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Vehicle Level Antenna Pattern & ADAS Measurement

Presenter

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BEYOND MEASURE™

Today’s complexity.

Automotive Development

1960's

Cruise Control

Seatbelt reminder

1970's

ABS

Airbags

1990's

Electronic Stability Control

Embedded cellular

BYOD

Advanced Air curtains

Pre-tensioners

2010's

Autonomous Parking

Lane departure warning

Autonomous braking

Adaptive cruise

V2V

Level 2 Autonomy

Passenger detection

DSRC (Japan, USA)

2020's

Fully Autonomous

Level 5

- No pedals

- No steering wheel

Connected Vehicles

Vehicle-to-Vehicle (V2V):

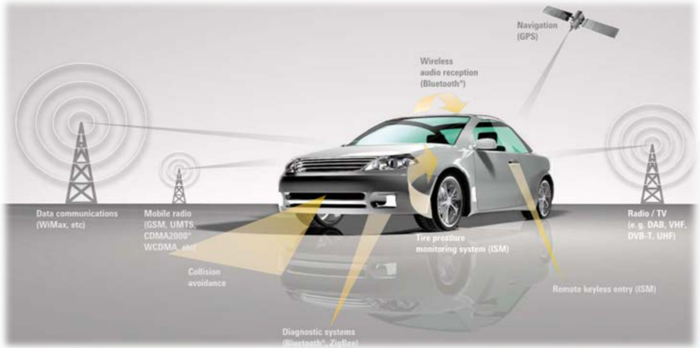
- Electronic hand shaking
- Collision avoidance
- Platooning

Vehicle-to-Infrastructure (V2I):

- Incident detection/ warning
- Weather/ice detection / warning
- Broadcast traffic signal timing
- Dynamic re-routing

Vehicle-to-Cloud (V2C):

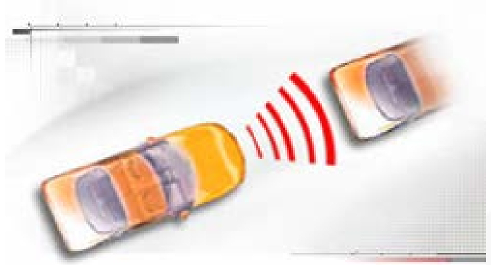
- Broadcast of updates
- Vehicle status monitoring



Wireless Testing Performance

Tests need to address various frequency ranges:

- FM Radio from 70MHz
- HD radio
- Cellular from 700MHz to 60GHz (3G, 4G,LTE, 5G)
- Satellite from 1.6GHz
- WiFi from 2.4/5.8GHz
- DSRC 5.9GHz
- RADAR 24GHz/ 79GHz



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What’s In Development – Highly RF Dependent

In Development
V2X and Traffic Signal recognition
Lane keeping
Autonomous parking
Pedestrian/object avoidance
Night Vision
Platooning
Sign, Image recognition
Augmented Reality HUD
3D HUD

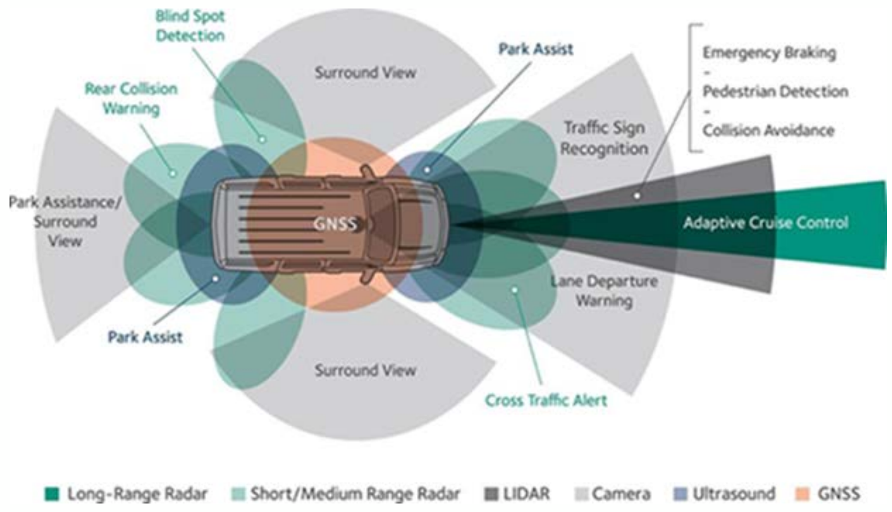


Image courtesy Texas Instruments

RADAR Module

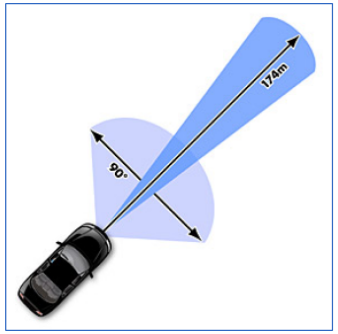
- RADAR used as the primary detector for many ADAS features
  - ESR RADAR – ACC, FCW, AHC, LDW, EAB, pattern recognition,

DELPHI

Delphi Adaptive Cruise Control

The Delphi Advantage

- Multimode electronically scanning radar
  - Lower-cost: Simultaneous long- and mid-range functionality allows one radar to be used for multiple safety systems helping to keep safety system cost down
  - Solid-state: Technology is extremely reliable and is resistant to vibration
  - Class-leading performance and durability
    - Innovative design provides excellent multi-target discrimination plus precise range, approach speed and angle data
    - Dual-mode classification enhances object reliability
    - Simultaneous Transmit and Receive Pulse Doppler (STAR PD) Waveform provides independent measurements of range and range-rate and superior detection of clustered stationary objects
  - Compact design makes it easier to locate the sensor on the vehicle without compromising vehicle styling
  - Proven manufacturing processes increase affordability for high-volume automotive segments where radar systems have not previously been available



Wide mid-range coverage not only allows vehicles cutting in from adjacent lanes to be detected but also identifies vehicles and pedestrians. Long-range coverage provides accurate range and speed data with effective object discrimination.

The radar module, including electronics, measures just 173.7 x 90.2 x 49.2 millimeters including mounting features.

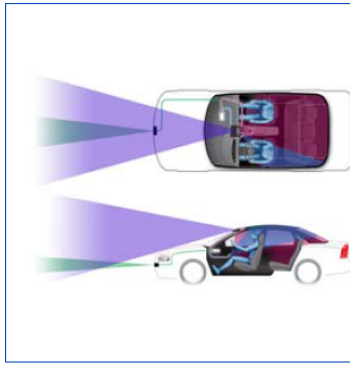
DELPHI

SAFETY

Delphi Collision Mitigation System

Delphi's Collision Mitigation System (CMS) uses unique data fusion algorithms that combine the input from radar and vision sensors to enhance safety system functionality. The system consists of a camera, sophisticated vision control module and multimode electronically scanning radar. It is designed to warn drivers if it estimates a high risk for collision when the equipped vehicle approaches a pedestrian or another vehicle. If the driver does not react to the warnings, the system automatically applies the brakes to avoid or considerably reduce the effects of the collision.

Unlike most competitive systems that limit braking power to 50 percent, Delphi's CMS uses input from its vision and radar sensors to allow full automatic braking power when it senses a collision is imminent. The system fuses the data from the two sensors using image processing modules and complex algorithms. Then, it classifies the detected objects, and assesses the threat. Once risk has been assessed, the algorithms define an appropriate mitigation strategy and enact a defined set of countermeasures.



Data fusion algorithms combine inputs from radar and vision sensors to enhance safety system functionality.

CMS- Enabled Features

- Full Speed Range Adaptive Cruise Control
  - Maintains driver-set time-gap from vehicle ahead
  - Detects stationary vehicles
  - Reduces driver workload and enhances convenience
- Forward Collision Warning
  - Helps reduce the potential for an accident or injury
  - Helps reduce the potential for property damage
- Lane Departure Warning
  - Forward looking camera monitors lane markings and alerts the driver when the vehicle approaches or crosses the lane markings
  - Alert suppressed when turn signal is used

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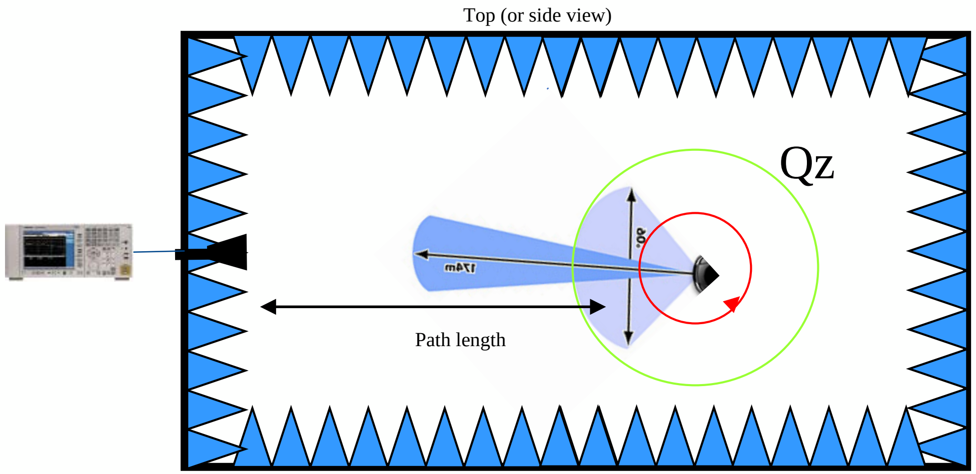
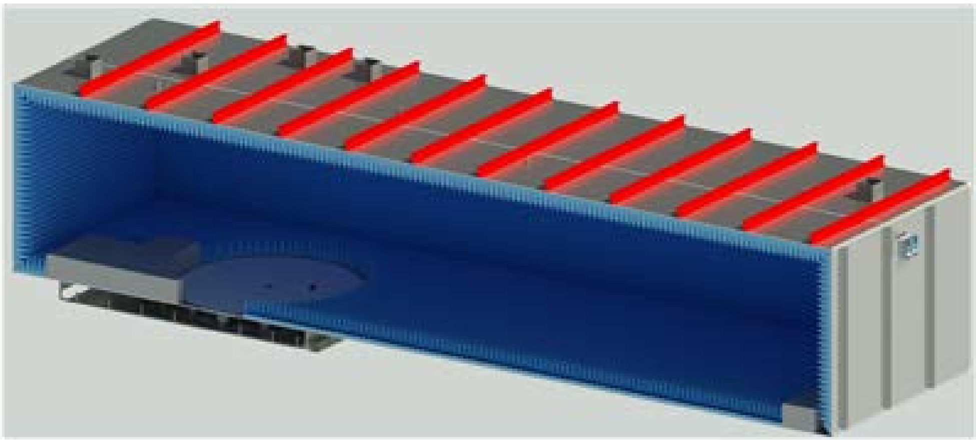
RADAR Module Test System

- Used for RADAR module performance and target recognition testing
- Measure: Beam width, pattern, transmit power, and sensitivity in the 24GHz, 77GHz and 79GHz bands
- Most useful for module level development and production testing
- Optional RADAR Simulator integration available

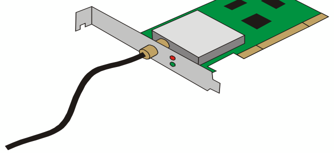
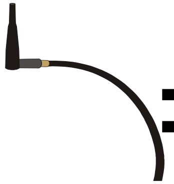
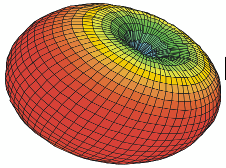


RADAR Test



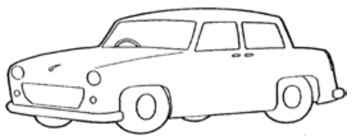
Antenna - Wireless Testing

- In the small handset world, Over-The-Air (OTA) testing refers to the radiated performance of an EUT
- This was originally characterized by the conducted device performance with the isolated antenna pattern
  - Conducted performance + Antenna characteristic = OTA ?

 +  =  ?

