

CST STUDIO SUITE®

AUTOMOTIVE WORKSHOP SERIES

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



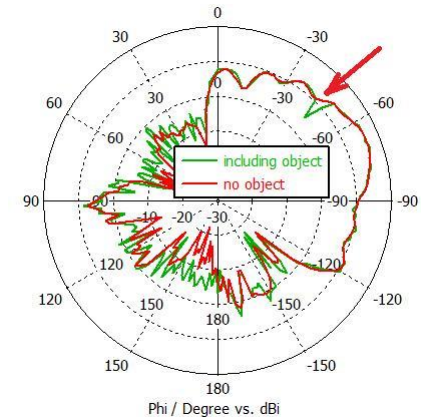
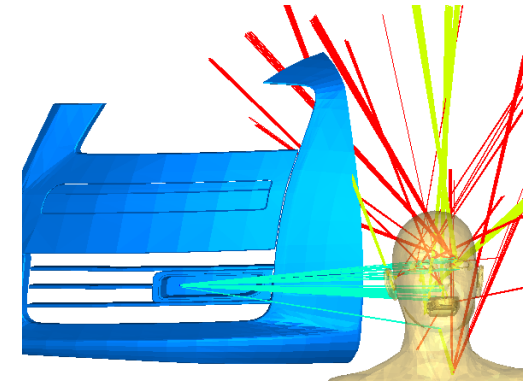
Franz Hirtenfelder CST / AG

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)

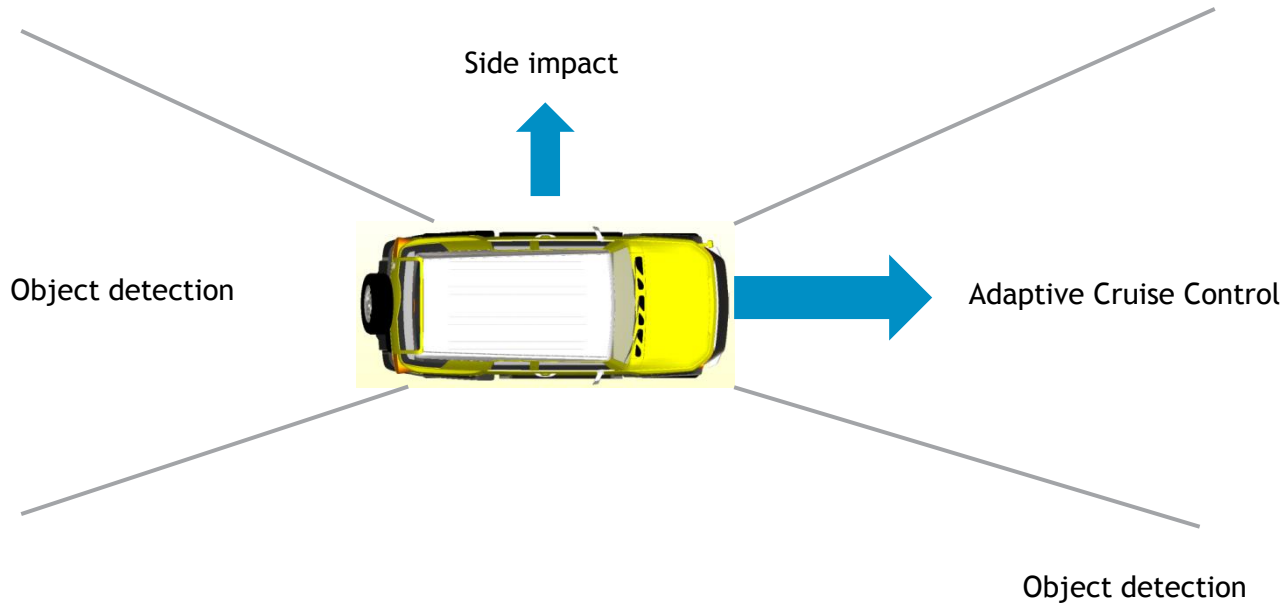
Automotive industry's efforts to achieve a goal of zero automotive-related fatalities, meeting consumer demand and government legislation, are driving adoption of advanced automotive safety systems.

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 (Advanced Driver Assistance System)

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

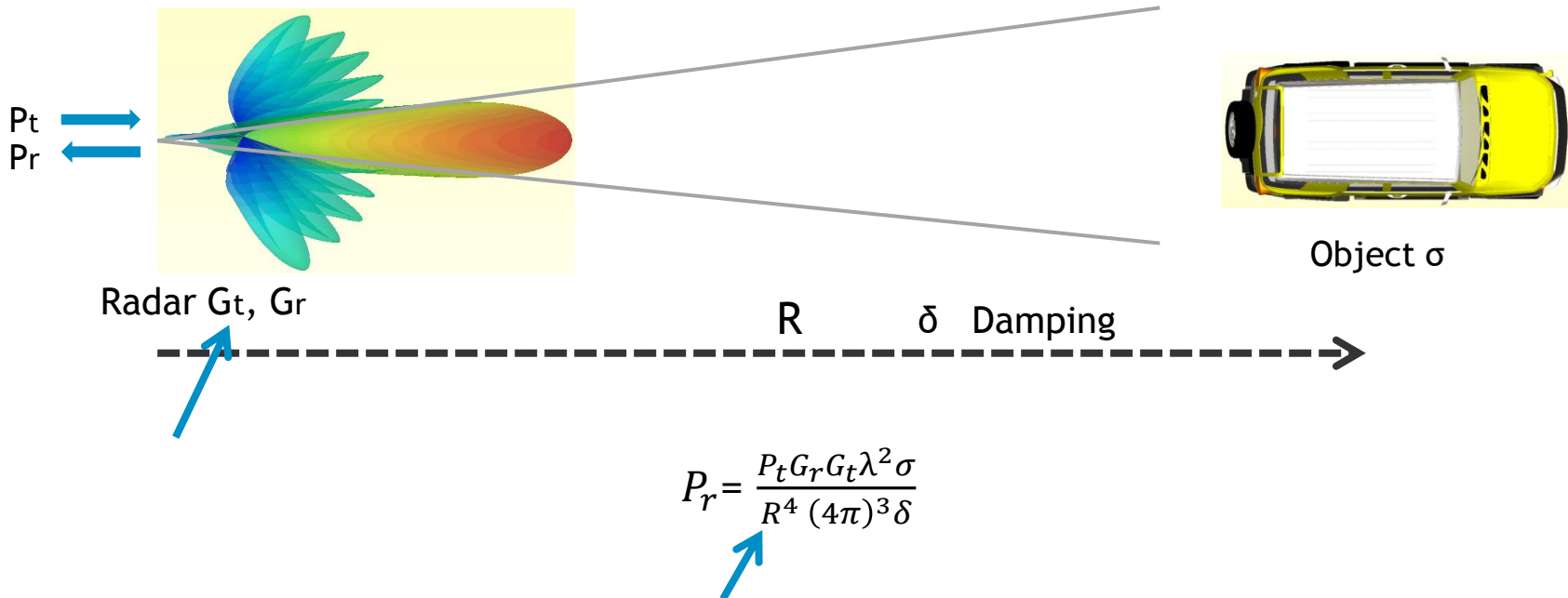
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Introduction (Radar)

1. Radar Equation (Range)

Relation between Receive and transmit power at the radar unit



Introduction (Radar)

2. Direction of Arrival Estimation

All conventional direction of arrival (DOA) estimation methods

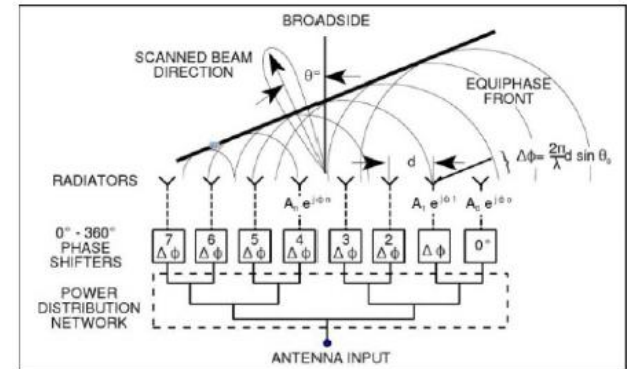
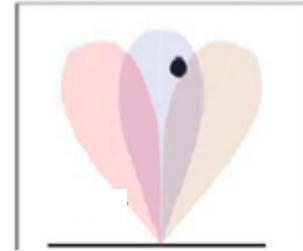
- monopulse techniques (comparison of the received signals in partially overlapping beams)
- Spatial power spectrum measurement techniques (mechanical scanning, phased array)

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.

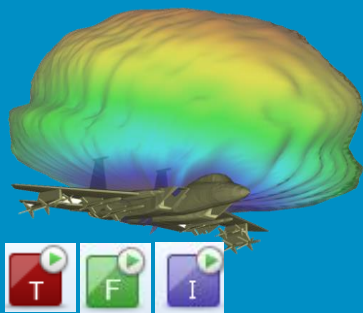


Overview

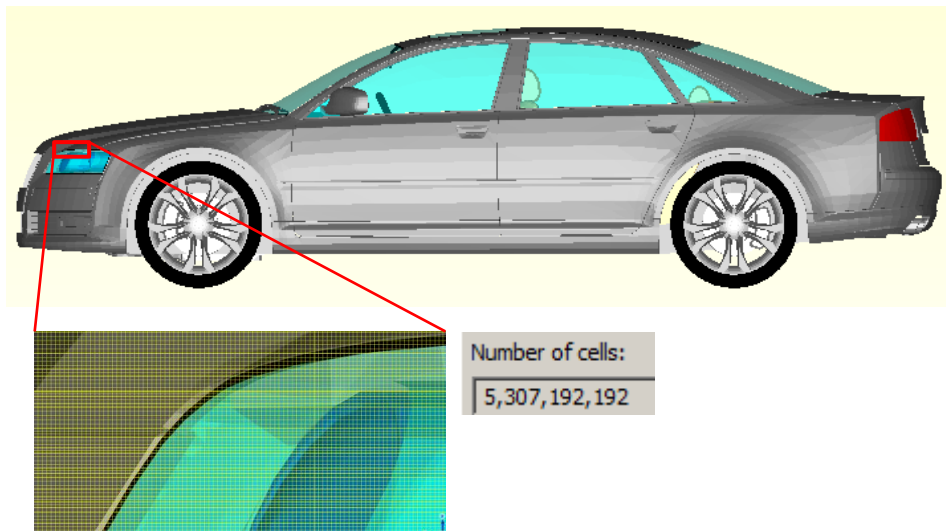
- Introduction
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How to simulate (@77GHz)?

