Automotive Radar Module Test and Measurement.

Choi, Ji-Hoon
Agenda

– ADAS Technologies overview
– Automotive Radar 79GHz
– Keysight’s Radar Solution
– How to Measure Radar Module
– Q&A
ADAS Technologies

– Sensors
  • Radar
  • LIDAR
  • Cameras

– Wireless connections
  • 2/3/4G and coming 5G
  • 802.11p WAVE / DSRC

– Automotive high speed serial buses and Car Ethernet
  • BroadR-Reach, MOST150
  • CAN/CAN FD, FlexRay, CXPI, and etc.
ADAS Technologies

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ADAS Technologies

Ultrasonic  Camera  Radar  Lidar

Four-Layer
Laser scanner
Single-Layer
Laser scanner
Radar
Mono Camera
Ultrasonic
Automotive Radar – Government Motivation

Road traffic deaths by WHO region

Worldwide approximately 1.23 million fatalities per year

source: global status report on road safety, WHO 2009
Automotive Radar – Government Motivation

Evolution of European Road Fatalities (EU-27)

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Source: CARE or national publications; EC Directorate General Energy and Transport December 2007
Automotive Radar – Regulatory

76 – 81 GHz band primary users from ITU-R

77 – 81 GHz band allocated to “Radiolocation Service” on a Co-Primary basis
- The device must operate/ behave as a Radar
- Wherever applicable, the device must be licensed under the Radar rules
- It cannot operate as an unlicensed short-range device per ITU-R definition
  - Except US, where FCC permits unlicensed vehicular radar SRD within 76 - 77 GHz band

ITU-R propose to allocate 77.5 – 78 GHz region to “Radiolocation Service” on a Co-Primary basis to support “global frequency harmonisation” and appropriate international protection status for automotive SRR, essential for safety application needs.

ITU-R Technical Studies ongoing for completion prior to WRC-15
- Report at WRC-15 on compatibility studies with other Co-Primary band users:
  - Radioastronomy, Space Sciences, Amateur Radio
Automotive Radar – Regulatory

77 – 81 GHz band global availability status

24 GHz NB (12.7dBm, 200 MHz → 50m range*, 75cm resolution)

24 GHz UWB (-41.3dBm/MHz, 2.5GHz → 15m range*, 6cm resolution)

No China (planned)
No Korea (planned)
No India
No Israel
No Argentina

77 GHz NB (50dBm, 1000 MHz → 200m range*, 15cm resolution)

Japan: 500 MHz BW only
- no Laos
- no Vietnam
- no Cambodia
- no Myanmar

No Argentina

79 GHz (-9dBm/MHz, 4GHz → 30m range*, 4cm resolution)

Recommended by ITU-R M1452 for forward looking applications

$\Delta R_{min} > \frac{c}{2B}$
Estimated value with 1 sqrm RCS

Move by 2018
Automotive Radar – 24Ghz ➔ 79GHz Transition

Why move from 24GHz SRR to 79GHz SRR?

– Smaller wavelength at 79GHz ($\lambda = 3.8$mm) compared with 24GHz ($\lambda = 12.5$mm) leads to improved spatial and angular resolution
– Smaller wavelength ($\lambda$) leads to smaller Antenna’s and smaller Sensor Modules
– From 2018, the 24GHz will be limited to 200MHz BW (Europe), 250MHz BW (Japan) ISM band only, 79GHz will have 4GHz BW available
  • More bandwidth supports improved spatial resolution applications
  • More bandwidth supports improved interference mitigation (hopping)
– Rapid signal attenuation at 79GHz good for interference mitigation reasons (~30m max for SRR, ~100m max for MRR)
– Maximum allowed Tx Power limit is higher at 79GHz (-3 dBm/MHz mean e.i.r.p) compared with 24GHz (-41.3 dBm/MHz mean e.i.r.p)

Recent statement from CSA 79GHz Project in Nov 2012 regards cost

– “79GHz is cost comparable with 24GHz and will gain at the same time higher performance”
Automotive Radar – 24Ghz ➔ 79GHz Transition

79 GHz Functions & Technology

Target separation capability

B = 250 MHz

Typ. Long Range Radar Bandwidth

B = 1500 MHz

Typ. High Resolution Radar Bandwidth
Automotive Radar – 24Ghz ➔ 79GHz Transition

79 GHz Functions & Technology

Bandwidth Influence on Range-Velocity Processing

Measurement Setup
- Carrier frequency: 79 GHz
- Polarization: vertical
- Amount of chirps: 32
- Chirp duration: 144 μs (@B=1.35GHz)
- Ramp rep. interval: 160 μs
- Velocity resolution: 1.36 km/h
- Max. range: 49.9m
- Max. velocity: ±21.69 km/h

B_{net}: 0.5 GHz

→ Increased bandwidth resolves pedestrian and car.