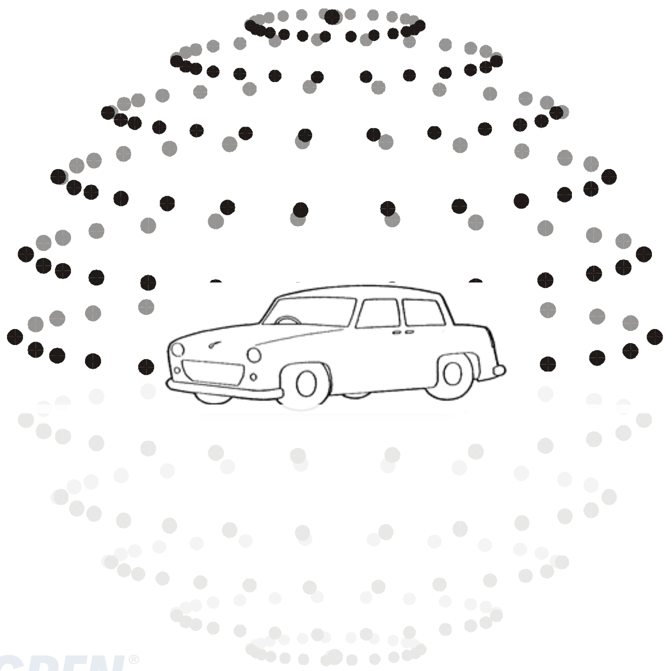
- This was found to be inadequate and developed into the full OTA tests used today

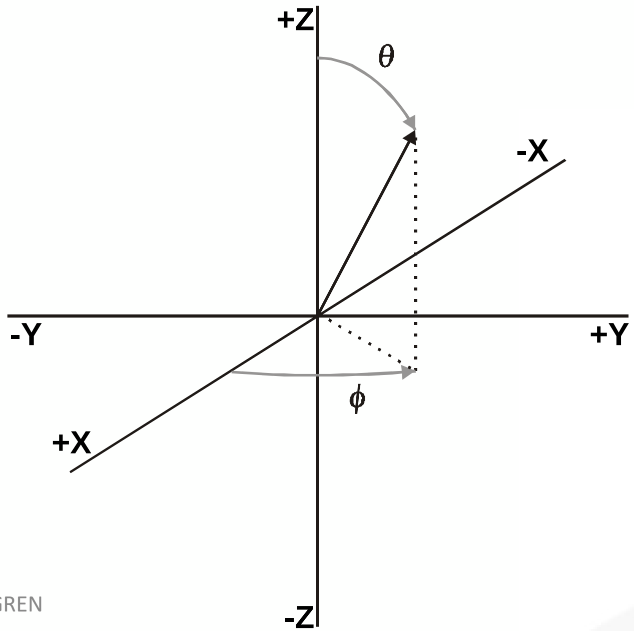
- In the Auto industry:

 +  =  ?

Antenna - Wireless Testing

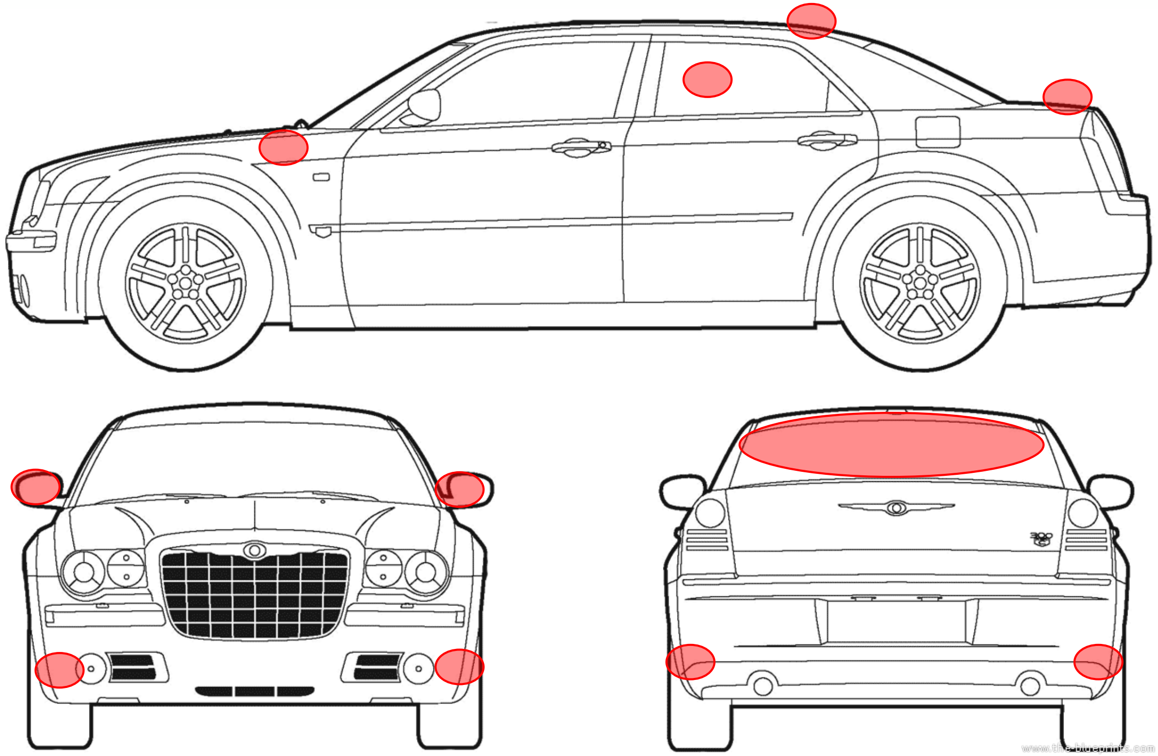
- The positioner or multiple sensors allows capturing data points on the surface of a sphere a fixed distance from the DUT
- A spherical coordinate system is used to represent the angular location of each measured data point.





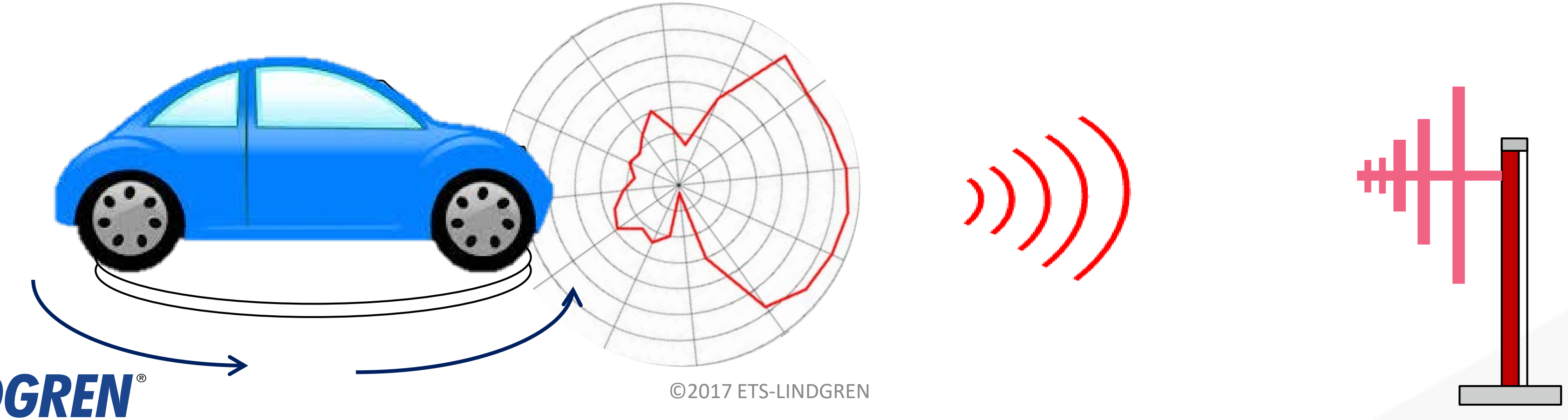
Automotive Antennas

- Antennas are mounted in various locations inside or outside of the vehicle
- These antennas are highly integrated with the automotive body for aesthetic, practical and performance reasons
- And they must perform as an integral part of the vehicle



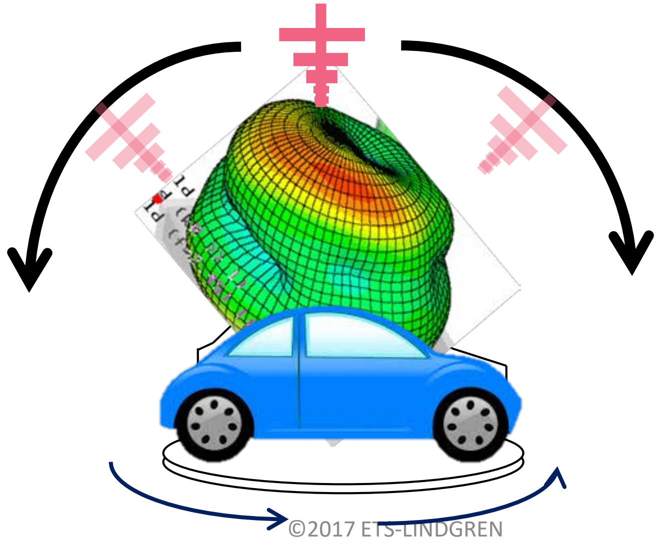
Wireless Testing - 2D vs 3D

- Scan over the major radiation area
- If the antenna is radiating most power near the horizontal plane, a 2D azimuth cut may be preferred
- Overall scanning may not be necessary
- The applications of ETC and Cruise control radar may fall into this category
  - Pattern, Gain, sensitivity, EMC etc. can be evaluated



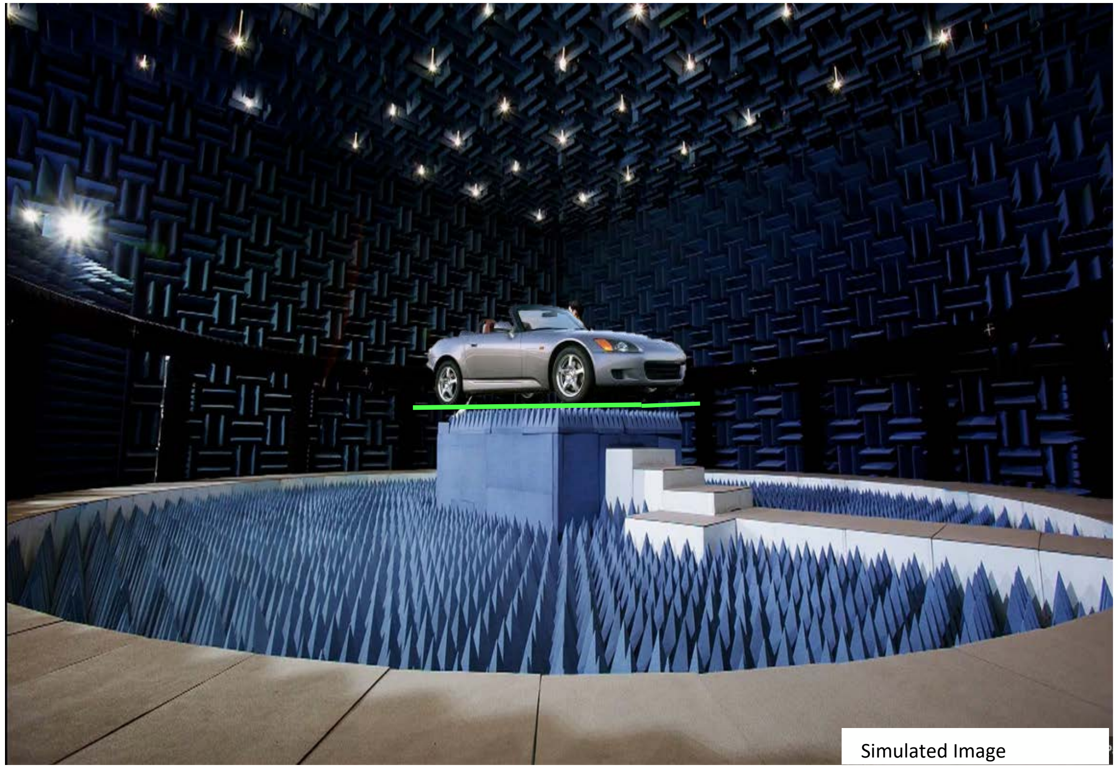
Wireless Testing - 2D vs 3D

- If the radio signal propagates more towards the sky - 3D scanning is preferred
- 3D scanning is over the upper hemisphere
- Not suitable for long test distance (requires very tall tower and ceiling height)
- FF range and Spherical NF scanner can be used



