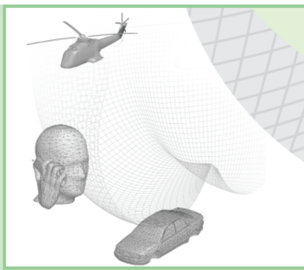


field computations involving objects of arbitrary shape

FEKO

QUARTERLY: March 2005

News:

- Launch of Student Competition 2005
- FEKO Short Course
- ANSYS China Hosts FEKO Training Course
- Special FEKO Session at ACES
- Exhibition Schedule

Modelling of Dielectric Materials in FEKO

The majority of structures of electromagnetic interest contain regions of non-metallic materials. Subsequently a number of techniques have been developed to consider these materials in the Method of Moments (MoM), and implemented into FEKO. Each of these techniques has certain applications that it is better suited to. The optimal technique to use is often not immediately evident to the inexperienced user. This article will briefly introduce each of the available techniques, and then demonstrate, by way of an example, how the choice of technique can influence the efficiency and accuracy of the simulation.

The techniques for modelling dielectric material in FEKO are currently: the surface equivalence principle (SEP), the volume equivalence principle (VEP), special Green's functions, thin dielectric sheet approximation, dielectric coating for wires and coated metallic surfaces/dielectric solids for Physical Optics. Each technique will be discussed below, before an example is presented. A more thorough discussion on these techniques can be found in [2].

Technique: Surface Equivalence Principle (SEP) The SEP in FEKO uses the PMCHW formulation. The MoM for metallic structures solves for the electric currents on the surface of all objects, to determine other electromagnetic observables. When using the SEP, surfaces of a dielectric are discretised for both the electric and magnetic currents on the surface. In FEKO, the same surface mesh is used for both currents. This formulation makes no assumptions and is therefore applicable to arbitrarily shaped bodies. It is possible to model structures with arbitrary embedding and junctions.

Considerations: All sides of a dielectric have to be modelled, making a closed solid. When using the SEP, both electric and magnetic currents are modelled. This means that there are now 2 basis functions for each triangle pair which correlates to a memory requirement of four times what it would be if the same structure was metallic. Mesh refinement might be required now in places where the magnetic current varies rapidly, as well as regions where the electric current varies rapidly. The benefit offered by the MLFMM decreases rapidly as dielectric constant and loss increases.

Technique: Volume Equivalence Principle (VEP) The VEP in FEKO is implemented for cuboidal elements. The MoM is used to solve for a set of equivalent currents located at the centre of the cuboid. Similarly to the SEP, the VEP makes no assumptions about the shape of the object, and it is therefore generally applicable. Three basis functions are introduced for each cuboid. A cuboid can either be dielectric or magnetic, but not both. If a material is both, two cuboids should be placed at the same location, one to model the dielectric effect, and the other to model the magnetic effect.

Considerations: As a result of the type of basis function that a cuboid uses, there is no restriction on connectivity, as in the case of triangular elements. The large number of basis functions introduced for each cuboid, and the fact that three dimensional discretisation must be used, results in high memory requirements for larger structures. Inhomogeneous structures are easily considered, since each cuboid can have unique properties. As in the case of the SEP, the benefit offered by the MLFMM decreases rapidly with an increase in dielectric constant, or loss factor.

Technique: Special Green's Functions A Green's function describes the response in space to a point excitation or source. The simplest form of a Green's function is the free space Green's function which is used in the default MoM implementation. It is possible to use special Green's functions to incorporate features of the propagation space into the model. This means that properties of the structure are modelled implicitly, which is very computer resource efficient, but is limited to a few special cases. In FEKO, special Green's functions are implemented to model layered dielectric spheres, and multi-layer substrates.

Modelling of Dielectric Materials in FEKO.... continued

Surface Equivalence Principle (SEP)

Volume Equivalence Principle (VEP)

Special Green's Functions

Thin Dielectric Sheet approximation

Dielectric coating/ Dielectric bodies with Physical Optics

"The Green's Function is widely accepted to be the preferred method for solving problems involving planar substrates.."

