Comprehensive Electromagnetic Solutions

FEKO

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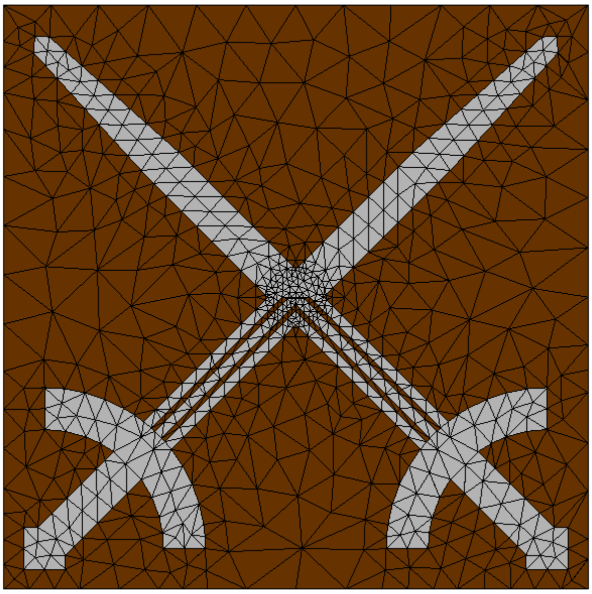
FEKO is continually being applied to new fields of study. In this issue of the FEKO quarterly we focus on the application of FEKO to RFID design and deployment as a case study. We also present some guidelines to help users understand how their models influence resource requirements and how to estimate such requirements before running simulations. As always, your comments on the quarterly are welcome. If you would like to contribute an article, please send it to *quarterly@emss.co.za*.

An Electromagnetic Perspective on RFID

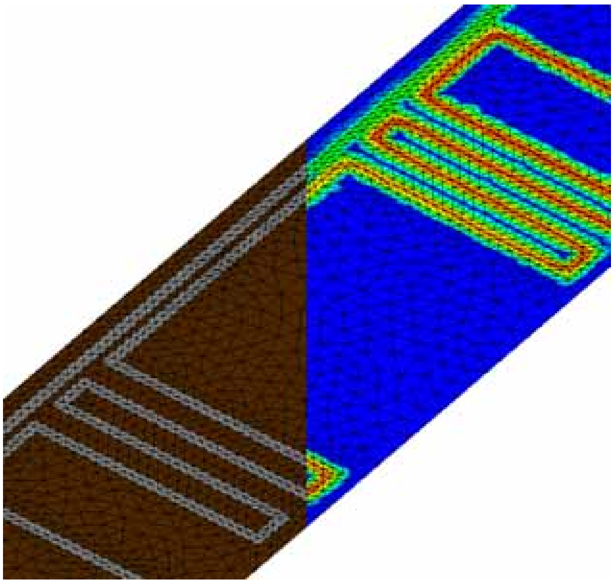
Radio Frequency Identification (RFID) has become an invaluable tool in inventory tracking in recent years. New applications for RFID technology are devised almost daily, requiring rethinking and redesigning of the underlying elements of the technology.

One of the most affected elements of a new application of RFID is the tag antenna. The nature of RFID tag usage dictate that tag antennas are thin planar structures that offer manufacturing ease and low cost, typically simple etched or printed structures.

To ensure optimal transfer of energy from the antenna to the chip, RFID antennas are typically designed in free space (or with thin dielectric sheets) to have an input impedance resulting in a complex conjugate match of the chip input impedance. RFID tags are mostly placed on moveable objects, so no specific antenna orientation can be guaranteed and an omni-directional radiation pattern is sought. As such the radiation pattern is another important design metric at an early stage of tag development. FEKO's Method of Moments (MoM) is ideally suited to this stage of RFID design, presenting designers the option to simulate thin wire segments or planar metallic structures with equal ease. The currents on the metallic elements of the antenna are easily computed and used to extract radiation patterns and input impedance.



KSW Excalibur GEN 2 tag antenna.



Meander line tag antenna with metallic elements (left) and surface currents (right).

