The World's First Real-Time Millimeter wave Radar Simulator using High Precision 3DCG MAP and Objects, Use CASE.

COSIDE® UGM 2017 @ Munich
October 19, 2017

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Hiroshi Naganawa from DENSO International of America

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Key Words:

MMR: Millimeter Wave Radar
FMCW: Frequency Modulation Continuous Wave
MMIC: Monolithic Microwave Integrated Circuit
RFE: Radio Frequency Front End
LIDAR: Light Detection and Ranging
NIR: Near Infrared
MUSIC: Multiple Signal Classification
ESPRIT: Estimation of Signal parameters via Rotational Invariance Techniques

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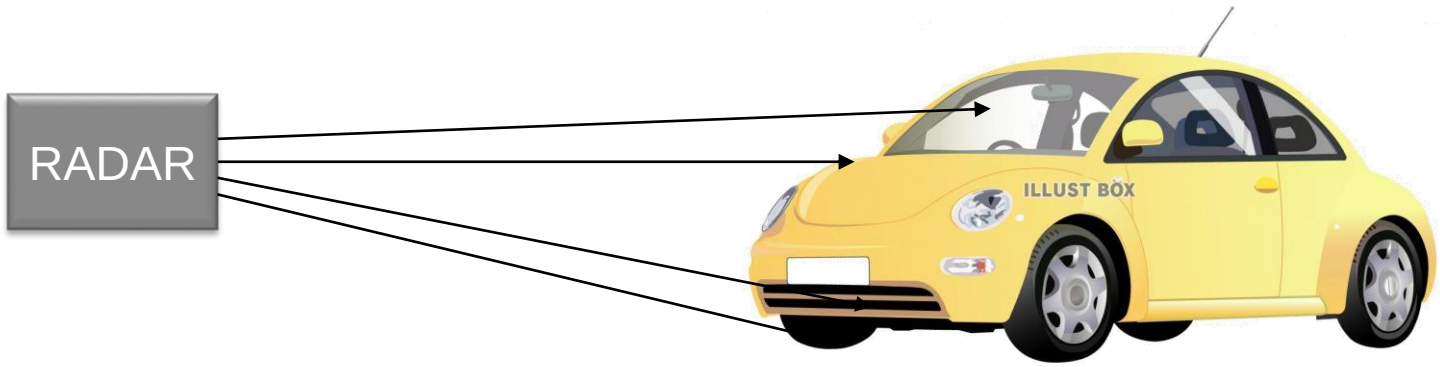
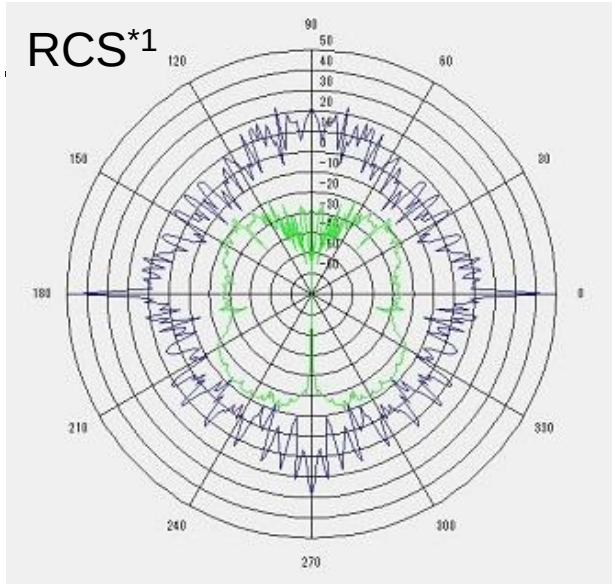
Why The World's First?

There are various real-time radar simulator.....

- MOST Competitive simulator use RCS, which depend on only angle.





- RCS (monostatic or bistatic) is not to be able to express the reflection of each objects which are tire, license plate and body …..)
- Especially, How does it treat road surface????

Our Simulator can reproduce any reflections from any objects.
And enable real-time simulation.
So Our simulator is the World's first !!

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Objective

- External Sensing device are very important for Autonomous driving
- In order to keep secure for Autonomous driving, it need a lot of TEST drive, so we need acceleration test which use something simulator to realize it.
- Current simulator for Autonomous driving has CAMERA, LIDAR and RADAR, but CAMERA image is quite difference from LIDAR, especially RADAR. Because objects have each reflectivity for LIDAR(870nm to 905nm) and RADAR(77G-79G), and there are few simulators in which these reflectivity is implemented.
- As for LIDAR and RADAR, we think they need High precision map. We can make high precision 3D CG MAP for LIDAR and RADAR.
- Our Simulator have reflectivity and physical based reflection model which can reproduce specula and diffuse for any materials.

We focus on high accuracy simulation for autonomous driving, and move forward to realize autonomous driving standard.

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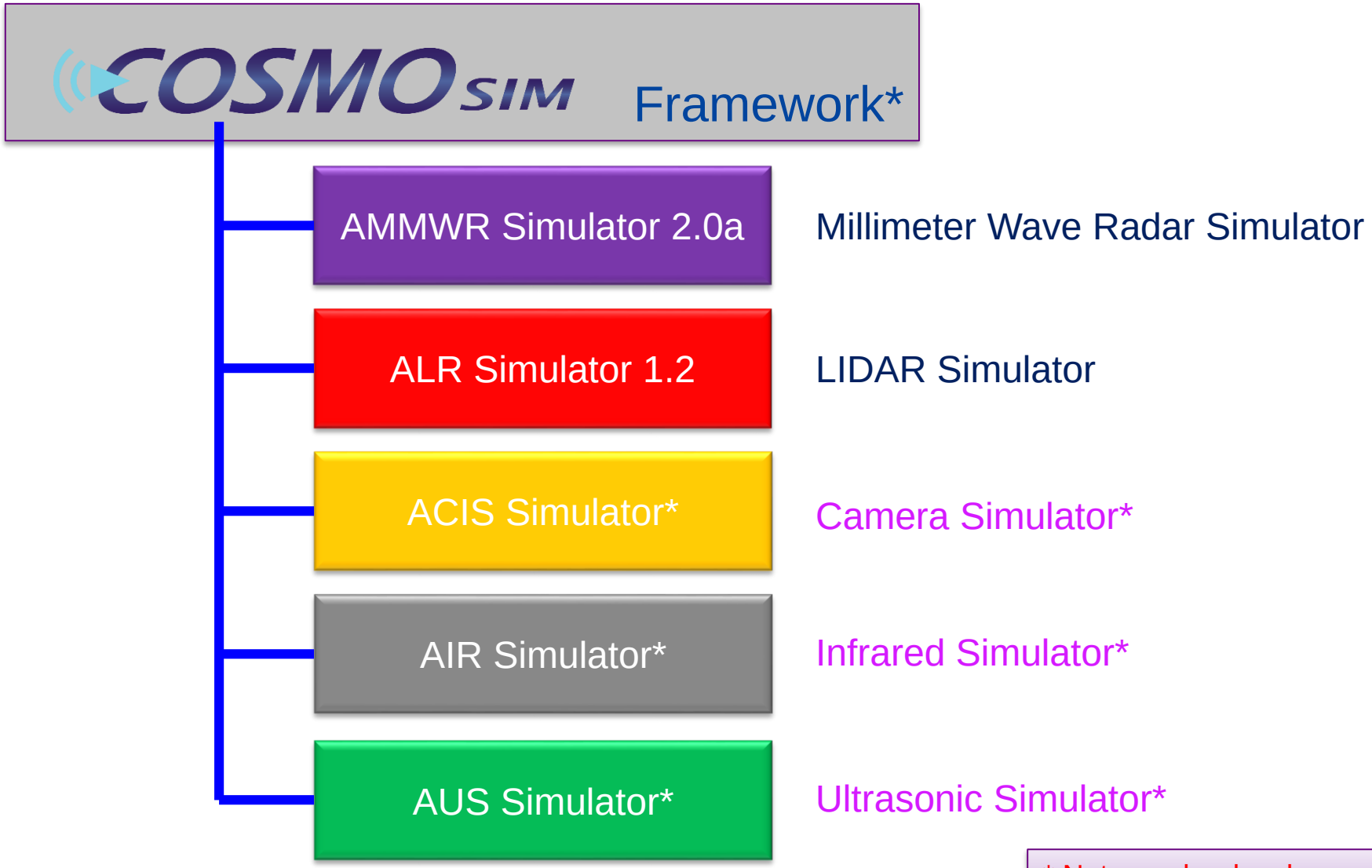
Radar & Sensor Simulator : COSMOsim™ Framework



* Note: under development

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Support OS & System requirements

1. OS: Windows 7 /8 /10 Professional 64bit　(Linux* : in near future)
2. Support Multi Core and GPU calculation
   - CPU:　Core i7 higher/ Xeon Multi CPU recommended
   - GPU:　GTX1080(Ti)/ Tesla K40/K80/P100 /Quadro M5000/M6000
3. 3DCG Engine:
   - UE4*1 :　version 4.12 or later (our recommend 4.12/4.17)
4. Parallel Computing*2 : need Windows server OS and Infiniband　I/F card

*1: UE4: Unreal Engine *EPIC GAMES
*2 : Under Development

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Features:

Product Name	Function	Features
AMMWR	・3DCG Scenario Simulation ・Radar Map	Support: MMR simulation with MMIC RFE system Available: Detection Algorithm: MUSIC, ESPRIT
ALR	・3DCG Scenario Simulation ・3DPoint Cloud/Depth display	Support: LIDAR inside geometries (i.e. Mechanical polygon mirror/MEMS/Flash)
ACIS	・3DCG Scenario Simulation ・Recognition Algorithm (Pedestrian Classifications and Distance measurement…)	Support: Various Lens model (i.e. Planner/Fish Eye…) Available Lens model :（Seidel aberration, Optical axis deviation） and Recognition Algorithm
AIR	under development	
AUS	under development	

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Advantage for Competitor :

Product Name	Advantage for competitor
AMMWR	Inside Specular/Defuse model Support Pulse Doppler/ FMCW/First Chirp
ALR	almost same as competitor LIDAR Simulator, but little bit different (our reflection model is better accuracy, because OTSL simulator has reflection model for NIR)
ACIS	・Original Camera(i.e. Fish eye..) model with Calibration technology ・Various Recognition Algorithm
AIR	under development
AUS	under development

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AMMWR Simulator 2.0a

Introduction of inside AMMWR

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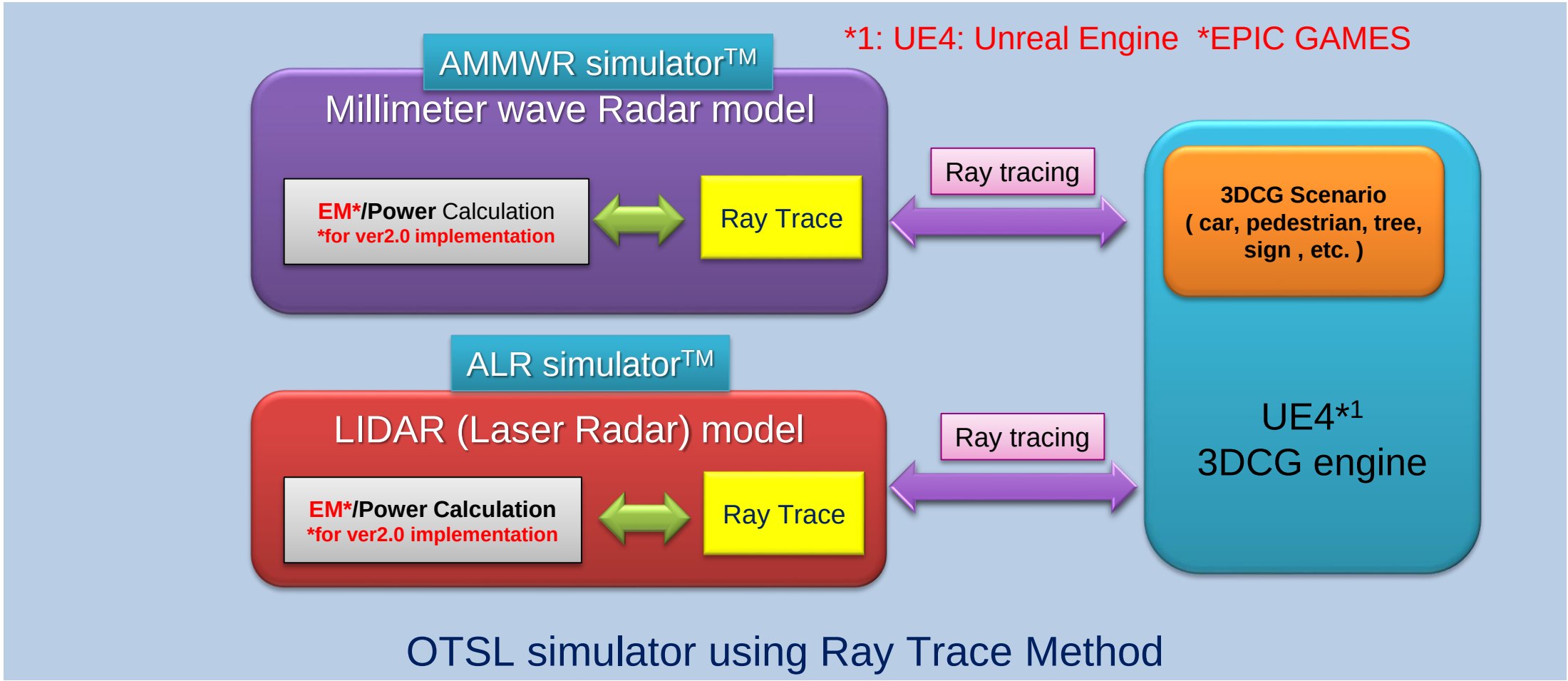
COSMOsim® Framework for Automotive Rader Simulation



