## COUPLING SIMULATION OF TWO MONOPOLES ON A GENERIC AIRCRAFT

A very simplified aircraft structure is presented below. It has been chosen so that it can be rapidly meshed and its CAD description can be exchanged easily. It consists solely of truncated canonical objects (cylinders, half spheres and flat surfaces), yet it should contain many of the EM characteristics of a real aircraft.

The test case antennas are:

- Antenna1 (active) : a quarter wavelength (0.075m) monopole at 1 Ghz , mounted on the upper portion of the fuselage , 2 m from the aircraft nose(in the symmetrical plane).
- Antenna2 (passive) : a quarter wavelength (0.075m) monopole at 1 Ghz , mounted on the upper portion of the fuselage , 12 m from the aircraft nose(in the symmetrical plane).

### Definition of Geometry

Geometrical configuration:

- Fuselage 18 m: Cylinder (15 m long, diameter 3 m) terminated by 2 half sphere.
- Wings span 18 m: conical section (half sphere, radius 0.2 m).
- Tail height 2.5 m. The same conical section as the wings.

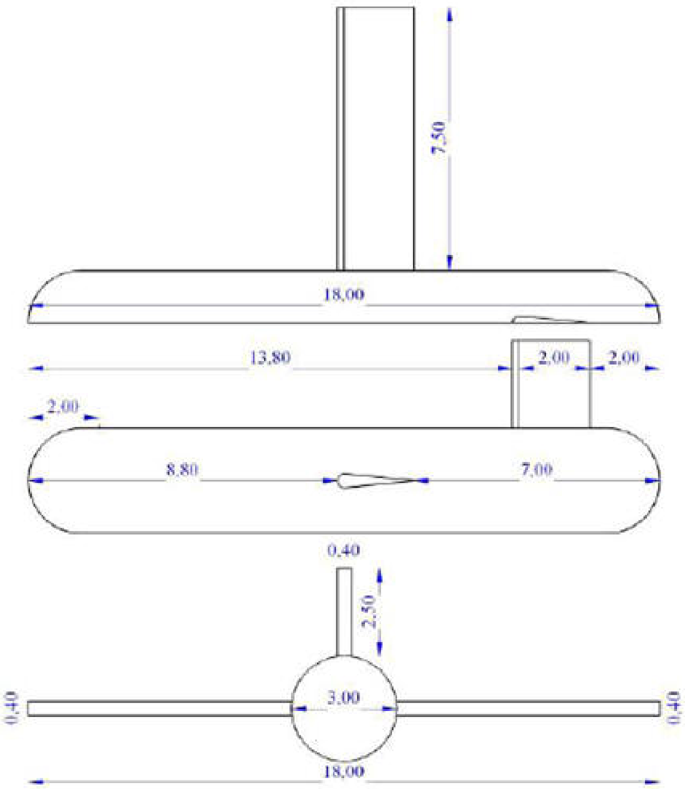



***Figure 1: Definition of geometry of aircraft***

Two monopole antennas, 1 GHz, quarter wavelength (0.075 m), the first position 2 m from the nose tip and the second 12 m from the nose tip. The monopole antennas are modelled as cylinders with a radius $r_a$=2.0 mm. A coaxial surface with outer radius $r_b$=4.6 mm. The airplane fuselage with monopoles are modelled as a closed surface.

**Mesh Generation**

The mesh density was λ/7.5 except for the monopole with its nearby surrounding were a higher density was used. Two different mesh densities close to the monopoles were tested. The coarse mesh was used in "model 1" and the fine mesh in "model 2".