Source: Daimler AG

Chassis Systems Control

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Automotive Radar – 24Ghz ➔ 79GHz Transition

Comparison of sensor performance showing key parameters
Range resolution, Angular resolution, Doppler resolution

Legend:
\( \Delta V \) : Velocity Axis
\( \Delta \phi \) : Angle Axis
\( \Delta R \) : Range Axis

- Doppler resolution of object distance is RF frequency dependant. Higher RF frequency enables better Doppler resolution.
- For a given aperture, the resolution increases with frequency. Angular resolution depends on antenna aperture.

The smaller the cubic the better the radar performance!
Automotive Radar – 24Ghz ➔ 79GHz Transition

<table>
<thead>
<tr>
<th>Frequency range (see note 1)</th>
<th>Narrowband 24 GHz</th>
<th>24 GHz/26 GHz UWB</th>
<th>76 GHz</th>
<th>79 GHz</th>
<th>122 GHz ISM</th>
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<td>Sensor performance for proposed applications (summary of all three parameters/resolutions) (see notes 2, 3 and 4)</td>
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<td>+</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
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<td>ΔV: Velocity Axis</td>
<td>ΔR</td>
<td>ΔV</td>
<td>ΔR</td>
<td>ΔV</td>
<td>ΔR</td>
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<tr>
<td>Δφ: Angle Axis</td>
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<td>200 MHz</td>
<td>&gt; 2 GHz</td>
<td>1 GHz</td>
<td>4 GHz</td>
<td>1 GHz</td>
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<tr>
<td>Regulated output power</td>
<td>++</td>
<td>0</td>
<td>++</td>
<td>4 GHz</td>
<td>+</td>
</tr>
<tr>
<td>Radar Cross Section influence (cooperative contribution)</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Technology available</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+ technology 0 for sensor realization</td>
</tr>
</tbody>
</table>

NOTE 1: Other frequency ranges below 24 GHz were not taken into account, because of possible/reachable sensor performance for the proposed applications.

NOTE 2: The smaller the cubic, the better the radar performance.

NOTE 3: Doppler resolution of object distance is RF frequency dependent, Higher RF frequency enables better Doppler resolution.

NOTE 4: For a given aperture, the resolution increases with frequency. Angular resolution is directly related to antenna aperture.
Automotive Radar Chipset

Second-generation long-range radar

Third-generation long-range radar

6cm x 6cm cmos RFIC
Radar Theory

FMCW Radar

(a) First Chirp

Frequency

First Chirp

Second Chirp

Time

K = (f_2 - f_1)/T

(b) Radar Image

R = 20 m, Differential Vel = 20 mi/h

R = 10 m, Differential Vel = 0

Doppler FFT Across P Range Transformed Samples Yields Speed of Target at R_1

Range-Doppler Plot by 2-D FFT of the Radar Mixer Output

Received Signal

Range FFT Across N Fast Time Samples of the Radar Mixer Output

Keysight Technologies
How to Test Radar Module
FMCW Radar

How to Test Millimeter Wave Frequency?
- 76~77GHz (1GHz)
- 77~81GHz (4GHz)

How to Verify Each Section
- Digital (Oscilloscope)
- VCO, PLL Phase noise (SA)
- Tx, Rx (SG, SA)
How to Test Radar Module
Test Challenges – Millimeter Wave and Analog Section

• **Frequencies** – include 24GHz, plus 77GHz and 79GHz mmW.

• **Bandwidth** – from 100MHz up to 4 GHz BW at mmW.

• **Power** – need to validate both wanted power levels plus unwanted emissions against ETSI conformance specifications (*e.g.* ETSI EN 302 264 for 79GHz).

• **Increased Levels of Integration** integrated amplifier and antenna structure

• **Reduction in cost** move to Si Ge components for the front end
How to Test Radar Module
Test Challenges – Digital Control Section

- **Modulation & Phase Noise** – both need to be verified to ensure sensor provides required range, velocity and target identification/separation performance.

