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The Research of Typical Target RCS Calculation and Comparative Analysis Based on FASTEM and FEKO

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Abstract: *In recent years, the world's enterprises have formed a head of commercial software, these commercial electromagnetic components are mainly concentrated in European and American countries, which can be divided into two categories, the first category is for radar target electromagnetic scattering modeling software, the second category is the general electromagnetic modeling software. In usual, these commercial software possess a wide range of service areas, spanning electromagnetic compatibility, antenna design, electromagnetic broadcasting, etc. But there is a significant gap between military softe in complex target and enviorment scattering modeling ability. In this paper, FASTEM, FEKO, CST were compared by calculating electromagnetic sacttering of typical targets, and the relevant testing components were carried out to illustrate the validity of FASTEM. The analytical efficiency comparision results of FASTEM, FEKO and CST were analyzed, and a reasonable set of comparative analysis content was given at last.*

Keywords: *Radar cross section (RCS), Analytical efficiency, Parallel computing, Electromagnetic simulation*

1. Introduction

Table 1: Common target feature calculation methods

Calculation method	Advantages and application range	limitations	Use advice
MoM	It is applicable to the frequency domain problems described by any unknown field quantity, and does not require dealing with incident, reflected shadow boundary, so the calculation accuracy is in the high level	Large size structure requires large enough computer memory and long enough computing time, so special fast method is needed	It can be applied to the target where the electrical size is small and medium distribution is simple
MLFMA	As a fast optimization method of MoM, the simulation speed is greatly increased	The method of the same moment requires higher memory of the computer	It can be applied to the target where the electrical size is small and medium distribution is simple
FDTD	Directly solve maxwell's equations, the calculation method is independent of the complexity of the target, suitable for parallel calculation, calculation accuracy is the highest	The computer memory requirement is strict, and the operation speed is only related to size, not complexity, and it takes a long time	It can be applied to the target with small electrical size and the target with complex medium distribution
PO, PTD, SBR	It is suitable for the calculation of wave length which is smaller than the target size, high calculation efficiency, low memory requirements, suitable for parallel computing	Because the high frequency method ignores the electrical interaction between different structures, the calculation accuracy is slightly lower, and it can not deal with special structures such as cavities, so the coating requirement of medium is simple	It can be applied to large and oversized targets

Since the 1980s, foreign electromagnetic scattering modeling software led by XPatch has achieved great success in the modeling of stealth targets such as F-117, B2, F22 and F35 through the cultivation of DARPA in the United States and DEMACO's industrial operation. After entering the 21st century, electromagnetic scattering modeling of foreign targets develops in two aspects. On the one hand, modeling technology spreads from the United States to other countries, and modeling application spreads from stealth design of air targets to modeling analysis of surface and sea targets (and environment). On the other hand, targeted modeling technology is developed for complex components and materials, and multi-algorithm coupling is attempted to solve the real complex electrical large size target modeling problem. After years of research and development, relevant enterprises have formed a large number of commercial software.

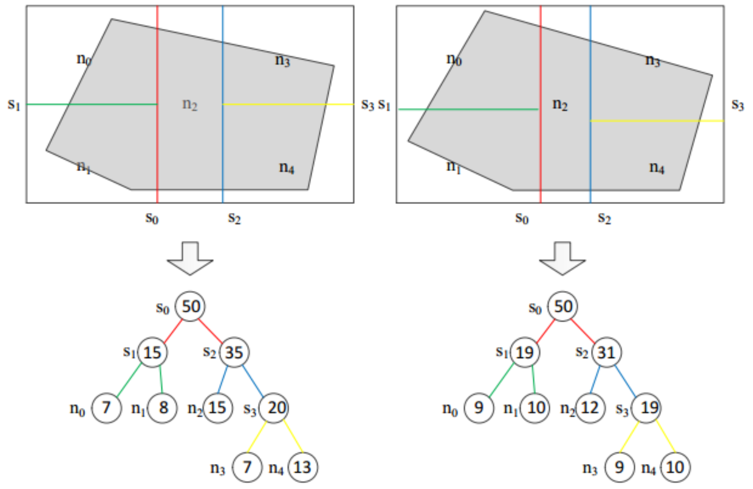
These commercial software usually have good visualization interface, friendly operation interface and a wide range of service fields (including electromagnetic compatibility, antenna design, electromagnetic propagation, etc.), but there is a significant gap between them and professional software in the modeling ability of complex targets and environmental scattering. Common target characteristics calculation method for such as shown in table 1 of the wave equation is deduced from Maxwell's equation only in the research problems of geometric meet only 11 kinds of coordinate system can be solved, the high-frequency asymptotic solution is one kind of approximate solution, only when the research problem of high frequency can give satisfactory accuracy, the higher the frequency, the higher the precision.

