Comprehensive Electromagnetic Solutions

FEKO

QUARTERLY: March 2009

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This issue of the FEKO quarterly focuses on the Periodic Boundary Condition (PBC) solution method that was released with FEKO 5.4. In addition to details on this feature general tips are provided for minimising computational cost of simulations.

If you would like to comment or ask questions about contents in this issue, please send us an email, or contact your local distributor or reseller.

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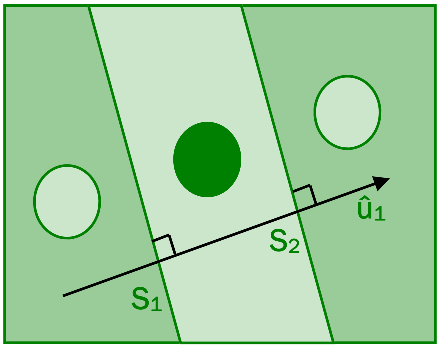
Periodic Boundary Conditions (PBC)

FEKO Suite 5.4 introduced PBC to the list of special computational features available to users. PBCs enable users to simulate infinite periodic geometries, while defining and simulating only the unit cell of the geometry.

The periodicity of a structure can be defined in one or two dimensions with appropriate specification of lattice vectors ($\hat{u}_1$, $\hat{u}_2$) relative to three geometry points (S_1, S_2, S_3). These lattice vectors do not have to be orthogonal and can form skew unit cells. The unit cell does not have to bound the geometry as features that cross the unit cell boundary are treated with appropriate half basis functions.



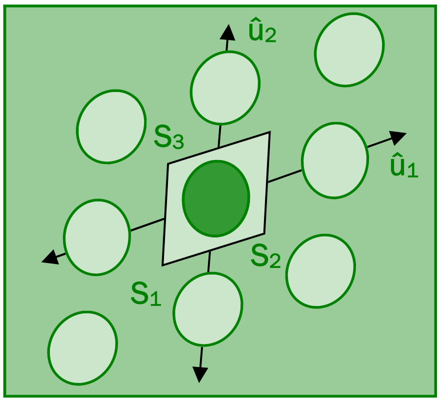
Schematic 1 dimensional unit cell

Unit cells can act as radiators or scatterers and periodic phase shifts specified by the user can be applied to local sources in the lattice vector directions. Plane wave phase shifts are determined automatically from cell to cell.

"Unit cells can act as radiators or scatterers and periodic phase shifts specified by the user can be applied to local sources in the lattice vector directions."

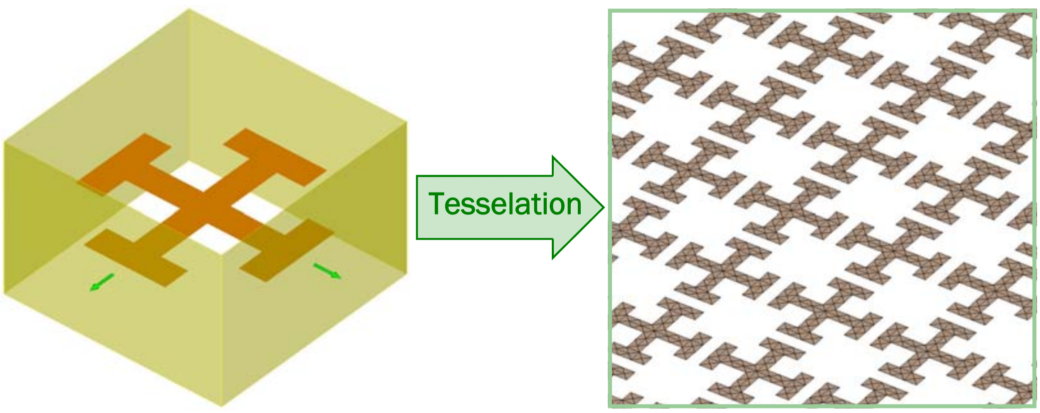
Example problems that are ideally suited to analysis with PBCs include:

- Reflection coefficient analysis of Frequency Selective Surfaces (FSS) , such as the well known Jerusalem Cross.
- Transmission analysis of regularly spaced apertures in metallic screens.
- Characterisation of the effective permittivity and permeability of Split Ring Resonator (SRR) arrays.
- Analysis of finite antenna arrays with many regularly spaced elements.



