The Challenges of 5G OTA (Over The Air) Measurements for ICV (Intelligent connected vehicles)

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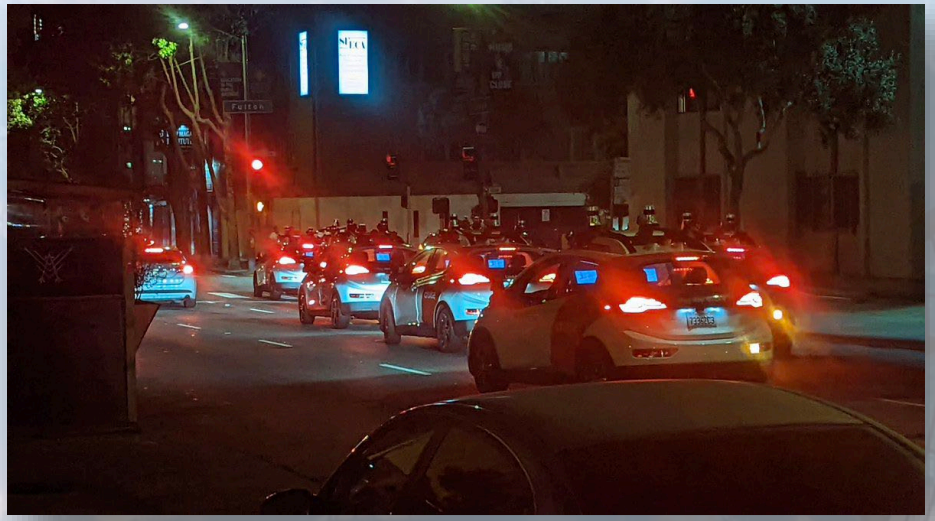
Why is Automotive OTA Test Necessary?

10 year ago

Today's ICV

Why is Automotive OTA Test Necessary?

Confused autonomous vehicles
getting lost on San Francisco road



Dozens of Autonomous Vehicles Getting Lost on a dead-end street

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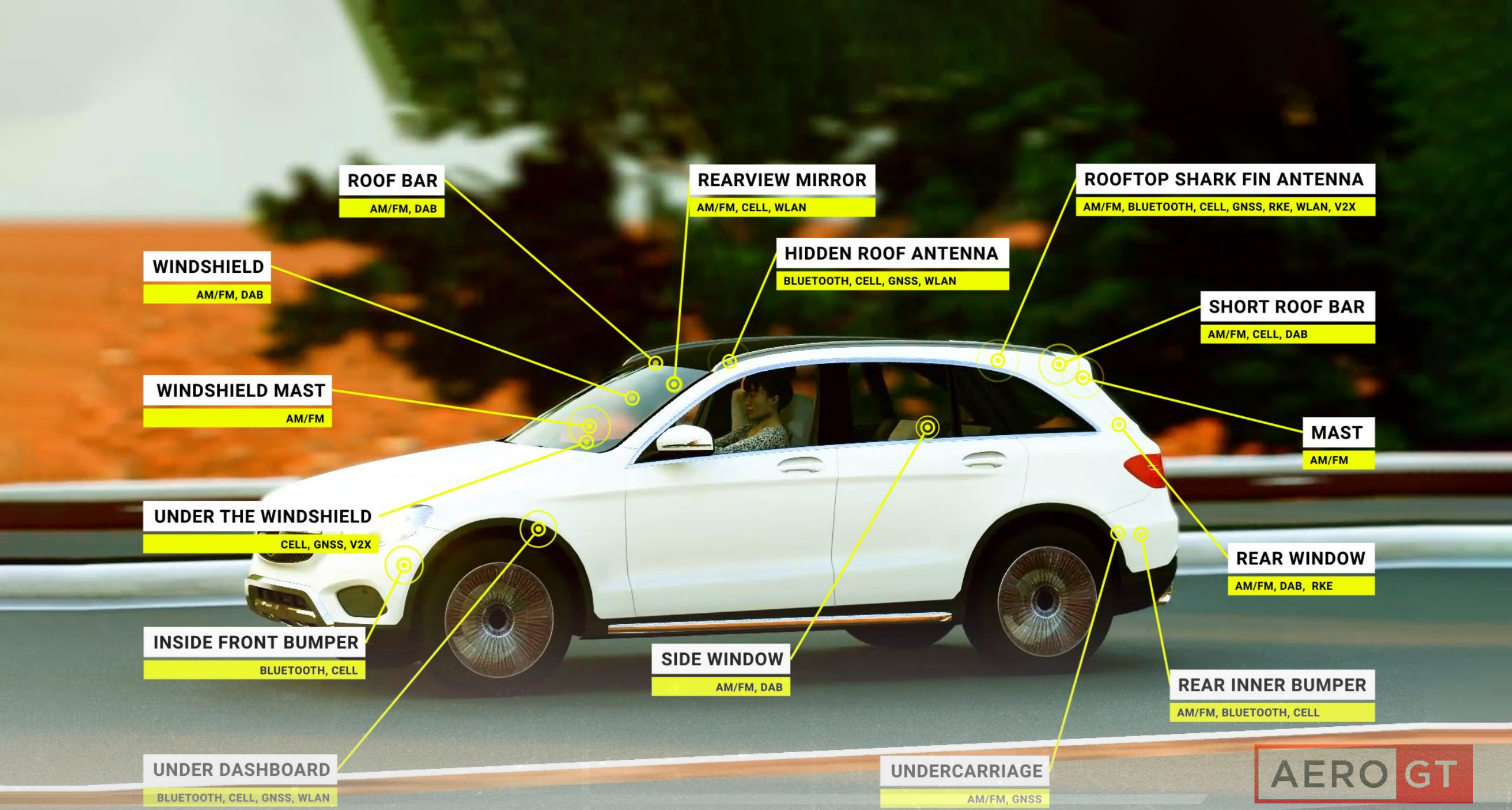

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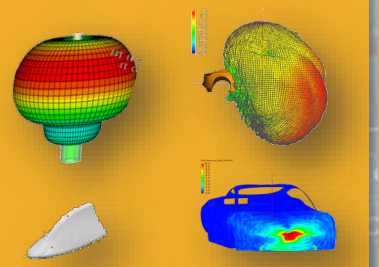
Why Full Vehicle OTA Measurements is Critical?



