AUTOMOTIVE CONNECTIVITY

OVERVIEW

mvg
Microwave Vision Group

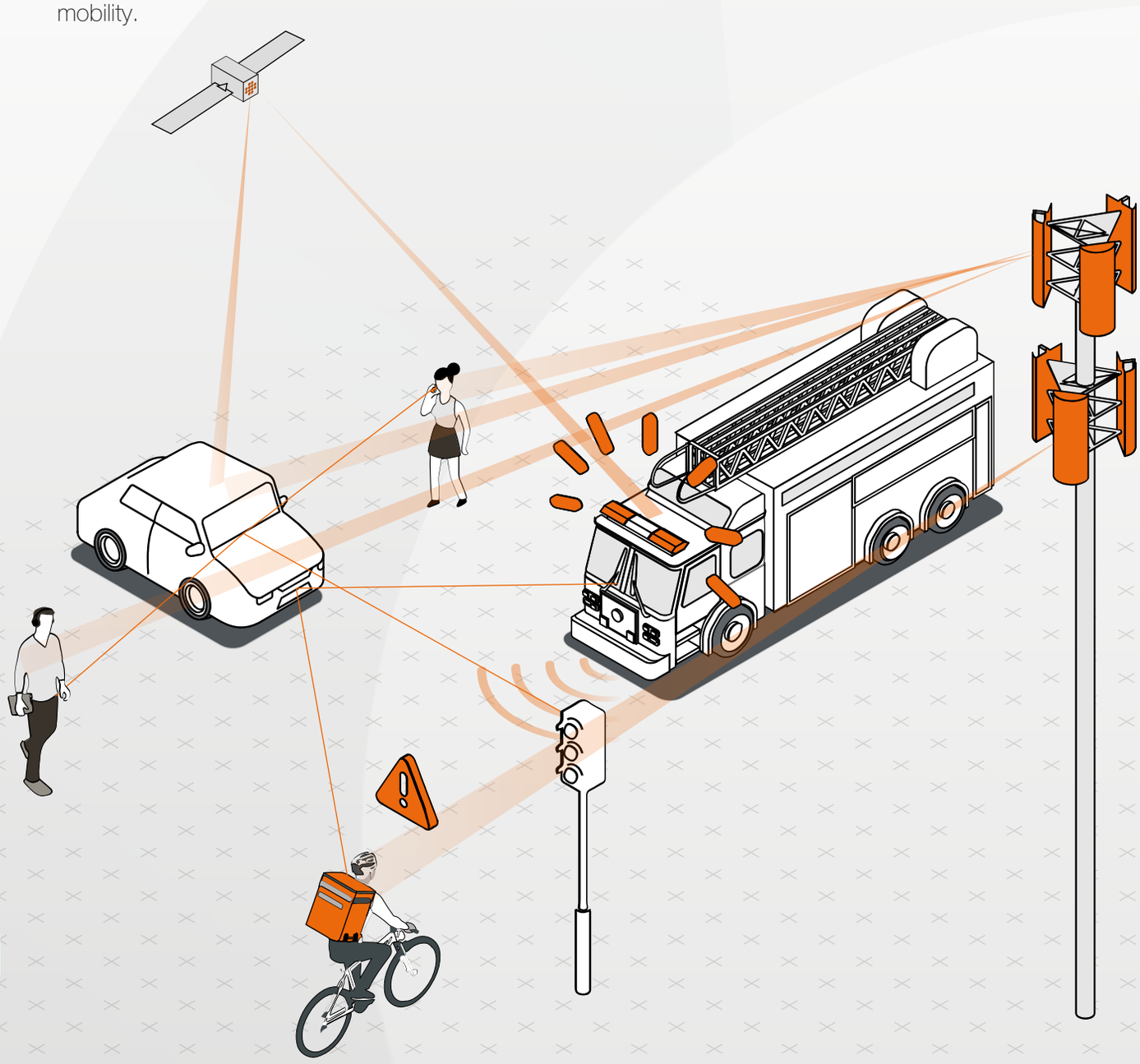
Introduction to Automotive Connectivity

Enabling Seamless Communication for Connected and Autonomous Vehicles

Modern ground vehicles integrate a broad array of antennas for navigation, detection, communication, and data reception. Within the connected mobility ecosystem, these vehicles leverage direct (PC5) and cellular (Uu) communication technologies to interact with their environment (V2X), other vehicles (V2V), pedestrians (V2P), infrastructure (V2I), and mobile networks (V2N). C-V2X communication technology, with its higher data rates and lower latency, plays a crucial role in enabling connected vehicles and advancing the development of autonomous driving technologies.

