CST STUDIO SUITE®

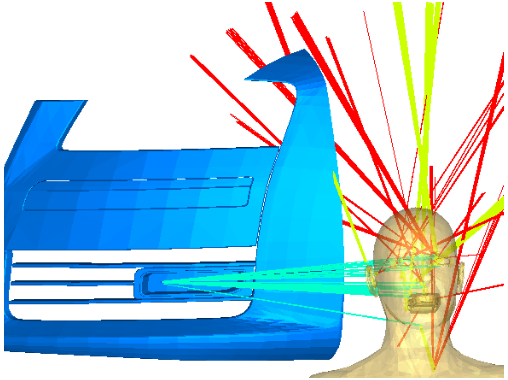
Automotive Workshop Series

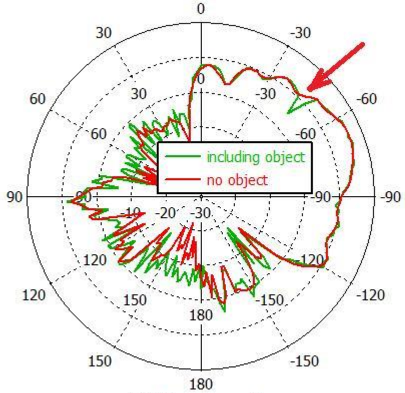
Automotive Radar @ 77GHz; Coupled 3D-EM / Asymptotic Simulations

Franz Hirtenfelder CST / AG

Abstract

Active safety systems play a major role in reducing traffic fatalities, including adaptive cruise control, collision warning systems, automatic steering and braking intervention. In a collision warning system, a 77 GHz transmitter emits signals reflected from objects ahead of the vehicle and are captured by multiple receivers. Antennas, antenna-arrays and receiver-arrays are common components in sensing applications and can be used at high frequencies.
3D EM-simulation tools help greatly to gain more inside into the interaction of detailed car geometries, antennas and receivers. Due to the size and the related frequencies these simulation models are far too complex to be simulated in a 3D full-wave simulator.
CST MICROWAVE STUDIO® (CST MWS) now incorporates an asymptotic solver: This solver is based on the Shooting Bouncing Ray method, an extension to physical optics, and is capable of tackling simulations with an electric size of many thousands of wavelengths.
This presentation shows how antenna near- and far-field patterns can be positioned into complicated car geometries. Resulting near- and far-field patterns can be inspected and optimized, reflected ray paths help to identify wrong propagation paths visually.





Overview

- Introduction
    - ADAS
    - Radar Basics
- How to simulate?
- A-Solver
- Theory
- SBR
- Features
- Demo
- Application
- Summary

Introduction (ADAS)

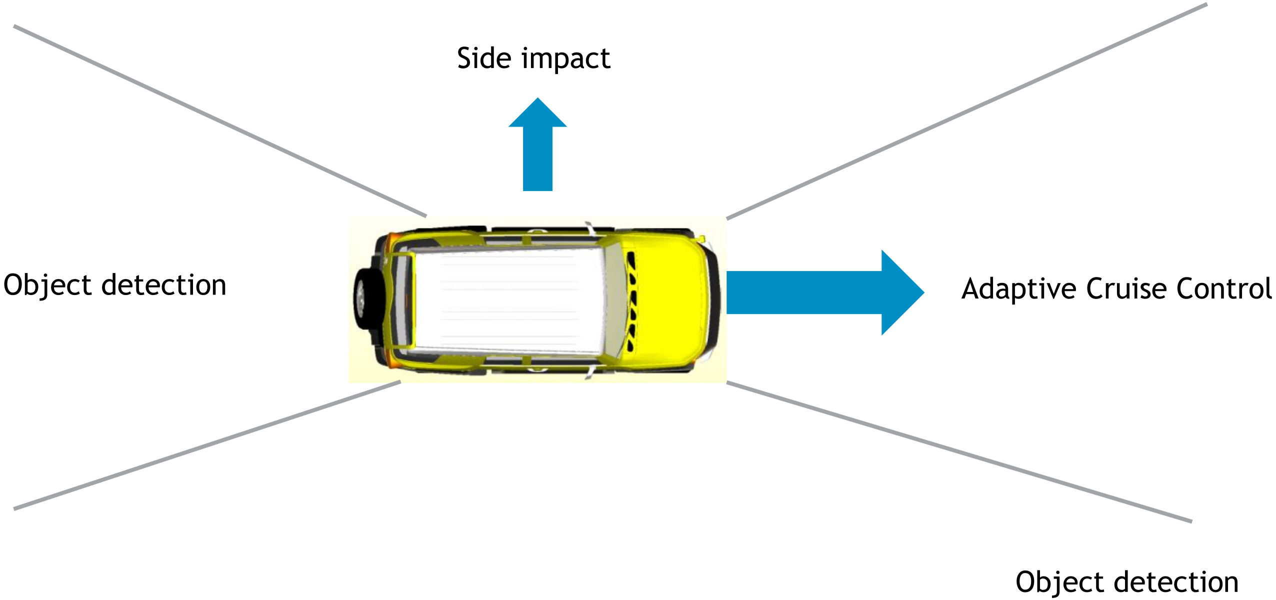
Automotive industry's efforts to achieve a goal of zero automotive-related fatalities, meeting consumer demand and government legislation, are driving adoption of advanced automotive safety systems.

Advanced driver assistance systems (ADAS)

- one of the fastest-growing segments in automotive electronics
- automate/adapt/enhance vehicle systems for safety and better driving
- avoid collisions and accidents, alert the driver to potential problems
- provide adaptive cruise control, automate braking,
- incorporate GPS/ traffic warnings, connect to smartphones, alert driver to other cars or dangers, keep the driver in the correct lane, or show what is in blind spots.

Introduction (AdvancedDriverAssistanceSystem)

ADAS technology can be based upon vision/camera systems, sensor technology (**radar**), car data networks, Vehicle2Vehicle, or Vehicle-to-Infrastructure systems.



Requirements

- Simultaneous measurement
- of moving/stationary objects
- Distance
- Relative velocities
- Angular position

- Detection of Multiple objects
- Robust
- Low cost
- reliability

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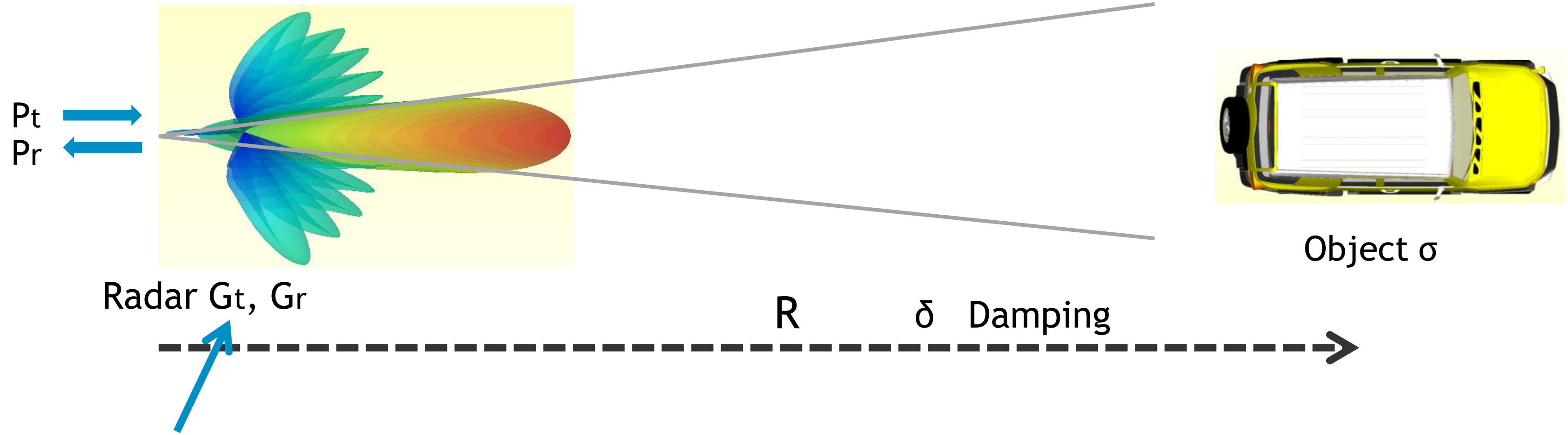
Introduction (Radar)

1. Radar Equation (Range)

Relation between Receive and transmit power at the radar unit



$$P_r = \frac{P_t G_r G_t \lambda^2 \sigma}{R^4 (4\pi)^3 \delta}$$

Introduction (Radar)

2. Direction of Arrival Estimation

All conventional direction of arrival (DOA) estimation methods

- monopulse techniques (comparison of the received signals in partially overlapping beams)

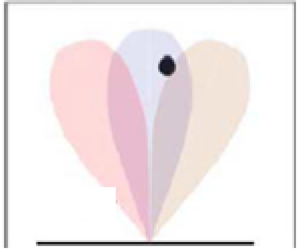
- Spatial power spectrum measurement techniques (mechanical scanning, phased array)

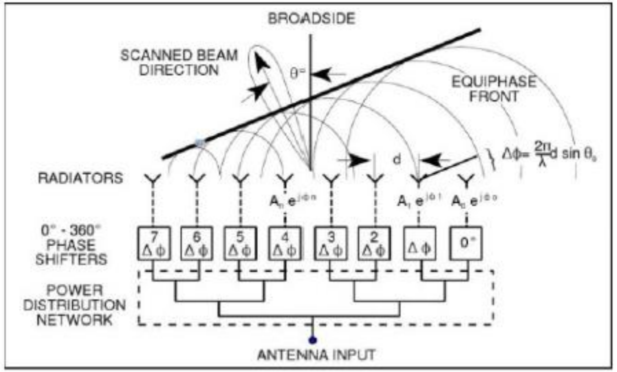
have an angular resolution in the range of the half-power beamwidth.

Half-power beamwidth $\theta \sim \lambda / D$

angular resolution directly depends on the aperture size D

The angular resolution of long range 77 GHz sensors is typically in the range of 2 .. 5 degrees.





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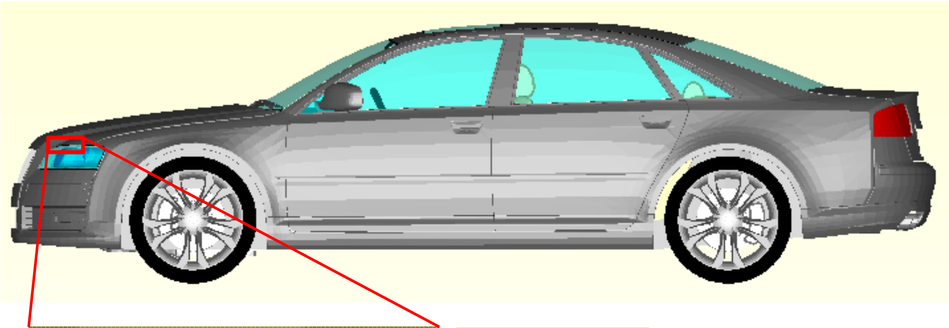
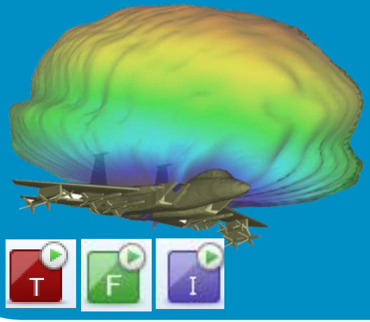
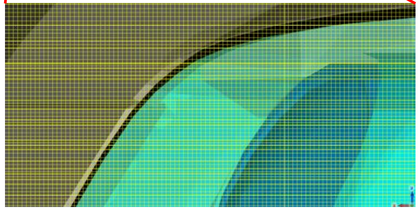
How to simulate (@77GHz)?



