Application of Adaptive Cross Approach (ACA) to Industrial EM Problems

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- Fast Iterative Solution (FIS)
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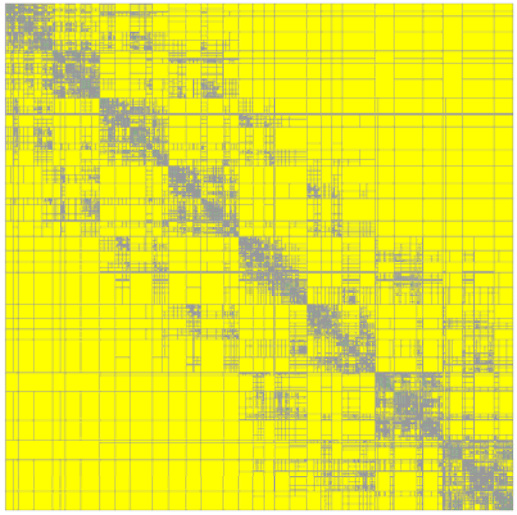
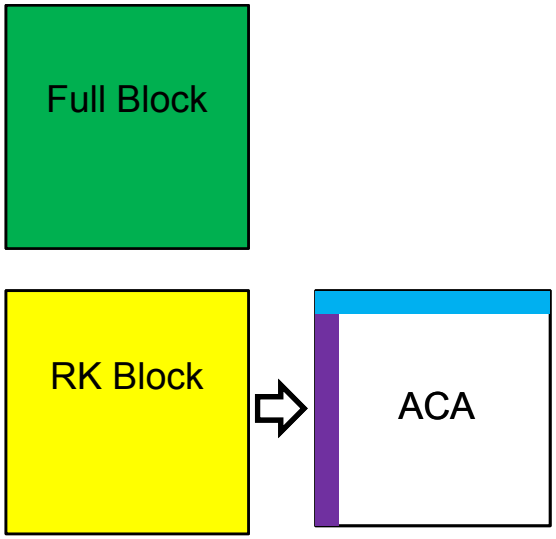
Introduction

- Method of Moments uses system of linear equations: Ax=b
- Direct solution of MoM matrix (matrix inversion, LU decomposition) with large number of unknowns is non - practical, since N^3 dependence of calculation time and N^2 dependence of required memory.
- One of the ways to avoid long calculations is usage of iterative solvers.
- The Adaptive Cross Approximation (ACA) is proposed as a method to accelerate the matrix-vector products in the iterative process.

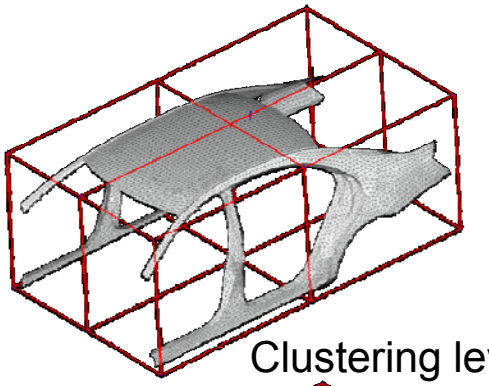
Fast Iterative Solution (FIS)

FIS – combination of following techniques: Matrix compression, iteration process with good preconditioning
Advantages – Less computational time and less computer resources

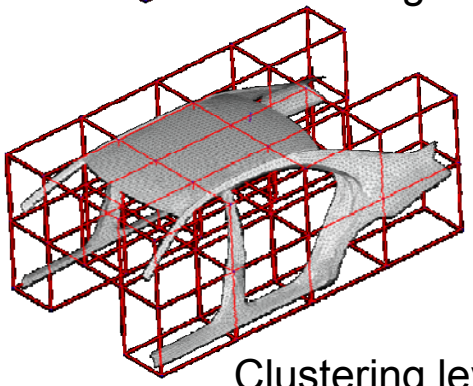




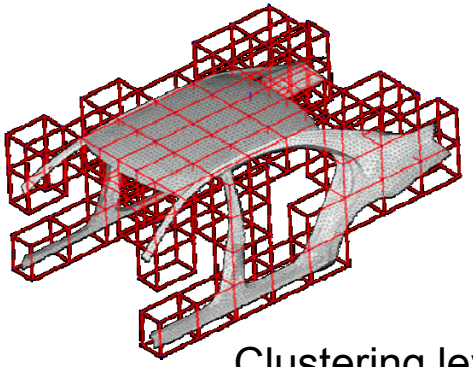
- Geometry decomposing recursively into boxes
- Near positioned boxes refer to matrix Full blocks
- Far positioned boxes refer to matrix RK blocks
- Hierarchical matrix is constructed using RK and Full blocks
- Full Block elements are calculated directly, while RK blocks are compressed using ACA algorithm
- Compressed matrix is solved iteratively