1 MULTIPLE ANTENNAS ON CAR

2 NOISE & INTERFERENCE

3 EVALUATE PERFORMANCE IN REAL ENVIRONMENT

4 PROBLEM DIAGNOSIS & SYSTEM OPTIMIZATION

- A. Antennas
  - Radiated pattern
  - Antenna gain
- B. Transceiver
  - Throughput
  - TRP/TIS
- C. EMC
  - Interference
  - Immunity

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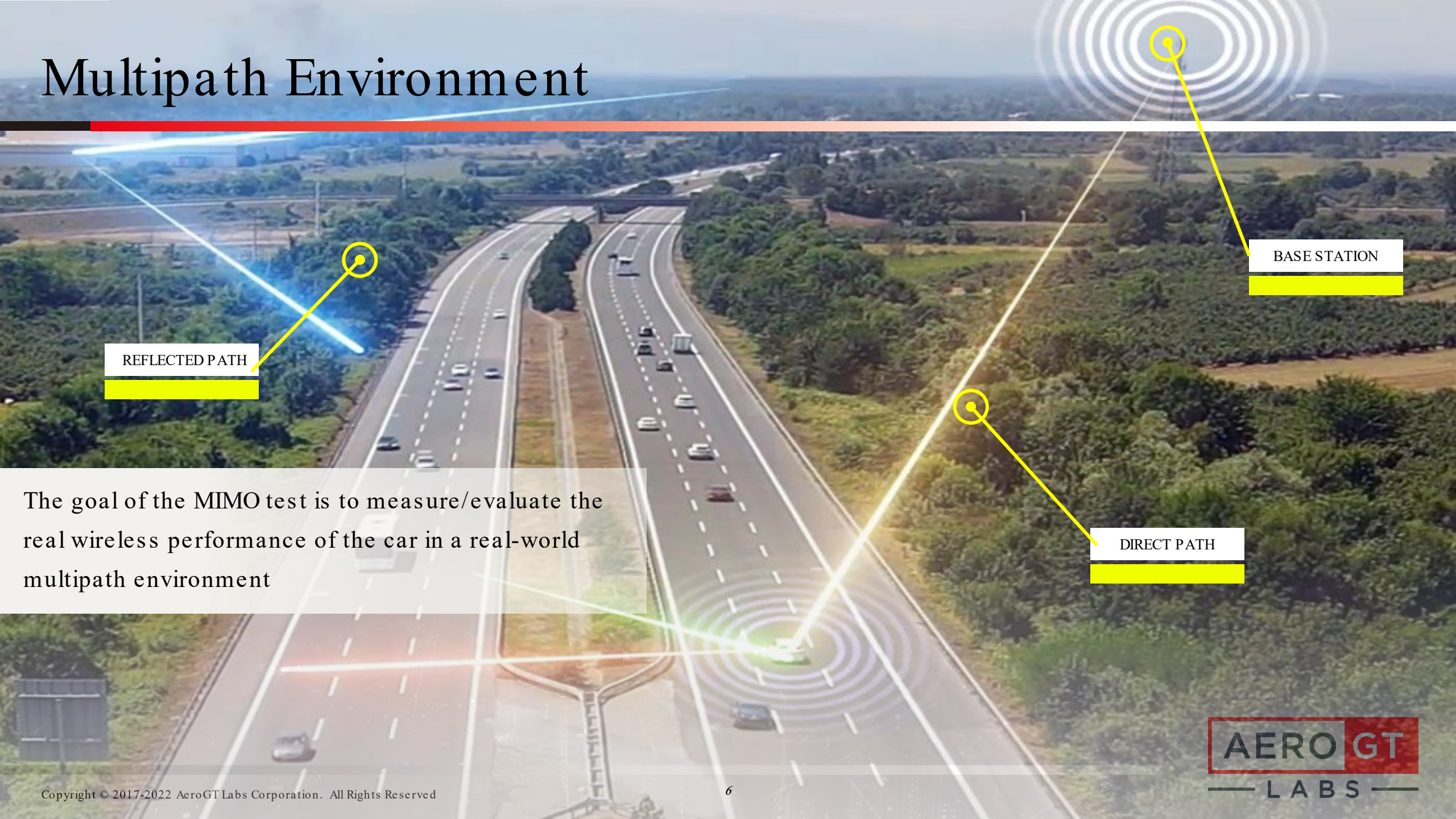
Multipath Environment



The goal of the MIMO test is to measure/evaluate the real wireless performance of the car in a real-world multipath environment

Four Levels of Automotive OTA Test

PASSIVE ANTENNA TEST

(3D PATTERN, EFFICIENCY)

1

SISO TEST

(EIRP,EIS)

2

MIMO TEST

(2X2/4X4/V2X MIMO WITH DIFFERENT CHANNEL MODELS..)

3

DESENSE TEST

(INTERFERENCE, IMMUNITY)

4

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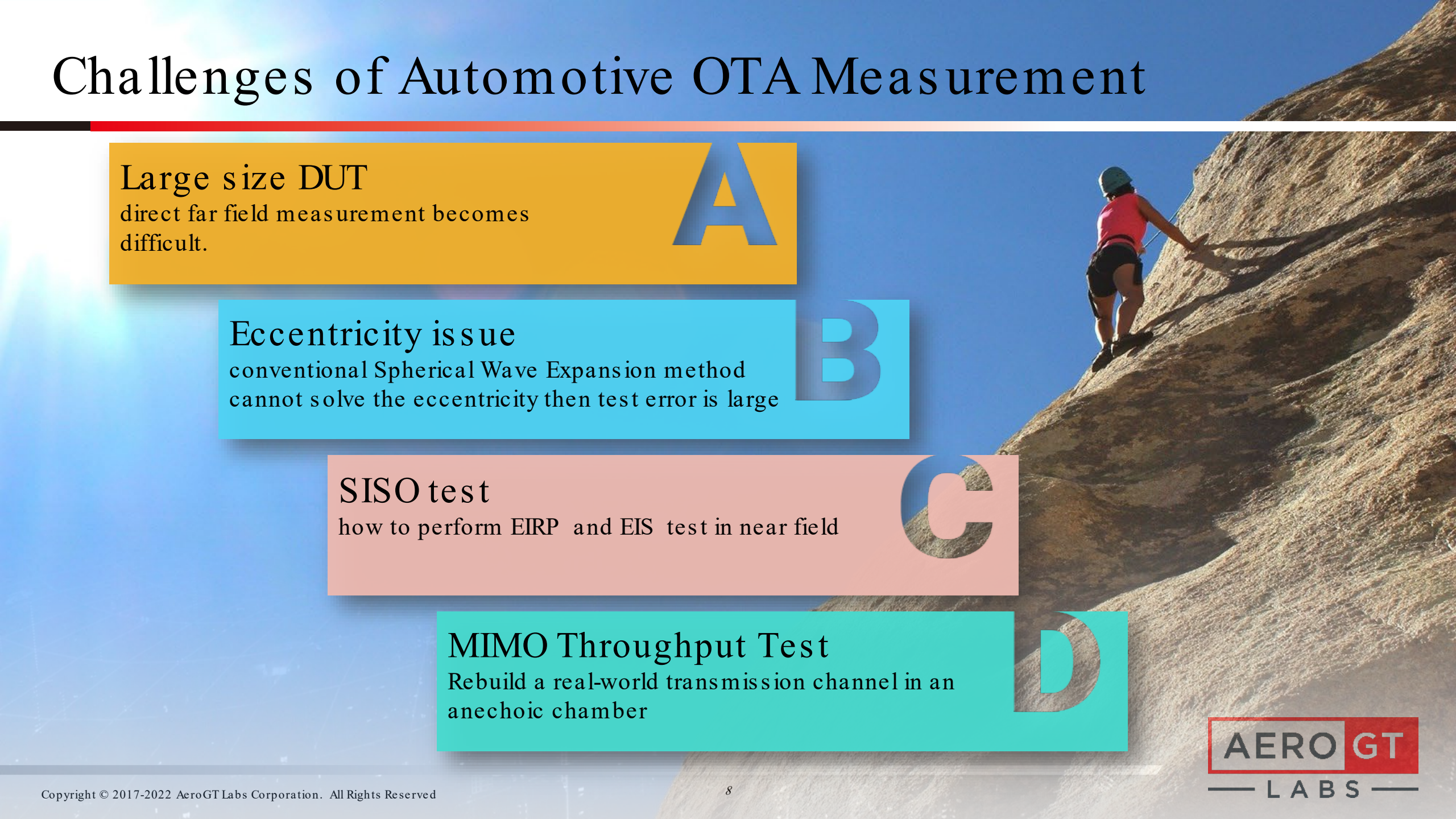
Challenges of Automotive OTA Measurement



Large size DUT

direct far field measurement becomes difficult.