Installed Performance

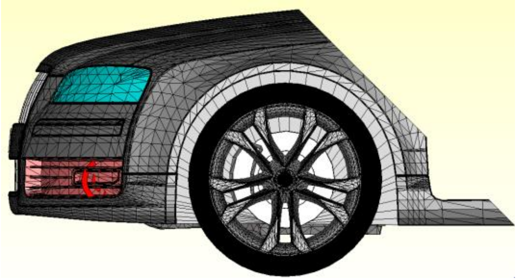


6GHz



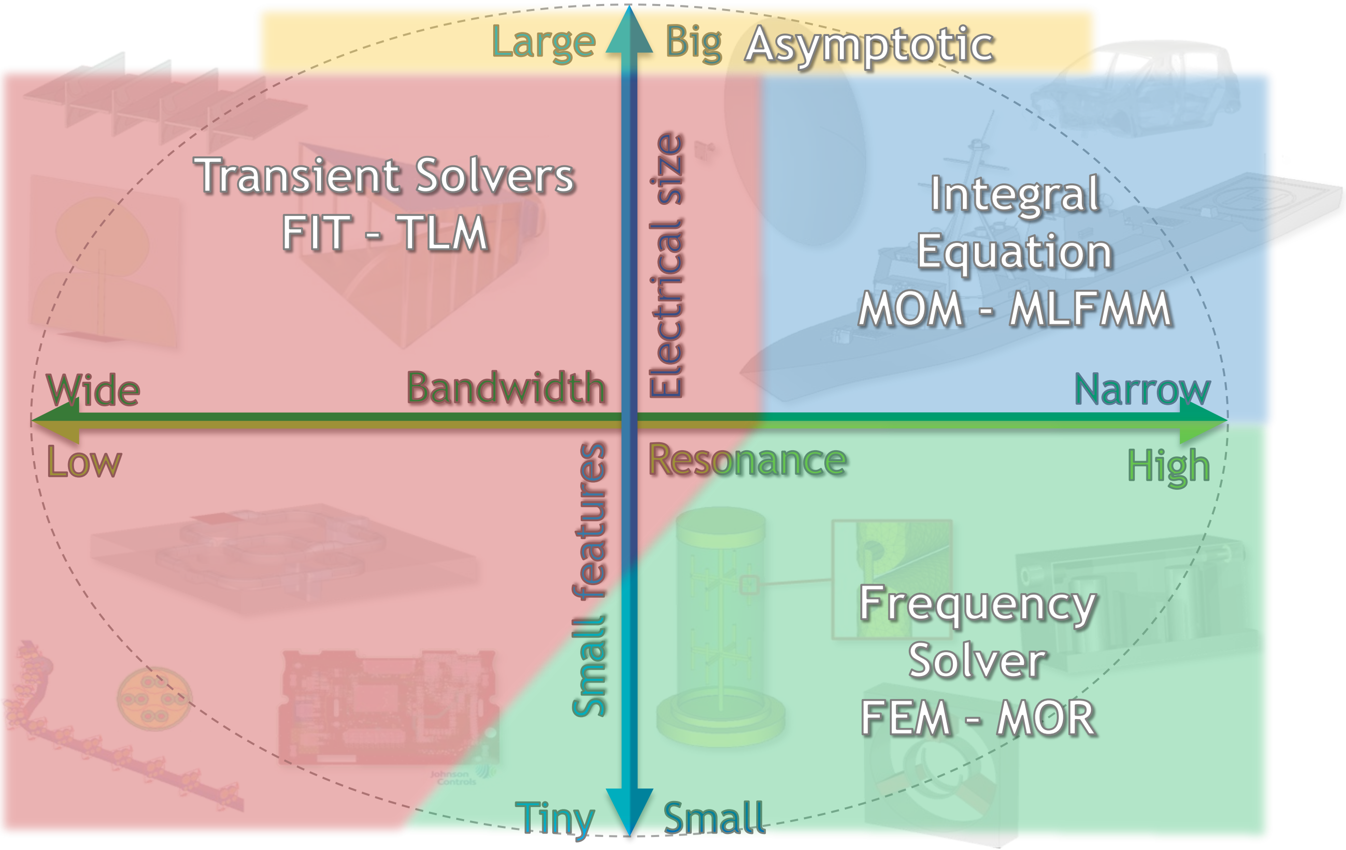
Number of cells:
5,307,192,192

77GHz

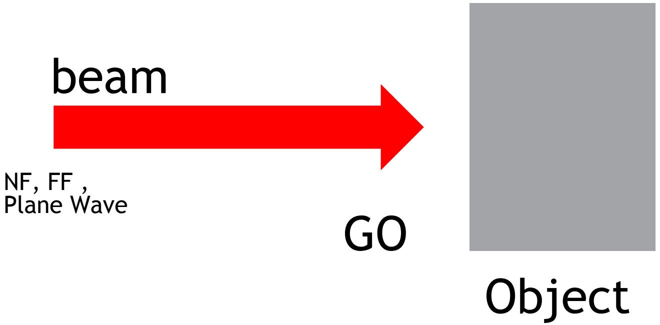


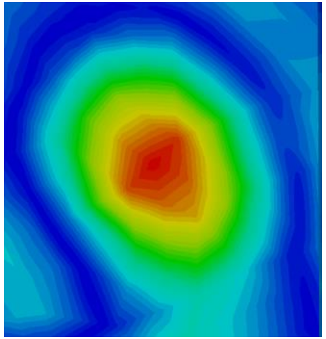
Meshcells=7,100,873,489,424

Simulation Techniques



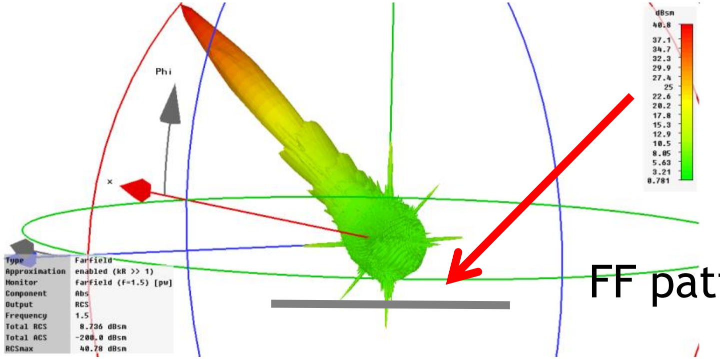
Asymptotic Solver (Basics)





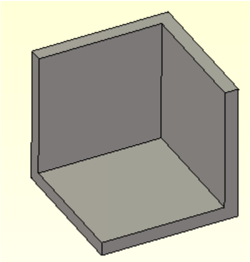
PO

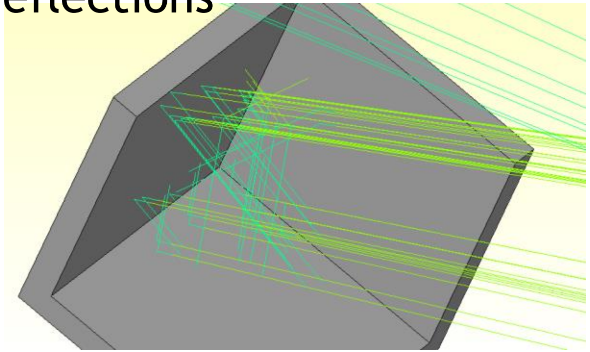
Current pattern



FF pattern

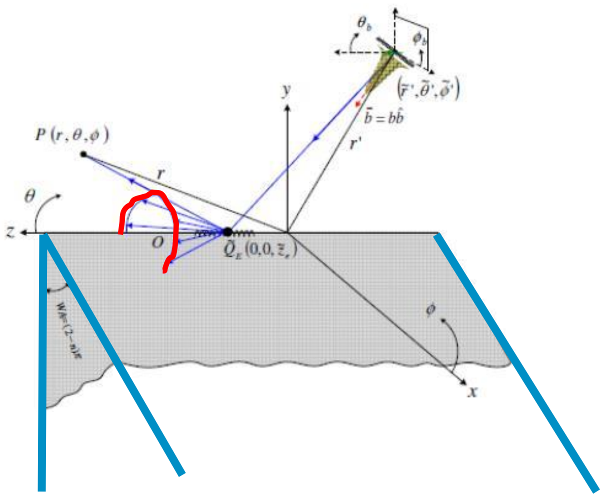
GO : multi reflections

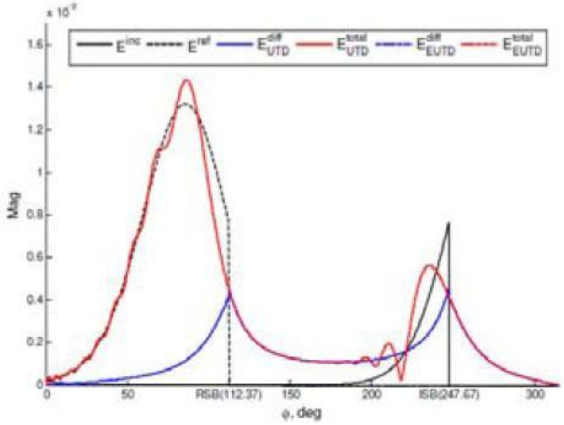




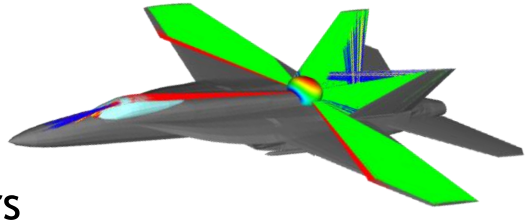
Asymptotic Solver (Basics)