Installed
Performance



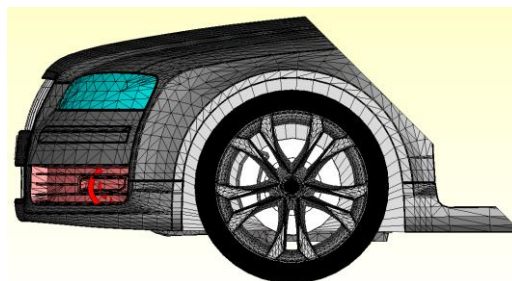
6GHz



Number of cells:

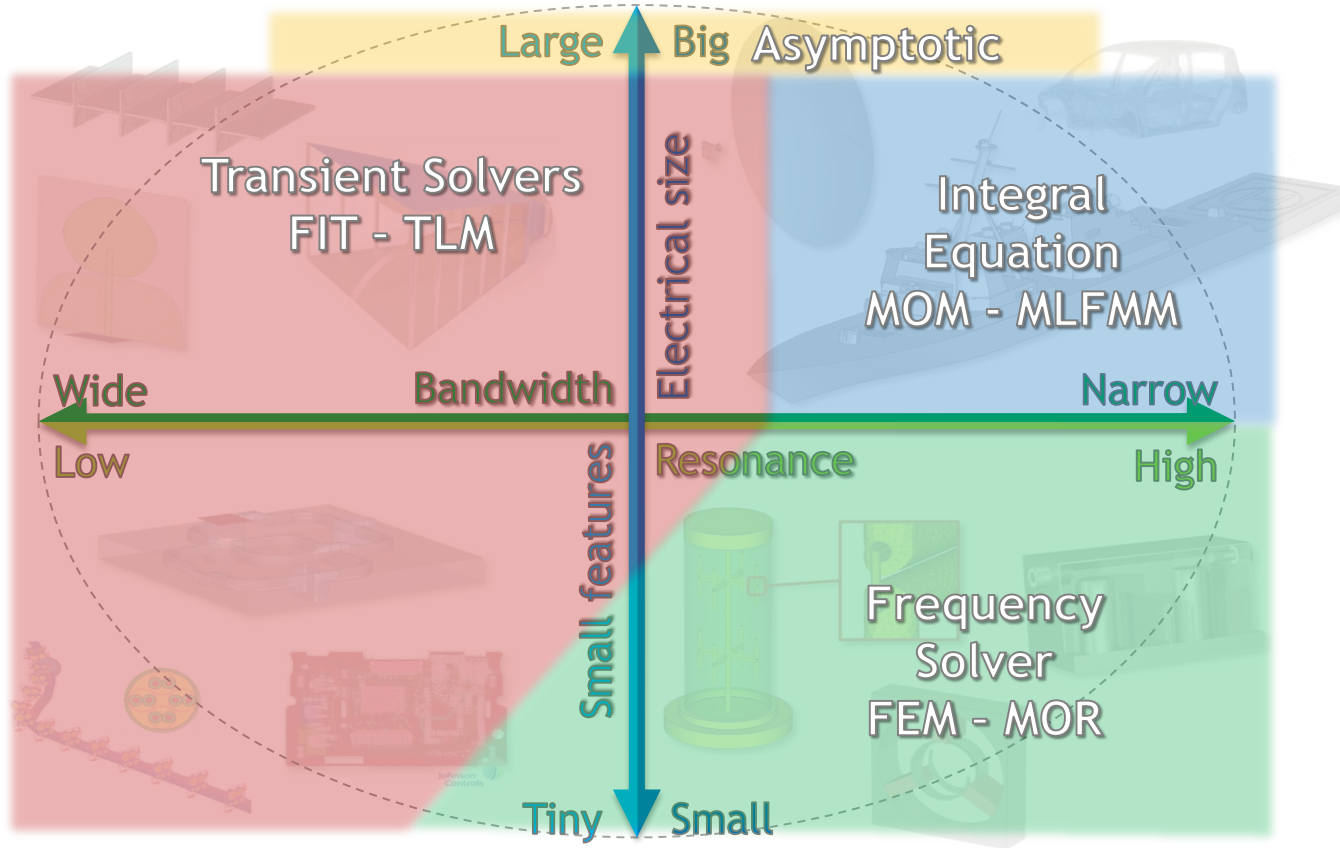
5,307,192,192

77GHz

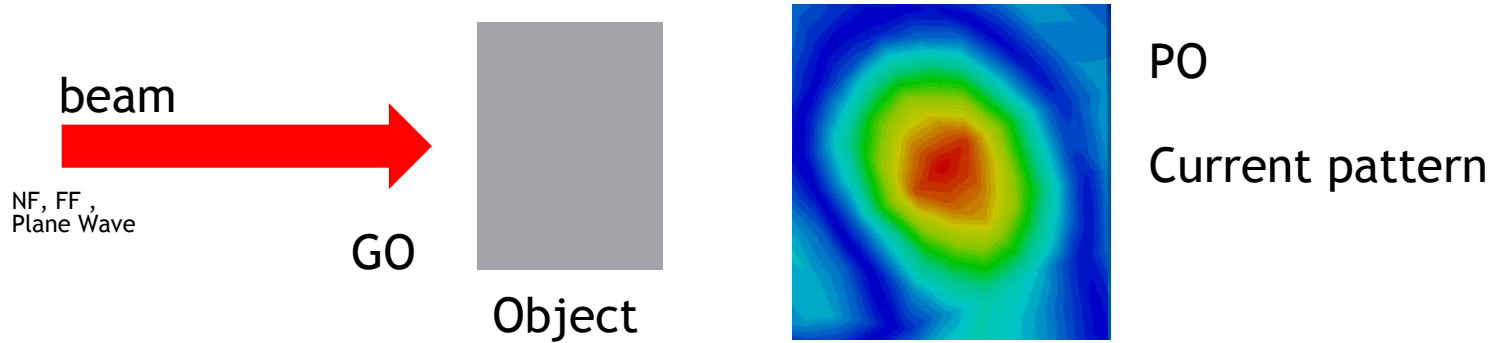


Meshcells=7,100,873,489,424

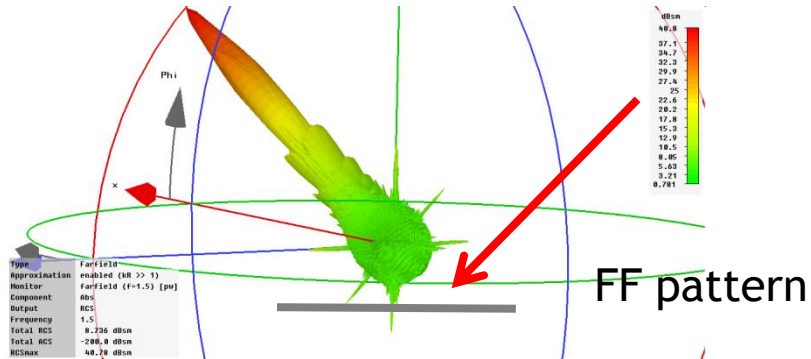
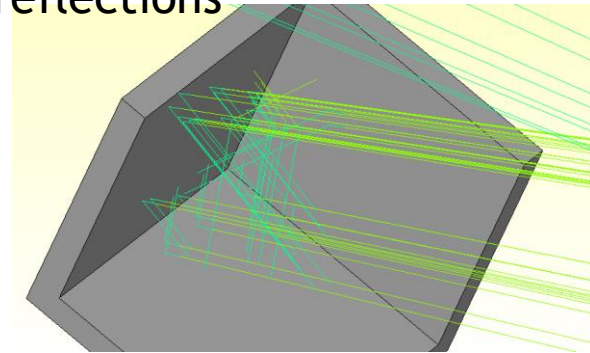
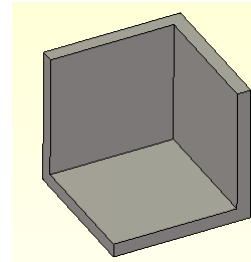
Simulation Techniques



Asymptotic Solver (Basics)

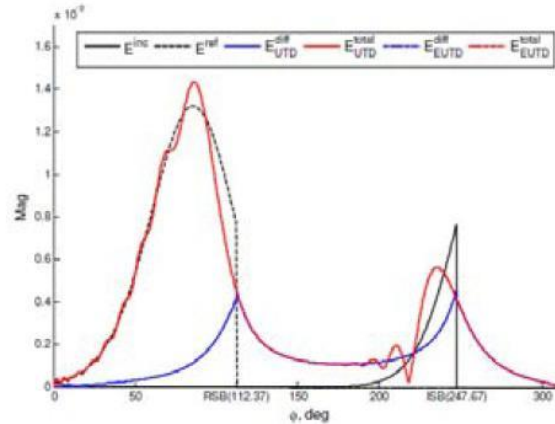
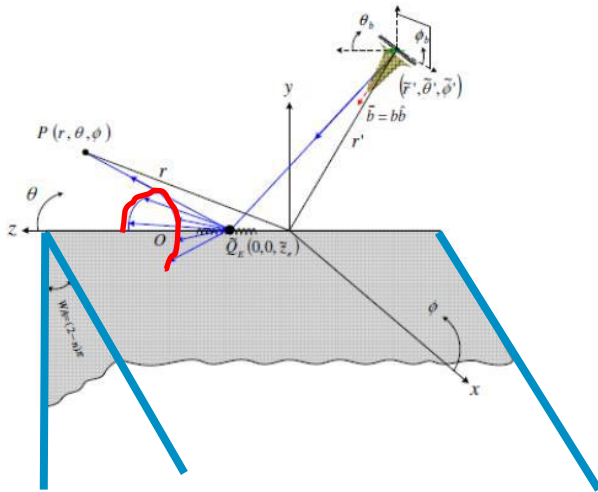


GO : multi reflections



Asymptotic Solver (Basics)