A

Eccentricity issue

conventional Spherical Wave Expansion method cannot solve the eccentricity then test error is large

B

SISO test

how to perform EIRP and EIS test in near field

C

MIMO Throughput Test

Rebuild a real-world transmission channel in an anechoic chamber

D

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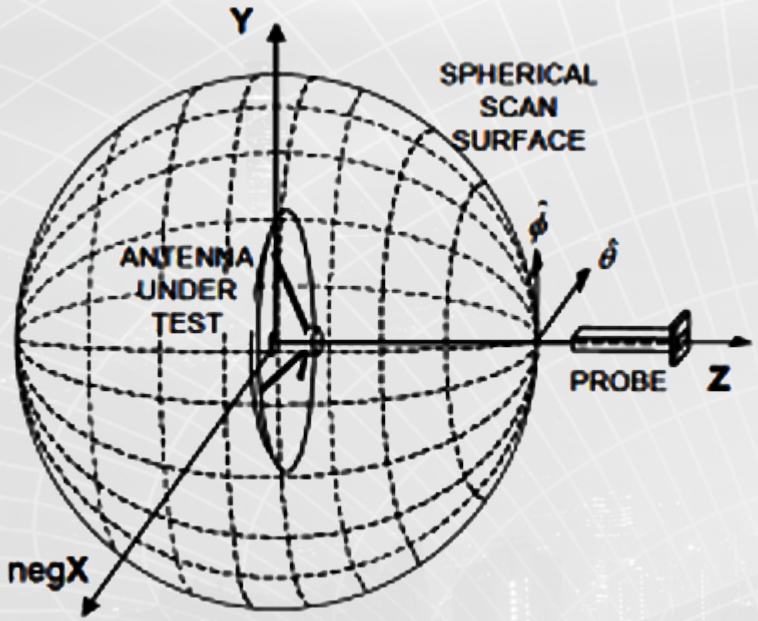
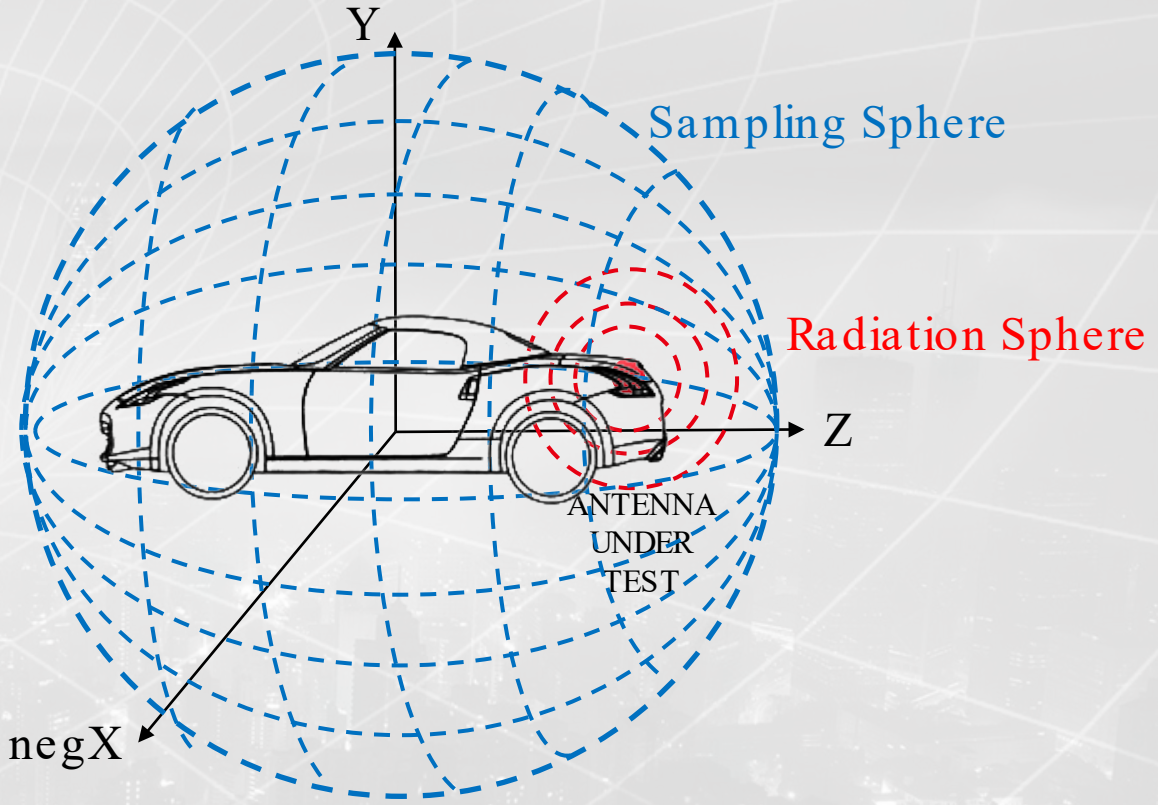
AUT/DUT at Different Positions