Edge Diffraction PTD





A-Solver: SBR Methodology

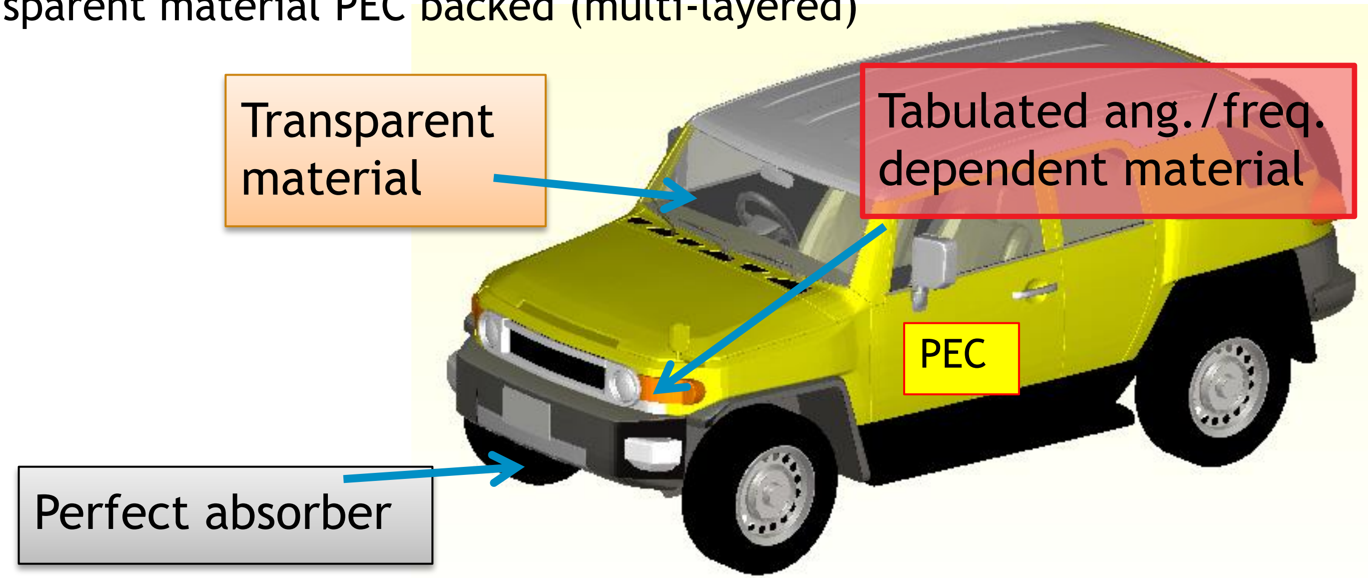


- What is SBR?
  - Shooting and Bouncing Rays
    - Asymptotic technique
      - Complimentary capability to full-wave solvers
      - Electrically large platforms (*i.e.*, many wavelengths in dimension)
    - Extends PO to multiple bounces with GO ray tracing
      - Incident Field = free space fields of antenna
      - Scattered Field = from PO currents painted on platform
  - Improvements to basic SBR
    - Physical Theory of Diffraction (PTD)
  - Material Modeling
    - Multi-layer dielectric stacks
    - Transparent materials

Materials Overview

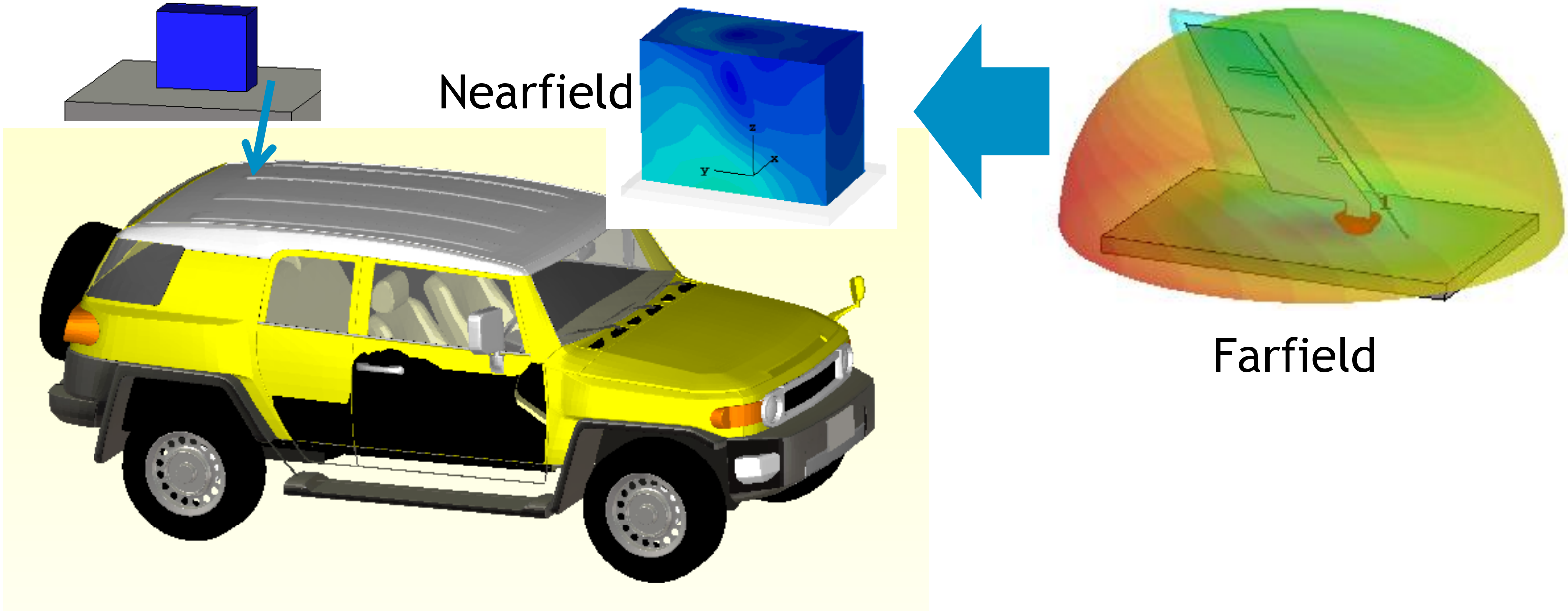
Materials

- Tabulated angular & freq. dependent material
- Perfect absorber material
- Thin HF-transparent material (multi-layered)
- Thin HF-transparent material PEC backed (multi-layered)
- PEC



NFSource and FFSource Excitation

- Installed performance on car
- NearFieldSource generated from blade antenna



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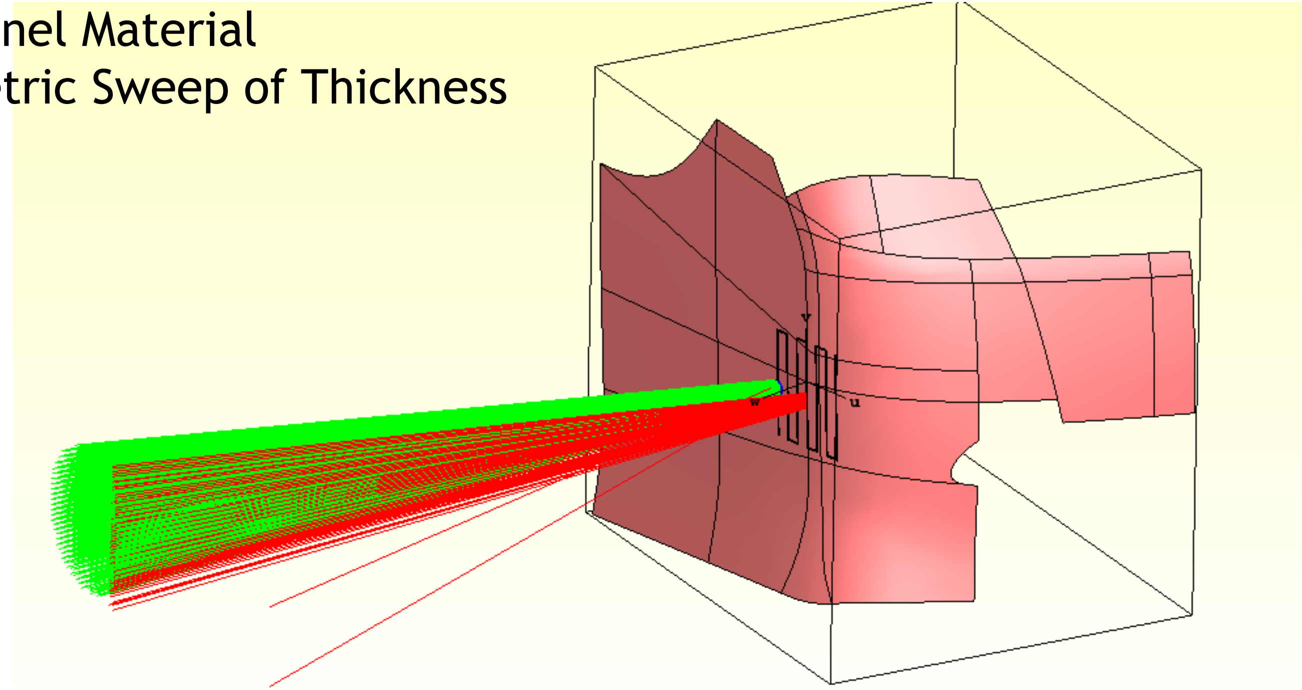
Simple Demo: Bumper + NFSource

Thin Panel Material
Parametric Sweep of Thickness



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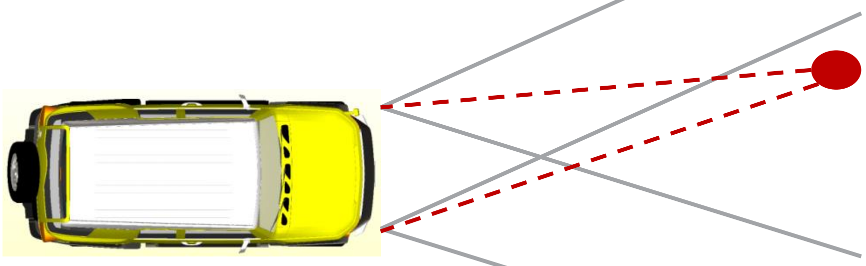
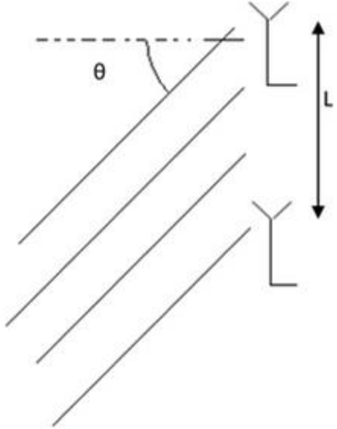
Direction of Arrival Estimation II

Multistatic approach using multi distributed sensors

By using two or more antennas with a separation of L, the angular position of the detected object can be determined, based on the phase difference between the signals received at each of the antennas.

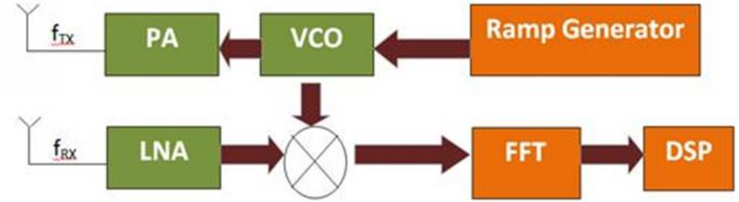




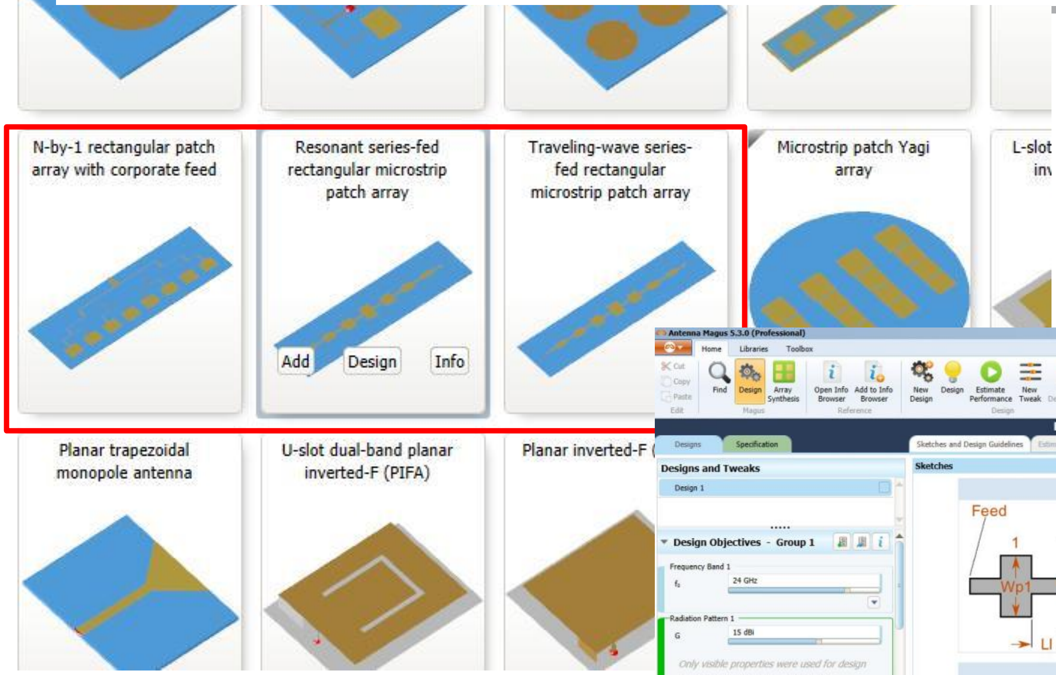
$$\Delta\varphi = \frac{L\sin\theta}{\lambda} = L\sin\theta\frac{f}{C}$$