2. Parallel algorithm

FASTEM, FEKO, and CST all use the CPU parallel acceleration function to improve computing efficiency. Parallel hardware system is the foundation and the physical carrier of parallel computing. Parallel software environment provides necessary parallel programming support. The parallel research and design of the algorithm is the core of the whole process. There are two strategies for implementing cluster-based parallel bounce-ray methods. As shown in the figure below, the first is the Angle allocation strategy, which assigns the computation tasks corresponding to the continuous Angle to each processor core. The other is the reference surface division strategy, at each incident angle, the virtual aperture is divided into multiple sub-apertures according to the number of processor cores participating in the calculation.

Angle allocation strategy based on the fact that adjacent Angle calculation load is almost the same, in the Angle of the need to calculate the number is not just a multiple number of processor cores, in order to avoid some processing nuclear capacity calculation and other processor idle, to divide the remaining after the Angle of the still need to adopt the strategy of aperture plane division. An intuitive implementation of the strategy is to evenly divide the entire reference plane into subapertures of the same area containing the same number of ray tubes. The apertures are first divided into two sub-apertures along the longer side of the entire apertures by using a dividing line perpendicular to the coordinate axes.

If the measurement of each ray tube is assumed to be the same, the segmentation position should be S=([N/2]/N)×L, where N is the number of processor cores participating in the calculation of this aperture plane, and L is the length of the edge of the aperture plane being segmented. To balance the load, the left subaperture will be calculated with [N/2] processors, and the right subaperture will be allocated with [N/2] processors. The above two subapertures will continue to be divided recursively, and the information of the apertures and the number of processor cores participating in the calculation will be updated continuously during the division process. When the number of processors calculating the subapertures N=1, the subapertures will be terminated. The following figure shows the virtual aperture partitioning process, which also builds a binary tree. When the entire partition is complete, each of the resulting subapertures is a leaf node of the binary tree, which is assigned to each processor for computation (As shown in Figure.1).



(a) (b)

Figure 1: Virtual space surface recursive partition strategy

In the bounce ray method, each ray emitted from the virtual aperture is recursively tracked, and then the electromagnetic calculations are performed on the valid tubes, so that only those that intersect the target are involved in the whole calculation process, and those that do not intersect the target are discarded at the beginning. It can be said that the amount of calculation of the bouncing ray tube is determined by the number of ray tubes intersecting the target, and the number of rays intersecting the target is proportional to the projection area of the target. However, the projected area of the target does not cover the entire virtual aperture, and the projection of the target is not evenly distributed to each sub-aperture. As shown in the figure, the projected area of the target contained in each sub-aperture generated by uniform division is greatly different. As analyzed above, this will lead to unbalanced load allocated to each processing node of the cluster. To solve this problem, the apertures partition that dynamically adjusts the current Angle using the calculation time of each subapertures of the previous Angle represents the internal nodes, due to the high projection similarity of the targets on the virtual apertures between adjacent angles and the nearly identical computation time of the corresponding ray tubes. At each incident Angle, the calculation time of each sub-aperture corresponding to the blade node is recorded.

Firstly, the calculated time of the sub-aperture corresponding to the inner node is calculated by using the recorded calculation time of the blade node at the previous incident Angle. The calculation time of internal nodes can be calculated by traversing the tree from leaf node to root node. The time of each internal node is the sum of the calculation time of its left and right child nodes. Tl and TR are used to represent the calculation time of its left and right child nodes respectively. Then, the average computation time for each row or row of tubes at each node of the tree except the root node is calculated. Finally, the partition position of each internal node is recursively adjusted, starting with the root node.

3. Overview of FASTEM and FEKO

FEKO is a comprehensive computational electromagnetics (CEM) software which is widely used in the communications, automotive, aerospace and defense industries. FEKO offers multiple frequency and time domain electromagnetic solvers under a single license. Together, these methods enable efficient analysis of a wide range of EM problems, including antennas, microstrip circuits, rf components, biomedical systems, antenna layout in large structures, scattering calculations, and electromagnetic compatibility (EMC) studies. FEKO offers a range of different solvers, allowing the user to choose the best solution for the problem or to cross-verify with multiple solvers. Solvers include full-wave solvers in time domain and frequency domain and asymptotic solvers, in which the full-wave solvers in frequency domain include MoM, FDTD, FEM and MLFMM, and the asymptotic solvers include PO, LE-PO, RL-Go and UTD. FEKO solvers are fully parallelized and optimized to utilize multi-CPU distributed memory resources, support GPU-based solver acceleration, fully automate Lua script processing, enable modeling, configuration, and post-processing, and support macro recording.

