh Engine

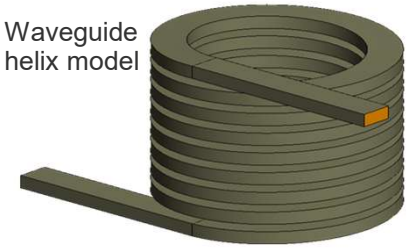


- Generates improved meshes
- Meshes often consist of fewer mesh elements
  - Reduction of resources and faster simulation
- Faster mesh creation
- Adheres more strictly to specified mesh sizes
- Successfully meshes some models that were previously problematic
- Legacy mesh engine still available, but will be discontinued in future releases

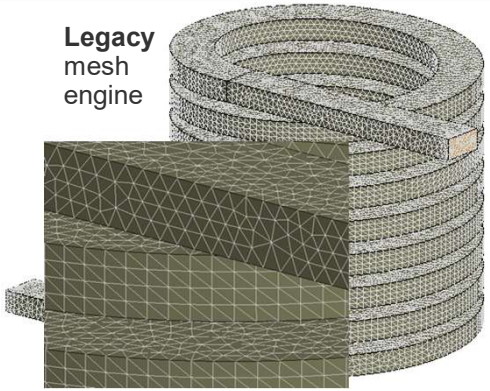
New Mesh Engine

Faster mesh creation

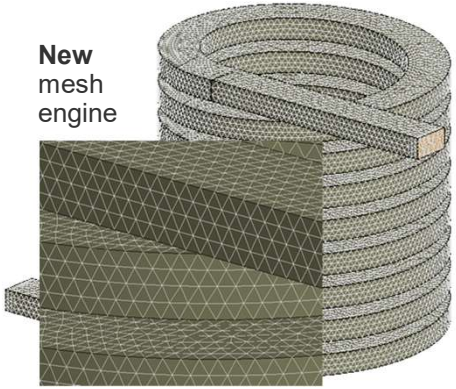
Waveguide helix model



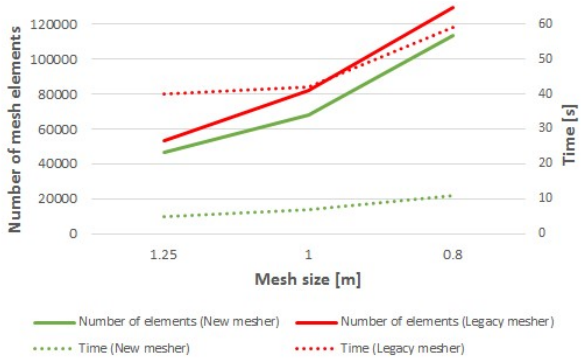
Legacy mesh engine



New mesh engine



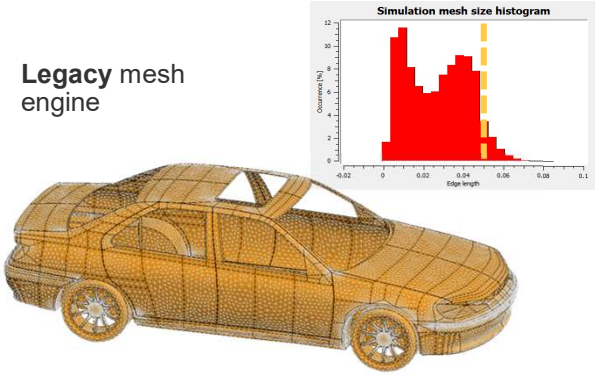
Relative mesh size	Number of elements		Time (s)	
	Legacy	New	Legacy	New
*1.25*λ/8*	53 512	46 800	40	5
λ/8	82 186	68 226	42	7
*0.8*λ/8*	129 457	113 454	59	11