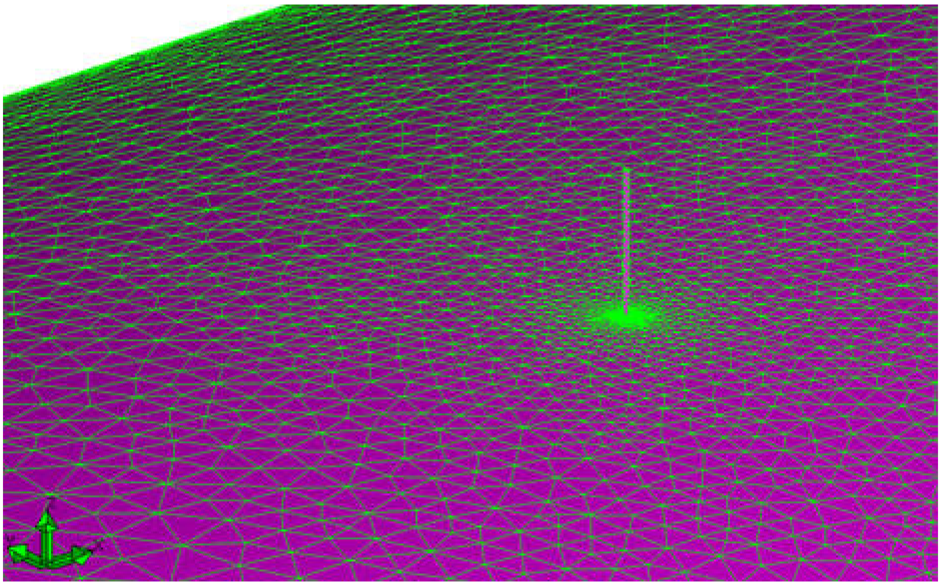
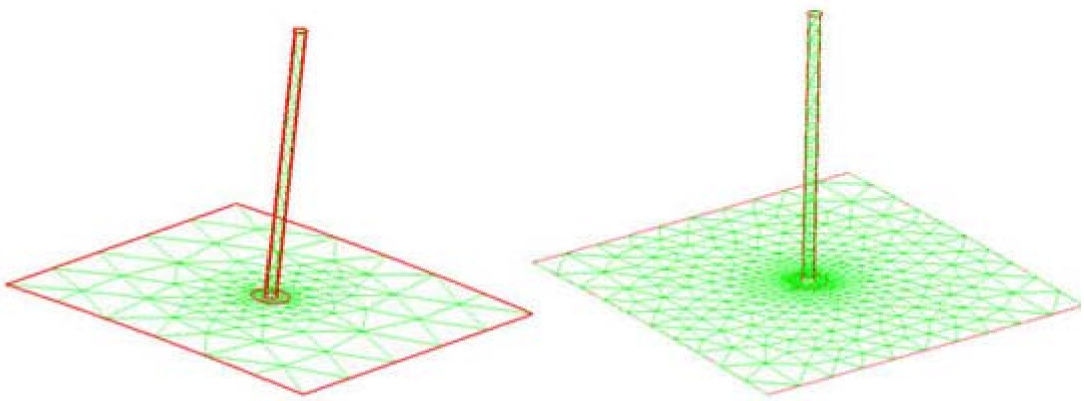


*Figure 2: Mesh of monopole on aircraft*



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**Simulation results**

The scattering parameters were calculated for the generic aircraft with the monopoles using the Efield Multi Level Fast Multipole Method (MLFMM). A Combined Field Integral Equation (CFIE) was used to speed up the convergence.

 

$$CFIE = \alpha\, EFIE + (1-\alpha)\, MFIE$$

Different α parameters were tested

- α =1.0 (pure EFIE) with Model 1
- α =0.8 with Model 1
- α =0.8 with Model 2 ("FINE")

Data for the simulations is presented in Table 1. The simulation was run on one processor on an AMD Dual Core Opteron 285 2.6 GHz with 16 GB memory. Scattering parameters are presented in Figure 3 and Figure 4.

Table 1: Simulation data.

| | Number of unknowns | Number of elements | Mesh resolution | Memory | CPU-time |
|---|---|---|---|---|---|
| Model 1 | 457230 | 304820 | λ/7.5[1] | 4.4 Gb | 3.4 hours/freq. |
| Model 2 | 471789 | 314526 | λ/7.5[2] | 4.6 Gb | 3.5 hours/freq. |

