KEYSIGHT WORLD 2020

Enabling Real World Multiple Object Radar Simulation in a Small, Controlled and Confined Test Environment without Compromise

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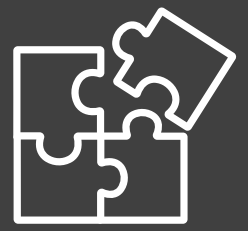
Agenda

Autonomous Vehicle and Automotive Radar Market Overview

Challenges Faced by Automotive Radar



Keysight's Contribution to Address the Automotive Radar Challenges

Keysight Radar Portfolio

Autonomous Vehicle and Automotive Radar Market Overview

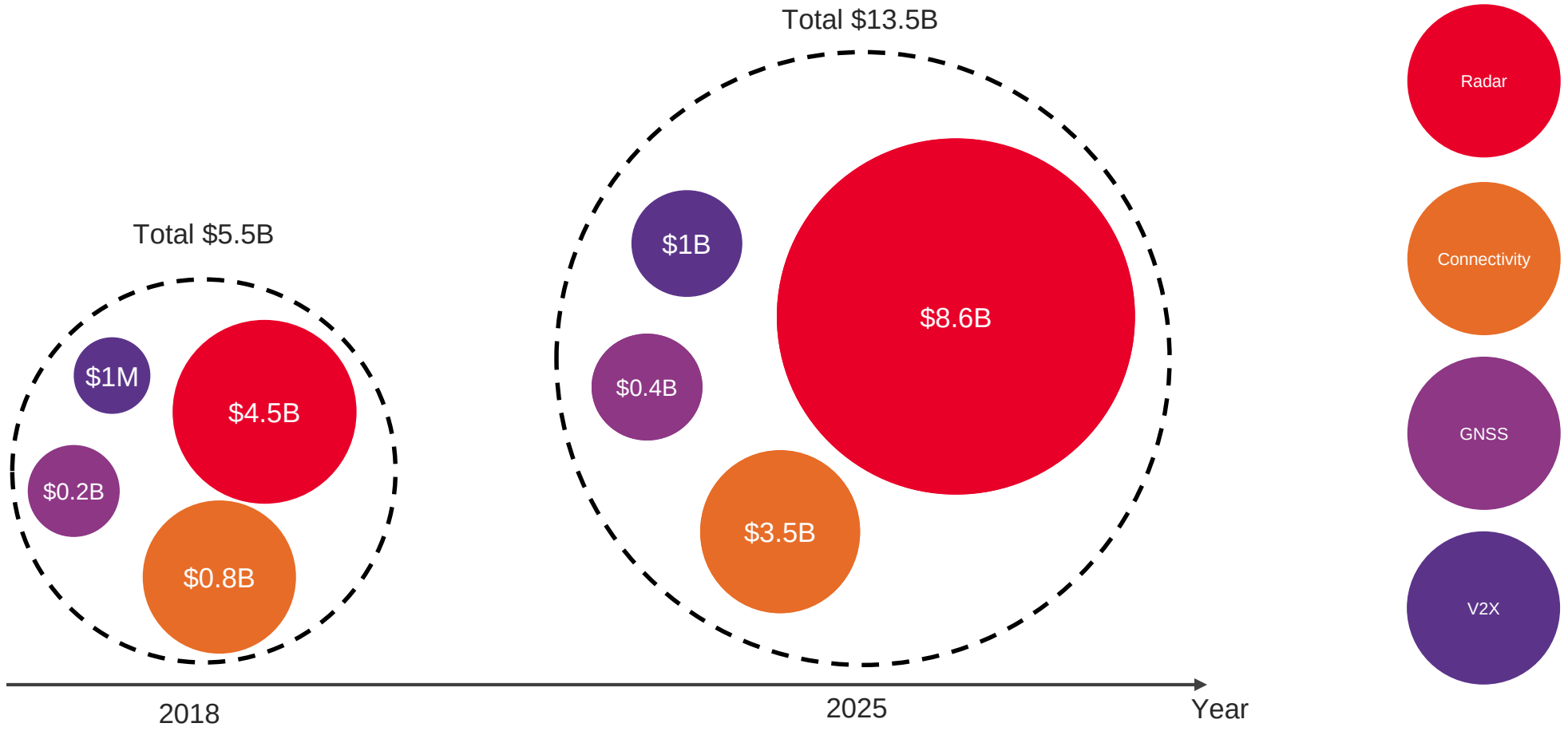
Autonomous Vehicle Overview

ENABLING TECHNOLOGY AND TYPICAL SENSORS CONTENT

Autonomous Driving Level / Type of Sensors	Level 1 (Drive Assistance) 	Level 2 (Partial Automation) 	Level 3 (Conditional Automation) 	Level 4 (High Automation) 	Level 5 (Automation) 
Human level monitoring of Environment	Driver ***maintains overall control*** but can cede limited authority	Driver responsible for ***monitoring the roadway*** and control at all times	Driver must be ***available to take control*** of the vehicle at all times with short notice	Vehicle is capable of ***performing all driving*** functions ***with conditions***. Driver may have the option to control the vehicle	Vehicle is capable of ***performing all driving*** functions ***unconditionally***. Driver may have the option to control the vehicle
Application Example	Adaptive Cruise Control or Lane Centering	Adaptive Cruise Control and Lane Centering at the same time	Traffic jam chauffeur	• Driverless Taxi • Driving with or without pedals or steering wheel	
Ultrasonic	4	8	8	8	8 to 10
Long Radar	1	1	2	2	2 to 4
Short Radar	2	2 to 4	2 to 4	4 to 6	4 to 8
Camera / Short Lidar	1	2 to 4	7	7 to 8	9 to 10
Long Lidar	0 to 1	0 to 1	1 to 2	2 to 4	4
V2X	0 to 1	0 to 1	1	1	1 to 2
GNSS	0 to 1	0 to 1	1	1	1
Total	8 to 11	13 to 20	22 to 25	25 to 30	29 to 39
Rollout Timing	2012	2016	2018	2020	> 2025