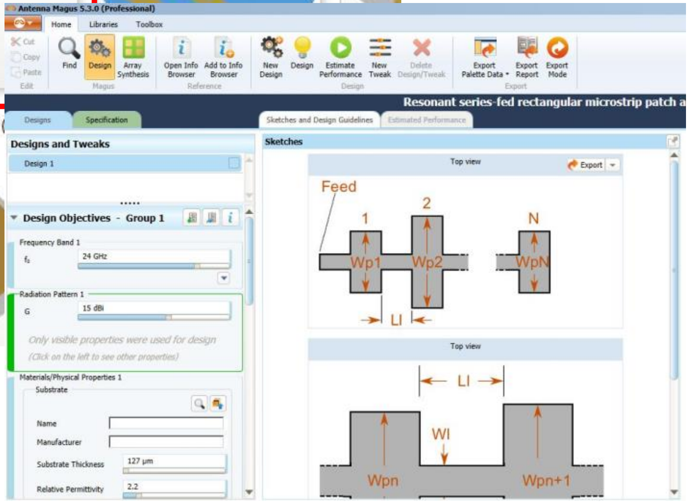
The two antennas can be spaced closer, e.g. λ/2 free space distance apart to allow direction of arrival (DOA) estimation of a target detected by the radar.

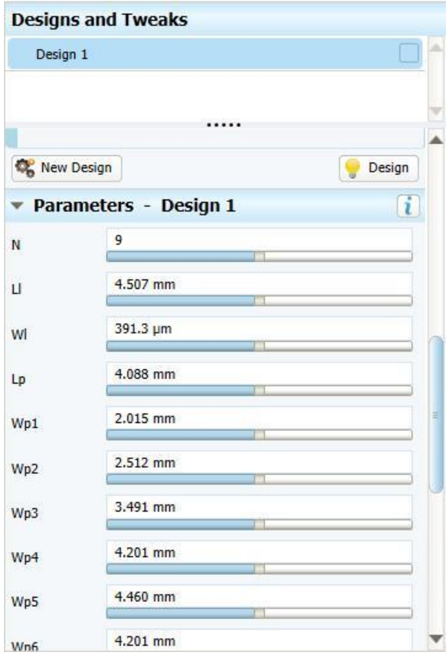
Radar Transceiver Architectures



Antenna Definition

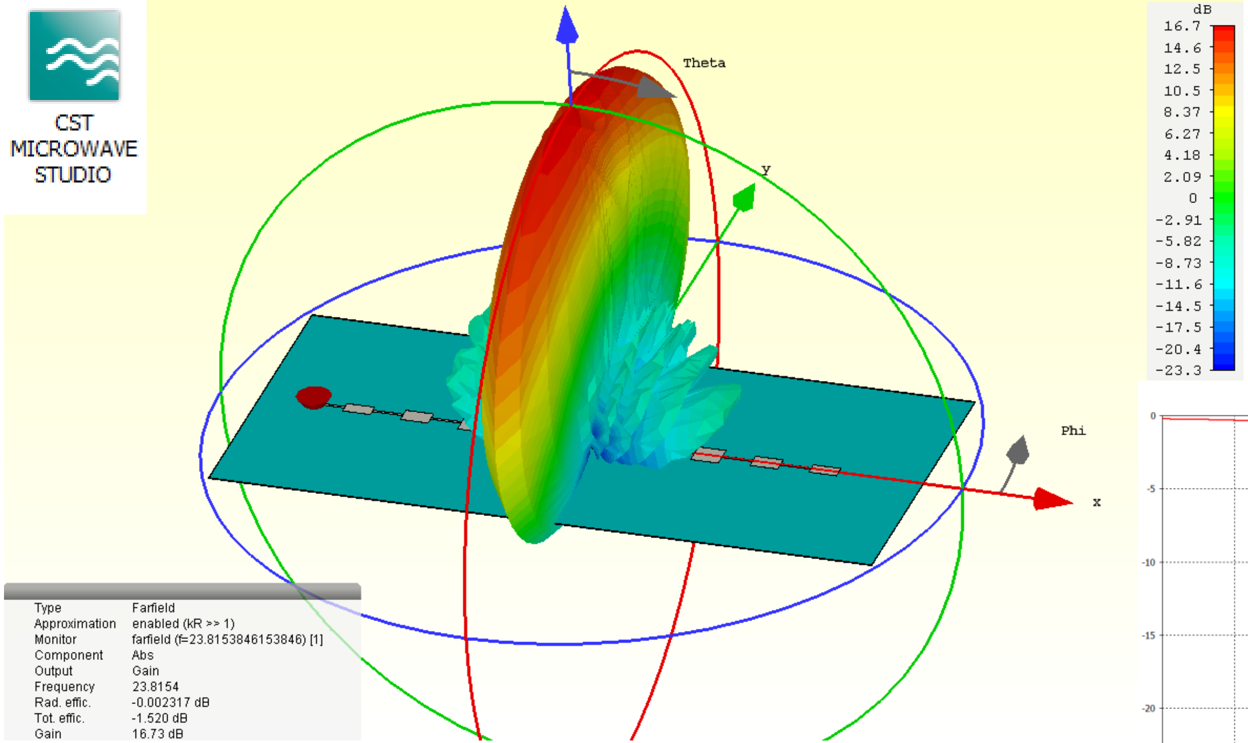


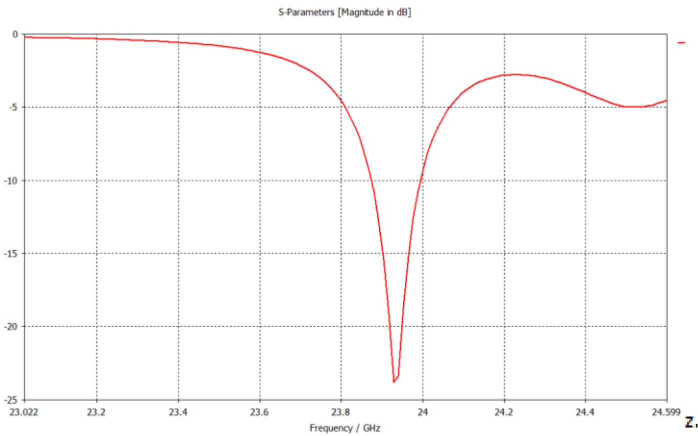




Import into CST-MWS

CST
MICROWAVE
STUDIO





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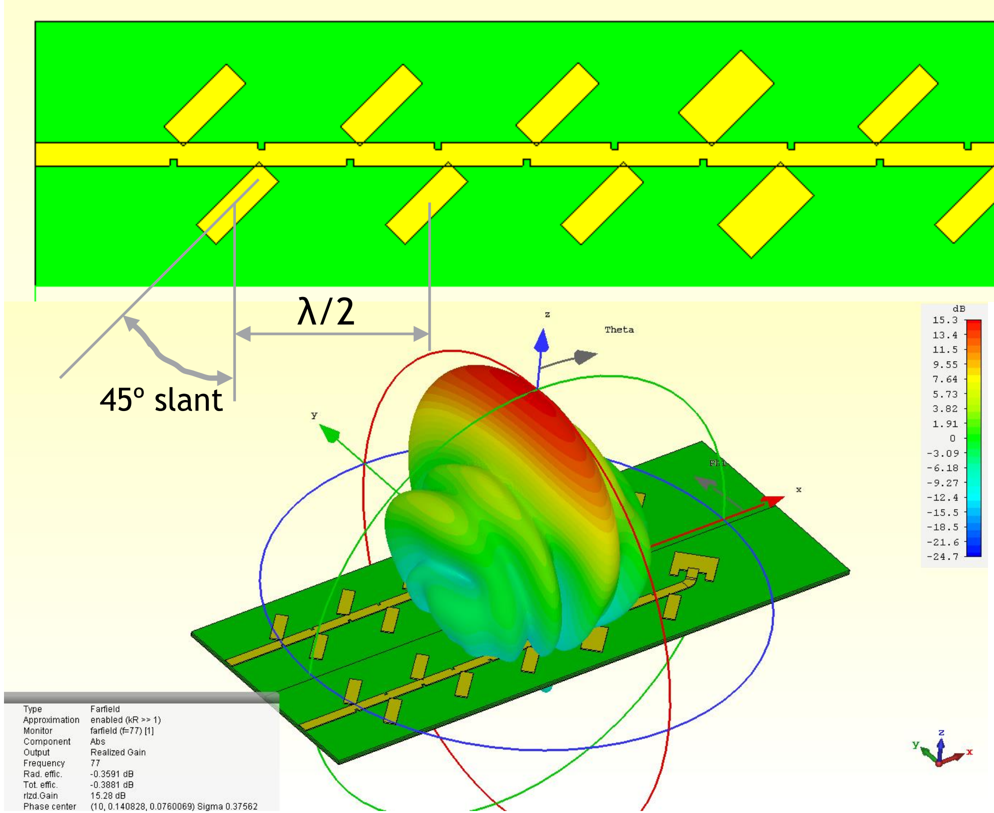
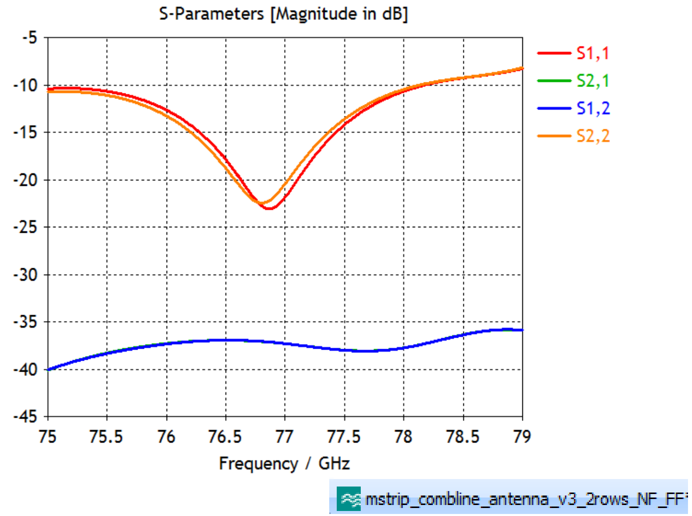
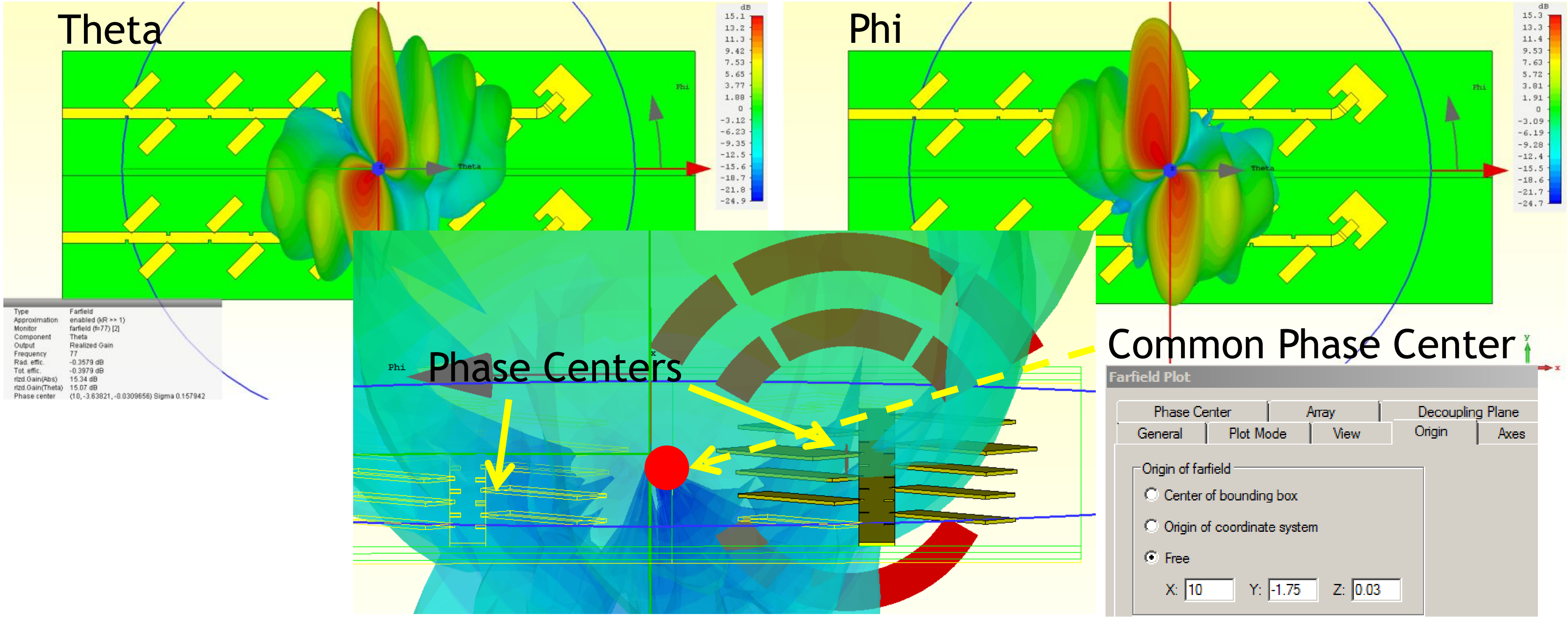
Microstrip Comb-Line Antenna Array





