Radar Target Simulation in the Context of Radar MMIC Lab Validation

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Infineon Technologies Automotive Sense & Control
About the Authors

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Philipp Freidl
Lead verification engineer responsible for the verification planning towards the future Infineon radar chip generation
Agenda

1. Introduction
2. Measurement of Radar IC Key Parameters
3. System Measurements using Radar Target Simulation
4. Conclusion
More sensors required for each automation level

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</thead>
<tbody>
<tr>
<td>Front looking camera</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Front looking radar</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Front looking lidar</td>
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<td>–</td>
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<tr>
<td>Surround camera</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>4</td>
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<tr>
<td>Corner radar</td>
<td>–</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
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<tr>
<td>Surround radar</td>
<td>–</td>
<td>–</td>
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<td>–</td>
<td>4</td>
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<tr>
<td>Rear looking camera</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Rear looking radar</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>1</td>
</tr>
<tr>
<td>Driver monitoring Camera</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>V2X Sensor</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>1</td>
</tr>
<tr>
<td>Ultrasonic sensors</td>
<td>10-12 sensors per car</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surround Radar</td>
<td>8 radar sensors e.g. for garage parking</td>
<td></td>
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</tbody>
</table>

* Euro-NCAP is focusing on collision avoidance, requirements are changing over time
Evolution of Infineon Radar Modules and Chipsets

- **Long-Range**
  - 1st SiGe 77 GHz Transceiver

- **Mid-Range Radar**
  - 1st 77 GHz product in eWLB package

- **Three-Chip Radar Solution**
  - 1st complete System solution: MMIC, µC, power supply

- **Cost-Optimized assisted driving (ACC,AEB)**

- **Highly automated driving**

- **Next Generation Three-Chip Radar Solution**
  - MMIC, AURIX™ 3rd Gen, power supply

- **Single-Chip Radar Solution**

Innovation for passengers, pedestrians and other vulnerable road users (VRU)

“Vision Zero”
+ Autonomous driving

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Latest Infineon 77/79GHz Frontend Radar IC

› Benefits
- Power consumption reduction (up to 40%)
- Significant system BOM reduction (>20%)
- Reduced CPU overhead
- Supports Infineon radar system solution with AURIX2G™ and TLF power supply
- Digital and serial BB interface between RF and μC for easier PCB design

› Innovations
- Integration of digital and analogue building blocks in BiCMOS technology
- Dedicated monitoring functions to support ASIL-C/D radar systems
Latest Infineon 77/79GHz Radar Chipset

› Compact RF
  - Single RXS8160PL device
    3 transmit and
    4 receive channels covers
    the typical NCAP applications
  - Direct high-speed LVDS interface to
    MCU (Radar Interface, RIF)

› Compact AURIX2G™
  - Up to 6 Real-Time cores
  - Various flash sizes

› TLF Safety Power Supply
  - Integrated watchdog
Infineon Radar Transceiver Measurements

Radar Transmitter
› Output power
› Transmit spectrum
› Phase noise
› Frequency ramp parameter

Radar Receiver
› Receiver gain
› Spurious free dynamic range / intermodulation
› Noise figure / noise floor

Radar System
› Radar system measurements
  - Free space experiments
  - Radar target simulator (RTS)
› Cross talk (TX-TX, TX-RX, RX-RX)
› Firmware integration
› System integration

The increasing integration of additional features provides new challenges to the IC verification
Verification Board Assembly

Breakout Board: distribution of signals < 2.5 GHz

eWLB Board

IRPLI board: read out LVDS data

IRP: SPI communication
Receiver Setup for Single/Dual-Tone Tests

- Power meter
- Temperature forcing system
- Wave guide setup for dual-tone generation
- RF signal generators
- Power sensor
- Phase noise analyzer
- Single-tone generation
<table>
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<th>Introduction</th>
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<td>Measurement of Radar IC Key Parameters</td>
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<td>3</td>
<td>System Measurements using Radar Target Simulation</td>
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<td>4</td>
<td>Conclusion</td>
</tr>
</tbody>
</table>
System Measurements utilizing Radar Tunnel (Over The Air)

› Advantages
  – Phase coherence of different TX channels
  – Good signal performance of physical target (corner cube)

› Disadvantages
  – Limited maximum range
  – Over the air measurement
  – Sensitive to clutter signals
  – Multiple reflections
  – No Doppler frequency shift

› Usage
  – Phase balance measurements
System Measurements utilizing Waveguide Delay Line

› Advantages
  - Very good signal performance
  - Good repeatability

› Disadvantages
  - Limited maximum range (<50m)
  - Only single target
  - Fixed target distance
  - No Doppler frequency shift
  - Spurious reflections

› Usage
  - Investigation/verification regarding peak shape requirements
  - Validation of radar target simulator measurements
System Measurements utilizing Radar Target Simulator (RTS)

› Advantages
  – Very flexible setup
  – Several independent targets
  – Adjustable target distance and velocity
  – “Unphysical targets”

› Disadvantages
  – Signal quality (e.g. spurs)
  – Without OTA configuration only a single transmit channel can be evaluated

› Usage
  – SFDR measurements
  – Ramp linearity evaluation
## Comparison of Different Methods for Radar Target Simulation