Considerations: When using multi-layer substrates, it is important to remember that the substrate is modelled as if it were infinite in extent. This can cause some problems if one was analyzing, for instance, a printed end-fire antenna. If a ground plane is included in the Green's function, it too is modelled as if it were infinite in extent. It is possible to model a finite ground plane explicitly using triangular elements. The implementation in FEKO is for fully 3D structures embedded into the substrate. The MLFMM cannot be used in conjunction with a special Green's function. FEKO includes special excitations and loads for use when modelling substrates.

Technique: Thin Dielectric Sheet Approximation

This approximation changes the surface impedance of triangular elements so that the effect of the elements is similar to that of a thin dielectric sheet. Magnetic currents are not modelled on the surface – only the boundary condition is affected.

Considerations: The implementation in FEKO includes a formulation for anisotropic dielectric sheets. This technique is not suitable for analysing structures with embedded antennas or metallic segments. The MLFMM is fully applicable to this technique, and has the same properties as the case when no dielectrics are present.

Technique: Dielectric Coating of Wires

The effect of dielectric coated wires can be considered in FEKO in two ways. The first is by using equivalent impedance and the second by using an equivalent volume current. Using both of these techniques is fully automated in FEKO.

Considerations: Of these two treatments, the equivalent volume current is the preferred technique. When using the equivalent impedance method, the losses in the dielectric should be the same as the losses in the surrounding medium. The MLFMM is fully applicable to this technique, and has the same properties as the case when no dielectrics are present.

Technique: Dielectric Coating/ Dielectric Bodies with Physical Optics

This technique is applicable when using the MoM/PO hybrid in FEKO. The formulation uses the same discretised form of PO in FEKO as when metallic structures are analysed. The discretisation is in terms of surface triangles.

Considerations: It is only suitable for analysing structures that are illuminated by an incident field (i.e. not direct current excitation). The field inside the dielectric is not determined accurately.

The different techniques that are available in FEKO have now been presented, and the main considerations highlighted. An example will now be presented where all the applicable techniques are used to generate a result.

Example

Consider the stacked annular ring antenna [1]. The outer and inner radiuses of the upper patch are b2 and a2 respectively. Similarly, the outer

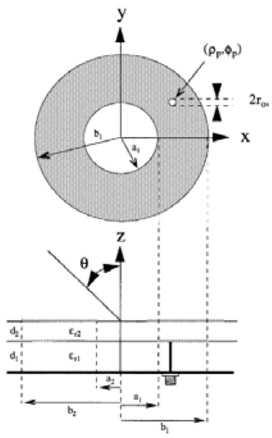


Figure 1: Geometry of a stacked probe-fed printed annular ring with appropriate symbols.

and inner radiuses of the lower patch are b1 and a1 respectively. The thickness of the upper and lower dielectric layers are d2 and d1. The lower ring is fed at $(\rho_p , \varphi_p = 0)$, therefore at $(x , y) = (\rho_p , 0)$ mm. The radius of the feed pin is r_0.

Solution: The first step is to determine which techniques can be applied to this structure. The SEP and VEP are applicable to any dielectric structure. The planar multi-layered Greens function can also be used to model the substrates, making this example ideal for this technique. The thin dielectric sheet approximation, dielectric coating for wires and PO are not applicable in this case.