Microstrip Comb-Line Antenna Array

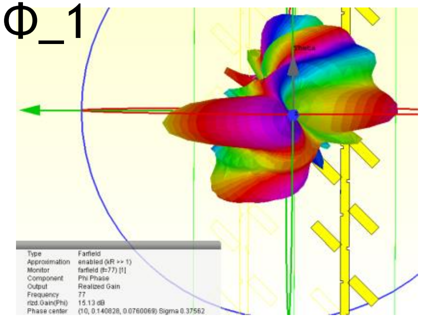
Transceiver Configuration: N*λ/2 apart (to determine the phase difference)

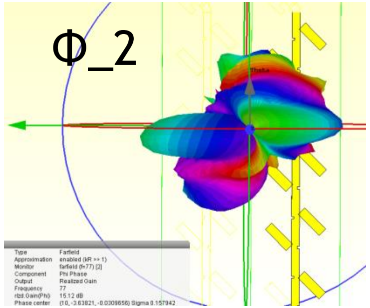


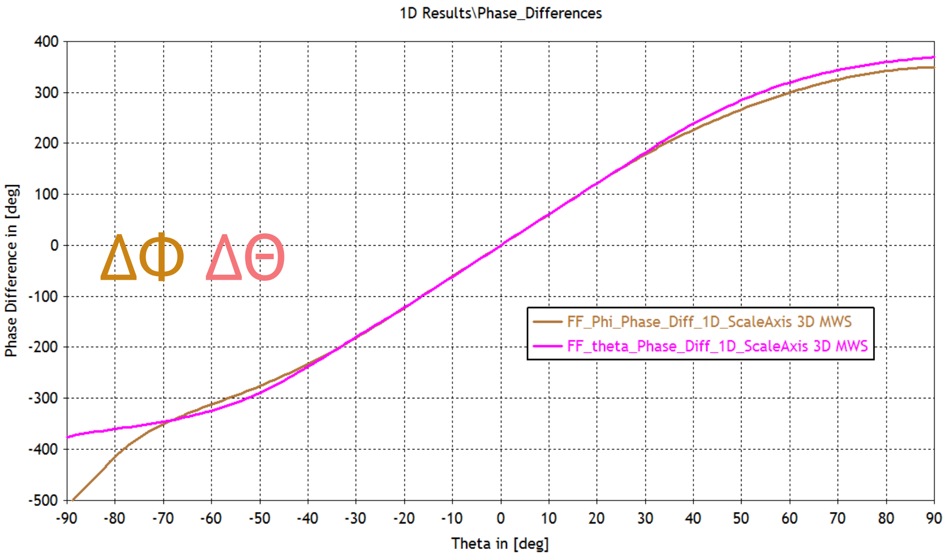
Microstrip Comb-Line Antenna Array

Computing the phase difference: ΔΦ and ΔΘ

Φ_1

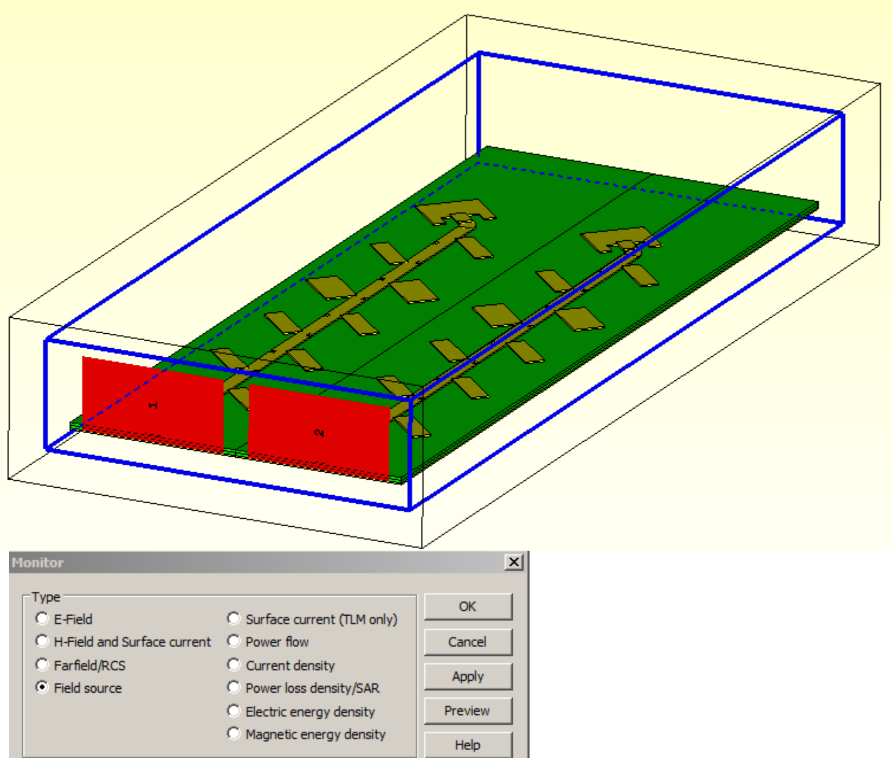


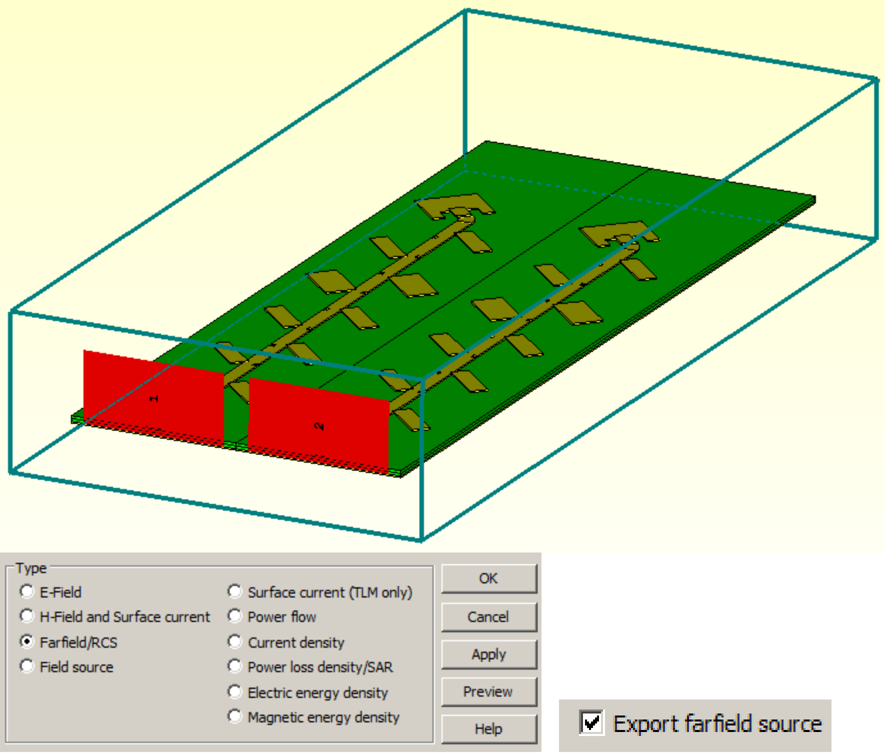




Near- and Farfield Generation

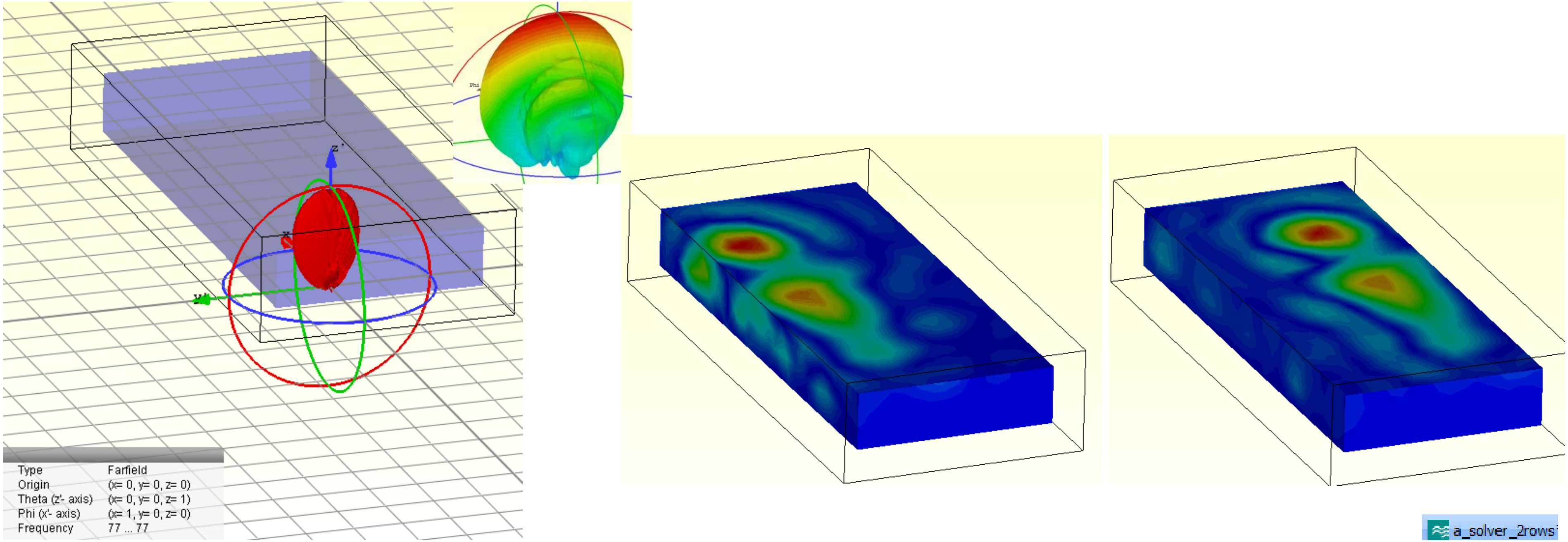
…as feed for the A-Solver



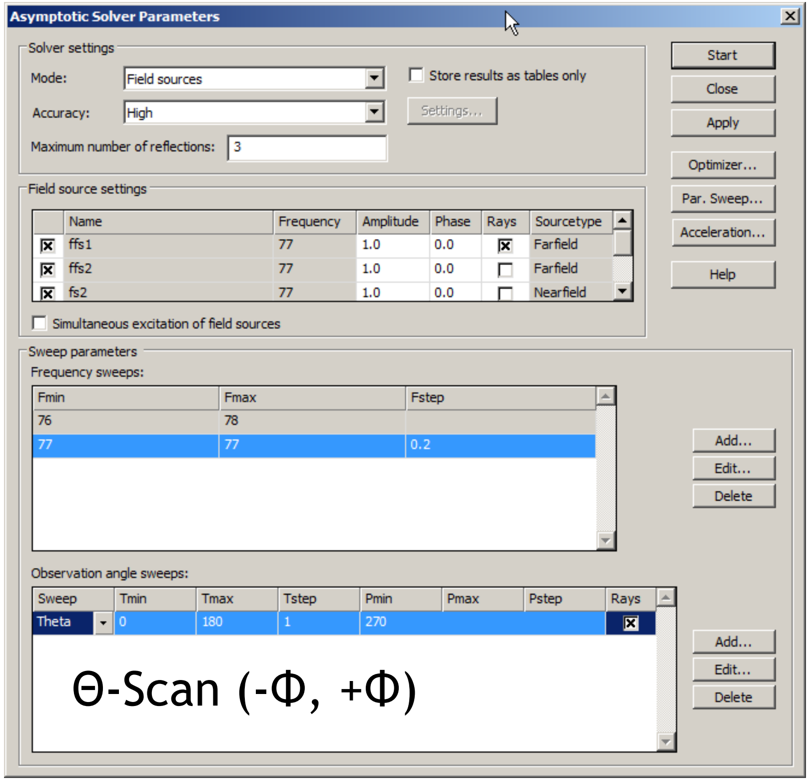


