Executive Summary

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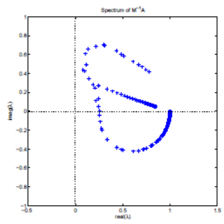
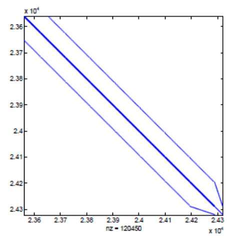
Solution of the vector wave equation using a Krylov solver with an algebraic multigrid approximated preconditioner

Problem area
Radar cross section prediction techniques are used to analyze the radar signature of military platforms when the radar signature cannot be determined experimentally. This may be the case when, for example, the platform is in the design, development or procurement phase; or when the platform belongs to a hostile party.

For jet powered fighter aircraft, the radar signature is dominated by the contribution of the jet engine air intake for a large range of forward observation angles. The intake can be regarded as a one-sided open large and deep forward facing cavity. Although the contribution of the outer mould shape of the platform can be efficiently and accurately computed using scattering models, these cannot be used to accurately compute the contribution of the jet engine air intake. The storage requirements of the existing solution algorithm for the jet engine air intake, are too stringent which prohibits the application to the relevant excitation frequency band.





Description of work
To deal with the storage requirements of the existing solution algorithm, alternative solution methods are analyzed and compared to the original formulation. More specifically, it is analyzed how to incorporate so called multigrid acceleration in the existing algorithm. To derive an optimal strategy to solve the current application, a model problem is used for testing purposes.

Results and conclusions
Based on the computational results with the model problem, it is estimated that the application of the algorithms developed in this report, will result in a speedup in both computing time and memory usage of two to three orders in magnitude.

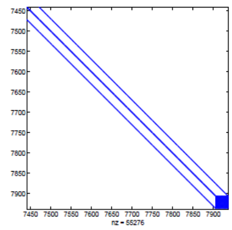
Applicability
The developed technology will be applied for the analysis and possible optimization of jet engine air intake geometries of current intermediate observable and future low observable fighter aircraft.

Mathematics

- Dimensionless vector wave equation

$$\nabla \times \nabla \times \mathbf{E} - k_0^2 \varepsilon_r \mathbf{E} = -jk_0 Z_0 \mathbf{J}.$$

- Sparsity pattern of the discretization matrix A



- Use shifted Laplace preconditioner[1)]
- Krylov solver with inner and outer loop
- Incorporate IDR[2)](s) and algebraic multigrid to obtain a more efficient solution method

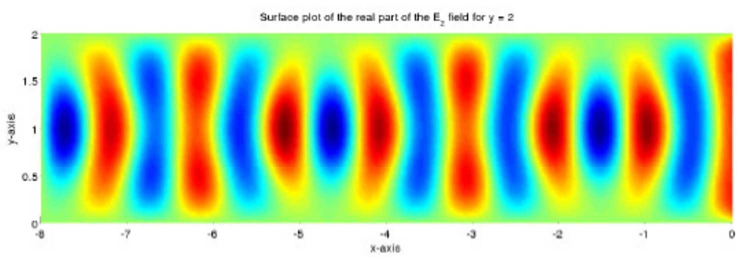
Mathematical conclusions:

- Do not use optimal real shift
- Do not use the block upper preconditioner
- Incorporate IDR(s) Krylov method
- Incorporate multigrid algorithm
- Use a preconditioner based on local absorbing boundary conditions

Expected gain in:

- number of matrix-vector products: decrease by a factor 1000
- memory: decrease by a factor 225

Example given: two dimensional Maxwell solver (in Matlab)
surface plot for two dimensional cavity with dimensions 8 x 2 wavelengths.



1) P.B. Hooghiemstra – *Full Wave Analysis of the Contribution to the Radar Cross Section of the Jet Engine Air intake of a Fighter Aircraft.* Report NLR-TR-2007-310, NLR, 2007
2) P. Sonneveld and M.B. van Gijzen – *IDR(s): A Family of Simple and Fast Algorithms for Solving Large Non-Symmetric Linear Systems.* 07(07), 2007