The Role of 5G NR in Advancing C-V2X Technology

The integration of 5G New Radio (NR) into Cellular Vehicle-to-Everything (C-V2X) is transforming how vehicles connect with their surroundings. By enhancing reliability, speed, and responsiveness, 5G NR supports critical applications like Advanced Driver Assistance Systems (ADAS), real-time hazard detection, precision navigation, and next-generation infotainment, paving the way for safer roads and smarter mobility.



What is C-V2X

C-V2X connects vehicles with other vehicles, infrastructure, pedestrians, and cloud services. It operates in two modes:

Direct Communication (PC5):
Enables vehicles to exchange data without cellular networks, ideal for collision avoidance and cooperative driving.

Cellular Communication (Uu):
Uses cellular networks for real-time navigation, software updates, and infotainment.

These modes combine to support real-time safety and enhanced vehicle services.

The Role of 5G NR in Enhancing C-V2X

5G NR elevates C-V2X by delivering significant advancements in performance, enabling transformative applications that enhance safety, efficiency, and the driving experience:

Enhanced Safety:
- Enables real-time sharing of Cooperative Awareness Messages (CAM) and Decentralized Environmental Notification Messages (DENM) to alert drivers about hazards, road conditions, and unexpected events.
- Improves ADAS features such as lane-keeping assistance, adaptive cruise control, and emergency braking.

Low-Latency Performance:
Ultra-Reliable Low-Latency Communication (URLLC) ensures instantaneous response times, critical for collision prevention and cooperative driving.

Precision Navigation:
Integrates GNSS and 5G NR capabilities to deliver highly accurate location data for advanced routing and autonomous driving.

Advanced Infotainment:
Supports high-bandwidth applications like streaming, cloud gaming, and augmented reality dashboards, enhancing the in-car experience.

Energy Management:
Enables electric vehicles to interact seamlessly with the power grid for optimized charging and energy efficiency.

Future-Ready Scalability:
- Seamlessly integrates Software Defined Vehicles (SDVs), enabling over-the-air updates and the deployment of new features.
- Establishes a foundation for Mobility-as-a-Service (MaaS) ecosystems, supporting shared, on-demand, and multimodal transportation solutions.

The Importance of Connectivity in Consumer Choice

As vehicles become more connected, the reliability of onboard systems significantly impacts consumer satisfaction. Consider the implications of a poorly implemented infotainment system that freezes during use or fails to support essential connectivity. In a world where passengers increasingly rely on integrated systems for navigation, entertainment, and safety, a seamless experience is more than a luxury—it's a necessity. For manufacturers, robust connectivity systems not only enhance the driving experience but also serve as a critical differentiator in an increasingly competitive market.

Key Takeway

5G NR-based C-V2X represents the future of automotive connectivity. By providing ultra-reliable communication, precise navigation, and enhanced bandwidth, it transforms C-V2X into the cornerstone of safer, smarter, and more efficient transportation systems.

Thorough testing and validation of C-V2X systems are critical to ensuring reliability in real-world scenarios. From advanced ADAS features to grid integration for EVs, **rigorous evaluation guarantees the seamless performance of next-generation transportation solutions**, driving the evolution of intelligent mobility.

Testing Strategies for Vehicular Antennas

Vehicular antennas play a pivotal role in enabling modern connectivity, supporting telecommunications, direct communication, and GNSS applications. Key considerations include precise measurement configurations at both the component and system levels, as well as evaluating critical metrics like realized gain, radiated power, and isotropic sensitivity. These principles are essential for ensuring reliable performance in connected and autonomous vehicles.