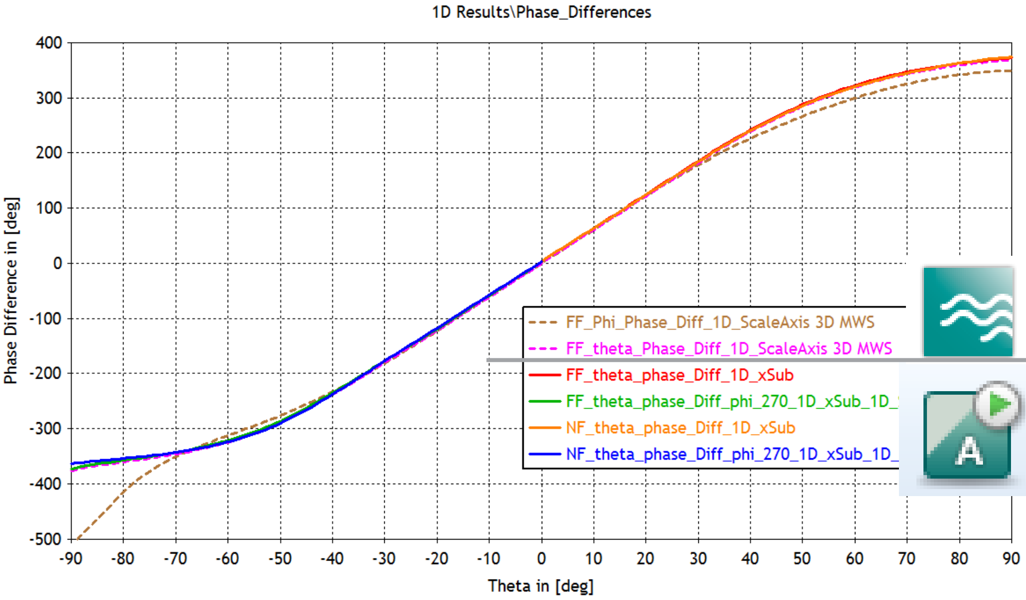
Import of Near/Farfield

Near and Farfield imported in a empty project, run A-Solver

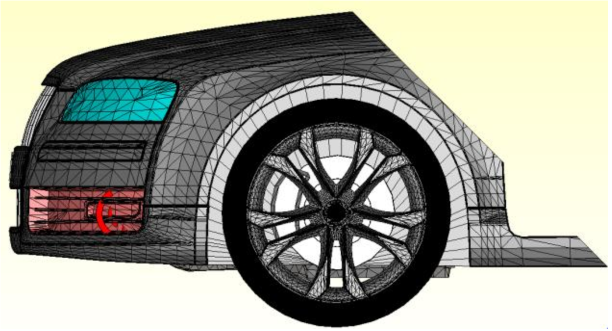


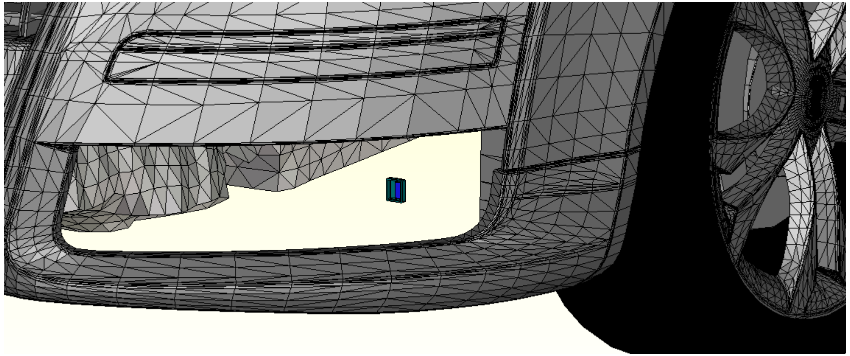
A-Solver Setup and Results

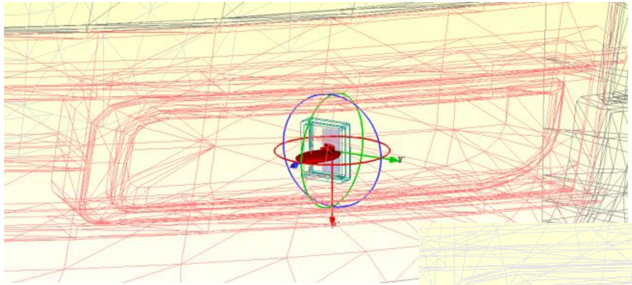


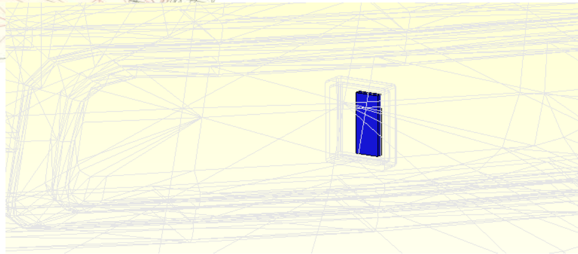


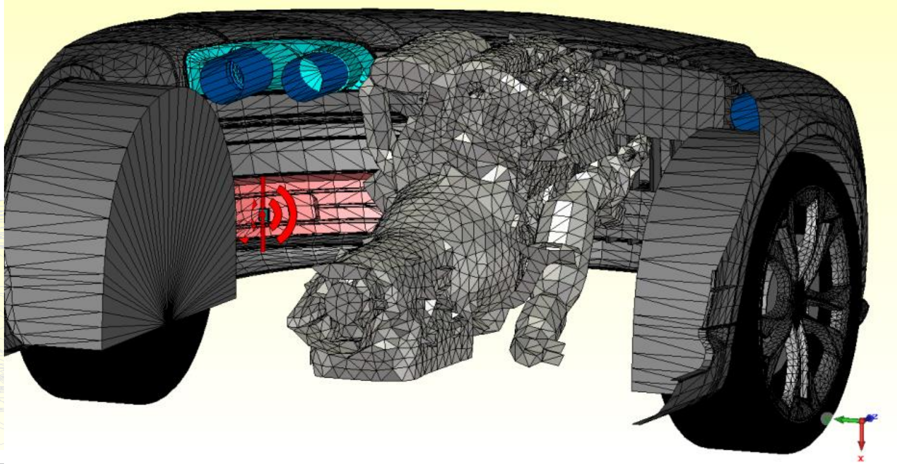
NF/FF + automobile environment



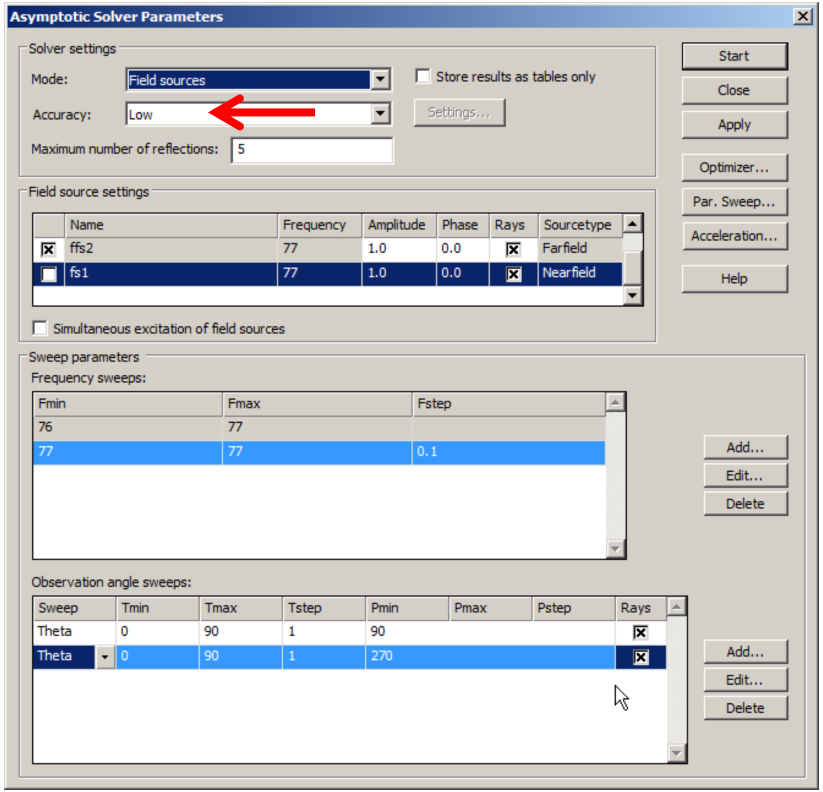


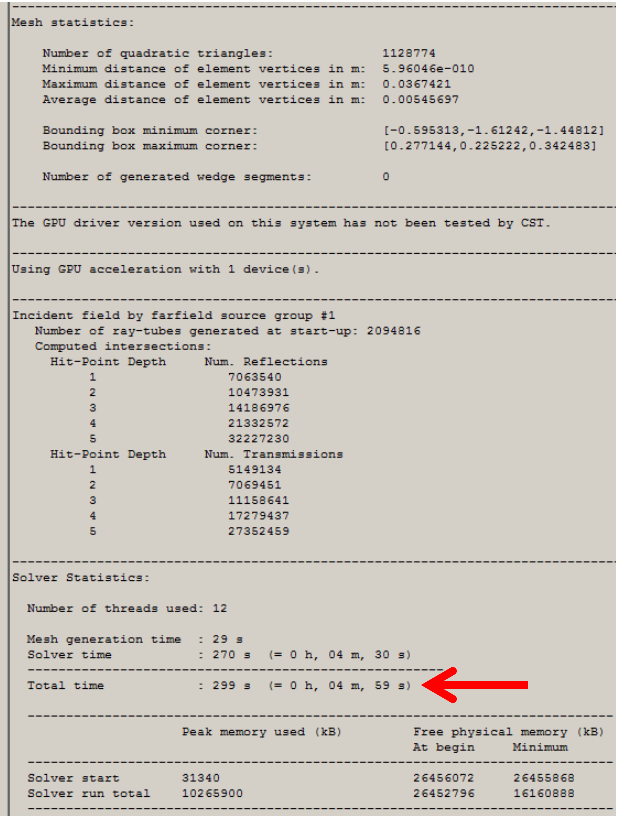




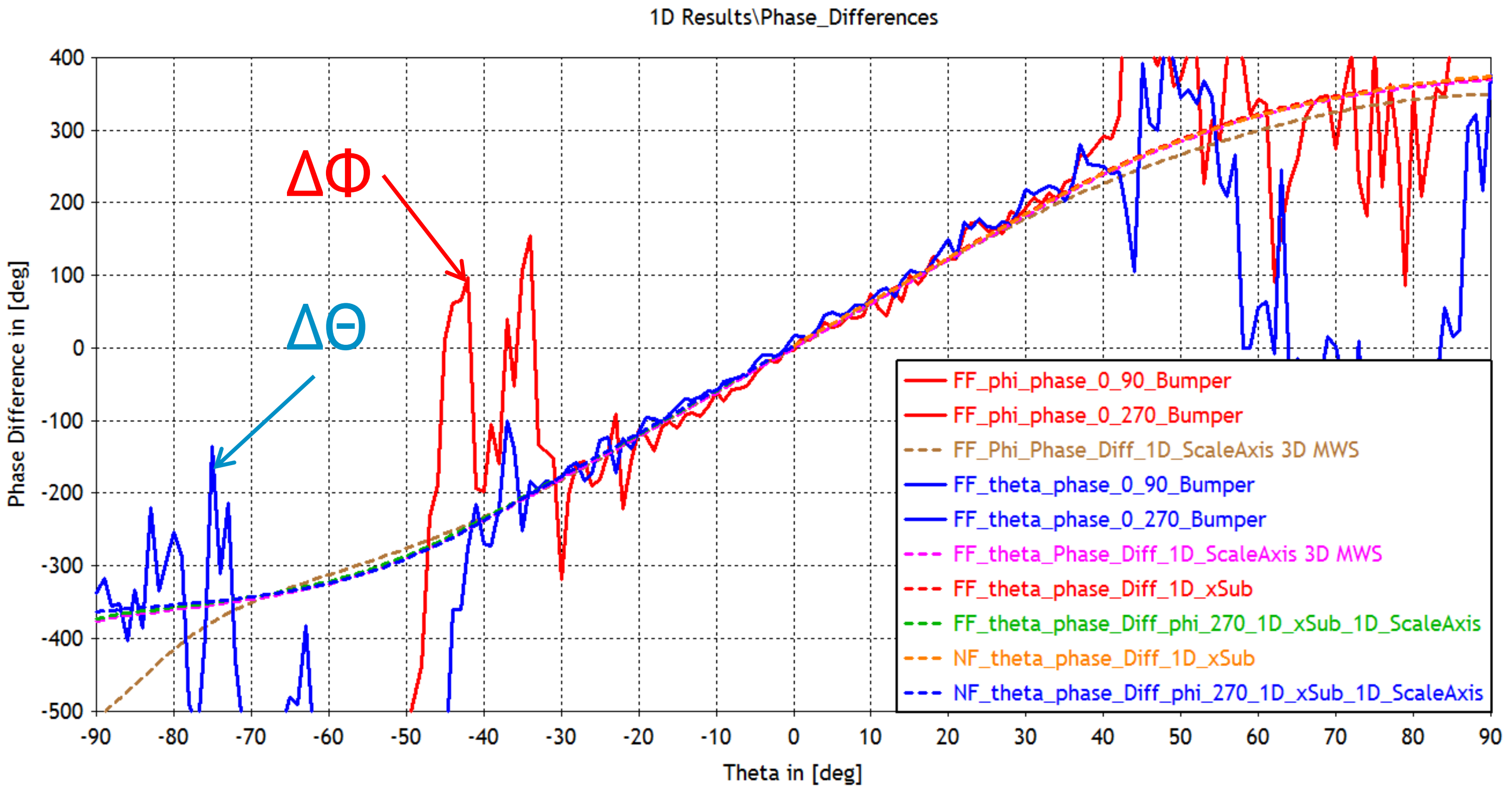


A-Solver Setup /Runtime