- **Protocol** – ensure communication bus compliance to CAN, CAN-FD, FlexRay, Ethernet (BroadR-Reach) standards

- **Complex real-world environment** scenarios, includes multiple moving targets, multi-scattering RCS, unwanted clutter and interference.
How to Test Radar Module
FMCW Radar

How to Test
Millimeter Wave Frequency?
- 76~77GHz (1GHz)
- 77~81GHz (4GHz)

How to Verify Each Section
- Digital (Oscilloscope)
- VCO Phase noise (SA)
- Tx, Rx (SG, SA)
Automotive Radar – Power Measurement

- Method with an average power meter
- Measurement time shall be sufficiently long to cover the EUT cycle time
- Use rms Meter

\[
\text{Peak Power} = \frac{\text{Measured Mean Power}}{\text{Power Duty Cycle}}
\]
Automotive Radar – Power Measurement

<table>
<thead>
<tr>
<th></th>
<th>Average power meter</th>
<th>Peak power meter</th>
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<tbody>
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<td>Frequency range</td>
<td>110 GHz</td>
<td>40 GHz</td>
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<tr>
<td>Bandwidth</td>
<td>Broadband average</td>
<td>Narrow</td>
</tr>
<tr>
<td>System rise time</td>
<td>Slow</td>
<td>Fast</td>
</tr>
<tr>
<td>Pulse parameter analysis capability</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Power range</td>
<td>~96 dB</td>
<td>~55 dB</td>
</tr>
<tr>
<td>Dynamic range</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

Trading off flatness for responsiveness and bandwidth

![VBW filter On](Image1)

![VBW filter OFF](Image2)
Automotive Radar – Power Measurement Method with a spectrum Analyzer

- Start frequency: lower than the lower edge of the operating frequency range
- Stop frequency: higher than the upper edge of the operating frequency range
- Resolution bandwidth: 1 MHz
- Video bandwidth: \( \text{VBW} \geq \text{RBW} \)
- Detector mode: RMS
- Display mode: clear write
- Averaging time: larger than one EUT cycle time
- Sweep time: averaging time \( \times \) number of sweep points
Automotive Radar – Signal Analysis
FMCW Radar Tx Test <2GHz BW

- RF output from N5183B signal generator to LO/IF input of M1971E smart mixer
- Aux output from M1971E Mixer to channel 1 input of S-series oscilloscope
- USB from M1971E smart mixer to S-series oscilloscope
- USB from N5183B to S-series oscilloscope
Automotive Radar – Signal Analysis
FMCW Radar Tx Test <2GHz BW

• Signals exists between 55/60-90 GHz
• Signal bandwidth up to 2.5 GHz

• DSOS404A
  • 4 GHz scope
  • w/ option 100
• N5183B-513
  • 13 GHz analog sig gen
  • w/ option 513, UNY
• M1971E
  • 55/60-90 GHz mixer
• 89601B VSA
  • w/ options 200,300,BHP
• N8838A
  • Mixer support
Automotive Radar – Signal Analysis
FMCW Radar Tx Test <2GHz BW

– Dual Channel Configuration
Automotive Radar – Signal Analysis

Infiniium FFT
Automotive Radar – Signal Analysis
Demodulation

[Image of a radar signal analysis software interface with various plots and data measurements.]
Automotive Radar – Signal Analysis

FMCW Radar
Automotive Radar – Signal Analysis
FMCW Radar Tx Test <2GHz BW

– Hardware connections

MXG RF output to Mixer LO/IF input

Mixer Aux output to Scope input

Mixer device USB to Scope USB

MXG device USB to scope USB

MXG RF output to Mixer LO/IF input
Automotive Radar – Signal Analysis
FMCW Radar Tx Test <2GHz BW

- This menu becomes available when the user has a license for the N8838A external mixer assistant software option.
- With the option enabled, the user must have a M1971E smart mixer SN >=MY56130101 connected to the oscilloscope for the mmW (ext. mixer) signal type to be selectable.
- Supported scopes
  - DSOS/MSOS404,604,804
  - No raptor, GREX, V, Q, Z or Infinivision
- Supported signal generators
  - N5183B-513,520,532,540
- Supported smart mixers
  - M1971E only
  - Must be newer hardware, SN break TBD.
Automotive Radar – Signal Analysis

FMCW Radar Tx Test <2GHz BW

**Source**: Selects the scopes channel to be used, 2 channels supported (max) channels 1&3 (recommended) or 2&4 can be used simultaneously.