Multi Sensor Array

- Single ring MIMO chamber with multiple sensors (antennas)
- The number of sensors relative to DuT position define measurement angular resolution



OTA Measurements

- The basic device and components can be measured
  - At bench level for conducted transmit power, throughput, receive sensitivity, etc.
- The fully assembled module can be measured OTA
  - Pattern, sensitivity, operation and interoperability…
- Measurements can be done on an antenna range
- Selecting the appropriate range is very important
  - Outdoor far field antenna range (elevated or ground reflection)
  - Indoor far field antenna range
  - Indoor compact range
  - Indoor near field range

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    - Innovative design provides excellent multi-target discrimination plus precise range, approach speed and angle data
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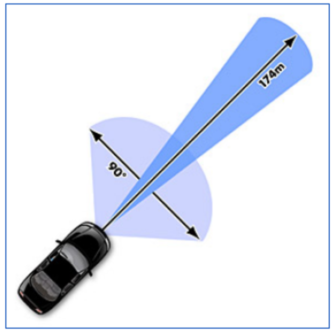

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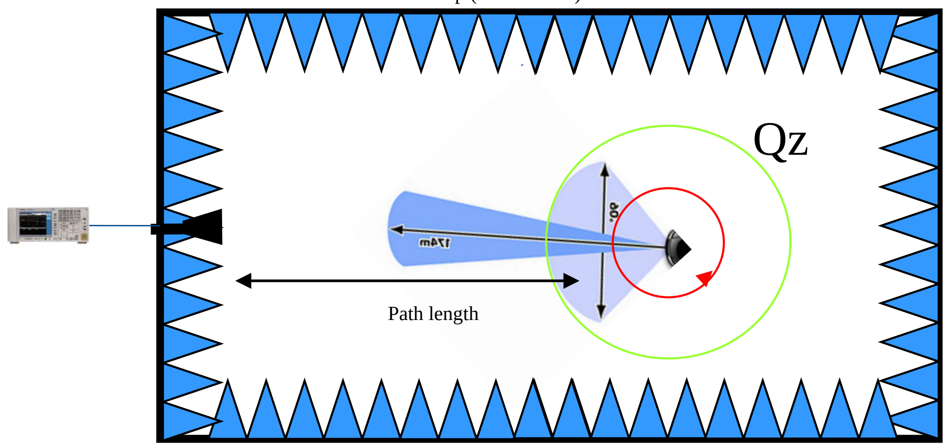
The radar module, including electronics, measures just 173.7 x 90.2 x 49.2 millimeters including mounting features.

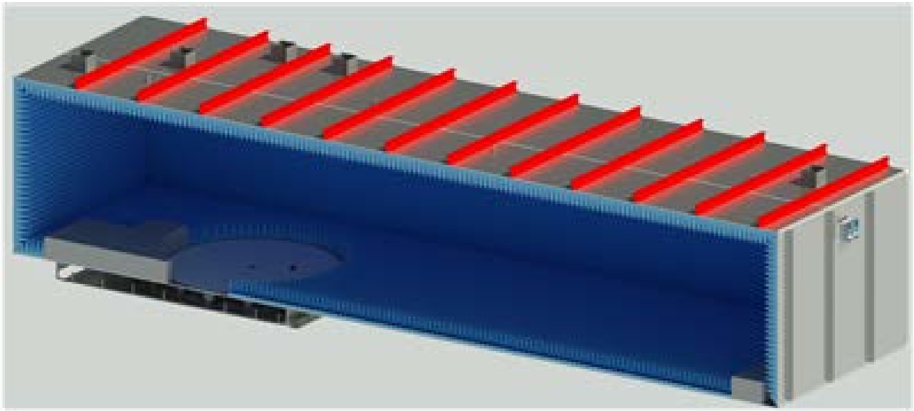
Courtesy Delphi

RADAR Test System

- Used for RADAR module operation and target recognition testing using target emulation
- Measure beam width, pattern, transmit power, sensitivity, and target discrimination in the 24GHz, 77GHz and 79GHz bands
- Approximately 5m x 1.5m x 1.5m test system.
- Most useful for module level development and production testing
- Relevant Test standard is EN 301091-1



RADAR Test

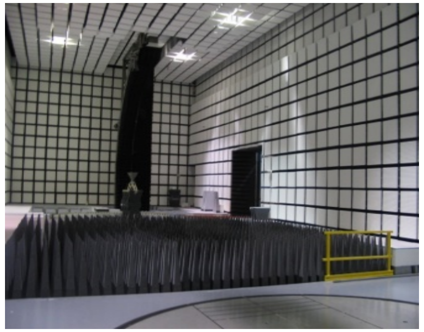


NSI-MI Solutions

Applications:

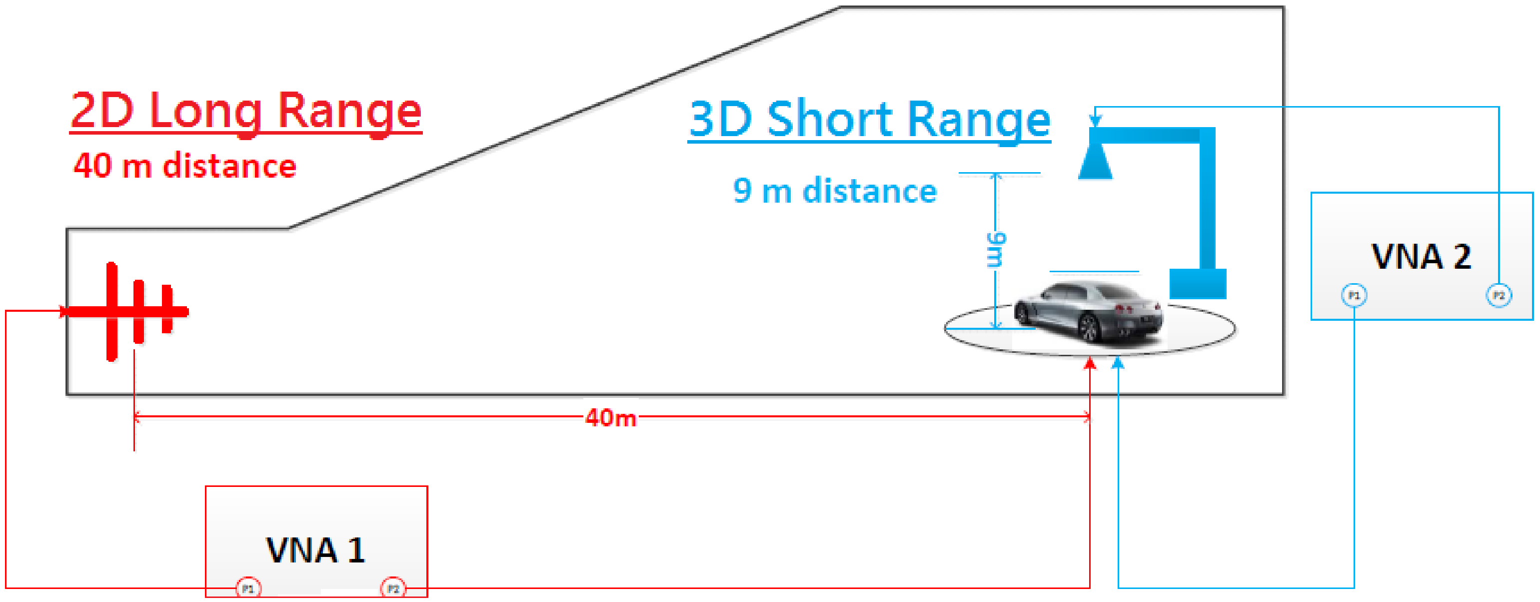
- Outdoors
  - Far-Field ranges
  - Spherical Near-Field Ranges
- Indoors
  - Spherical Near-Field Ranges
    - Free Space and Infinite Ground
  - Quasi-Far-Field
- Combined
  - Radome protected Spherical Near-Field
  - Outdoor Far-Field add-on



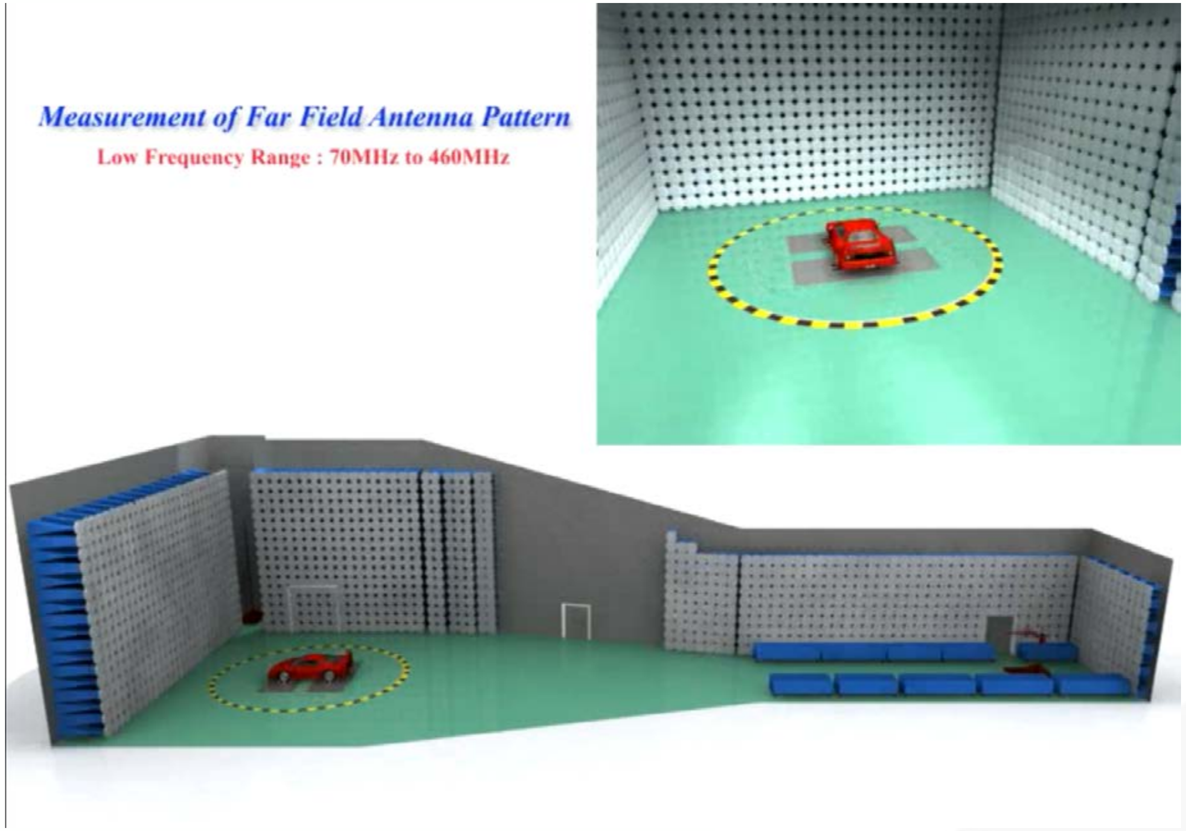
Wireless Testing – Hybrid FF Range

- Large tapered chamber, designed for dual purposes, APM and EMC measurement
- Antenna Pattern Measurement System
  - 2D Long range – taper
    - 70 MHz to 3 GHz
    - 40 m test distance
  - 3D Short range – roof scanning
    - 1GHz to 6 GHz
    - 9 m test distance



