Multiple Ray Tracing based Complex Environment Modeling for Automotive Radar System Simulation

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KEYSIGHT TECHNOLOGIES

Agenda

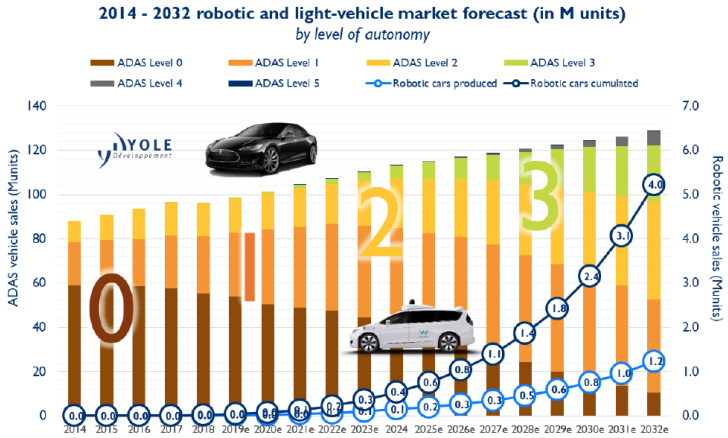
- Overview of Automotive Radar Simulation Platform
- What is MRT (Multiple Ray Tracing)
- Basic Theories behind MRT
- Performing MRT Analysis on Real-life Scenarios
- Summary

What Does It Mean for Radar When ADAS and Autonomous Driving Come

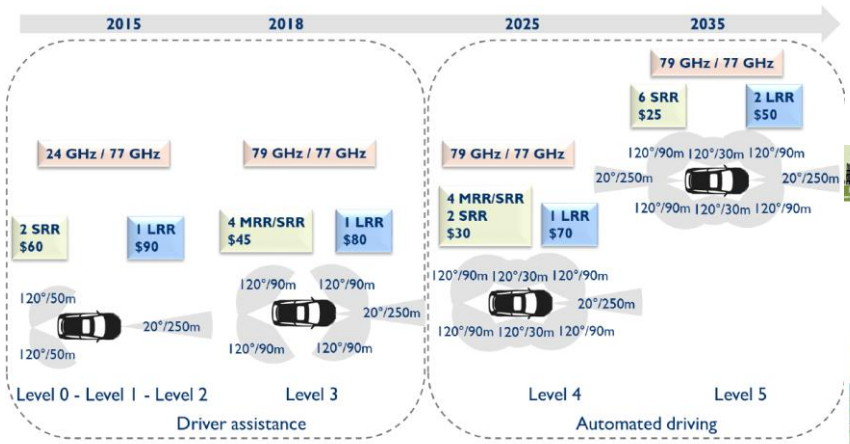
Market

Automotive Volume Forecast

ADAS technology's gradual improvement is pushing regular cars towards a higher autonomy level
Robotic car technology has begun providing AD levels 4 and 5 to street environments

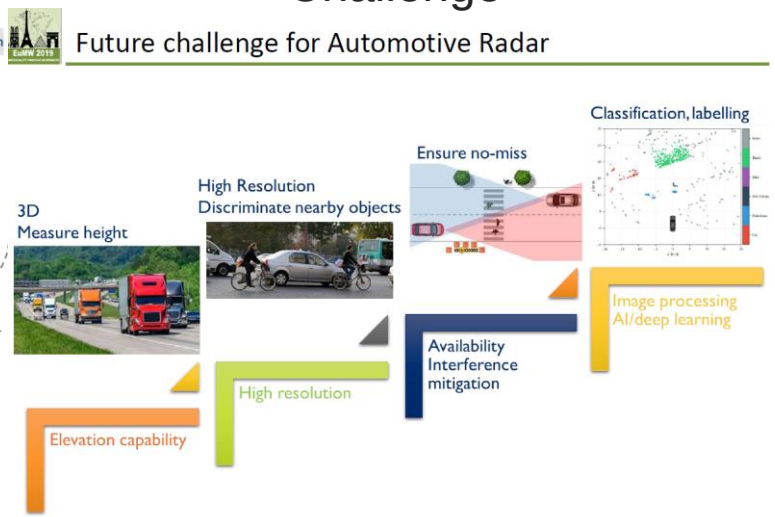


Cost



Challenge

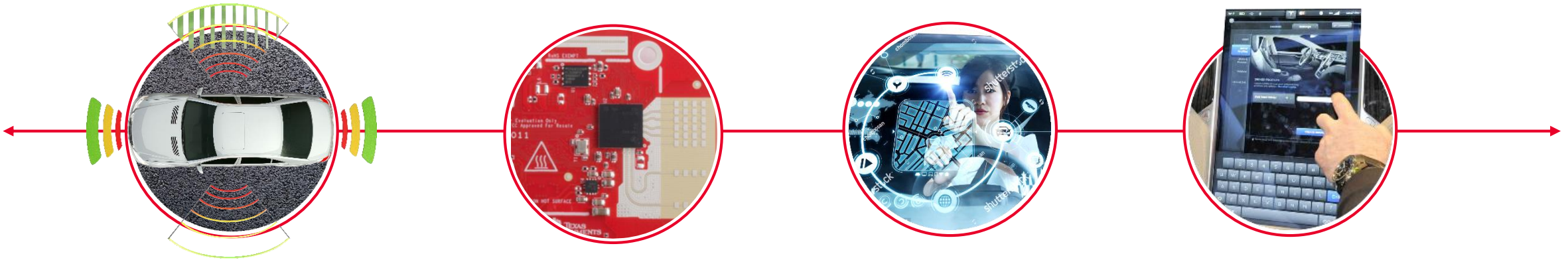
Future challenge for Automotive Radar



Courtesy of Yole Developpement at EuMW 2019

EEsof Automotive Electronics Design and Sim Category

ACCELERATE AND ROBUST YOUR AUTOMOTIVE ELECTRONICS DESIGN



Automotive Radar

- System Architecture
- Algorithm Design
- Environment Modeling and RTS
- System Verification

RF/uW/mm-Wave

- mm-Wave IC
- Automotive radar Module
- Antenna

V2X

- DSRC (802.11p)
- C-V2X (3GPP)*
- 5GAA**

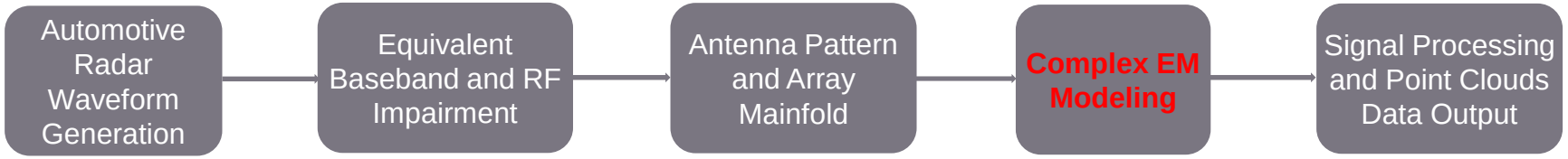
*Service
**Follow up

Electronics Board

- SI/PI
  (Ethernet/DDR/D-PHY/A-PHY/HDMI/PCIe)
- EMI/EMC
- Power Electronics

What We Need on Automotive Radar Simulation Platform

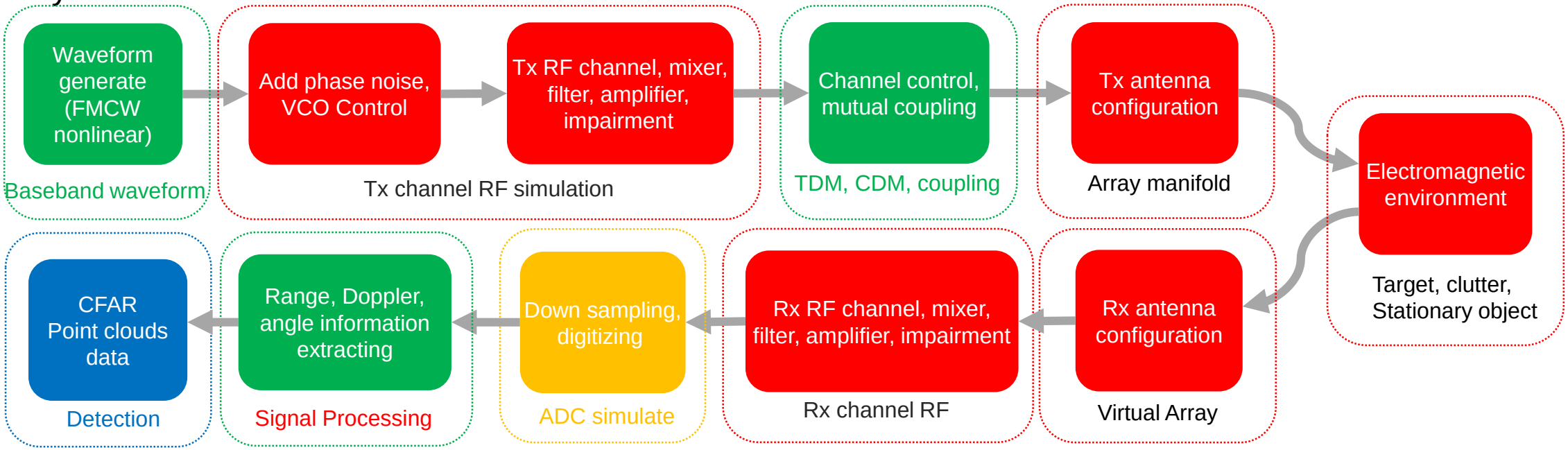
➢ System Framework for Simulation



Automotive Radar Design Challenges:

- Multiple Modes
- Multiple Functionalities
- Multi Domain Signal
- Complicated Environment Scenarios

➢ SystemVue Simulation Platform



➢ Compare HW prototype and SystemVue simulation results, verify the consistency of the simulation results with the measured data, prove the effectiveness and value of the simulation system.

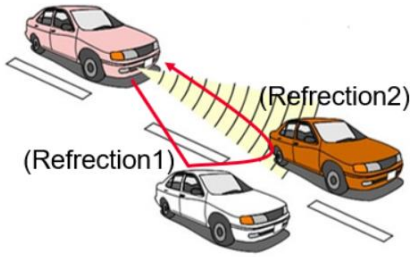
What is MRT (Multiple Ray Tracing)

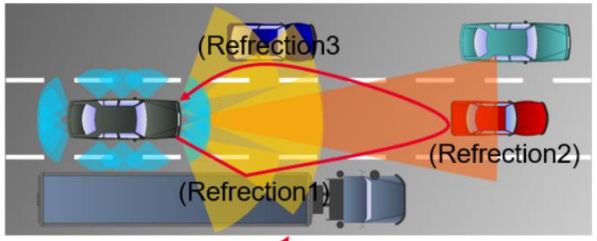
TYPICAL CUSTOMER REQUESTS

reflection

According to their measurements, these **affected to the detection results of radar.** So, they'd like to simulate the effect of these.