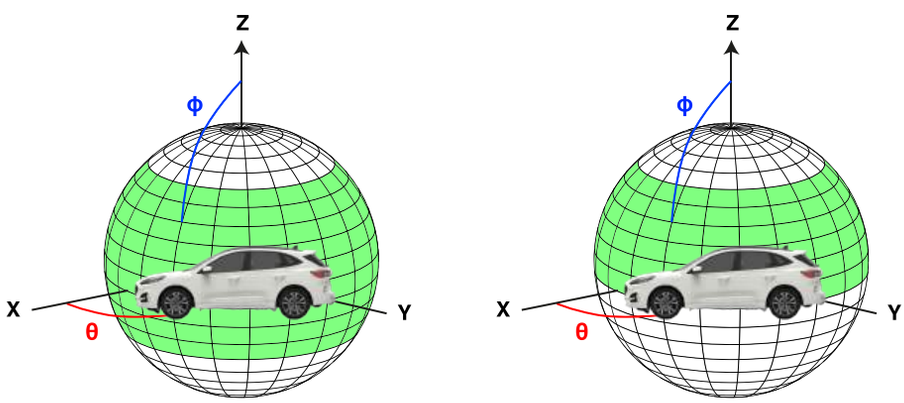
WHAT TO TEST:

- Vehicular antennas for telecommunications (2G, 3G, 4G, 5G (< 7.125GHz))
- Vehicular antennas for direct communication between vehicles and vehicles to road infrastructure (operation in designated ITS frequency spectrum (5.9GHz range))
- GNSS-Antennas
- RSE Testing (Radiated Spurious Emissions) minimizing interference and optimizing system performance.
- UWB Testing for secure keyless entry, key fob, and passenger detection, ensuring accuracy and seamless operation.

MEASUREMENT CONFIGURATION:

- Passive at component level (antenna element at its installation location at the vehicle) Measured values: e.g. realized gain
- Active at system level (antenna element at its installation location at the vehicle + cabling + on board control unit) Measured values: e.g. radiated power, isotropic sensitivity
- Combinations of passive and active Resulting values: e.g. radiated power, isotropic sensitivity

ANGULAR AREA OF INTEREST:



	Telecommunication	Direct Communication	GNSS
Angular Coverage of Measurement	60˚ – 120˚ / 90˚	80˚ - 100˚/ 90˚	0˚ - 60˚

The 5GAA Vehicular Antenna Test Methodology provides a detailed framework for these assessments, offering valuable guidance for industry professionals:

Key Challenges and Considerations in Automotive Antenna Development

The development of antennas for modern vehicles presents unique challenges, particularly in integrating them seamlessly into the vehicle's design while ensuring optimal performance. Key considerations include compact size, robustness to withstand environmental conditions, and strategic placement to maximize communication capabilities. Furthermore, compatibility with increasingly complex electronic architectures is essential to support the diverse wireless communication systems required for connected and autonomous vehicles operating in dynamic environments.

	Measures	Frequency Bands	Solutions
Passive Components Testing	Radiation pattern (ϑ,φ), Gain(ϑ,φ), Directivity(ϑ,φ) Efficiency, Polarization, Diagnostic	70MHz to 70GHz+	Starlab 50GHz ; SG Systems ; Compact Range
Active OTA Components Testing	TRP & EIRP (Φ , θ) (power) TIS / TRS & EIS (Φ , θ) (sensitivity) Throughput & Channel Emulation	70MHz to 70GHz+	Starlab 50GHz ; SG Systems
Passive and Active OTA Full-vehicle Testing	Radiation pattern (ϑ,φ), Gain(ϑ,φ), Directivity(ϑ,φ) Efficiency, Polarization, Diagnostic TRP & EIRP (Φ , θ) (power) TIS / TRS & EIS (Φ , θ) (sensitivity) Throughput & Channel Emulation	76 MHz to 6-10 GHz	SG 3000 ; Gantry Arm
Virtual Drive Testing	TRP & EIRP (Φ , θ) (power) TIS / TRS & EIS (Φ , θ) (sensitivity)	fmax = 26 GHz	Starlab 50GHz ; SG Systems ; SG 3000 ; Insight
Radar Testing	Radiation pattern (ϑ,φ), Gain(ϑ,φ), Directivity(ϑ,φ) Efficiency, Polarization, Diagnostic	24 GHz ; 77 – 81 GHz	CATR ; Mini Compact range
RSE Testing	TRP & EIRP (Φ , θ) (power) TIS / TRS & EIS (Φ , θ) (sensitivity	fmax = 26 GHz	Starlab 50GHz ; SG Systems ; SG 3000 ; Compact Range ; Gantry Arm
UWB Testing	Radiation pattern (ϑ,φ), Gain(ϑ,φ), Directivity(ϑ,φ) Efficiency, Polarization, Diagnostic	3.1 GHz to 10.6 GHz	StarLab ; SG 3000 ; Compact Range
EMC Testing	CISPR, IEC and FCC	30 MHz to 1 GHz	EMC pre-compliance chambers