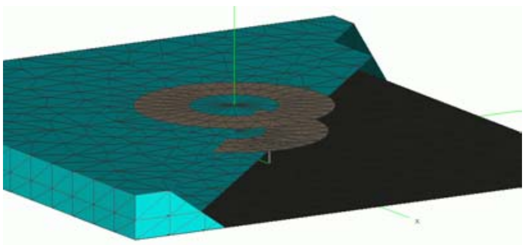


Figure 2: Geometry of the annular ring in FEKO (SEP model)

The Green's Functions is widely accepted to be the preferred method for solving problems involving planar substrates, and an experienced user would probably try this technique first. At times other methods have to be employed due to some limitations in the Green's Functions, for instance, when the dielectric is shaped, or when the finite size of the substrate should be considered. For the purposes of this example, all the applicable techniques are used, so that results can be compared. If a user is unsure that a technique is the

Modelling of Dielectric Materials in FEKO…. continued

optimal solution, experiments with other options should be considered, and results compared.

Special Green's Functions: The geometry (excluding the substrate and ground plane) is constructed using the KR card. The substrates and ground plane are specified in the GF card. It must be noted that FEKO also allows the specification of a finite ground plane when using Green's functions. If this option is exercised the user has to create and mesh the ground plane similarly to the other metallic structures in the problem. Only the dielectric layers are then assumed to be infinite. The finite ground plane enables the computation of field values below the ground plane (horizon). Both the finite and infinite ground plane solutions will be shown.

Surface Equivalence Principle (SEP): The SEP is used when solving electromagnetic problems including dielectric and metallic structures of arbitrary shape. In the case of the example problem, the surface equivalence method enables the user to exactly specify the geometry i.e. the finite size ground plane and finite size dielectric. KR cards are used to define the surfaces (usually the PM card is used for rectangular surfaces) and the ME card specifies whether the surface is metallic or dielectric.

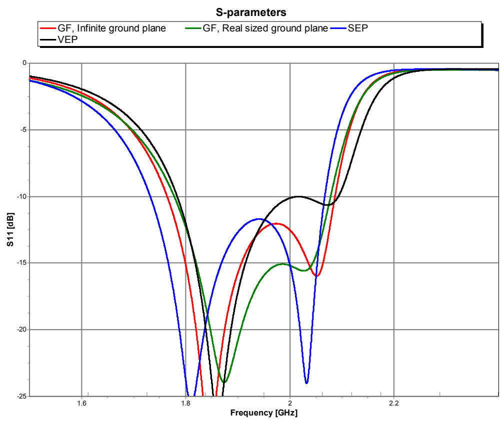


Figure 3: Comparison of the input impedance as obtained through 3 different solution methods.

Volume Equivalence Principle (VEP): The VEP can also be used for the solution of arbitrarily shaped dielectric structures. The metallic surfaces are defined by KR cards as usual, but the volume of the dielectric is subdivided into cuboids by using a QU card.

Results

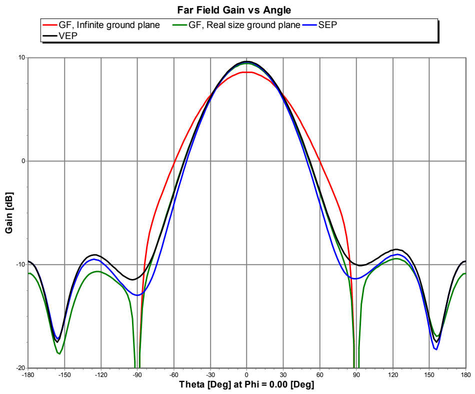


Figure 4: Radiation pattern comparison for the 3 methods.

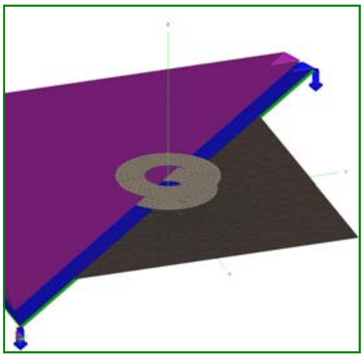
The impedance of the ring antenna, as calculated with the different techniques, is shown in Figure 3. The differences are well bounded, and all techniques give acceptable accuracy.

The radiation patterns for the 3 techniques are shown in Figure 4. The Green's functions pattern for the infinite ground is zero for all angles below the horizon.