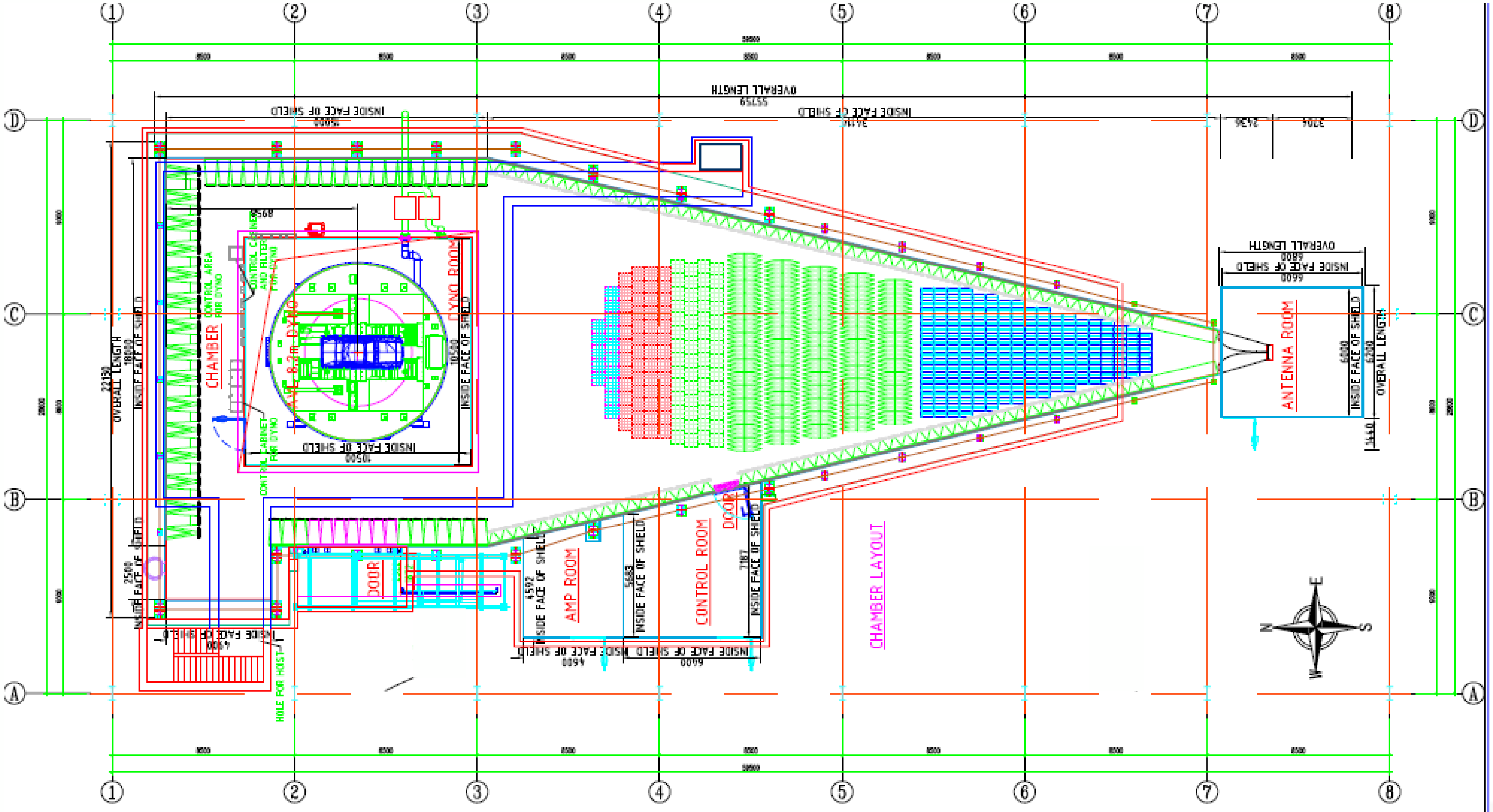
FF Antenna Measurement Layout

- Large tapered chamber, designed for dual purposes, APM and EMC measurement
- Antenna Pattern Measurement
  - 2D Long range – Taper
    - 70 MHz to 3 GHz
    - 40 m test distance
  - 3D Short range – Hemisphere
    - 700MHz to 6 GHz
    - 9 m test distance
  - Single or multi-Vehicle V2X
    - Performance test



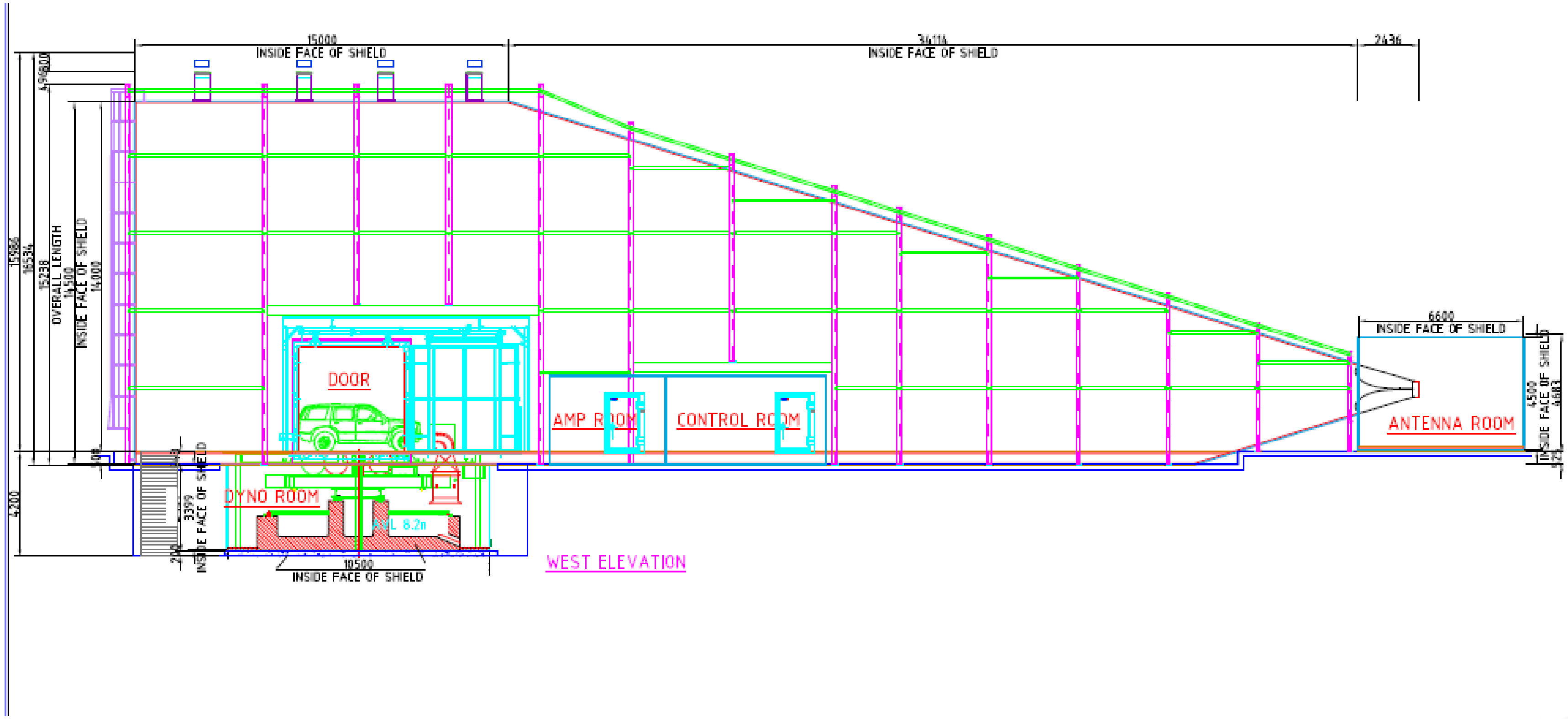
Hybrid-Chamber Approach

- Semi-Tapered Far-Field Range for Full-Vehicle Antenna, EMC, ADAS Testing



Hybrid-Chamber Approach

- Semi-Tapered Far-Field Range for Full-Vehicle 2D Measurement
- Gantry FF/NF range for full vehicle 3D measurement



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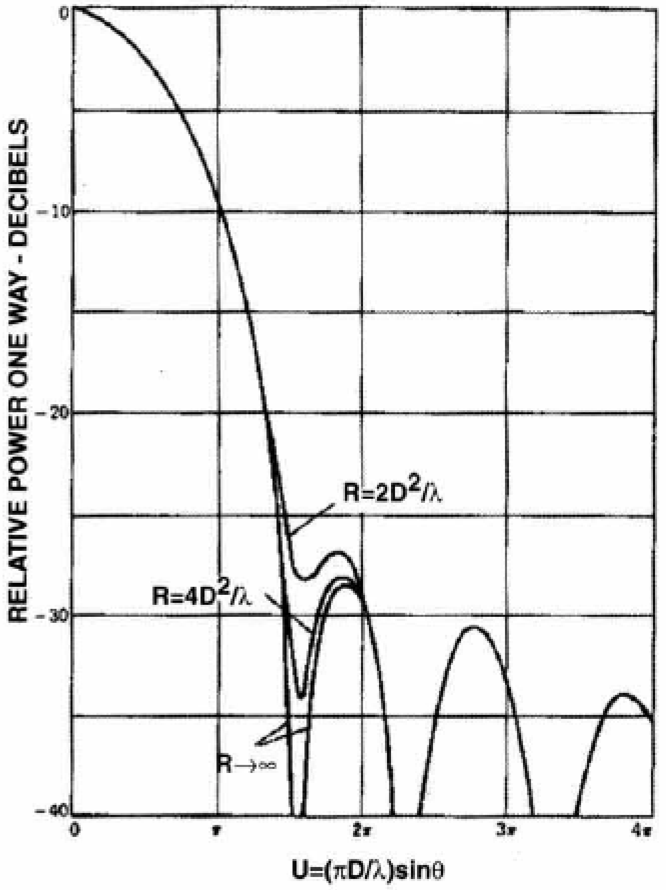
Far-Field vs Near-Field

- Far-field condition may not be met when the test frequency goes higher and the radiation aperture goes larger.
- The far-field condition $2D^2/\lambda$ is really the condition when the phase taper reaches to $\frac{\pi}{8}$.
- How far is far enough is really a question of the level of measurement accuracy to achieve.
- For example of a typical radiation patterns for a 30 dB Taylor aperture distribution, the shorter ranges cause null filling, even at the $2D^2/\lambda$ distance.