1/medium resolution at the monopoles

2/fine resolution at the monopoles

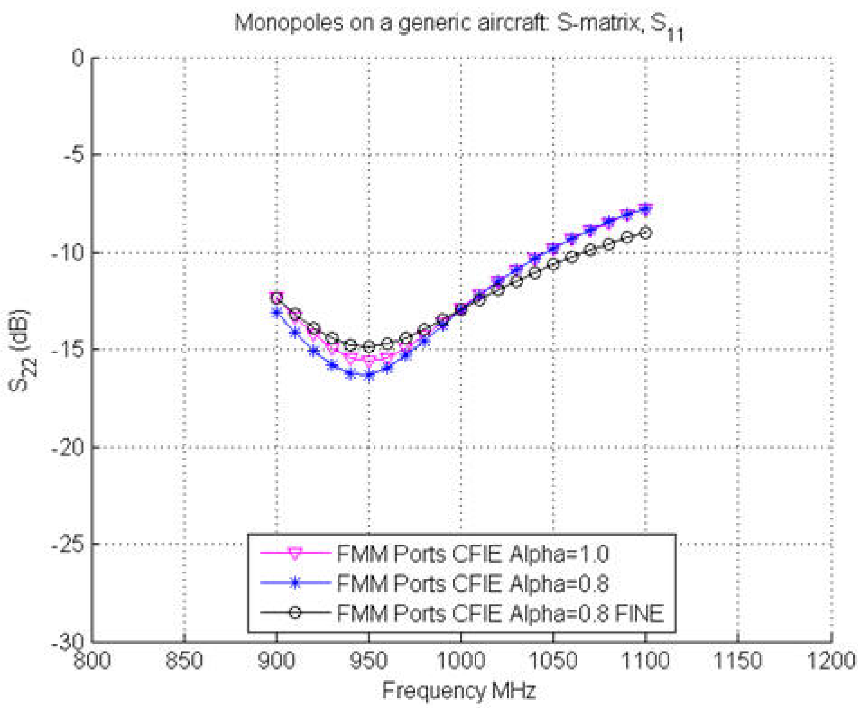


***Figure 3:*** $S_{11}$

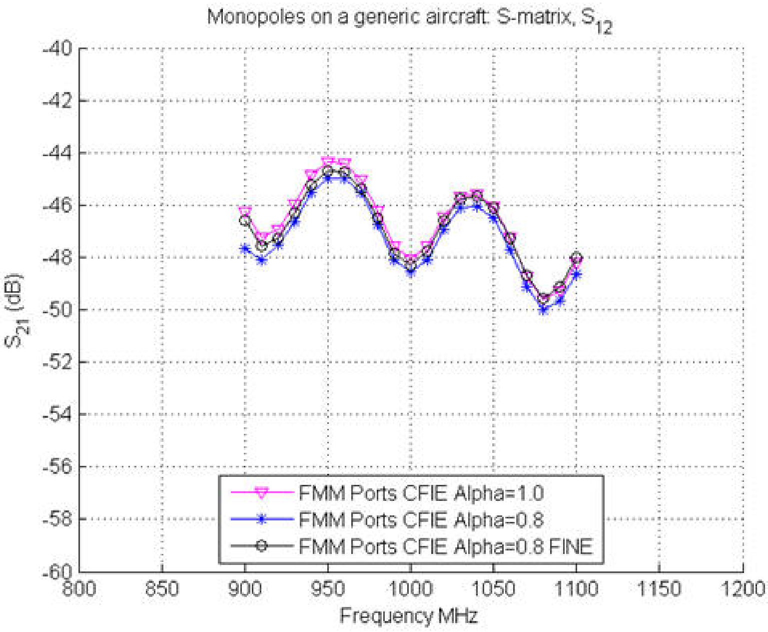


***Figure 4: $S_{12}$***

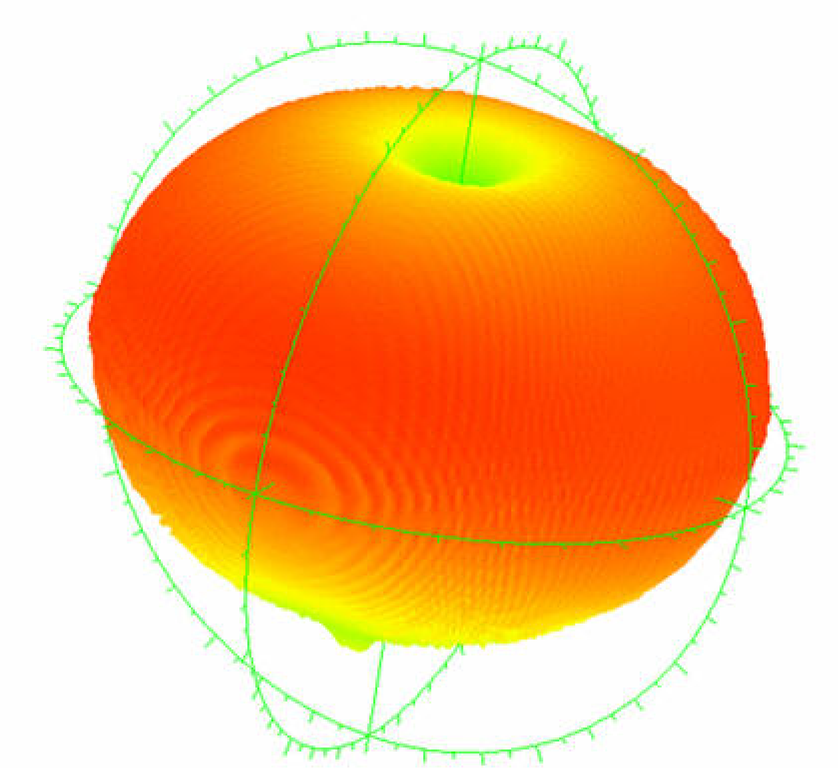

***Figure 5: Far field when antenna 1 is excited***

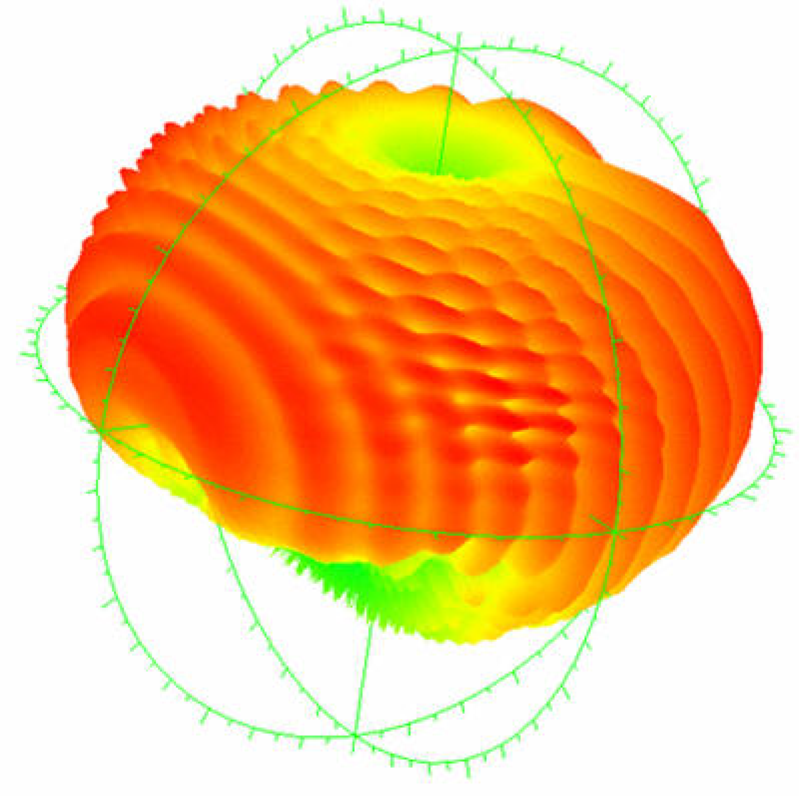