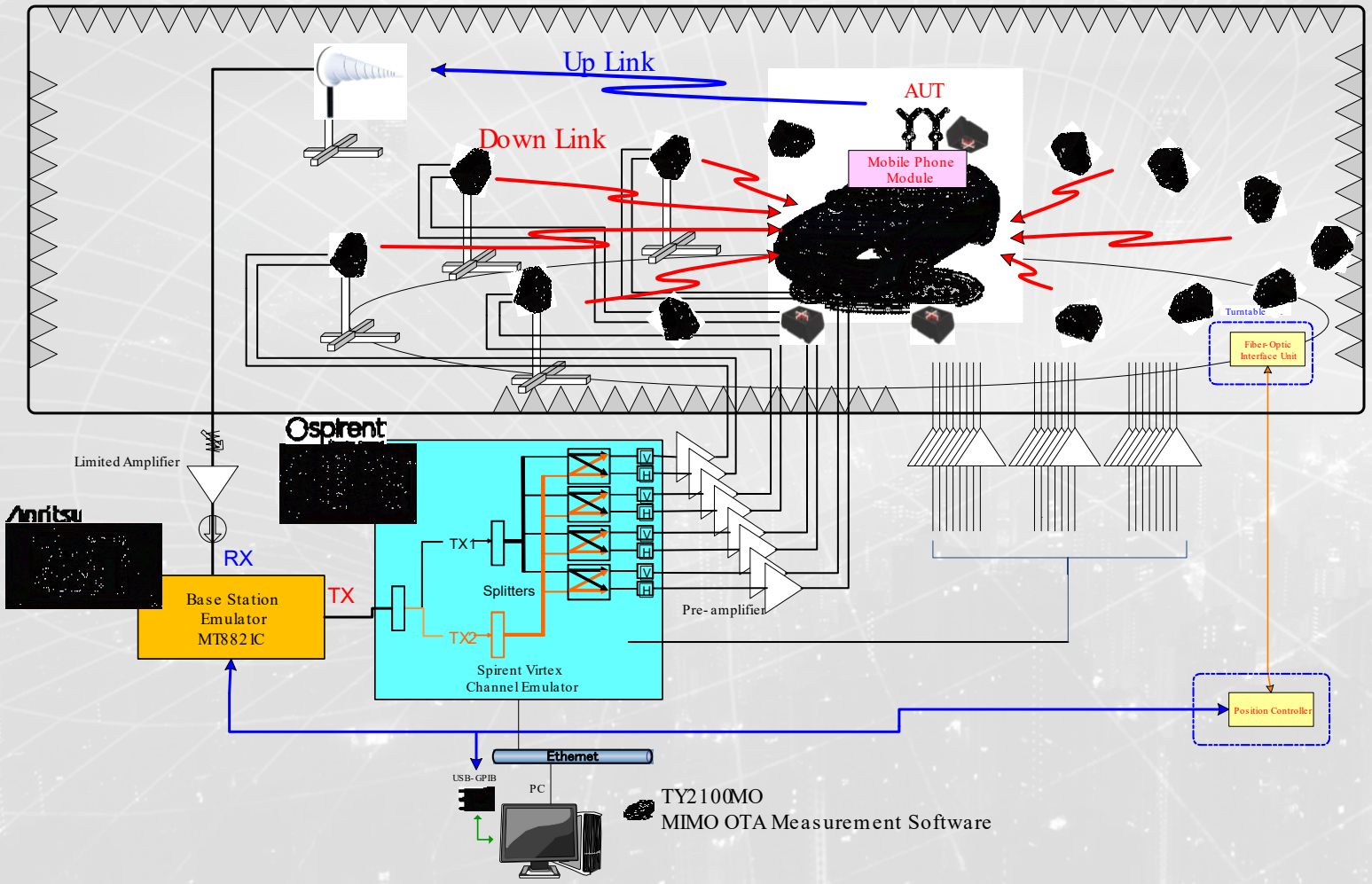


Classic SWE
Sampling Sphere = Radiation Sphere



Sampling Sphere ≠ Radiation Sphere

MPAC Solution for Automotive MIMO testing



ESTIMATED NUMBER OF PROBES*

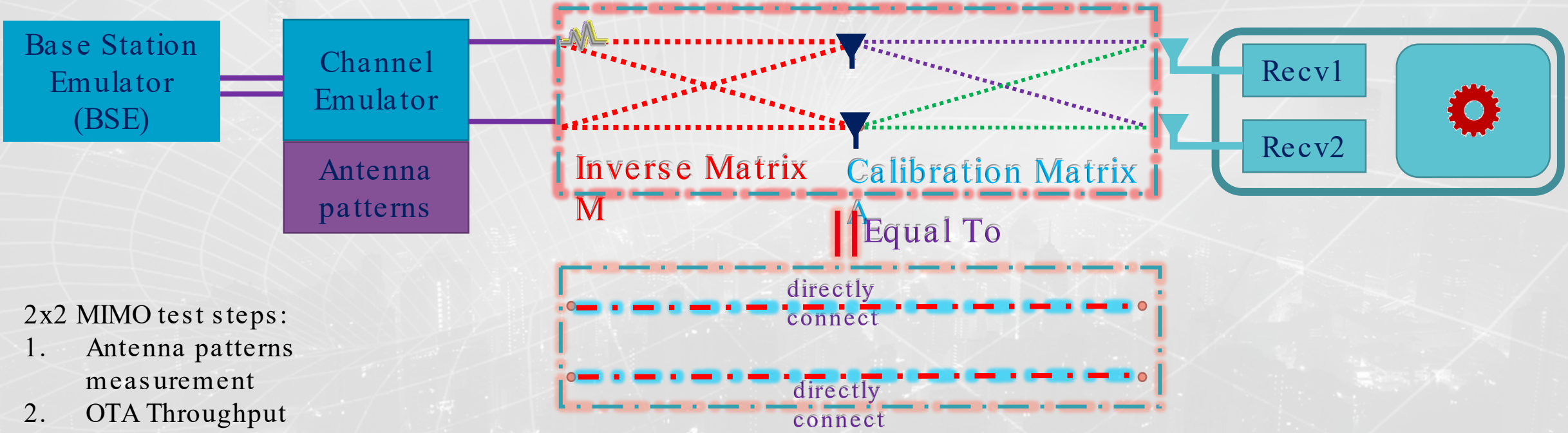
Frequency	Small car	Large truck
410MHz	49	68
7.125GHz	851	1178

* M. Berbeci, P. Pelland and T. Leifert, "Challenges for the Automotive Industry on MIMO OTA Testing," 2020 Antenna Measurement Techniques Association Symposium (AMTA), Newport, RI, USA, 2020, pp. 1-5.

Radiated Two Stage (RTS) Theory

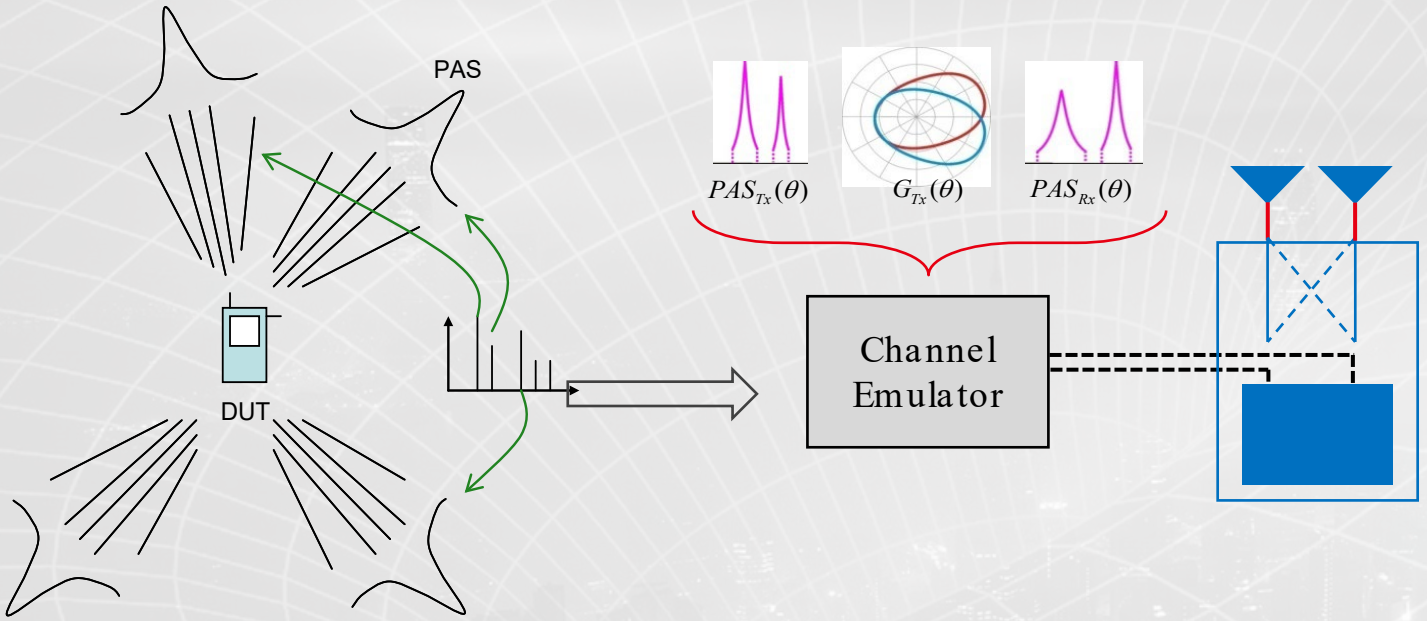
Target:
- trans1 signals only be sent to recv1,
- trans2 signals only be sent to recv2