OTSL simulator using Ray Trace Method

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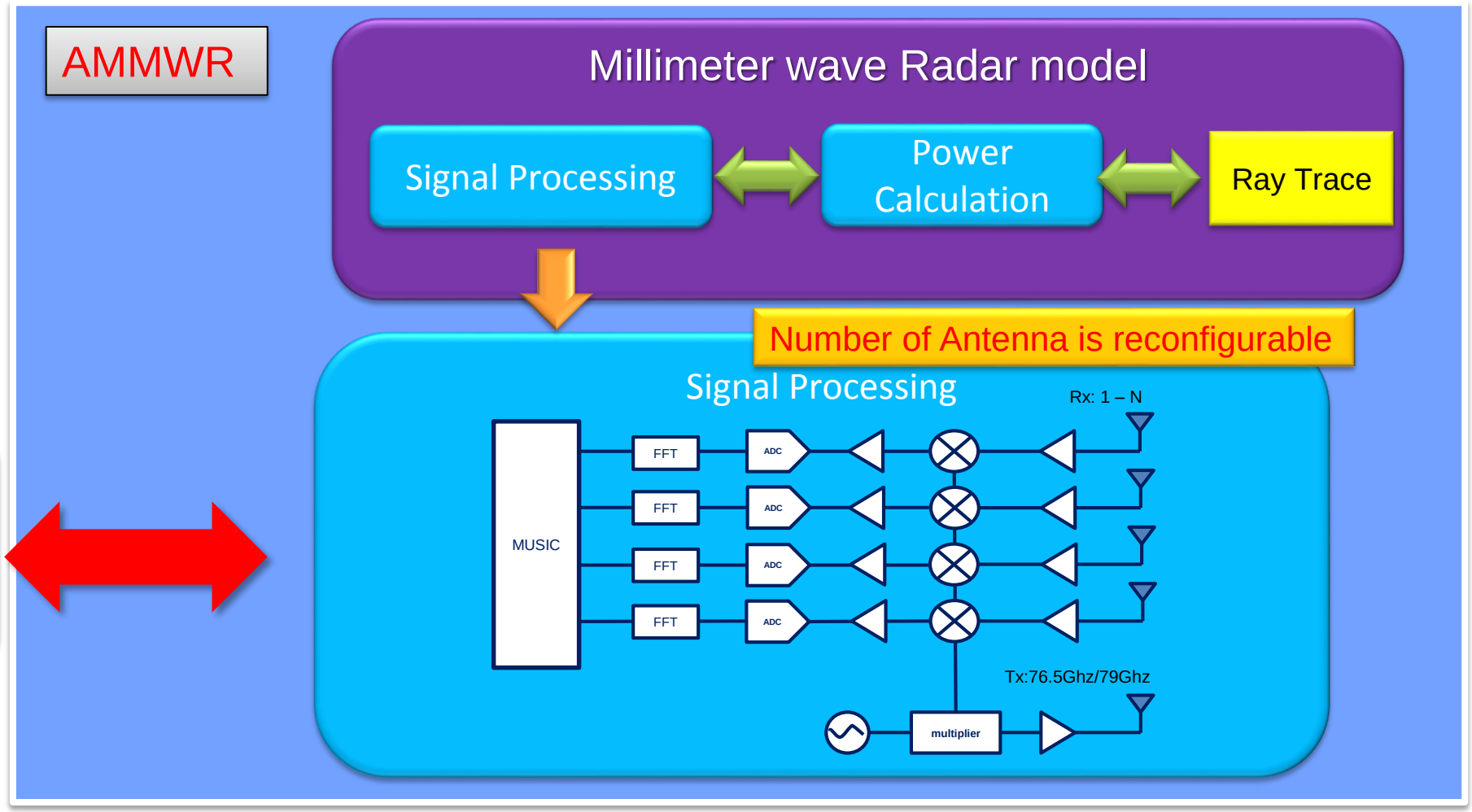
Inside AMMWR Simulator ver 2.0a details



Fit for Customer I/F*
(i.e. MILS/SILS…)

Available various direction detection algorithm
(i.e. ESPRIT, root MUSIC …)

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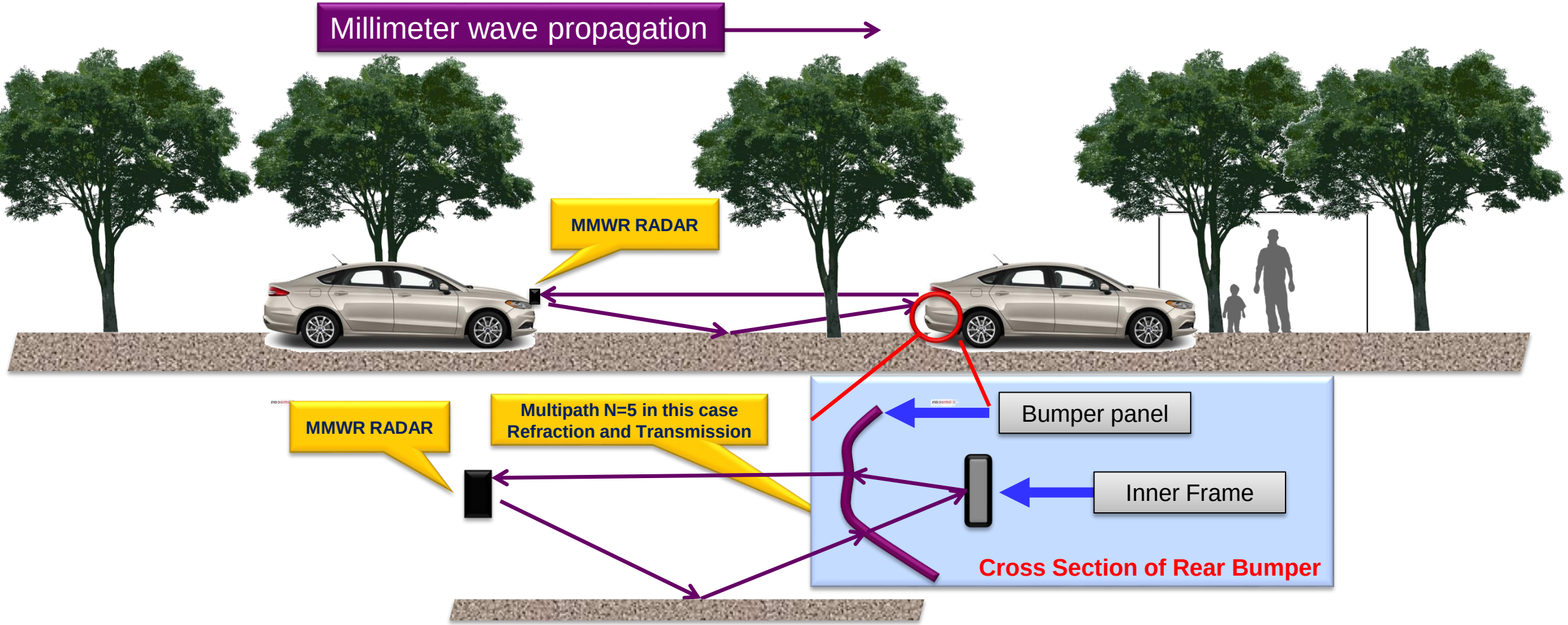
Inside AMMWR Simulator : Multipath of Ray tracing



AMMWR can calculate refraction and transmission

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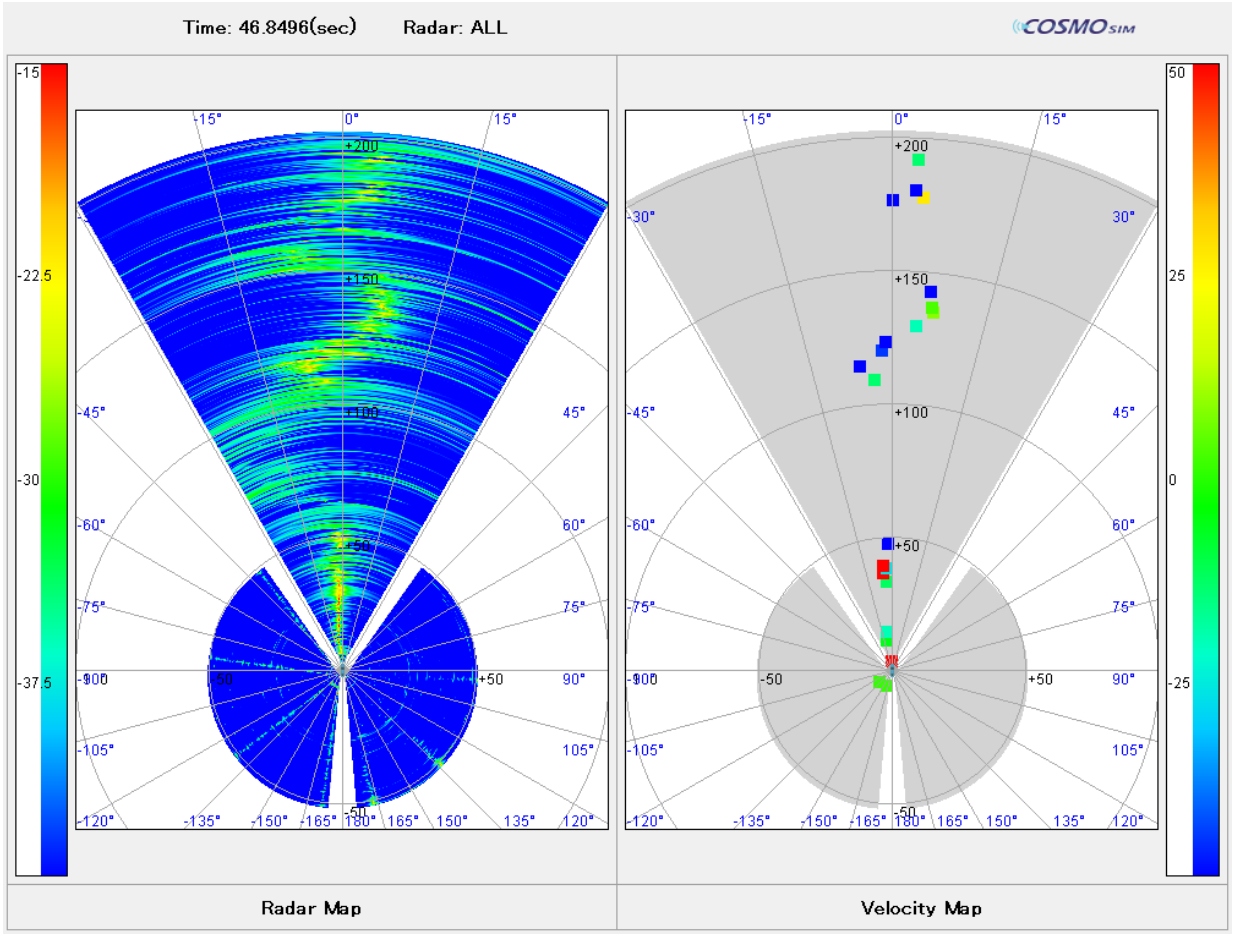
AMMWR using high precision 3DCG MAP