RFID tags are placed on many different items consisting of dielectric and metallic materials. These structures significantly influences the tag antenna impedance and effectively detunes it from the chip that it is coupled to. Gain and radiation patterns of the antenna is also significantly influenced by such structures. Different tag designs will respond differently to the materials that it is placed on and the suitability of a given tag design should therefore be validated for the application that it is intended for. This stage of the RFID application process is also

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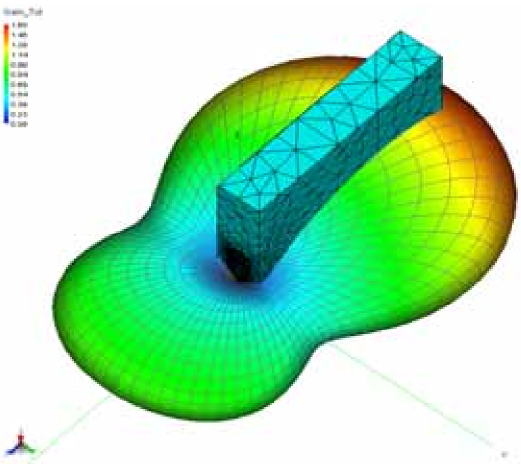
catered for by FEKO with accurate approximations of dielectrics, e.g. the thin dielectric sheet (TDS). TDS sheets approximate thin dielectric layers with a single layer of infinitely thin triangles, while taking the effect of the finite thickness dielectric into account in the computation of surface currents on the antenna.

"FEKO's surface equivalence principle (SEP) extension to the MoM is a good method for the solution of homogeneous dielectric shapes."

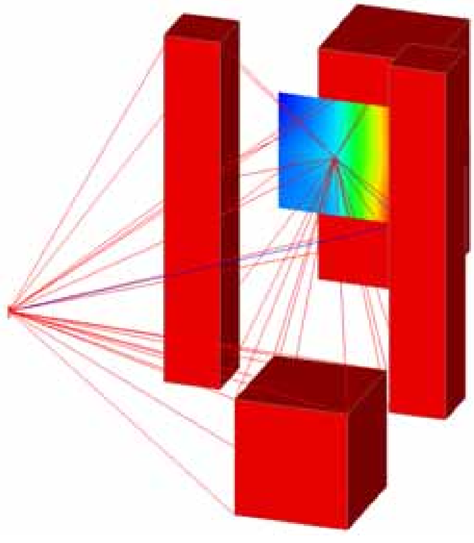


Deformed radiation pattern of a meander line antenna on a book.

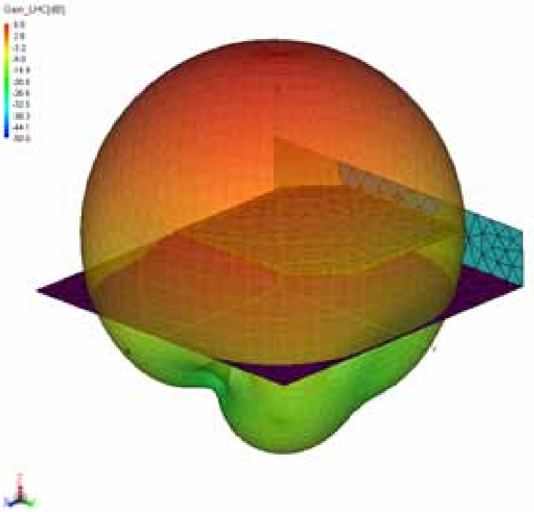
More complex dielectric shapes, e.g. cool drink bottles, are also encountered in the validation of RFID tag antennas. FEKO's surface equivalence principle (SEP) extension to the MoM is a good method for the solution of homogeneous dielectric shapes. Equivalent magnetic and electric currents are modelled on the surface that form the boundary between regions with different dielectric properties.

The SEP is not well suited to the solution of in-homogeneous dielectric objects as too many dielectric triangles will be required in such models. In-homogeneous dielectric objects are better modelled with the finite element method (FEM), which meshes the dielectric regions into neighbouring tetrahedrals without decreasing the efficiency of the solution.

"FEKO may be applied to the visualisation of signal paths from tag antennas to interrogator antennas by using a combination of MoM and uniform theory of diffraction (UTD) modelling."