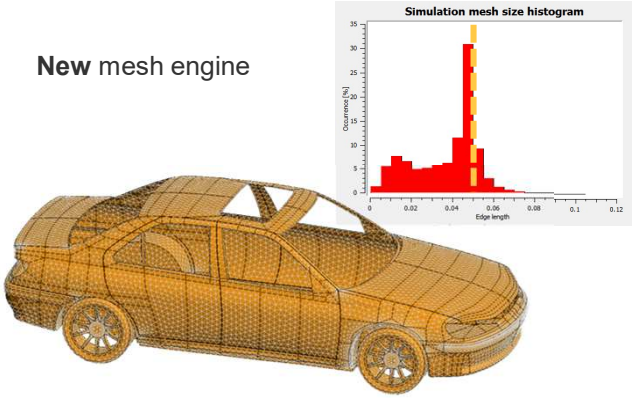
New Mesh Engine

Faster mesh creation

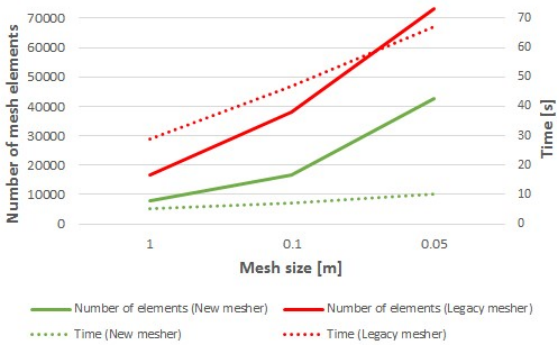
Legacy mesh engine



New mesh engine

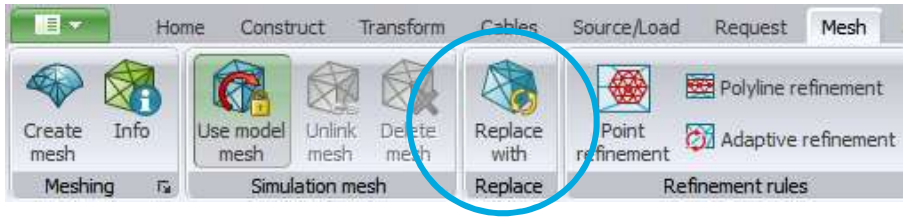


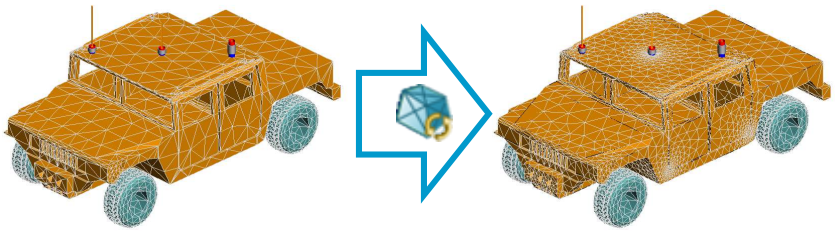
Mesh size [m]	Number of elements		Time (s)	
	Legacy	New	Legacy	New
1	16 819	7 964	29	5
0.1	38 026	16 681	47	7
0.05	73 295	42 619	67	10



Replace Mesh

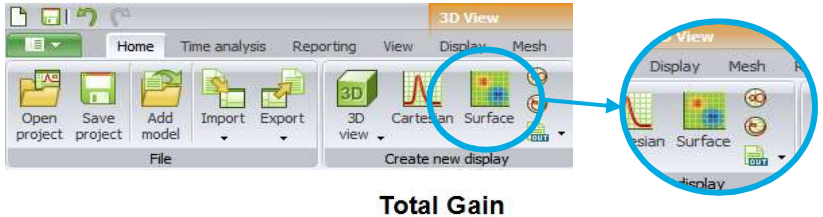
- Replace the mesh of an unlinked mesh or model mesh
- Typical workflow
  - Create model with configurations, ports and solution settings applied to the mesh elements
  - Export the mesh and modify it with other tools such as HyperMesh or SimLab
  - Re-import the mesh into CADFEKO
  - Solution settings and ports are transferred to the new mesh
  - Default mesh properties applied to any new mesh labels that did not exist before

