1. Abstract

Solutions of the large-scale electromagnetic scattering problems are typically obtained with Rao-Wilton-Glisson (RWG) Method of Moments (MoM) accelerated with Multi-Level-Fast-Multipole-Algorithm (MLFMA). Due to the low-order RWG MoM discretization and iterative nature of MLFMA such solutions present various challenges when realistic large-scale targets are considered. The most salient of these challenges are: 1) inefficient error control of solution beyond 2-3 digits, 2) poor conditioning of the matrix resulting from LU compression = 75% Z compression = 81% for compression Full blocks computed similarly Full block throughput is optimized to maximize GPU utilization even further Out-of-Core operation Extremely complex, real-world geometry with >1.5M RWG unknowns solved in 1.1 days

2. Rokhlin’s Dogma

MLFMA/ACA

- Methods must be fast
- Errors must be controlled
- Methods must be high order
- Discretization must be point-based
- Formulae must be well conditioned

MLFMA/ACA Accelerated LCN Discretization is Desirable

3. High-Order LCN Discretization Modelled with NURBS

Please refer to Shaefiour et. al. poster, same session:

High-Order Locally Corrected Nyström Solution of the Combined Field Integral Equation Based on Geometric Modelling with NURBS

4. Fast Matrix Fill

- Fast direct solver based on IERUS’s V-Lox CEM software
- Adaptive Cross Approximation (ACA) for matrix fill and LU decomposition
- Multi-threaded and Multi-GPU accelerated with Out-of-Core option
- Mesh clustering required to achieve matrix block structure for fast compressed block-LU decomposition
- Clustering simplified using binary tree method

5. Fast Direct Solve

- LU decomposition compressed with modified ACA based on compressed Z
- Standard LU formulae with compressed block representations substituted as appropriate

6. GPU Acceleration

- GPUs provide massive parallelism for significant application speed-up
- LU decomposition is accelerated via multiple GPU threads
- LU blocks are assigned to GPU threads
- To maximize throughput, full block is generated on GPU
- Block fed into ACA algorithm for compression
- Full blocks computed similarly
- Block throughput is optimized to maximize GPU utilization even further
- Out-of-Core operation
- Extremely complex, real-world geometry with >1.5M RWG unknowns solved in 1.1 days

7. Study of Accuracy: Exact at 100GHz

- Geometry: Analytical Cube-to-Sphere Mapping
- Solution: Surface Current Density
- Mean Relative Error vs. Max Relative Error Current Produced by CFIE (ε=0.5)

8. Study of Efficiency: Torus at 100GHz

- Geometry: NURBS Torus Example (MFIE)
- Solution: Surface Current Density
- Reference Solution (LUD)

9. Study of Efficiency: Torus at 6.5GHz

- Mean Relative Error vs. Max Relative Error Current Produced by CFIE (ε=0.5)
- Reference Solution: Me-Series

10. Study of Efficiency: 82-Aircraft at 1.25GHz

- Mean Relative Error vs. Max Relative Error Current Produced by CFIE (ε=0.5)
- Reference Solution (GMRES)

Table 1: Orders, CPU vs. GPU Speedup

<table>
<thead>
<tr>
<th>Orders</th>
<th>CPU vs. GPU Speedup</th>
<th>Reference Solution (LUD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>~2.0 Times</td>
<td>Reference Solution (GMRES)</td>
</tr>
<tr>
<td>4</td>
<td>~1.5 Times</td>
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</tbody>
</table>

Table 2: Study of Accuracy: Torus at 100GHz

<table>
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<tr>
<th>Geometry</th>
<th>Solution</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Geometry: Torus Example (MFIE)</td>
<td>Solution: Surface Current Density</td>
<td>Reference Solution (LUD)</td>
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Table 3: Study of Efficiency: 82-Aircraft at 1.25GHz

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Figure 3: MLFMA/ACA Accelerated LCN Discretization is Desirable

Figure 4: GPU Acceleration

Figure 5: Fast Direct Solve

Figure 6: Fast Matrix Fill

Figure 7: Study of Accuracy: Exact at 100GHz

Figure 8: Study of Efficiency: Torus at 100GHz

Figure 9: Study of Efficiency: Torus at 6.5GHz

Figure 10: Study of Efficiency: 82-Aircraft at 1.25GHz