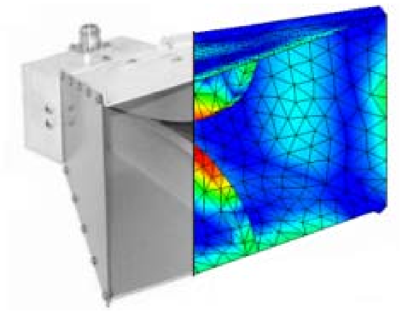
Introduction to the FEKO Suite

FEKO is a suite of tools that is used for electromagnetic field analysis of 3D structures. FEKO simulations are based on the Method of Moments (MoM) approximation to Maxwell's equations and features several extensions to the MoM for the solution of complex problems, including large structures (MLFMM) and human tissue (FEM). Various output parameters can be computed and displayed in a number of formats to make FEKO a leading electromagnetic simulation software suite.

Solution Methods	*Applications*	*Special Features*
• Method of Moments (MoM), extended to a wide range of applications e.g. dielectric volumes, planar multilayered structures, dielectric and magnetic coatings, thin dielectric sheets, ground plane reflections. • Multilevel Fast Multipole Method (MLFMM) • Finite Element Method (FEM) • Physical Optics (PO) • Geometrical Optics for dielectrics (GO) • Uniform Theory of Diffraction (UTD)	• 3D Antenna design • Microstrip antennas (Planar and conformal) • Microstrip circuits • Antenna placement • EMC analysis (Including complex cable harness) • Dielectric bodies (SAR) • Scattering analysis (RCS)	• True hybridisation (MoM with FEM, PO, GO, UTD) • Parallel processing • Out-of-core solution (Memory swapped from RAM to hard drive) • Wide range of hardware supported (Including 64-bit) • Time domain data (TIMEFEKO manages the excitation pulse description and required FFT) • Optimisation (Fully specified in CADFEKO GUI) • Adaptive Frequency Interpolation (AFS)



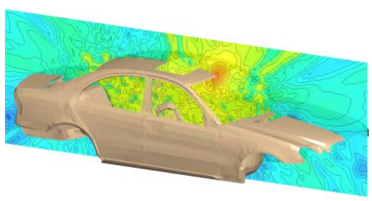
Applications

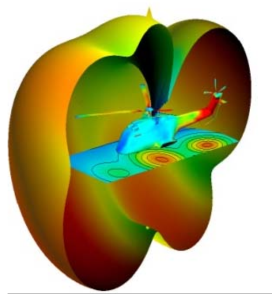
Antenna Analysis

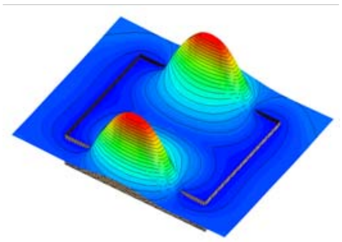
Wire antennas, horn and aperture antennas, reflector antennas, microstrip antennas, phased array antennas, helical antennas. Many special formulations enable the analysis of practical antenna problems.

Antenna Placement

The MoM/FEM, MoM/PO, MoM/UTD hybridisations and the MLFMM enable the analysis of antennas mounted on electrically large platforms where the interaction with the nearby structures influences the antenna characteristics, e.g. UHF antennas on aircraft or ships, GSM antennas on motor vehicle, etc.

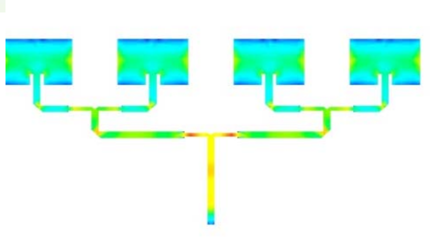






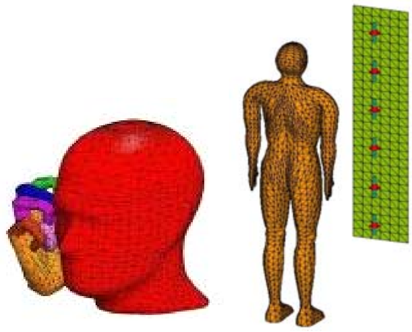
EMC

FEKO is used extensively for EMC analysis in the motor industry and is very useful for computing the coupling between antennas and cables. The range of EMC problems that can be solved with FEKO has been extended significantly through an interface with CableMod. E.g., complex cabling problems in automobiles and aircraft can be solved.