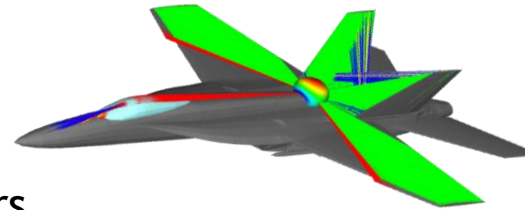
Edge Diffraction PTD



A-Solver: SBR Methodology



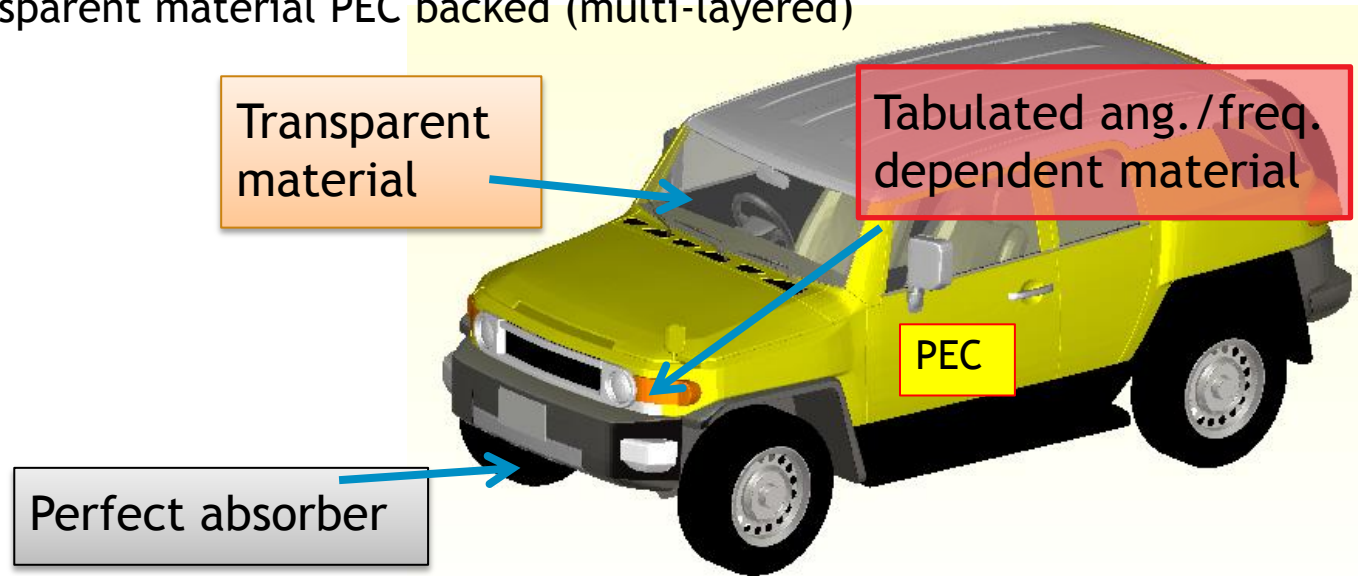
- What is SBR?
 - Shooting and Bouncing Rays
 - Asymptotic technique
 - Complimentary capability to full-wave solvers
 - Electrically large platforms (*i.e.*, many wavelengths in dimension)
 - Extends PO to multiple bounces with GO ray tracing
 - Incident Field = free space fields of antenna
 - Scattered 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

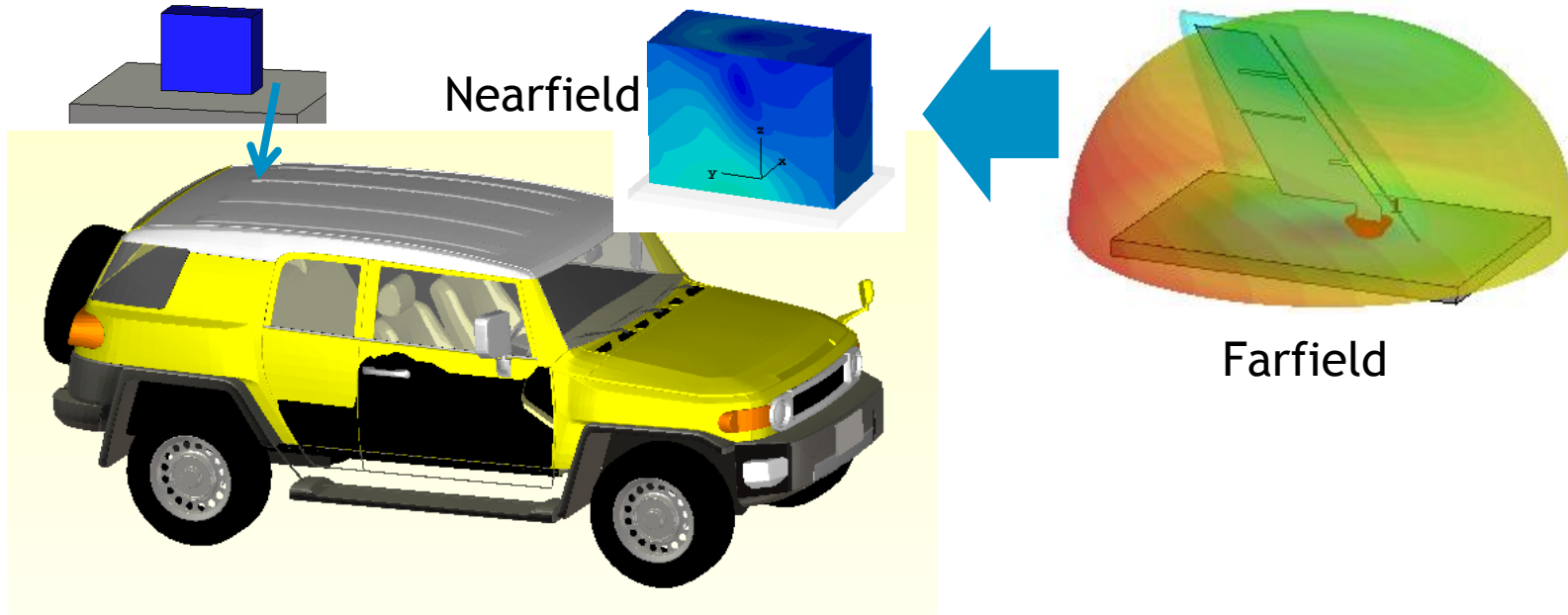
Materials

- 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

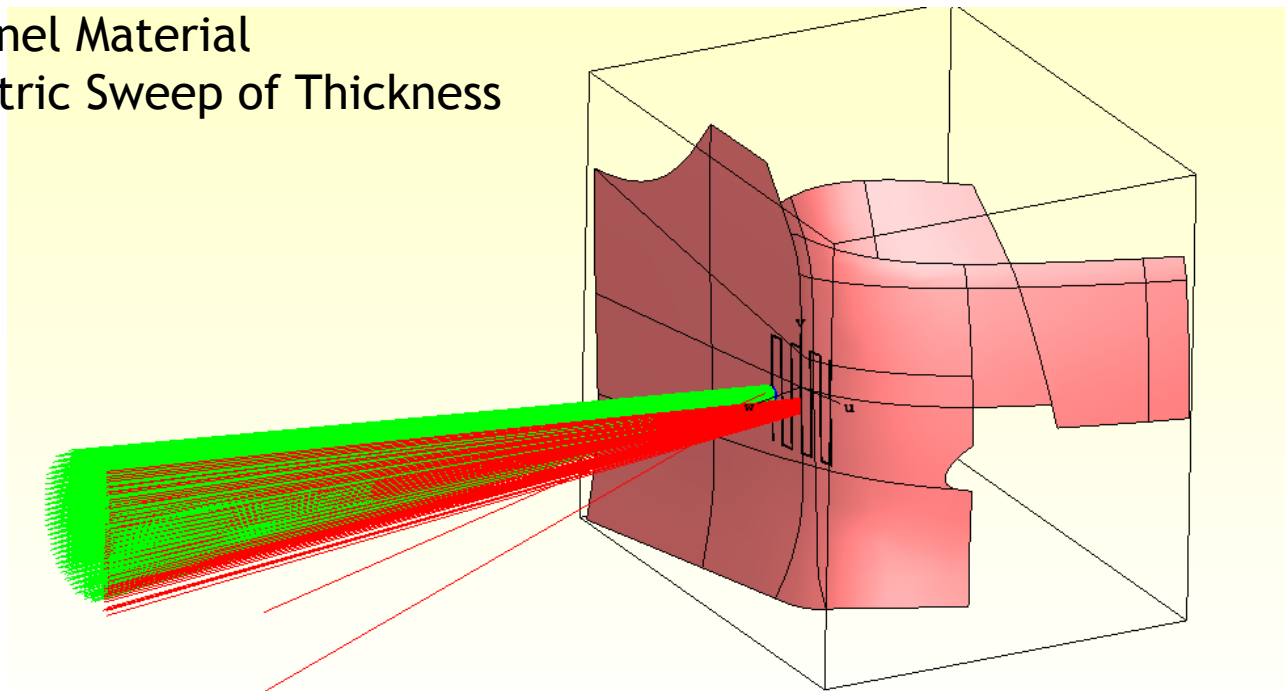


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Simple Demo: Bumper + NFSource

Thin Panel Material
Parametric Sweep of Thickness



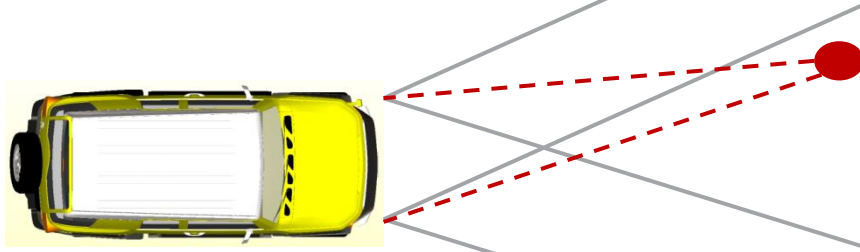
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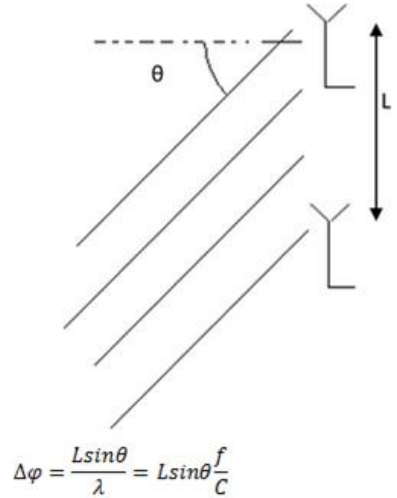
Direction of Arrival Estimation II

Multistatic approach using multi distributed sensors

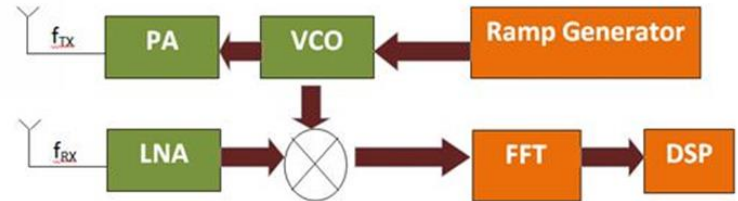
By using two or more antennas with a separation of L , the angular position of the detected object can be determined, based on the phase difference between the signals received at each of the antennas.