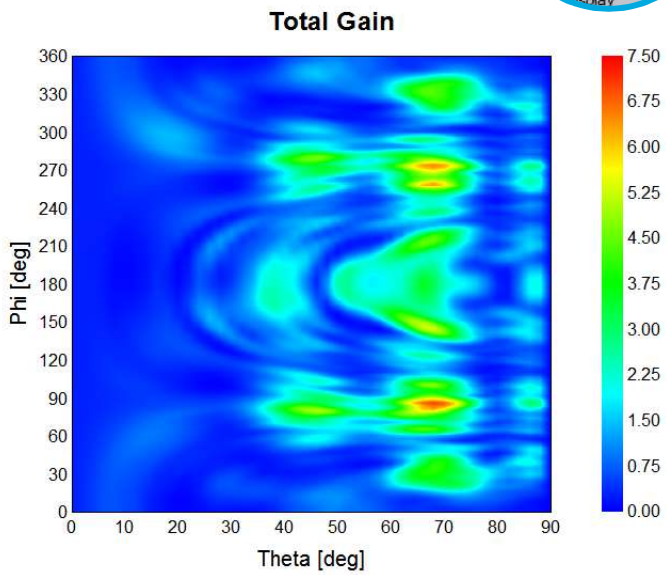




Cartesian Surface Graphs

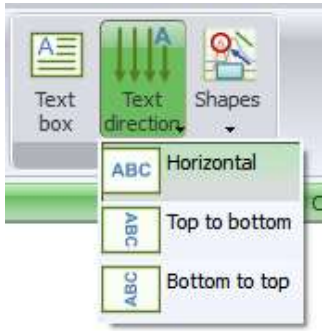
- Released with 14.0.430, extended in 2017
- Allows 3D data to be displayed on a 2D graph
- Axes represent independent parameters
  - Angles (for example, theta and phi)
  - Frequency and position
- Quantities like radar cross section (RCS), gain or near fields plotted by colour
- Result types supported in this release
  - Far fields, near fields, S-parameters, custom datasets, maths scripts, and data imported from file

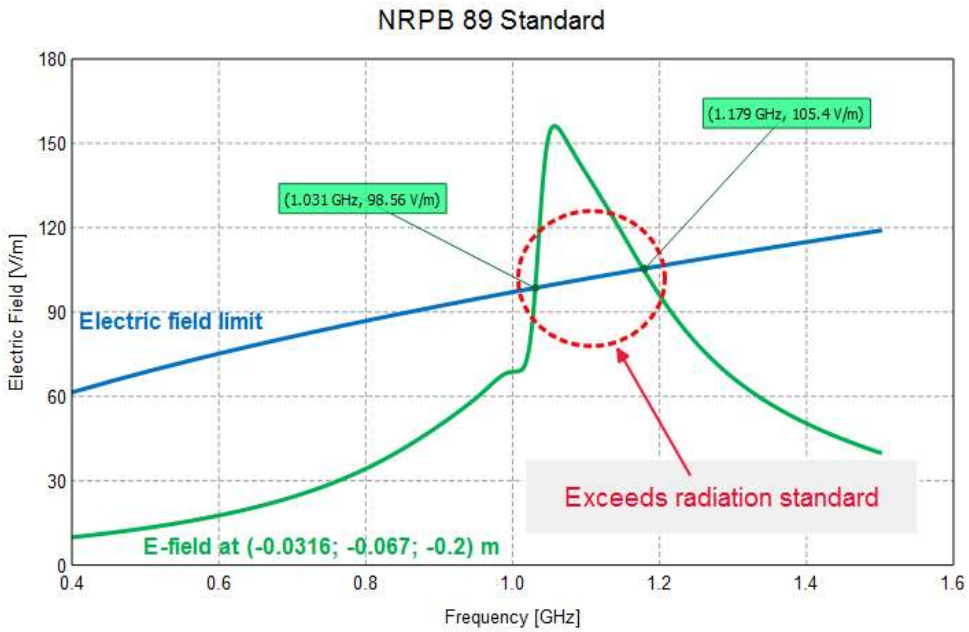




2D Graph Text and Shapes

- Graphs have been extended with options to add text and shapes that allow improved reporting from within the FEKO interface
- Text boxes (horizontal or vertical text)
- Shapes
  - Lines
  - Single arrows
  - Double arrows
  - Rectangles
  - Circles

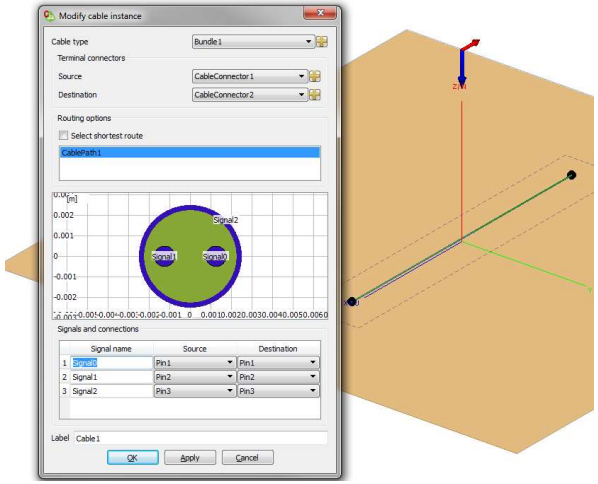




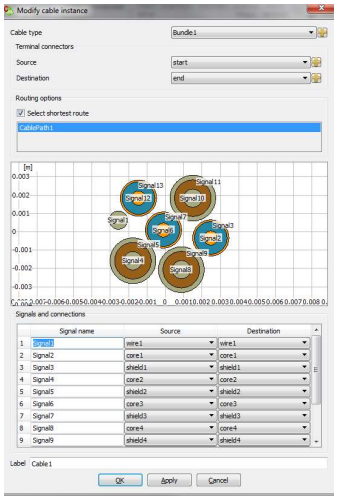
Graph with text and shapes to indicate where the field values exceed the standard