Microwaves
Cellular
1 m
10 cm
1 cm
LF
MF
HF
VHF
UHF
L
S
C
X
Ku
K
Ka
V
W
SHF
EHF
100 KHz
30 KHz
1 MHz
10 MHz
100 MHz
300 MHz
600 MHz
1 GHz
2 GHz
3 GHz
4 GHz
8 GHz
10 GHz
12,5 GHz
18 GHz
26,5 GHz
30 GHz
40 GHz
75 GHz
100 GHz
110 GHz
300 GHz
DCF 77
RADIO CLOCK
AM
DRM
DRM+
TV
FM
HD RADIO
4m BAND
CB RADIO
2m BAND
DMB
DAB+
ORBCOMM
DVB-T2
RKE / TPMS
TETRA
ISDB-T
DAB-L
2G
SDARS
3G
4G
5G FR1
GLOBALSTAR
GALILEO
GLONASS
BEIDU
GNSS
GPS
GNSS L2-L5
IRIDIUM
ZIGBEE
BLUETOOTH
WLAN
ISM
DSRC
V2X, C-V2X
SR RADAR
LR RADAR

AUTOMOTIVE
FREQUENCY BANDS

Improving automotive connectivity allows for better software performance, enhanced navigation systems and exploring the possibilities of Vehicle to Everything communications. The introduction of 5G ultra-wideband technology and C-V2X will take our vehicles to new levels of automation, provide better on-board experiences and increased safety. Successfully integrating multiple antennas requires predicting their coexistence and evaluating their performance to ensure the operation of these new augmented mobile services, driver assistance features and other connectivity-enabled innovations.

	PROTOCOLE	FREQUENCY BAND
KHz	DCF 77	77,5 KHz
	DRM	100 KHz - 30 MHz
	AM (longwave)	148,5 KHz - 283,5 KHz
	AM (mediumwave)	531 KHz - 1602 KHz
MHz		
	AM (shortwave)	2,3 - 26,1 MHz
	CB Radio	26.965 - 27.405 MHz
	DRM+	30 MHz - 300 MHz
	Television	41 - 44 MHz
	FM Band I	47 - 87 MHz
	4m Band	70 MHz
	HD Radio	88 - 108 MHz
	FM Band II	88 - 108 MHz
	Orbcomm	137 - 150 MHz
	2m Band	144 - 148 MHz
	DMB	174 - 216 MHz
	FM Band III	174 - 216 MHz
	DVB-T2	174 - 230 MHz
	DAB+	174 - 240 MHz
	RKE/TPMS	315 MHz
	Tetra	380 - 460 MHz
	5G FR1	410 MHz - 7.125 GHz
	RKE/TPMS	434 MHz
	ISDB-T	470 MHz - 770 MHz
	DVB-T2	470 - 870 MHz
	4G(LTE)	450 MHz - 5 GHz
	2G (GSM 850/900)	850 MHz - 900 MHz
GHz	Galileo	1176 - 1575 MHz
	Beidu	1176 - 1575 MHz
	GNSS L2	1227.6 MHz
	GNSS L5	1176,5 MHz
	DAB-L	1452 - 1492 MHz
	GPS	1575.42 MHz
	GNSS	1598.0625 - 1609.3125 MHz
	Glonass	1597.6 - 1609.8 MHz
	Iridium	1610 - 1626.5 MHz
	2G (GSM1800/1900)	1900 MHz
	3G (UMTS/CDWA/EDGE)	800 MHz - 2,1 GHz
	SDARS	2,3 GHz
	Zigbee	2,4 GHz
	Globalstar	2,4 GHz
	Bluetooth	2,4 - 2,485 GHz
	WLAN	2.4 GHz, 3.6 GHz, 4.9 GHz, 5 GHz, 5.9 GHz
	ISM	5,8 GHz
	DSRC C-V2X V2X	5,9 GHz
	5G FR2	24,250 - 52,600 GHz
	WiGig	60 GHz
	LR Radar	76 - 77 GHz
	SR Radar	77 - 81 GHz