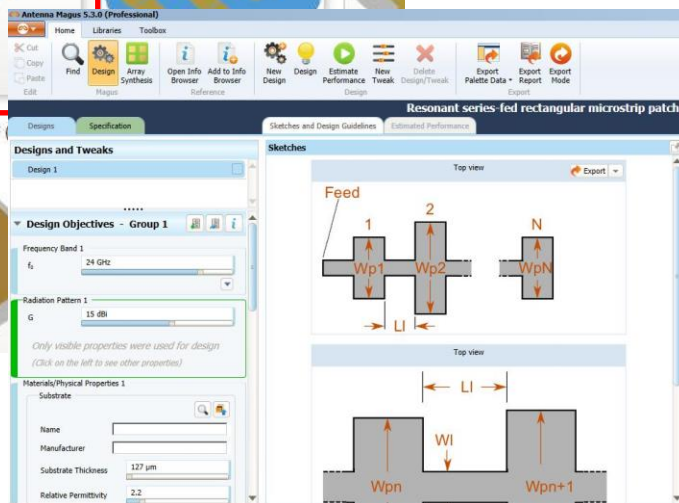
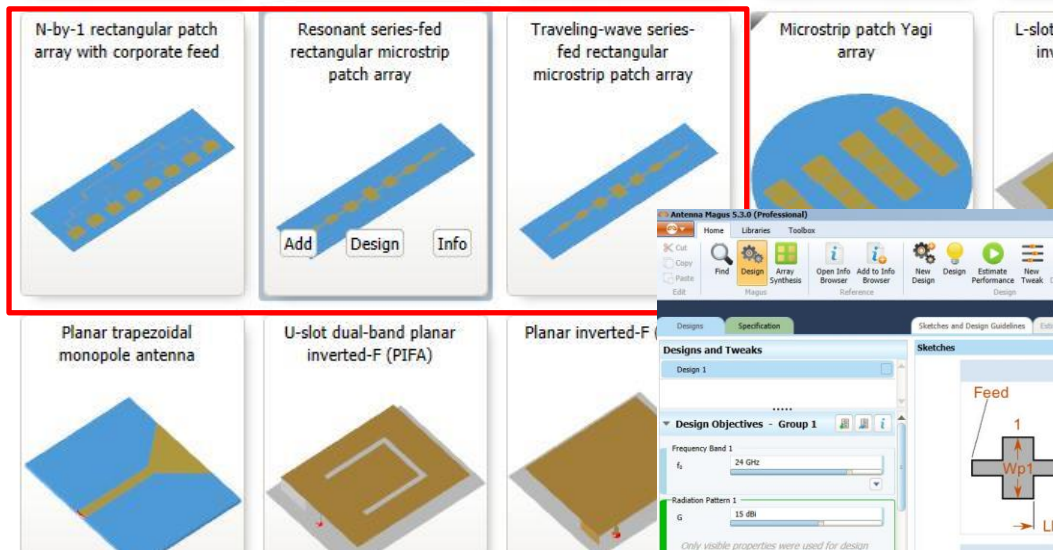
The two antennas can be spaced closer, e.g. $\lambda/2$ free space distance apart to allow direction of arrival (DOA) estimation of a target detected by the radar.



Radar Transceiver Architectures



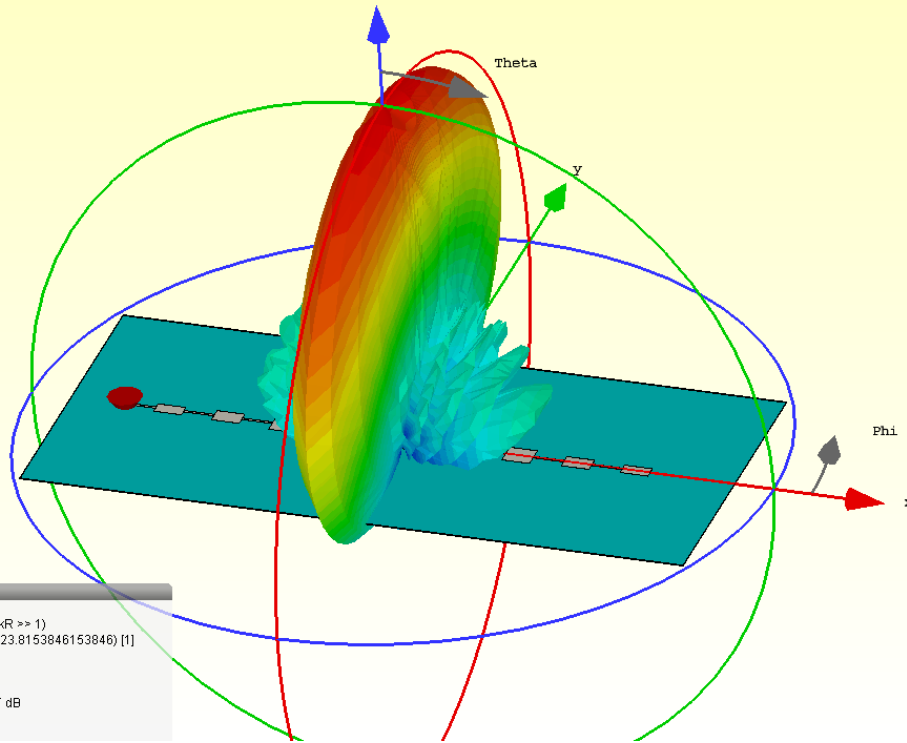
Antenna Definition



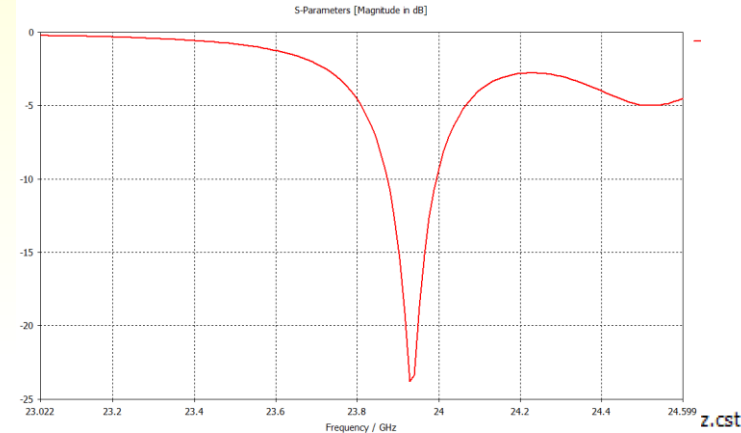
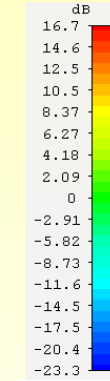
Import into CST-MWS



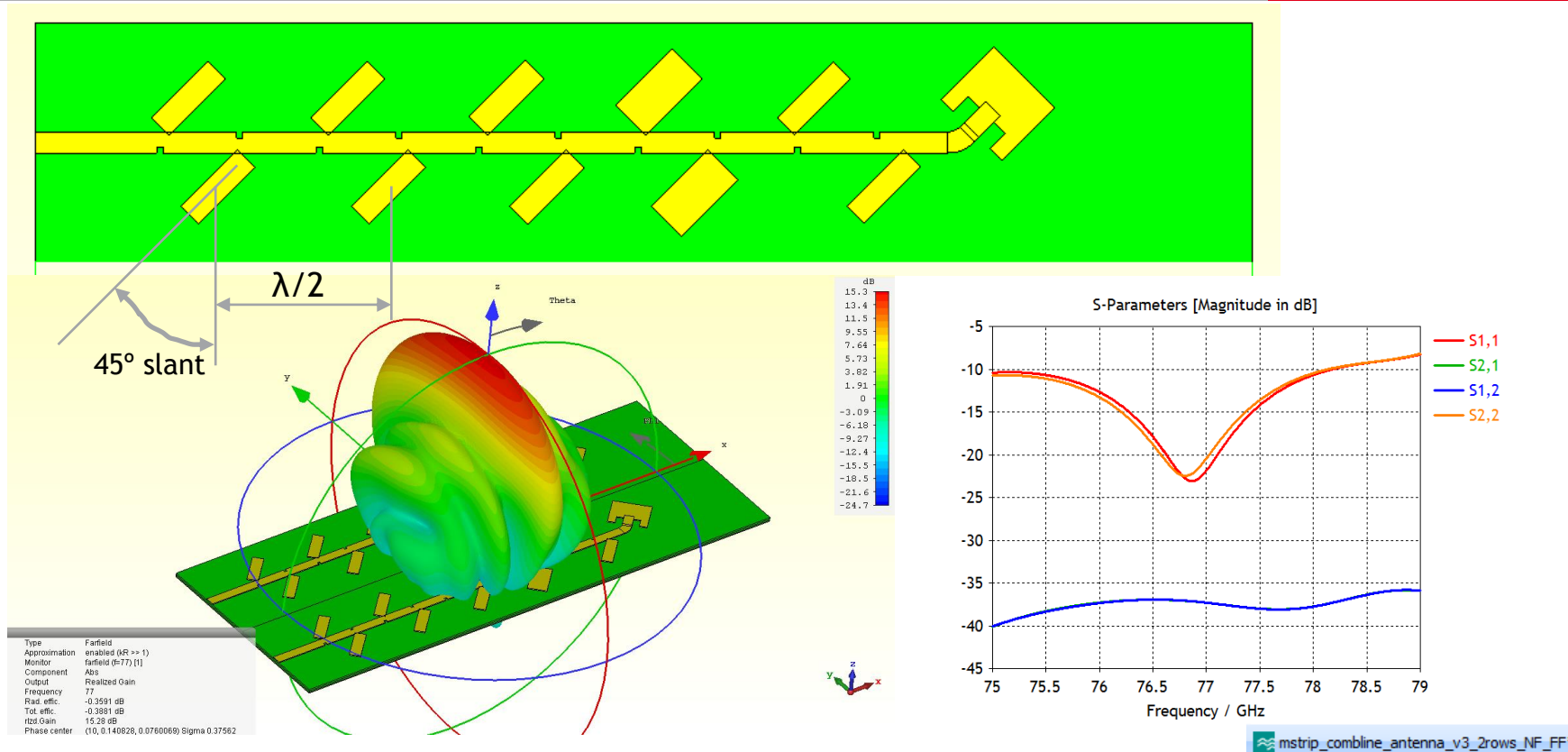
CST
MICROWAVE
STUDIO



Type	Farfield
Approximation	enabled (KR >> 1)
Monitor	farfield (f=23.8153846153846) [1]
Component	Abs
Output	Gain
Frequency	23.8154
Rad. eff.	-0.002317 dB
Tot. eff.	-1.520 dB
Gain	16.73 dB