Autonomous Vehicle Market Dynamic

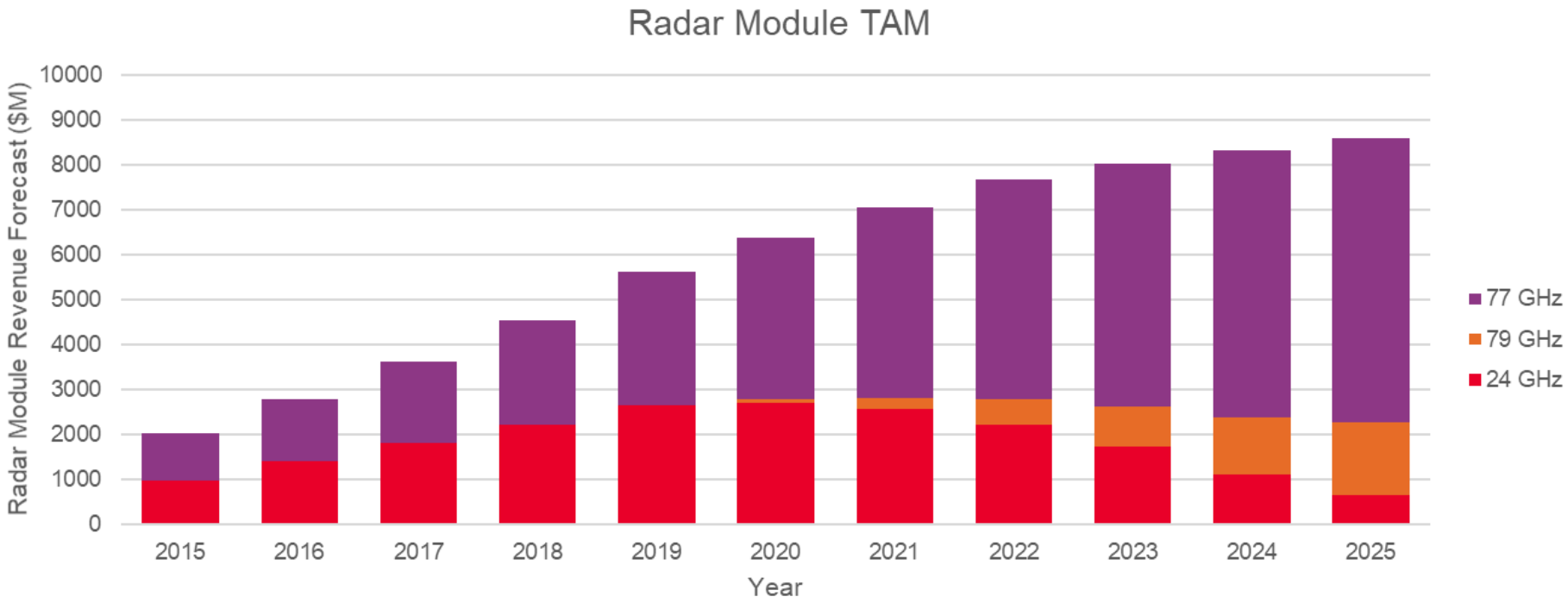
RADAR VS OTHER WIRELESS TECHNOLOGIES MARKET TAM



Source: Radar and Wireless for Automotive market and Technology Trends 2019 by Yole

Autonomous Radar Market Dynamic

RADAR TRENDS AND OUTLOOK

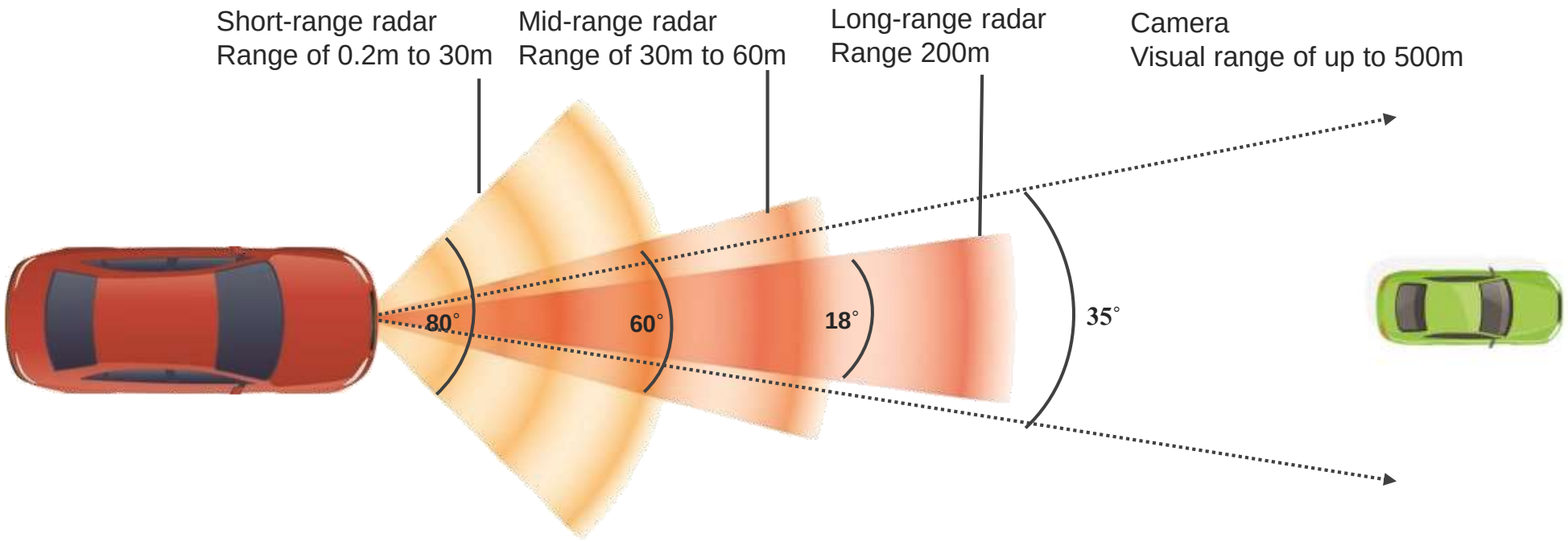


Source: Radar and Wireless for Automotive market and Technology Trends 2019 by Yole

- 77 GHz LRR representing > 50% of the Radar module TAM
- Observed similar trend as the semiconductor outlook with 24 GHz ramping down and replaced by 79GHz
- Initiative of migrating from 24 GHz to 79GHz to improve resolution and accuracy. In addition, there is also cost leverage between 79GHz and 77 GHz.