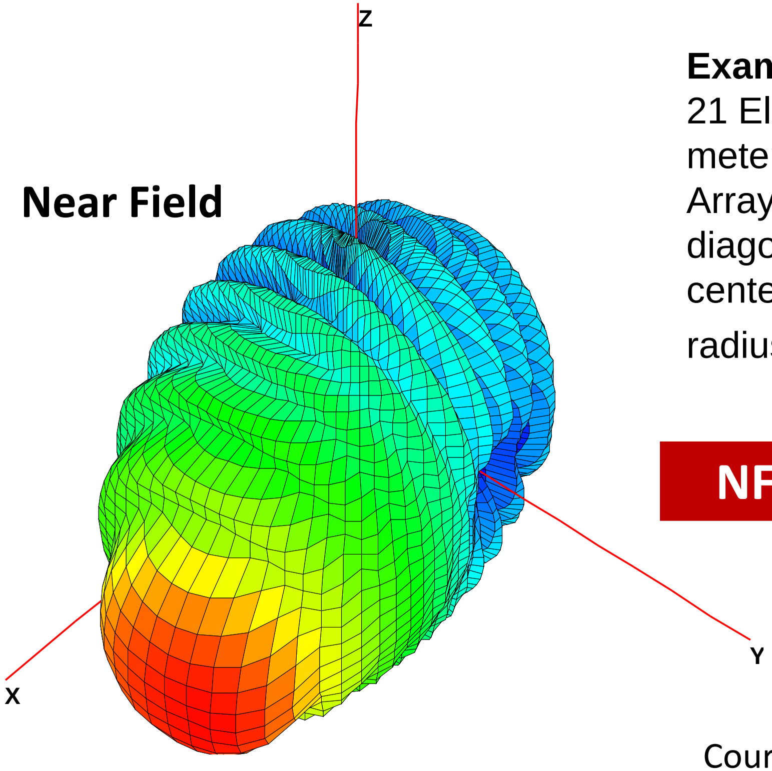


Courtesy NSI-MI Technologies

Far-Field vs Near-Field

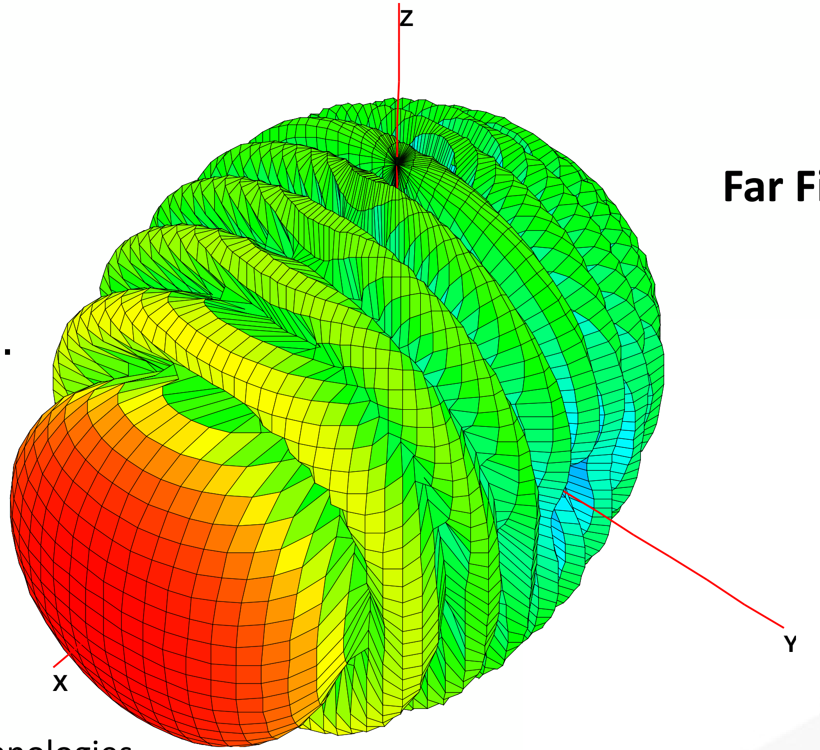
- If we cannot have far enough distance due to the limitation of the available space, near-field-to-far-field conversion can be applied.
- NF2FF is nothing more than taking sufficient samples at one wave front in the short range, then re-radiate the sampled wave front (Huygens principle) to the far range.

Near Field



Example
21 Element, 1.0 meter long Phased Array offset 0.7 m diagonally from center of 1.5 m radius test system.

NF2FF



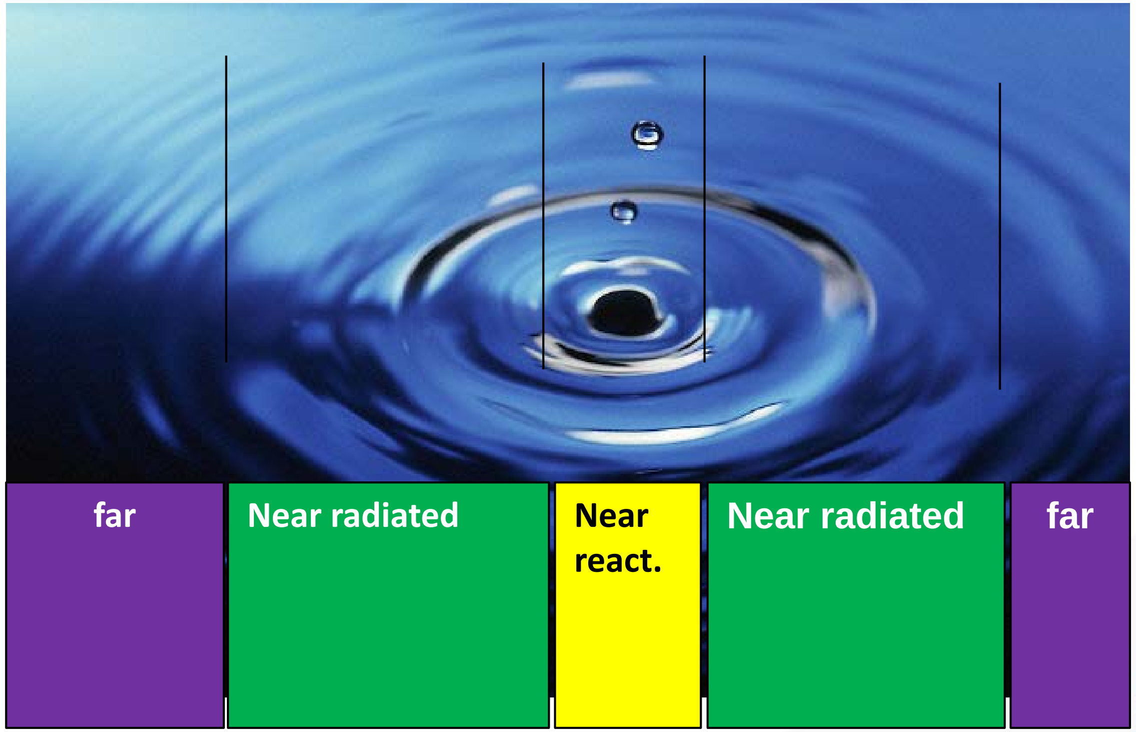
Far Field

Courtesy NSI-MI Technologies

Far-Field vs Near-Field

- Near Field
  - Reactive near field vs Radiated near field
- Reactive Near-Field
  - Energy stored as electric (capacitive) or magnetic (inductive) field.
  - $r < 2\lambda$ is usually a good rule of thumb for half-wave sources
  - $r < 0.62\sqrt{D^3/\lambda}$ is the generally accepted definition.

- Radiating Near-Field
  - Primarily propagating RF energy into uniform wave front.
  - Within radiating near-field, patterns are function of distance.
  - $r < 2D^2/\lambda$ is the accepted definition.
  - Referred to as the *Fresnel* region.

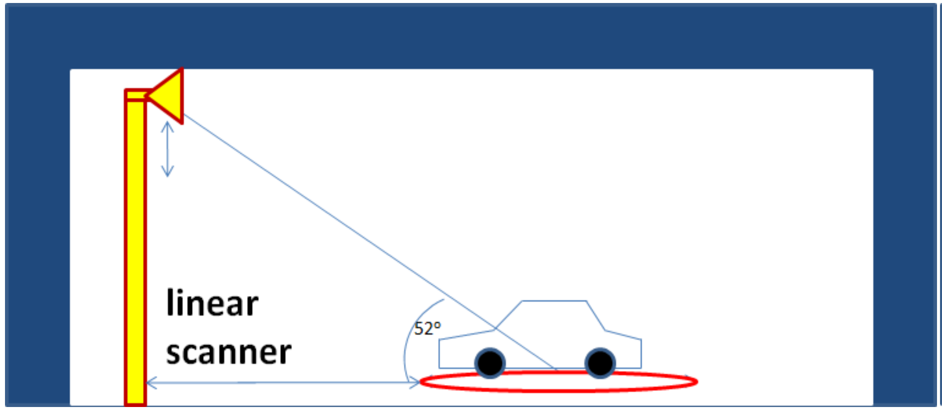


Courtesy NSI-MI Technologies

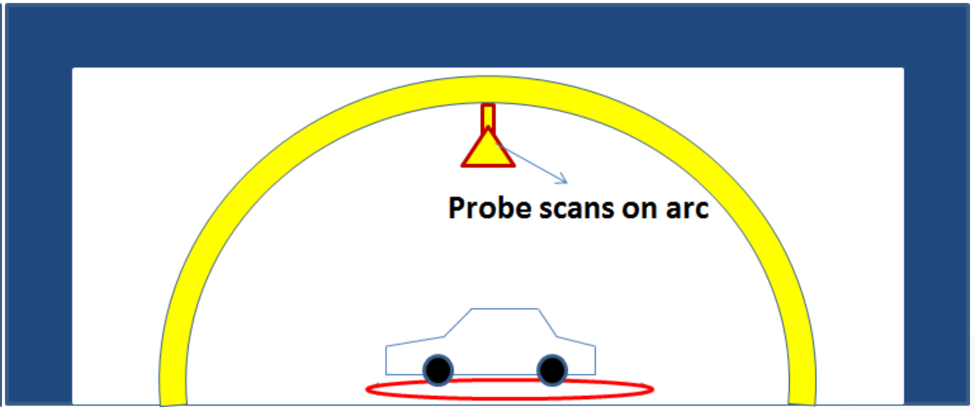
Near Field Scanning

- For a NF2FF system, it is important to sample over the major radiation area, which may again be over the upper hemisphere.
- There are several NF scanning methods, for example, cylindrical scanning and spherical scanning.
- Cylindrical scanning is suitable for AUT radiating pattern more confined near the horizontal.
- Spherical scanning is suitable for AUT pattern radiating more towards the sky (upper hemisphere).

Cylindrical Scanning



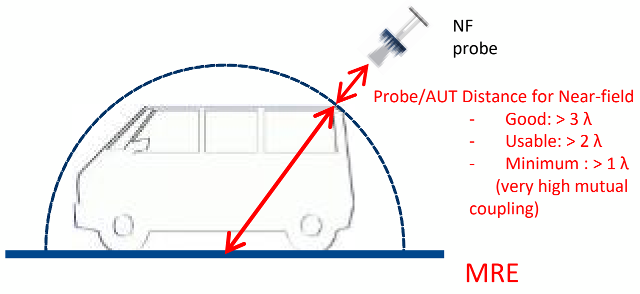
Spherical Scanning



NF- Spherical Sampling Spacing (Steps)

- The complete vehicle is the AUT
  - Interest : measure the performance of the antenna mounted in the vehicle, not the antenna alone
  - Vehicle body and shape affects the antenna performances
- Full vehicle size dictates MRE (Maximum Radial Extent of AUT)
  - MRE is used to calculate the measurement angular step needed according to Nyquist (1/2 λ)
- Low frequency probe vehicle spacing require large scan radium supported by double-sided gantry

AUT Size	6.3x2.3x2	m.
MRE	3.6	m.
FREQ.	Nyquist requirement Probe angular step	
250 MHz	6	Deg.
1600 MHz	1.25	Deg.
2200 MHz	1	Deg.
2700 MHz	0.8	Deg.
4000 MHz	0.5	Deg.
6000 MHz	0.375	Deg.