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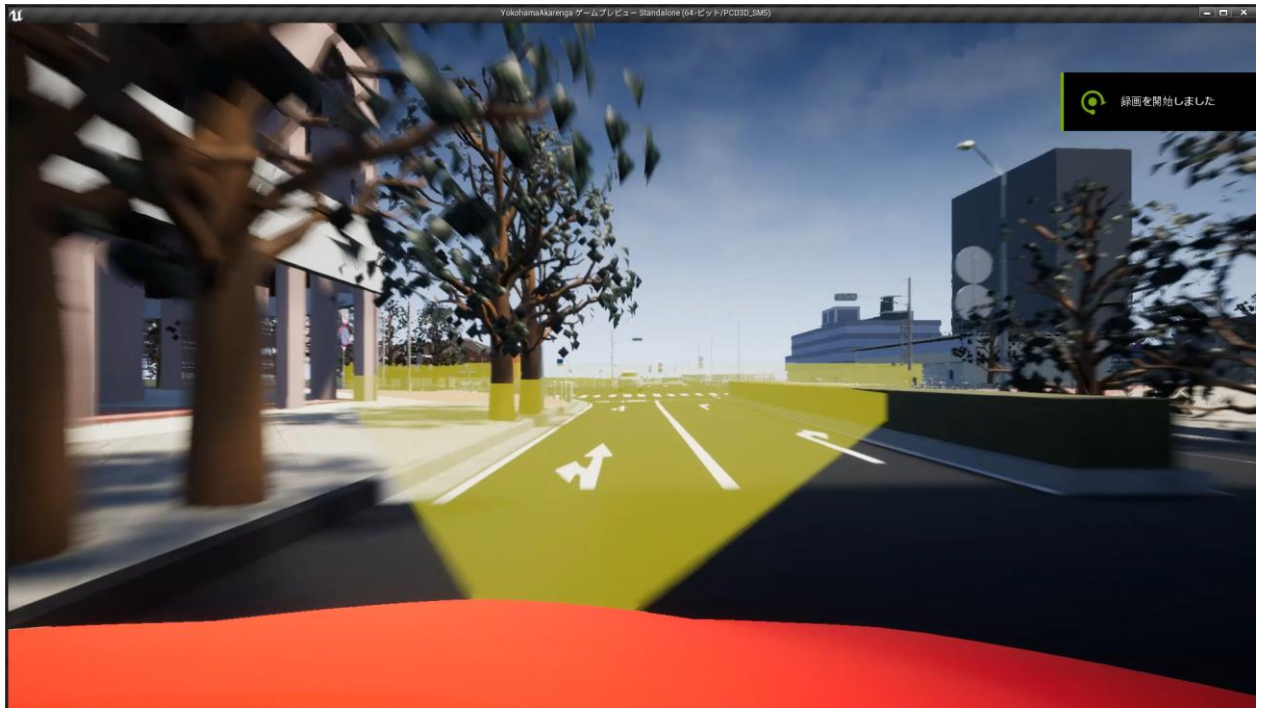
AMMWR movies （easy to change view point）



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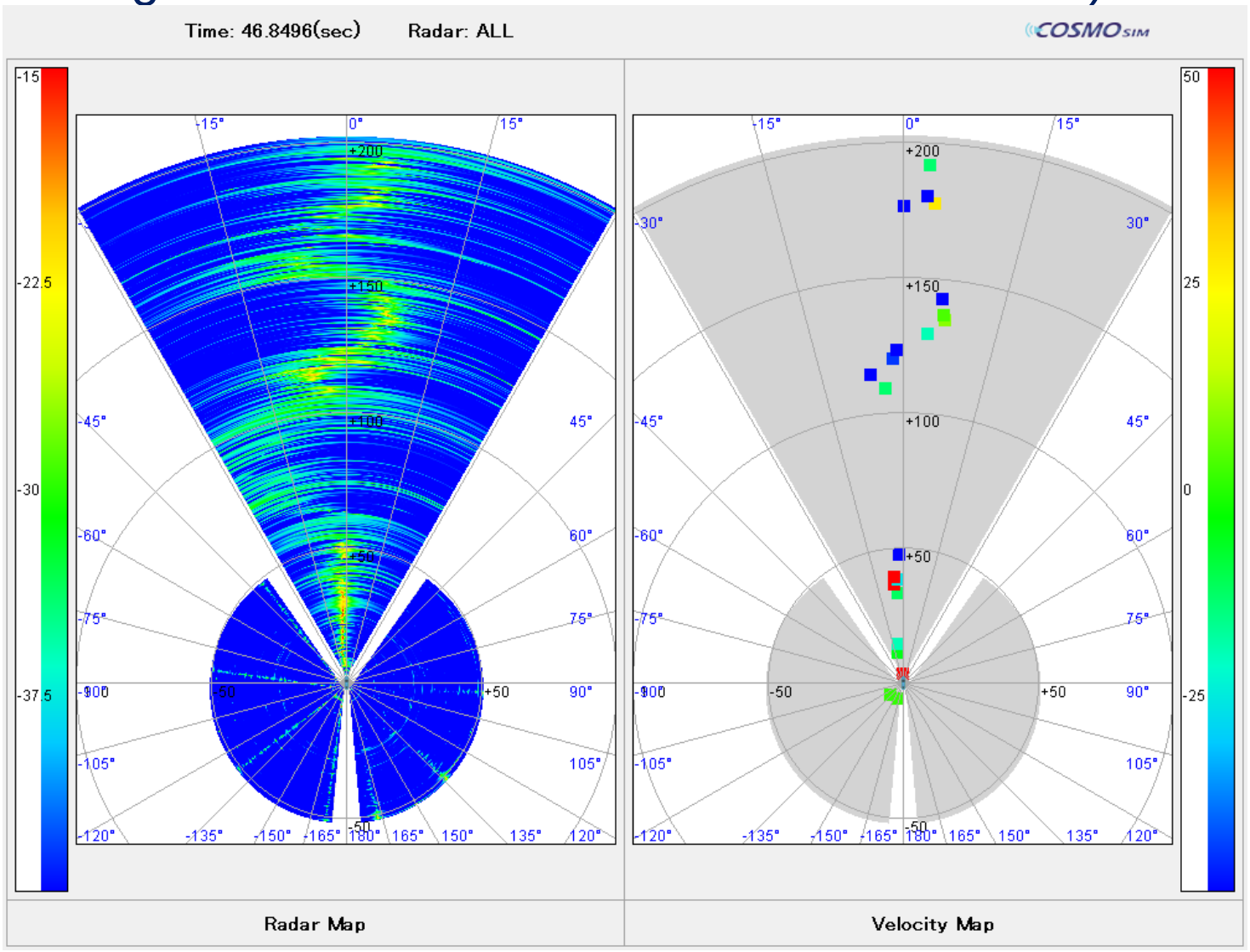
NEW Radar Map (this figure has front radar and 2 backside radar)



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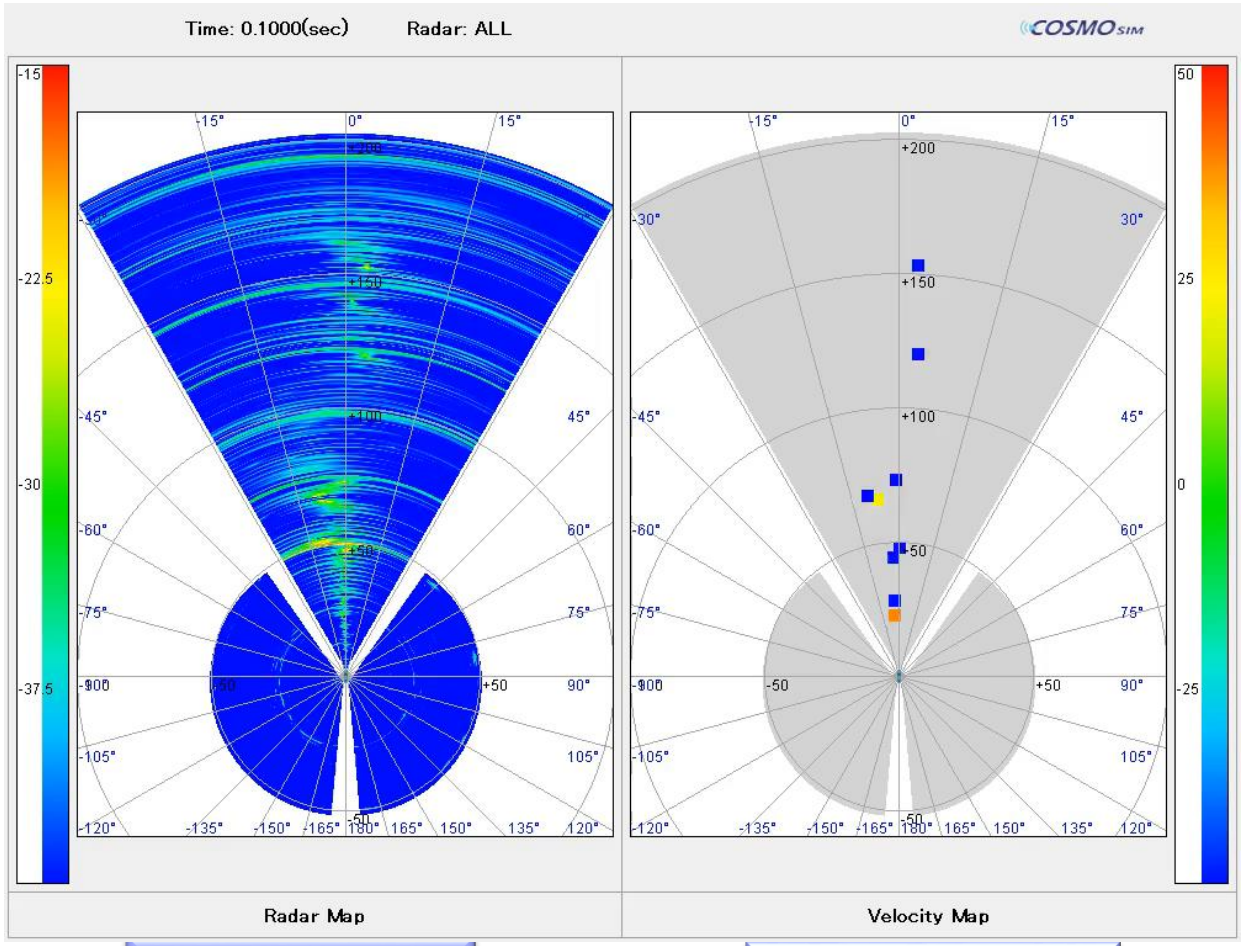
AMMWR simulator movie