Automotive Radar Technology

RADAR SENSORS CHARACTERISTIC



SRR

24 GHz
77 GHz – 81 GHz
4 GHz BW

MRR

76 GHz – 77 GHz
77 GHz – 81 GHz
4 GHz BW

LRR

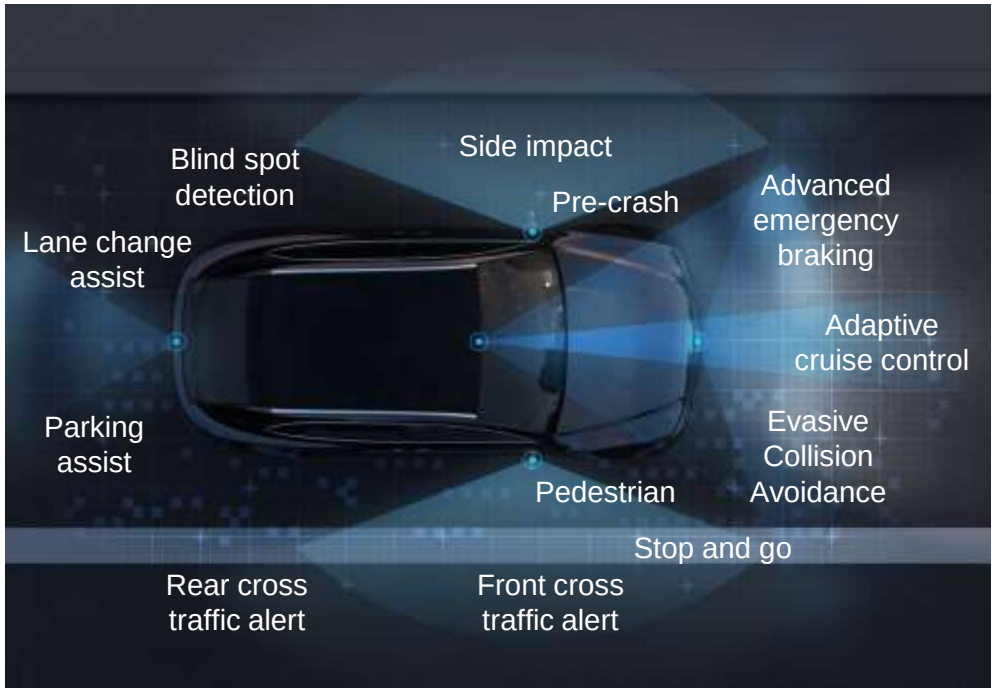
76 GHz – 77 GHz

1 GHz BW

- Operating Freq 76 – 81 GHz
- Support up to 4GHz BW
- Simulate up to 300m
- FOV up to 80 degree

Automotive Radar Application Examples

MAKING ROAD SAFER



Making Roads Safer with 360 Degree Vision!

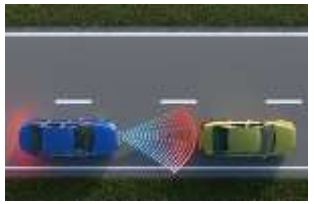
Making Autonomous Driving Possible!

Auto Emergency Braking / Pre-tensioning Seatbelts

Blind Spot Monitoring

Lane Change Assist

Real Collision Protection



Adaptive Cruise Control

Stop & Go Cruise Control

Automotive Radar Testing

KEYSIGHT BRINGING REAL WORLD TEST ENVIRONMENT TO LAB

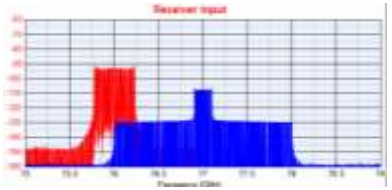
Radar Target Simulator
Emulating Real World Object

D: distance to object

Dblock: distance between DUT and interference source

Object size
RCS (dBsm)

Spectrum Analyzer
Enabling Signal Analysis



Arbitrary Waveform Generator
Emulating Interference Source

Challenges Faced by Automotive Radar

Automotive Radar Sensor Test Challenges

FUTURE RADAR TOWARDS LEVEL 5 AUTONOMOUS DRIVING

Emulate dynamic real world simulation:
Complex multi-target scenario simulation

Differentiate nearby objects from one to another:
High resolution testing

Enable imaging radar sensor far field simulation:
Cost effective ways to test imaging radar

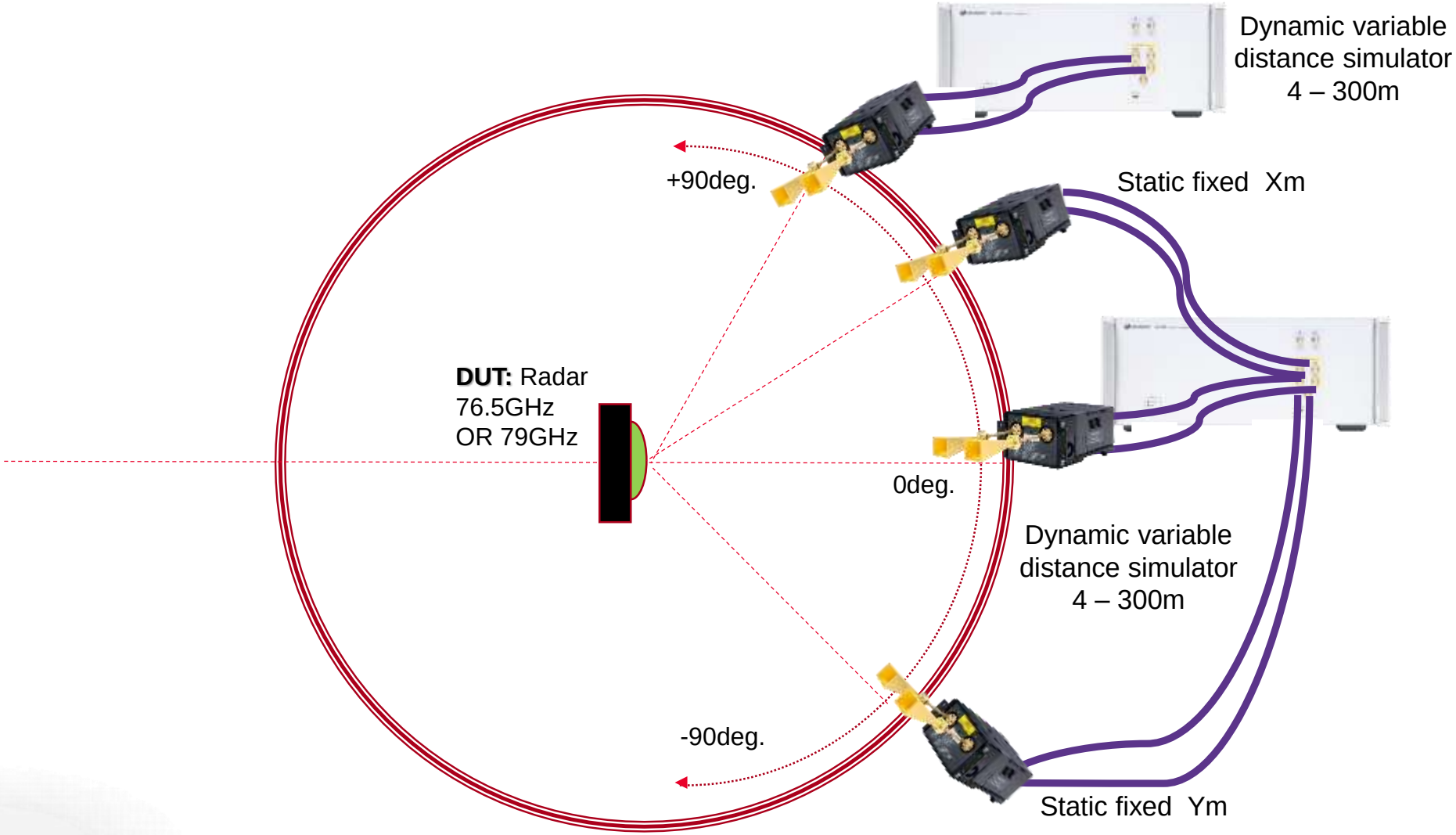
Contrast large object:
3D elevation testing and characterization