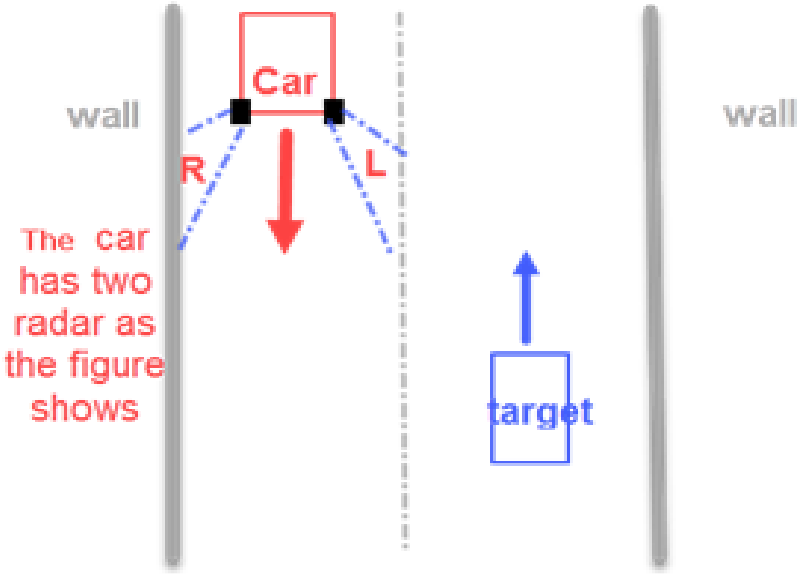
(5) the multiple refection





(like as)

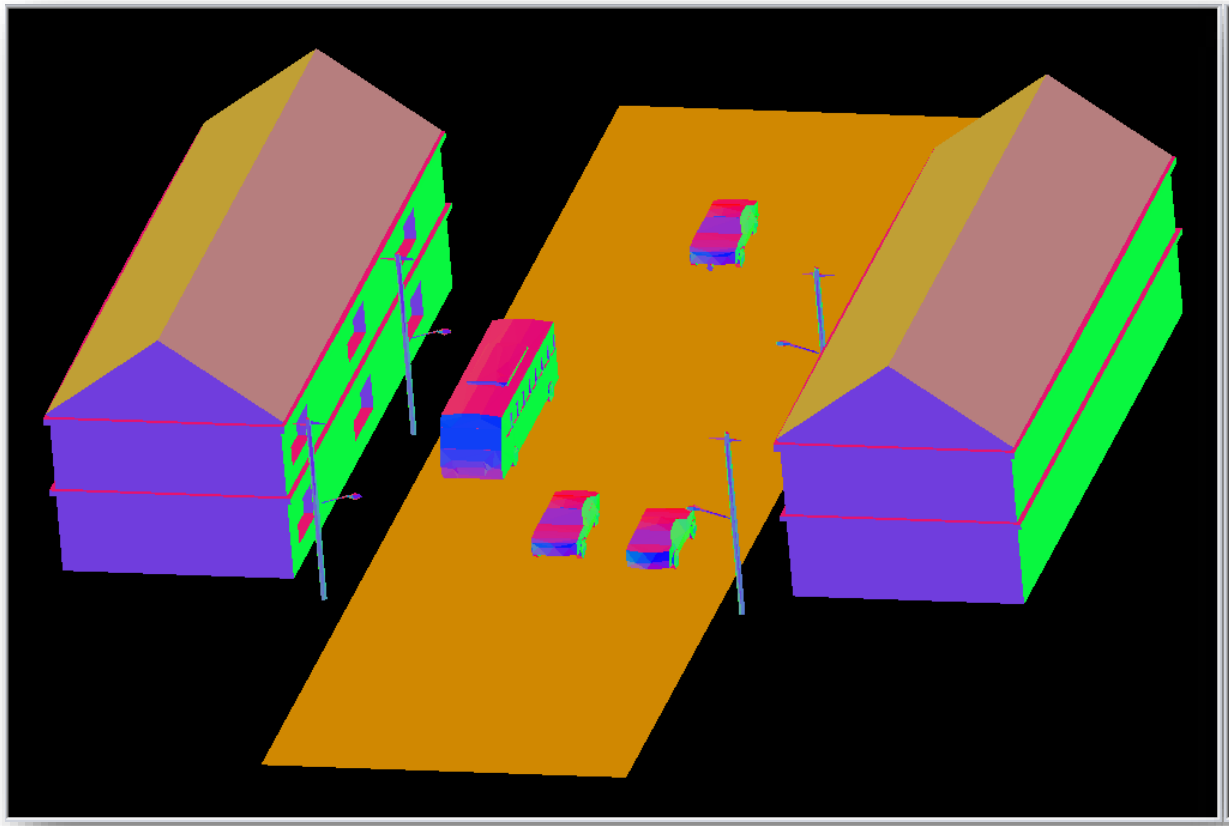
We'd **strongly** like to **clearly** create the desired scenario **on the map** as figure instead of the current setting **XYZ coordinate** as the **unclear numeric value**.

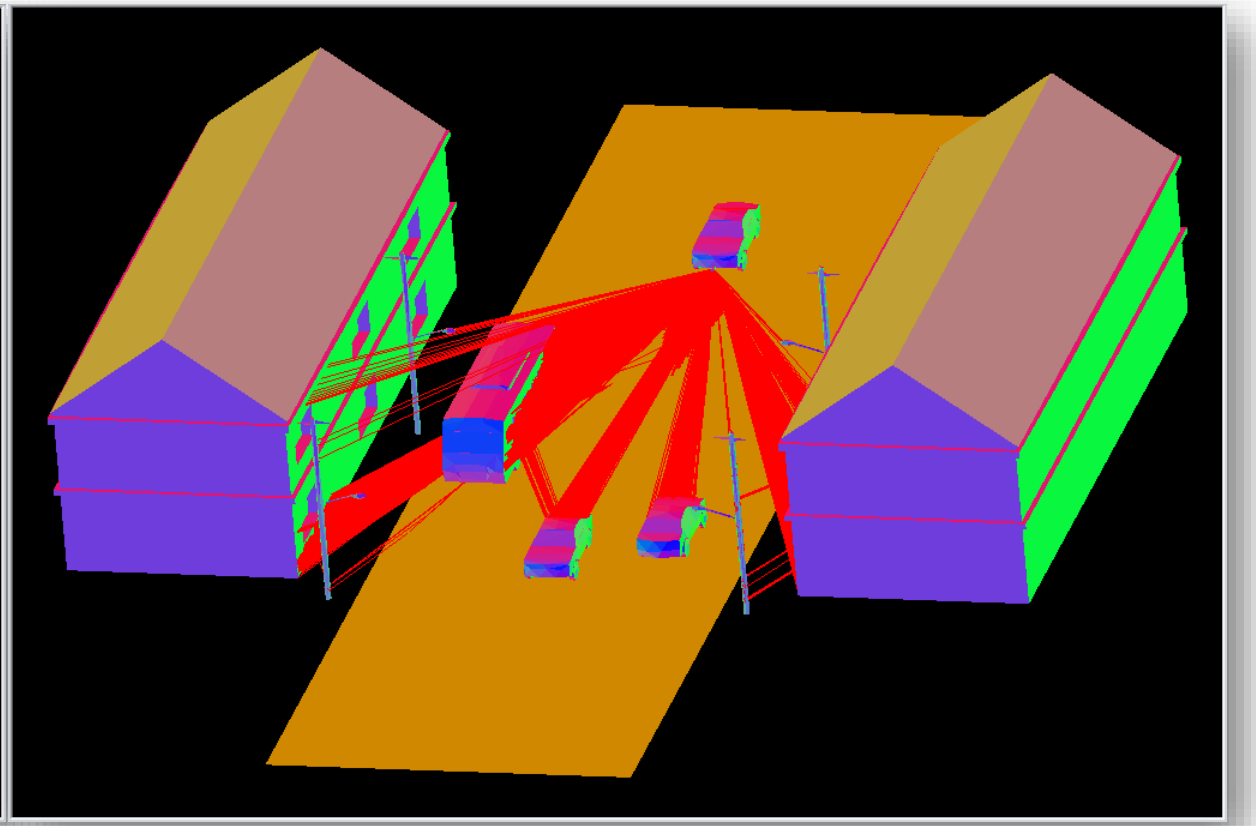


The Right Radar should not find the target, but due to wall reflection, it can find the target in received echo.

What is MRT (Multiple Ray Tracing)

MRT-BASED COMPLEX SCENARIO MODELING IN SYSTEMVUE 2020





What is MRT (Multiple Ray Tracing)

WHY USING MRT

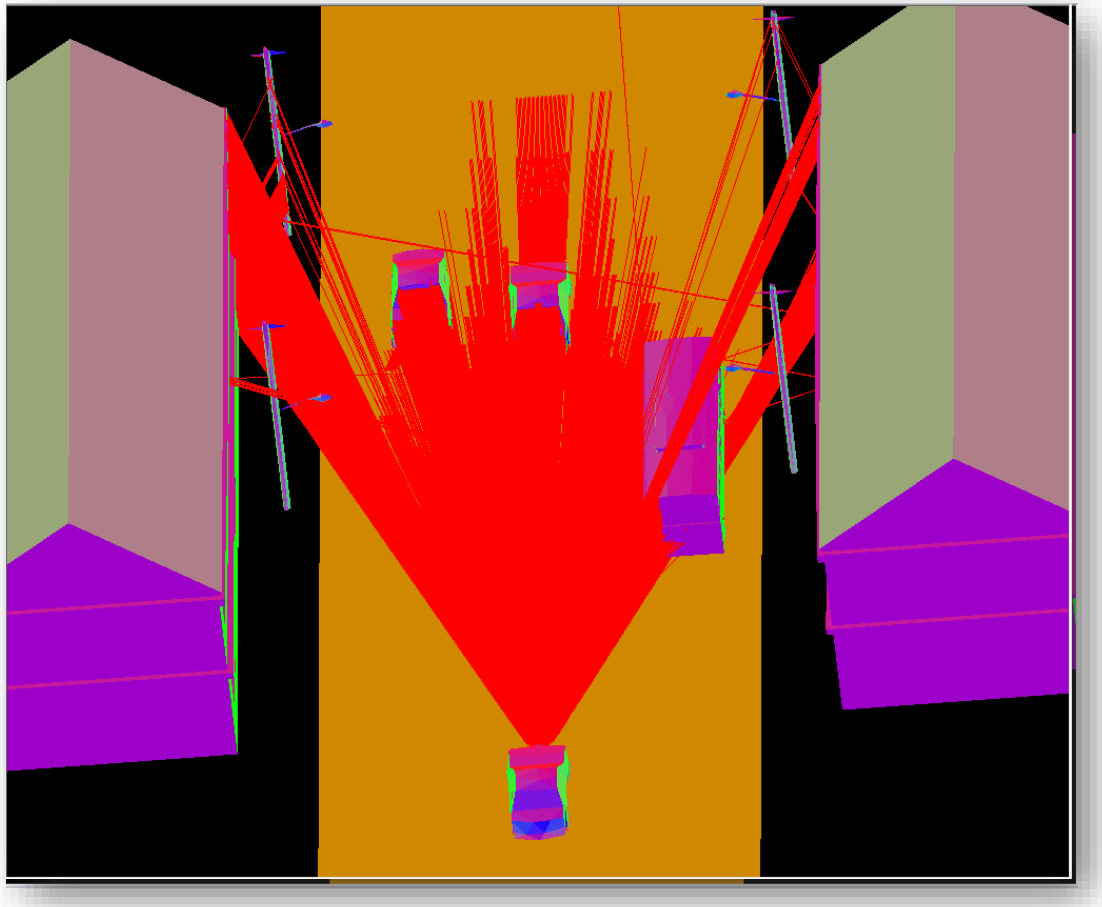
MRT is an established technology to characterize EM wave travelling behaviors in Complex Scenarios.
MRT is a Built-in Library for SystemVue that can help automotive radar designers to realize:

- Complex Scenario Modeling with built-in 3D CAD Targets
- Authentic Radar Echo from Real-World Sensing Scenarios
- Integrated System-Level Radar Design with SV Dataflow
- Cross-check with Target Detections from other Sensors

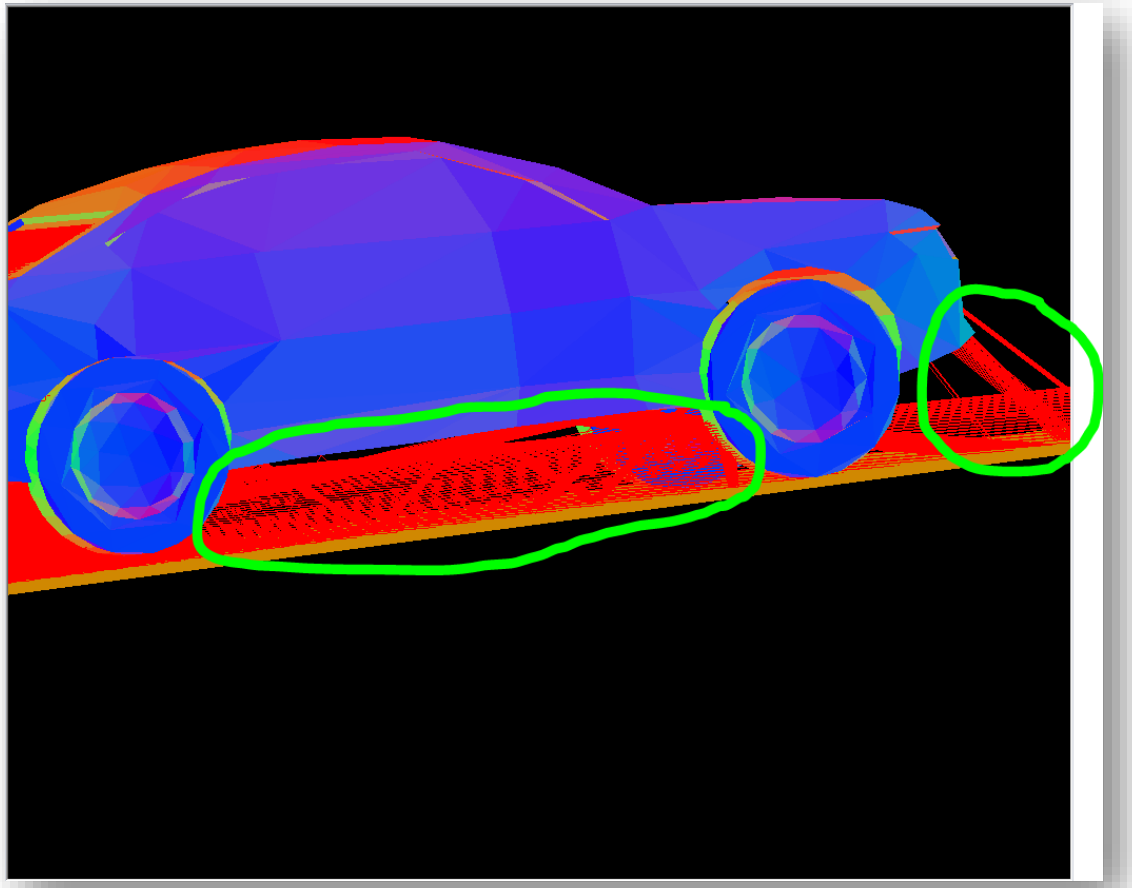
What is MRT (Multiple Ray Tracing)

SYSTEMVUE MRT CAPABILITIES

Ray Tracing -> Complex Scenario

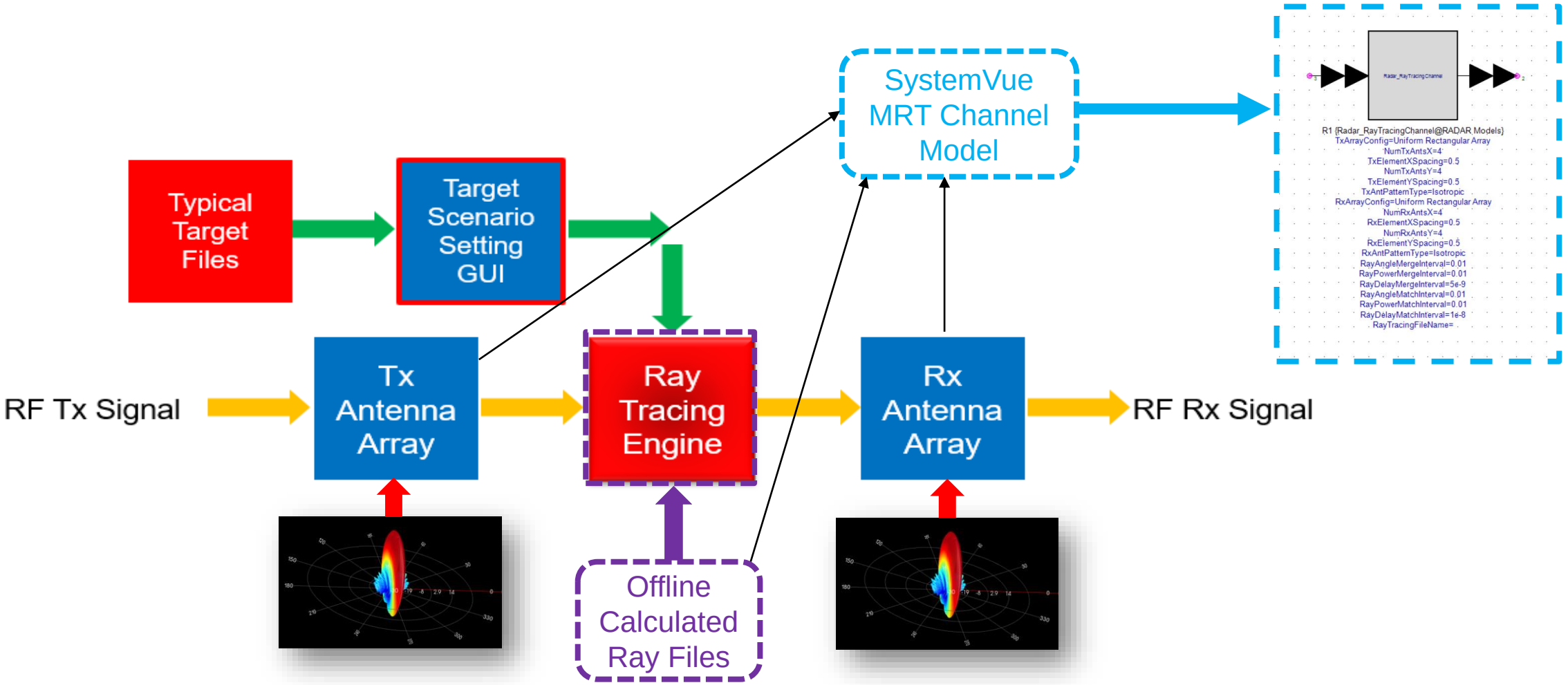


Multiple Bouncing -> Bumper & Chassis Impacts



What is MRT (Multiple Ray Tracing)

JOINT SIGNAL PROCESSING SIMULATION USING SYSTEMVUE 2020



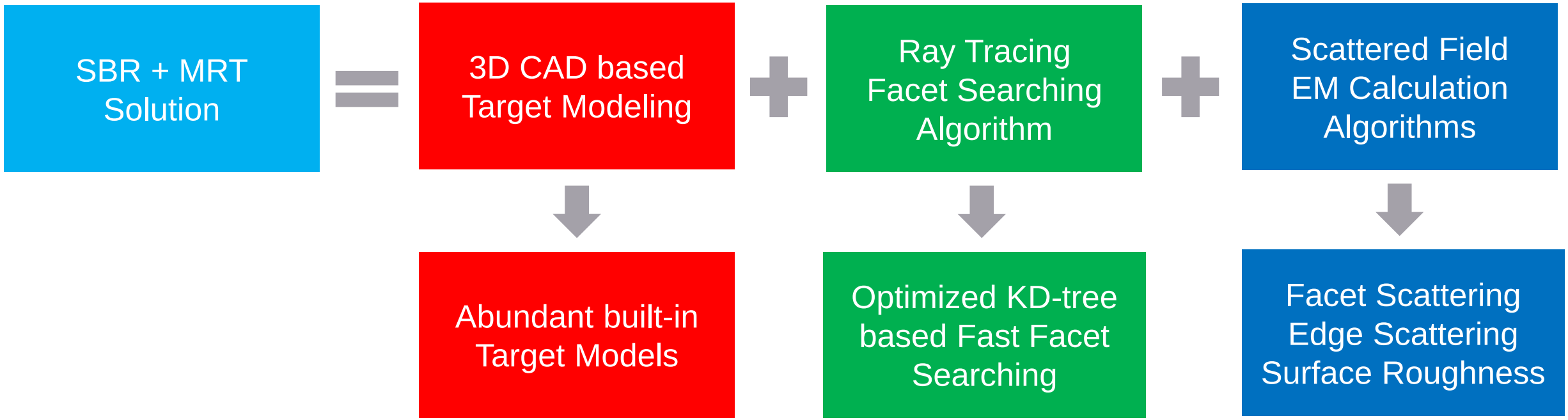
What is MRT (Multiple Ray Tracing)

COMPARISONS BETWEEN TRADITIONAL ENVIRONMENT MODELING AND MRT

Comparison Items	Traditional Environment Modeling	MRT (Multiple Ray Tracing)
Target Scenario Modeling	Manual Multi-Scatter Placements	3D CAD Facet Fidelity based Targets
Analysis Granularity	BB ***Time Sample by Time Sample***	BB **(Sample Time, PRI)**
License Configuration	W1465 + W1908	W1465 + W1908 + W1725 (MRT)
Waveform Support	Triangle, Sawtooth, Stepped Freq CW, etc.	
General Analysis Time Span	1-CPI (N*Pulses, N = 64, 128 , etc.)	
Simulation Efficiency	High (20 sec typ. , 1-CPI)	Medium (3-5 min typ., 1-CPI)
Simulation Accuracy	Medium	High
Possible contributors to accuracy degradations	Subjective Multi-Scatter Placements Subjective Scatter RCS Assignments	Target CAD Modeling Fidelities Radar/Ray Parameter Configurations
Operational Difficulty	Medium	High