***Figure 6: Far field when antenna 2 is excited***

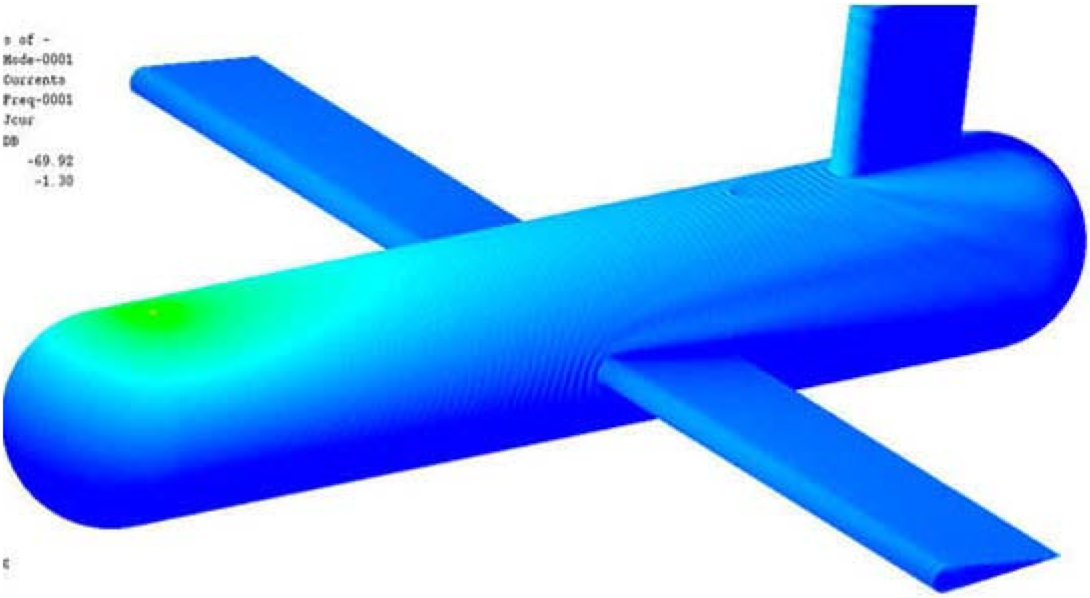


***Figure 7: Surface currents when antenna 1 is excited***

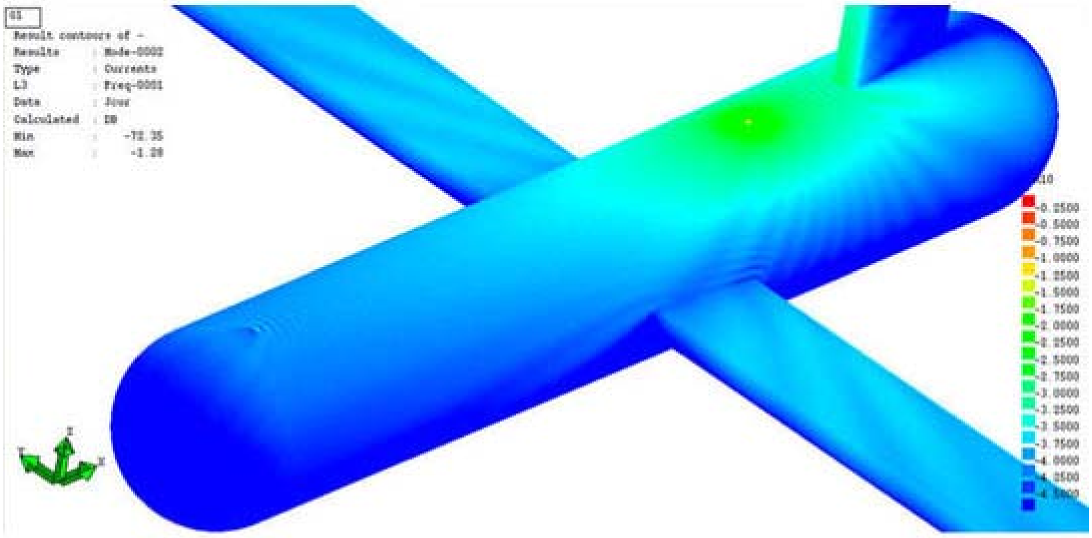


***Figure 8: Surface currents when antenna 2 is excited***

**Comparision with Efield FDTD**

The generic aircraft model was also simulated with the Efield FDTD solver. FDTD should be considered as a useful alternative to frequency domain MLFMM when a wide frequency band response is the desired outcome. The simulation details are presented in Table 2. Two different grids were tested with cellsize 25 mm and 15 mm respectively. The calculated S-parameters are presented in Figure 10.