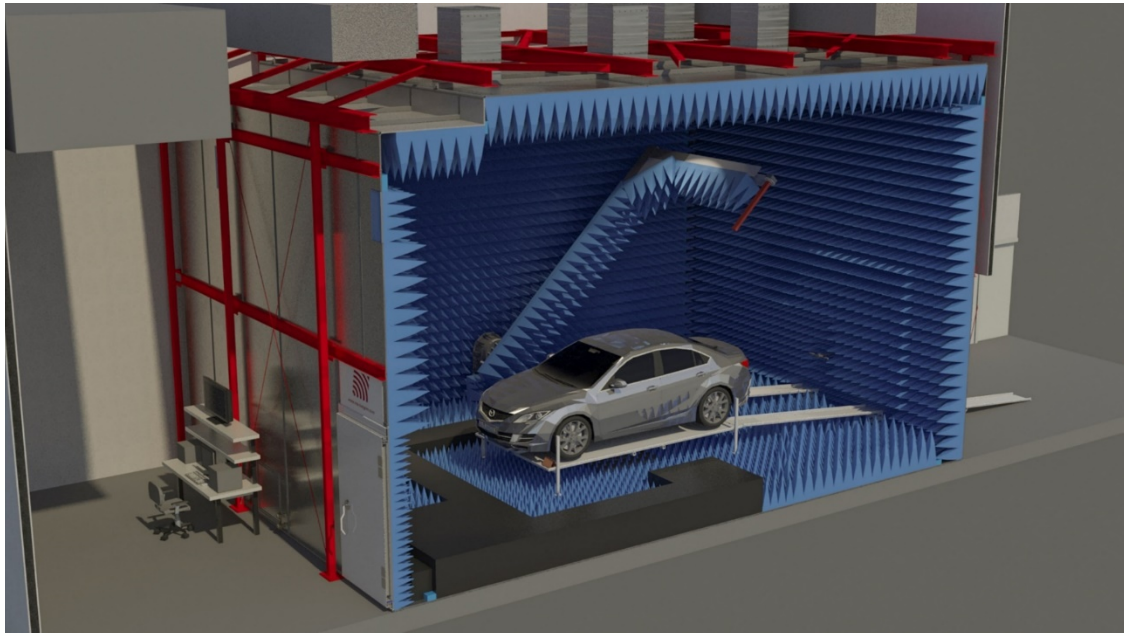


Courtesy NSI-MI Technologies

Near Field Scanning

- For a NF2FF system, the chamber absorber performance is less critical.
- The probe to QZ distance is typically 2-3 λ, equivalent to less than 2m.
- Gating can be used to control signals from other reflection boundaries.
- Installation in existing EMC chambers may be feasible without absorber changes.
- Most suitable for measurements at frequencies greater than about 800MHz.
- Not a real time antenna measurement so cannot be used for sensitivity measurements.

NF Antenna Measurement Layout

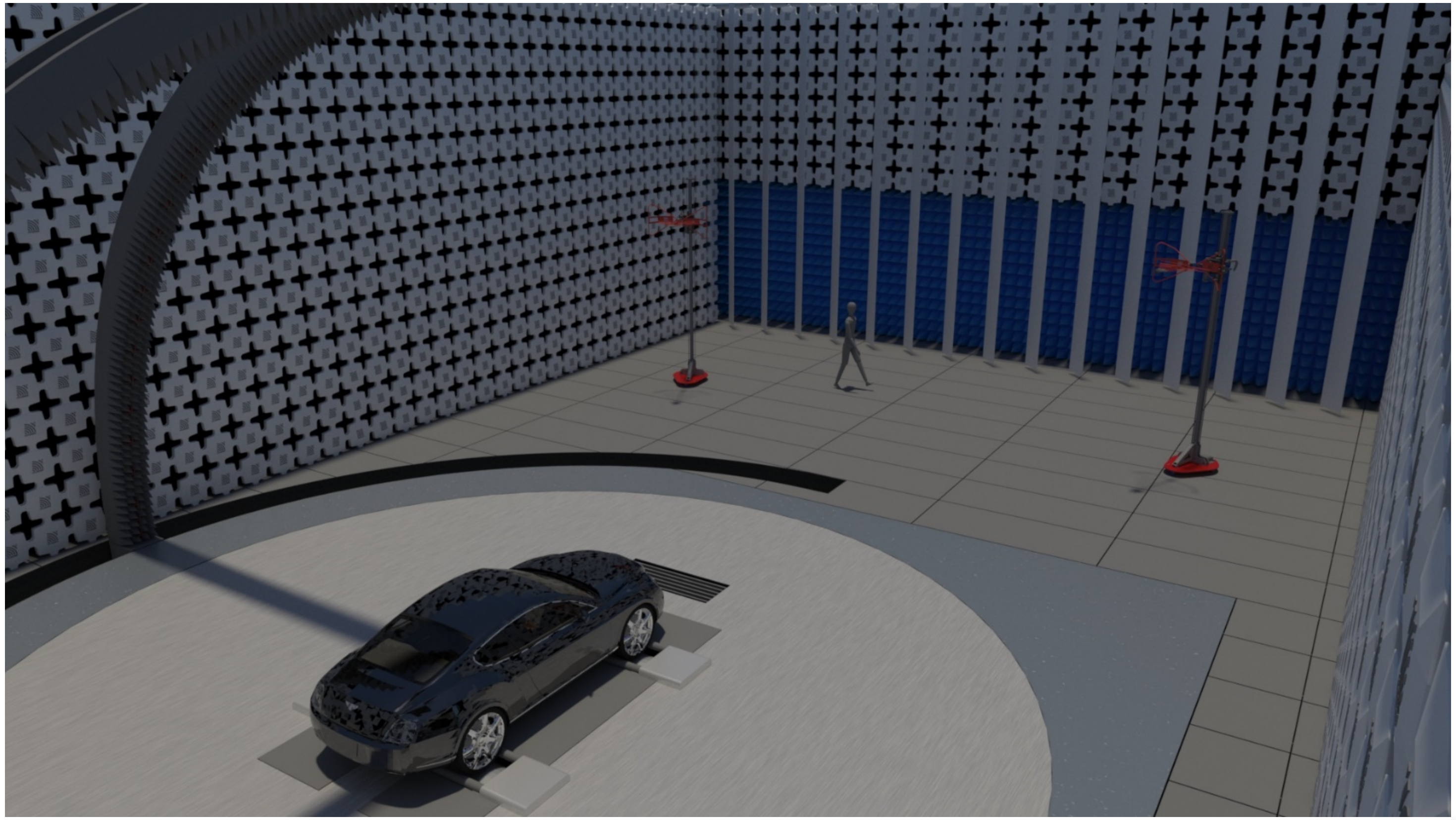


Partnership with NSI-MI

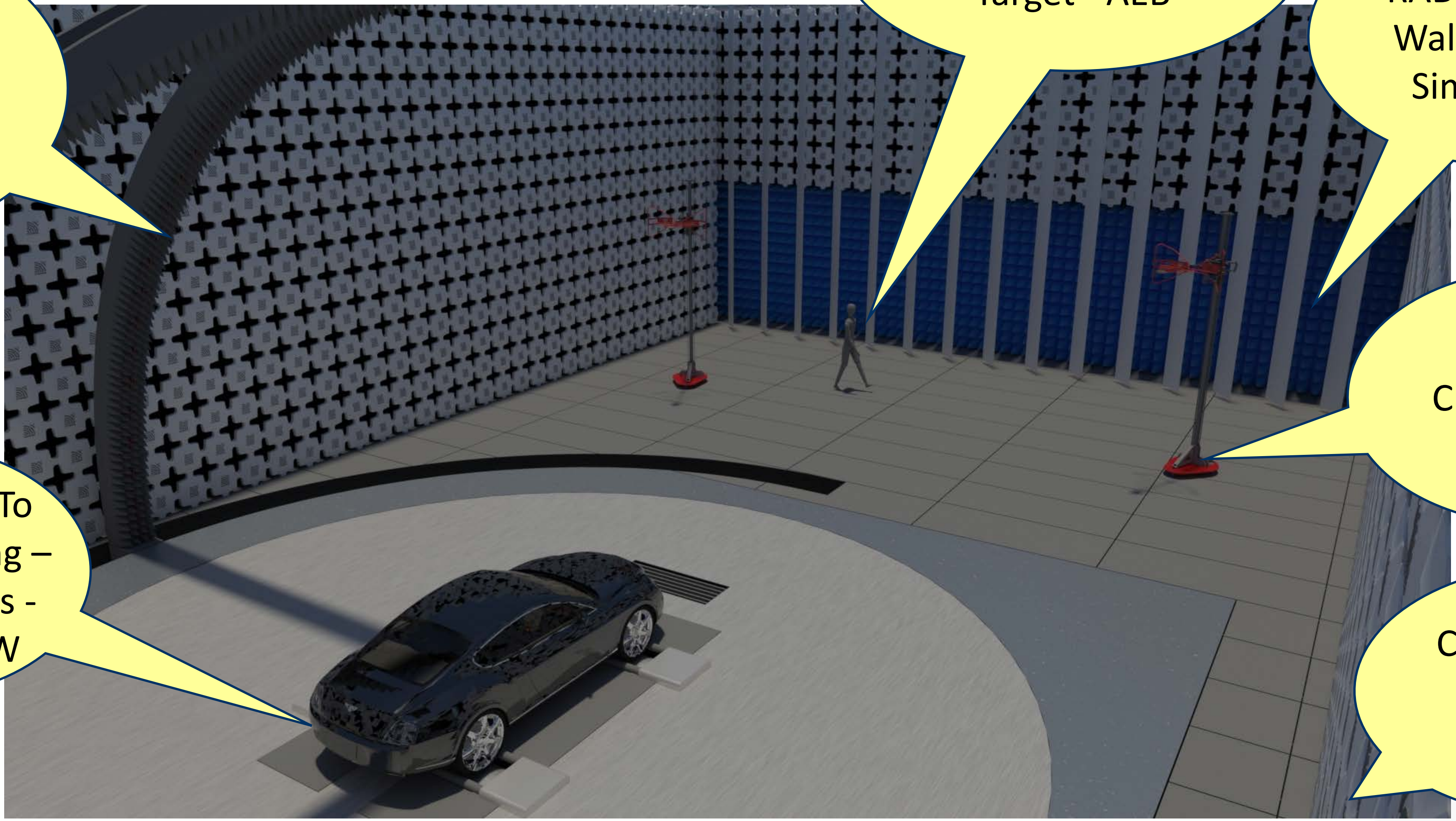
NSI MI

Integrated Solution

- Support for “ADAS feature” testing in 10m Chamber
  - ESR RADAR – ACC, FCW, AHC, LDW, EAB, Sign recognition, Pedestrian detection (E-NCAP), Park assist