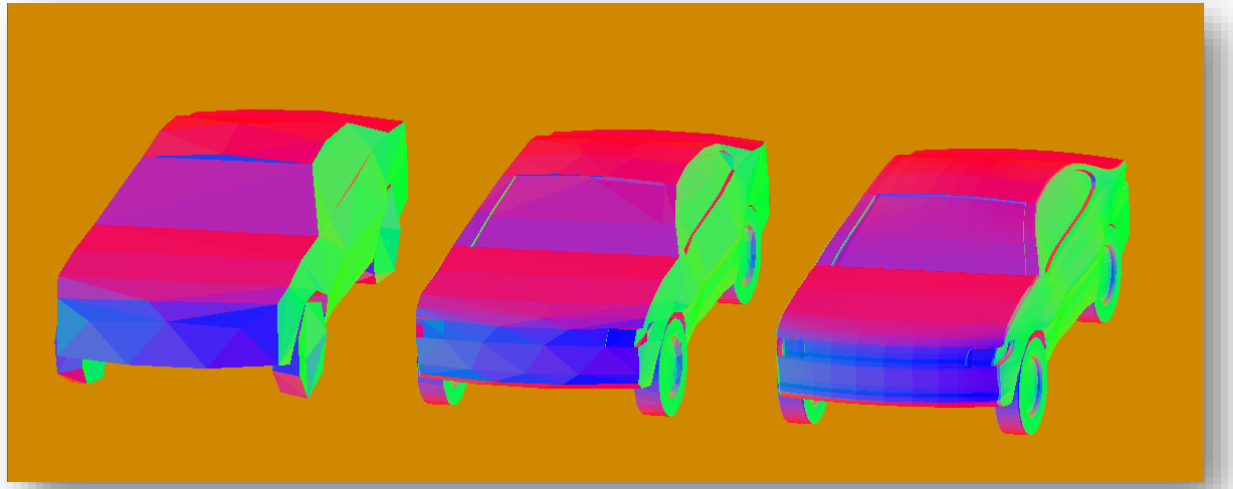
Basic Theories behind MRT

CORE ENABLING TECHNOLOGY ARCHITECTURE



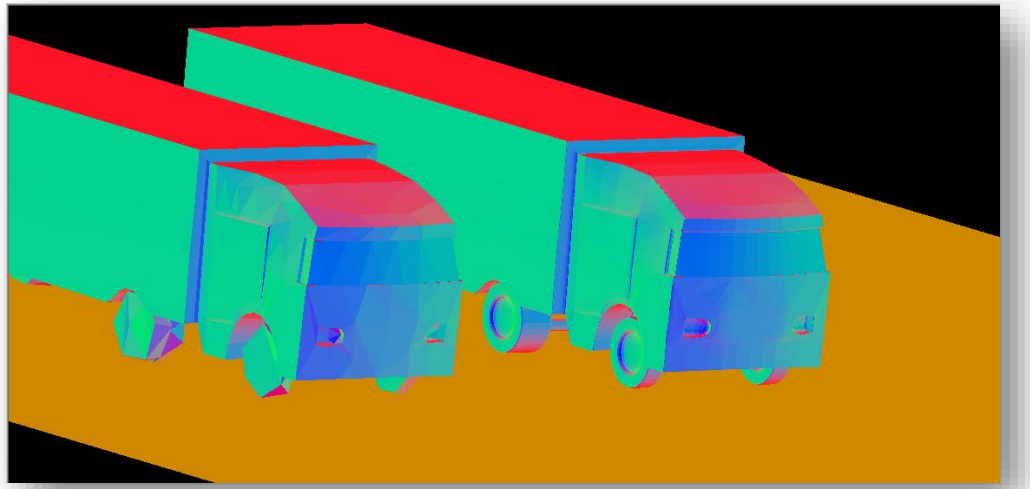
Basic Theories behind MRT

3D CAD BASED TARGET MODELING -> VEHICLES



Facet No.: ~0.3k Facet No.: ~1.5k Facet No.: ~460k

Cars -> 3 levels of fidelities

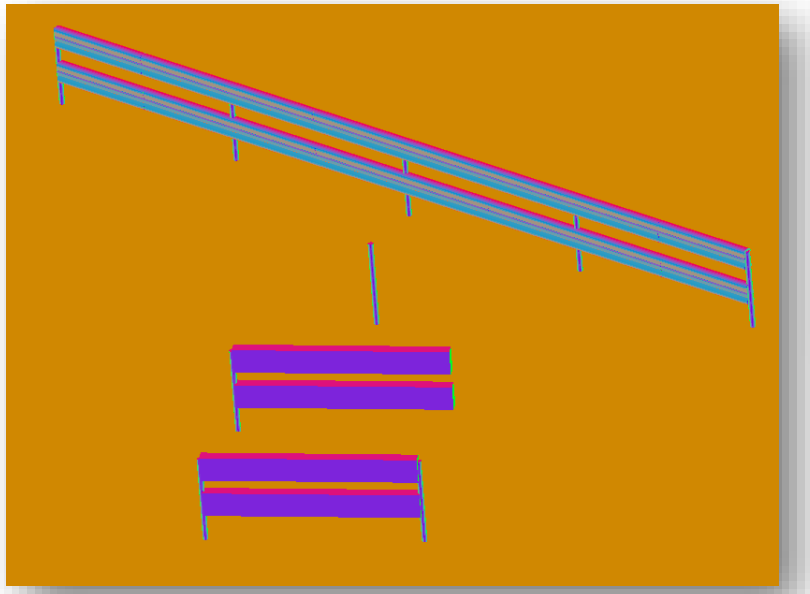


Facet No.: ~1k Facet No.: ~130k

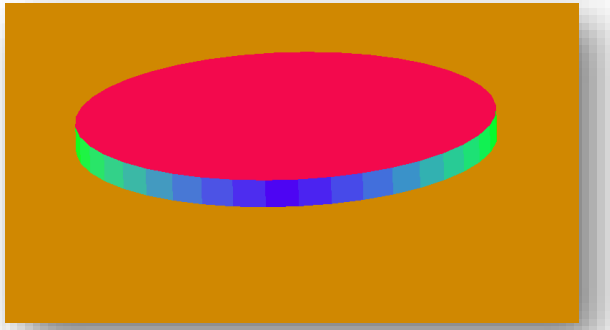
Trucks/Buses -> 2 levels of fidelities

Basic Theories behind MRT

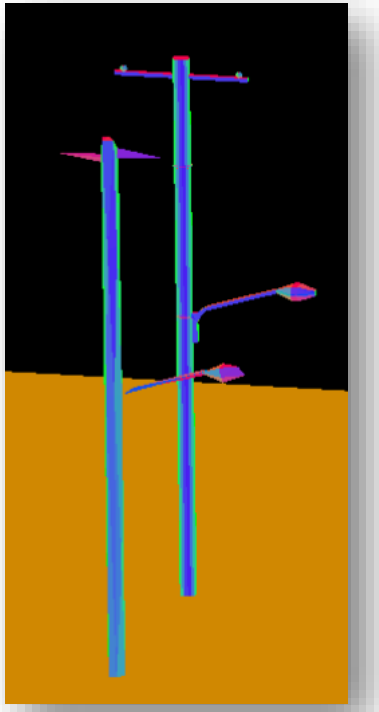
3D CAD BASED TARGET MODELING -> MORE TARGETS