ABOUT MVG TEST SYSTEMS

StarLab 50 GHz

The StarLab is a compact multi-probe spherical near-field measurement system for antennas up to 45 cm, designed for fast and precise 3D radiation pattern testing. With options for 650 MHz to 50 GHz, ideal for mm-wave applications, or 6 GHz to 18 GHz, both models support OTA testing, ensuring versatility for a wide range of applications.

Applications: Antenna Measurement, Linear array antenna measurement, OTA Testing
Technology: Near-field / Spherical ; Near-field / Cylindrical
Frequency bands: StarLab 6 GHz: 650 MHz - 10 GHz
StarLab 10 GHz: 650MHz - 10 GHz
StarLab 18 GHz: 650 MHz - 18 GHz
StarLab 50 GHZ: 650 MHz - 50 GHz
Max Size of DUT: 45 cm for spherical 270 x 45 cm for cylindrical

Passive measurement capabilities:

- Gain
- Directivity
- Beamwidth
- Cross polar discrimination
- Sidelobe levels
- 3D radiation pattern
- Radiation pattern
- Antenna efficiency

With OTA capabilities, active measurements possible:

- TRP, TIS, EIRP and EIS

SG 3000

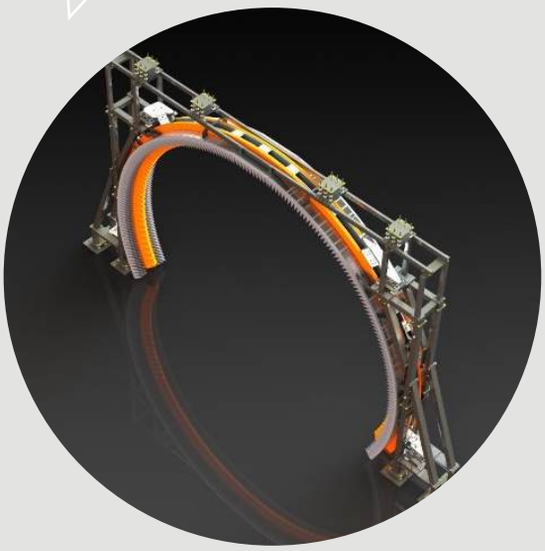
The SG3000 is a multi-probe spherical near-field measurement system, purpose-built for full-scale vehicle antenna testing. Using a probe array for fast electronic scanning, it eliminates the need for mechanical probe movement. Covering a frequency range from 70 MHz to 18 GHz, its fixed demi-arch design delivers precise and efficient full-sphere measurements. With a vehicle typically elevated and the ground floor covered with absorbing materials, it closely emulates free-space conditions, making it an ideal solution for automotive antenna evaluations.

Applications: Full-vehicle testing
Technology: Near-field / Spherical
Frequency bands: SG 3000 10GHz: 70 MHz - 10 GHz
SG3000 18 GHz: 70MHz - 18 GHZ
Max Size of DUT: 2.4 m x 6 m

SG 24

The SG 24 is a multi-probe spherical near-field antenna measurement and OTA testing system. Covering a frequency range from 400 MHz to 6 GHz, extendable to 10 GHz, it delivers ultra-fast and precise full-sphere measurements with high dynamic range, ideal for compact to large devices under test.