Clustering level 1



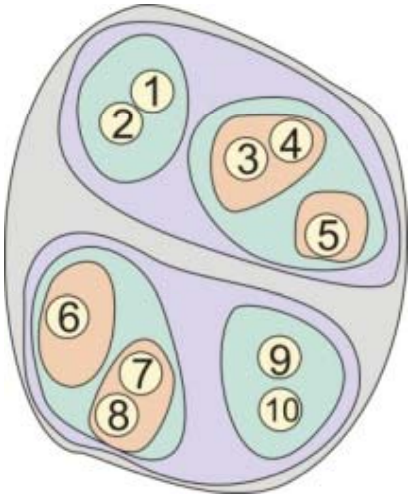
Clustering level 2



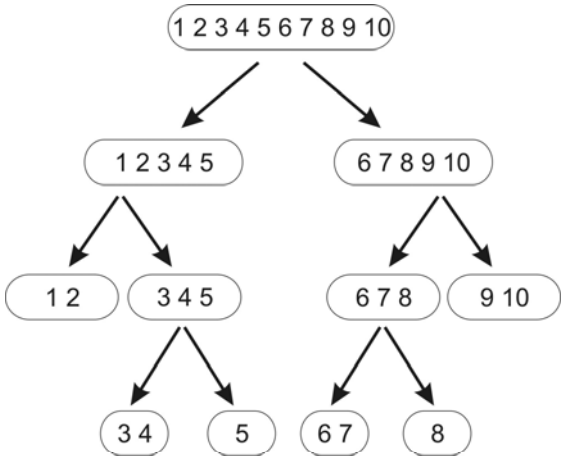
Clustering level 3

Theoretical background

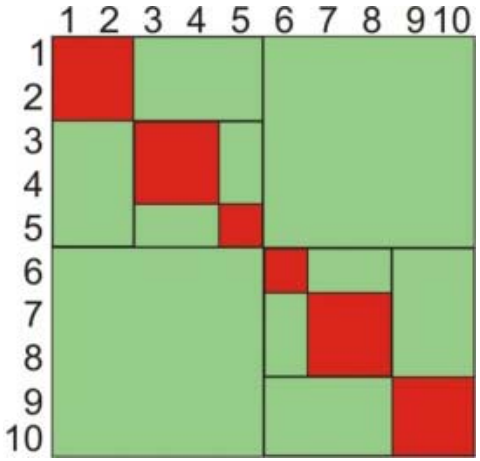
Matrix compression technique using ACA



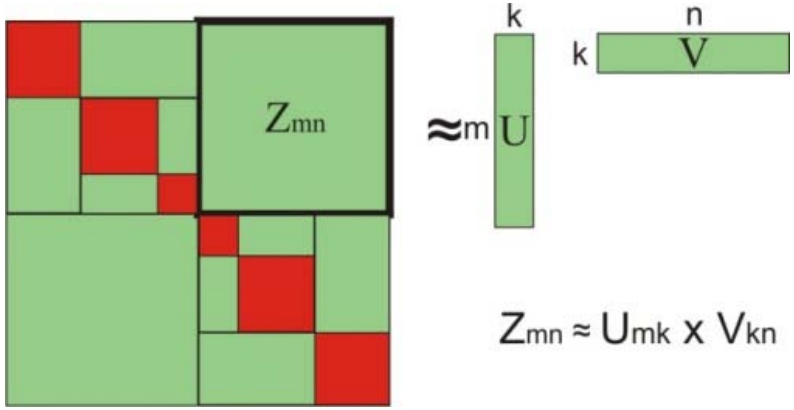
Geometry



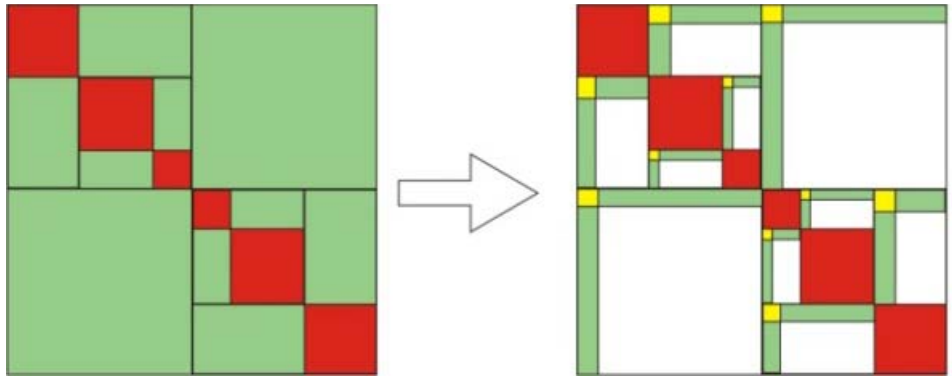
Cluster tree



Hierarchical Matrix

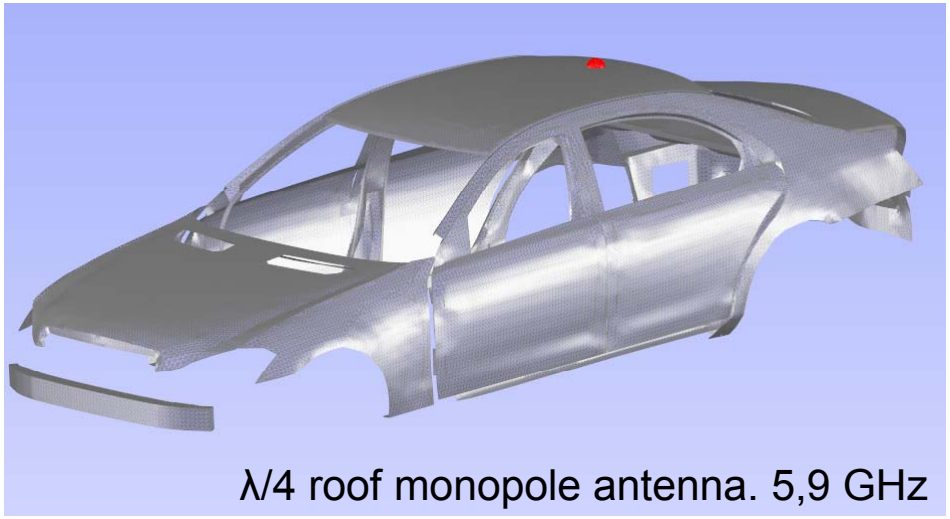


ACA decomposition of RK block

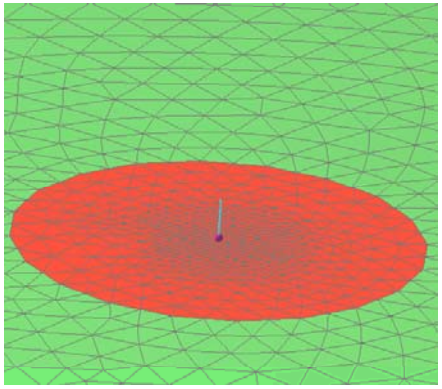


Matrix compression using ACA

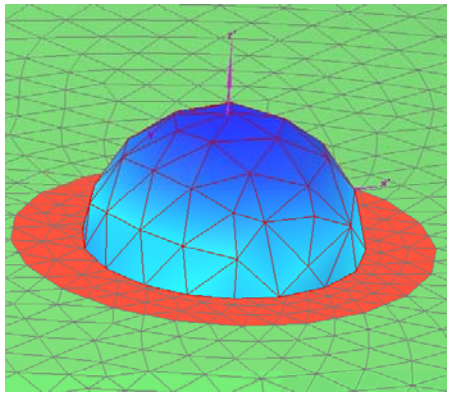
Radiating from car roof antenna



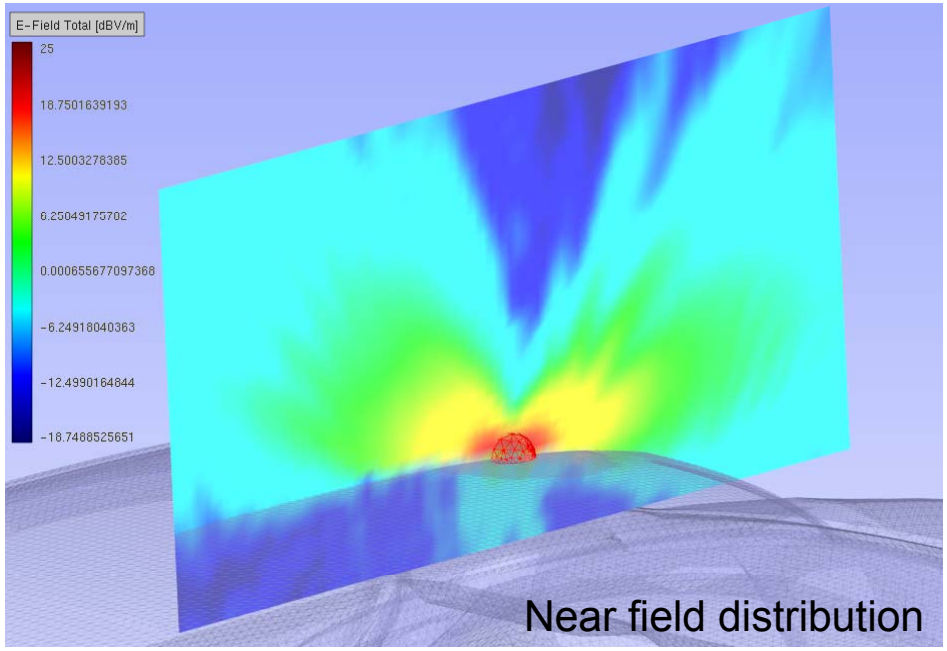
λ/4 roof monopole antenna. 5,9 GHz



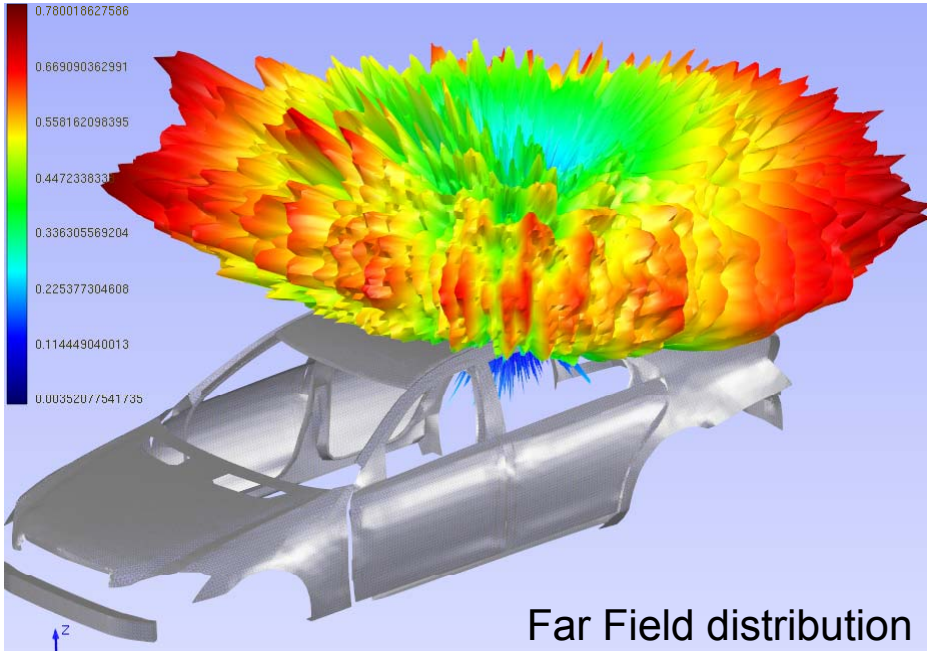
Monopole antenna



Equivalent NF source



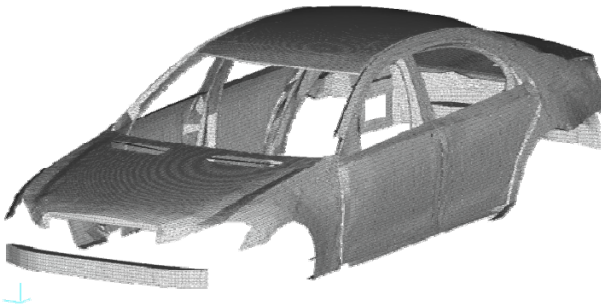
Near field distribution



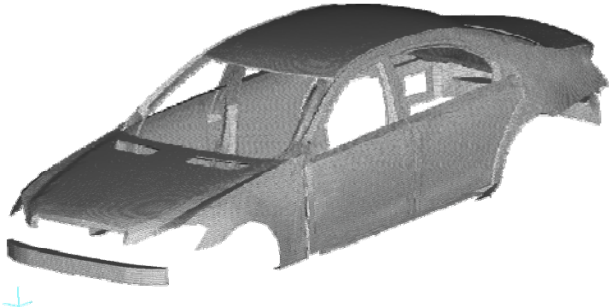
Far Field distribution

Radiating from car roof antenna

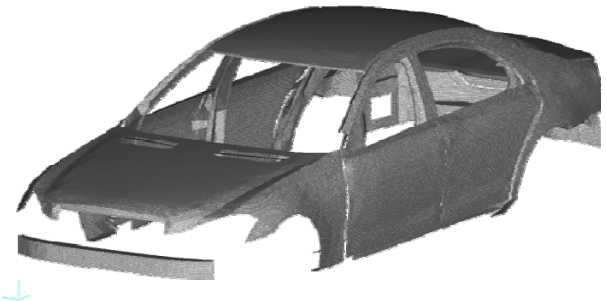
Car model with different triangulation sizes used in simulations