Distance-power

Distance-velocity

Scenario

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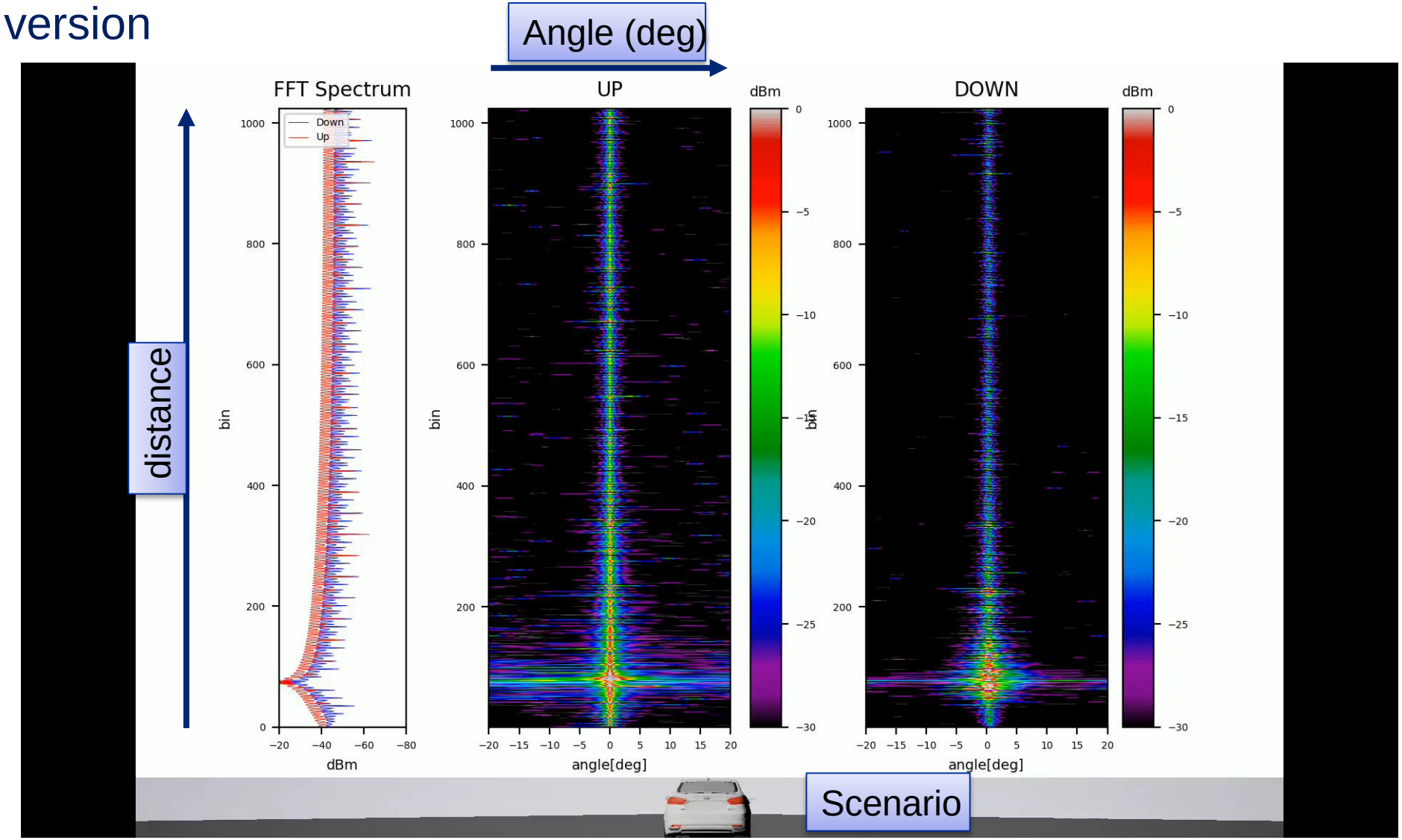
AMMWR DEMO Movie (Object : Vehicle rotation) with old version



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DENSO
Crafting the Core

MMWR Simulation USE CASE
October 19, 2017

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DENSO INTERNATIONAL AMERICA, Inc.

6/29/2017

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関係者外秘

ALR: LIDAR Simulator 1.2

Introduction of inside ALR

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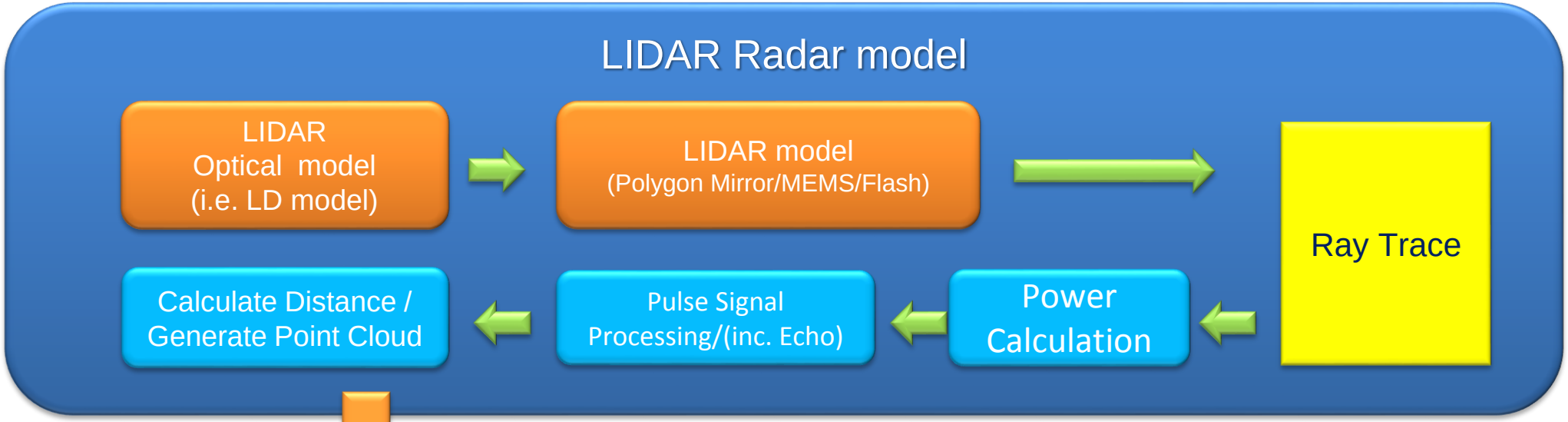
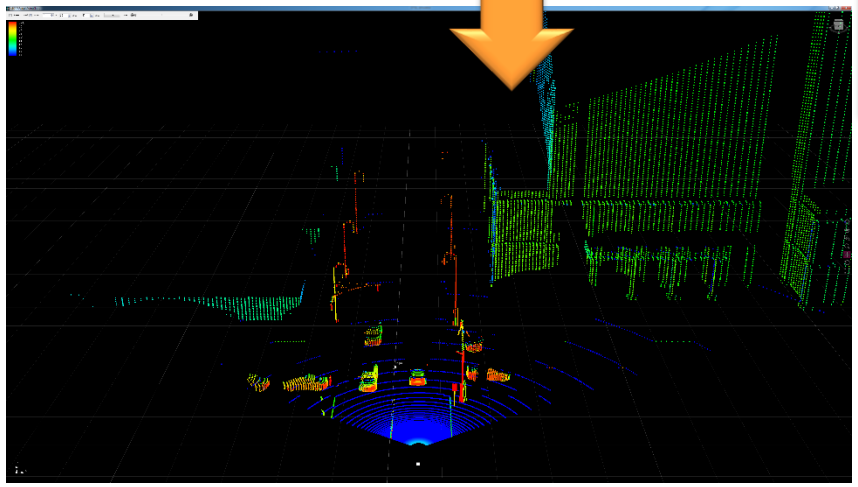
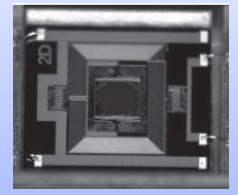
Inside ALR Simulator 1.2





1. Output distance between own vehicle to objects.
2. Output Point Cloud data


ALR support above 3 types

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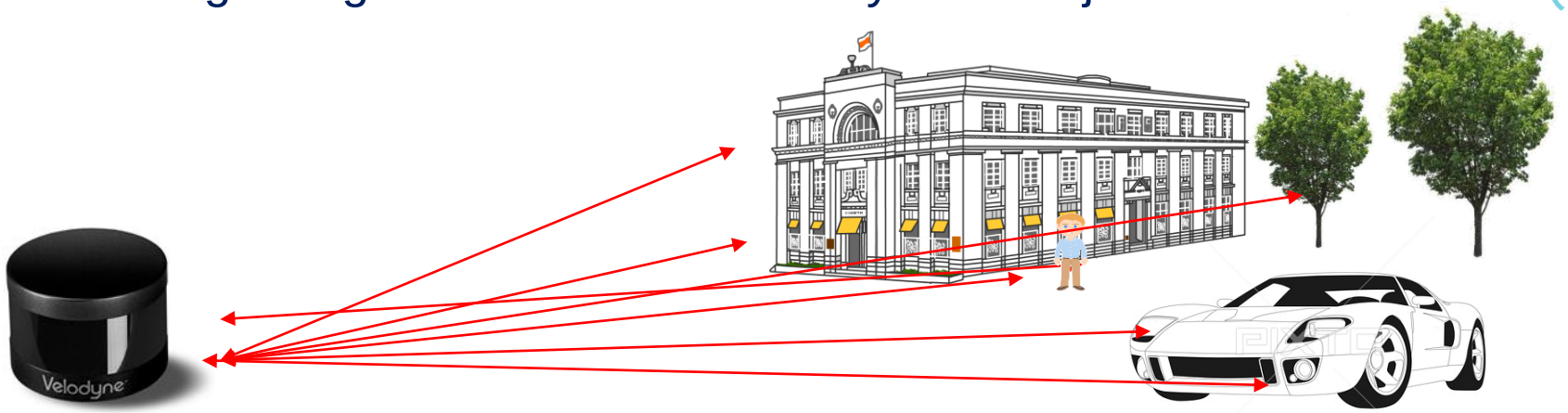
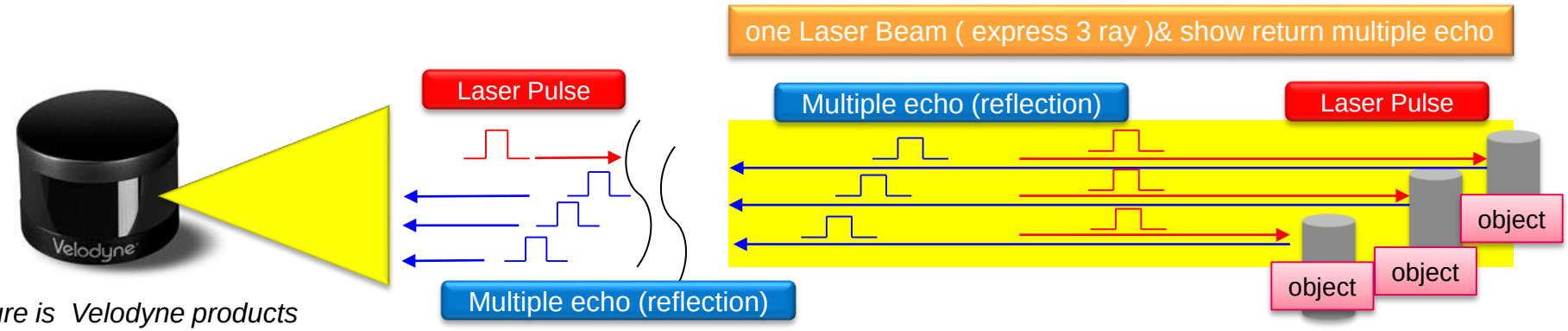
Regarding Calculation Return Ray from Object reflection





LIDAR picture is Velodyne products

Real (Pulse) LASER BEAM has SPREAD, so
LIDAR Simulator NEED calculate Multiple reflection ray (echo).
It is available to calculate multi echo (n=1-3)