ADAS and Communication Testing



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- Antenna Pattern Measurement
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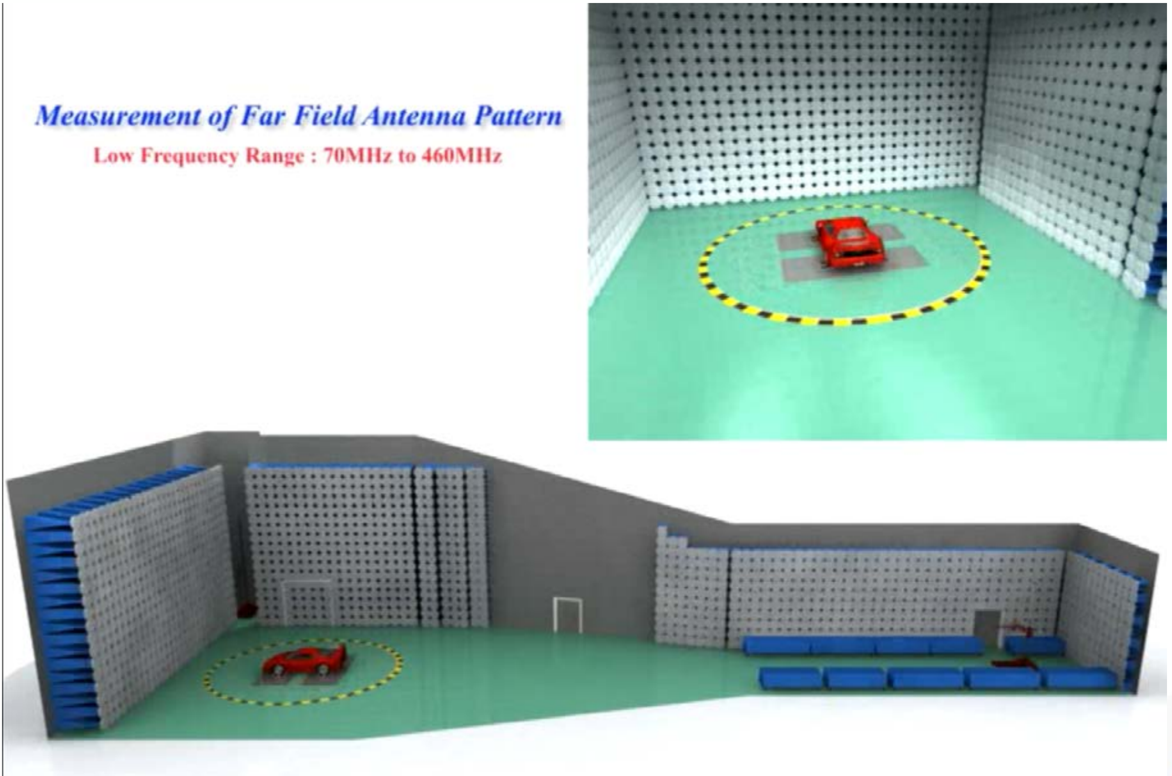
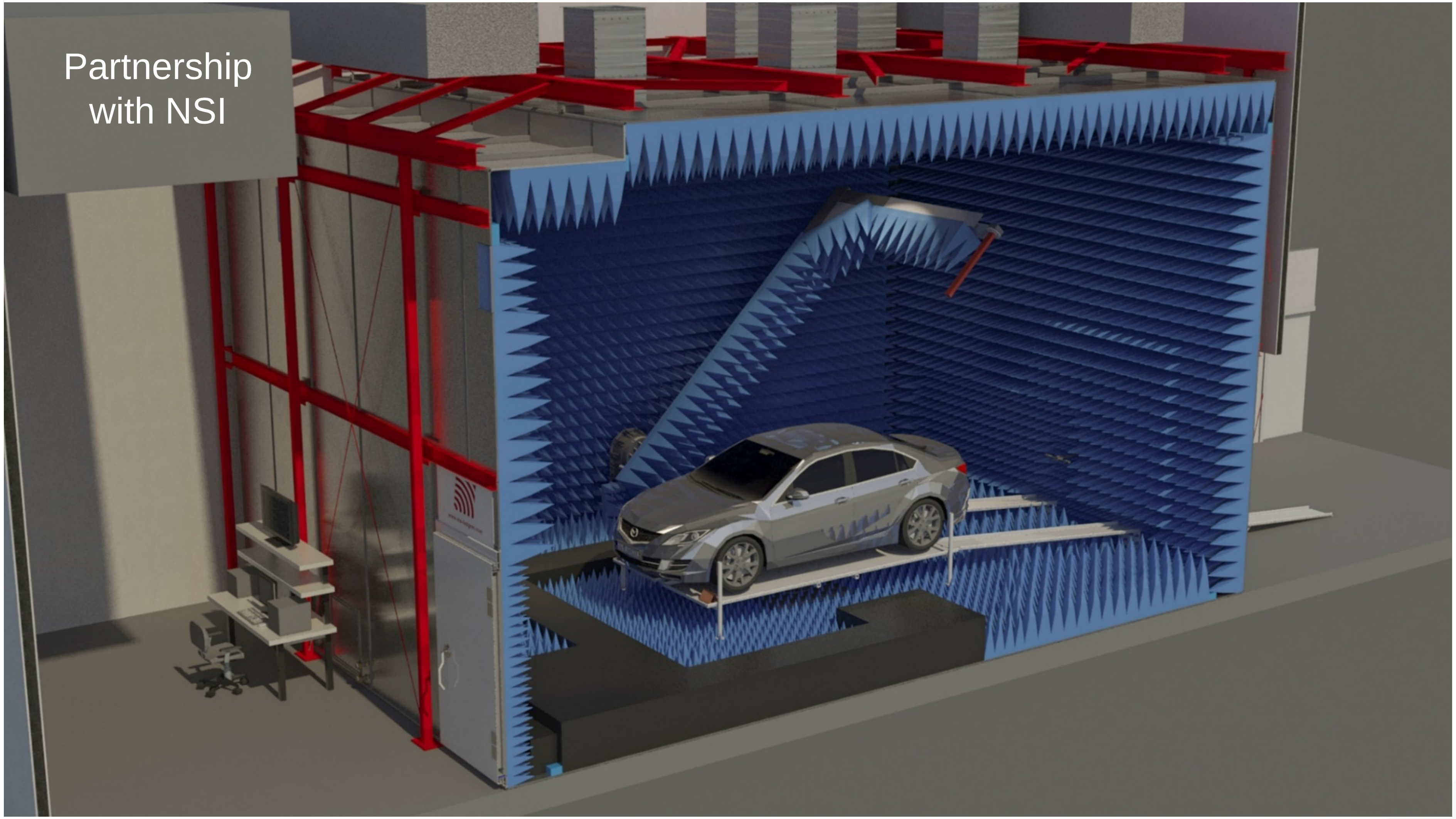
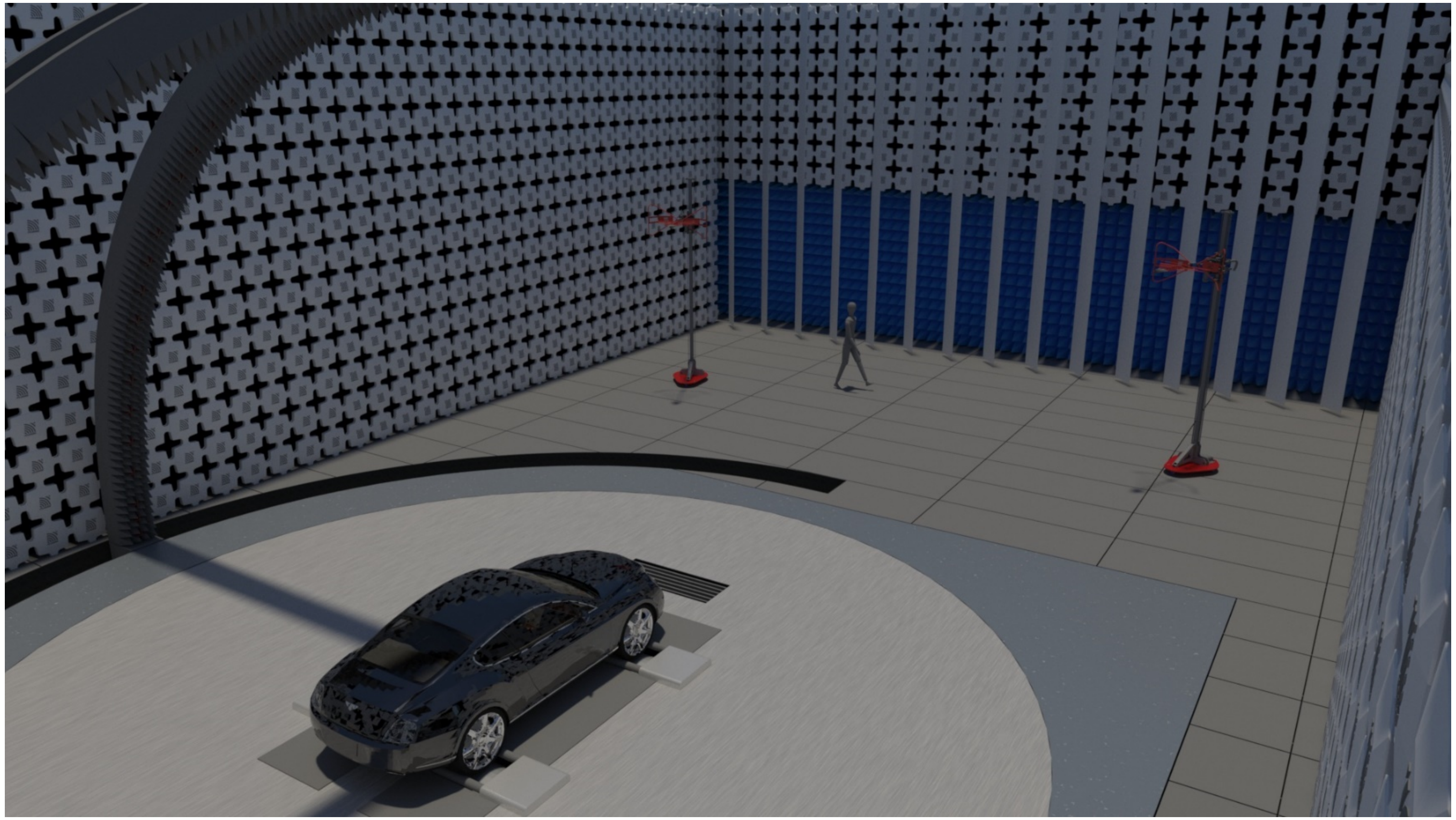


NF Antenna Measurement Layout



Full Vehicle Integrated Range

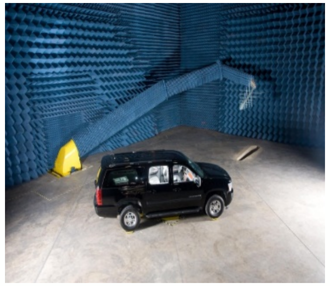
- Support for “ADAS feature” testing in 10m Chamber.
  - ESR RADAR – ACC, FCW, AHC, LDW, EAB, Sign recognition, Pedestrian detection (E-NCAP), Park assist.

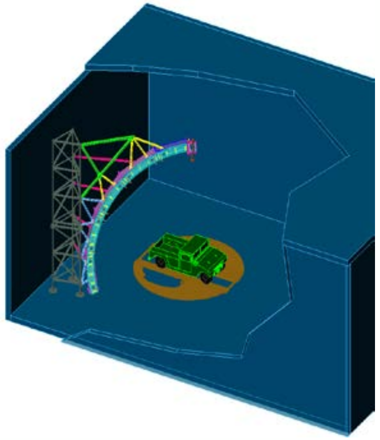


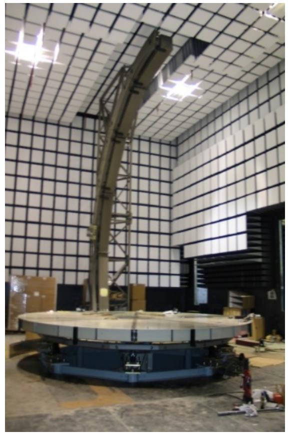
NSI-MI Automotive Test Solutions

Configurations:

- Single Arm
- Dual Arm (Gantry)
- Fixed arch





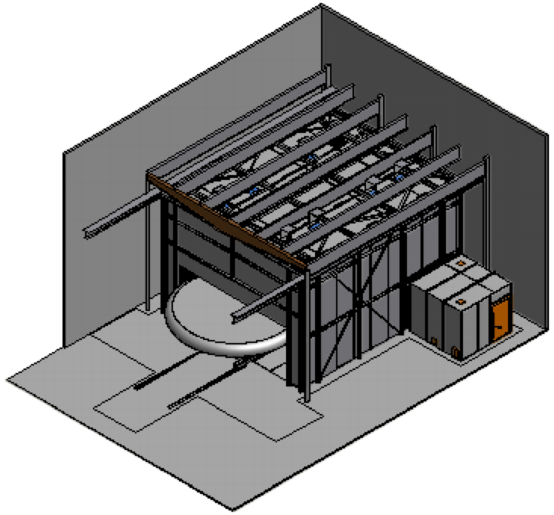


NSI-MI includes:

- Complete RF Subsystem
- Project Management
- Advanced Antenna Measurements Software