Zero missed, ensuring all objects are accountable:
Interference mitigation

Keysight’s Contribution to Address the Automotive Radar Challenges

Emulate Dynamic Real World Complex Scenario

KEYSIGHT MULTI TARGET FLEXIBLE REMOTE HEAD RTS



Ease Complex Scenario Implementation

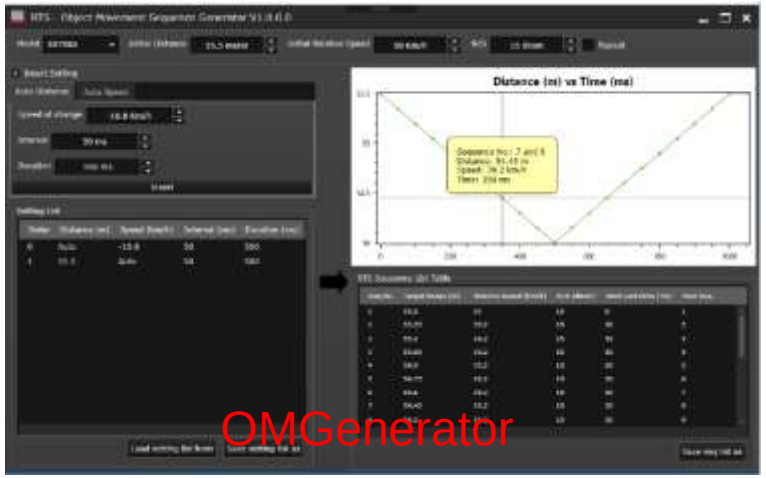
KEYSIGHT OBJECT MOVEMENT GENERATOR SEQUENCE CONTROL

Simulate moving Object

- Configurable ***sequence setting*** for , RCS and Doppler
- Sequence table will display all ***sequence list up to 1024*** (0 to 1023 sequences)
- Option to use OMGenerator to create sequence list or load from predefined text or excel spreadsheet

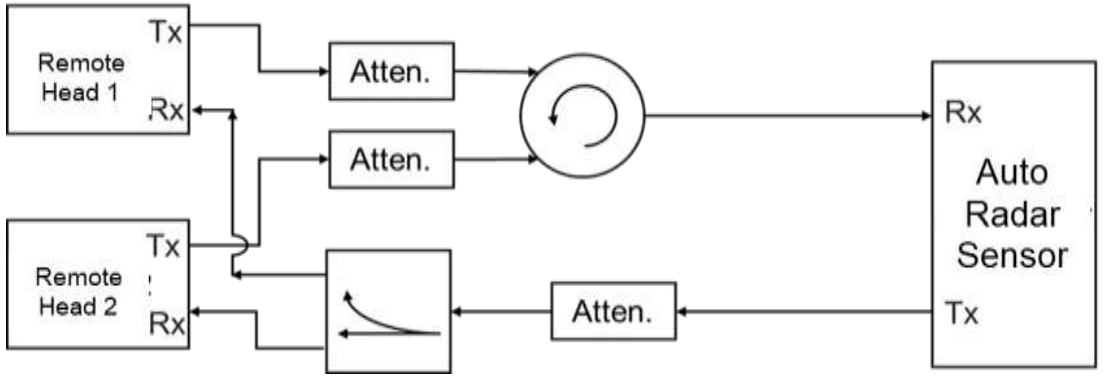
OMGenerator

- A standalone tool ***to assist*** user to ***create object movement sequence*** before import to RTS SFP
- Option to ***control*** either ***distance*** or ***speed***
  - Auto Distance: Define object speed and time duration and interval
  - Auto Speed: Define object distance and time duration and interval
- With preview ***graph display***



Differentiate Nearby Object

KEYSIGHT MULTI TARGET FLEXIBLE REMOTE HEAD RTS



Objective of testing

- ❑ To differentiate two independent objects at the same velocity but different distances and vice versa same distances but different velocity
- ❑ Two flexible remote head with independent from 3m to 300m, velocity form +/- 700Km/h and different RCS from -20 to 40 dBsm
- ❑ Direct connection via WR12 waveguide or Over The Air via horn antenna

Independently Control Individual Simulated Target

KEYSIGHT MULTI TARGET SIMULATION SOFTWARE GUI

Remote Desktop
or
Webpage service

LAN

Multi Target GUI

Radar Target Simulator
Up to 4 Targets

Keysight Multi Target GUI

Scalable and Configurable Radar Target Simulator

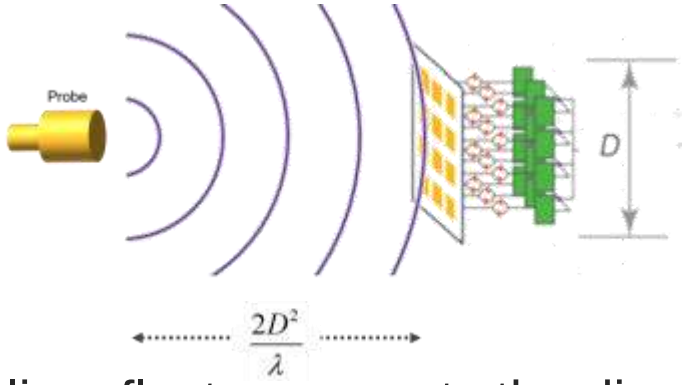
KEYSIGHT E8718A HIGH RESOLUTION RTS

Description	Fixed distance RTS	+ variable distance	+ Doppler	+ SA	+ Multi AoA variable & fixed distance	+ Multi AoA variable distance RTS
Key Features	• Dual Horn • ***76-81GHz*** • ***4GHz BW*** • 75 & 150m • RCS • Laser alignment	• ***4*** – 300m with 0.1m resolution • ***0,03m*** resolution step (future option)	• +/- 360 Km/h with 0.1Km/h resolution	• Enable DUT ***EIRP*** and ***OBW*** parallel measurement	• ***3 AoA*** with ***1x Dynamic*** Scenario ***2x Fixed Distance*** • 76-81GHz with 4GHz BW, distance & Doppler	• ***Multi AoA*** with ***Dynamic Scenario*** • 76-81GHz with 4GHz BW, distance & Doppler
Hardware Configuration	 Core System	 Core system internal HW or SW upgrade			 Multi-Head	 Multi RTS

Enable Imaging Radar Sensor Far Field Simulation

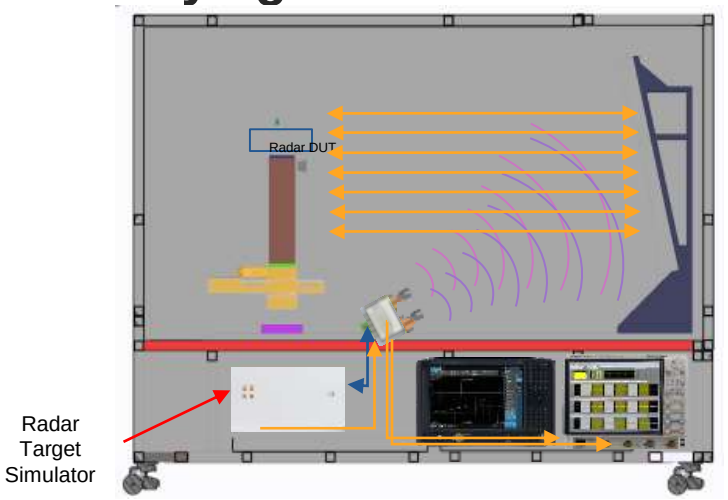
COST EFFECTIVE SIMULATION WITH KEYSIGHT CATR ANECHOIC CHAMBER

Imaging Radar Challenges



- Parabolic reflector converts the diverging beam into a plane-wave (far-field) beam
- DUT to be placed in the Quite Zone
- Rotation allows Azimuth characterization
- Reciprocal operation enables Tx and Rx test
- Integrated and calibrated OTA test solution