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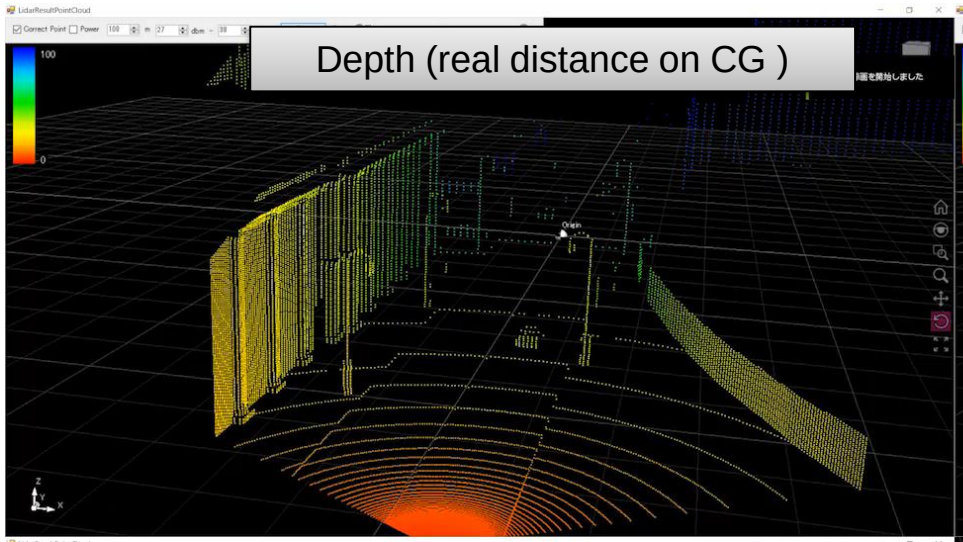
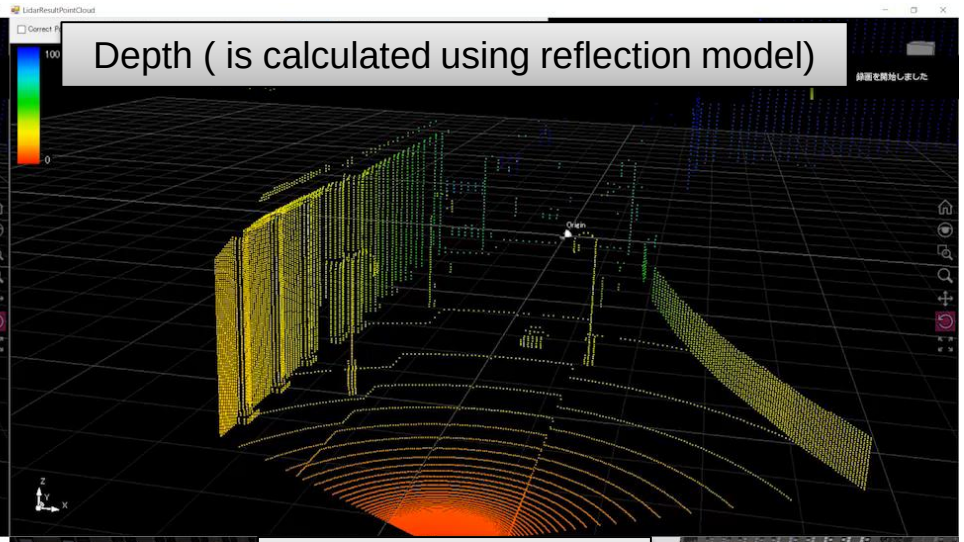
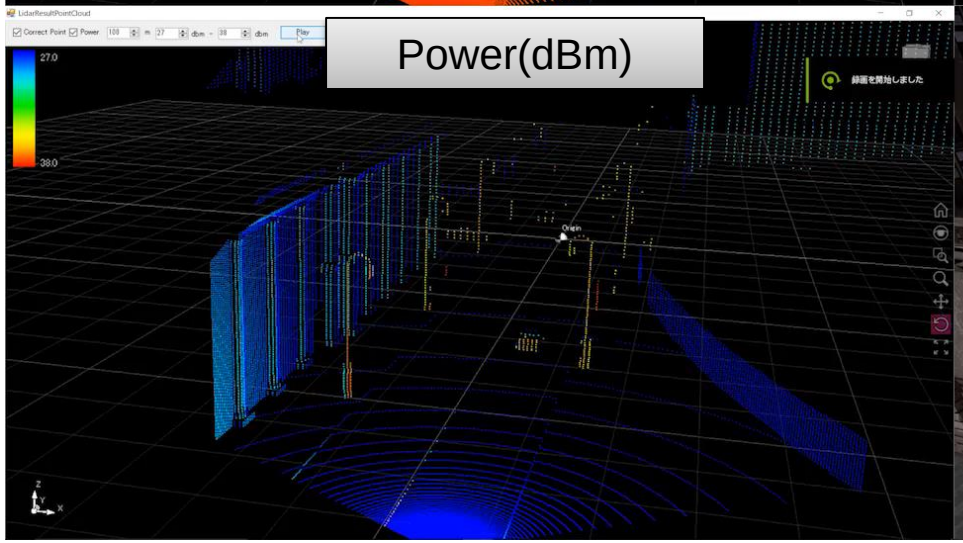
LIDAR 3D Point cloud (* FOV exaggerated, not real)







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Scenario using High Precision 3DCG MAP　(TEST Sean)

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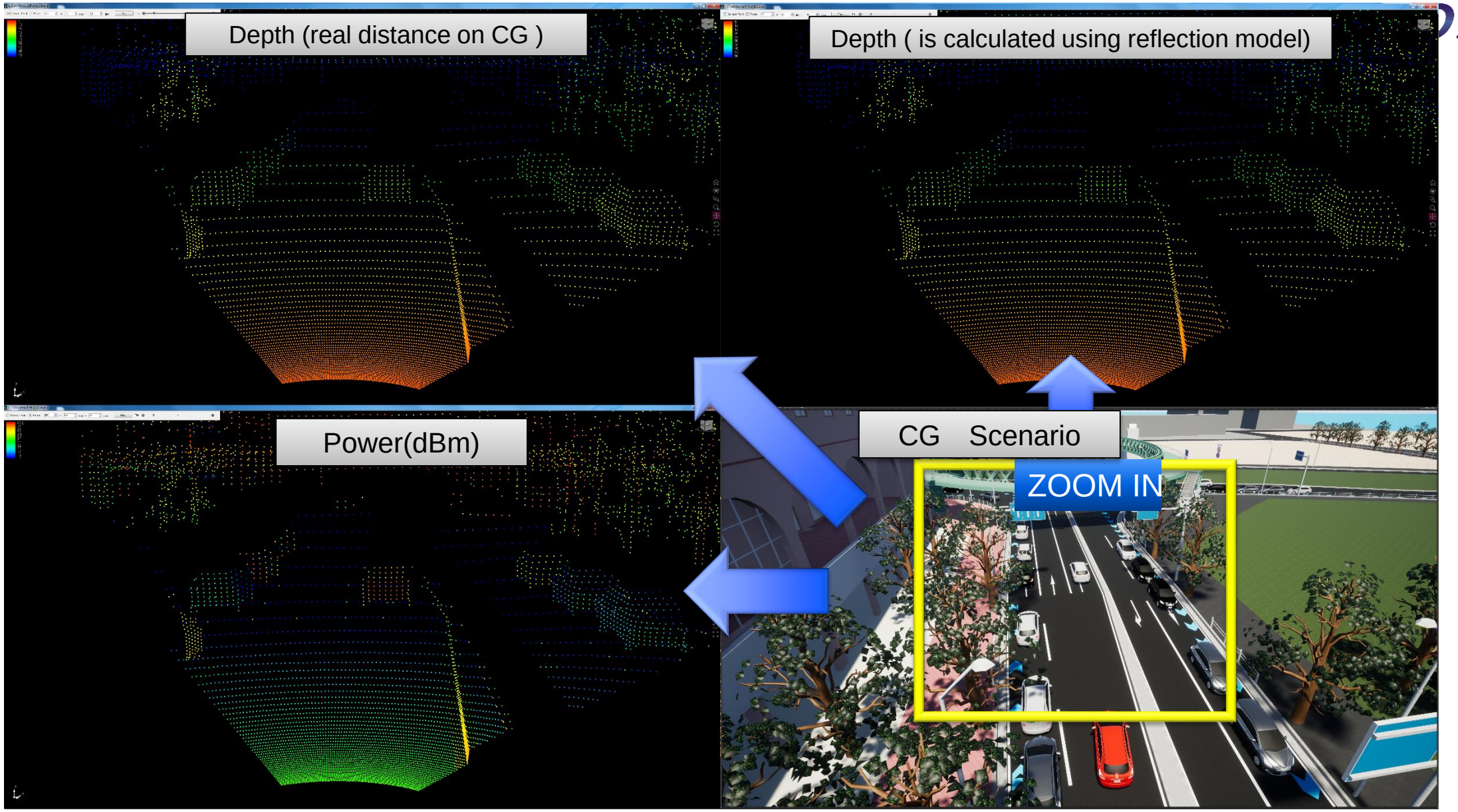
LIDAR 3D Point cloud (Look at different color of Vehicles)



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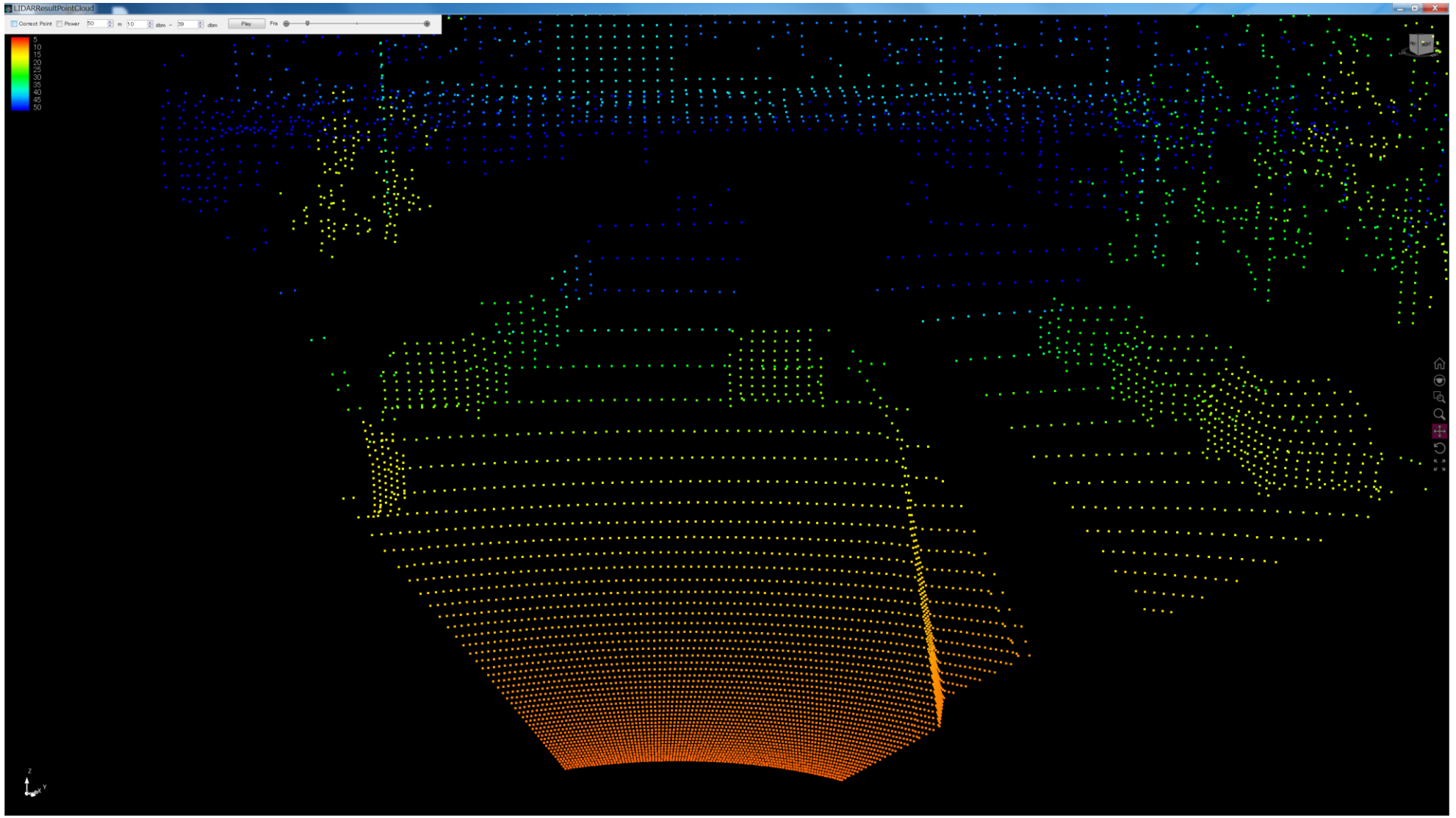
Depth from ALR: LIDAR simulator FOV:60degree