Cable Modelling Speedup

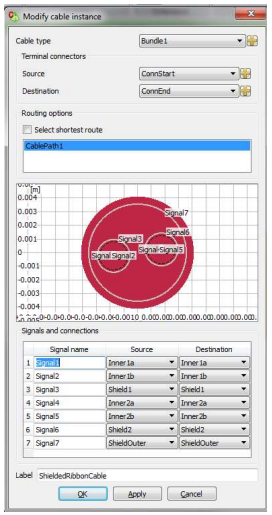
- Several phases within the MTL calculation have been optimised to accelerate run time
- Speedup factors of 2x to 34x (and even higher) are observed depending on
  - The cable problem (harness details and cross section)
  - The solution request (radiation or irradiation)
  - The frequency range



Speedup factor x34



Speedup factor x2



Speedup factor x15

FEKO 2017.1 Feature Update

April 2017

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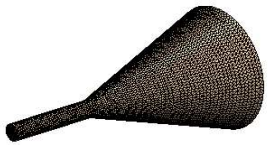
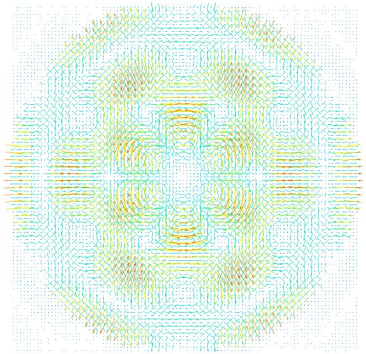
FEKO 2017.1 Major Features

- Cache file stores cable per-unit-length parameters
  - Speeds up continuous frequency range calculations
- Near field aperture source optimisation for PO and LE-PO
  - Speeds up near field aperture processing
- Network voltage sources supported together with the RL-GO solver
- Current and charge requests are now stored in separate *.os and *.ol files
- Parameter sweep extended to allow sweeps of more variables

PO and LE-PO Aperture Source Optimisation

- Speedup of near field aperture processing
- Automatically converts an equivalent aperture excitation into its corresponding spherical mode representation
- Similar to the extension for RL-GO released in FEKO 14.0
  - Computational requirements of simulations with aperture excitations are proportional to the number of near field points used in the source
- Supported for full PO coupling or no coupling
- Not supported for the iterative hybrid MLFMM-PO/LE-PO method





FEKO 2017.2 Feature Update

July 2017

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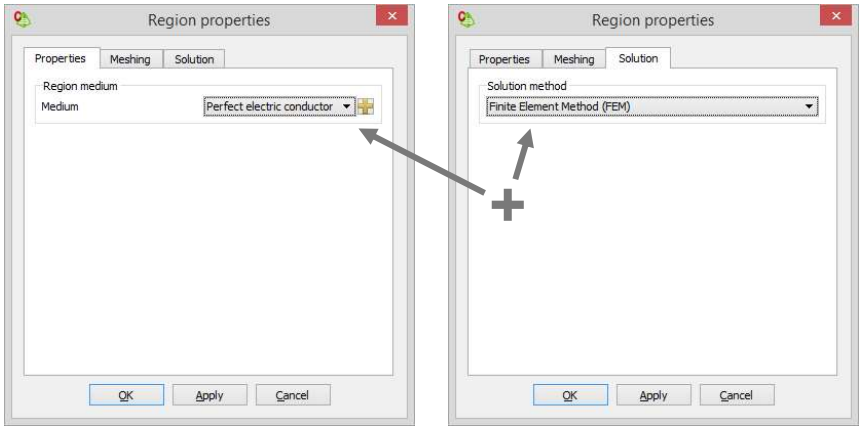
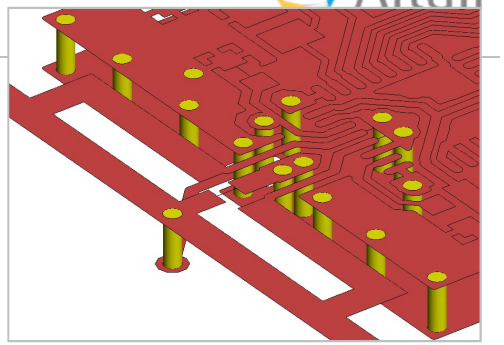
FEKO 2017.2 Major Features