Model with 2cm triangles
Triangles – 66,520
Unknowns – 98,136
RAM– **146,954 MB**



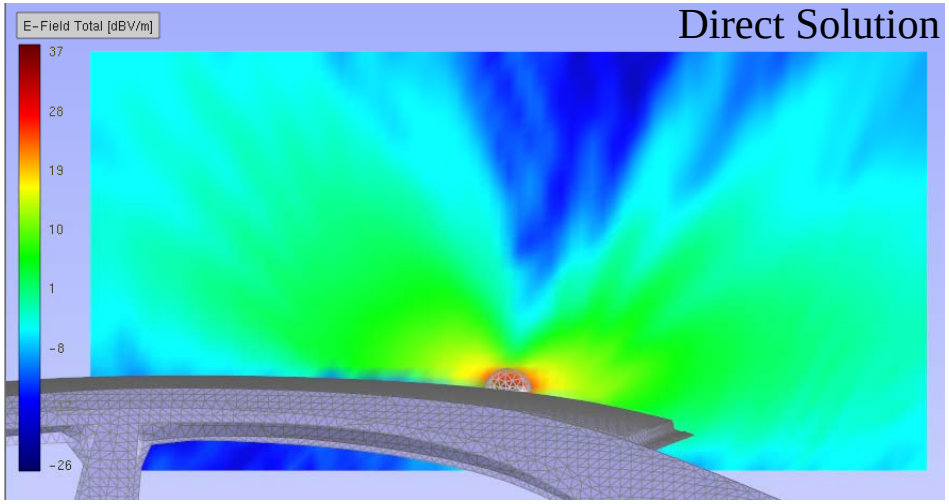
Model with 1.5cm triangles
Triangles – 111,164
Unknowns – 164,578
RAM – **413,301 MB**

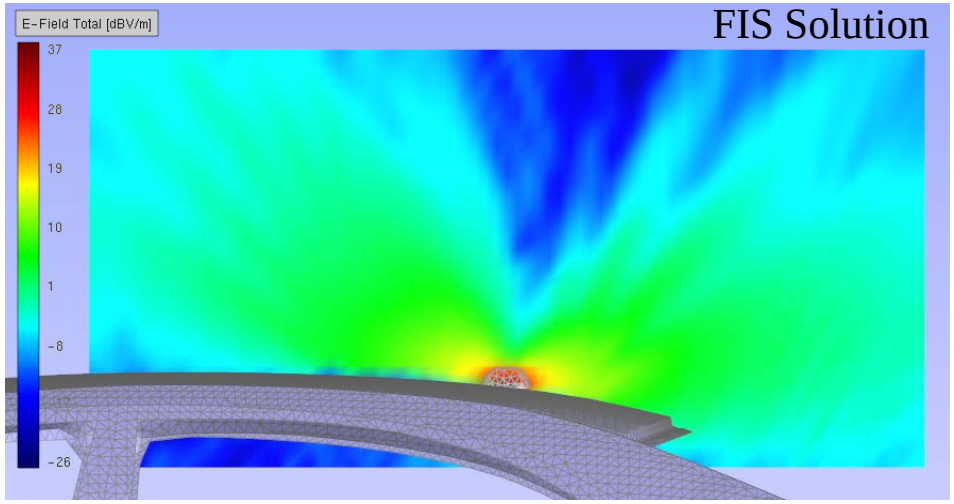


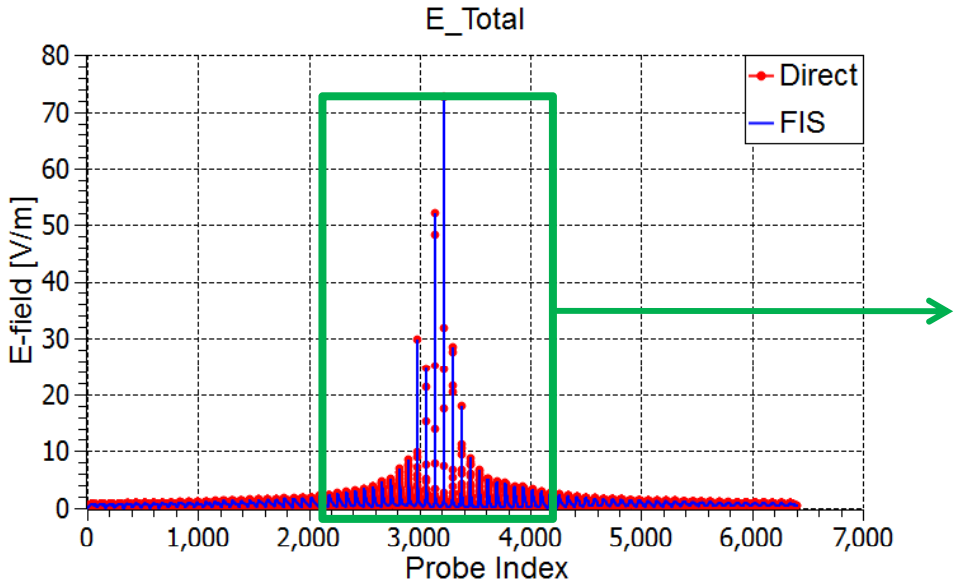
Model with 1cm triangles
Triangles – 266,080
Unknowns – 395,604
RAM– **2,388,045 MB**

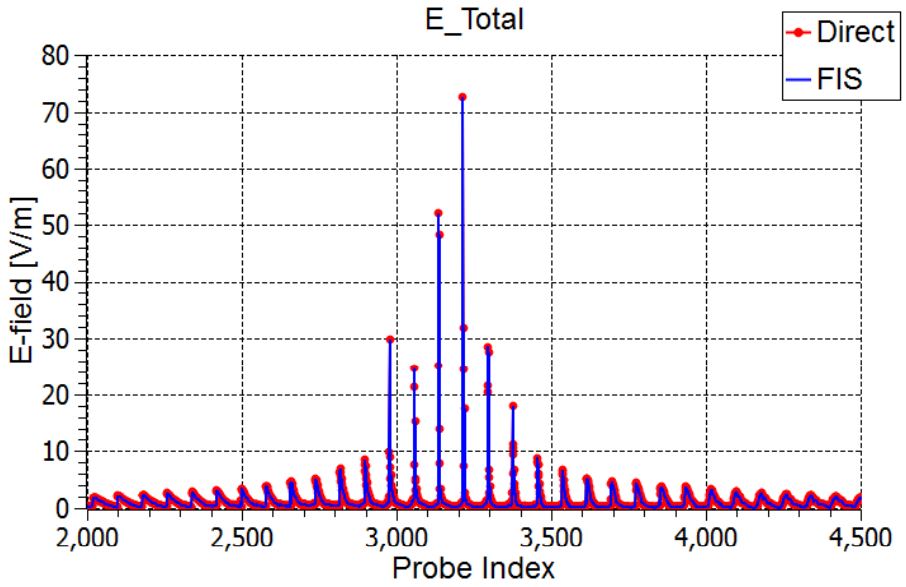
Wavelength at **5.9GHz** equals to **5.08cm**.