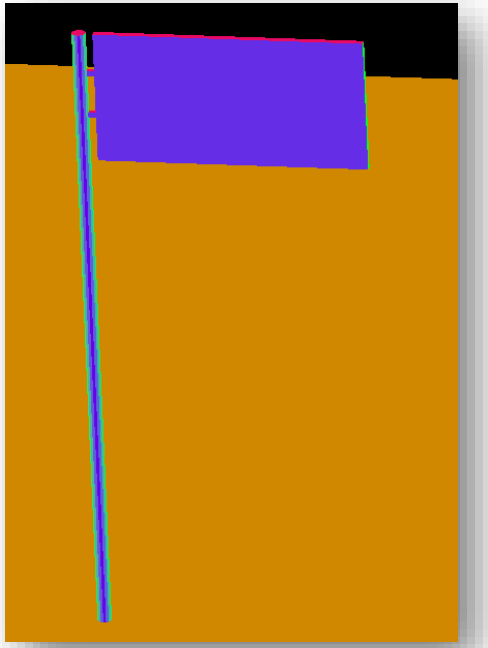
Guardrails
4 Models Available



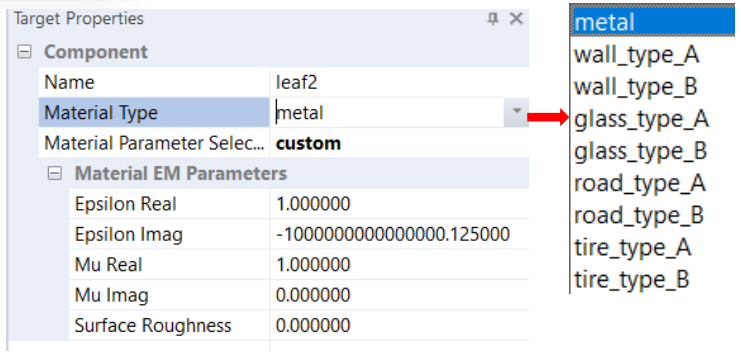
Manhole Cover



Lampposts
2 levels of fidelity

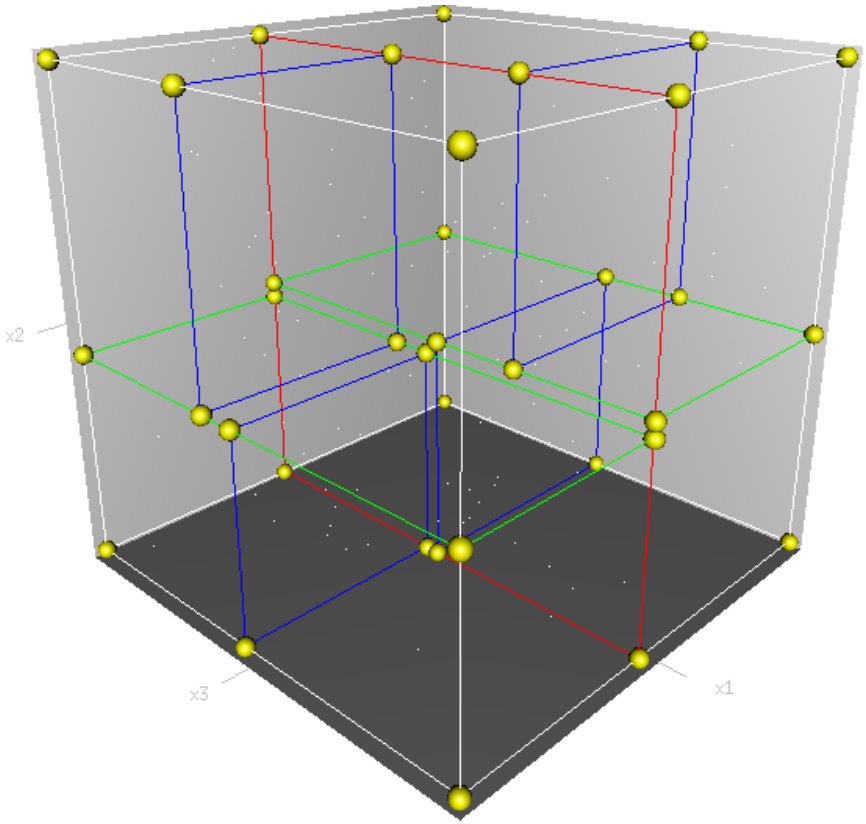


Road Signs



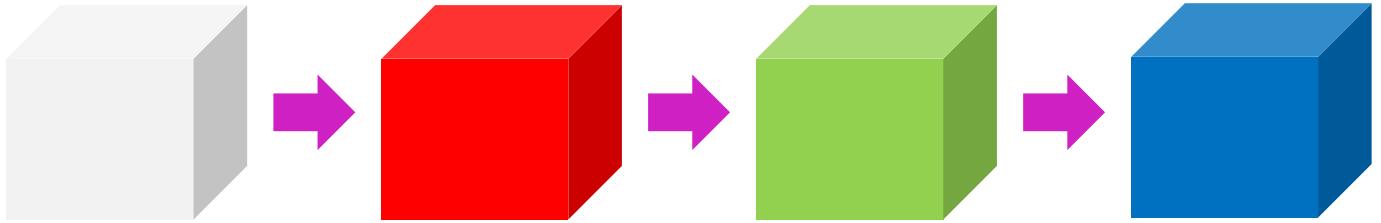
Basic Theories behind MRT

K-D TREE BASED RAY TRACING FACET SEARCHING



https://en.wikipedia.org/wiki/K-d_tree

How to determine which facet is hit in a ray's bouncing paths?



The KD-tree algorithm narrows down the region of possible ray hitting:

White -> Red -> Green -> Blue

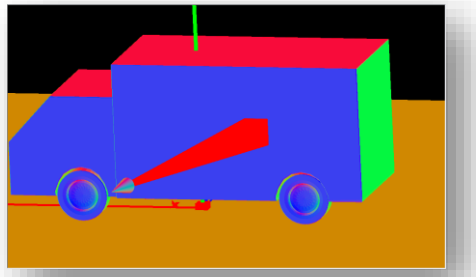
Basic Theories behind MRT

SCATTERED FIELD EM ALGORITHMS

Which can solve one fundamental and two additional EM field calculation headaches for customers:

Scattered Field Electromagnetic Algorithms

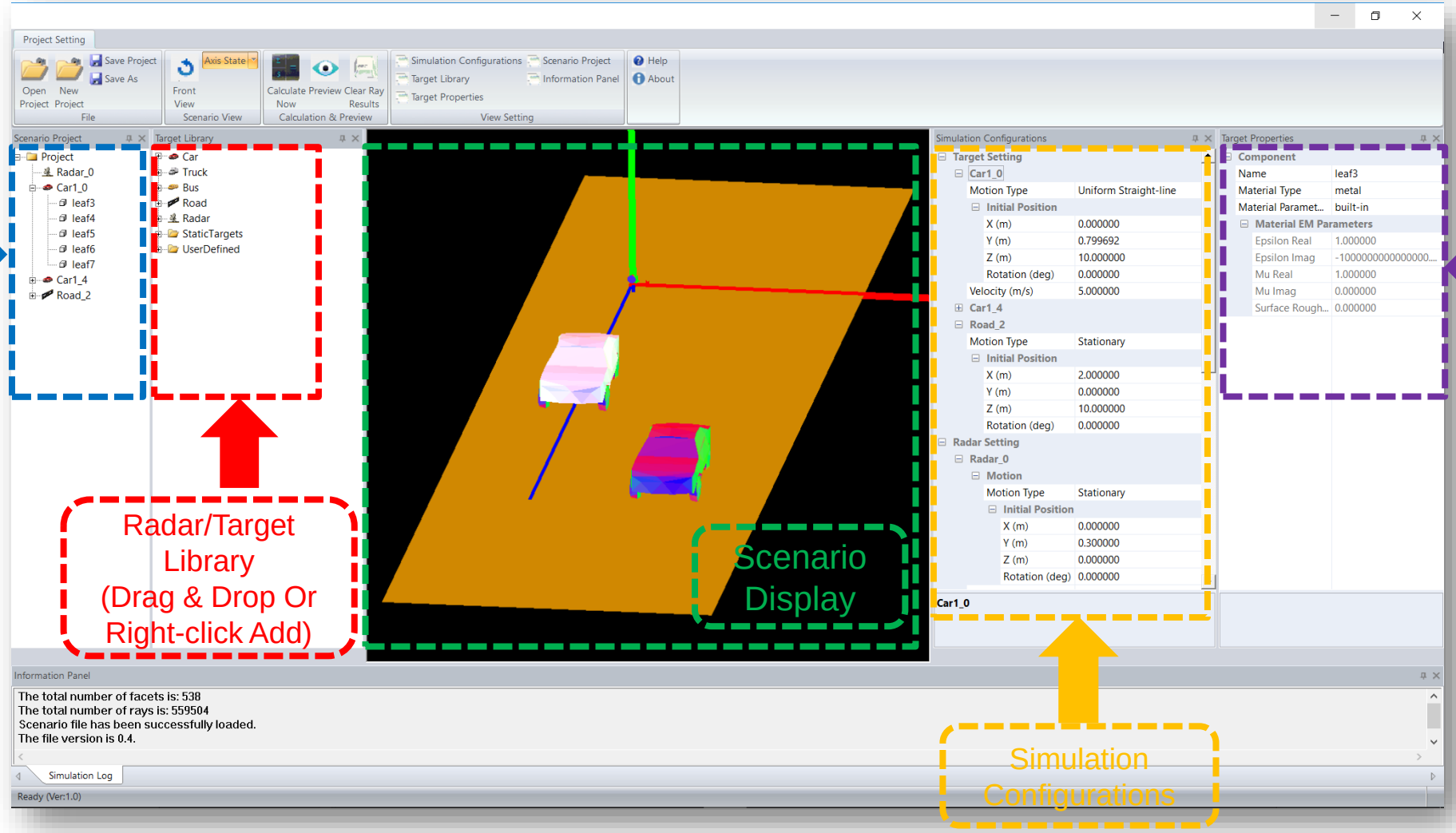
- Facet Scattering → Basic Ray Tracing Capability Enabled (GO + PO + Ray Tubes)
- Edge Scattering → Target sharp edges caused additional scattered rays
- Surface Roughness → Rough surfaces caused EM field fluctuations



Ray Tubes illuminating Trucks

Performing MRT Analysis on Real-life Scenarios

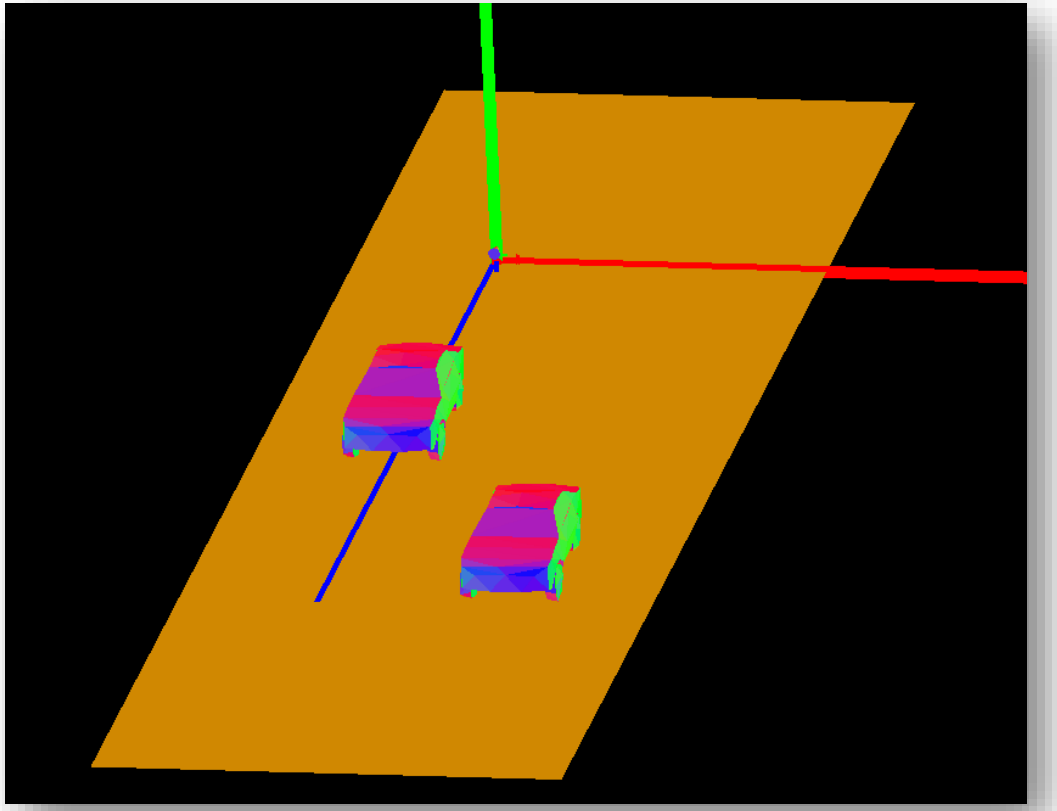
ESTABLISHING A WORKING SCENARIO FOR MRT



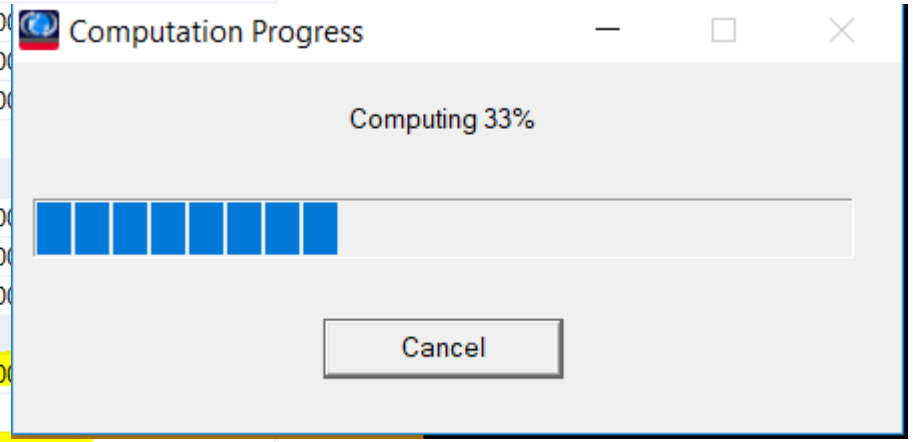
Performing MRT Analysis on Real-life Scenarios

