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

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Overview

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

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,
- GPS/traffic warnings, connect to smartphones, alert driver to other cars or dangers, keep the driver in the correct lane, blind spot monitor

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.
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

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

\[ \theta \sim \frac{\lambda}{D} \]

Depends on the wavelength and 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

77GHz

6GHz

Meshcells = 7,100,873,489,424
Simulation Techniques
Asymptotic Solver (Basics)

beam

PO
Current pattern

GO
Object

NF, FF, Plane Wave

multi reflections

FF pattern
Asymptotic Solver (Basics)

Edge Diffraction  PTD
A-Solver: SBR Methodology

- What is SBR?
  - Shooting and Bouncing Rays
    - Asymptotic technique
    - Complementary capability to full-wave solvers
    - Electrically large platforms (i.e., many wavelengths in at least one 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)
Materials Overview

Materials
- PEC
- Transparent materials
- Multi-layer dielectric stacks
- Tabulated angular & freq. dependent material
- Perfect absorber material
- Thin HF-transparent material (multi-layered)
- Thin HF-transparent material PEC backed (multi-layered)
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
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.
Antenna Definition
Import into CST-MWS
Microstrip Comb-Line Antenna Array

45° slant

λ/2

S-Parameters [Magnitude in dB]

Frequency / GHz

75 75.5 76 76.5 77 77.5 78 78.5 79

-45 -40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 40

S1,1  S2,1  S1,2  S2,2
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: $\Delta \Phi$ and $\Delta \Theta$
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

Θ-Scan (-Φ, +Φ)
NF/FF + automobile environment
A-Solver Setup /Runtime
**Phase Diagramm**

![Phase Diagramm](image)

- $\Delta \Phi$
- $\Delta \Theta$

Graph showing phase differences in $\text{deg}$ as a function of $\Theta$.
Ray-Tracing: Initial Hitpoints
Ray-Tracing: Observation Angles

0°

theta=20, phi=270, ffs1

Reflections

0 1 2 3 4 5 6
Nearfield Features: triple-reflector
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 transceiver model
• A-Solver special features
  • Range profiling
  • Hot Spot visualization
Any Questions?

Many thanks for your attention!