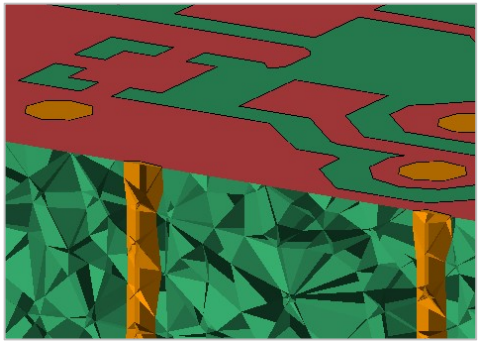
- FEM solver
  - Improved handling of PEC regions embedded in dielectric regions
- FDTD solver
  - Specification of convergence criteria
  - Irradiation MTL cable analysis
- POSTFEKO
  - Near field quantities for electric and magnetic flux density display
- Optimisation
  - Near field optimisation goal: normalised electric and magnetic flux density
  - Far field optimisation goal: realised gain

FEM Handling of PEC in Dielectric Regions

- Easier to model PEC parts such as vias and pins in FEM models
  - PEC regions can now be included as part of the FEM solution
  - Alternative 1: Model regions as free space – FEM/MoM boundary
  - Alternative 2: Model regions as dielectric – adds to FEM unknowns
- May reduce memory and runtime requirements





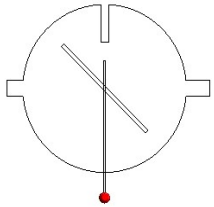


Cutplane view showing vias from the model (zoomed out view top) meshed as PEC tetrahedra

FDTD Termination Criteria

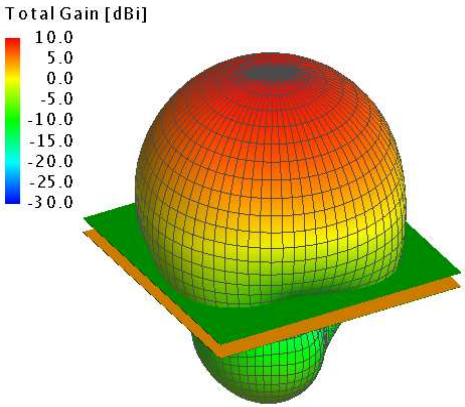
Example: GPS aperture-fed CP patch antenna

- Aperture-fed circularly polarized patch with one slot and two stubs[1]
- Far field calculated at 1.55 GHz
- Reflection coefficient calculated from 1.4 GHz to 1.7 GHz



Top view of patch antenna model (geometry outlines and source only)

Convergence threshold	Number of iterations	Total simulation time [min]	Convergence at termination
Auto	162 000	37.5	-101.3 dB
1e-3	82 000	25.0	-60.6 dB
5e-3	72 000	19.6	-46.2 dB