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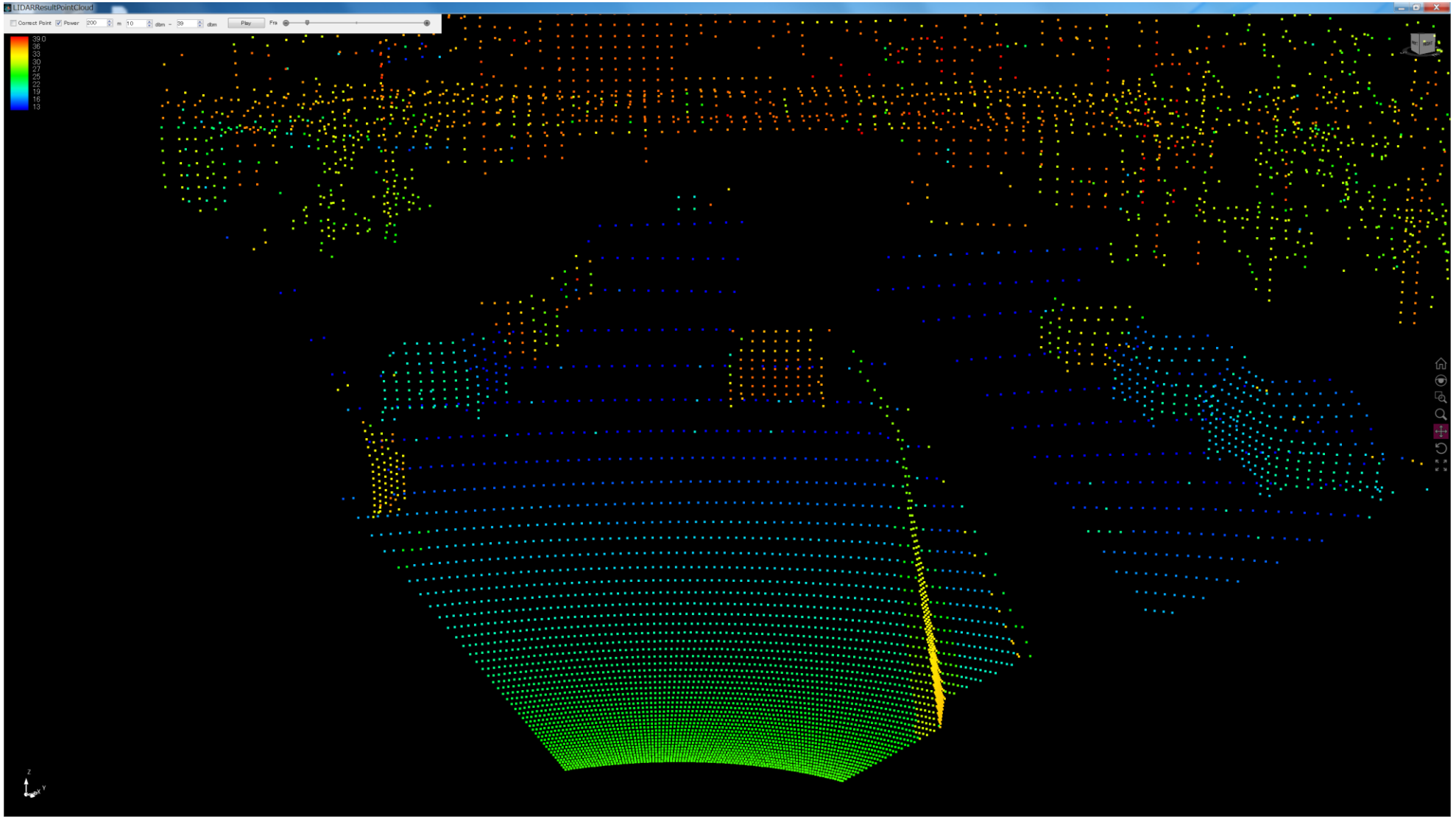
Receive Power from ALR: LIDAR simulator FOV:60degree



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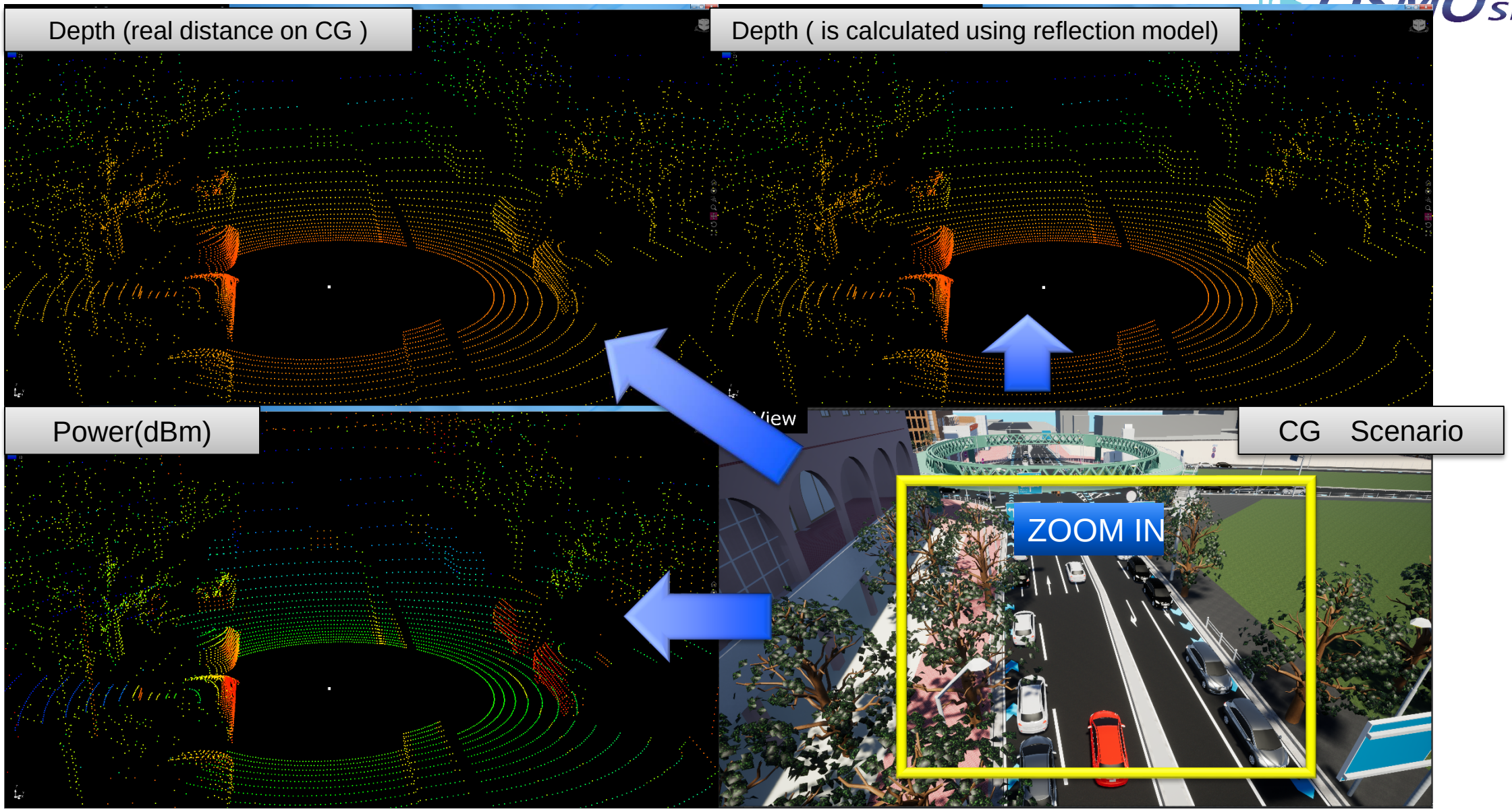
LIDAR 3D Point cloud (Look at different color of Vehicles)



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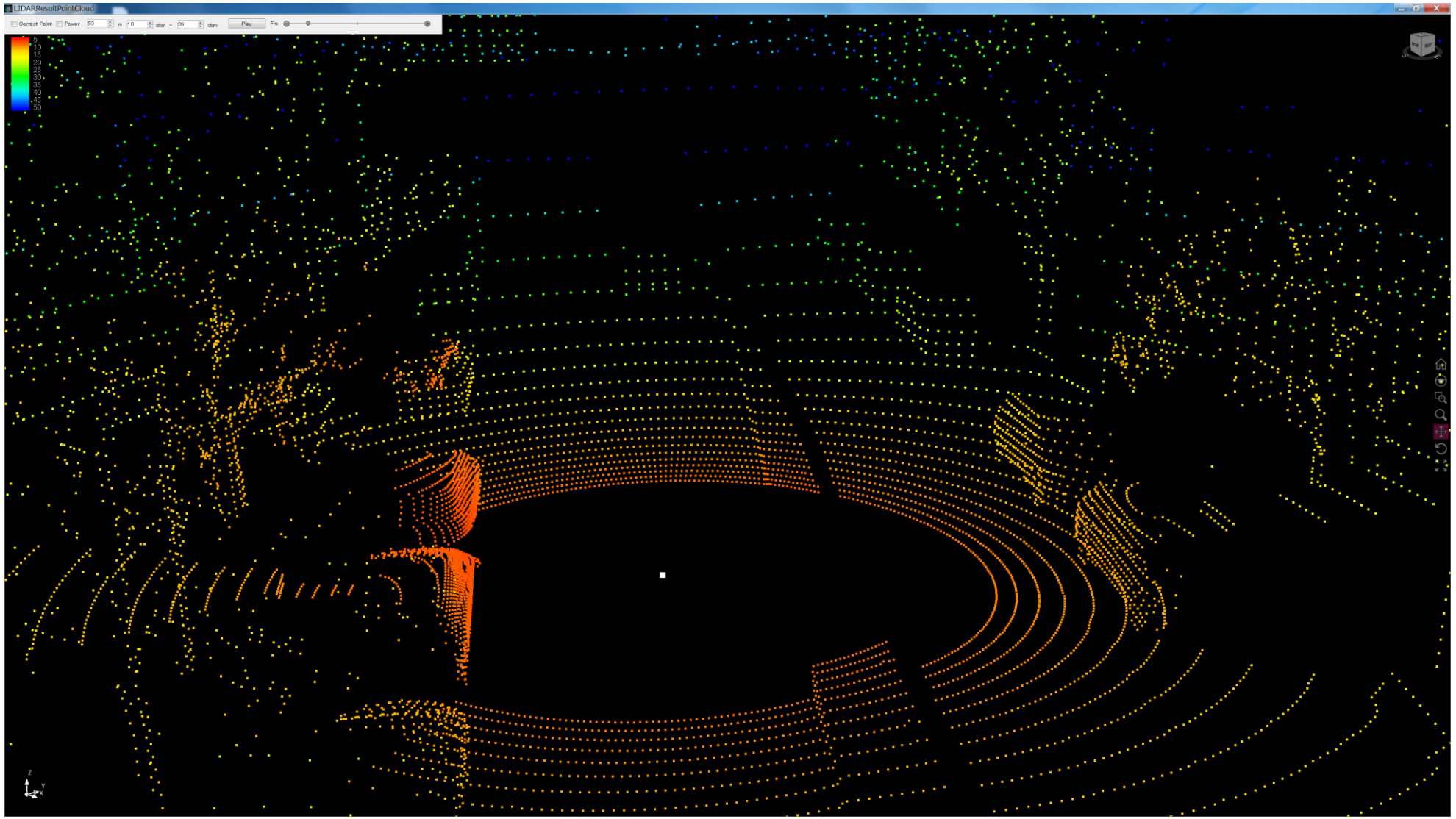
Depth from ALR: LIDAR simulator FOV:360degree