Radiating from car roof antenna



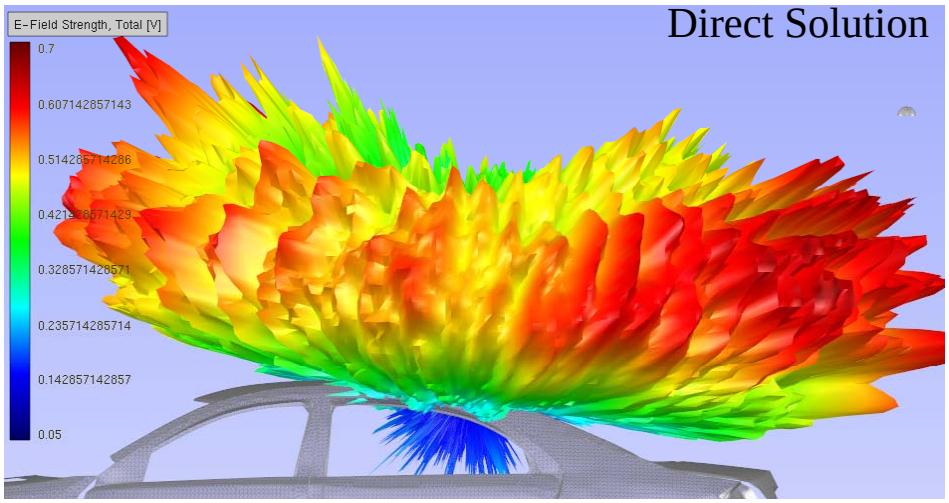


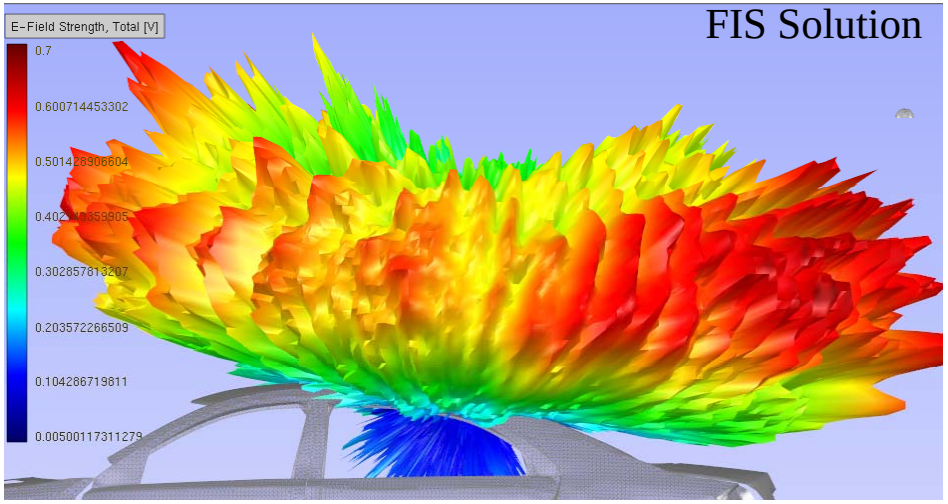


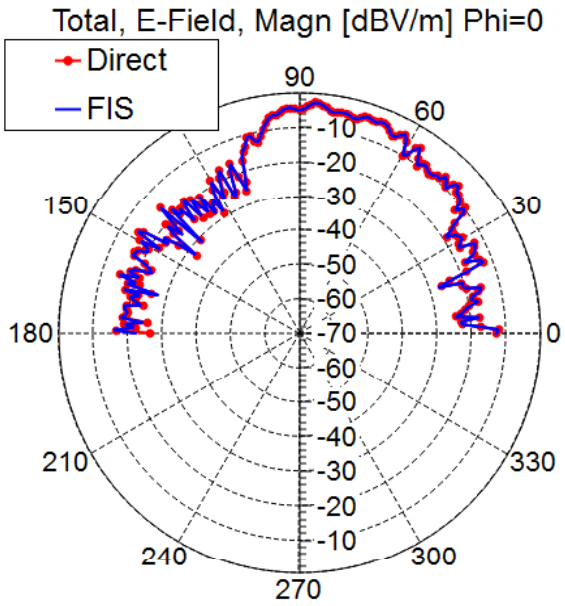


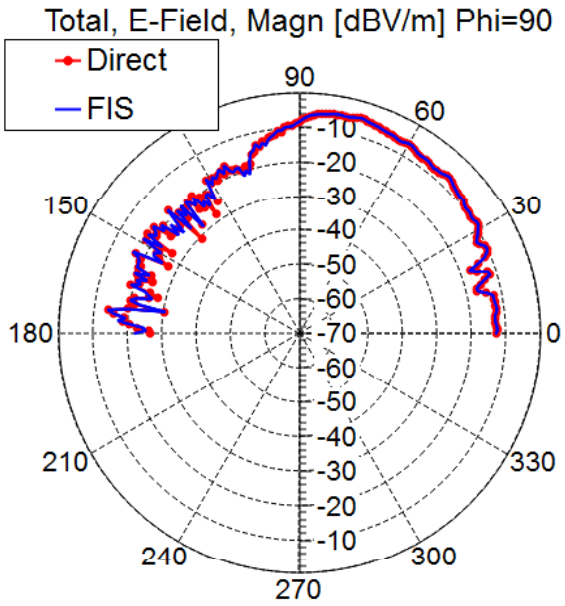
Model with 1.5cm triangulation

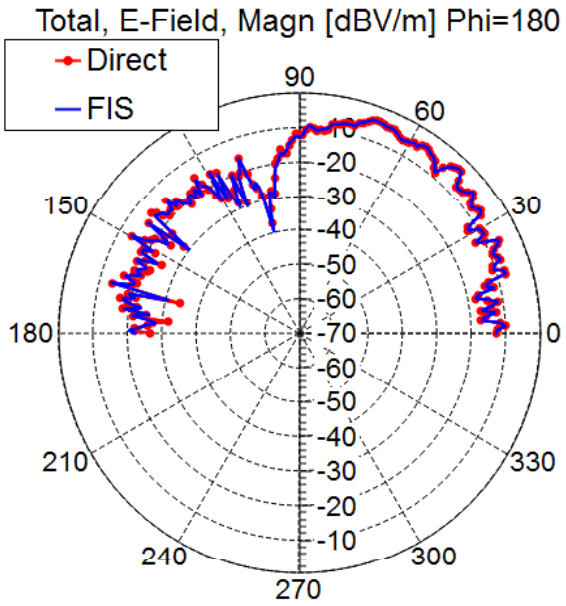
Radiating from car roof antenna







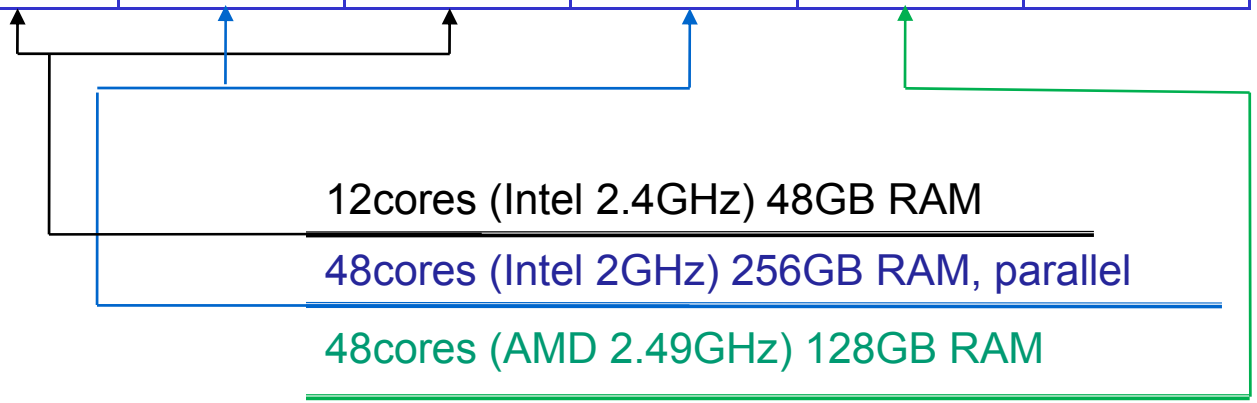




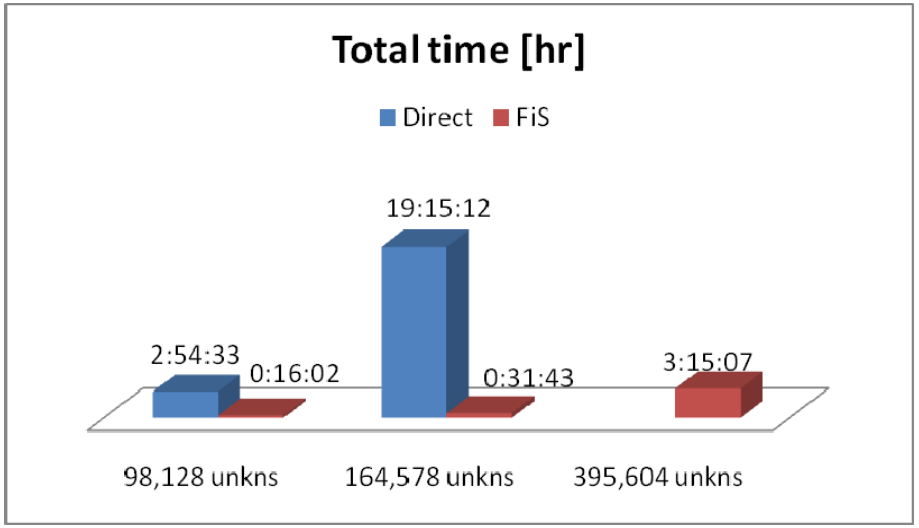
Model with 1.5cm triangulation

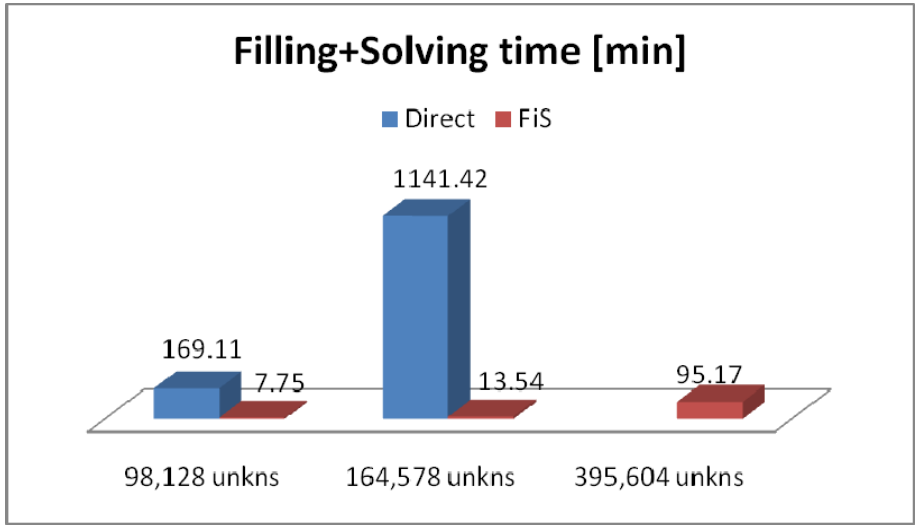
Radiating from car roof antenna

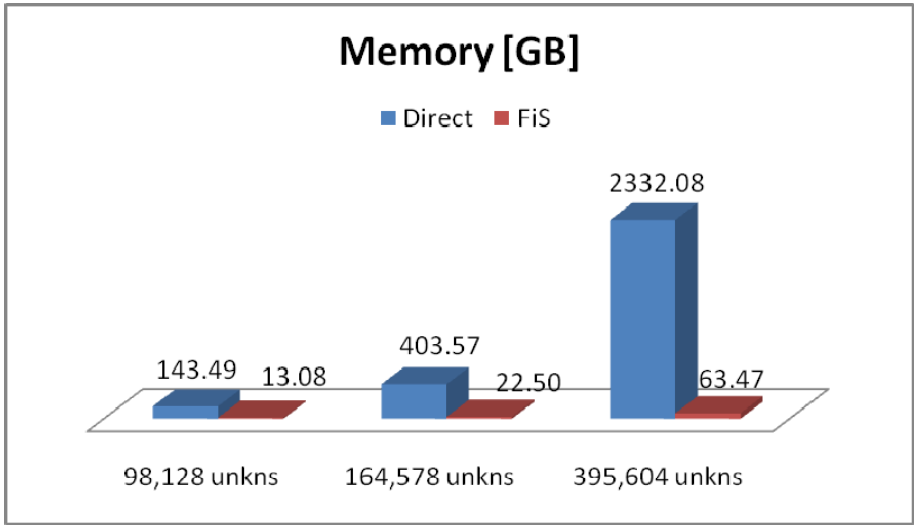
	N=98,136 (2cm)		N=164,578 (1.5cm)		N=395,604 (1cm)	
	FIS	Direct	FIS	Direct	FIS	Direct
Filling [sec]	428.65	1803.91	737.03	15456.18	4158.37	No data
Solving [sec]	36.16	8342.45	75.30	53028.75	1552.11	No data