Result:
- trans1 signals only be sent to recv1,
- trans2 signals only be sent to recv2



2x2 MIMO test steps:
1. Antenna patterns measurement
2. OTA Throughput Measurement

Radiated Two Stage Method – Patented Technology



- RTS based MIMO OTA test solution for ICV is the only realistic technique available today

- Features:
  - Theoretically correct, international standards
  - Small error, stable, cost-effective, simple system

$$y(t) = \sum_{n=1}^{N} \begin{bmatrix} \begin{bmatrix} F_1^{rx(V)}(\Omega_n^{rx}) \\ F_1^{rx(H)}(\Omega_n^{rx}) \end{bmatrix}^T \cdot \left(\sum_{m=1}^{M} e^{-j(\Omega 1)} \cdot \begin{bmatrix} \chi_{n,m}^{V,V} & \chi_{n,m}^{V,H} \\ \chi_{n,m}^{H,V} & \chi_{n,m}^{H,H} \end{bmatrix} \cdot \begin{bmatrix} F_1^{tx(V)}(\Omega_m^{tx}) \\ F_1^{tx(H)}(\Omega_m^{tx}) \end{bmatrix} \right) & \cdots & \begin{bmatrix} F_1^{rx(V)}(\Omega_n^{rx}) \\ F_1^{rx(H)}(\Omega_n^{rx}) \end{bmatrix}^T \cdot \left(\sum_{m=1}^{M} e^{-j(\Omega 1)} \cdot \begin{bmatrix} \chi_{n,m}^{V,V} & \chi_{n,m}^{V,H} \\ \chi_{n,m}^{H,V} & \chi_{n,m}^{H,H} \end{bmatrix} \cdot \begin{bmatrix} F_S^{tx(V)}(\Omega_m^{tx}) \\ F_S^{tx(H)}(\Omega_m^{tx}) \end{bmatrix} \right) \\ \vdots & \ddots & \vdots \\ \begin{bmatrix} F_U^{rx(V)}(\Omega_n^{rx}) \\ F_U^{rx(H)}(\Omega_n^{rx}) \end{bmatrix}^T \cdot \left(\sum_{m=1}^{M} e^{-j(\Omega 1)} \cdot \begin{bmatrix} \chi_{n,m}^{V,V} & \chi_{n,m}^{V,H} \\ \chi_{n,m}^{H,V} & \chi_{n,m}^{H,H} \end{bmatrix} \cdot \begin{bmatrix} F_1^{tx(V)}(\Omega_m^{tx}) \\ F_1^{tx(H)}(\Omega_m^{tx}) \end{bmatrix} \right) & \cdots & \begin{bmatrix} F_U^{rx(V)}(\Omega_n^{rx}) \\ F_U^{rx(H)}(\Omega_n^{rx}) \end{bmatrix}^T \cdot \left(\sum_{m=1}^{M} e^{-j(\Omega 1)} \cdot \begin{bmatrix} \chi_{n,m}^{V,V} & \chi_{n,m}^{V,H} \\ \chi_{n,m}^{H,V} & \chi_{n,m}^{H,H} \end{bmatrix} \cdot \begin{bmatrix} F_S^{tx(V)}(\Omega_m^{tx}) \\ F_S^{tx(H)}(\Omega_m^{tx}) \end{bmatrix} \right) \end{bmatrix} * x(t).$$

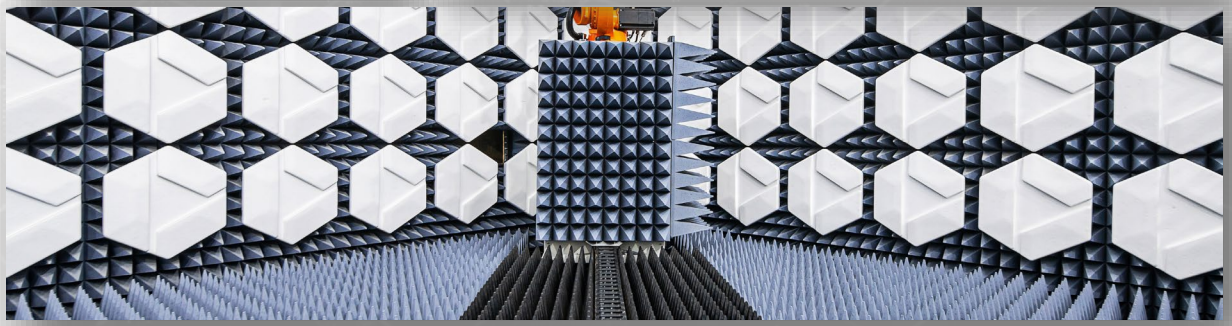
Total Solution for Automotive OTA Testing

from test algorithm to software platform, from key component to whole system

MIMO OTA Sub-Working Group Certification Program Working Group (CPWG) Contribution	
Contribution Number	MOSG200405
Contributor's Name (Company Name)	Thorsten Hertel, Ya Jing (Keysight Technologies), Yihong Qi, Wei Yu (General Test Systems), Pat Connor (Qualcomm Incorporated), Jose M. Fortes (Rohde & Schwarz)
Contribution Date	May 19, 2020
Contribution Type	(P) Proposal
Contribution Intent	(E) Endorsement
Contribution Title	On including RTS into the MIMO OTA Test Plan

CTIA Certification Program Working Group Contribution	
Contribution Number	MOSG171204
Contributor's Name	Moray Rumney (Keysight Technologies), Thorsten Hertel (Rohde & Schwarz), Penghui Shen (GTS)
Contribution Date	December 3, 2017
Contribution Topic	Inclusion of RTS into MIMO OTA test plan