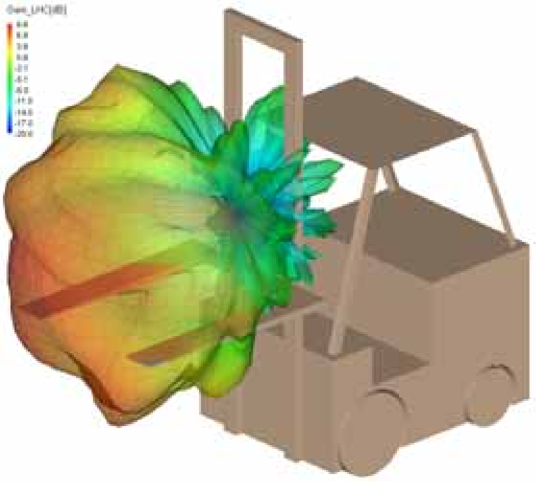


Optimising interrogator antenna placement in a warehouse or factory with UTD ray tracing.



Radiation pattern of interrogator antenna.

Another critical element in the RFID tool chain is the interrogator antenna and its environment of application. The orientation of an interrogator antenna is typically much easier to guarantee than that of a tag antenna. Interrogator antennas are therefore fairly standard in design, but need to be optimally deployed in any given environment.



Interrogator radiation pattern near a forklift.

The electromagnetic problems involving interrogator antennas are typically very large problems involving walls, pillars, conveyor belts, etc. FEKO may be applied to the visualisation of signal paths from tag antennas to interrogator antennas by using a combination of MoM and uniform theory of diffraction (UTD) modelling. The UTD presents RFID designers with a clear picture of how a signal propagates from tag to reader, allowing the designers to relocate the antenna, or perhaps select an antenna with directivity characteristics that better suit the current scenario.

FEKO clearly provides good insight into a wide range of RFID implementation problems. Tag antenna design and placement, interrogator antenna placement and the design op RFID operating procedures are only a few of the areas where such analysis will benefit RFID professionals.

Estimating Resource Requirements for Simulations

It is often important that users are able to estimate reasonably accurately how much resources will be required for a FEKO simulation. FEKO support engineers have developed rules of thumb that may be used for such estimates and maintain a page in the FEKO website help centre with the latest information on these techniques. Here are some of the most useful techniques.

MoM

The number of unknowns for the MoM (**Nmom**) are roughly 1.5 times the number of triangles (**T**) in the model. Dielectric triangles are the exception to the rule because each triangle require an electrical and magnetic basis function, which means that dielectric triangles contributes roughly 3 unknowns per triangle:

$$\mathbf{RAM = Nmom*(Nmom+1)*p/(1024^2)}\ \text{(MByte)}$$

where **p** is 8 when single precision storage is used and 16 when double precision storage is used. For large problems the mathematical operations required to analyse the model are roughly:

$$\mathbf{OPS = (8/3)\ x\ Nmom^3}\ \text{(FLOPS)}$$

Runtime may thus be estimated in seconds by dividing OPS by the processor speed in FLOPS. (Modern CPUs feature 5 to 8 GFLOPS.)

PO

The PO solution process requires much less memory than the MoM (as long as the MoM elements are few), making it applicable to large metallic structures. In such large geometries, the storage of the mesh requires significant amounts of memory and should be taken into account. Roughly 370 bytes are required to store a triangle (true for all formulations). The total memory required for a MoM-PO solution is therefore:

$$\mathbf{RAM = [\ 2(Nmom+1) * Npo * p + Nmom * (Nmom+1) * p + (370 * T)] / (1024^2)}\ \text{(MByte)}$$

where **p** is 8 when single precision storage is used and 16 when double precision storage is used, where **Nmom** is the number of unknowns for the MoM region, **Npo** the number of unknowns for the PO region and **T** is the number of triangles in the model.

FEM / MoM

A significant component of the memory required for a FEM/MoM model is the MoM matrix, comprising the unknowns of the FEM/MoM boundary and that of the MoM region. If the dielectric surface of the FEM region is large, the memory requirement will often be dominated by the FEM/MoM boundary. The memory required for the MoM matrix can be estimated as follows:

1. Run FEKO in check-only mode and open the resulting OUT-file.
2. Find the heading "Memory requirement for MoM matrix" and note the number of complex numbers (**Ncomplex**) that result from the row/column multiplication.

Memory requirement for the MoM matrix can be estimated with the formula: **RAMmom = Ncomplex x p/256^2** (MByte), where **p** is 8 when single precision storage is used and 16 when double precision storage is used.

