electromagnetic modeling of composite metallic and dielectric structures

Stochastic Trees

Introduction

RCS of trees is of interest in geosciences, propagation analysis in the vicinity of forests, radar applications etc. Full-wave EM analysis of such complex structure poses a challenge due to the geometrical complexity and the random nature.

Decades ago, **WIPL-D Pro** was able to simulate wire models of stochastic trees. Wires of different radii with distributed loadings were used as modelling elements. Such an approach allows significant reduction of the number of unknown coefficients for the current approximation compared to the numerical analysis of the model made of dielectric. However, the drawback is limitation in the frequency range for which such an equivalence stays valid (up to approximately 100 MHz, for real-size trees).

This application note presents **an advanced meshing algorithm** for stochastic tree models and **GPU accelerated solver**. The tree models are completely automated closed surface assemblies. The mesh made of quadrilateral elements **reduces the total number of unknowns** approximately two times, compared to triangular mesh. The WIPL-D MoM is inherently capable to solve electrically large structures in reasonable time owing to **higher order basis functions (HOBFs)** instead of low-order basis functions. The quality factor of mesh elements is maximized in order to minimize the total number of unknowns and the total analysis time.

Generating Stochastic Trees

The algorithm for generating trees starts from the model where tree branches are represented as truncated cones. The tree generation is stochastic (the size and the orientation in space). An example of an assembled tree is shown in Fig. 1. The relative permittivity of wood is at the order of ε_r = 10.

Fig. 1. An example of a stochastically generated tree model

The tree model has been imported into **WIPL-D Pro CAD** with wires been replaced with dielectric rods. This overcomes the fundamental limitation in frequency range for the wire models.

An example of wires to solids conversion of a branching region is shown in Fig. 2.

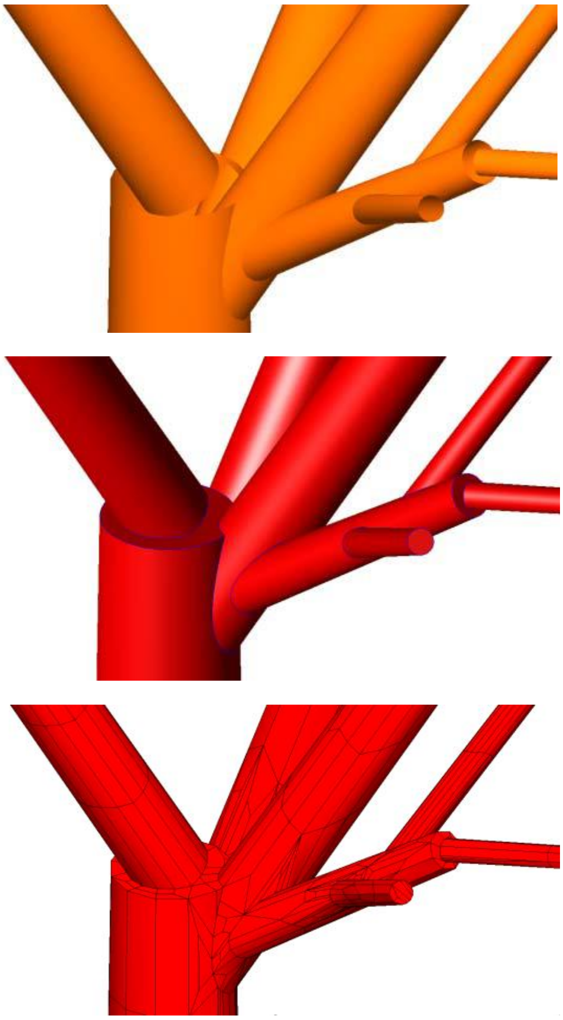

Fig. 2. Detail of tree-branching

The final step in the modeling is meshing, with the automatic in-house quad mesher. The WIPL-D Pro CAD yields simulation ready EM projects with:

- small mesh elements over tiny or curved model parts,
- large mesh elements (up to 2× 2 wavelengths) over flat or smooth parts,
- elongated elements over parts which are flat or smooth along one dimension, and curved along the other, and
- large shape quality factor for all mesh elements.

The final mesh of the tree branching is also shown in Fig. 2 as the last image.

The WIPL-D Pro CAD meshing algorithm enables **automatic de-featuring**. Branches which radius is larger or comparable with wavelength are meshed with full number of segments per circumference, while branches with very small radius are meshed with lower number of segments per circumference. Transition from 16 segments per circumference (thick branch) to 4 segments (thin branches) is illustrated in Fig. 3.