Filling + Solving [min]	7.75	169.11	13.54	1141.42	95.17	No data
Total time	0:16:02	2:54:33	0:31:43	19:15:12	3:15:07	No data
Memory [GB]	13.08	143.49	22.50	403.57	63.47	2332.08



Radiating from car roof antenna

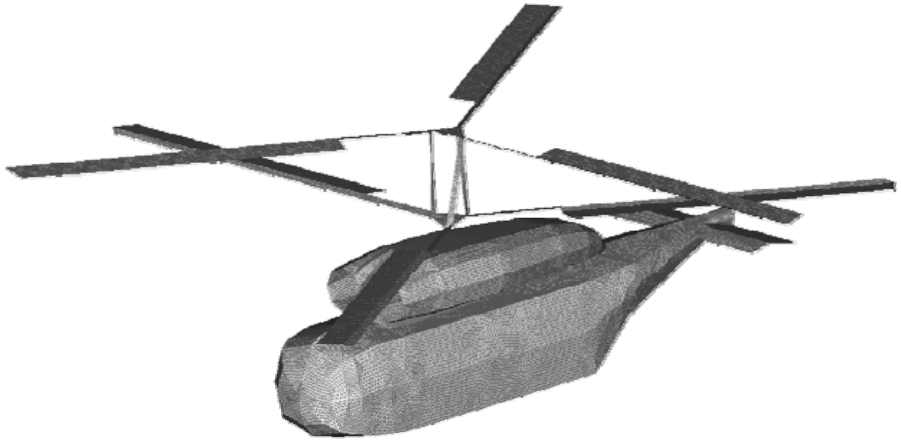




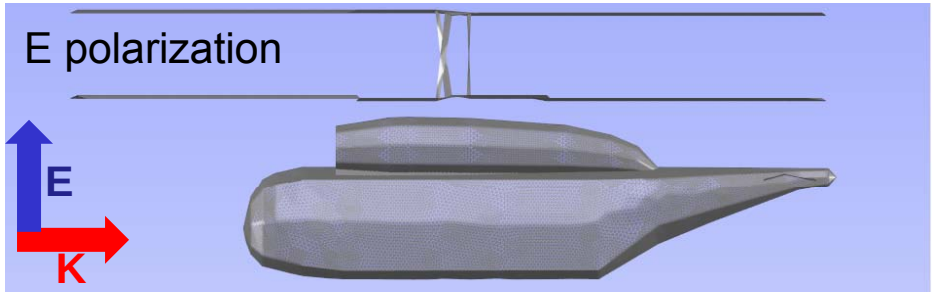


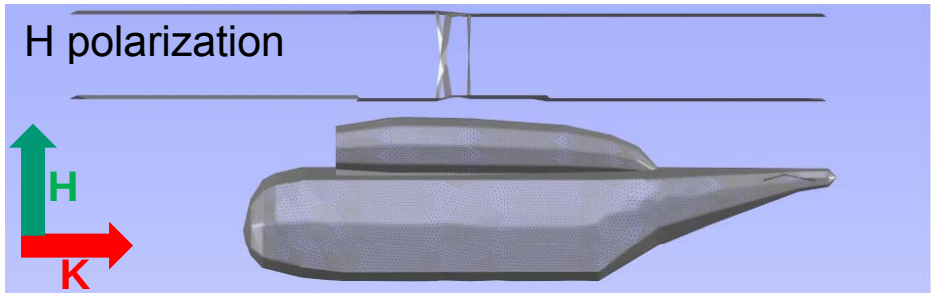
- FIS calculation (Total) is 10.9 times faster than direct solution for N=98k , 36.4 times faster for N=164k. For N=395k Direct solution is inaccessible
- Filling&Solving with FIS is 21.9 faster than direct solution for N=98k, 84.3 faster for N=164k. For N=395k Direct solution is inaccessible.
- Memory required by FIS is 10.9 times less than direct solution for N=98k, 17.9 times less for N=164k and 36.7 times less for N=395k