**Signal Type**: mmW (Ext. Mixer) this is the N8838A feature.

**Measurement Bandwidth**: sets the span of the FFT display, user adjustable up to 2.5 GHz.

**Center Frequency**: sets the center frequency of the FFT display. After connection/calibration, changing the center frequency will also automatically tune the signal generator (LO) to the correct frequency.
Automotive Radar – Signal Analysis
FMCW Radar Tx Test <2GHz BW

**Cable loss**: user settable to compensate for the IF cable loss from the mixer to the input channel of the scope. 0-6dB. If cable has more than 6dB of loss, use a better cable.

**LO VISA address**: user input field, the VISA address of the N5183B must be input to this field before the “connect” button is pressed. Recommended to use USB connection from scope to signal generator (LO)
When using VSA:

- The LO address input field is in the Input>Extensions menu.
- Similar to the Infiniium operation, make sure to input the N5183B USB VISA address before setting up the measurement.
- NOTE: you may have to enter the VISA address in quotes (i.e. “USB0::0x….”)
Automotive Radar – Signal Analysis
FMCW Radar Tx Test <2GHz BW

Bandpass Filter recommended (76 - 81GHz)

RF (mmW)

1.5 GHz
75.5 GHz
77GHz

x6/x8

9.4375GHz

75.5 GHz

LO

IF
Keysight Vector Signal Analyzers

16900 Series Logic Analyzer

PSA/ESA Spectrum analyzer

X-Series Signal Analyzers

89601B VSA Software

Infiniium Series Oscilloscopes

PXI/AXI Module VSA & Digitizers

Keysight ADS or SystemVue

Even more?
Automotive Radar – Signal Analysis

FM Linearity – Integral Non-Linearity (%)

FM Error Peak (Hz) = max( Measured FM – LFM Best-fit )

INL Best-fit (%) = \[ \frac{\text{FM Error Peak (Hz)}}{\text{LFM Best-fit Pk-Pk Deviation (Hz)}} \] * 100
Automotive Radar – Signal Analysis
FMCW Radar Analysis - 89600 VSA Solution

Solution Description:

The new FMCW Radar Analysis solution provides:

2. Trace results of synchronized Frequency (FM, FM Slope), Phase and Power modulation performance and errors.
3. Tabular Result Metrics (per Linear FM region)
4. Accumulated Statistical results
5. Accumulated Trend and Histogram results.
7. BW Scalable - supports X-Series SA, Scopes and Modular Digitizers
Automotive Radar – Signal Analysis

Overlay time traces

Amplitude Measured, Reference, Error

FM Measured, Reference, Error

FM Slope Measured, Reference, Error
Automotive Radar – Signal Analysis
Automotive Radar – Signal Analysis

![Graph showing signal analysis](chart.png)

<table>
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<tr>
<th>Region</th>
<th>Ref Region</th>
<th>Power Mean (dBm)</th>
<th>Power Pk-Pk Dev (dB)</th>
<th>Time Start (sec)</th>
<th>Time Length (sec)</th>
<th>Best-Fit FM Mean (Hz)</th>
<th>Best-Fit FM Pk-Pk Dev (Hz)</th>
<th>Best-Fit FM Slope (Hz/µs)</th>
<th>Best-Fit FM INL (%)</th>
<th>Phase Error RMS (deg)</th>
<th>Phase Error Peak (deg)</th>
<th>FM Error RMS (Hz)</th>
<th>FM Error Peak (Hz)</th>
<th>FM Slope Error RMS (Hz/µs)</th>
<th>FM Slope Error Peak (Hz/µs)</th>
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Automotive Radar – Signal Analysis – Phase Noise
FMCW Radar Tx Test

E5052B Signal Source Analyzer

Key Features:
1. Phase Noise and AM Noise
   • Simple, fast and accurate
   • Uses cross-correlation (noise-cancelling) technique along with heterodyne digital discriminator

2. Frequency / Phase / Power Transients
   • Dual heterodyne and divided path analysis
   • Narrowband path (up to 80MHz BW)
   • Wideband path (up to 4.8GHz BW, band dependent, up to 500 MHz BW when using E5053A input port)

Measure Phase Noise directly at mmW using:
• E5052B SSA + E5053A Microwave Downconverter
  …plus 11970W 75 to 110 GHz Harmonic Mixers
Two-channel Cross-Correlation Technique

\[ N_{\text{meas}} = N_{S.U.T.} \left( N_1 + N_2 \right) / \sqrt{M} \]

Assuming \( N_1 \) and \( N_2 \) are uncorrelated.