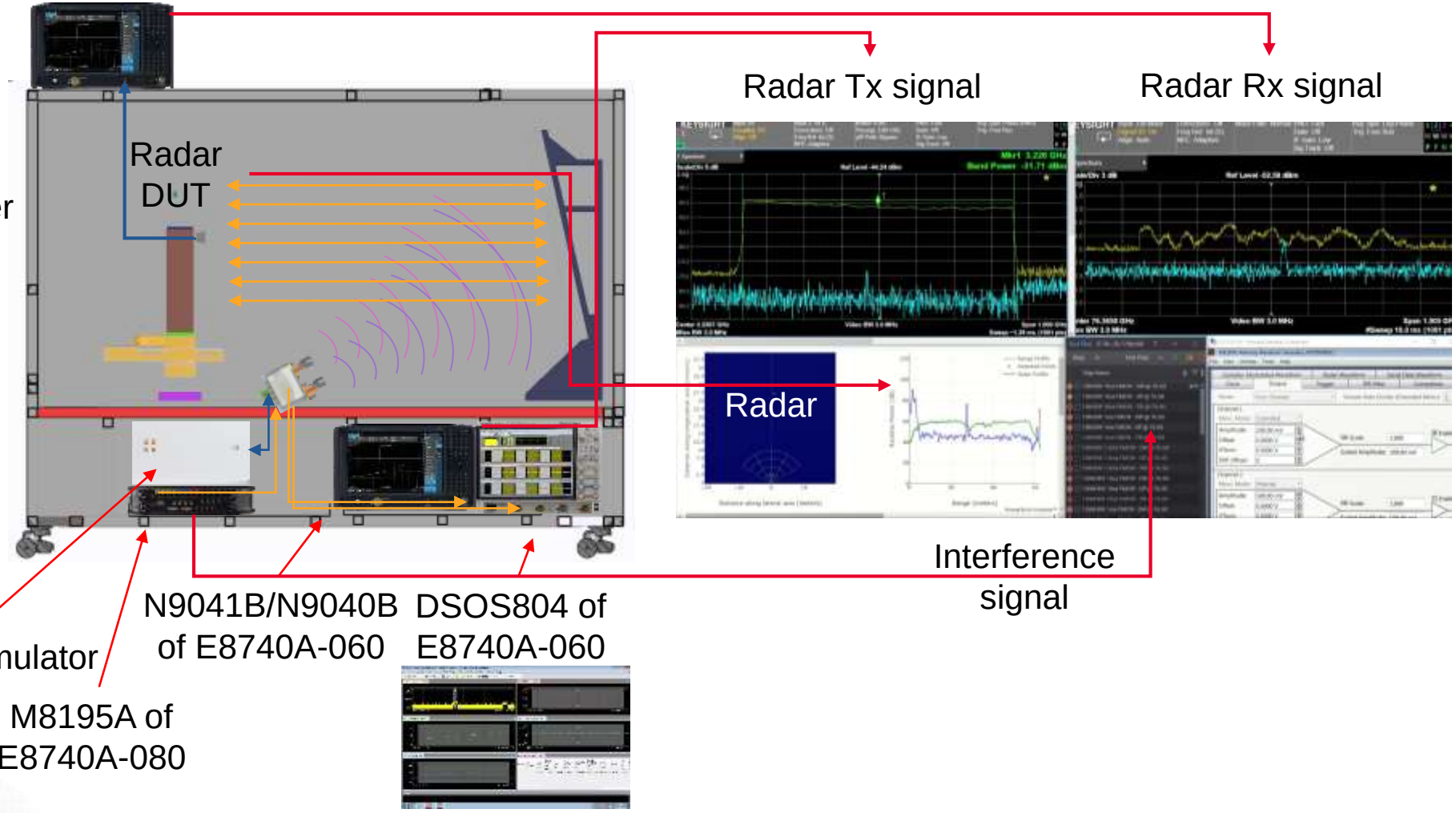
Keysight CATR Chamber



- Operate up to 110 GHz
- Quite Zone 30cm
- Amplitude Tape 1 dB
- Amplitude Ripple < +/- 0.5 dB
- Phase Variation < 10 deg

Zero Missed, Ensuring All Objects Are Accountable

KEYSIGHT AUTOMOTIVE INTERFERENCE TEST SOLUTION



Keysight’s Automotive Radar Regulator Test Solution

E8740A Automotive Radar Solution

>5GHZ UP TO 110GHZ SIGNAL ANALYSIS AND FLEXIBLE SIGNAL GENERATION

Radar Target Simulator

E8718A – 77 / 79 GHz with 1 / 4GHz BW

Radar Target simulator for Automotive radar functional test

- 76-77GHz w/1GHz B/W
- 77-81GHz w/4GHz B/W
- Range from 4m to 300m, 0.1m Resolution
- 1 (full) + 2 Fixed Targets
- Options for OBW and PWR
- Options for dual or single antenna

OBW and Power measurement

Signal Analysis Solution (Tx)

E8740A-010 Radar RF SA

Leading cost effective Auto Radar RF test tool

- 10 Hz to 26.5 GHz, 60 GHz to 90 GHz
- FMCW RF analysis

E8740A-020, 030 Basic SA

Optimum choice for Auto radar signal quality test

- 60 GHz to 90 GHz,
- 2.5 GHz BW, >5GHz BW FMCW Quality analysis

E8740A-040, 050 Advanced SA

Benchmark for demanding applications

- 10 Hz to 26.5 GHz, 60 GHz to 90 GHz
- 2.5 GHz BW , >5GHz BW FMCW Quality analysis

E8740A-060 Performance SA

Wide-open performance

- 3 Hz to 110 GHz
- >5 GHz BW for FMCW Quality analysis
- DANL-171dBm/Hz@1GHz, -150dBm/Hz up to 110GHz
- 2.4 mm, 1 mm input
- Spurious Emissions tests

E8740A-090 Emissions test solution

Conformance test

- 0 to 330 GHz
- Operating frequency range, peak power, unwanted emission, mean power, and more
- 2.4 mm, 1 mm input

89600 VSA software

Comprehensive demodulation & vector signal analysis

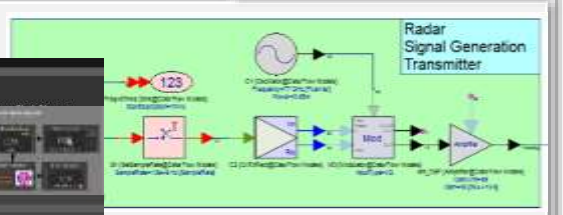
X-Series applications

Ready-to-use RF measurements

FMCW X-App for RF testing

Pre-defined RF test setting for standard

Integrated S/W platform for automotive radar testing



Signal Generation Solution (Rx)

E8740A-070 Performance SG

Wide-open performance

- 60 GHz to 90 GHz
- >5 GHz 3dB BW
- FM, PM, FMCW, pulse sequence, MFSK, custom OFDM

E8740A-080 Interference solution

Flexible wideband interference signal generation

- Full test set-up for ETSI interference test
- 60 GHz to 90 GHz
- >5 GHz 3dB BW
- CW, FMCW, pulse, MFSK, custom OFDM, 5G backhaul,….