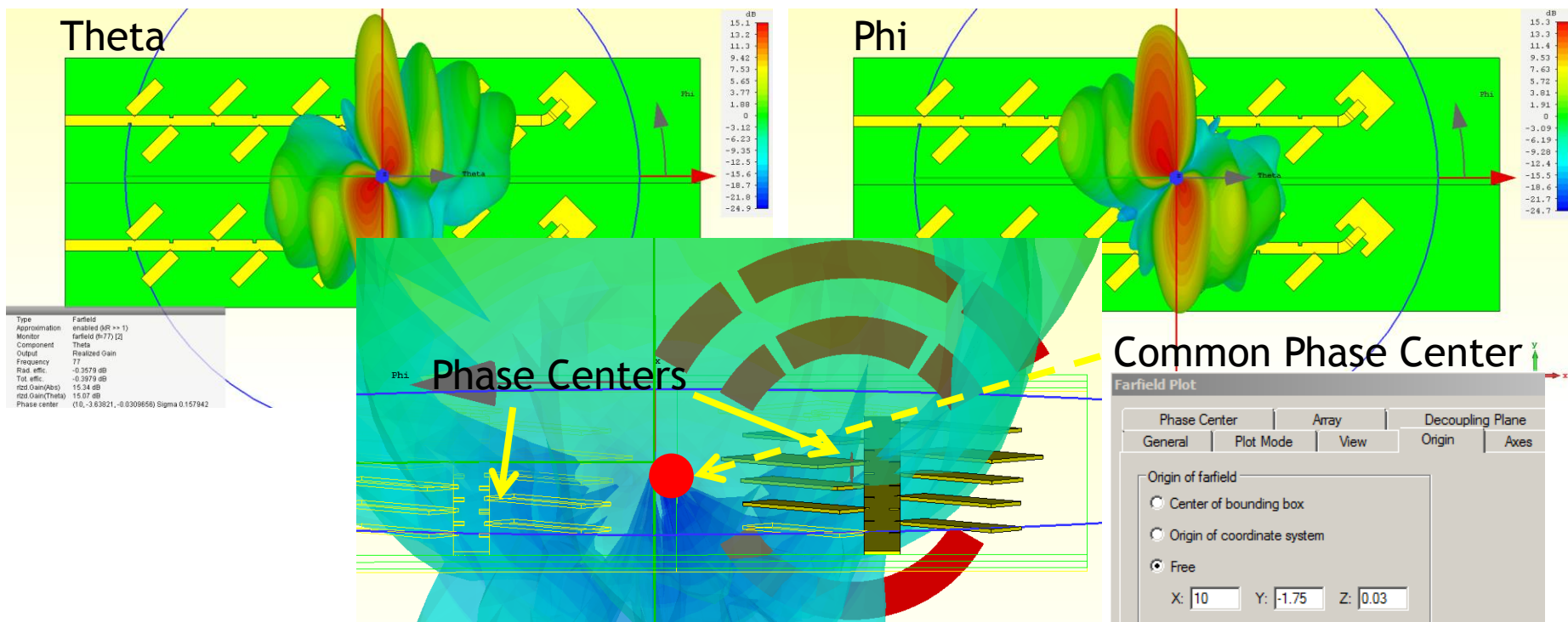


Microstrip Comb-Line Antenna Array



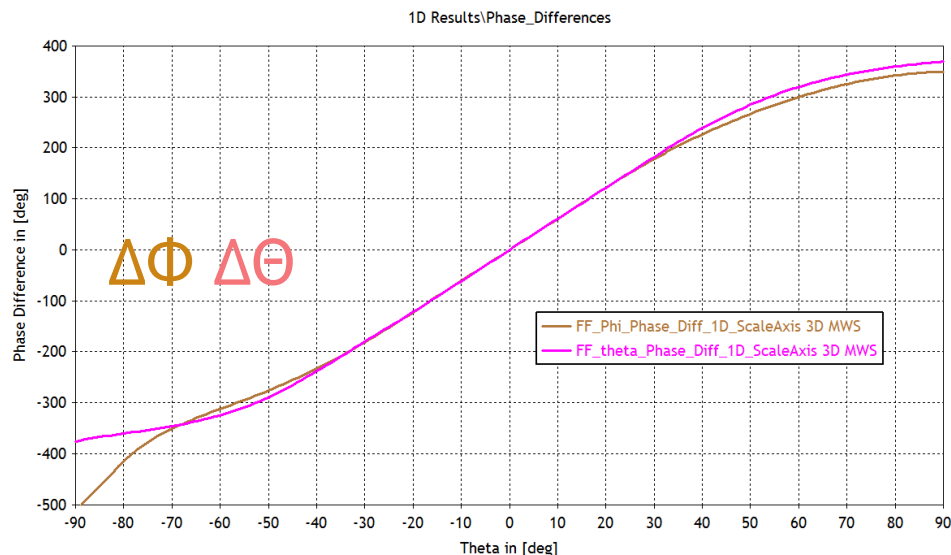
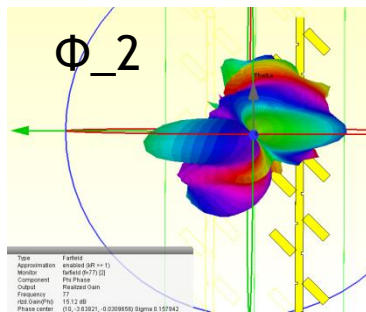
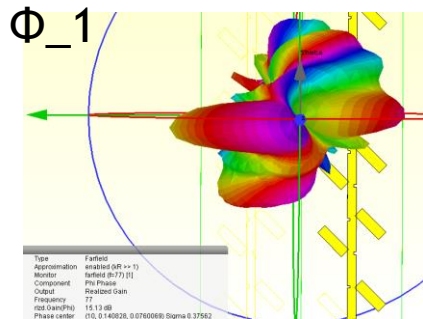
Microstrip Comb-Line Antenna Array

Transceiver Configuration: $N\lambda/2$ apart (to determine the phase difference)



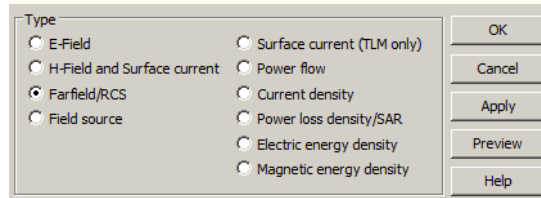
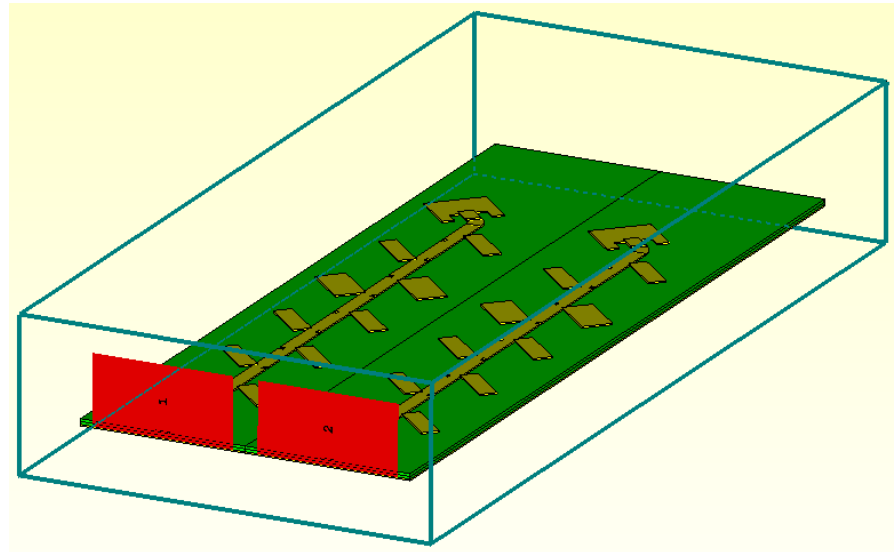
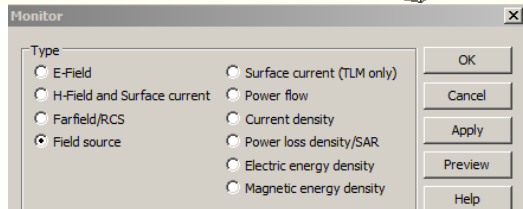
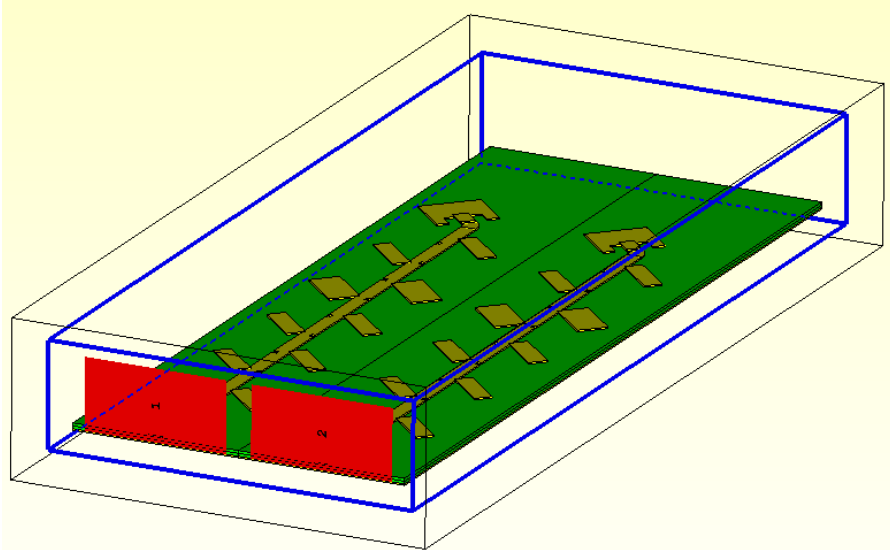
Microstrip Comb-Line Antenna Array