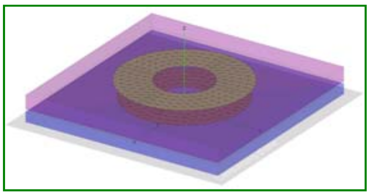
Resource Comparison: A comparison of the solution time and memory requirements for the 3 methods is done in Table 1. The results were computed on an AMD64 Opteron machine using the 64 bit FEKO version.

It is seen that the Green's function method, especially if an infinite ground plane is assumed, is significantly faster and uses significantly less computational resources compared to the SEP and VEP. Even though the remaining methods are less computationally efficient, they are more generally applicable and can be readily employed to solve this and other non-planar electromagnetic problems.

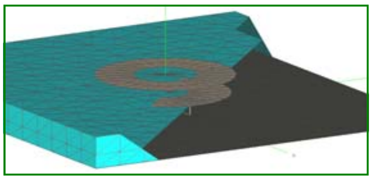
...continued on last page.



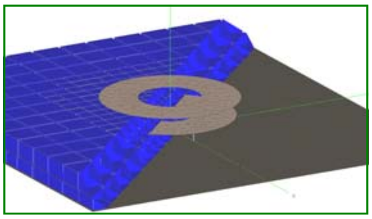
Green's Function with a finite sized ground plane



Green's Function with a infinite sized ground plane



Surface Equivalence Principle (SEP)



Volume Equivalence Principle (VEP)

Table 1: Comparison of the solution methods for CPU time and memory requirements

Technique	Memory [MB]	Number of Unknowns	Time per Frequency Point
Green's functions (finite ground)	101	2565	1.5 min
Green's functions (infinite ground)	16	997	15 s
Surface Equivalence (SEP)	436	3753	2 min
Volume Equivalence (VEP)	524	5852	5.5 min

News and Events

Conclusion ... *Modelling of Dielectric Materials in FEKO*

The methods of dielectric material modelling in FEKO have been presented and special considerations concerning them discussed. An example has been given, to which three of the techniques have been applied. From the results of the example, it is clear that using the optimal technique can significantly affect performance.

References

[1] D.M. Kotokoff, J.T. Aberle, and R.B. Waterhouse, "Rigorous analysis of probe-fed printed annular ring antennas," IEEE Trans. On Antennas and Propagation, vol. 47, pp. 384-388, Feb. 1999.

[2] U. Jakobus, "Comparison of different techniques for the treatment of lossy dielectric/magnetic bodies within the method of moments formulation," AEÜ International Journal of Electronics and Communications, vol. 54, no. 3, pp. 163-173, 2000.

Launch of FEKO Student Competition 2005

The FEKO student competition is back again in 2005. This year the prize for students has been updated. The new prize is a laptop for the winning participant! The institution prize remains unchanged, at one year's free maintenance and support on all licences held by the institution.

The closing date for entries is the 30th September 2005. See web for details.

ANSYS-China hosts FEKO training courses

Distributors of FEKO, ANSYS-China, held a series of FEKO training seminars at three universities in December of 2004. The University of Electronic and Technology of Chengdu, XIDIAN University and Southeast University were the three universities that hosted the short courses. Each course was held over a period of three days, and had over 100 attendees. Further courses are planned at another three universities in 2005.

Special Session on FEKO at ACES Meeting in Hawaii, (3-7 April)

A special session on FEKO will be held at the annual Applied Computational Electromagnetics Society (ACES) meeting in Hawaii.

FEKO Short Course: Stuttgart (12-13 April)

EMSS-GmbH will be hosting a 2 day short course in Stuttgart. See web for details.

Exhibitions

Mar 7-9	IWAT 2005, Singapore.
Mar 15-17	EMV 2005, Stuttgart.
Apr 3-7	IEEE/ACES International Conference on Wireless Communications and Applied Computational Electromagnetics, Hawaii
June 12-17	IEEE MTT-S Int Microwave Symposium, Long Beach, California