FASTEM is a simulation software which specially designed for target-oriented electromagnetic characteristics calculation and diagnostic analysis, it can calculate the electromagnetic scattering characteristics of complex targets and obtain the scattering characteristics data of complex targets in full band, full space and full polarization conditions. Its electromagnetic computing engine is the high frequency hybrid (PO, PTD) method based on multi-scale adaptive ray tracing. Based on SBR, multi-scale adaptive ray tracing is developed, especially for electric large target calculation. It adopts high-order physical optics and physical diffraction, which has higher accuracy and efficiency. FASTEM is mainly used for military complex target scattering calculation, TV target calculation, supporting the calculation of metal and complex materials.

4. Comparative analysis of analytical efficiency

The effectiveness of FASTEM is demonstrated by comparing the electromagnetic scattering results of typical targets calculated by FASTEM and FEKO. Therefore, cases containing measured data or analytical solutions are prefered in the case design stage. In order to compare the analytical efficiency of FASTEM and FEKO, calculation accuracy, calculation time and memory usage are selected as the comparative test elements. Under the condition of using the bounce ray method and the same computer configuration, the far field single station RCS calculation case is designed, including the typical metal sphere and standard body (SLICY body) calculation case, and the comparative analysis of analytical efficiency is also carried out in this section.

4.1. Metal ball calculation case

In the scattering problem, there is a special class of low scattering targets whose RCS is very small, so the scattering field data must not be drowned by numerical noise. The effectiveness of FASTEM is demonstrated by comparing the simulation results of electromagnetic scattering of typical target metal spheres with the analytical results. The analytical efficiency of FASTEM and FEKO is analyzed by comparing the simulation results. Model parameters and calculation conditions are shown in Table 2.

Table 2: Model parameters and calculation condition

The model size	**The grid number**	**The simulation of frequency**	**RCS type**
Diameter of 1 meter	3968	1GHz	Double stand RCS

(1) Accuracy of calculation

Figure 2 shows the comparison of RCS results of various software and analytical solutions under the incident of 1GHz plane wave, when the incident Angle of metal sphere is 90°, azimuth Angle is 90°, scattering Angle is 90°, azimuth Angle is 0~180°. As can be seen from Figure 2, in the case of calculating metal sphere RCS, there are some errors in the simulation results and analytical solutions of FASTEM and FEKO, while there is little difference between the simulation results of FASTEM and FEKO.

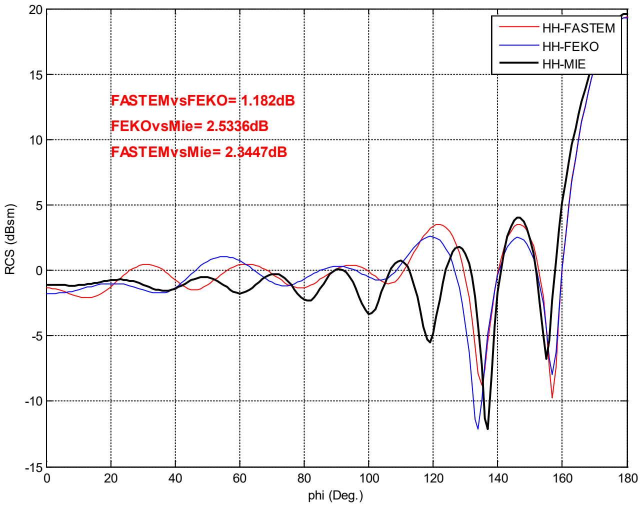


Figure 2: Comparison of metal sphere RCS results

(2) Calculation time and memory usage

The efficiency of FASTEM and FEKO's calculation of this case is shown in Table 3. As can be seen from the above table, FEKO's computational efficiency is relatively low when both parallel acceleration and SBR solution are used, and there is little difference in the computational memory usage between

FASTEM and FEKO.

Table 3: Efficiency comparison of FASTEM /FEKO metal sphere calculation cases

Num	Solver	Case	Software	Parallel auditing	Calculate memory footprint	Computation time
1	SBR(RL-GO)	Metal ball calculation case	FASTEM	7	530M	0.116s
			FEKO	7	195M	0.386s

4.2. SLICY Calculation case

SLICY model can be used to verify the standard model of electromagnetic software modeling capabilities, as a target scattering mechanism test datum, it contains the basic scatterer types, for example, planar, cylindrical and dihedral Angle, Angle, crown and cavity, as shown in figure 4, among them, the left side of the vertical cylinder without cover, forming a cavity structure, on the right side of the cylinder cover, form a closed entity. Based on the real machining model, the actual measurement and verification are carried out.