Schematic 2 dimensional unit cell

The current distribution on a Jerusalem cross can be used for visual confirmation that PBCs function properly. The cross is simulated at 6 GHz as a 2-dimensional PBC in comparison with a 21 x 21 finite

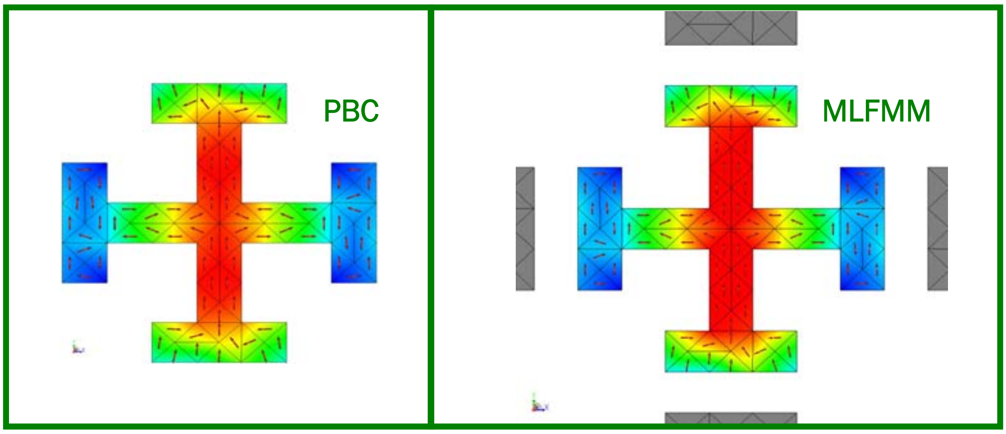


Applying a PBC to the analysis of a 2 dimentional infinite frequency selective surface.

Periodic Boundary Conditions... (continued)

array based on the same structure. The results compare very well, with the PBC computationally much cheaper than the MLFMM solution (3 GHz Intel Xeon CPU on an Altix XE210 computer).

Resource	PBC	MLFMM
Time (seconds)	6	1189
RAM (MByte)	0.143	1367



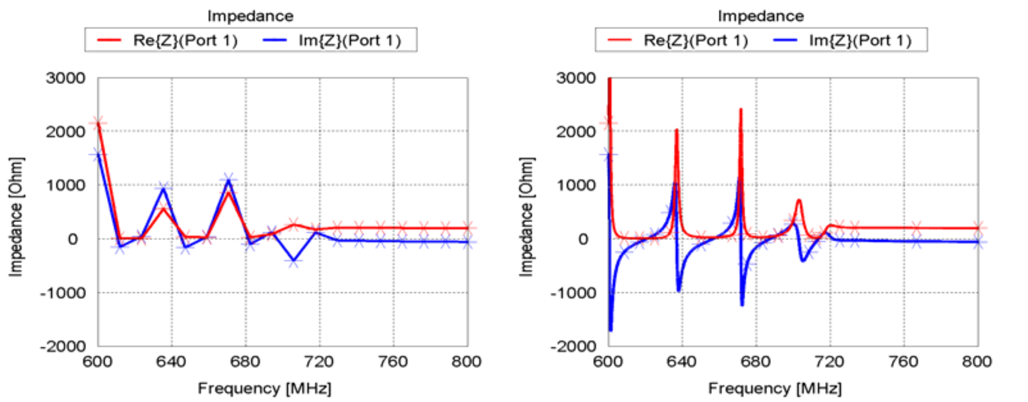
Experimental verification of PBC accuracy: Currents on a Jerusalem cross computed with PBC, compared with MLFMM computation of a 21 x 21 array.

Reducing Computational Cost of Simulations

General tips

- *Use adaptive frequency sampling for frequency band specification,* rather than linearly spaced sampling. FEKO will automatically pick the least number of frequency samples from which the requested result set can be accurately extracted.

"FEKO will automatically pick the least number of frequency samples from which the requested result set can be accurately extracted."