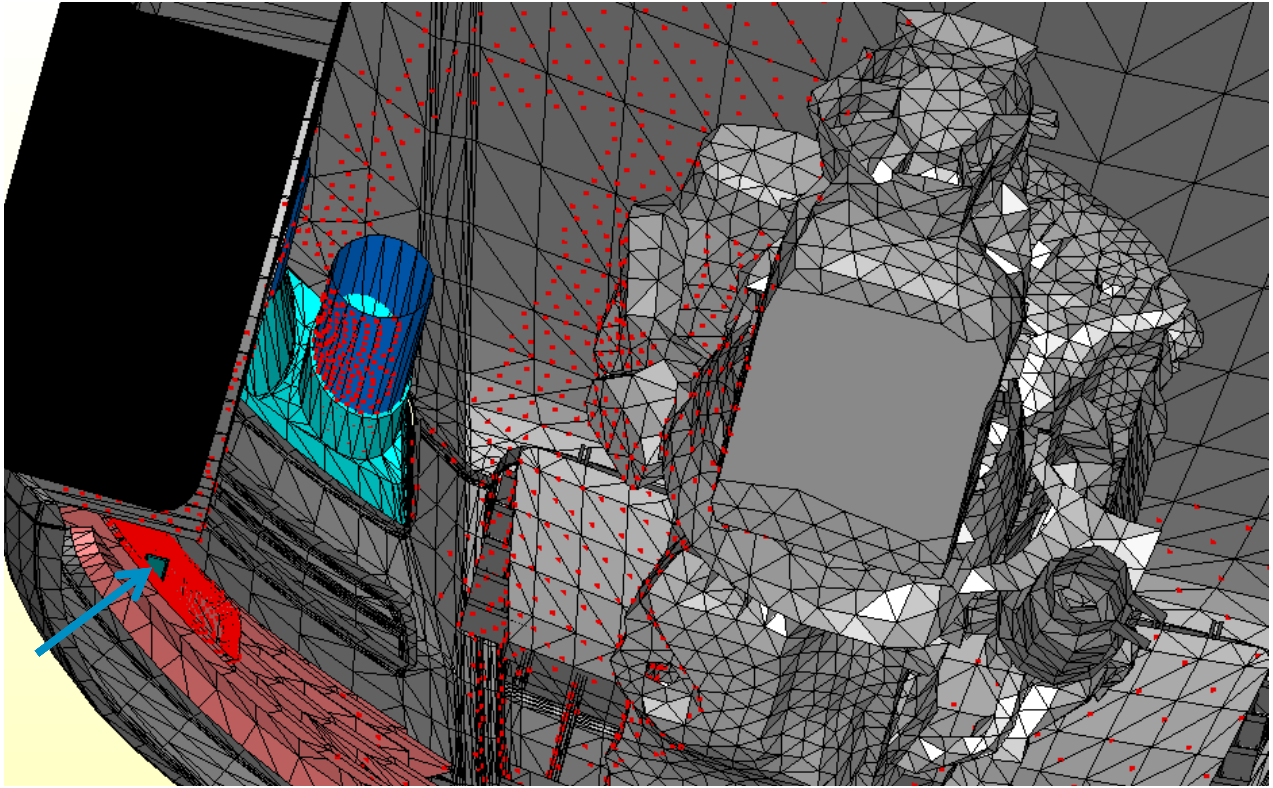




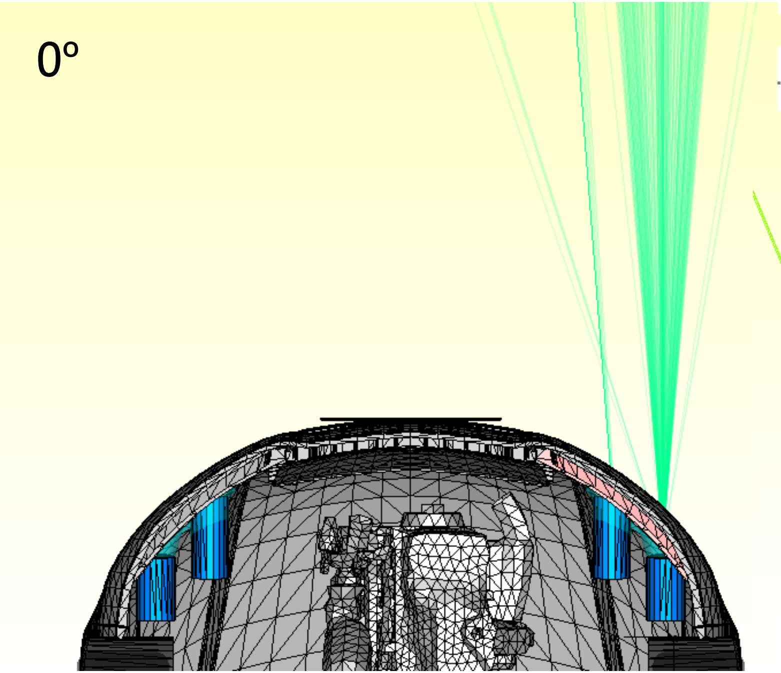
Phase Diagramm

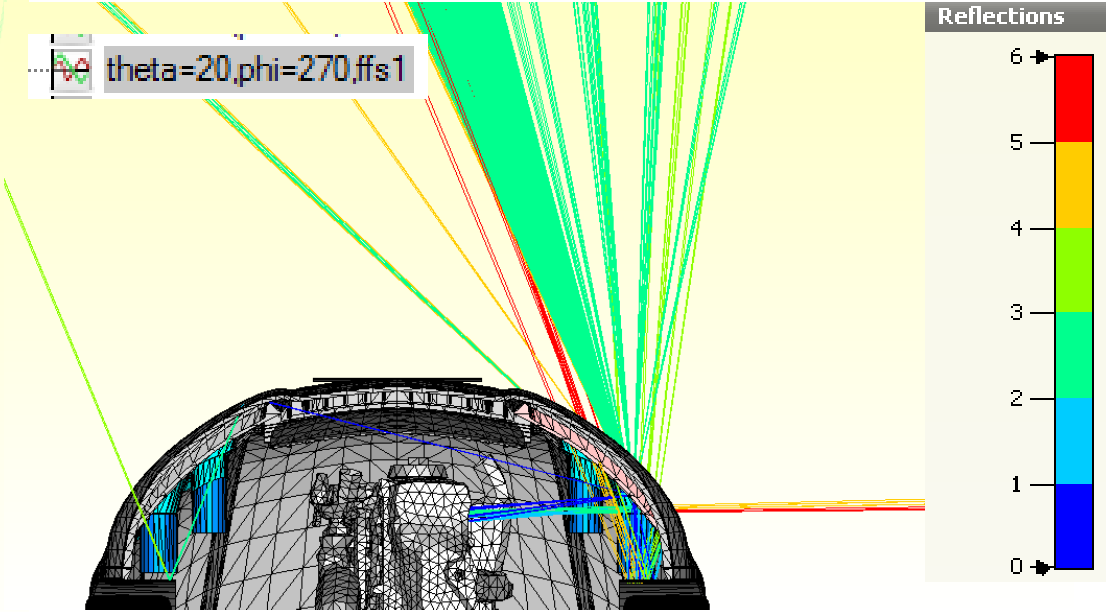


Ray-Tracing: Initial Hitpoints

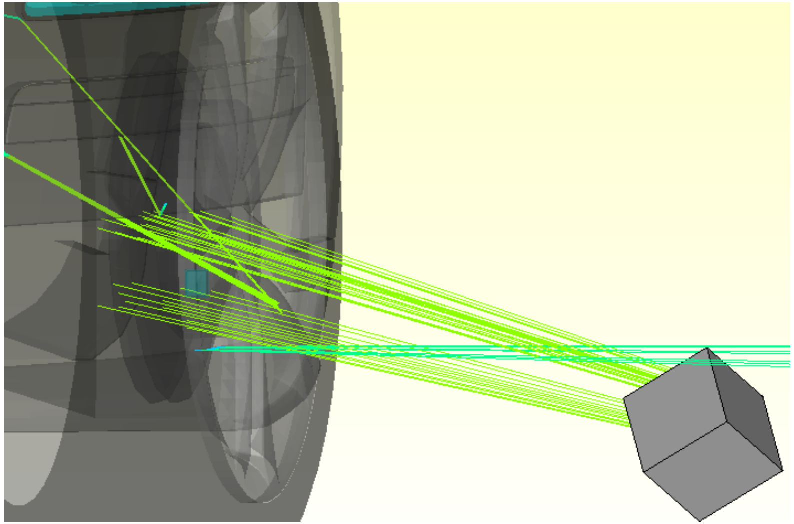


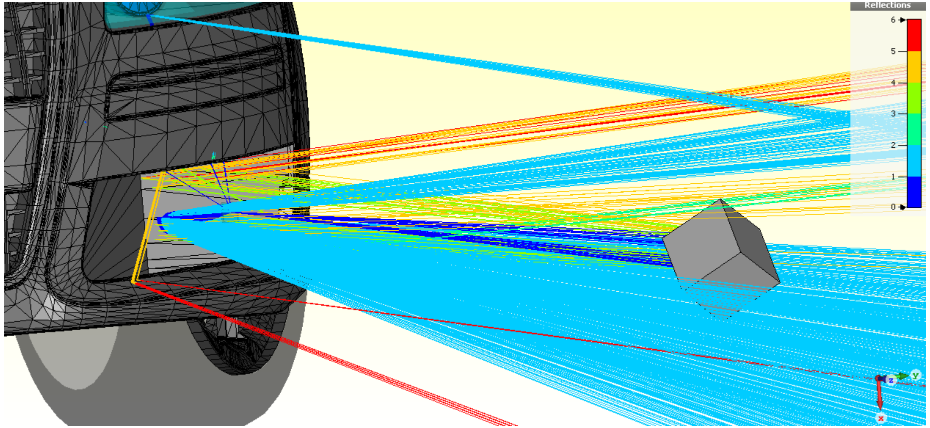
Ray-Tracing: Observation Angles

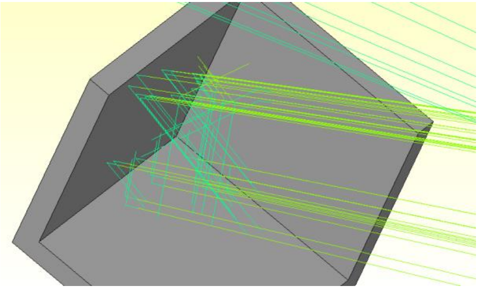


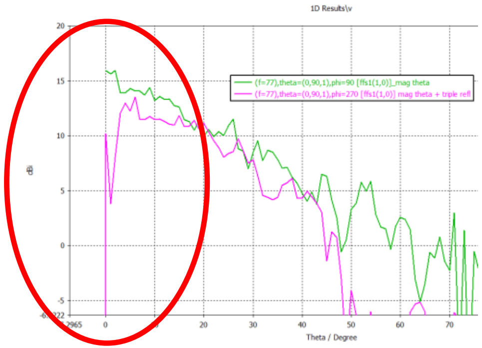


Nearfield Features: triple-reflector



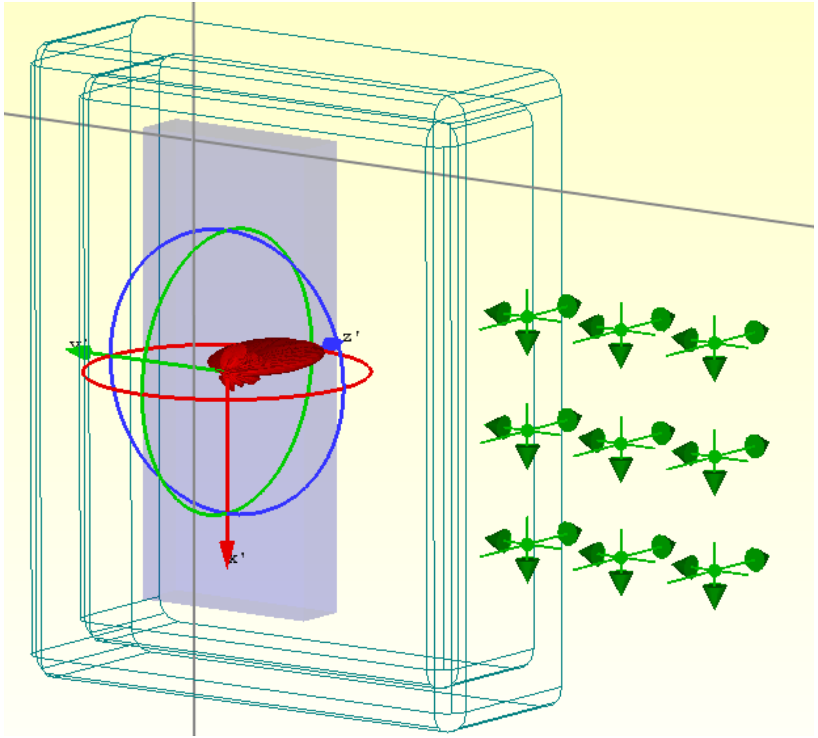


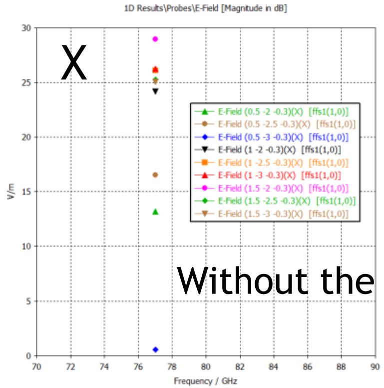


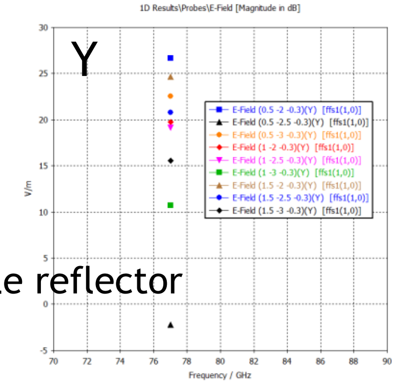


car+nf_ff+probes.cst