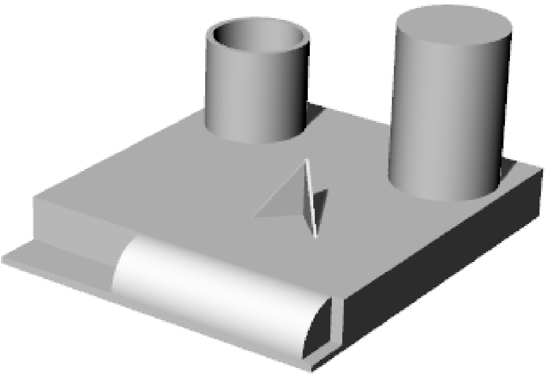


Figure 3: SLICY geometric model

The model parameters and calculation conditions are shown in Table 4.

Table 4: Model parameters and calculation condition

The model size	**The grid number**	**The simulation of frequency**	**RCS type**
Diameter of 0.7, 0.79, 0.48 meter	1218	9GHz	Single stand RCS

(1) Accuracy of calculation

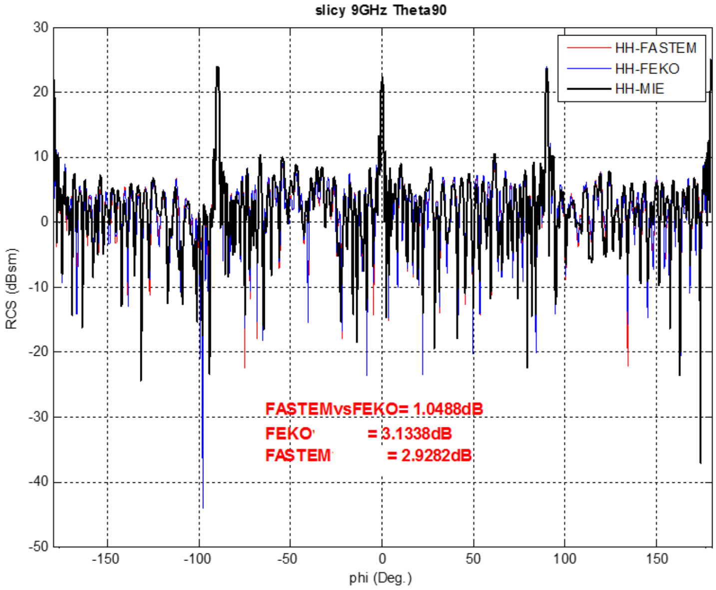


Figure 4: Comparison between FASTEM and FEKO calculation results and measured results

Figure 4 shows the comparison of the single-station RCS results of each software and measured SLICY body when the incident Angle of SLICY body is 90° elevation Angle and 180~180° azimuth Angle under 9GHz plane wave incidence. The root mean square error of FASTEM calculation result and measured result is 2.93dB, while the result is 3.13db for FEKO, which is bigger than FASTEM.

(2) Calculation time and memory usage

The efficiency of FASTEM and FEKO's calculation of this case is shown in Table 5. As can be seen from Table 5, in the SLICY body calculation case, when both software use parallel acceleration and SBR solution, FEKO's computational efficiency is relatively low, and there is little difference between FASTEM and FEKO's computational memory usage.

Table 5: Efficiency comparison of FASTEM /FEKO metal sphere calculation cases

Num	Solver	Case	Software	Parallel auditing	Calculate memory footprint	Computation time
1	SBR(RL-GO)	SLICY calculation cases	FASTEM	7	194M	5.9s
			FEKO	7	212M	89s

5. Conclusions

This paper compared the functions between FASTEM and FEKO in the high-frequency approximation algorithm module, and designed the calculation cases of typical metal spheres, standard bodies and typical targets, and analyzed the calculation results and efficiency of each software. By testing different types of targets, at different frequencies, and at different polarimetry, FASTEM's results are less different from FEKO's in terms of computational accuracy. Compared with the analytical solution or the measured results, the agreement degree of FASTEM calculation results is better than that of FEKO.

In terms of computational efficiency, the calculation time of FASTEM is shorter than that of FEKO under the same calculation conditions. The amount of memory used in the calculation depends on the context, but in most cases the amount used by FASTEM calculations is larger. In general, FASTEM is comparable to FEKO in high frequency calculation accuracy, but its computational efficiency is superior to FEKO. In general, the effectiveness of FASTEM is proved in this paper.

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