Over-the-Air Real-Time Automotive Radar HiL

with CarMaker for ADAS and AD Validations

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• Radar verification and road safety
• Toyota Safety Sense HiL setup
• ASGARD1 radar testing system
• CarMaker HiFi radar model with ASGARD1
• CarMaker radar RSI with ASGARD1
• Conclusion
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Need for radar validation

• The EU regulations for road safety 2022 obligate new safety features for cars such as intelligence speed assistance, vulnerable road user detection and automatic emergency braking

• Radars are safety-critical sensors in driver assistance systems and autonomous driving

• Real-life deployment of radar functions requires high reliability and a lot of testing

• Radars need be tested under dangerous traffic scenarios

• **Radar target simulators** enable in-lab testing of radars in a repeatable and accurate manner

• **Hardware-in-loop** test benches are important for testing radars against a ground-truth
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• Radar verification and road safety

• **Toyota Safety Sense HiL setup**

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Toyota Safety Sense

• Toyota Safety Sense™ (TSS) is a bundle of active safety features

• TSS is designed to help protect drivers, passengers, people in other vehicles on the road, and pedestrians from harm

• TSS consists of camera- and radar-based driver assistance systems (ADAS)
Toyota Safety Sense HiL setup

- HiL Test Manager (Windows PC)
- Ethernet (IPG real-time system XPack4)
- Display Port
- 5K Display monitor
- ADAS Camera
- ADAS Radar
- CANoe for Diagnostics Testing
- ADAS Measurement System (Supplier specific)
- Local CAN
- Global CAN
- CANoe
- Toyota Safety Sense HiL setup
- ASGARD1 (RTS)
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ASGARD1 Automated Signature Generation for Automotive RaDar Verification

- ASGARD1 is a **patented** technology: **Frequency-based** over-the-air radar target simulator
- Translates 3D environment to **radar reflector points**
- Emulates targets by adding distance, speed and angle of reflector points to the radar spectrum rather than creating targets in delay domain
Radar testing technologies

- **Delay-based (Time-domain)**
  - Each target generated by a delay-line
  - Addition of targets requires adding to the number of delay-lines i.e. few targets
  - Not possible to create small minimum range due to processing delay
  - Angles of targets generated by mechanical rotation of antennas of target simulator

- **ASGARD1: Spectrum-domain**
  - Targets with arbitrary trajectory are simulated in frequency domain
  - New targets are easily added to the spectrum of radar signal i.e. supporting hundreds of targets
  - Minimum distance of 20 cm is possible
  - Large dynamic range for RCS
  - Real-time signal generation and adaptation
  - Angles perception can be generated completely electronically
ASGARD1 - Radar target simulator for HiL
Scalable solution for full vehicle (multi-radar) HiL testing
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CarMaker HiFi radar model with ASGARD1

Integration of ASGARD1 and IPG CarMaker in a HiL setup
ASGARD1-CarMaker HiL setup

CarMaker for real-time scenario generation through Xpack4

ASGARD1 for emulation of targets in the scenario
Point target information

- Radar targets are based on CarMaker HiFi Radar Sensor model
- IPG user C-interface extracts and sends targets information
- ASGARD1 receives information of point targets from CarMaker via UDP communication
  - Range
  - Radial velocity
  - Azimuth angle
  - Elevation angle
  - RCS
Our tool for comparing radar outputs with ground-truth

Time-referenced radar detections can be recorded for comparison against simulated scenario in CarMaker
Comparing radar range measurements with ground-truth

CarMaker output is the ground-truth
Analysis of target detections with different radars
Analysis of radar detections using two radars
Difference between ranges from CarMaker and radar output

Range analysis between CM and radar measurements

Range difference mean = 0.43 m
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ASGARD1 in Radar RSI HiL

1. Radar RSI
   - Point Cloud Processing (CarMaker 9.0 RSI)

2. TSS CarMaker HiL setup
   - Reflection List
     - Range: Distance in longitudinal direction (x)
     - Azimuth: Estimation of the distance in lateral direction (y)
     - Velocity: Relative radial velocity to the detected object
     - Elevation: Angle
     - RCS: Gain

3. Point Targets

4. Radar ECU (Mass Production)
   - C-Code (CAN)

5. Radar Over-the-Air Testing (ASGARD1)

6. Signal Comparison (Vector CANoe)
   - Target Position
   - Target Speed
   - …

7. Reference System (TI Radar ECU)

OTA
Radar RSI with ASGARD1

• Evaluation of RSI point cloud output in different scenarios
• Filtering of RSI detections
• Adapting RSI point cloud for ASGARD1 API
• Simulating Range, Radial velocity, Azimuth angle, Elevation angle, RCS
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Conclusion

• A full real-time over-the-air HiL for validating automotive radars is implemented
• ASGARD1 is interfaced to IPG CarMaker over UDP communication
• Time-referencing helps to accurately perform analysis of radars
• ASGARD1 capability in simulation of multiple point targets enables using high fidelity models for scenarios, such as Radar RSI model.
• OEMs could expect thanks to this technology to reduce ADAS systems vehicle validation on the road and its environmental impact.
• This approach will make ADAS quality easily reachable.