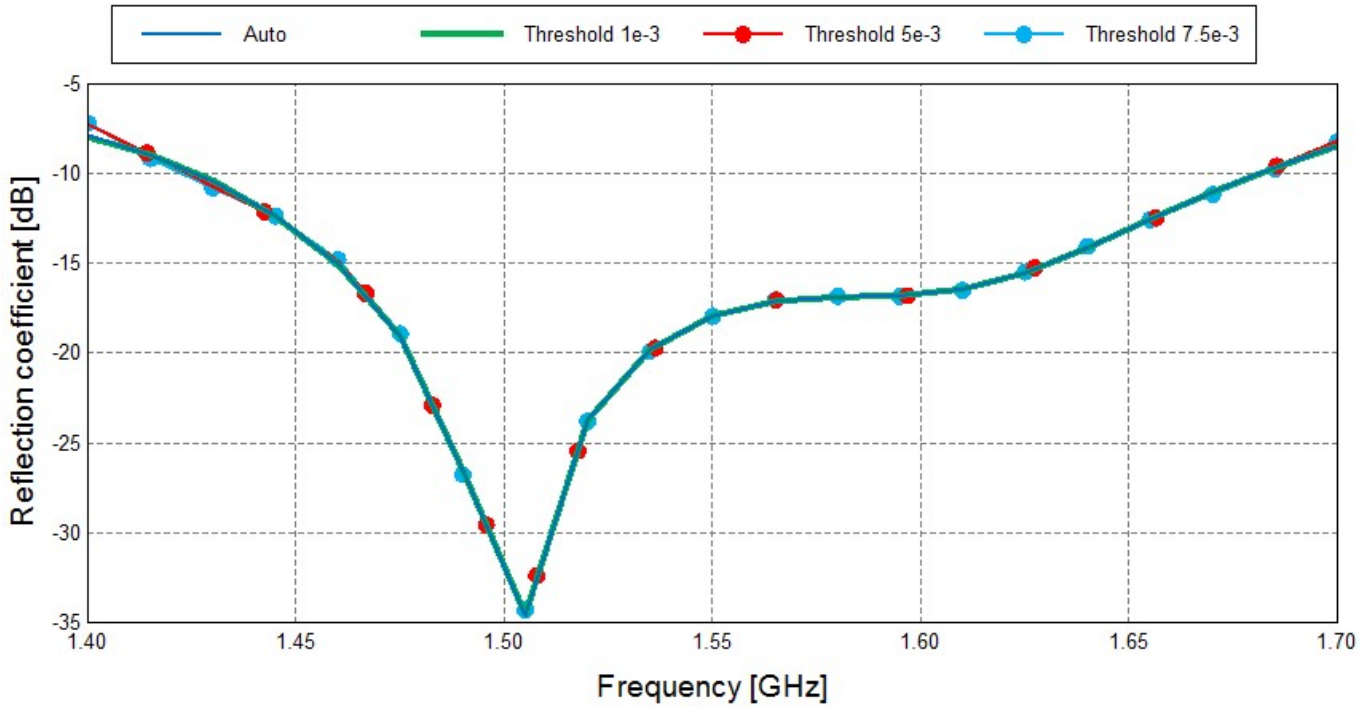


Patch far field (total gain) at 1.55 GHz

[1] C. Wang and K. Chang, "A novel CP patch antenna with a simple feed structure," *IEEE Antennas and Propagation Society International Symposium 2000.*

FDTD Termination Criteria

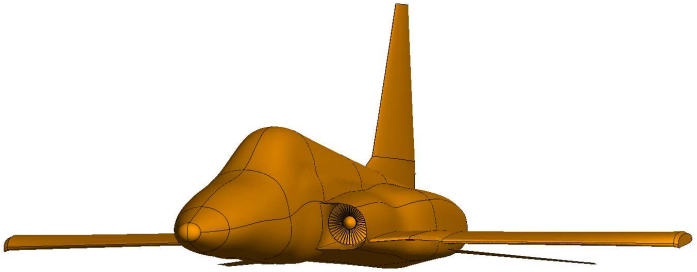
Example: GPS aperture-fed CP patch antenna



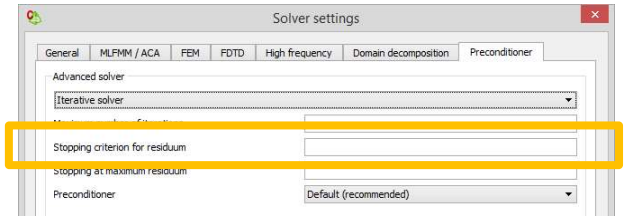
MLFMM Improvements

- The stabilised MLFMM supports specifying the residuum for the stopping criteria

- The MUMPS sparse LU preconditioner is used for extremely large MLFMM problems
  - Problems where matrices have more than $2^{31}-1$ entries can now be solved with either the MUMPS sparse LU preconditioner or the fall-back SPAI preconditioner



An aircraft including engine inlets with fan blades as example of a large MLFMM problem that could benefit from additional stabilisation.



The *Solver settings* menu showing the “Stopping criterion for residuum” field that now also applies to the stabilised MLFMM.

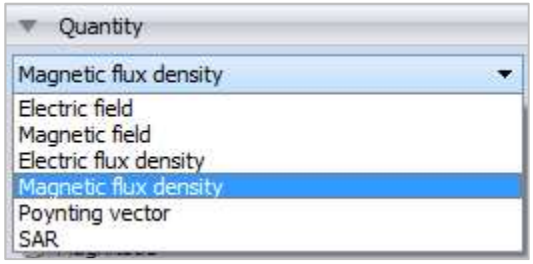
Electric and Magnetic Flux Density Display and Optimisation

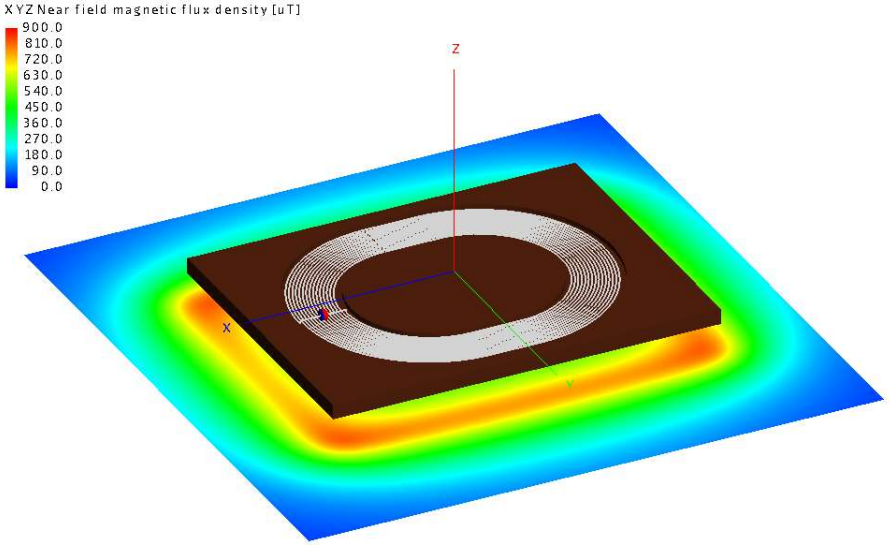
- New POSTFEKO near field result quantities for flux densities
- Electric flux density (electric displacement field, D) [C/m^2]