*Input impedance of a helix antenna. **Left**, 18 equally spaced frequency points, **right**, 18 adaptive frequency samples, capturing the resonant behavior more accurately at no extra computational cost.*

- *Use the batch mesher or mesh models in part for large meshes.* CADFEKO_BATCH is a command line version of the mesher in CADFEKO. This means that CADFEKO can be closed while the model is meshed from the command line, saving the memory and processing time that would be required to render the model. It is also possible to mesh only a part of the model and then use symmetry or copy operations in EDITFEKO to form the complete mesh.
- *Store and re-use solutions.* The current coefficients of the solution can be stored to a file (*.str) when a run completes. If only post-processing changes are requested for a subsequent run, FEKO will load the current coefficients and immediately compute the output parameters.

MoM tips

- *Use symmetry.* Geometric symmetry will save on the time it takes to compute the triangle integrals while electric and magnetic symmetry will save computation time as well as memory. Symmetry cannot be used together with the MLFMM.

"Electric and magnetic symmetry will save computation time as well as memory."

Reducing Computional Cost of Simulations... continued

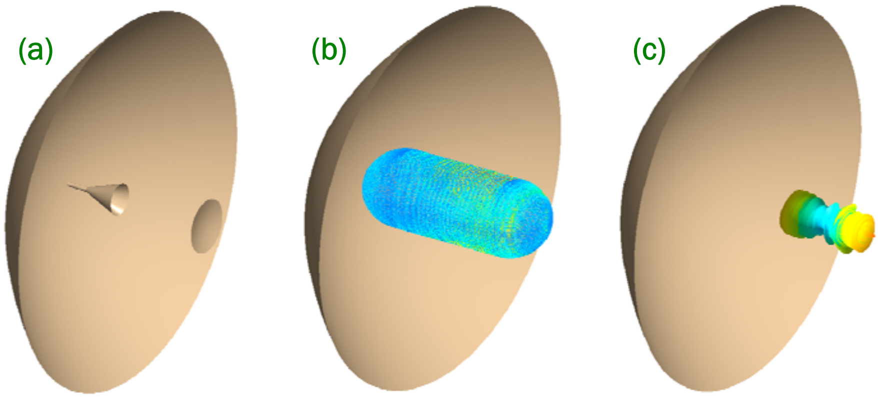
MLFMM tips

- ***Use a lower fill level, the SPAI preconditioner or a reduced box size to reduce MLFMM memory requirements.*** The fill level influences convergence of the iterative phase of the MLFMM. The default fill level for sequential runs is 12 but can be reduced to 8, 4 or 0, risking slow or non-convergence if this number is too low. The SPAI preconditioner is typically used for the parallel MLFMM and is very memory efficient. It will use less memory in a sequential run, than setting the fill level to 0. The default box size is 0.23 for all MLFMM runs, but may be reduced to 0.2.
- ***Use the CFIE (Combined Field Integral Equation), a lower fill level or less incident angles (plane wave excitation) to reduce runtime.*** The CFIE is a different integral equation that provides better convergence but should be applied with caution if the surfaces it is applied to contain many sharp corners. A smaller fill level generates a smaller preconditioner, requiring less computation time. Each plane wave excitation requires rerunning the LU-decomposition phase of the solution (users will recognize this stage as the stage during which the residuum is computed).

"The CFIE is a different integral equation that provides better convergence."

Hybrid MoM/PO tips

- ***Decouple the MoM and PO parts of the solution.*** If the PO areas of the model do not influence the MoM areas significantly, then decoupling the solution by removing the coupling matrix will save computational resources.

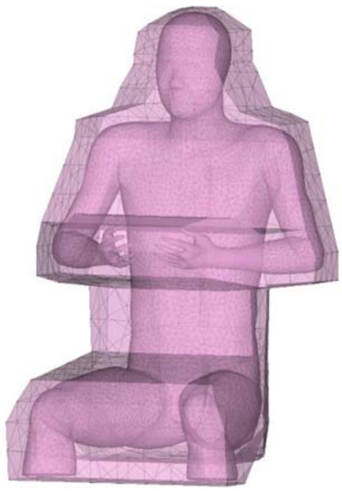


*Decoupling the MoM and PO parts of a problem: Three options are shown. **(a)** the main reflector is treated with PO, without coupling to the feed horn and sub-reflector which are treated with the MoM. **(b)**, the horn and sub-reflector are first analysed in isolation with the MoM. A closed surface of near field sample sources are then used to excite the PO main reflector. **(c)** uses a similar approach to **(b)**, except that the radiation pattern of the horn and sub-reflector is used as a point source to excite the main reflector, leading to a further reduction in computational cost.*

- ***Use special ray tracing options,*** e.g. "always illuminated" and "only illuminate from front". These options reduce the ray tracing time for applicable models, e.g. a reflector antenna.
- ***Minimise the number of MoM elements.*** If coupling can not be ignored, minimise the number of MoM elements to reduce computation time.
- ***Minimise the number of field points.*** Each far and near field point requires a contribution to be calculated from each PO element. Reducing the number of observation points thus reduces computation time.