- 2021 "Temperature Effects in OTA MIMO Measurement," in IEEE Transactions
- 2020 "Inverse Matrix Autosearch Technique for the RTS MIMO OTA Test," in IEEE Transactions
- 2020 "A 2×2 MIMO Throughput Analytical Model for RF Front End Optimization," in Journal of Communications and Information Networks,
- 2020 "3-D Printing Conformal K-Band Lens Antenna for a Smart Parking Space Detection System," in IEEE Transactions
- 2020 "Rugged Linear Array for IoT Applications," in IEEE Internet of Things Journal
- 2020 "Calibration Loop Antenna for Multiple Probe Antenna Measurement System," in IEEE Transactions
- 2020 "Review of the EMC Aspects of Internet of Things," in IEEE Transactions
- 2020 "Total Isotropic Sensitivity Measurement in Switched Beam Antenna Systems," in IEEE Transactions
- 2020 "Small Anechoic Chamber Design Method for On-Line and On-Site Passive Intermodulation Measurement," in IEEE Transactions
- 2019 "Directional Antenna With Consistent H-Plane Dual-Band Beamwidth for Wi-Fi Applications," in IEEE Transactions
- 2019 "An RTS-Based Near-Field MIMO Measurement Solution—A Step Toward 5G," in IEEE Transactions
- 2019 "OTA Measurement for IoT Wireless Device Performance Evaluation: Challenges and Solutions," in IEEE IoT Journal,
- 2018 "Dual-Band Directional Slot Antenna for Wi-Fi Application," in IEEE Transactions
- 2018 "A Decomposition Method for MIMO OTA Performance Evaluation," in IEEE Transactions on Vehicular Technology
- 2018 "Horizontally Polarized Antenna for Calibration of a Multiple Probe Antennas Measurement System," in IEEE Transactions
- 2018 "An Equivalent Circuit Model to Analyze Passive Intermodulation of Loose Contact Coaxial Connectors," in IEEE Transactions



We hold 150+ patents, and published 280 papers on Antenna noise temperature, NF-FF transformation, Fast sensitivity measurements, RTS and Absorbers

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Challenges of Automotive OTA Measurement

Large size DUT

Direct far field measurement becomes difficult.

A

Spherical near field sampling + Near field to far field transformation

A ✓

Eccentricity issue

If conventional Spherical Wave Expansion method cannot solve the eccentricity then test error is large

B

Customized Test Probe + 3D calibration

- Wide probe beam width (beam is required to cover the entire DUT)
- Low Cross polarization ratio (Cross polarization at a wide angle)
- High Probe beam symmetry
- Calibration of the 3D pattern of the probe in the NF-FF transformations

B ✓

SISO test

How to perform EIRP and EIS test in near field

C

Optimized NF-FF transformation algorithm

- Antenna aperture coupling theory based EIRP/EIS test

C ✓

MIMO Throughput Test

Rebuild a real-world transmission channel in an anechoic chamber

D

MIMO Throughput Test

- Radiated Two Stage (RTS) MIMO method

D ✓

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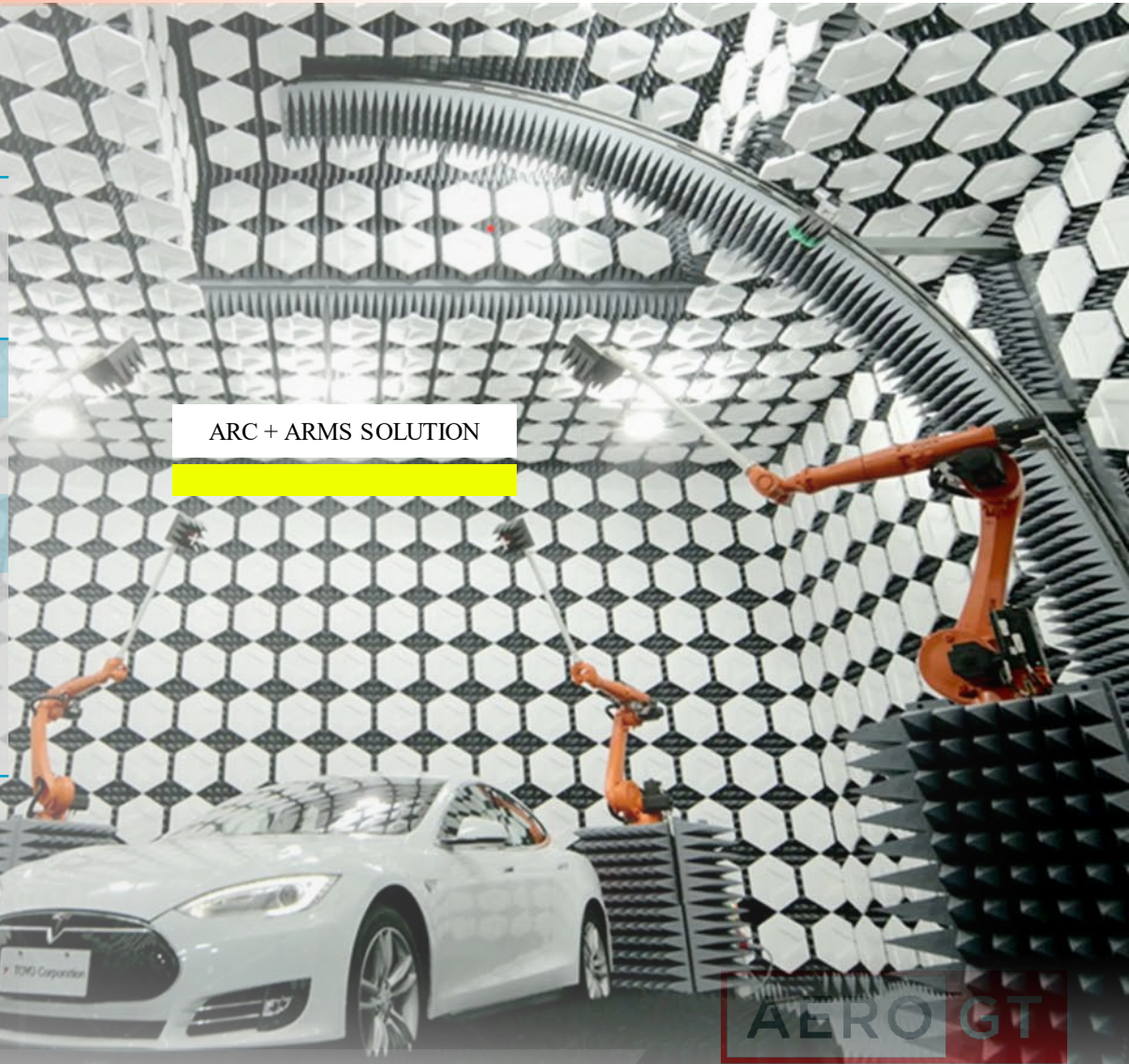
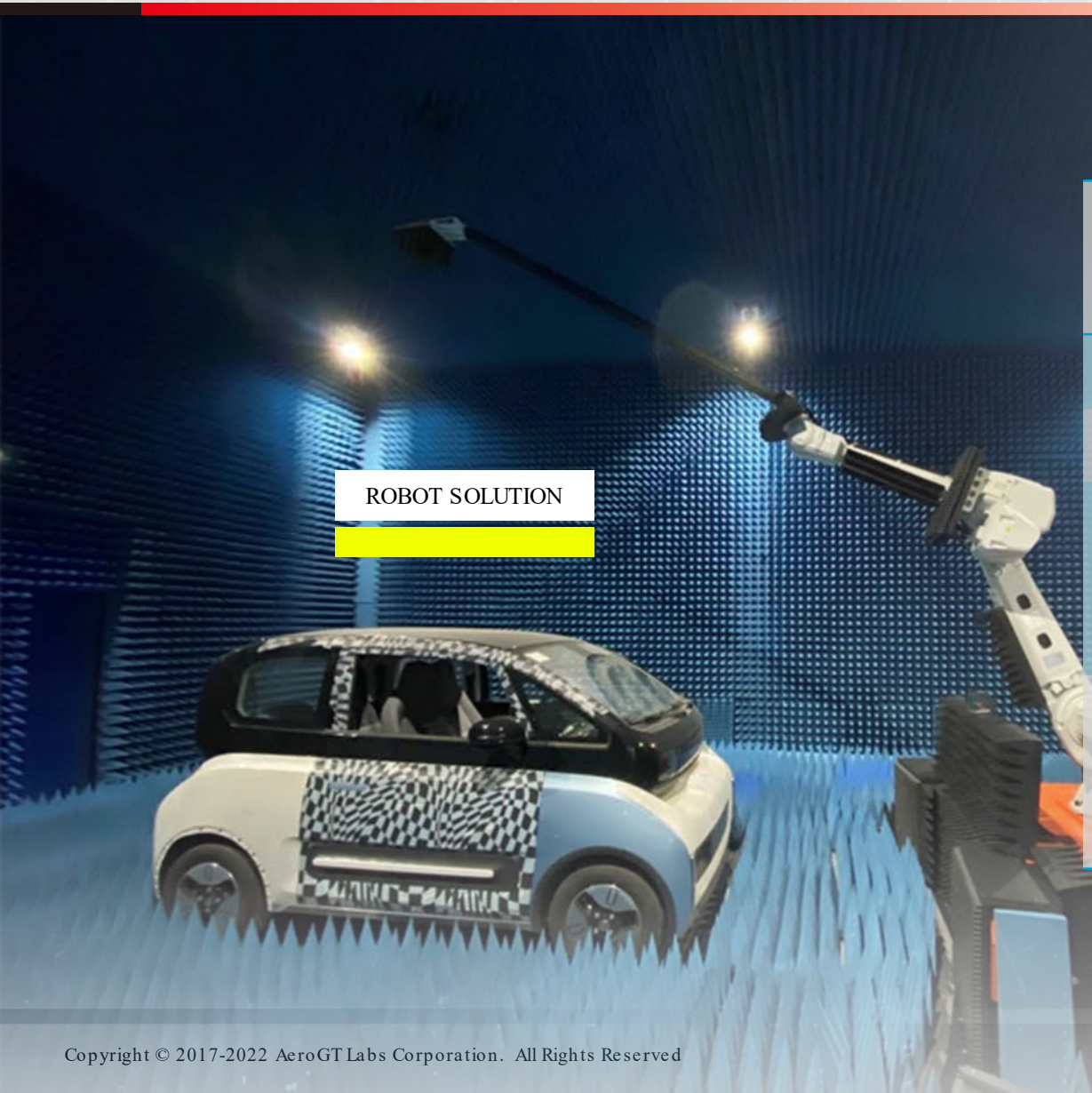
Next-Gen Full-Vehicle OTA Testing Solutions