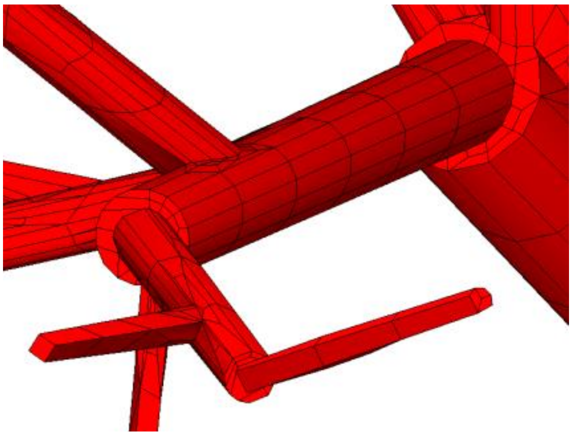

Fig. 3. Comparison of mesh of thick and thin branches

Results and Simulations

The **monostatic RCS** for tree resting on infinite PEC plane at 0.2, 0.5 and 1.5 GHz has been simulated on computational platform Intel® Xeon® CPU E5-2650 v4 @ 2.20 GHz (2 processors) with 256 GB RAM and four inexpensive GPU cards NVIDIA GeForce GTX 1080 Ti. Matrix fill-in was performed on CPU with matrix inversion done on GPU.

Number of plates, total number of unknowns and simulation times for all simulated models are shown in Table 1. The strong vertical component of RCS (Fig. 5) is the **consequence of the infinite PEC plane** underneath the tree.

Table 1. Simulation details.

Frequency [GHz]	Number of plates	Number of unknowns	Simulation time [sec]
0.2	3,221	41,223	426
0.5	3,749	119,453	1,521
1.5	6,056	421,484	29,187

Fig. 4. Wire model and corresponding dielectric model

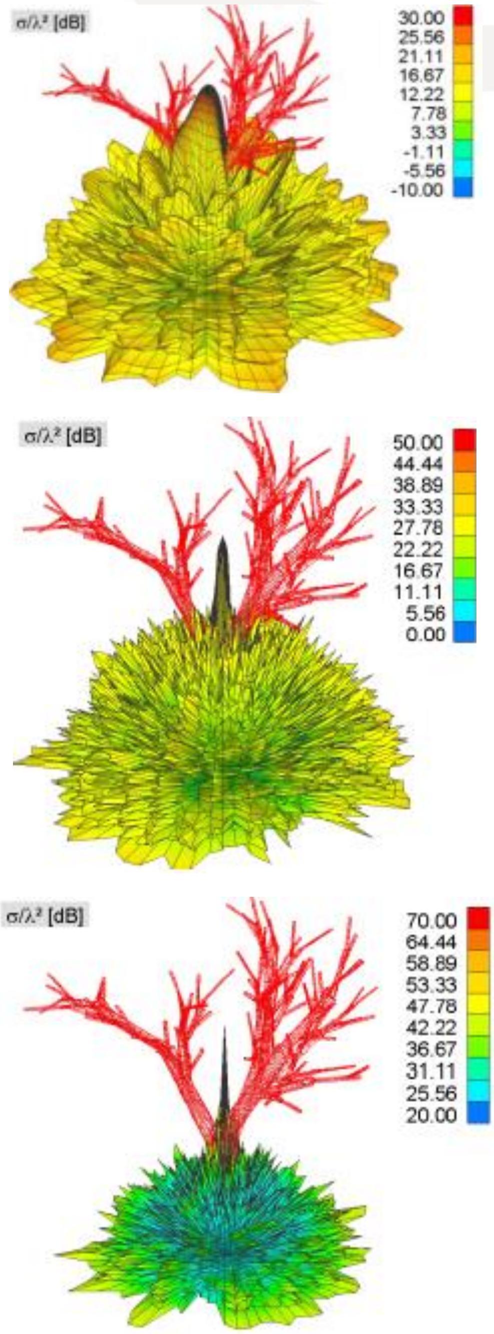

Fig. 5. Monostatic RCS at 0.2,0.5 and 1.5 GHz

Conclusion

The application note presented the results of utilization of an algorithm used to generate stochastic model of a tree as solid dielectric model. The simulation at 3 frequencies shows the MoM scaling, with simulations carried out using WIPL-D GPU solver at inexpensive GPU based workstation.

References

[1] Branko Lj. Mrdakovic; Dragan I. Olcan; Branko M. Kolundzija: “Full-wave modeling of stochastic trees for radar cross section calculation”, EUCAP 2015, Lisbon, Portugal