Memory requirement for the FEM region will vary with the size of the FEM region. It has been observed that the memory required for the FEM region can be approximated with the following formula:

$$\mathbf{RAMfem = RAMmom + c*RAMmom}\ \text{(MByte),}$$

where **c** is a constant that varies with the size of the MoM region. If the FEM region is small compared to the MoM region, **c** can be smaller than 1 and if the FEM region is large compared to the MoM region, **c** can be as large as 3.

UTD

Models that employ the UTD require little RAM as such models the runtime is roughly linear to the number of source and observation points in the model. The following process may be followed to estimate the runtime for a UTD model:

Replace all radiating segments with a single Hertzian dipole and request a single near field point.

Run FEKO and note the runtime for this simplified setup (**U**).

The runtime for the full model scales with the number of radiating elements (**S**) and the number of far field points (**F**) in the full model.

$$\mathbf{RUNTIME = U * S * F}$$

MLFMM

The memory requirements for an MLFMM model can be estimated with the following procedure:

1. Run FEKO, but abort FEKO when the following line appears in the text output: "Calculation of near-field matrix elements".
2. Open the OUT-file of the model and find the following heading: "SUMMARY OF MEMORY REQUIREMENT FMM (in MByte)". This section estimates the MLFMM memory requirement, with the "total" value excluding the memory required by the preconditioner (**RAMte**).
3. The RAM required by the preconditioner is typically 2 to 3 times the amount reported for the near-field matrix in the OUT-file as shown above (**RAMnf**).

$$\mathbf{RAMmlfmm = RAMte + 3*RAMnf}$$

> **"It is often important that users are able to estimate reasonably accurately how much resources will be required for a FEKO simulation."**

9th Annual German FEKO Users Meeting

The 9th annual German FEKO User Meeting 2007 took place in Stuttgart, Germany on 23. October. This year almost 40 users attended the user meeting and some customers gave presentations about their work with FEKO in their companies or universities. Contributions included simulation and optimisation of VHF log.-per. monopole antennas, electric design of radomes, integration of antennas on flying platforms, FEKO for EMC applications and design and analysis of a modal spectrometer. In the afternoon EMSS presented details on many aspects of the latest enhancements in FEKO Suite 5.3, focussing on the major new extensions of this FEKO version (hybrid MoM-GO method, network modelling in FEKO, new optimiser in CADFEKO), and also gave an outlook on the future development of FEKO. A general discussion, including feature requests from the customers, concluded the meeting.


Lectures during the German FEKO user meeting 2007.

Exhibitions

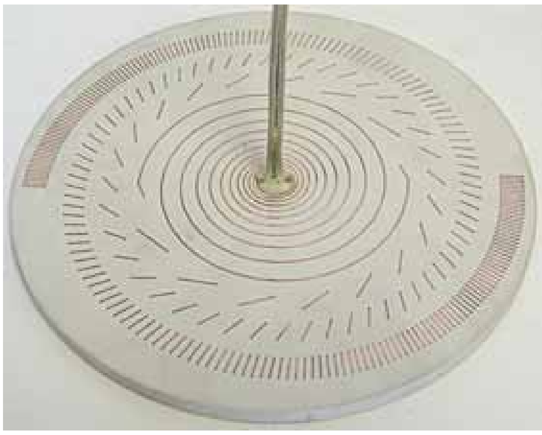
FEKO will be exhibited at many conferences this quarter.

13 - 14 December	FEKO short course, Hampton, Virginia, USA
19 - 21 February	EMV 2008, Düsseldorf, Germany
30 March - 4 April	ACES 2008 - Niagara Falls, Canada

FEKO Student Competition 2007 Winner

The 2007 FEKO student competition drew a record number of entries. What made this year's edition of the competition special is the fact that all the entries were of an exceptionally high standard. Deciding on a winner was a very difficult task and after much deliberation Brad Kramer was selected as the winner. Brad studies under John Volakis and Chi-Chih Chen at Ohio State University and his entry was titled "Size Reduction of a UWB Low-Profile Spiral Antenna via Inductive Loading". An innovative design was presented which required skilled FEKO modelling and compared the simulated results to a measured result from the prototype antenna.

Given the high standard of the entries, an extra three prizes were awarded to the outstanding entries of Kichul Kim (CEM modelling of carbon nanotubes), Gideon Wiid (RF interference modelling for the South African KAT radio telescope project) and Taeyoung Yang (novel antennas for cellular phone in proximity of hearing aids).


A prototype of Brad Kramer's UWB spiral antenna.