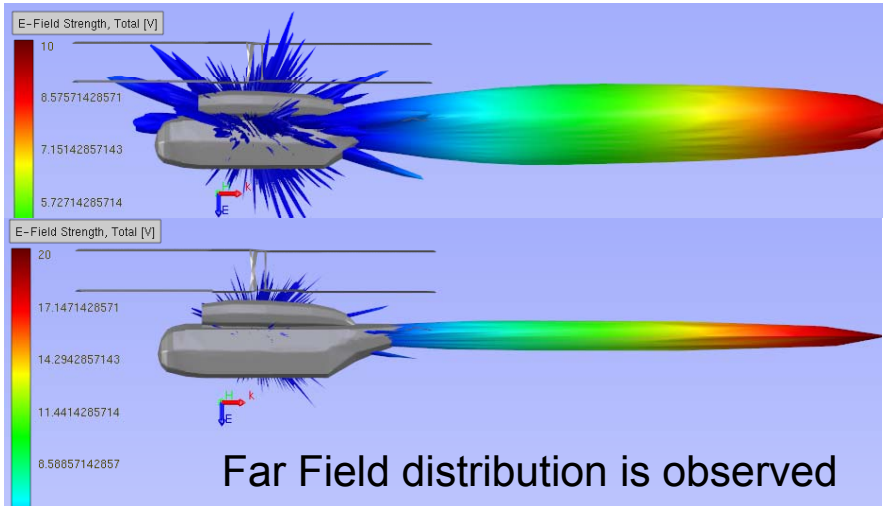
Scattering from helicopter



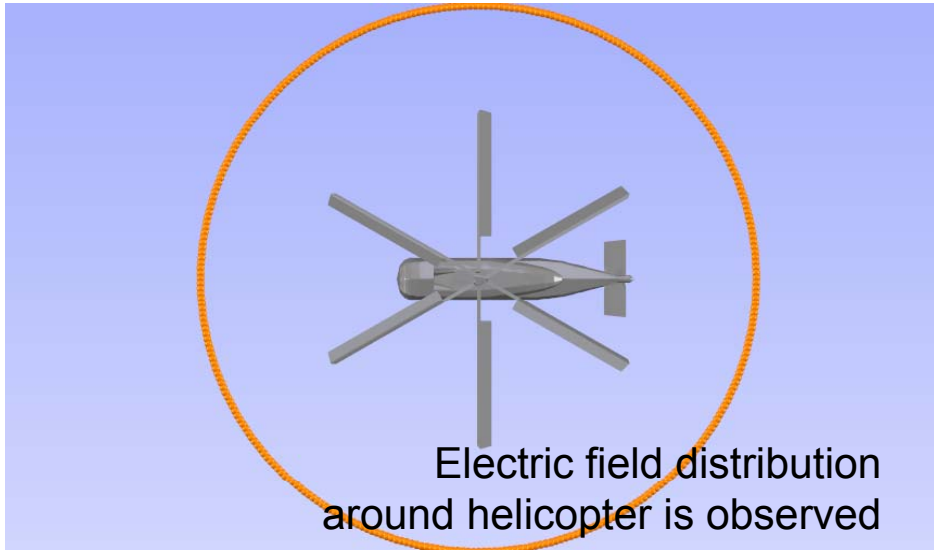
Helicopter model with 72384 triangles







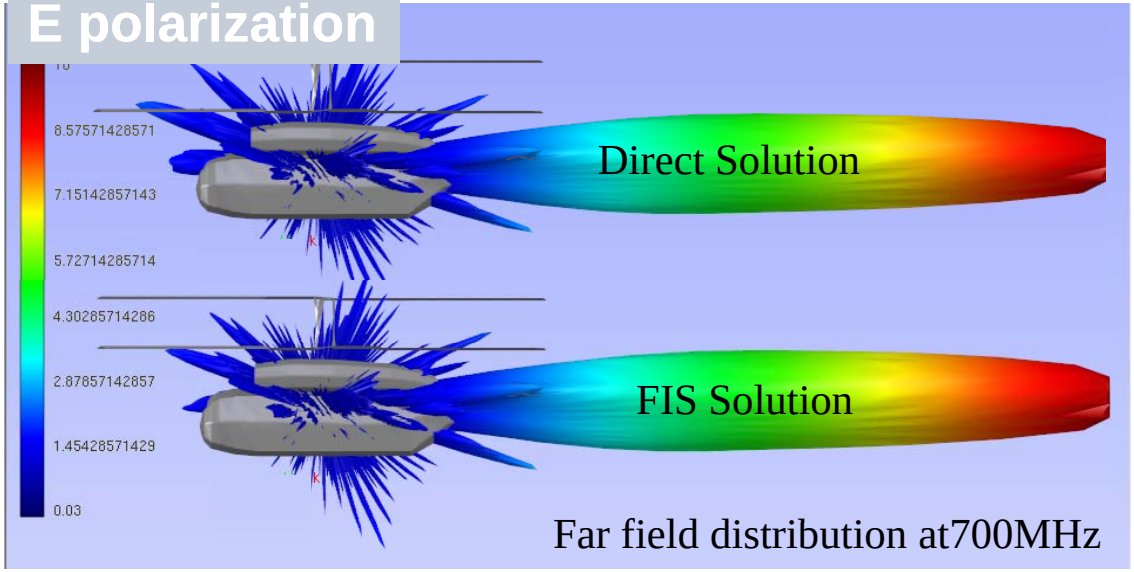
Far Field distribution is observed

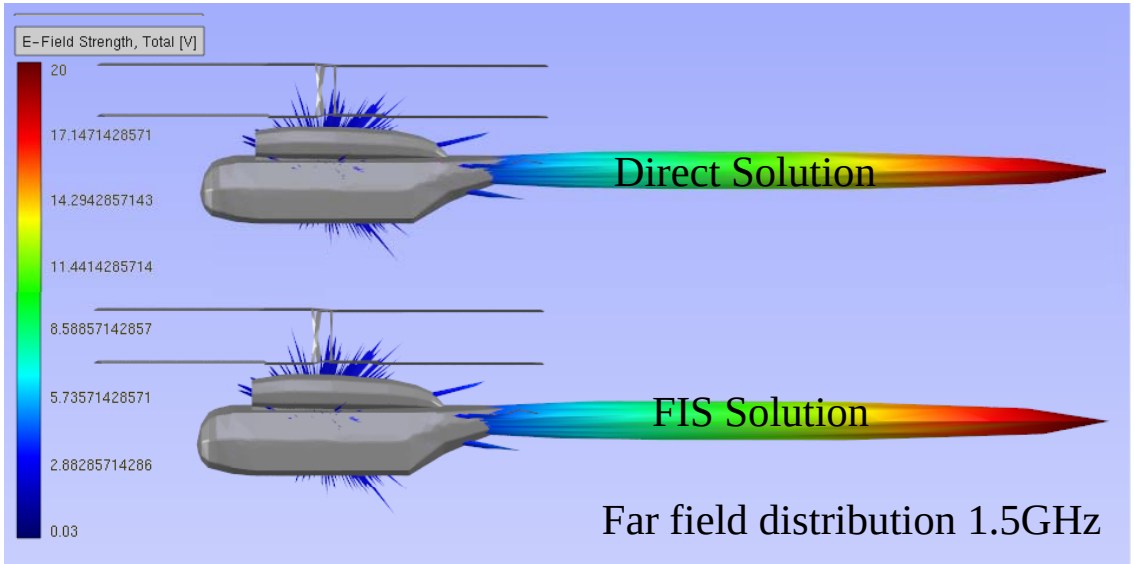


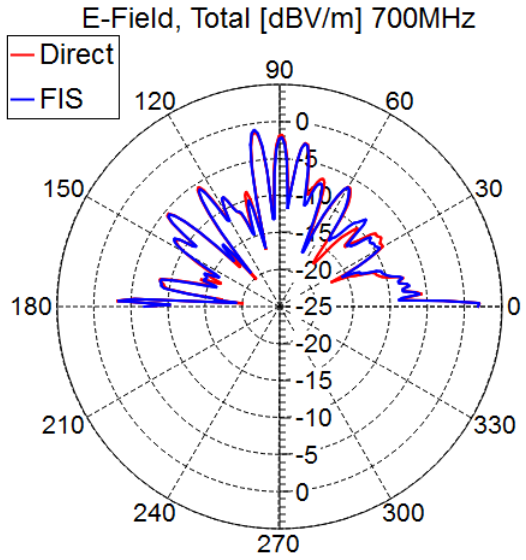
Electric field distribution
around helicopter is observed