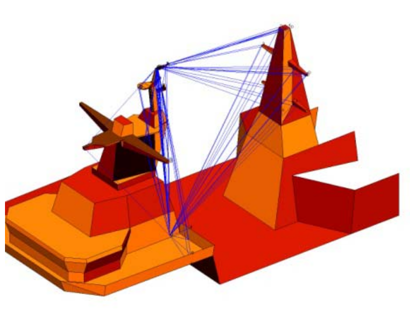
Planar microstrip antennas and circuits

A full 3D MoM formulation is available for the analysis of microstrip antennas with arbitrarily oriented metallic wires and surfaces in multi-layered dielectric media. Interpolation tables are used for faster simulation times.



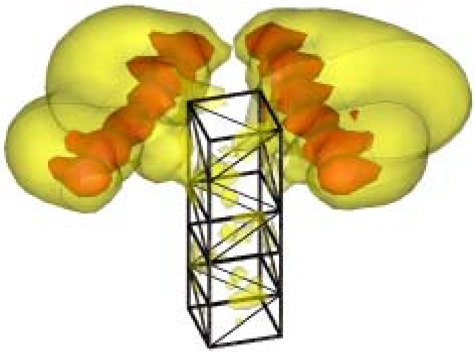
Dielectric bodies (e.g. SAR computation)

Field values can be calculated inside multiple dielectric regions, each with different dielectric parameters. These fields may be used for computation of the Specific Absorption Rate (SAR) in these regions. This functionality has found wide application in the analysis and design of mobile phones and has also been applied extensively in studies regarding the compliance of cellular base stations to international radiation exposure guidelines.



UTD ray tracing for RF antennas

The visualization of UTD rays can be very informative in identifying high frequency scattering and reflection points. Typical application of this technology is in the investigation of interantenna isolation, radiation pattern distortion, etc. Typical examples of this application include RF antennas on ship superstructures or mobile phone base stations in complex building environments.

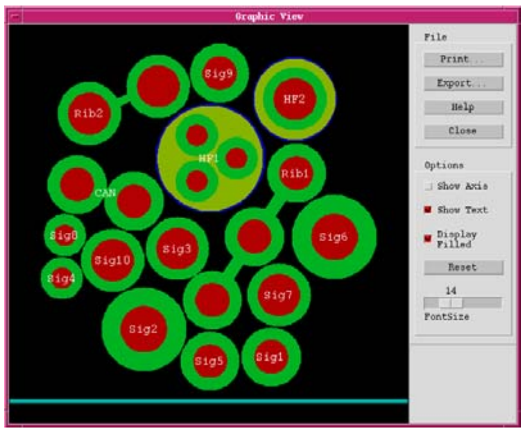


Radiation exposure safety studies

The MoM or MLFMM may be used to compute near-field values around complex building and antenna structures where people work. Isosurface plots are then instrumental in determining where the safety boundaries conforming to international radiation safety guidelines are located. Such information is typically used to place signage and barriers at the site, ensuring safety of the public and personnel in proximity to the transmitters.