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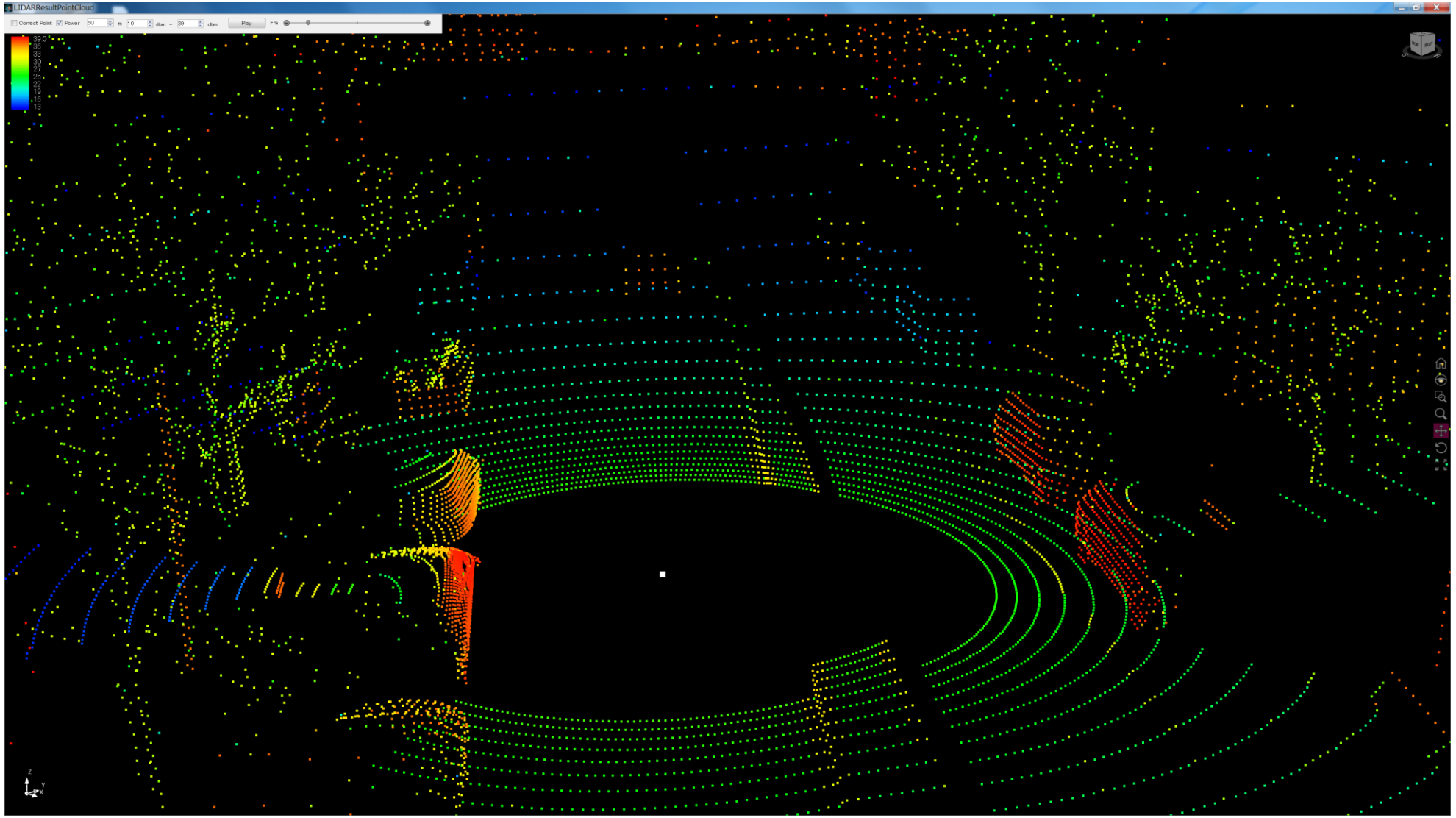
Receive Power from ALR: LIDAR simulator FOV:360degree



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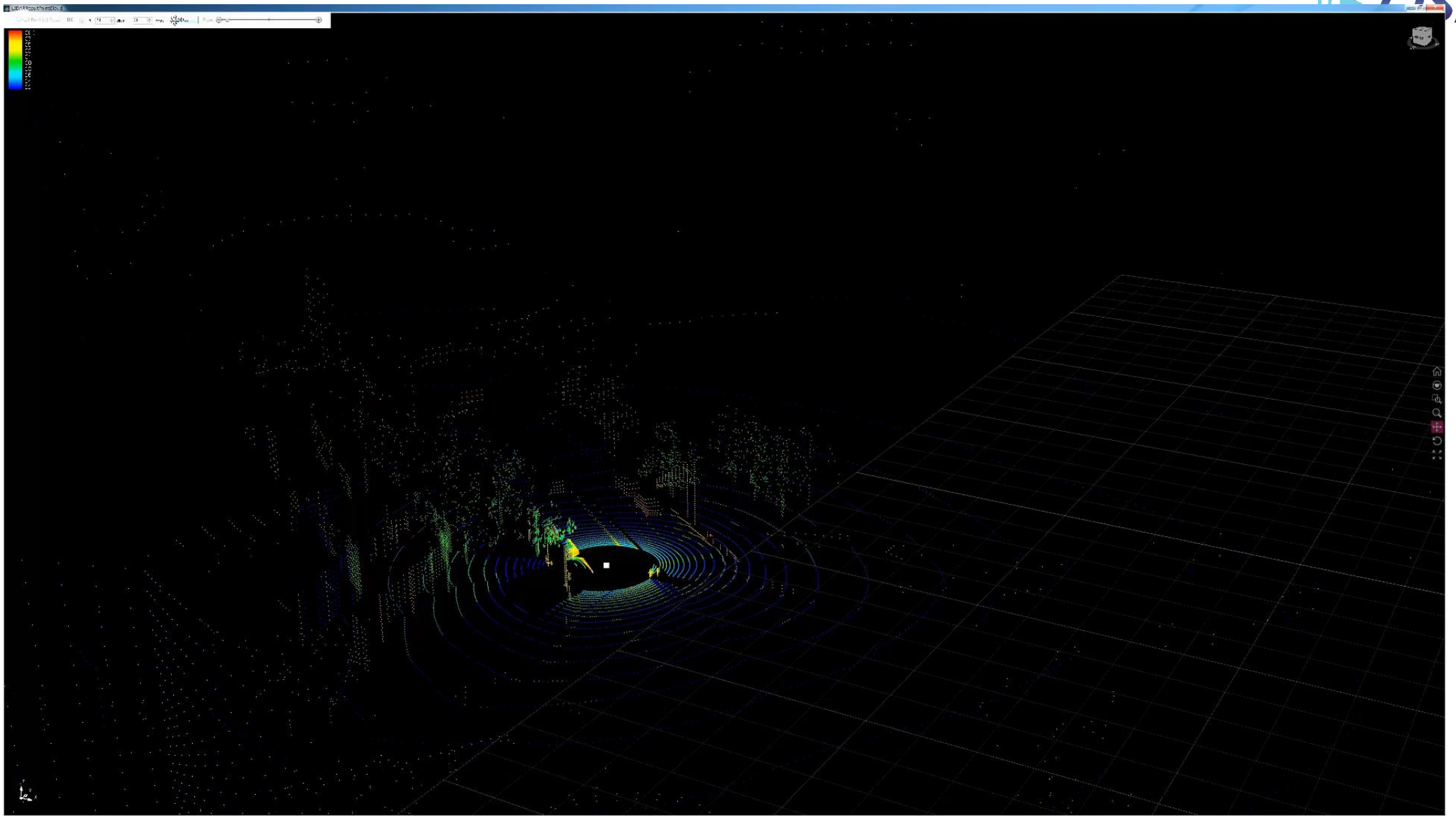
DEMO MOVIE



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Benefit of using COSMOsim™

For Car Maker

1. enable to decide RDAR specification easily
2. enable to decide Radar position and layout before car design
3. enable to find WORST CASE Scenario and Radar problems without real test.

For Tier-1 Supplier

1. enable to decide Radar specification
2. Enable to show own radar advantage on PC (for sales?)

For RF/semiconductor

1. Enable to simulate using own device (MMIC) on Virtual environments.
2. Enable to consider optimize and specification using radar simulation
3. Enable to accelerate MMIC design and TEST

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Data Sheet Summary for MC33MR2001T from NXP.

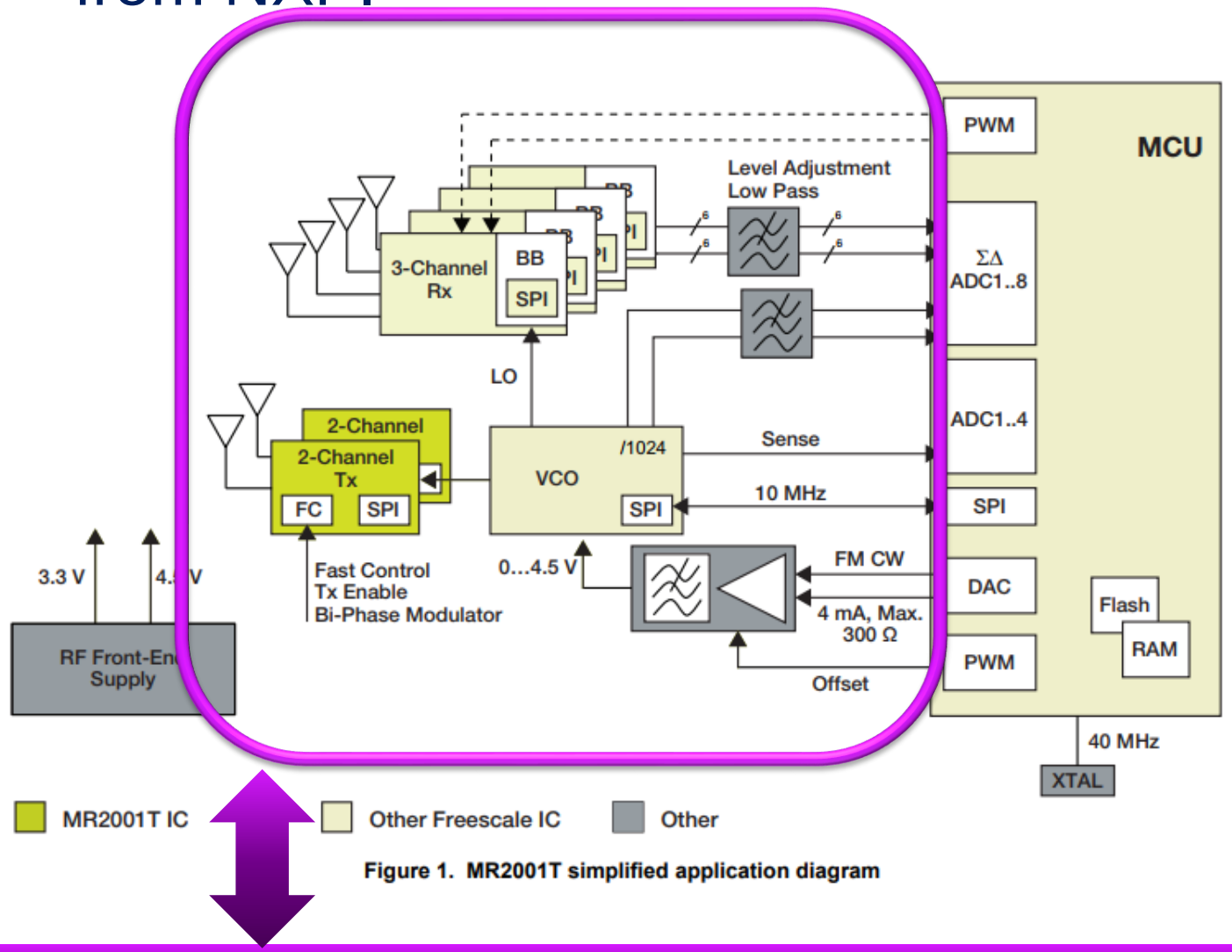

Figure 1. MR2001T simplified application diagram

Our AMMWR enable to consider various parameters for RADAR specifica

This datasheet from : https://www.nxp.com/docs/en/data-sheet/MC33MR2001TSM.pdf

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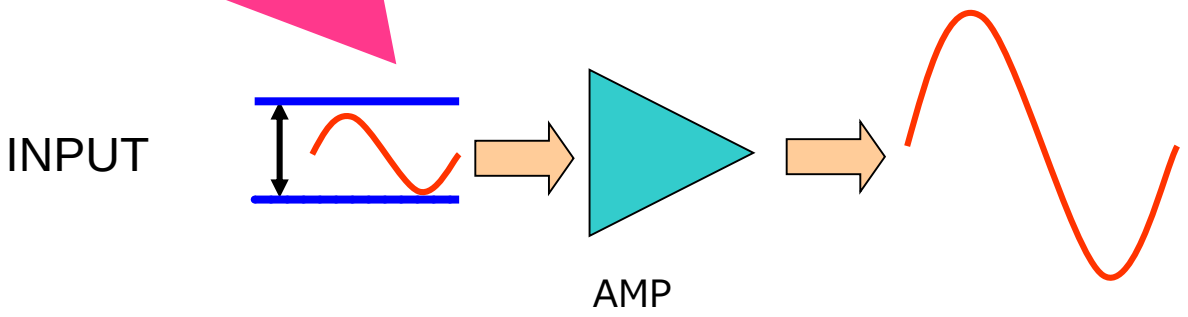
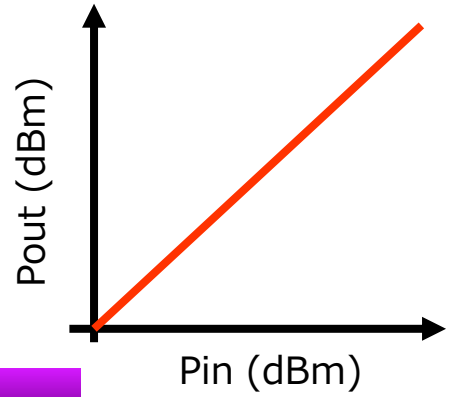
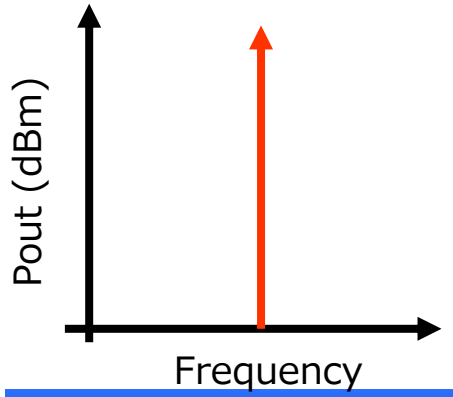
Large Signal and Distortion…..