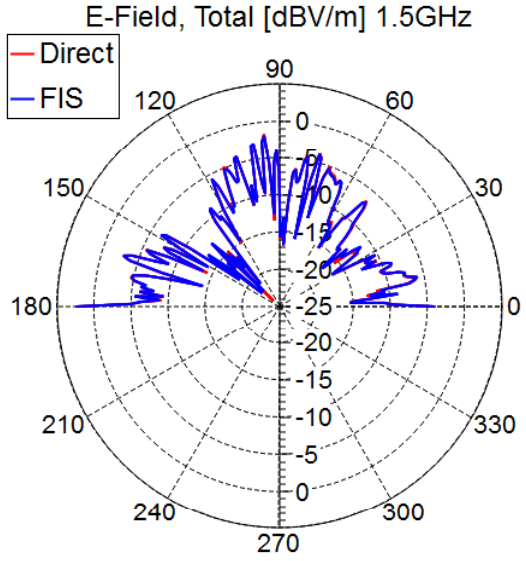
Scattering from helicopter

E polarization



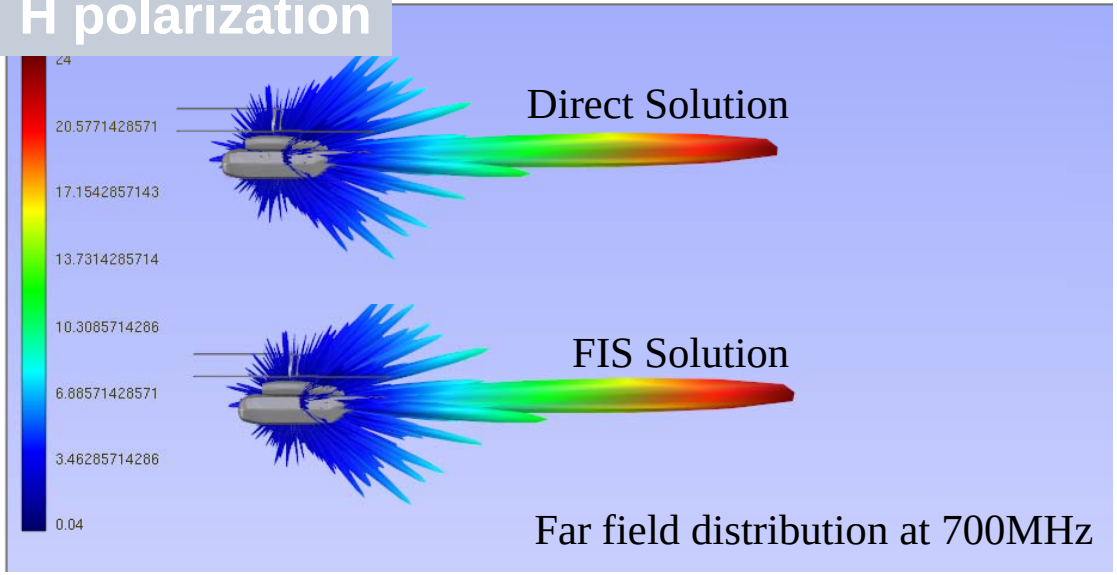


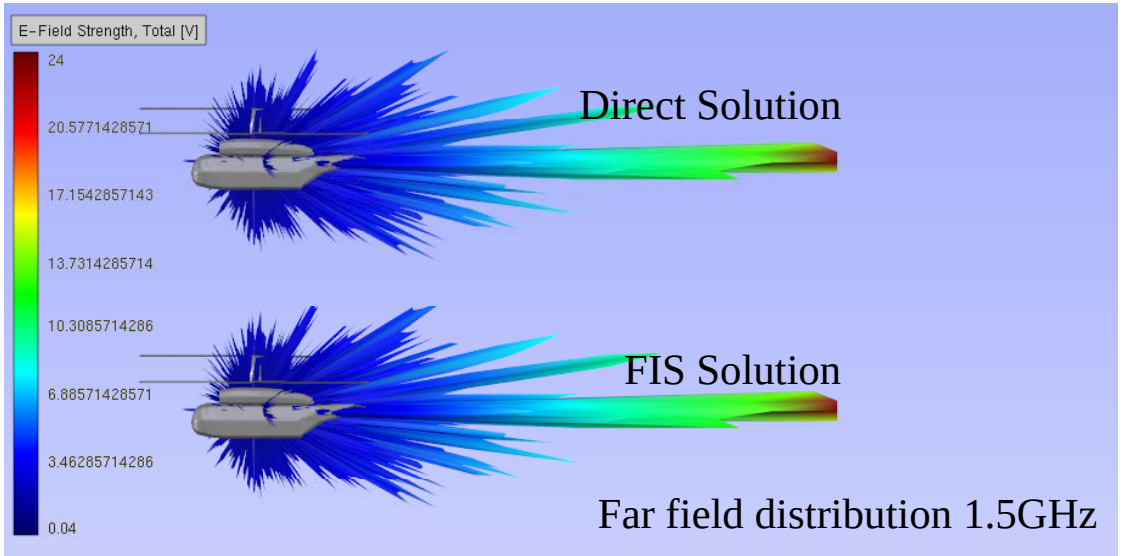


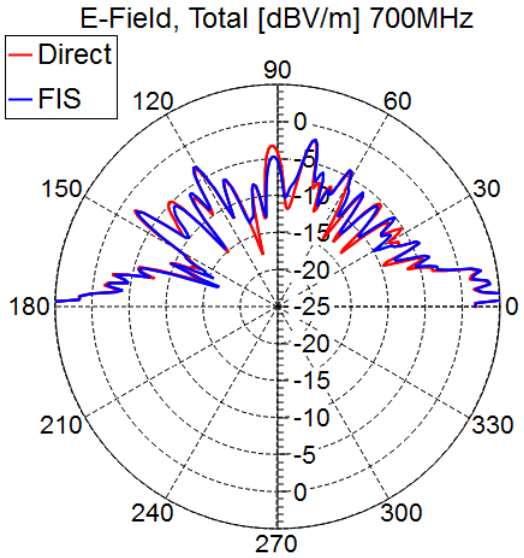


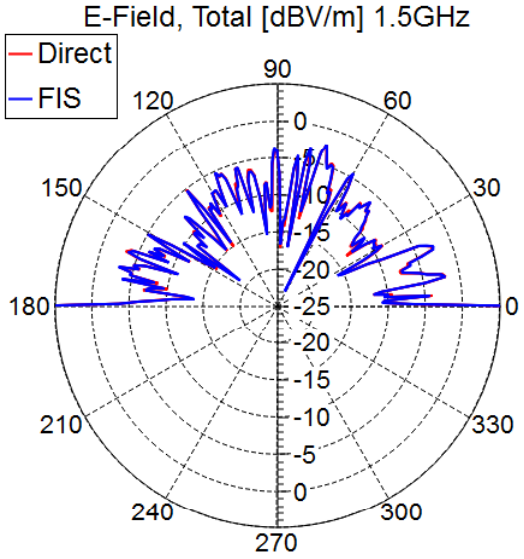
Scattering from helicopter

H polarization

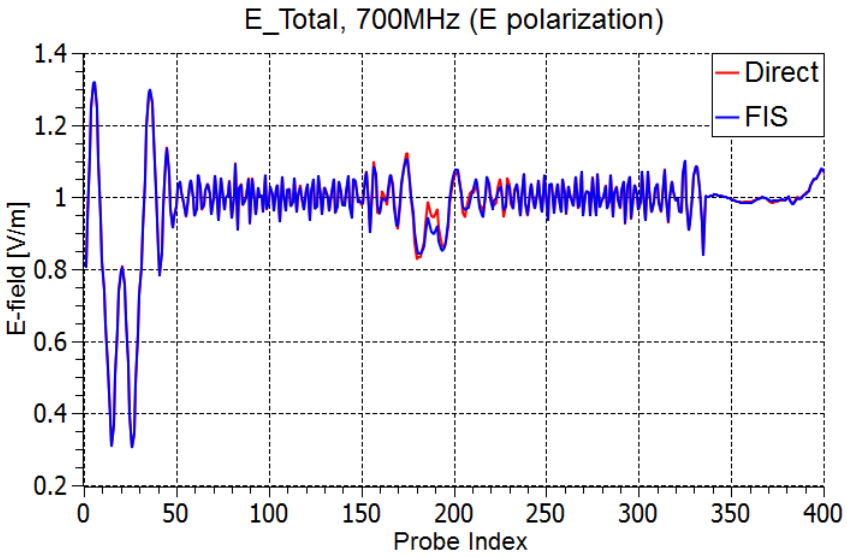


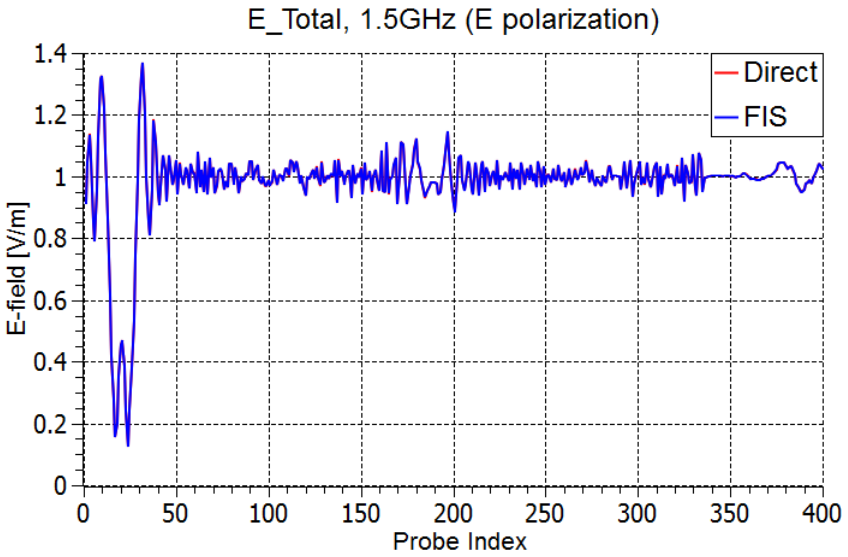


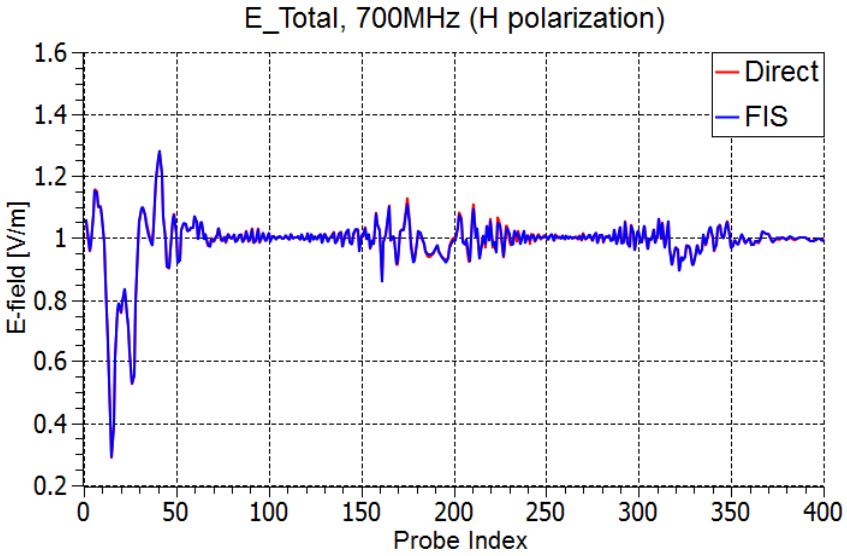


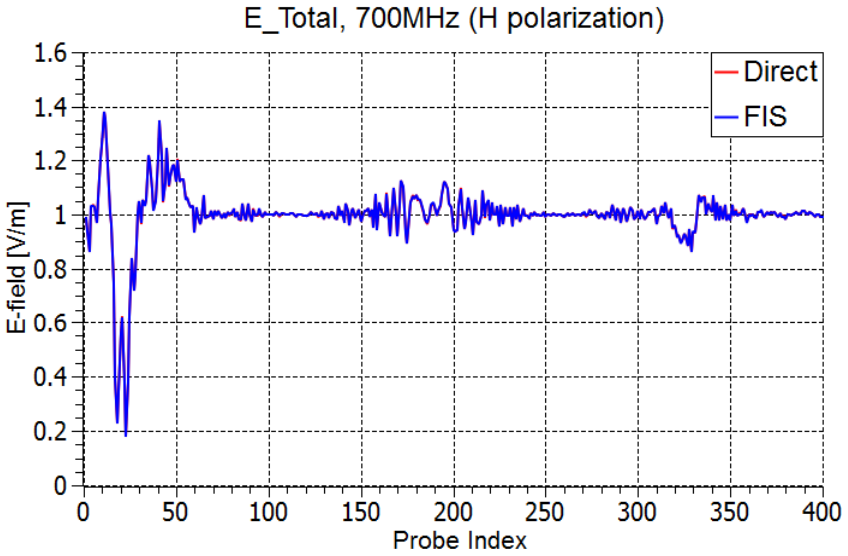


Scattering from helicopter









Scattering from helicopter

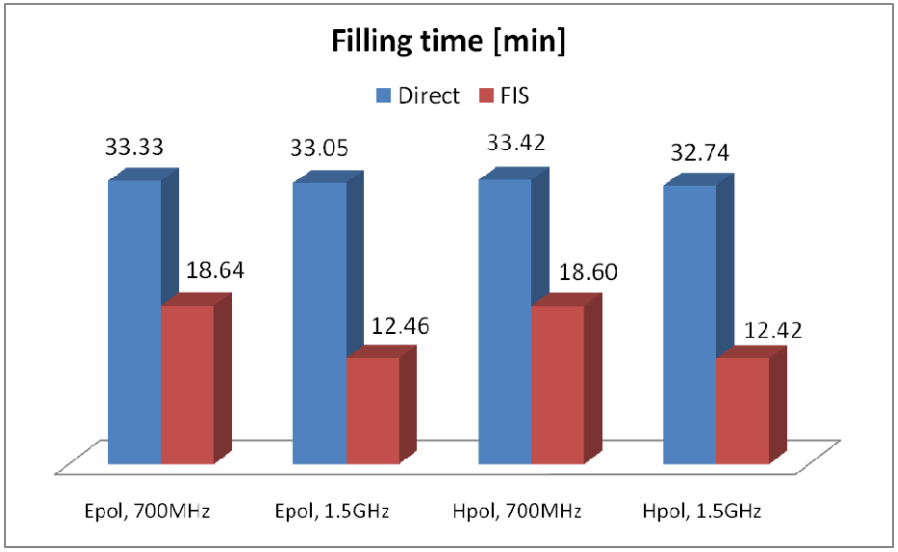
	E polarization				H polarization			
	700MHz		1.5GHz		700MHz		1.5GHz	
	FIS	Direct	FIS	Direct	FIS	Direct	FIS	Direct
Filling [min]	18.64	33.33	12.46	33.05	18.60	33.42	12.42	32.74
Solving [min]	3.52	179.10	18.16	178.10	1.00	178.28	30.62	177.82
Iterations	66	-	272	-	17	-	462	-
Memory [GB]	17.38	172.61	20.49	172.61	17.38	172.61	20.49	172.61

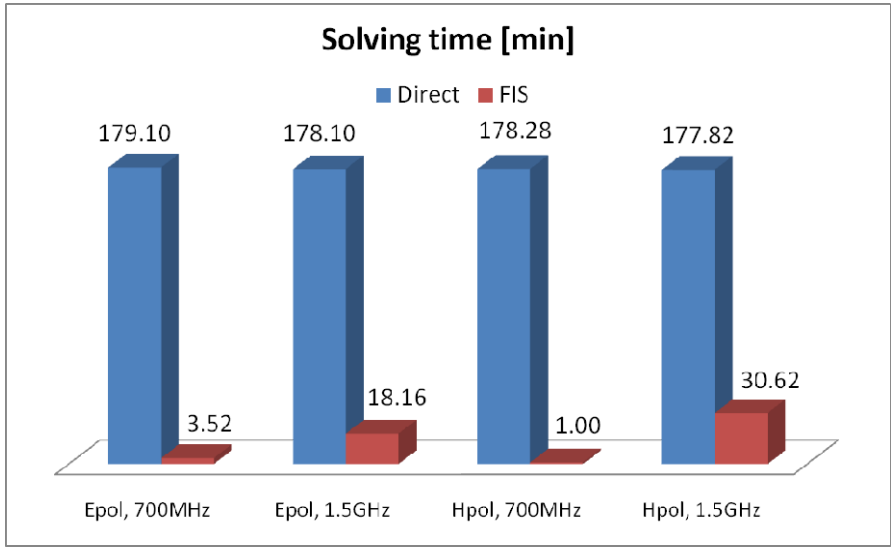
- Total time for E polarization: FIS - 1:10:49, Direct - 7:16:12