SystemVue

W1908 Auto radar library measurements

Signal Studio

N7608C Pulse/FCM/FMCW/MFSK signal creation

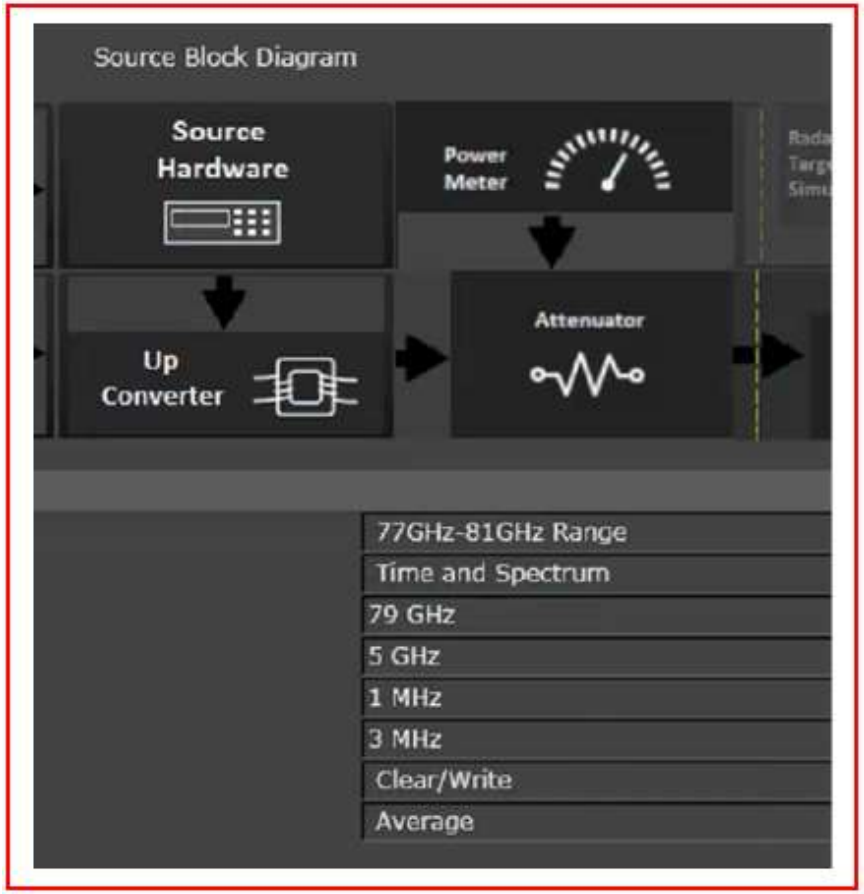
Integrated S/W platform for RX/interference test sequence

KS83RX0A Automation platform for automotive radar

Accelerate Your Radar-Test Workflow

KS8320A automation platform for automotive radar

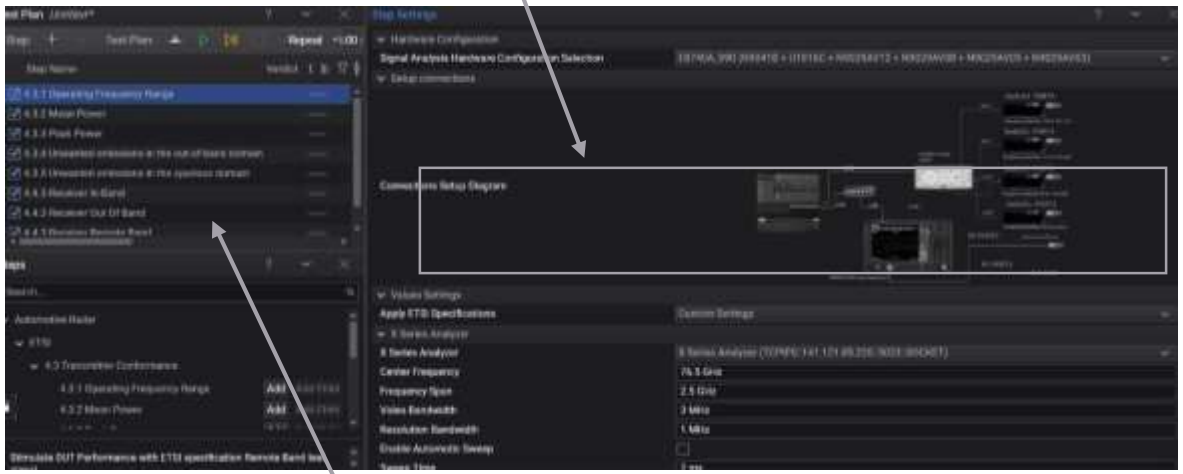
- **Provides suite of standards-compliant routines**
  - Automated functions simplify programming, customization & testing
- **Accelerates testing & validation**
  - Radar transmitters & receivers
  - Interference immunity
- **Keeps your team up to date with evolving standards**
  - Timely updates



Streamline test development

KS83200A automation platform for automotive radar

- Easy-to-use UI for test configuration & sequencing
- Libraries of test routines for specific automotive radars
- Pre-defined test setups for major standards
  - ETSI, TELEC, FCC, ARIB, KCC, & more
- Functional blocks for testing of transmitters & receivers
  - Signal analysis
  - Signal generation
  - Signal quality
- Functional blocks for testing versus interference requirements
- Customizable test scenarios that simplify creation of unique test cases
- Links to high-frequency instruments, with calibration information



Setup connection diagrams

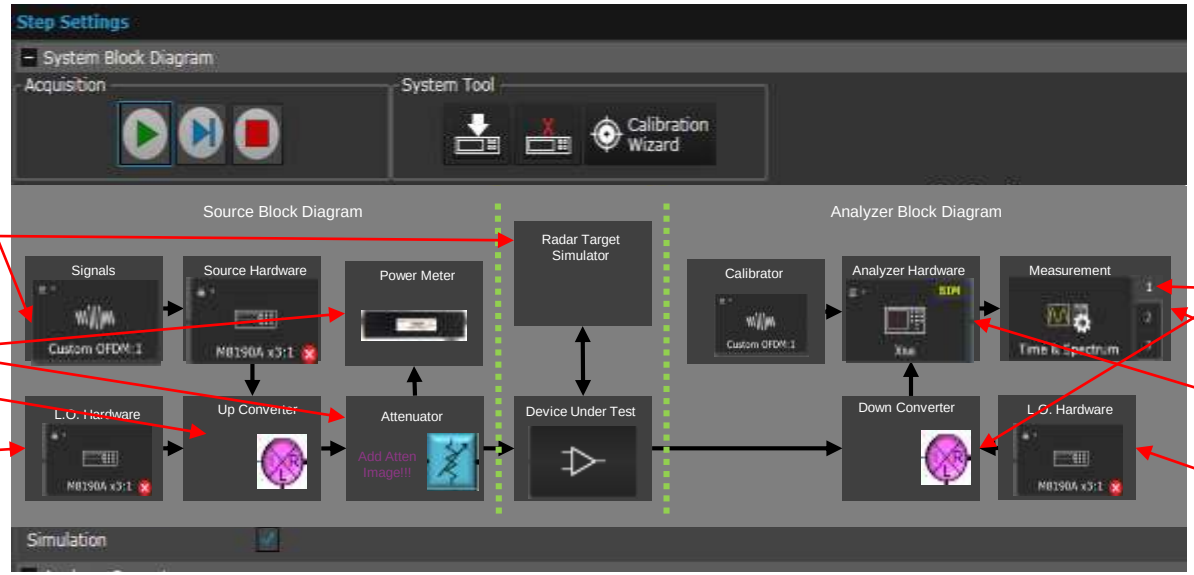
Correction/Calibration information incorporated