<table>
<thead>
<tr>
<th>M (number of correlation)</th>
<th>10</th>
<th>100</th>
<th>1,000</th>
<th>10,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise reduction on ((N_1+N_2))</td>
<td>-5dB</td>
<td>-10dB</td>
<td>-15dB</td>
<td>-20dB</td>
</tr>
</tbody>
</table>
Automotive Radar – Signal Analysis – Phase Noise

FMCW Radar Tx Test

E5052B Signal Source Analyzer

Phase Noise Floor at 77 GHz (for example)

SSB phase noise floor [dBc/Hz]

N9020A Signal Analyzer with M1971E Mixer
Automotive Radar – Regulatory
77 – 81 GHz band global availability status

24 GHz NB (12.7dBm, 200 MHz → 50m range*, 75cm resolution)

24 GHz UWB (-41.3dBm/MHz, 2.5GHz → 15m range*, 6cm resolution)

77 GHz NB (50dBm, 1000 MHz → 200m range*, 15cm resolution)
79 GHz (-9dBm/MHz, 4GHz → 30m range*, 4cm resolution)

Recommended by ITU-R M1452 for forward looking applications
Recommended by ITU-R M1452 for short range radar

\[ \Delta R_{\text{min}} > \frac{c}{2B} \]
Estimated value with 1 sqrm RCS

Move by 2018
How to measurement 4GHz Band Width
Difficulties to test mmWave signal

- Small Dimensions and Complex Test Setups
- Challenging Ultra Wideband mmWave Measurements
- Small Signal Strength
The New N9041B UXA Signal Analyzer, 110 GHz

“See the Whole Picture” to 110 GHz

1st  3 Hz - 110 GHz Continuous sweeps

1st  -150 dBm/Hz DANL up to 110 GHz

1st  Dual input rugged 2.4 mm and 1 mm connector

1st  Up to 1 GHz internal BW

1st  5 GHz BW (with external oscilloscope)
World’s First 3 Hz to 110 GHz Continuous Sweeps
Complexity solved – No complicated external mixers

3 Hz - 110 GHz
Continuous sweeps
1 mm input connector

Full suite of signal analysis tools available

10 MHz  See the whole picture  110 GHz

90 GHz option available for export controlled countries
World’s First 3 Hz to 110 GHz Continuous Sweeps
Fragility solved – 2nd rugged 2.4 mm connector < 50 GHz

Single instrument with flex connectivity for <50 GHz, up to 110 GHz and wave guide

RF Input 1
2.4 mm connector
3 Hz – 50 GHz

RF Input 2
1.0 mm connector
3 Hz – 110 GHz

EXM supports M1971 V/E/W waveguide “smart” harmonic mixers

KEYSIGHT TECHNOLOGIES
Best Dynamic Range at 110 GHz

Solved – Measure small signals in presence of high power

-150 dBm/Hz DANL up to 110 GHz

Superb DANL without preamp = Best SEM dynamic range
Unmatched BW at 110 GHz
Solved – Challenging ultra wide BW measurements

1st
5 GHz BW (Opt CRW) (to external oscilloscope)

1st
1 GHz internal BW

Very clean constellation – 2.3% EVM

5 GHz BW 16 QAM Signal in E-Band

Option CRW: Wideband IF Output (rear panel)
Convenient measurements of 5G, automotive and A/D signals
Automotive Radar – Signal Generation

How to Make WB Radar Signal

N5183B MXG Signal generator as clean LO

M8190A 12 GSa/s AWG
or
M8195A 65GSa/s AWG

Ch1 Data Out Direct-to-IF

LO In

IF Input

E-band upconverter

IQ Tools

Sample Rate (Hz) 8e+009
Repeat interval (s) 8e-6
Pulse width (s) 2e-6
Rise time (s) 50e-9
Fall time (s) 50e-9
Pulse Shape Raised Cosi...
Modulation Increasing
Amplitude (dB) 0
Frequency span 2e+009
Frequency offset 2e9
Apply Correction
Download IQ to channel 1+2
Visualize in MATLAB
Download
Automotive Radar – Signal Generation