ARC + ARMS SOLUTION | Multiple probes are fixed using electrical switching, and coordinate with the rotation of the vehicle on the turntable to perform 3D wireless performance test	
PRINCIPLE	Spherical near field sampling + NF-FF + RTS MIMO
SPEED	Fast
ACCURACY	High
MEASURABLE ITEMS	1) Passive measurement 2) ICV SISO 3) ICV MIMO 4X4 measurement (patented) option 4) GPS related OTA test



Next-Gen Full-Vehicle OTA Testing Solutions (upgrade)



ROBOT SOLUTION | An antenna is placed at the end of the movable robot and integrates with an EMC turntable to perform 3D wireless performance test – add OTA test functions to an existing EMC chamber	
PRINCIPLE	Spherical near field sampling + NF-FF
SPEED	Normal
ACCURACY	Normal Mechanical accuracy can match a large chamber, but the accuracy depends on the EMC chamber material
MEASURABLE ITEMS	1) Passive measurements 2) ICV SISO 3) ICV MIMO 2X2 measurement (patented) option 4) EMC test (patented) option

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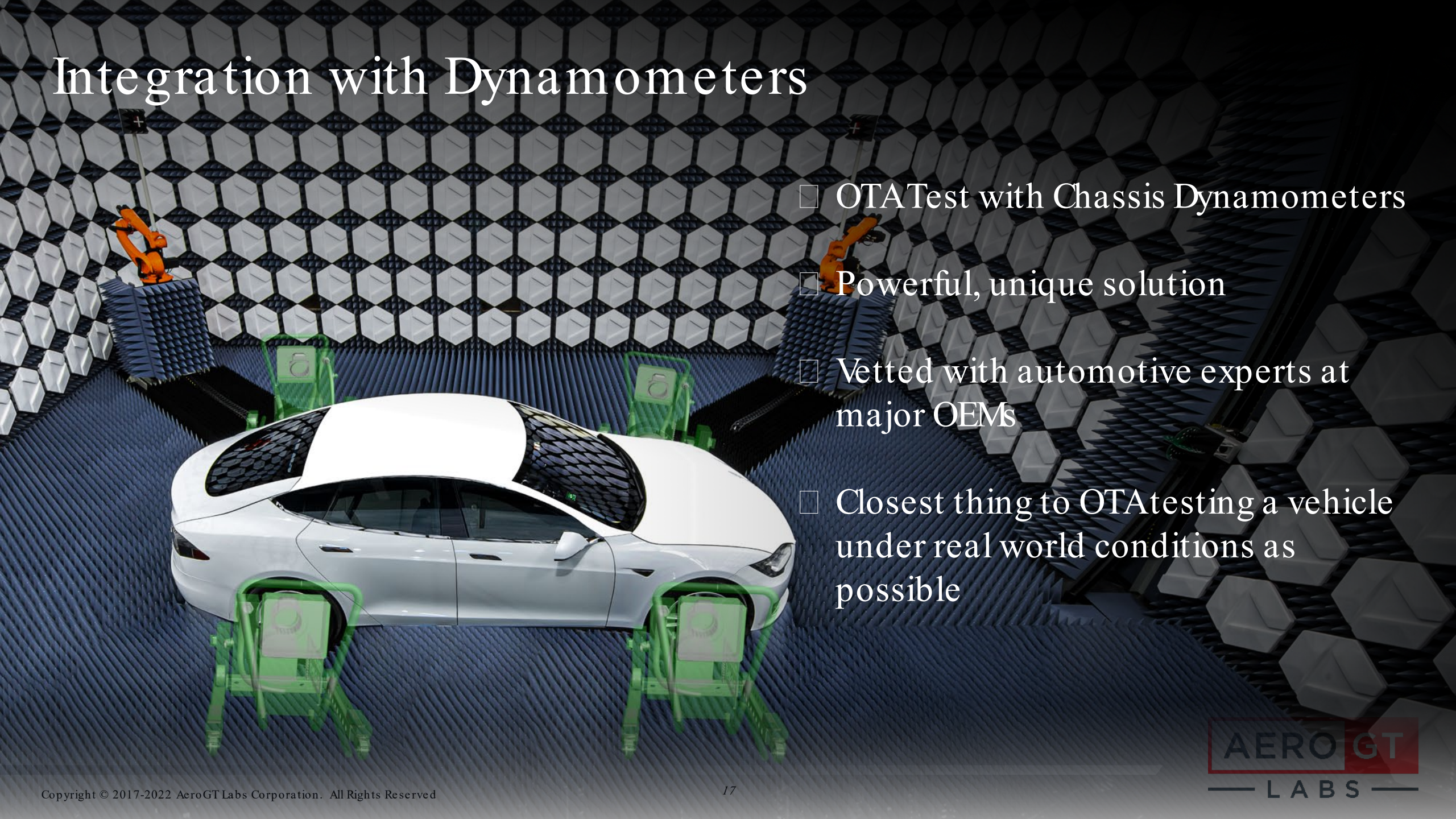
Integration with Dynamometers