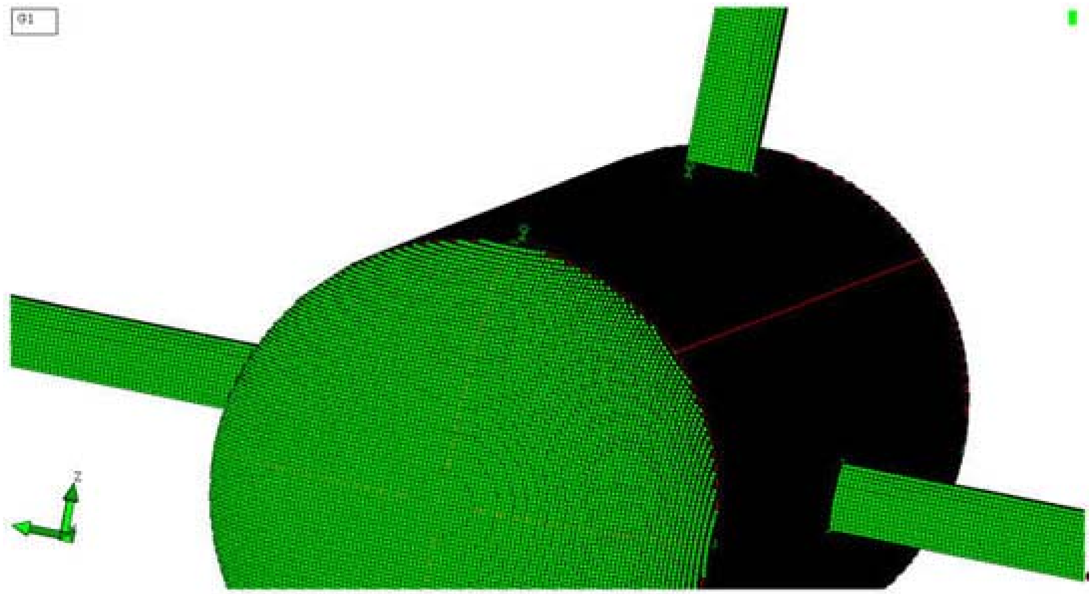

***Figure 9: Surface mesh using Efield FDTD***

| Table 2: Efield FDTD simualtion data for the generic aircraft model with monopoles. | | | | | |
|---|---|---|---|---|---|
| | Cell size | Number of cells | Mesh resolution | Memory | CPU-time |
| Model 1 | 25 mm | 131 424 000 | λ/12 | 6 Gb | 16 hours[1] |
| Model 2 | 15 mm | 605 160 000 | λ/20 | 31 Gb | 15 hours[2] |

1/ 4 AMD Dual Core Opteron 285 2.6 GHz with 16 GB RAM, 10 000 iterations

2/ 15 nodes processor cluster with 4 Itanium 2, 1.3 GHz per node, 10 000 iterations

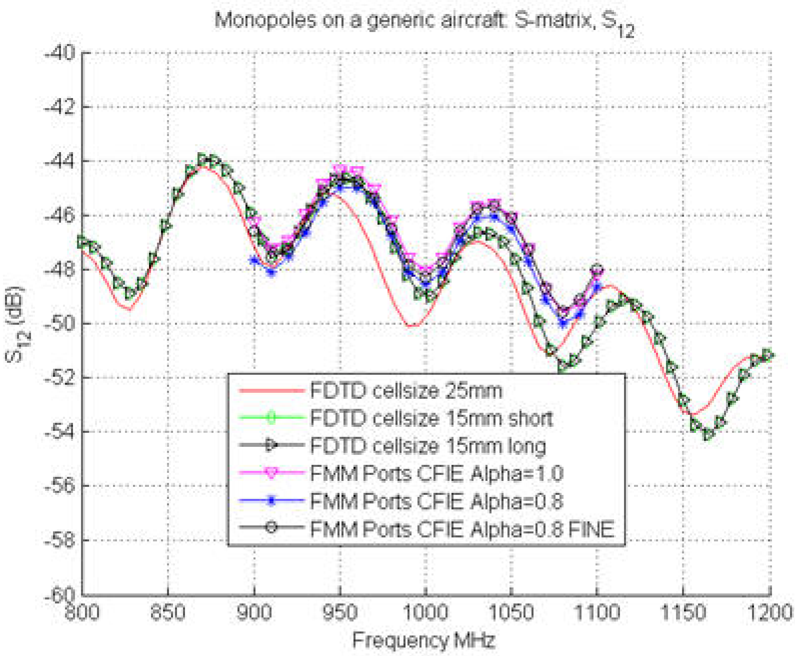


***Figure 10: $S_{12}$ computed using Efield FDTD***

## Conclusions

Some conclusions:

- Efield MLFMM is solving the problem well
- MLFMM with pre-conditioner and CFIE gives fast convergence
- Port excitations with closed surfaces and CFIE=0.8 gives fast convergence and sufficient accuracy
- Efield FDTD compute the scattering parameters for the whole frequency range in a single simulation

Very rapid convergence with the MLFMM can be achieved by using the Efield pre-conditioner in combination with CFIE. Using CFIE has the restriction that the model must consist of closed surfaces (required by the MFIE formulation). Usually that is not a problem. Point sources on wires and edge sources are only available in EFIE.

 

The alternative is using waveguide port excitation which can be combined with the CFIE (MFIE) method. Most practical antennas considered for installation include coaxial connectors or other kind of waveguides/transmission lines. The excitation can therefore easily be modelled by a waveguide port.

FDTD should be considered as a complement/alternative to MLFMM. A single FDTD-simulation gives the frequency response in a wide frequency range and therefore an effective method for calculating coupling of broadband antennas. The simulation example using 25 mm cellsize with the resolution of 3 cells/monopole still calculates a reasonable value of the coupling parameter. Using a finer grid (15 mm cellsize) with the resolution of 5 cells/monopole calculates a good value of the coupling comparable with MLFMM.

The Efield FDTD-FEM hybrid method is an alternative to pure FDTD with the potential to save computer resources for the user. Efield FDTD-FEM allows a coarse FDTD grid in combination with one or more domains with fine FEM grid for resolving the antenna elements as the monopoles.

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