Amplifier input Range(head room)

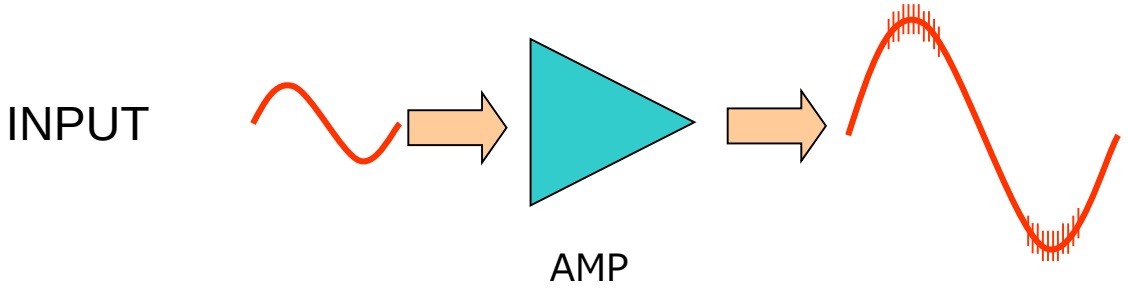


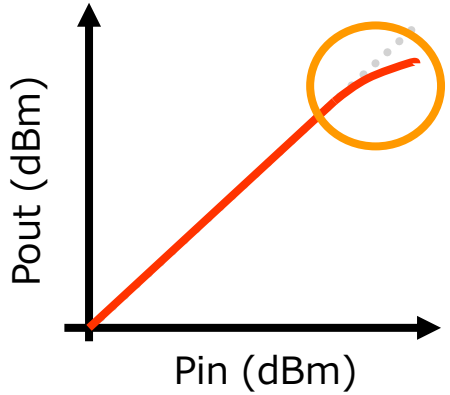


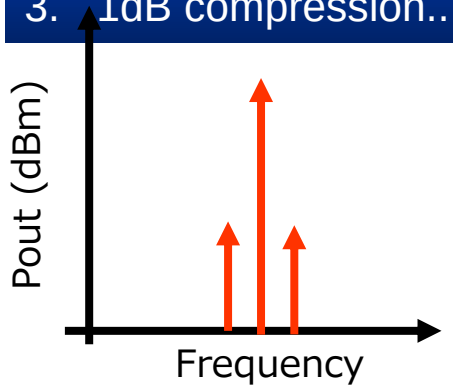


Now We support

Real condition:
1. Saturated AM-PM
2. IP3,
3. 1dB compression..







We can support these Characteristics and noise…..
But Speed will be slow….

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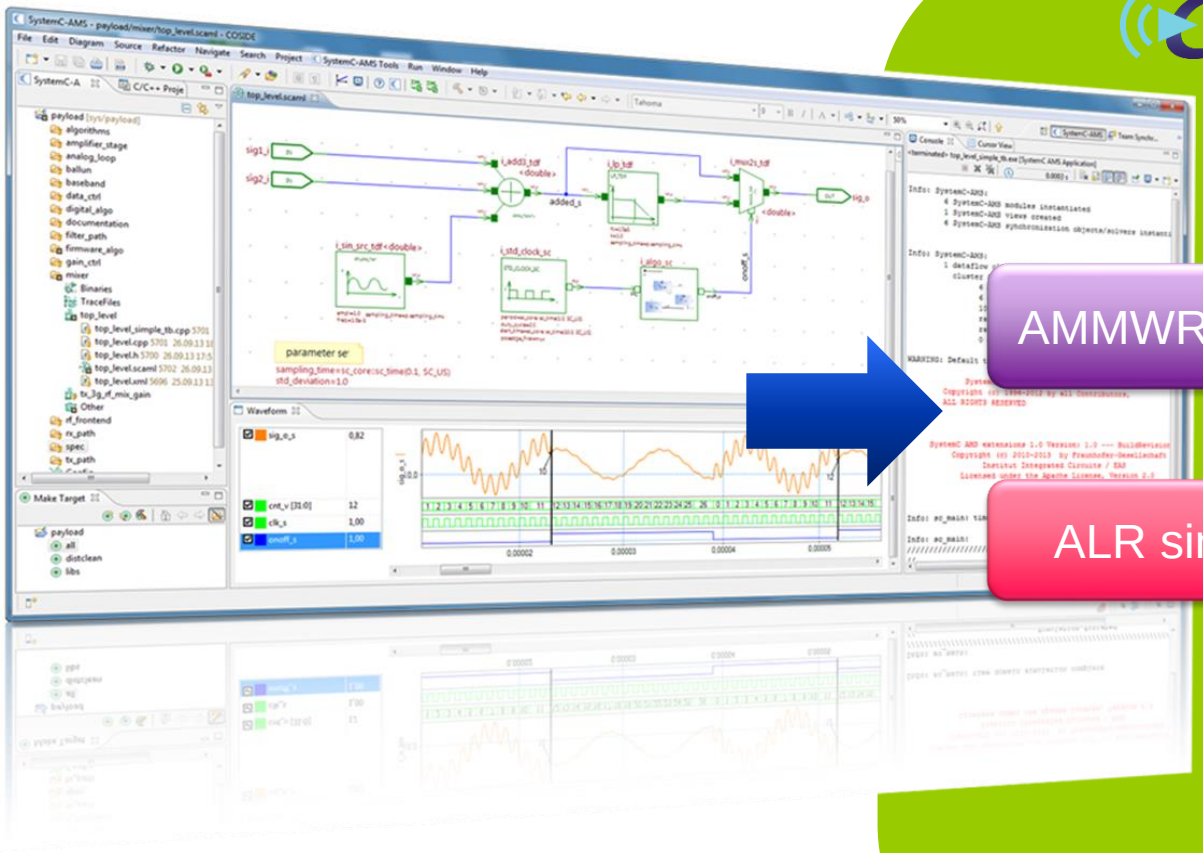
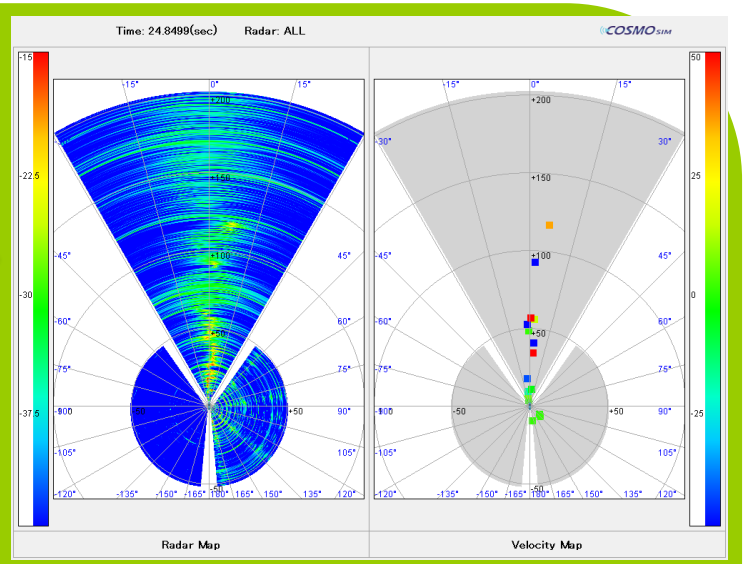
COSIDE® COSMsim (coming soon)

COSIDE® Driven OTSL RADAR Simulator

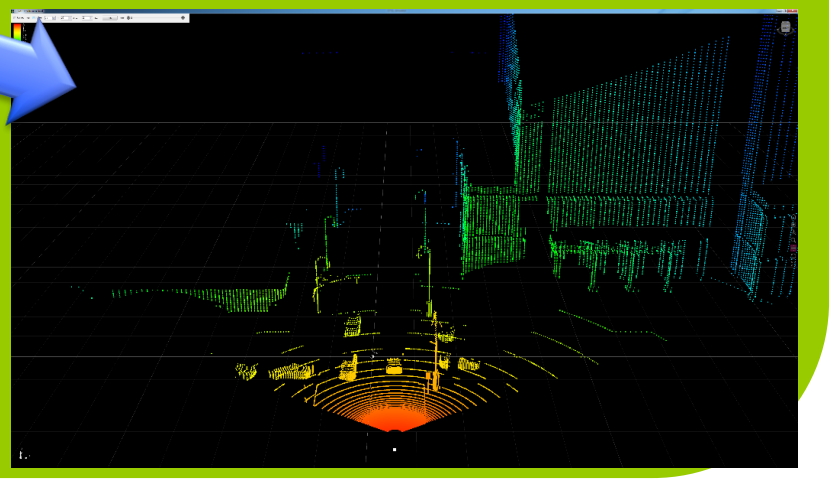
COSMOSIM



AMMWR Simulator 2.0a



ALR simulator1.2



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Current Implementations and Features:

- **Direct Rays:**
  un-obstructed by occlusion, possibly transmitted through absorbing semitransparent layers on thin surface layers or transparent surfaces.
  1. Optimized Rays launch
  2. Considering Antenna Characteristics including main lobe
- **Reflected Rays:**
  which bounce on a smooth mirror surface.
  1. Calculate Reflected Ray
  2. (Phong*/ Lambert * / etc) Reflection model
  3. Available RCS

$$I = k_d \cos\alpha + I_i W \cos^n \gamma + I_a k_a$$

- **Another Features:**
  1. GTD/UTD (inc: refraction/ diffraction/ reflection effects)

**1. UE4 adopt Phone refelection model*
**2.1973: Bui Tuong Phong Illumination for Computer Generated Pictures*
**3. Lambert, J.H. (1760): Photometria sive de mensura et gradibus luminis, colorum et umbrae (Augsburg ("Augusta Vindelicorum"), Germany: Eberhardt Klett).*

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Current Implementations and Features:

- EM Solver (FDTD)
  1. Dielectric absorption
  2. Spatial power calculation
  3. Impedance Calculation
  4. Antenna model Simulation

- GUI/3D CG Implementation into UE4(unreal engine)
  1. Car model
  2. Solver Control using Custom GUI
  3. Function control using Custom GUI

- Refection/Scattering(Dispersion)/Refraction model using (GTD/UTD)

  AMMWR can consider the following characteristics from GTD/UTD
  1. Diffraction Rays which emanate from a trimming curve joining two surface
  2. Creeping Rays which travel on surface from one shadow boundary to the next
  3. Double Diffraction Rays which emanate from one curve point by diffraction and diffract again on another curve point
  4. Double Reflected Rays which bounce twice on mirror surface
  5. Reflected-Diffracted Rayswhich are reflected from a surface and the diffracted by a trimming curve

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Reference

P2:http://www.keycom.co.jp/jproducts/sfw/sfw03/page.html

P17: MEMS Mirror :https://www.hamamatsu.com/resources/pdf/ssd/mems_mirror_koth9003j.pdf

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Vielen Dank für Ihre Aufmerksamkeit.

Thank you for your attention

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