<table>
<thead>
<tr>
<th></th>
<th>Radar tunnel</th>
<th>WG Delay Line</th>
<th>Analog RTS</th>
<th>Digital RTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximum range</strong></td>
<td>&lt; 10 m</td>
<td>&lt; 50 m</td>
<td>&lt; 300 m</td>
<td>&lt; 3600 m</td>
</tr>
<tr>
<td><strong>Minimum range</strong></td>
<td>&gt; 0.5 m</td>
<td>&gt; 0.5 m</td>
<td>&gt; 0.75 m</td>
<td>&gt; 8 m</td>
</tr>
<tr>
<td><strong>Range resolution</strong></td>
<td>“continuous”</td>
<td>fixed</td>
<td>&gt; 10 cm</td>
<td>&gt; 5 cm</td>
</tr>
<tr>
<td><strong>Velocity</strong></td>
<td>n/a</td>
<td>n/a</td>
<td>&lt; 300 km/h</td>
<td>&lt; 700 km/h</td>
</tr>
<tr>
<td><strong>RCS</strong></td>
<td>fixed</td>
<td>fixed</td>
<td>adjustable</td>
<td>adjustable</td>
</tr>
<tr>
<td><strong>Number of targets</strong></td>
<td>multiple</td>
<td>1</td>
<td>1-2</td>
<td>4</td>
</tr>
<tr>
<td><strong>Modulation bandwidth</strong></td>
<td>unlimited</td>
<td>30 GHz</td>
<td>&lt; 4 GHz</td>
<td>&lt; 1.2 GHz</td>
</tr>
<tr>
<td><strong>SFDR</strong></td>
<td>&gt; 70 dB</td>
<td>&gt; 70 dB</td>
<td>&gt; 35 dB</td>
<td>&gt; 65 dB</td>
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<tr>
<td><strong>Spurious signal sources</strong></td>
<td></td>
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<tr>
<td></td>
<td>• Clutter</td>
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<tr>
<td></td>
<td>• Multiple reflections</td>
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<tr>
<td></td>
<td>• Mismatch</td>
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<tr>
<td></td>
<td>• DUT/DL</td>
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<tr>
<td></td>
<td>• TX-RX crosstalk</td>
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<td></td>
<td>• LO signal</td>
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<tr>
<td></td>
<td>• Mismatch</td>
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<tr>
<td></td>
<td>• Binary switches</td>
<td></td>
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<td></td>
<td>• Converter/RTS</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>• TX-RX crosstalk</td>
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Infineon deployment of dSPACE C-DARTS for Single/Dual-Target Tests

RTS converter modules

Radar target simulator with 4 independent targets

eWLB Board/DUT

Magic-T
Dual Target Measurement with RXS8160
Setup impact – with internal tone combining
Dual Target Measurement with RXS8160
Setup impact – with external tone combining

Spectrum in dBFS

Target tones
Harmonics
2nd Order Intermod. Prod.
3rd Order Intermod. Prod.

Frequency in MHz
Dual Target Measurement with RXS8160 - Range sweep
Dual Target Measurement with RXS8160 - Velocity sweep

Range Doppler Map | OCP up | Target 1 @ 80.45m/s, 0km/h | Target 2 @ 93.85m/s, -30km/h

Range Doppler Map | OCP down | Target 1 @ 80.45m/s, 0km/h | Target 2 @ 93.85m/s, -30km/h

Range Doppler Map | OCP up | Target 1 @ 80.45m/s, 0km/h | Target 2 @ 93.85m/s, -30km/h

Range Doppler Map | OCP down | Target 1 @ 80.45m/s, 0km/h | Target 2 @ 93.85m/s, -30km/h
Phase Measurements with dSPACE C-DARTS - Concept

› Infineon specific feature in dSPACE C-DARTS
› Allows relative phase setting between the 4 RTS targets
› Can be used to emulate direction of arrival (DoA) without moving the DUT/RTS
Infineon deployment of dSPACE M-DARTS

› Advantages
  – Small form factor
  – Price

› Disadvantages
  – Only single target

› Usage
  – Ramp linearity evaluation
  – PSRR measurements
  – System board evaluation
Infineon evaluation of dSPACE S-DARTS

- Currently under evaluation for bandwidths > 1 GHz
  - Multi target measurements
  - Linearity measurements

- Available version needs huge adaptions in terms of
  - Higher ranges
  - Two targets
  - Improved SFDR

Source: https://www.dSPACE.com
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## Challenges for Radar Target Simulators

### Current Challenges

- **Real-time processing of the FMCW chirp**
  - No playback of previously recorded chirps

- **No over the air measurements**
  - Radar target simulator has to provide WR12 or PC1mm ports

- **At least two simultaneous targets**
  - No switching between targets
  - Phase coherence

- **Good analog performance - RTS needs to provide a better performance than DUT**
  - SFDR > 70dBc
  - Good linearity
  - Low phase noise
  - Low overall noise floor
  - High bandwidth (>4GHz)

### Future Requests

- **Cascading of Radar Target Simulators**

- **Phase noise in application**
  (phase noise measurement during a ramp scenario)

- **Time-resolved signal power of the ramp**
  (power emission mask)

- **Ramp characterization**
  - Ramp frequency
  - ETSI frequency masks
  - Linearity
  - Slope
  - Settling
  - Over- and undershoots
Conclusion

Radar target simulation plays a critical role in the development and verification process of radar chips.

In this context radar target simulators have proven to be a flexible and reliable tool.

Existing solutions from dSPACE allow Infineon to carry out the verification of today's radar chips.

But there are many challenges waiting for the next generation radar systems and therefore radar target simulators.
Part of your life. Part of tomorrow.