Computing the phase difference: $\Delta\Phi$ and $\Delta\Theta$



Near- and Farfield Generation

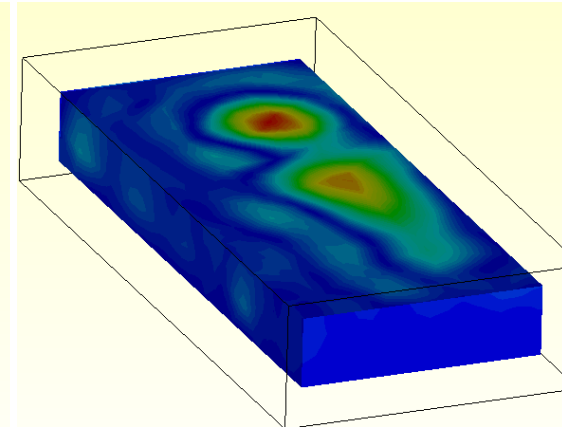
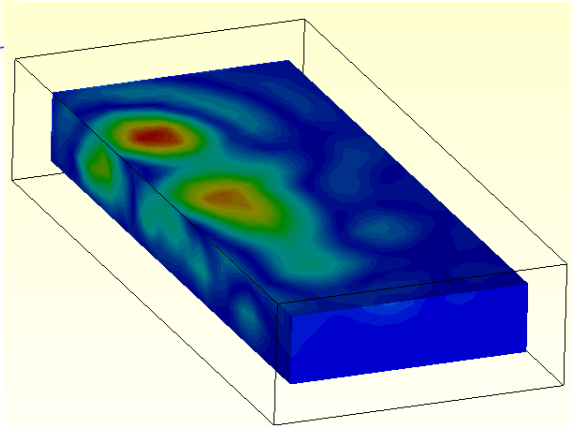
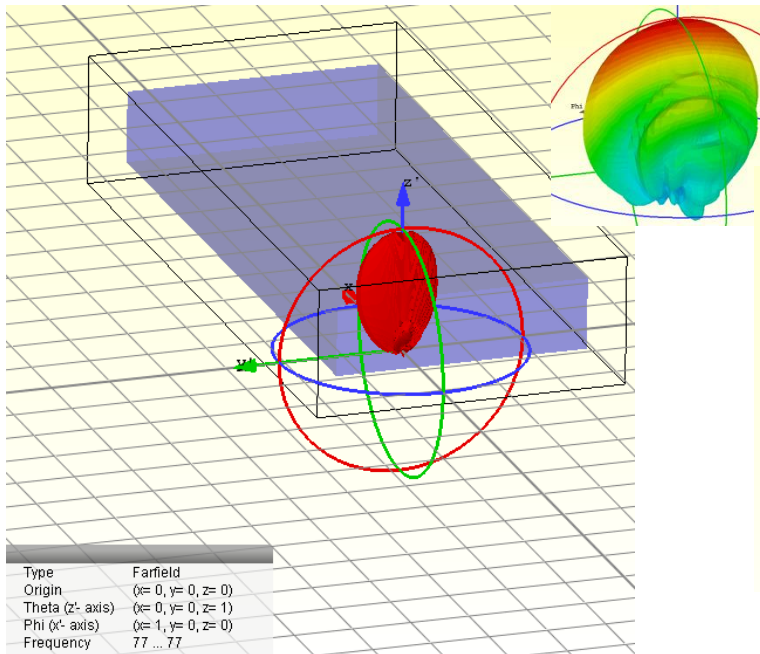
...as feed for the A-Solver



☒ Export farfield source

Import of Near/Farfield

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



A-Solver Setup and Results



Asymptotic Solver Parameters

Solver settings

Mode: ☐ Store results as tables only

Accuracy:

Maximum number of reflections:

Field source settings

	Name	Frequency	Amplitude	Phase	Rays	Sourcetype
<input checked="" type="checkbox"/>	ffs1	77	1.0	0.0	<input checked="" type="checkbox"/>	Farfield
<input checked="" type="checkbox"/>	ffs2	77	1.0	0.0	<input type="checkbox"/>	Farfield
<input checked="" type="checkbox"/>	fs2	77	1.0	0.0	<input type="checkbox"/>	Nearfield

☐ Simultaneous excitation of field sources

Sweep parameters

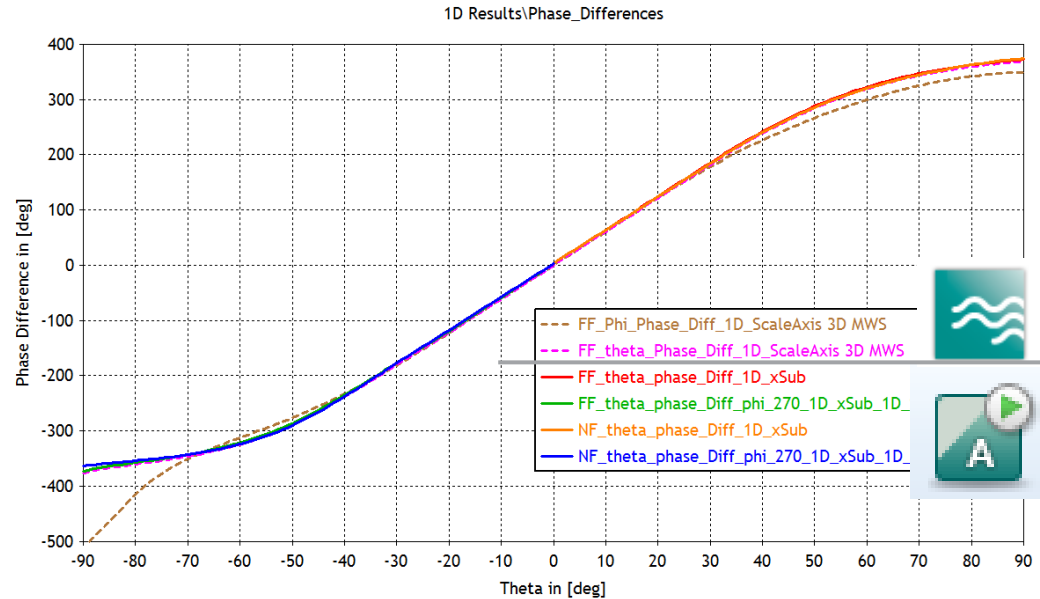
Frequency sweeps:

Fmin	Fmax	Fstep
76	78	
77	77	0.2

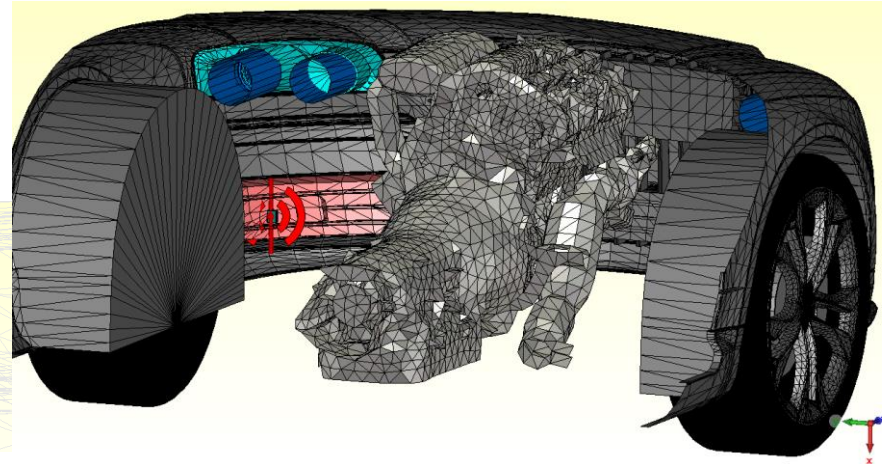
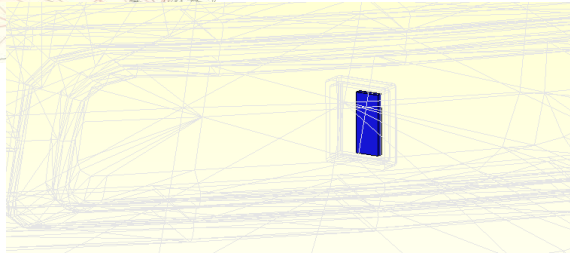
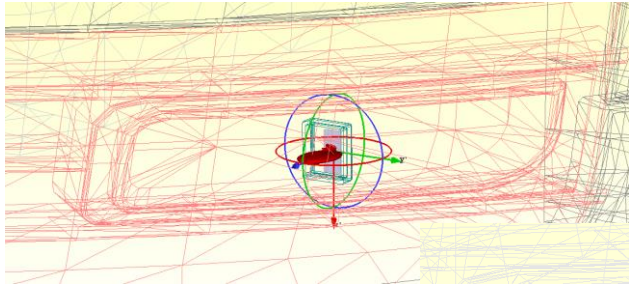
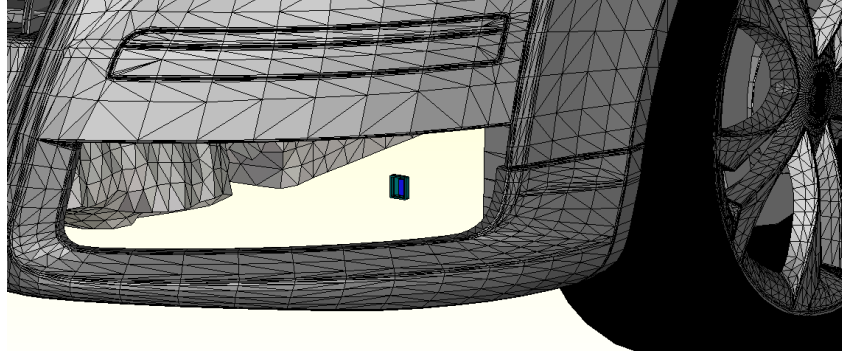
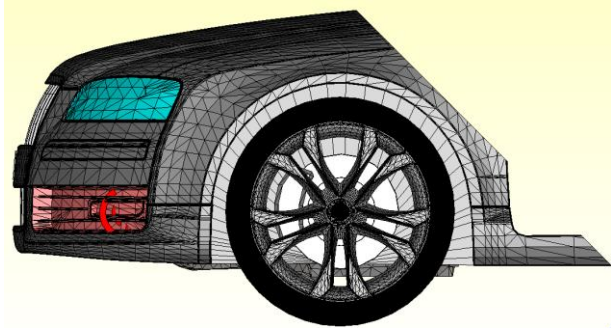
Observation angle sweeps:

Sweep	Tmin	Tmax	Tstep	Pmin	Pmax	Pstep	Rays
Theta	0	180	1	270			<input checked="" type="checkbox"/>

Θ -Scan ($-\Phi$, $+\Phi$)



NF/FF + automobile environment



A-Solver Setup /Runtime



Asymptotic Solver Parameters

Solver settings

Mode: **Field sources** ☐ Store results as tables only

Accuracy: **Low** Settings...