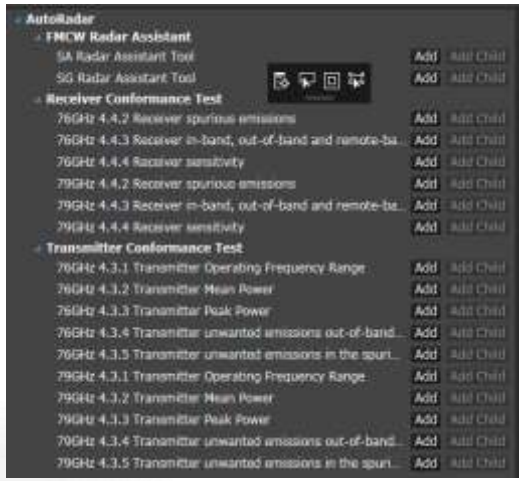
Standards and test cases available

Automotive Radar Test S/W platform

STRAIGHT FORWARD EASY SET UP AND TEST U/I AND TEST SEQUENCE

CHALLENGE
Changing test setup





BENEFITS
Preconfigured routines for testing
Easy test flow creation

ETSI Regulations in Europe

Freq

77GHz
ETSI EN 301 091-1 V2.1.1 2017
(since 1998)

76GHz to 77GHz
BW = 1GHz max
BW = 500-800MHz typ.

- Max Power: **+55dBm e.i.r.p.**
- Range: **LRR** (250m, 17-30deg FOV), **MRR** (60m, 56deg FOV)
- Resolution: **OK → LRR** (100cm,1deg), **MRR** (25cm, 4deg)

79GHz
ETSI EN 302 264 V2.1.1 2017
(since 2009)

77GHz to 81GHz
BW = 4GHz max
BW = 1-2GHz typ.

- Max Power: **-9dBm / MHz e.i.r.p.**
- Range: **SRR** (30m), **MRR** (80m)
- Resolution: **VERY GOOD** (4cm to 8cm)

24GHz UWB
ETSI EN 302 288 v2.1.1 2017
(since 2005)

22Hz to 26.65GHz
BW = 4.65GHz max
(until 2013+4yr for Europe)

24.25GHz to 26.65GHz
BW = 2.4GHz max
(until 2018+4yr for Europe)
BW = 1.5GHz typ.

- Max Power: **-41dBm / MHz e.i. r.p.**
- Range: **SRR** (30m, 120deg FOV), **MRR** (80m, 16deg FOV)
- Resolution: **GOOD → SRR** (20cm, 2deg), **MRR** (20cm, 0.6deg)

24GHz ISM NB
ETSI EN 302 858 v2.1.1 2016
(since 2011)

24.05GHz to 24.25GHz
BW = 200MHz max
BW = 100-200MHz typ.
24.05GHz to 24.50GHz
BW = 400MHz max

- Max Power: **+20dBm e.i.r.p.**
- Range: **SRR** (30m, 150deg FOV), **MRR** (70m, narrower FOV)
- Resolution: **NOT GOOD →** (~75cm)

2000 2005 2010 2017 Time

ETSI EN 301 489 V1.1.1 2016

Electromagnetic Compatibility (EMC) standard for radio equipment and services
EN 301 489-51 : Part 51: Specific conditions for Automotive, Ground based Vehicles and Surveillance Radar Devices using 24,05 GHz to 24,25 GHz, 24,05 GHz to 24,5 GHz, 76 GHz to 77 GHz and 77 GHz to 81 GHz

ETSI EN 303 396 V1.1.1 2016

Short Range Devices; Measurement Techniques for Automotive and Surveillance

RF Regulatory Test Items

ETSI

Transmitter Conformance Requirements

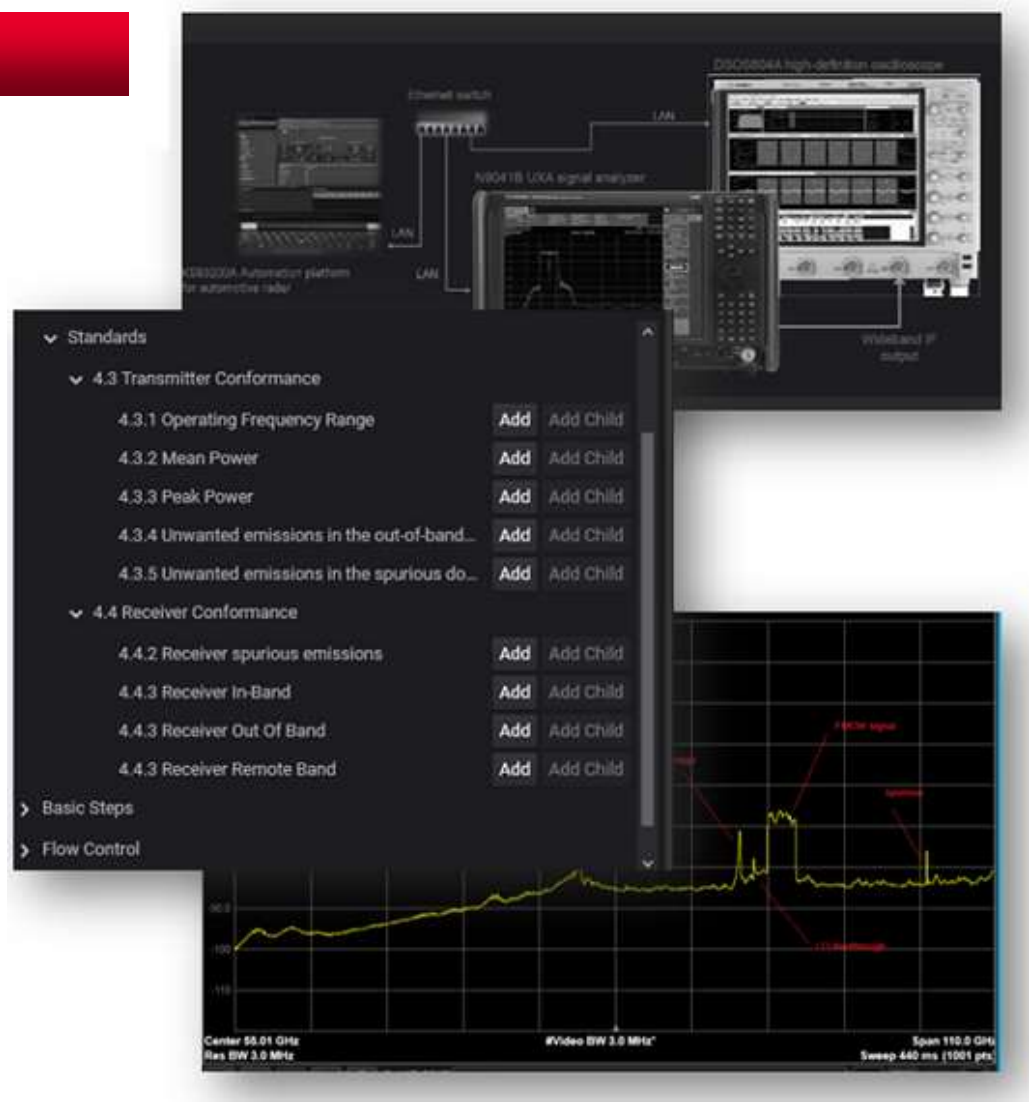
- Operating frequency range
- Mean power (EN 301 091-1)
- Mean power spectral density (EN 302-264)
- Peak power
- Unwanted emission in the out-of-band domain
- Unwanted emission in the spurious domain