- OTA Test with Chassis Dynamometers
- Powerful, unique solution
- Vetted with automotive experts at major OEMs
- Closest thing to OTA testing a vehicle under real world conditions as possible

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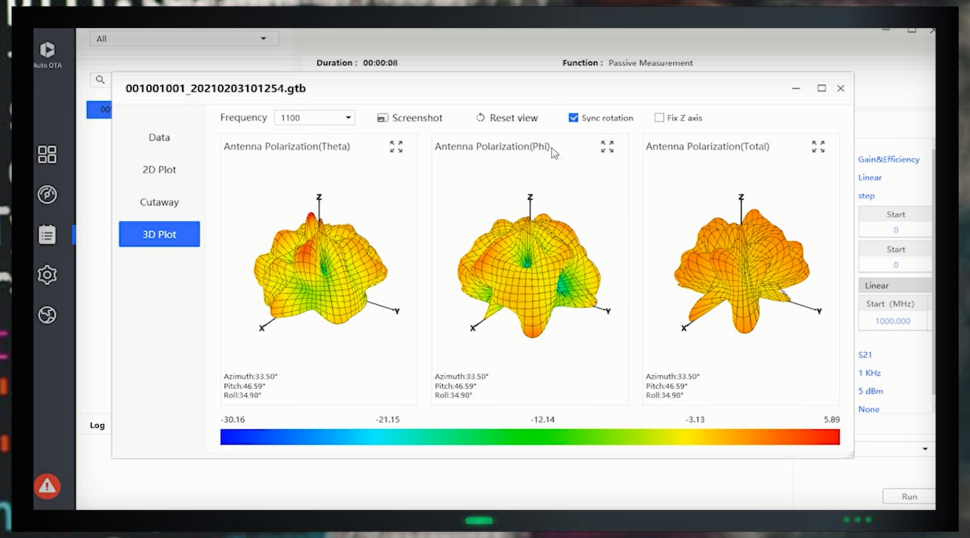
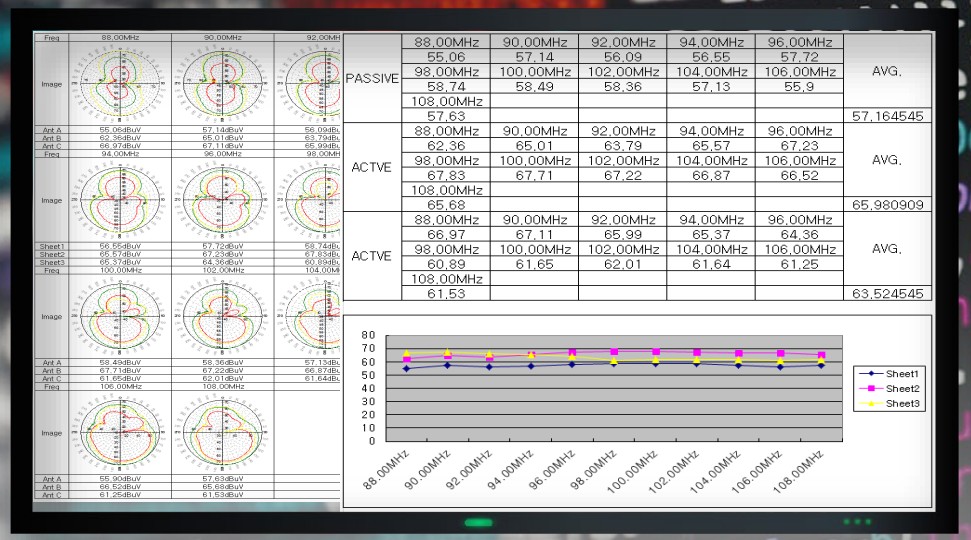
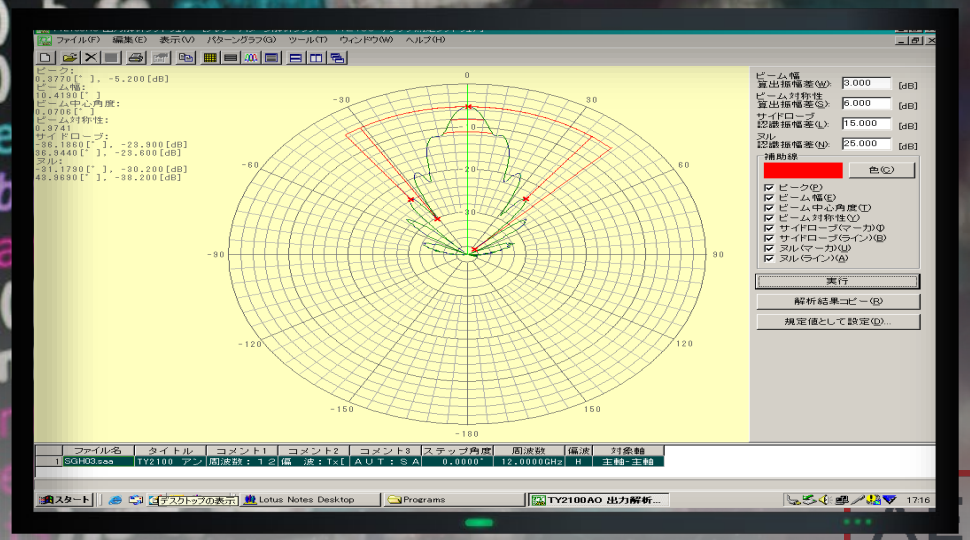
MaxSign_Auto Automatic Test Software





PASSIVE	88,00MHz	90,00MHz	92,00MHz	94,00MHz	96,00MHz	
	55,06	57,14	56,09	56,55	57,72	AVG.
	98,00MHz	100,00MHz	102,00MHz	104,00MHz	106,00MHz	
	58,74	58,49	58,36	57,13	55,9	
	108,00MHz					
	57,63					57,164545
ACTVE	88,00MHz	90,00MHz	92,00MHz	94,00MHz	96,00MHz	
	62,36	65,01	63,79	65,57	67,23	AVG.
	98,00MHz	100,00MHz	102,00MHz	104,00MHz	106,00MHz	
	67,83	67,71	67,22	66,87	66,52	
	108,00MHz					
	65,68					65,980909
ACTVE	88,00MHz	90,00MHz	92,00MHz	94,00MHz	96,00MHz	
	66,97	67,11	65,99	65,37	64,36	AVG.
	98,00MHz	100,00MHz	102,00MHz	104,00MHz	106,00MHz	
	60,89	61,65	62,01	61,64	61,25	
	108,00MHz					
	61,53					63,524545

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RESOURCES

Web: www.aerogtlabs.com

Linkedin: https://www.linkedin.com/company/aerogt-labs

Video: Next-Gen Automotive OTA Test: https://youtu.be/Gr1hojkvRmE

Contact: info@aerogtlabs.com