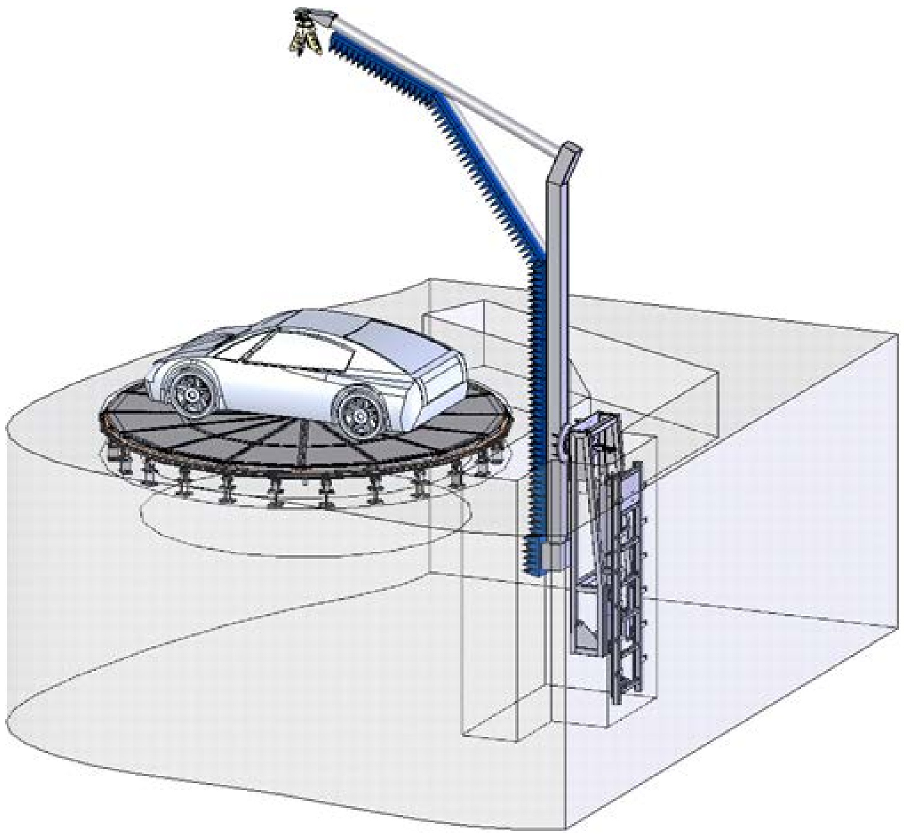
ETS-Lindgren / NSI Team Capabilities

RF-Shielded Anechoic Chamber



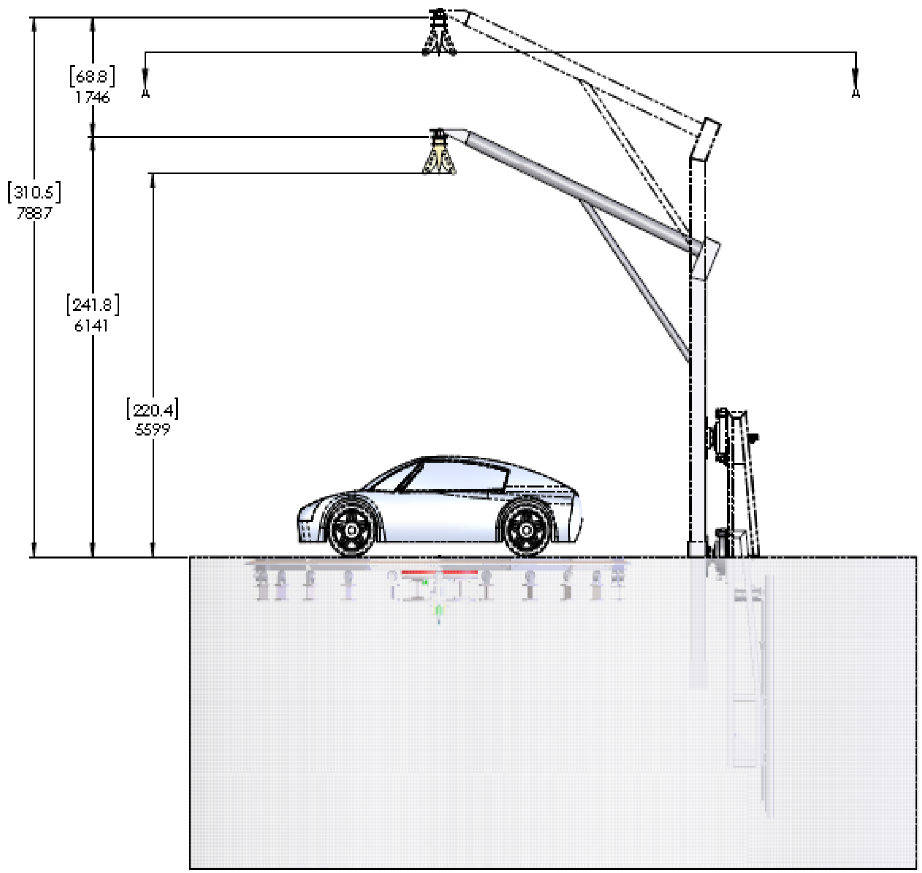
NSI-MI Retractable Design

- High Precision Spherical NF
- Single arm
- 3-Axis: Turntable, gantry arm and polarization
- 1.7m vertical arm adjustment
- Arm storage capability to allow other type of testing
- 7m. Turntable, 6000 Kg with RJ, SR
- Controller
- Complete RF Subsystem
  - Receiver, Sources, mixers, switches
- Probes and reference antennas
- Advanced antenna measurements Software

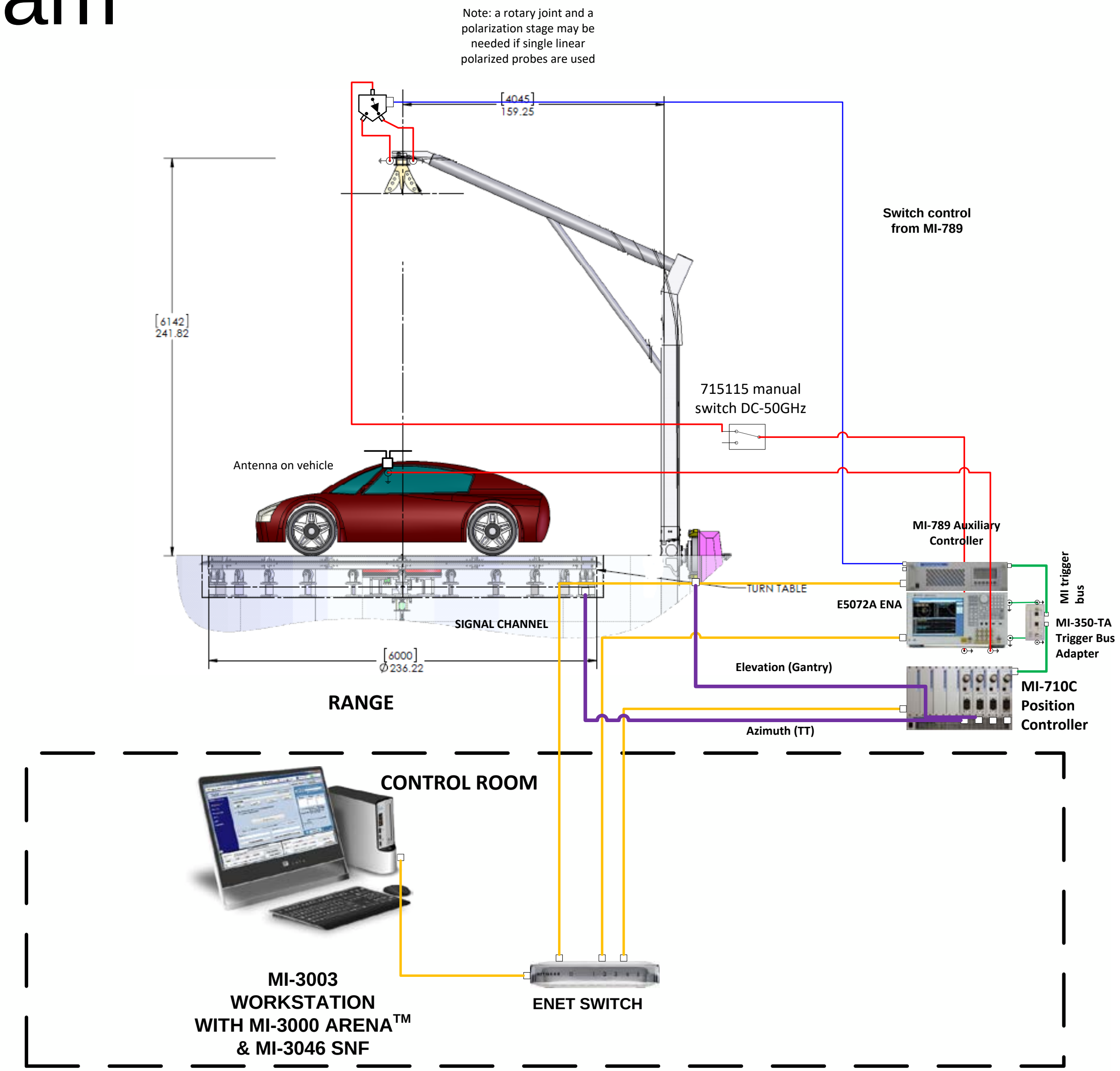


NSI-MI Retractable Design

- 5.6 m probe to Turntable
  - Higher elevating the Arm axis
- Optimal distance for >450 MHz testing
  - Vehicle: 6.3x2.3x2 m.
  - MRE=3.6m (reduced with smaller vehicles)
  - Probe to MRE distance= 200 cm
    - λ (450MHz) = 66 cm
    - Optimal NF test distance= >3λ
    - @450MHz -> 3λ=199 cm
- Testing below 450MHz is possible with increased uncertainty

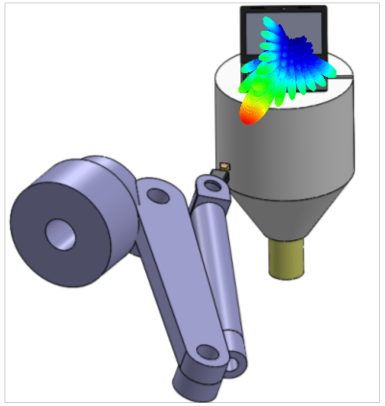


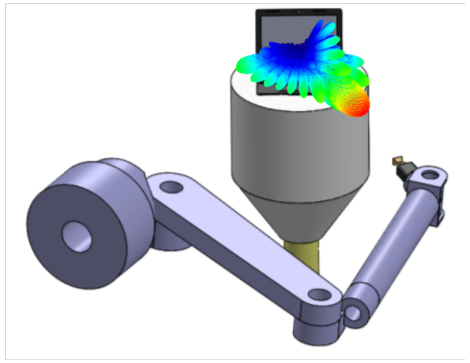
Block Diagram

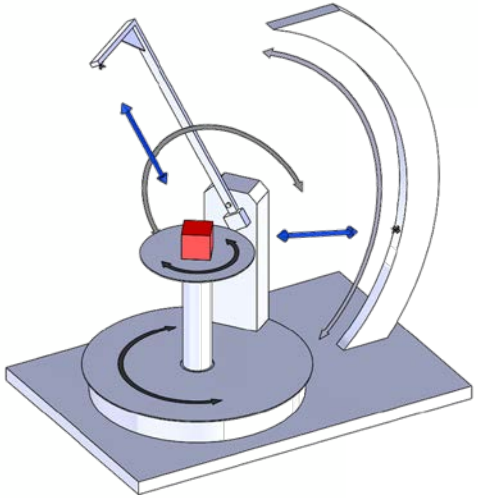


5G – Adaptive Beam Forming

- 5G adds another level of measurement complexity
- Beamforming / Beam steering / Null steering technology
  - Uses actively Adaptive Antenna System (AAS) to get the best performance where needed or alternatively deepest null to “filter” out the interferers in real time
- Vary the performance of array algorithm and throughput
- Perform Array Pattern, and sensitivity measurement







Patents Pending

Conclusions

- The industry is moving rapidly
- Already available
  - Radio connectivity
  - Autonomous cruise control, steering, breaking
  - Navigation
  - Collision avoidance
  - Blind spot warning
  - Integrated infotainment
  - BYOD support – Apple, Google
- In development
  - Fully Autonomous capability

Conclusions

- Autonomous Cruise Control
- Already available
  - Also known as adaptive or radar cruise control
  - Automatically adjusts vehicle speed to maintain a safe distance from vehicles ahead
- Control based solely on on board sensors
- Uses no communication with satellite or roadside infrastructure
- 77GHz Auto cruise system available
  - Has a forward range of up to 492 ft (150m)
  - Operates at vehicle speeds ranging from 18.6mph (30kph) to 111mph (180kph)

Conclusions

- New test facilities have already begun to appear designed to support
  - EMC
  - Wireless OTA and interoperability
  - Antenna measurements

- The demands on absorber design is more important
- Interoperability for wireless in EM environment
- With optimized chamber performance, and customized layout, the requirements for the EMC and APM chamber can both be met

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