CONTINUING TO ANALYSIS THE PREVIOUS DOUBLE-CAR SCENARIO

Modify the road size and
Radar/Ray Parameters as the 1st step:



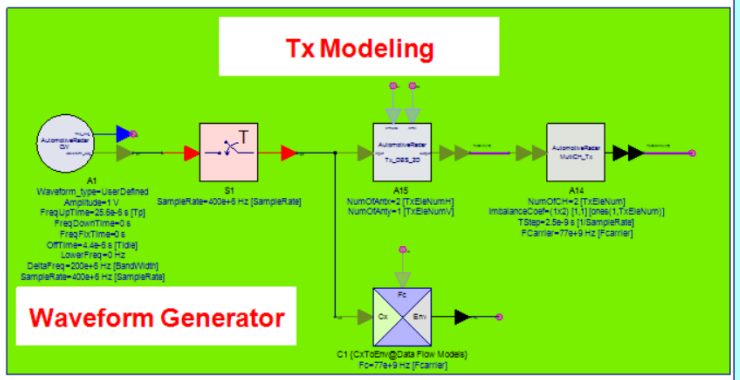
Radar Setting	
Radar_0	
Motion	
FoV (deg)	40.000000
Time Setting	
Start Time (sec)	0.000000e+00
Stop Time (sec)	3.840000e-03
Step Time (sec)	3.00(
Maximum Detection R...	20.0(
Frequency (GHz)	77.0(
Polarization	VV
Boresight Direction	
X	0.00(
Y	0.00(
Z	1.00(
Ray Setting	
Ray Density	0.20(
Maximum Bouncing Num...	2
Minimum Ray Threshold (...	-90.000000
Result Setting	
File Path	C:\TEMP
File Name	ProjectTracing
Clear Results	False
Time Delay Resolution (sec)	2.500000e-09
Angle Resolution (deg)	1.000000

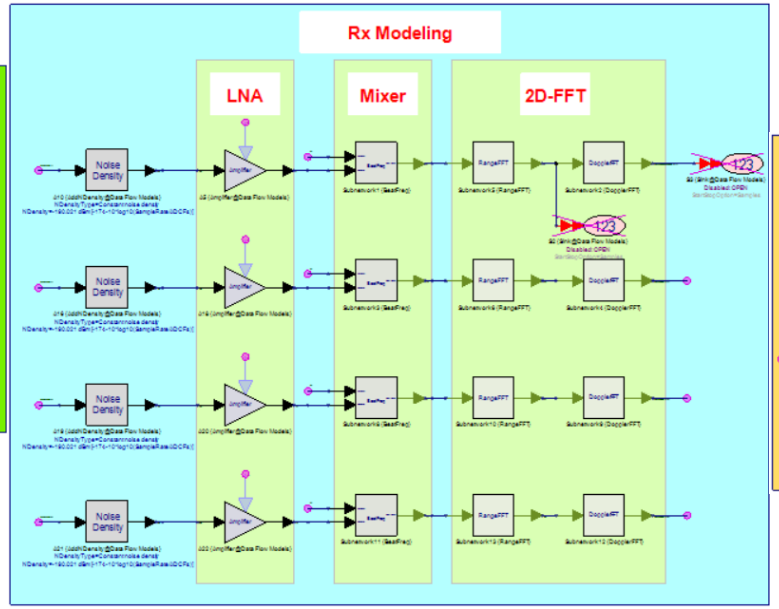


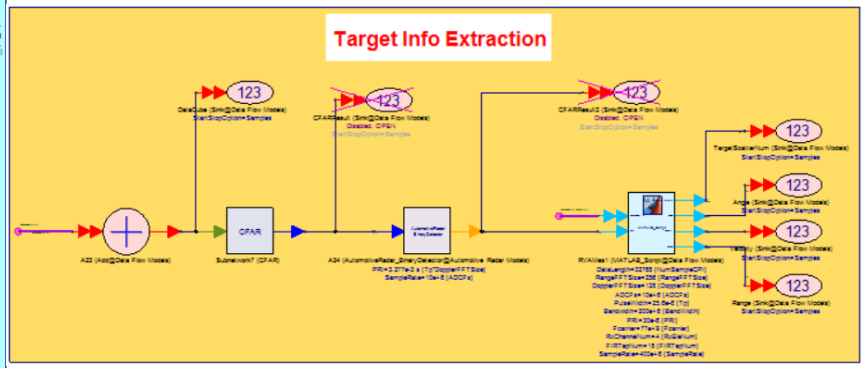
Performing MRT Analysis on Real-life Scenarios

MRT SIGNAL-LEVEL ANALYSIS WORKSPACE

2Tx -> 4Rx with MRT as Channel Simulator







Sawtooth Waveform Type

De-chirpped Sample Rate = 10 MHz

Range/Doppler FFTSize = 256/128

Performing MRT Analysis on Real-life Scenarios

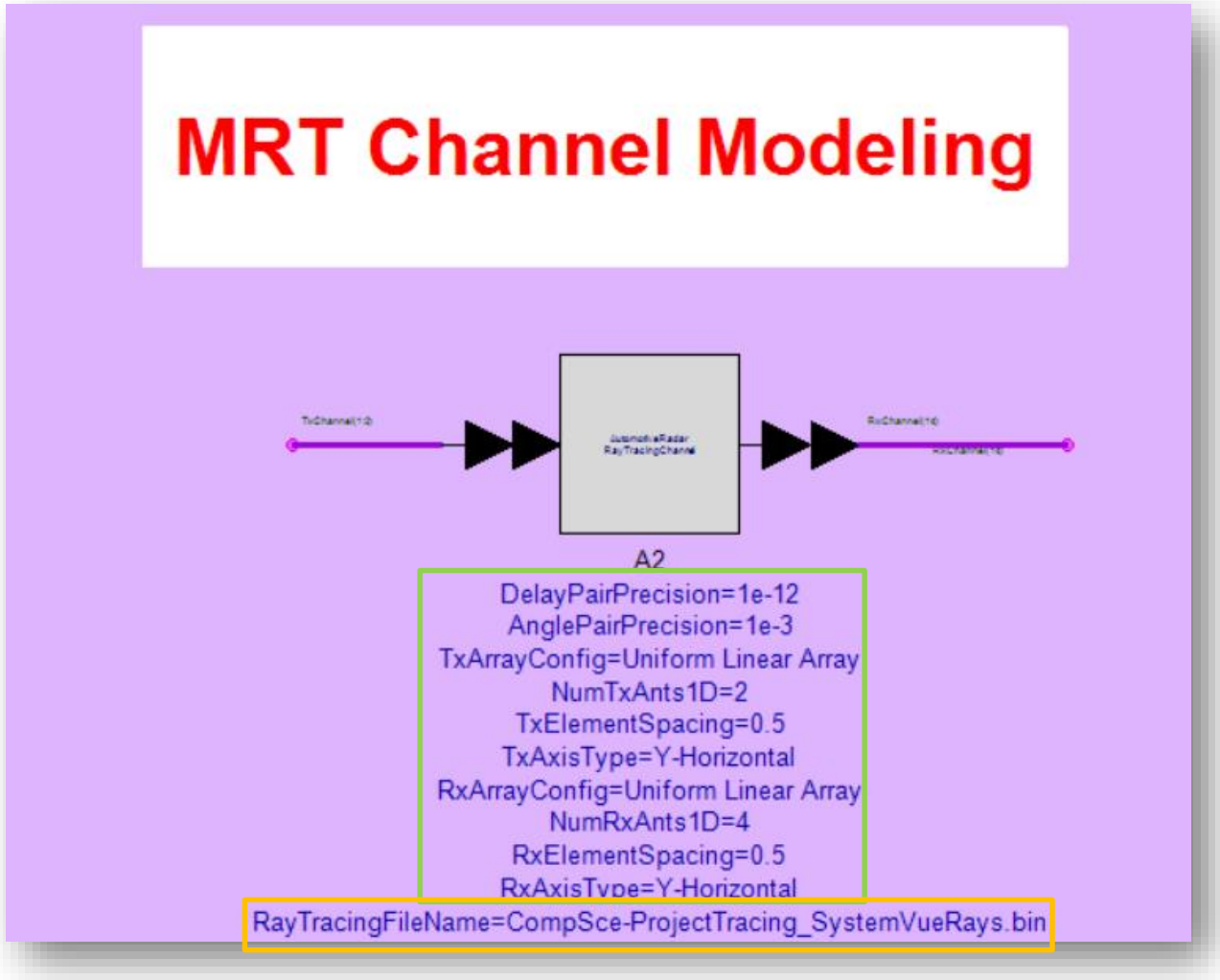
MRT SIGNAL-LEVEL ANALYSIS WORKSPACE

Antenna Structure Configuration

+

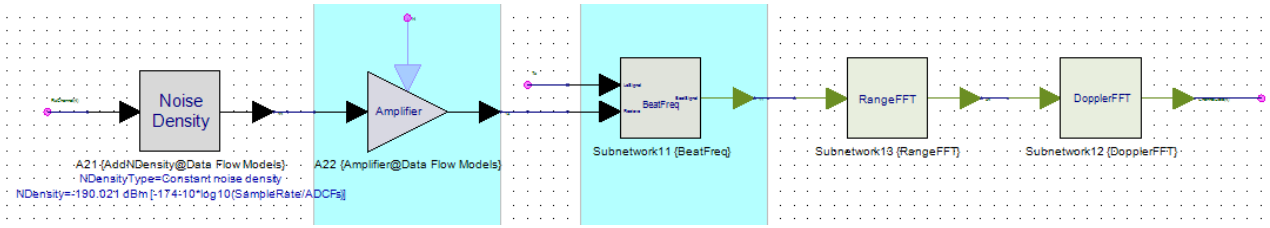
Ray Tracing Echo Result Import

=



Performing MRT Analysis on Real-life Scenarios

RANGE-DOPPLER MAPPING (WITH 1-RX)