Hybrid MoM/FEM tips

- ***Surround the FEM region with an air dielectric layer.*** Air triangles on the surface of the FEM region can be large relative to dielectric triangles, reducing the number of triangles by which the FEM and MoM regions couple.
- ***Replace internal free space regions in the FEM volume with air dielectric.*** These areas are then treated with FEM, rather than MoM via internal surface triangles. The coupling matrix is thus reduced significantly, while the increase in the FEM matrix size is very little.
- ***Use first order basis functions for finely meshed areas of the FEM region.*** If meshing has to be very fine compared to wavelength (e.g. due to geometric considerations), then rather use first order basis functions, to reduce computational cost.



The FEM region is modelled as a dielectric object encapsulated in air, to reduce computational cost of the hybrid MoM/FEM coupling.

"Air triangles on the surface of the FEM region can be large relative to dielectric triangles, reducing the number of triangles by which the FEM and MoM regions couple."

Exhibitions: FEKO will be exhibited at many conferences this quarter, including those listed below.

23 - 27 March '09	PIERS 2009, Beijing, China
30 March - 1 April '09	ESA Workshop on Aerospace EMC, Florence, Italy
1 - 5 June '09	IEEE APS / URSI 2009, Charleston, South Carolina, USA

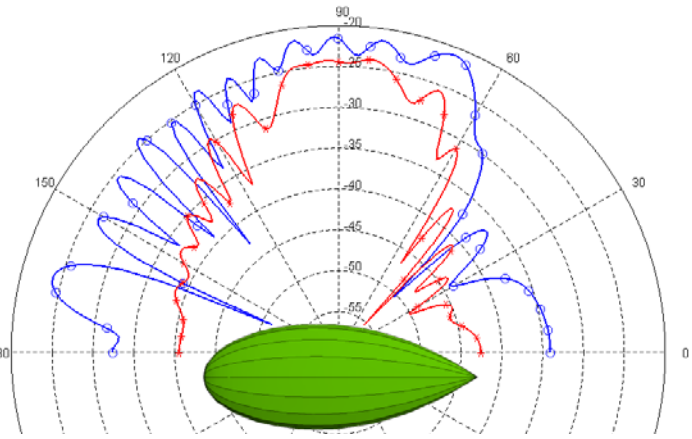
Japanese User Meeting

FARAD Corporation hosted the fourth Japanese FEKO users meeting in Tokyo early in December 2008. Mr. Mel van Rooyen and Mr. Ernst Burger attended the meeting as representatives of EM Software & Sytems in South Africa, the development centre of FEKO. Sessions were presented with general marketing and application information on FEKO as well as a review of new features that were released with the latest version of FEKO. User meetings are traditionally also excellent opportunities to learn more about the use of FEKO and this meeting was no exception. Topics that were covered ranged from basic but effective CADFEKO usage to advanced examples where EDITFEKO was leveraged for complex optimisation problems. One of the highlights of the user meeting was a session presented in Japanese by Prof. Naoki Inagaki from Nanzan University in Japan. Prof. Inagaki showed insightful examples of how FEKO can be applied to complex antenna and radiation problems. His valuable contribution was greatly appreciated.

Attendees listening to an overview of FEKO's abilities.

RCS Benchmarks

FEKO's full wave solution options provide highly accurate RCS results by taking all geometric features of the object under test into account. Industry standard shapes for the benchmarking of RCS simulation performance include the NASA almond, simple ogive, double ogive, cone-sphere and cone-sphere with a gap between the cone and sphere. Simulations were done to investigate FEKO's accuracy and performance for all these shapes. Results from this work compare excellently with published measurements. More information and models for these shapes are available on the FEKO website. Search for "NASA Almond RCS" to find the article titled "RCS Measurement and Simulation of Generic Simple Shapes".



NASA almond 7 GHz RCS for HH (blue) and VV (red) polarisation