Receiver Conformance Requirements

- Receiver spurious emissions
- Receiver in-band, out-of-band and remote band signals handling
- Receiver sensitivity
- *Rx / Interference testing

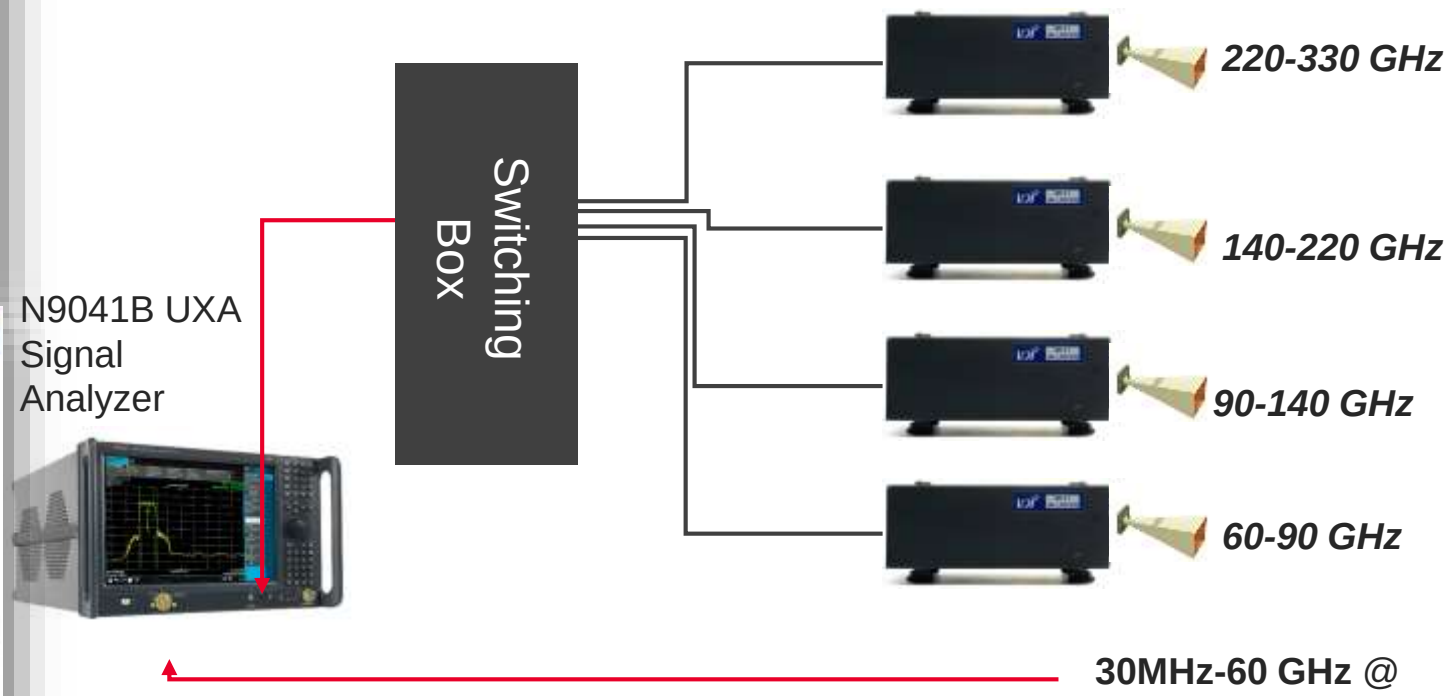
**Requirements for Spectrum Access (EN 302 858)

- Spectrum access duty cycle
- Dwell time and repetition time
- Frequency modulation range



*ETSI TS 103 568, TS 103 361 ** Items are for 24-GHz radar (EN 302 858 (24.05~24.50GHz))

Unwanted Emissions in Spurious-Domain Measurements

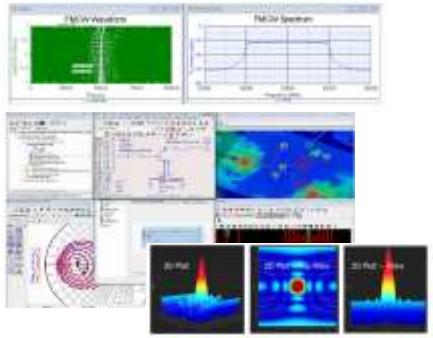


E8740A-090 Automotive Emission Test up to ~330GHz

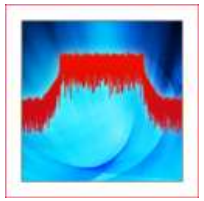
Keysight Radar Portfolio

Automotive Radar Test Solution

KEYSIGHT AUTOMOTIVE PRODUCT PORTFOLIO



ADS / SystemVue Simulation SW



89600 VSA SW with FMCW and PMCW Signal Studio IQTools

E9740A – 060 Radar Signal Analysis

E8740A-080 Radar Interference Test

Multi E8718A RTS

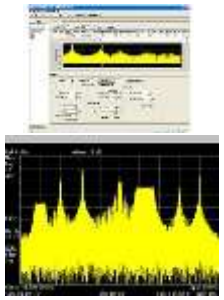
E8707A & E8708A Radar Target Simulator

Design | **Development** | Validation & Mfg.

Automotive Radar CATR Chamber

E8267D PSG Vector Signal Generator

M8190A Arbitrary Waveform Generator



Signal Studio for Pulse Building

Signal Source Analyzer

PNA Network Analyzers Banded mmW Solution

E-Band Power Sensor and Meter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