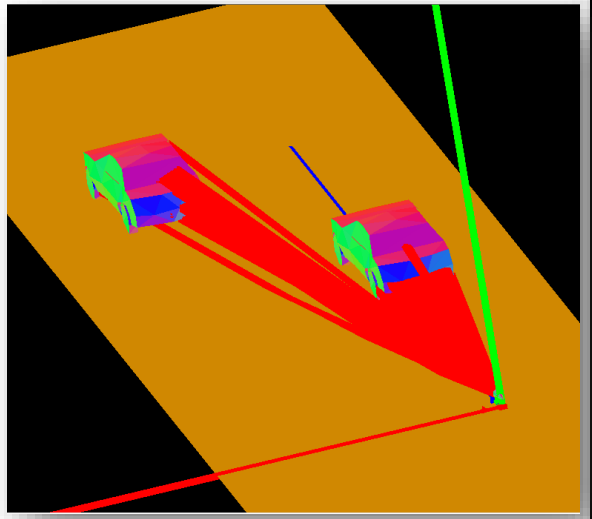


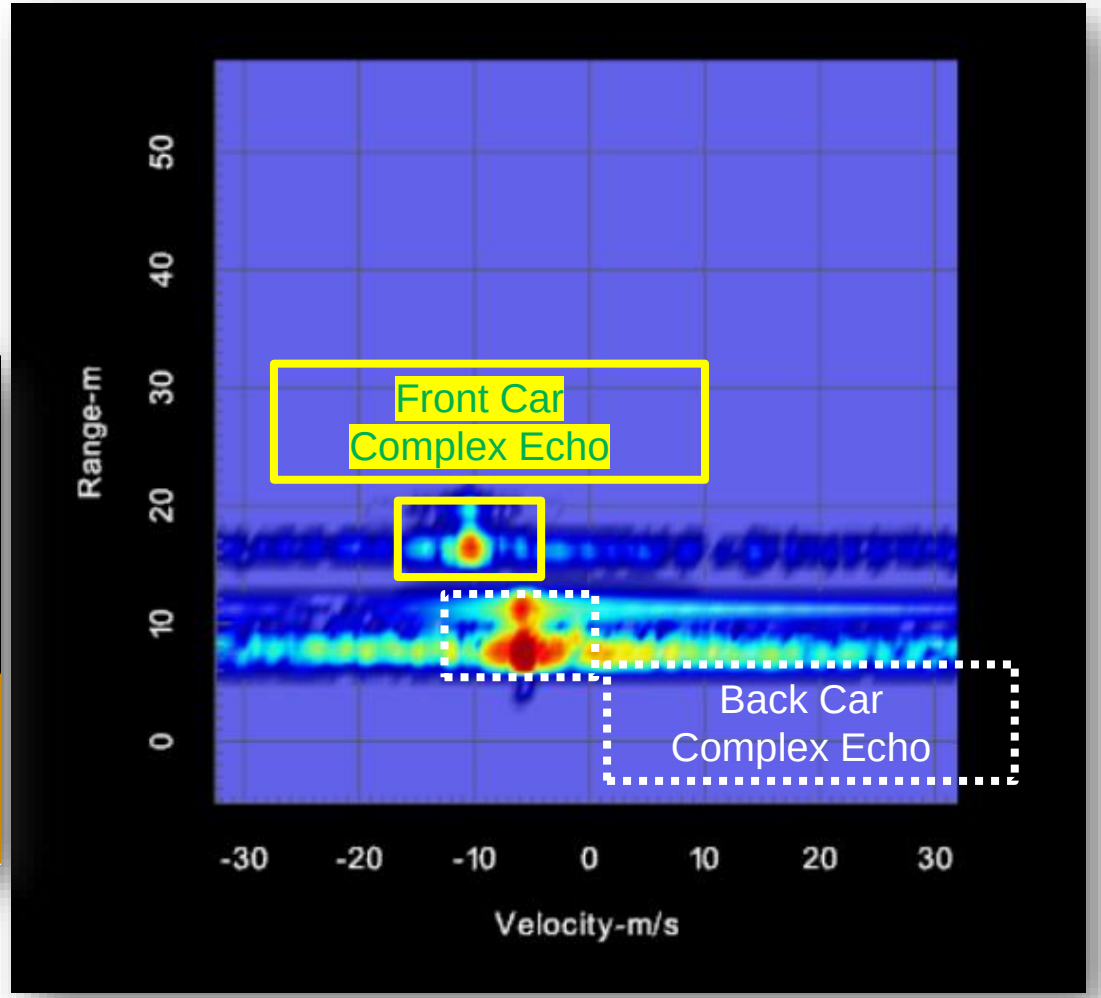
Target Characterization with MRT:

- ✓ True mmW Radar echoes obtained;
- ✓ Not point-scatter NOW!

- ✓ Range/Doppler Multi-Scatter Spreading clearly observed

- ✓ Range/Velocity hot-spot positions consistent with input values





Performing MRT Analysis on Real-life Scenarios

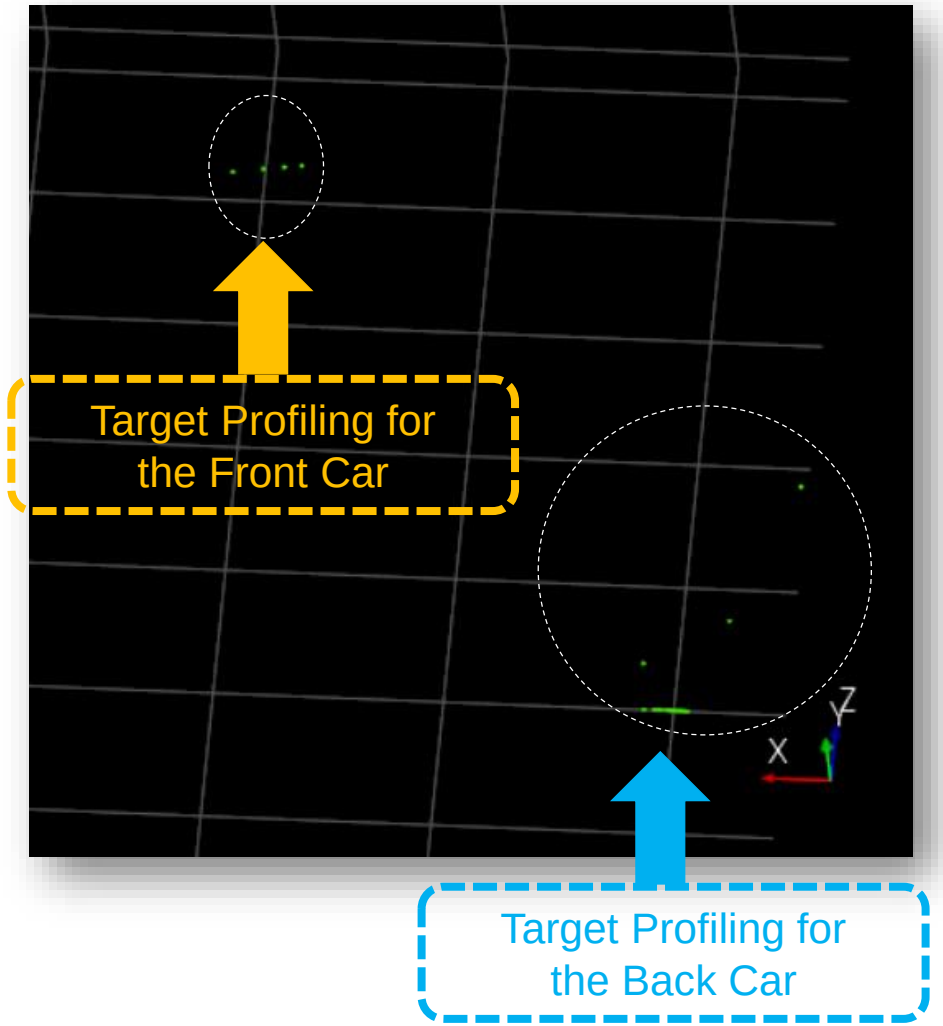
TARGET PROFILING WITH SCATTER POINT CLOUD