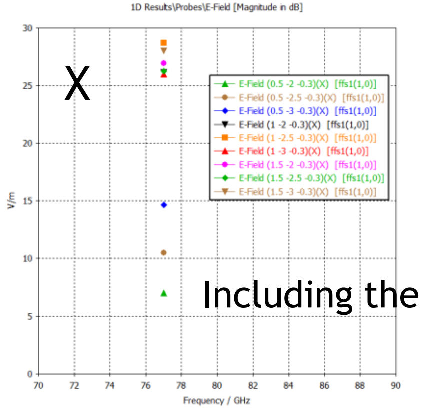
Nearfield Features: Probe locations

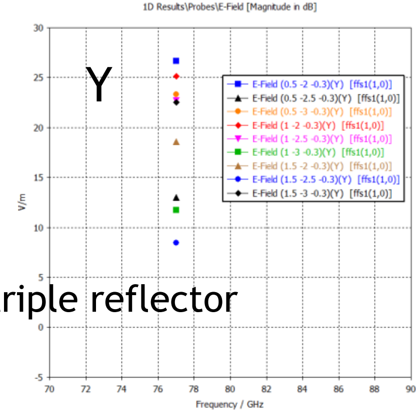






Without the triple reflector

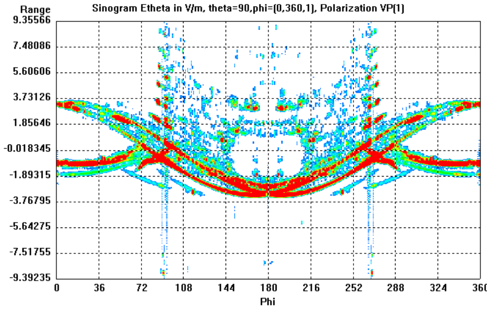


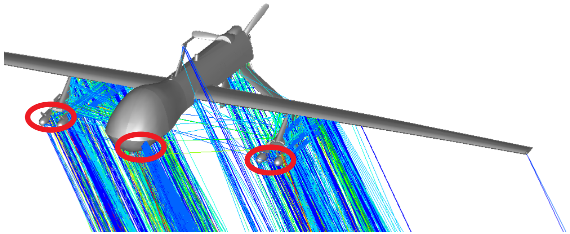


Including the triple reflector

Summary

- Complete Technology
- GUI easy to use and powerful
- A-Solver tailored for extremely high frequencies
- Application of a transeiver model
- A-Solver Special features
  - Range profiling
  - Hot Spot visualization





Any Questions?

Many thanks for your attention!