- Total time for H polarization: FIS - 1:20:09, Direct - 7:14:15

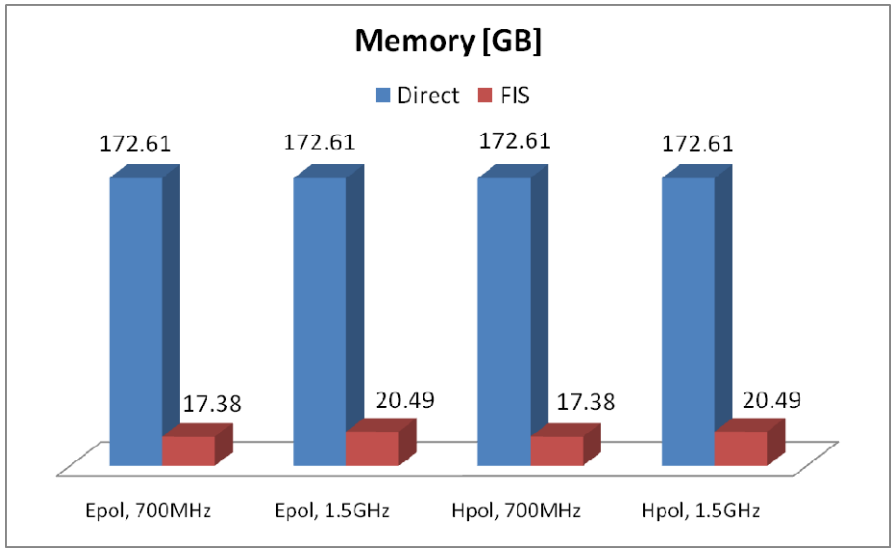
FIS calculation - 12cores (Intel 2.4GHz) 48GB RAM

Direct calculation - 48cores (Intel 2GHz) 256GB RAM, parallel

Scattering from helicopter







- Filling time for FIS is ~2.2 faster than filing time required by direct solution
- Solving time for FIS is ~61.4 faster than filing time required by direct solution
- Memory required for FIS calculation is ~9.2 times less than memory required for direct solution

Concussion

- Fast iterative solution (FIS) based on ACA technique and iterative sover is developed to solve large scale EM problems.
- It is shown, that FIS results are very close to direct MoM results for all presented applications
- Presented numerical experiments show that developed method is much faster compared to direct solution.
- Computational speed gain grows with increase of number of unknowns.
- Using FIS solver allows solving large scale problems inaccessible by direct solvers.

Thank you for your attention