$$\mathbf{D} = \varepsilon \mathbf{E}$$

- Magnetic flux density (B-field) [T]

$$\mathbf{B} = \mu \mathbf{H}$$





The **B**-field (magnetic flux density) of a wireless power transfer coil at 25 kHz (cut-plane view showing one of two coils).

FEKO 2017.2.1 Update

August 2017

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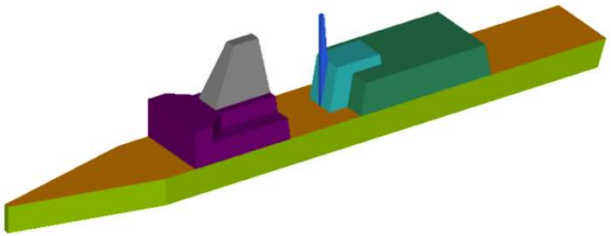
MLFMM Memory

Traditional distributed MPI implementation → poor parallel memory efficiency

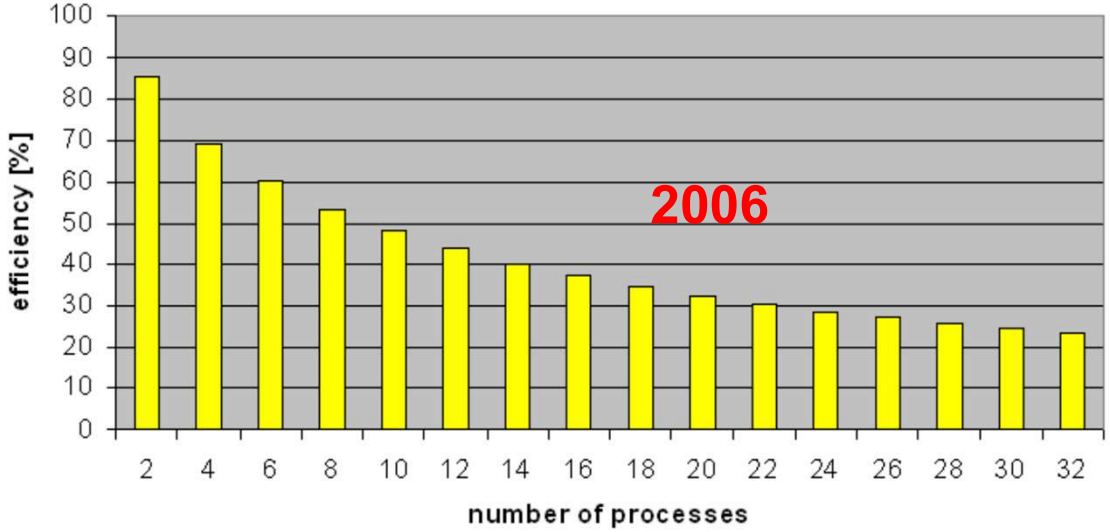
Caused by data duplication:

- transfer functions
- geometry



Generic ship
→ 3.18 million unknowns

Total memory efficiency



MPI-3 Shared Memory

Running with 40 procs on single node

Sum of the peak memory of all procs
985.6 GByte ➔ 659.6 GByte (33% reduction)

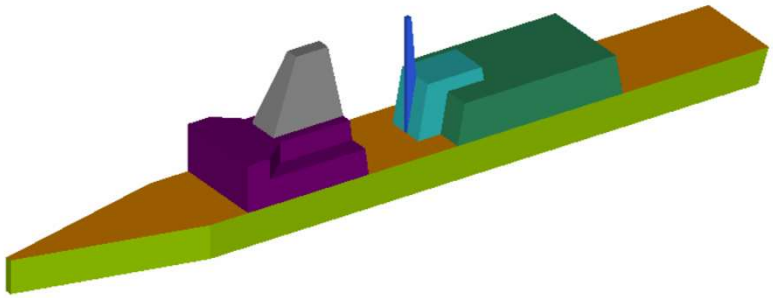
Breakdown in GByte:

Geometry arrays: 457.8 ➔ 226.8 (50% reduction)

Model setup and basis function:	236.9	➔ 5.9	Geometry arrays
Other, e.g. worker arrays:	220.9		

FMM arrays: 370.4 ➔ 276.5 (25% reduction)

FMM near field matrix:	22.3		FMM arrays
FMM far field matrix			
Fourier trans. basis functions:	101.8		
Transfer function:	104.5	➔ 9.7	
Interpolation and filtering:	38.1		
Matrix-vector-multiplication:	103.7		



Generic Ship Example
35.6 million unknowns
23.7 million triangular patches

Intel(R) Xeon(R) CPU E7-4820 v3 @ 1.90GHz;
4 physical CPUs with a total of 40 processors found
(multi-core CPUs with max. 10 cores per physical CPU)
(installed memory 1009.796 GByte)

MPI-3 Shared Memory

- Running with 64 procs on 8 nodes
- Previously 64 copies of geometry & transfer function arrays
- Now only 8 copies

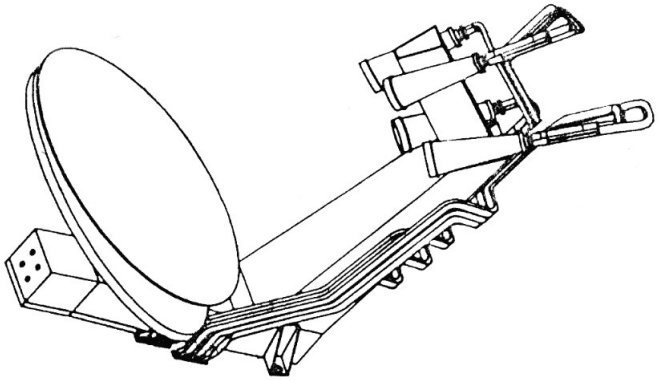
TABLE I
MEMORY CONSUMPSION IN GBYTE
64 Processes on 8 Nodes

	Distributed MPI	MPI3-SHM
Geometry	724	93
MLFMM	663	497
Other*	800	800
Total memory	2187	1390

36% reduction

* This includes everything else, i.e. preconditioner, work arrays, etc.

Reflector Antenna with Multiple-Feed Horns
58.1 million unknowns
38.8 million triangular patches



Intel(R) Xeon(R) CPU E5-2683 v4 @ 2.10GHz;
8 nodes with 512 GByte each; installed memory = 8*512 = 4096 GByte
each node has 2 physical CPUs with a total of 32 processors found (multi-core CPUs with max. 16 cores per physical CPU)

MPI-3 Shared Memory - Conclusions

- Stabilised MLFMM preconditioner improves convergence without sacrificing memory
- Parallel memory efficiency is improved using MPI-3 shared memory (multiple procs on the same node in a distributed memory cluster)
- “Fat” nodes with as much memory and cores preferable for MLFMM

FEKO 2018 and Beyond…

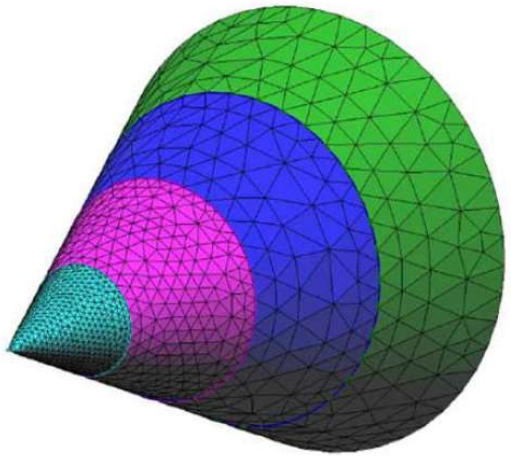
Altair

Coming Soon…

- FEM
  - Improved preconditioners
  - also for GPU
- Cable modelling
  - Cable core as return path – rather than geometry
- RL-GO
  - further performance improvements
  - Transmission\Reflection coefficients for complex surface modelling
- MLFMM
  - Further reductions in parallel memory usage
- CADFEKO
  - Refactoring to improve performance

Ongoing Research and Development

- MLFMM
  - Improve convergence and reduce memory further
- Domain Decomposition (DDM)
  - DDM allows non-conformal meshing (multiscale problems)
  - Multi-solver: each domain own solver (MoM / MLFMM / FEM / ACA / etc.)
  - Eliminates tedious mesh clean-up of mechanical CAD models



Questions?