Maximum number of reflections: 5

Field source settings

Name	Frequency	Amplitude	Phase	Rays	Sourcetype
<input checked="" type="checkbox"/> fs2	77	1.0	0.0	<input checked="" type="checkbox"/>	Farfield
<input checked="" type="checkbox"/> fs1	77	1.0	0.0	<input checked="" type="checkbox"/>	Nearfield

☐ Simultaneous excitation of field sources

Sweep parameters

Frequency sweeps:

Fmin	Fmax	Fstep
76	77	
77	77	0.1

Add... Edit... Delete

Observation angle sweeps:

Sweep	Tmin	Tmax	Tstep	Pmin	Pmax	Pstep	Rays
Theta	0	90	1	90			<input checked="" type="checkbox"/>
Theta	0	90	1	270			<input checked="" type="checkbox"/>

Add... Edit... Delete

Start Close Apply Optimizer... Par. Sweep... Acceleration... Help

Mesh statistics:

Number of quadratic triangles: 1128774
Minimum distance of element vertices in m: 5.96046e-010
Maximum distance of element vertices in m: 0.0367421
Average distance of element vertices in m: 0.00545697

Bounding box minimum corner: [-0.595313, -1.61242, -1.44812]
Bounding box maximum corner: [0.277144, 0.225222, 0.342483]

Number of generated wedge segments: 0

The GPU driver version used on this system has not been tested by CST.

Using GPU acceleration with 1 device(s).

Incident field by farfield source group #1
Number of ray-tubes generated at start-up: 2094816
Computed intersections:

Hit-Point Depth	Num. Reflections
1	7063540
2	10473931
3	14186976
4	21332572
5	32227230

Hit-Point Depth	Num. Transmissions
1	5149134
2	7069451
3	11158641
4	17279437
5	27352459

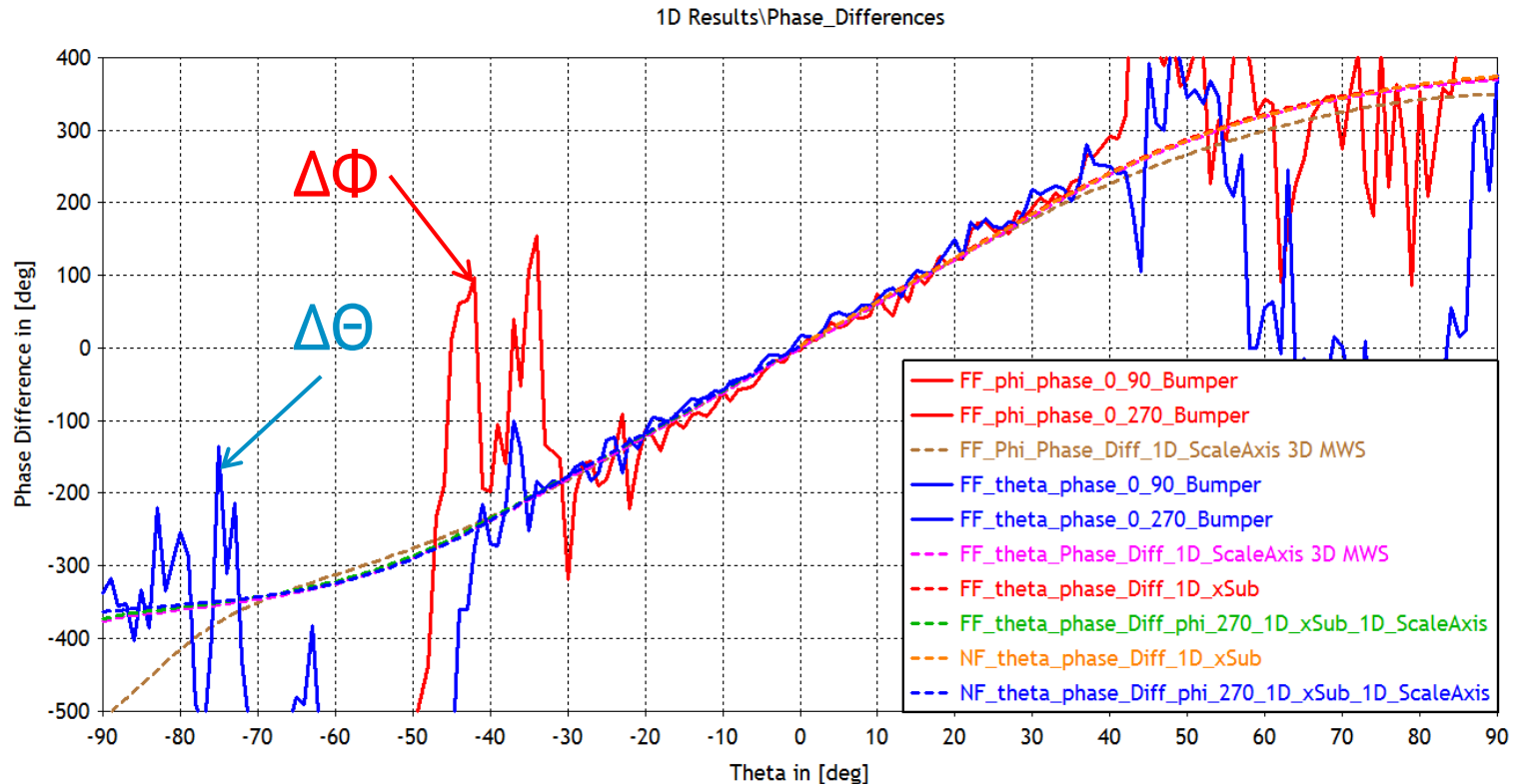
Solver Statistics:

Number of threads used: 12

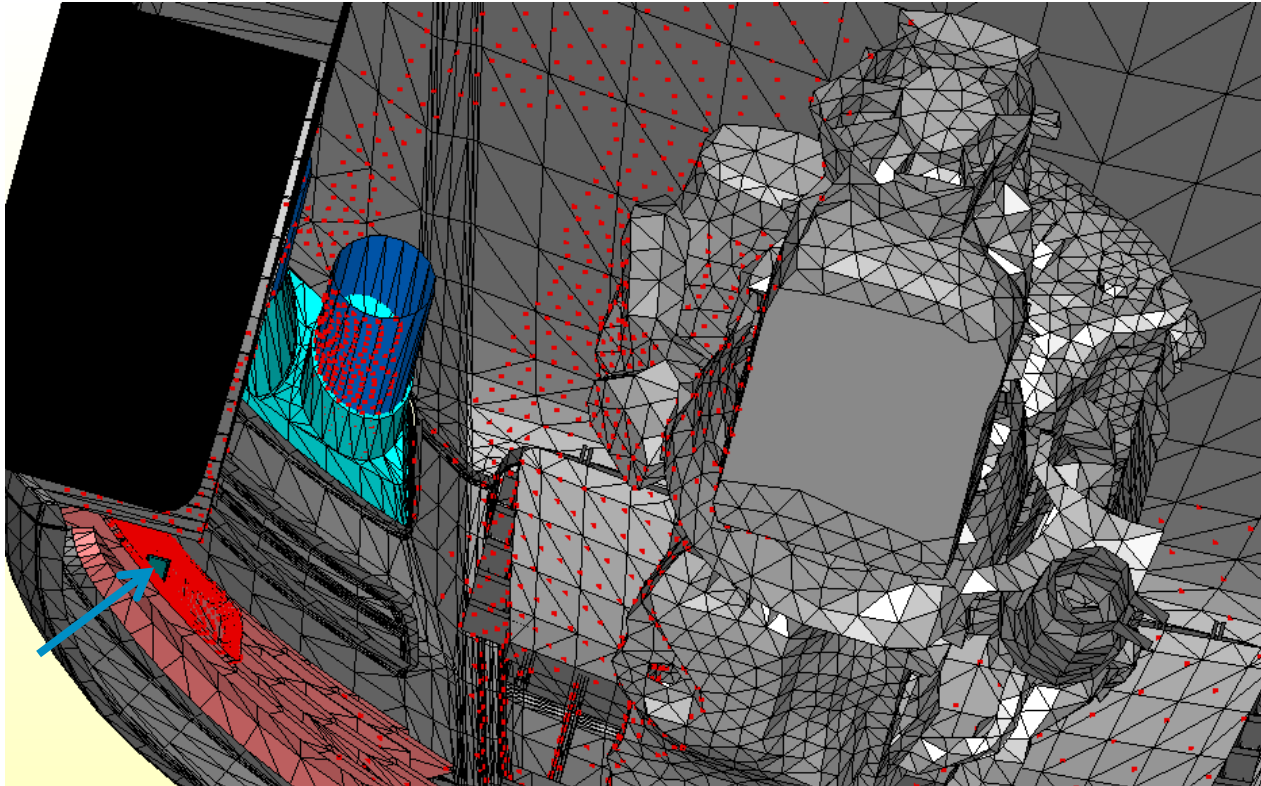
Mesh generation time : 29 s
Solver time : 270 s (= 0 h, 04 m, 30 s)
Total time : 299 s (= 0 h, 04 m, 59 s)

	Peak memory used (kB)	Free physical memory (kB) At Begin Minimum
Solver start	31340	26456072 26455868
Solver run total	10265900	26452796 16160898