Analysis of complex cable harnesses

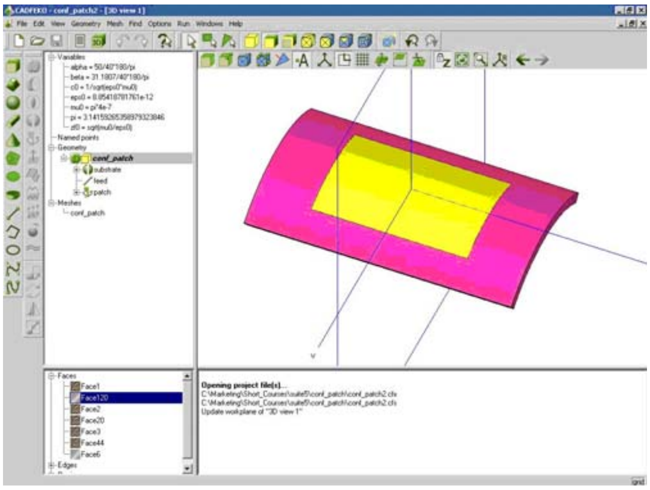
Built-in support is provided for simple transmission line (TL) modelling so that the currents and voltages induced at cable terminals, due to external sources, can be calculated directly. Several pre-defined shielded coaxial cable types, of which the transfer impedance is known, are readily available in FEKO (e.g. RG-58). User defined cable types are also supported. Single wires, coaxial, twisted pair, ribbon and more complex cable harnesses can be analysed via an interface to SimLab's CableMod product. The interface allows radiation from cables to influence the environment around it and vice versa.



GRAPHICAL USER INTERFACE (GUI)

The FEKO GUI consists of CADFEKO and POSTFEKO and is available for Windows and Linux.

CADFEKO



Functionality:

- Interactive geometry specification.
- Meshing
- Solution control
- Excitation specification
- Output requirements

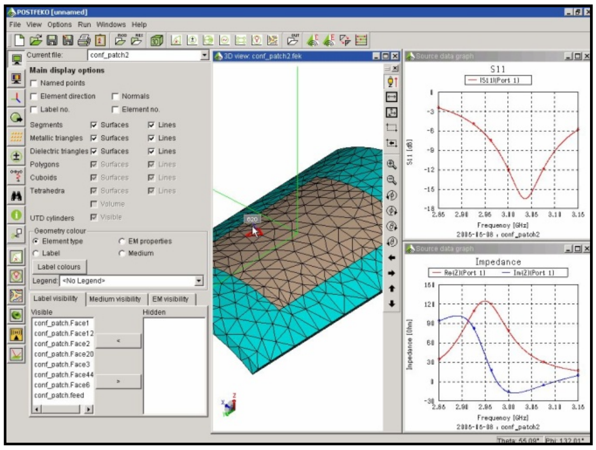
Features:

- Canonical structures such as cylinders, polygons, spheres, cones, etc. are created with the click of a button.
- Perform boolean operations such as splitting, unioning, intersection and subtraction on geometry objects.
- Create complex objects using spinning and sweeping of curves and surfaces.
- Create ruled surfaces between two edges or curves.
- Translate, rotate, scale and mirror objects.
- Projection of points, curves and surfaces onto surfaces or solids.
- All parameters can be entered in terms of variables and/or mathematical expressions which may be modified to change the geometry.
- Models may be organised by combining model elements into assemblies.
- Surface meshes (triangles) and volume meshes (tetrahedra) may be created with user specifiable mesh density for any specific region of the geometry.
- Import filters for complex geometry or mesh models in industry standard CAD formats.

POSTFEKO

Functionality:

- Model validation.
- Post-processing and visualisation of results.

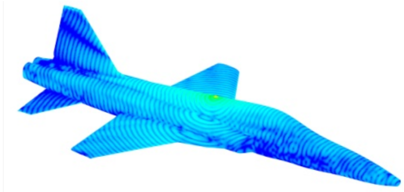


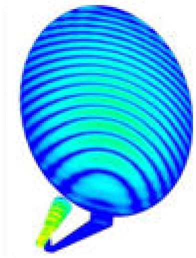
Features:

- Support for multiple 2D and 3D views with multiple geometry (*.fek) and result (*.bof) files in a single session.
- User specifiable dimensional grids can be placed in 3D views to assist in interpretation of dimensional information.
- Support for multiple results of the same type, e.g. displaying more than one near-field ortho-slice in the same 3D view.
- Multiple and arbitrarily oriented cut-planes are supported.
- Advanced Specific Absorption Rate (SAR) display options.
- UTD ray colours indicate their relative amplitudes.
- Electrical surface currents and electrical charge density display options.
- 2D graphs that automatically label axes with appropriate units.