How to Make WB Radar Signal
FMCW Radar Signal Generation

- Pulse Builder for Signal Studio
- SystemVue
- “iqtools” MATLAB utility

System Configuration

- PSG
  E8257D Analog (Low Phase noise LO)
- mmW Source Module
  WR12SAX (60 to 90GHz, N=6, SAX option)
- AXIe AWG
  M8190A (14bit @ 8GSa/s, 12bit @ 12GSa/s, 5GHz Analog BW)
- Scope Infiium
  S-Series DSOS804A
- External IF (Up to 5GHz)
- Spectrum Analyzer
  UXA N9041B up to 110GHz

FMCW Radar Solution

Keysight Solutions 77 / 79GHz (4GHz) – Generation + Analysis

89600 VSA Analysis Software

DUT

Tx/Rx Horns

LAN

LAN
Automotive Radar Test procedures

- [PCA Build]
- [ICT & Flash]
- [RF One-way Tx/Rx FCT anechoic chamber]
- [RF Two-way final FCT in chamber]
The actual UUT radar signal is
a) Received
b) manipulated
c) retransmitted

A radar target simulator will apply…

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Delay</td>
<td>Range (Distance)</td>
</tr>
<tr>
<td>Doppler Frequency Shift</td>
<td>Radial velocity</td>
</tr>
<tr>
<td>Attenuation</td>
<td>Radar Cross section (object size)</td>
</tr>
</tbody>
</table>
### Keysight Radar Target Simulator

#### Scalable system configurations

<table>
<thead>
<tr>
<th>Description</th>
<th>Fixed range RT S</th>
<th>+ Full Range</th>
<th>+ Doppler</th>
<th>+ DUT Tx Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key Features</td>
<td>• 76-77GHz&lt;br&gt;• 1 or 2 Horns&lt;br&gt;• 75 &amp; 150m&lt;br&gt;• 1GHz BW&lt;br&gt;• Full RCS&lt;br&gt;• DUT Tx simulated power</td>
<td>• 10 – 450m with 1m resolution</td>
<td>• +/- 360 Km/h with 1Km/h resolution</td>
<td>• Enable DUT Tx power measurement</td>
</tr>
<tr>
<td>Hardware Configuration</td>
<td><img src="image1.png" alt="Base System" />  &lt;br&gt;Base system internal HW upgrade</td>
<td><img src="image2.png" alt="N5183A MXG" /></td>
<td><img src="image3.png" alt="U2042XA Power Meter" /></td>
<td></td>
</tr>
<tr>
<td>Support &amp; Warranty</td>
<td>• 3 Years Keysight Factory warranty with calibration certificate valid for 1 year&lt;br&gt;• Optional 1 or 3 years contract&lt;br&gt;  o Return to Keysight or onsite calibration&lt;br&gt;  o Spare onsite swap</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Keysight Automotive Radar Solutions

RTS Chamber Configuration

Vertical Setup

Anechoic Chamber

RF Absorber

DUT

1 meter

Horizontal Setup

Anechoic Chamber

RF Absorber

DUT

1 meter

RTS
Keysight Radar Target Simulator

RTS Test with Radar Module
## Keysight Automotive Radar Solutions
### RTS Specification

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Range</td>
<td>76 – 77 GHz</td>
</tr>
<tr>
<td>Horn Antenna Configuration</td>
<td>Single and Dual Horns Antenna</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>1 GHz</td>
</tr>
<tr>
<td>Min Target Distance</td>
<td>10m</td>
</tr>
<tr>
<td>Simulated Range</td>
<td>10m to 450m with 1m step</td>
</tr>
<tr>
<td>Doppler Shift Range</td>
<td>+/- 360km/h with 0.1km/h step</td>
</tr>
<tr>
<td>Receive Transmit Gain Control</td>
<td>-63.5dB with 0.5dB step</td>
</tr>
<tr>
<td>Dimension (H x W x D)</td>
<td>222 x 425 x 574 (mm)</td>
</tr>
</tbody>
</table>
Keysight Automotive Radar Solutions

FMCW Radar Test

Architecture / Design

Development

Validation & Mfg.

Keysight Value #1

Additional equipment and software tools mentioned:
- 89600 VSA SW with FMCW option
- ADS / SystemVue Simulation SW
- S-Series Oscilloscope
- X-Series Signal Analyzer
- E-Band Power Sensor and Meter
- E8267D PSG Vector Signal Generator
- M8190A Arbitrary Waveform Generator
- Signal Studio for Pulse Building
- Signal Source Analyzer
- PNA Network Analyzers Banded mmW Solution
- Radar Target Simulator (RTS)