Phase Diagramm



Ray-Tracing: Initial Hitpoints



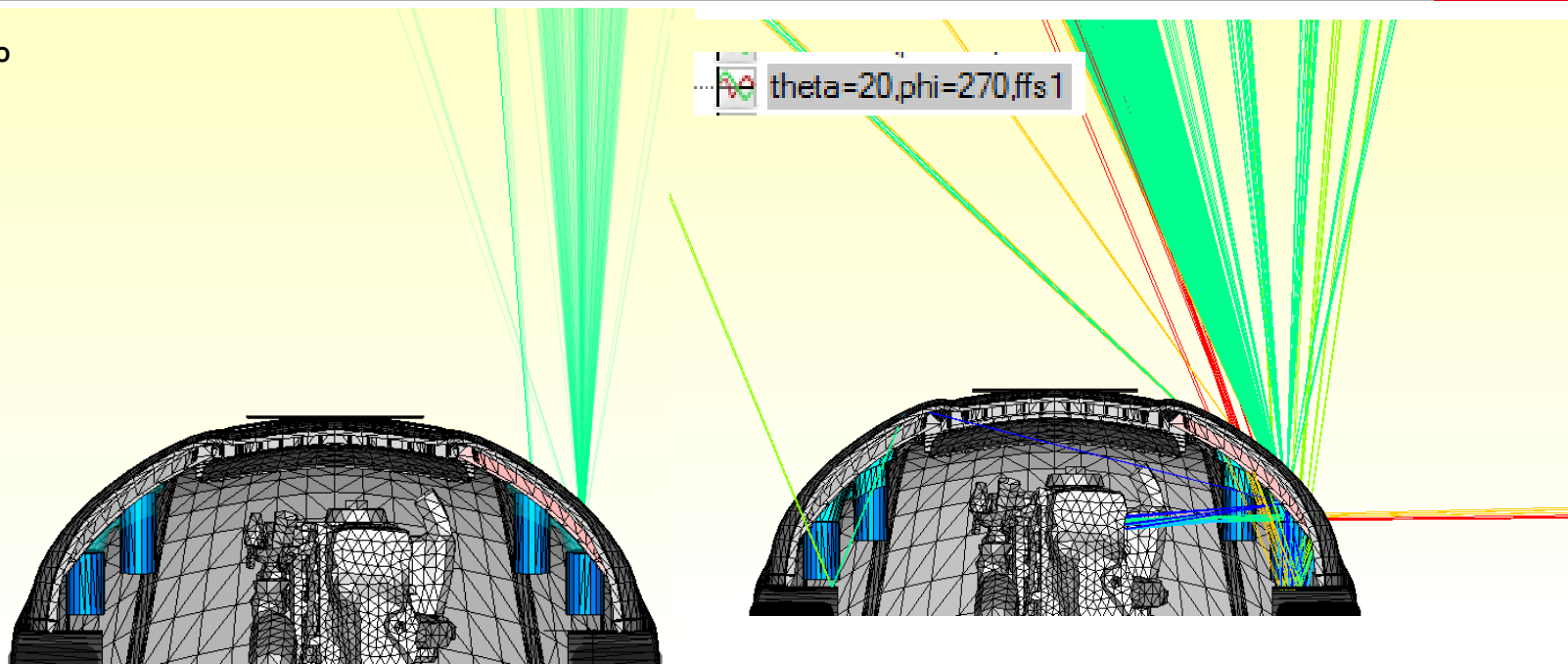
Ray-Tracing: Observation Angles

0°

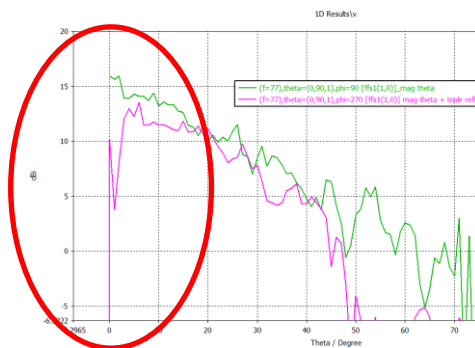
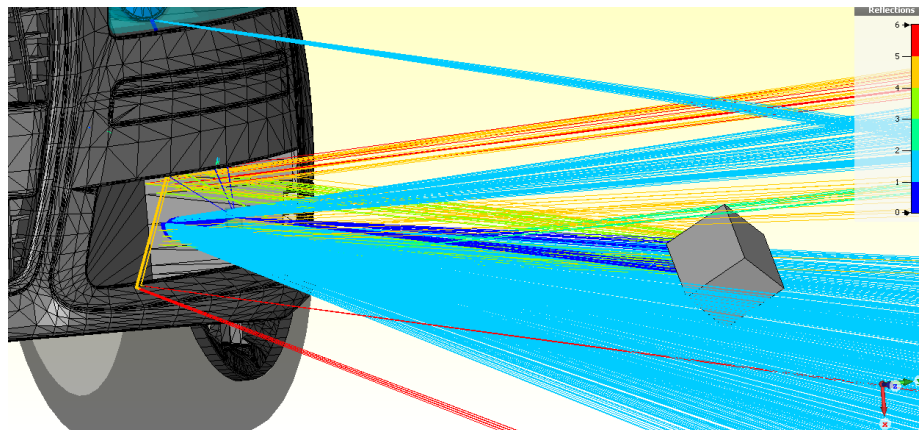
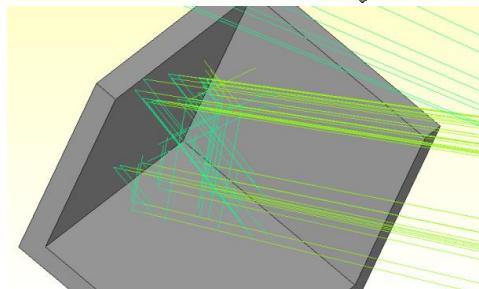
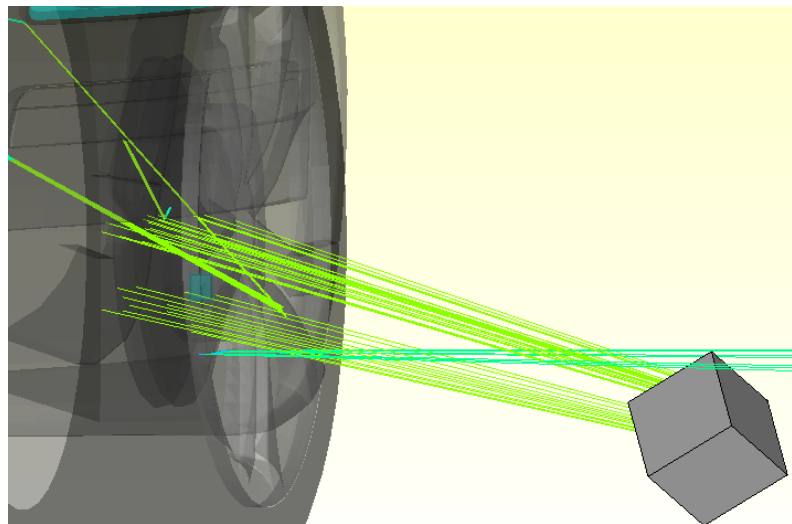
theta=20,phi=270,fs1

Reflections

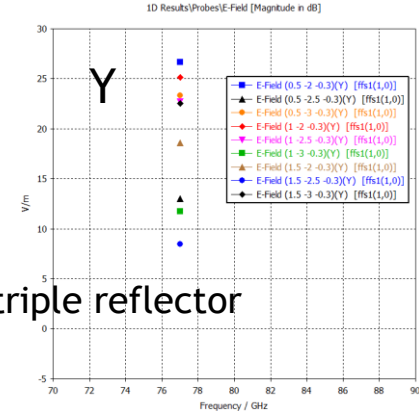
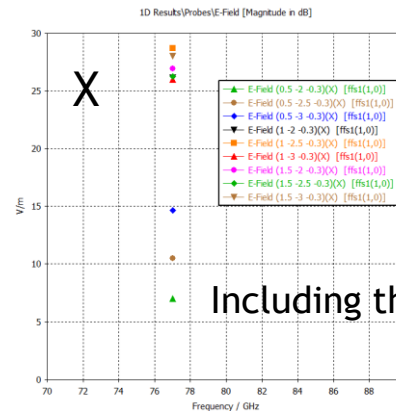
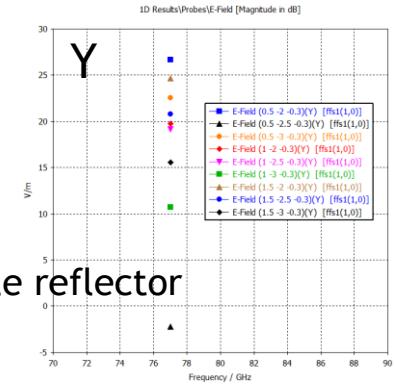
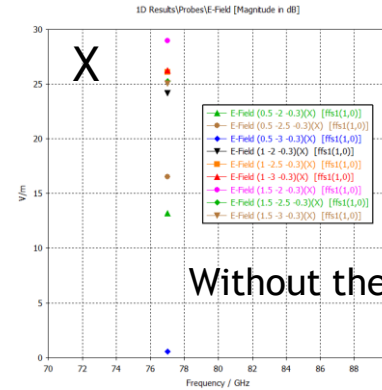
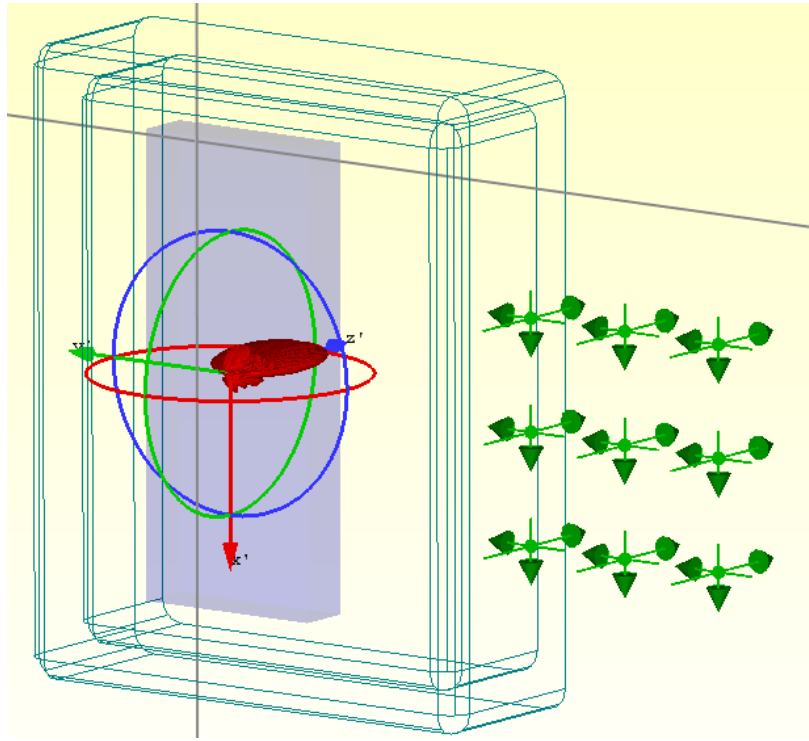
6
5
4
3
2
1
0



Nearfield Features: triple-reflector

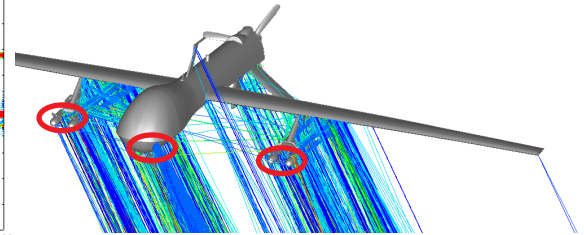
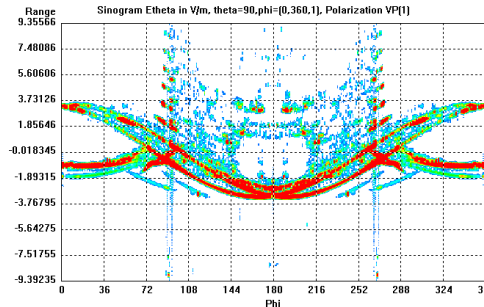


Nearfield Features: Probe locations



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



CST STUDIO SUITE®

AUTOMOTIVE WORKSHOP SERIES

Any Questions?

Many thanks for your attention!