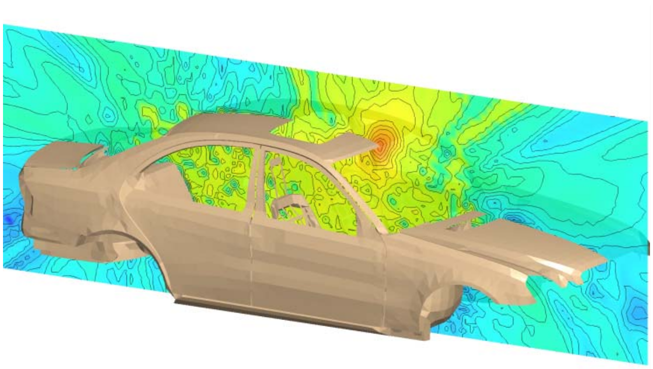
Solution of Electrically Large Problems

Full-wave techniques (MoM, FEM etc.) generally suffer from poor scalability. This limits the electrical size of the problems that can be solved on typical computers. When using field based solution techniques (FEM, FDTD), the discretisation of the field introduces a very small error as a wave propagates through the mesh. For very large meshes, these errors could add up, resulting in reduced accuracy in results. The error can be reduced by using a finer discretisation, but this increases the resource requirements.





The MoM does not require field discretisation, which means that the propagation distance does not degrade the accuracy of the results. With the MoM the memory required relates to the number of basis functions squared (N^2). For general structures, a basis function density of about 100 basis functions per λ^2 is recommended. For 1 GByte RAM, and using no symmetry, this translates to a surface area of approximately 82 λ^2 that can be solved in-core. Larger problems can be solved using an efficient out-of-core solver in FEKO, but this solution is slower than an in-core solution. Whereas the memory requirements for MoM is proportional



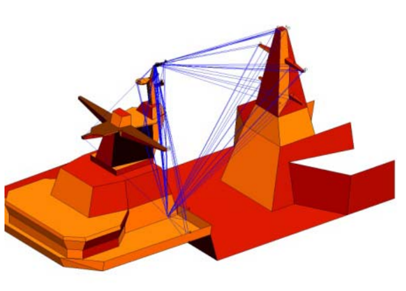
to N^2 that of the MLFMM is N*log(N) (for metallic surfaces $N \approx 100*(A/\lambda^2)$ with A the surface area). For large N this is a huge difference!

Asymptotic predictions of memory usage for the MoM with and without MLFMM			
N	MoM	MLFMM	Application
100,000	150 GB	1 GB	Military aircraft at 690 MHz Reflector antenna with aperture size 19λ.
200,000	600 GB	2 GB	Military aircraft at 960 MHz Reflector antenna with aperture size 27λ.
400,000	2.4 TB	4.5 GB	Military aircraft at 1.37 GHz. Reflector antenna with aperture size 38λ.
1 000,000	15 TB	12 GB	Military aircraft at 2.2 GHz Reflector antenna with aperture size 60λ.

Although the MLFMM enables the analysis of electrically large problems this accurate full-wave method is not sufficient for the solution of electrically huge structures (e.g. aircraft or ship at 10 GHz and above).

Asymptotic high frequency techniques (PO, GO for dielectrics and the UTD) offer a solution to the scalability problem for such problems. In the PO formulation the currents on the metallic surfaces are simply calculated from the incident field. The GO works by launching rays from each MoM element and placing Huygens sources on dielectric boundaries, while with the UTD only the closed form, reflection and diffraction (edge and corner) coefficients are used in the solution. The size of the object, therefore, does not influence the memory requirement. The coefficients (terms) and the number of interactions do however influence the run-time. The UTD formulation requires that the smallest dimension of the UTD objects be at least in the order of a wavelength.

Whereas the triangles (for PO and GO) are well suited to represent complex geometry the flat polygonal plates restrict the application of the UTD to geometries which can be modelled sufficiently with such plates (e.g. ship).



In FEKO, the generally applicable MoM has been hybridised with the Physical Optics (PO), Geometrical Optics (GO) and the Uniform Theory of Diffraction (UTD). This hybridisation enables the solution of large problems on small computers. The hybridisation allows for full wave analysis where required, and approximations to be used when applicable.