CFAR: SOCA

Target Grouping: Plots-Of-Centroid

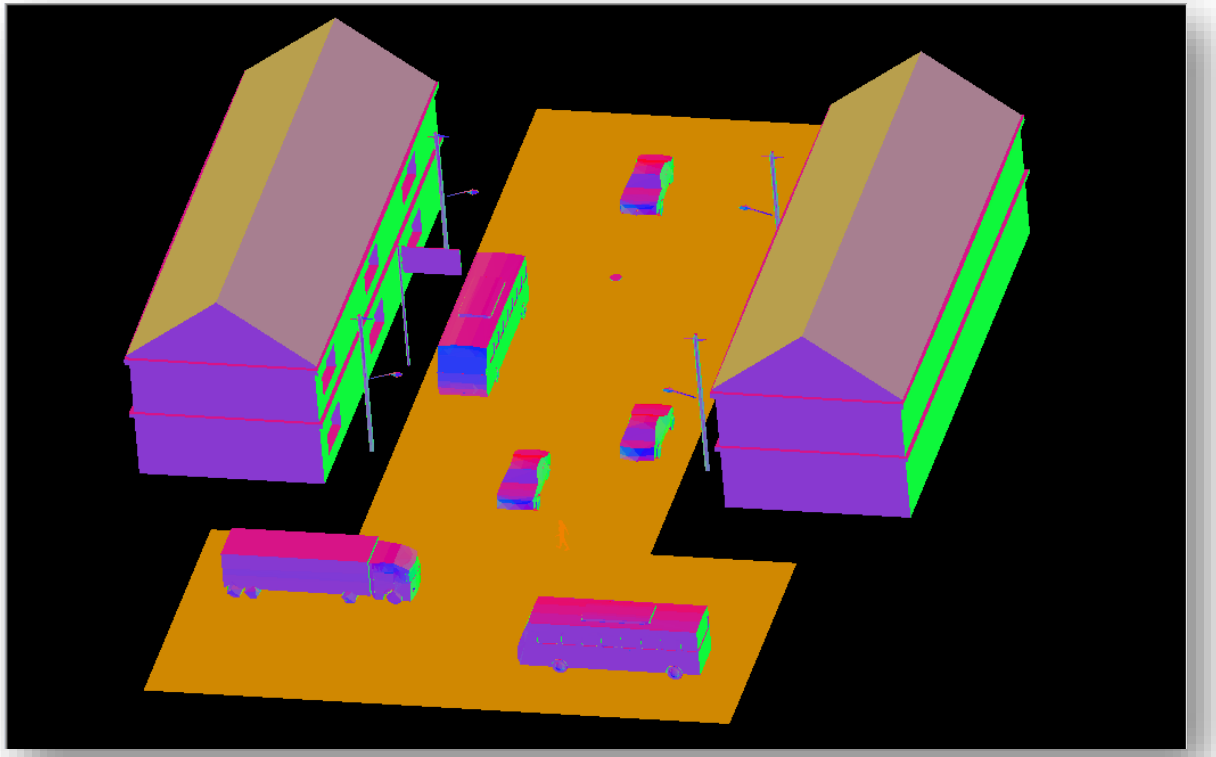
Range/Angle: Matlab Script

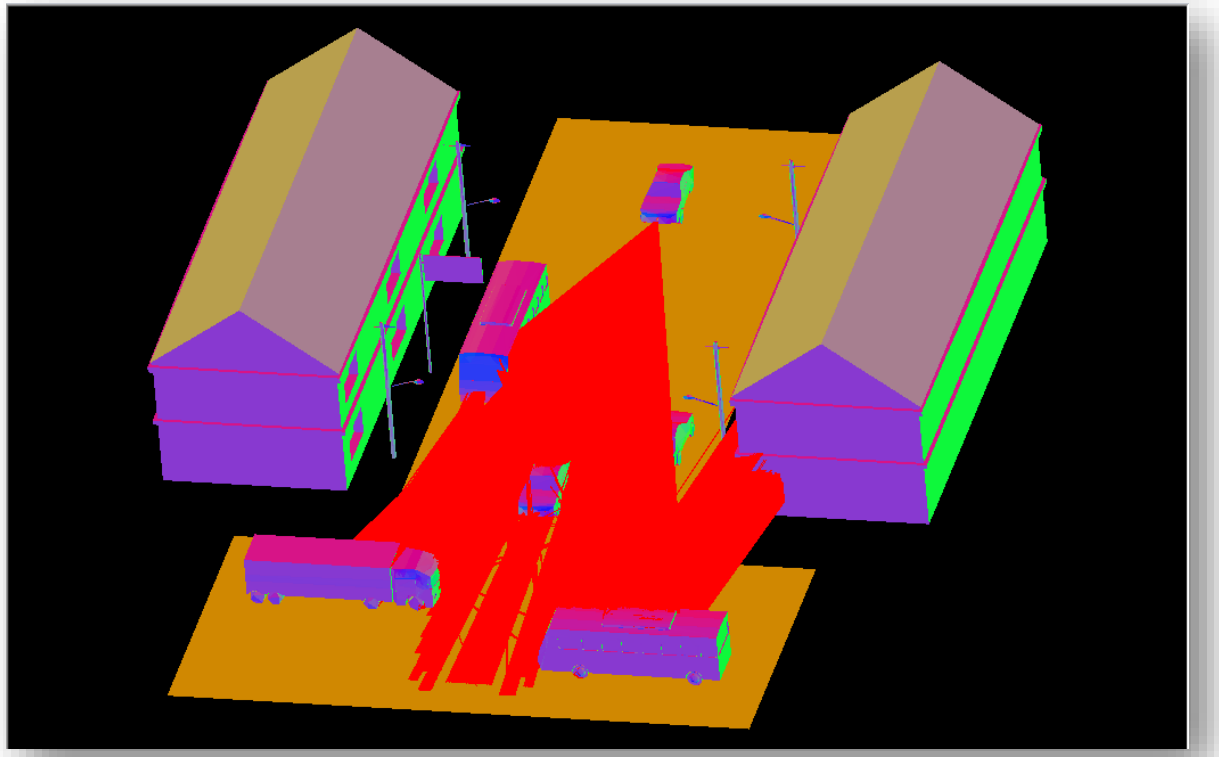
- ✓ **Detected Point-Cloud positions consistent with input values**
- ✓ **Both vehicles have been characterized by multi-scatter profiles**
- ❖ **(Wideband mmW radar ranging capability demonstrated)**



Performing MRT Analysis on Real-life Scenarios

COMPLEX ENVIRONMENT MODELING EXAMPLE

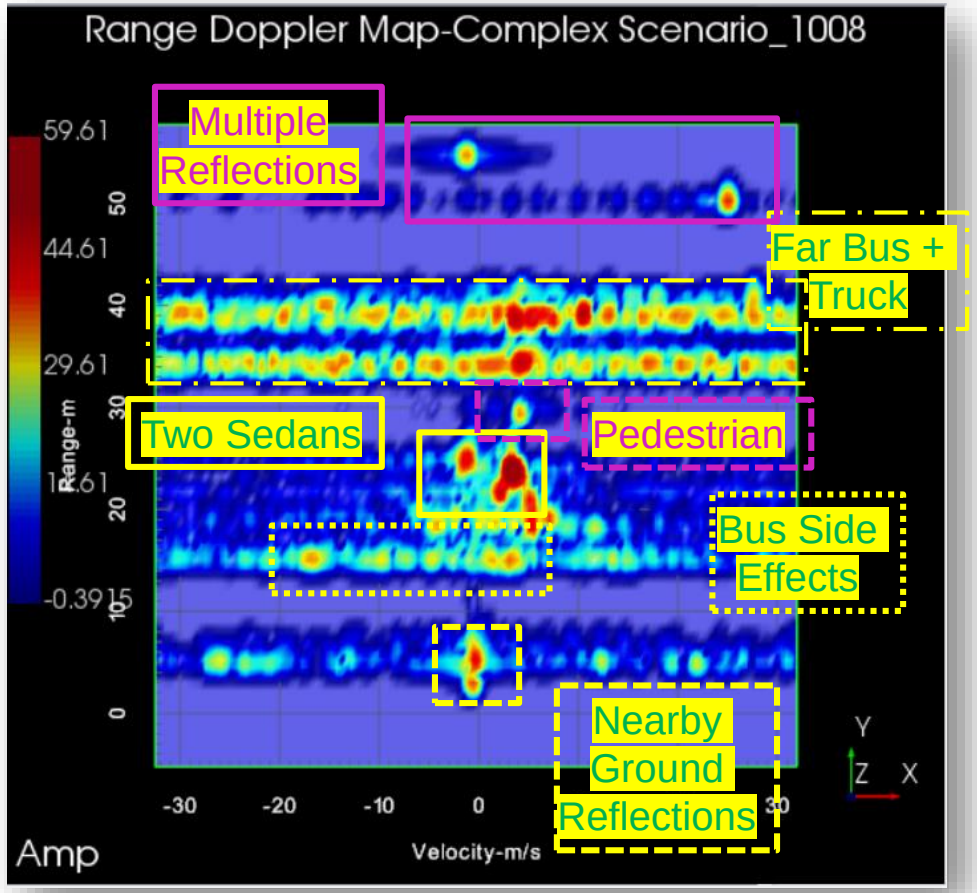




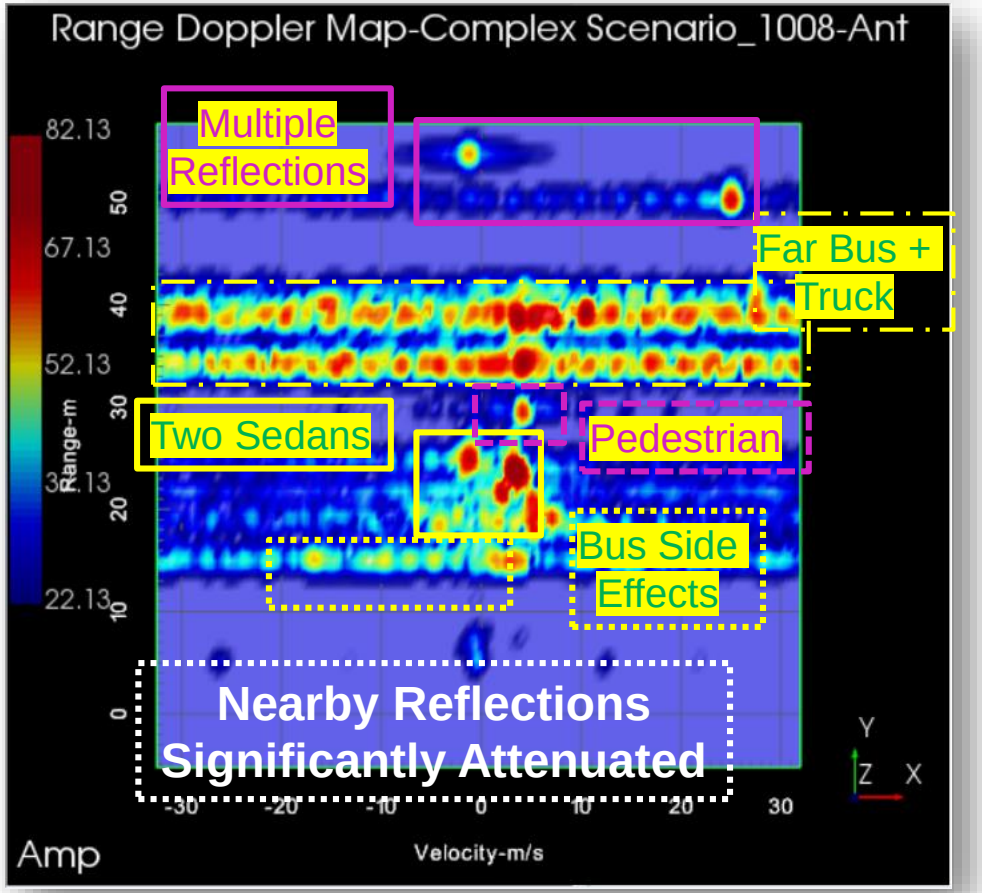
Multiple Ray Bouncing Clearly Visible

Performing MRT Analysis on Real-life Scenarios

COMPLEX ENVIRONMENT MODELING EXAMPLE



Raw MRT RD Mapping

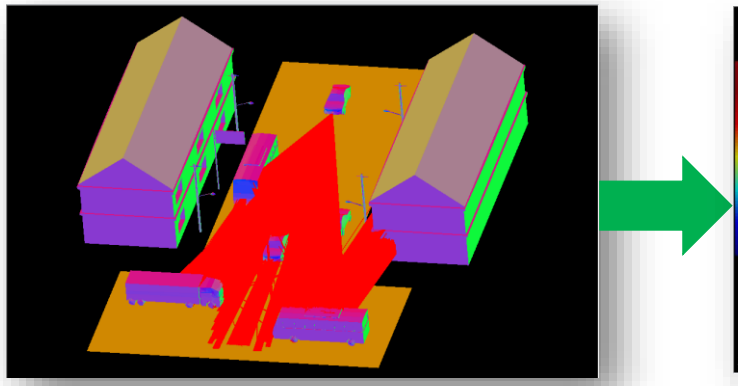


Tx+Rx Antenna Patterns Imported

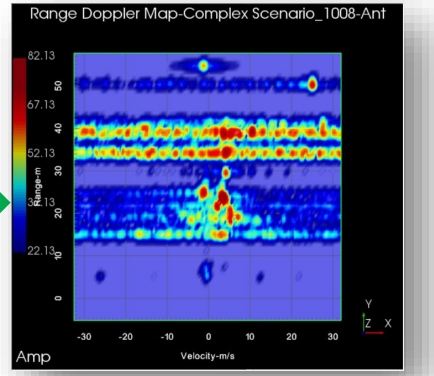
Summary

WHAT THIS SOLUTION ACHIEVES

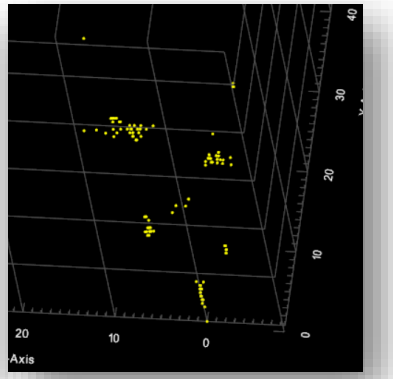
- PathWave SystemVue is an Electronic System-Level Design Software, which is the shortest path from imagination to verified hardware for physical layer systems design.
- SystemVue automotive radar accelerates your system architecture and verification with its built-in complex algorithm models and examples.
- MRT is new feature to model the complex environment in automotive radar system simulation, user-defined scenario can be extracted from MRT and brought into SystemVue automotive radar system level simulation. This solution makes user design more flexible, reliable and realistic.



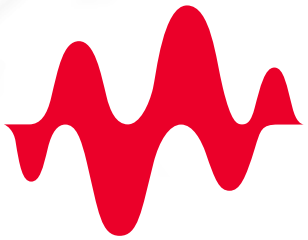
Scenario
MRT Simulation



Radar Signal
Processing Results



Target Scatter
Distribution Results



KEYSIGHT
TECHNOLOGIES