Applications: Antenna measurement, OTA testing, MiMo measurement, linar array antenna measurement, CTIA certifiable measurement
Technology: Near-field / Spherical ; Far-field
Frequency bands: SG 24 Compact: 650 MHz - 6GHz
SG 24 Standard: 400 MHz - 6 GHz
SG 24 Large: 400 MHz - 6 GHz ; 400 MHz - 18 GHz
Max Size of DUT: 1.79 m for SG 24 L



SG Evo

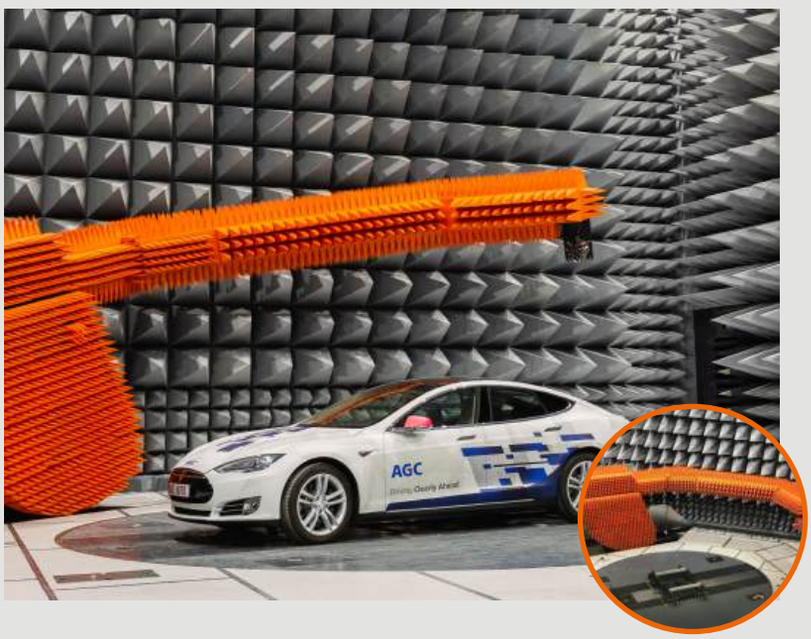
The SG EVO is an advanced multi-probe spherical near-field measurement system with a frequency range from 400 MHz to 50 GHz. It features a mechanically rotating demi-arch for unlimited sampling, designed for large-scale applications such as vehicle testing.

Applications: Antenna measurement, OTA testing, MiMo measurement, linar array antenna measurement, Payload testing, Full vehicle testing
Technology: Near-field / Spherical
Frequency bands: 400 MHz - 50 GHz (Customizable with a selection of seven types of precisions probes)
Max Size of DUT: Arch adapted to the DUT size

Gantry Arm

The Gantry Arm Single-Probe Measurement System is designed for precise vehicle antenna testing with a combination of elevation scanning via the gantry arm and azimuth scanning through turntable rotation. It offers flexible Az/El sampling density, customizable based on vehicle size, and is ideal for automotive antenna evaluations.

Applications: Antenna measurement, Full-vehicle testing
Technology: Near-field (NF) / Far-field (FF) Transformatio
Frequency bands: 400 MHz and up (depending on probe and RF system limitations)
Max Size of DUT: Vehicle size limits depend on system configuration



Enhancing Antenna Performance with Advanced Post-Processing Software

In modern antenna measurement, post-processing software is crucial for analyzing and optimizing performance. MVG's suite of advanced software tools, including WaveStudio™ and Insight™, provides powerful capabilities for transforming measurement data into actionable insights. Designed for precision and versatility, these tools bridge the gap between measurement and simulation, enabling users to enhance their designs and solve complex challenges with ease.

WaveStudio Comprehensive Measurement and Post-Processing

WaveStudio is MVG's core software for antenna and OTA measurement systems, offering a range of specialized post-processing modules to handle various data transformation tasks:

MV-Sphere: Efficiently transforms spherical near-field data into far-field patterns for precise characterization and enables coupling evaluation from measurements for enhanced system analysis.

MV-Holography: Extends near-field transformation to surfaces closer to the antenna under test, visualizing radiation on the antenna's structure.

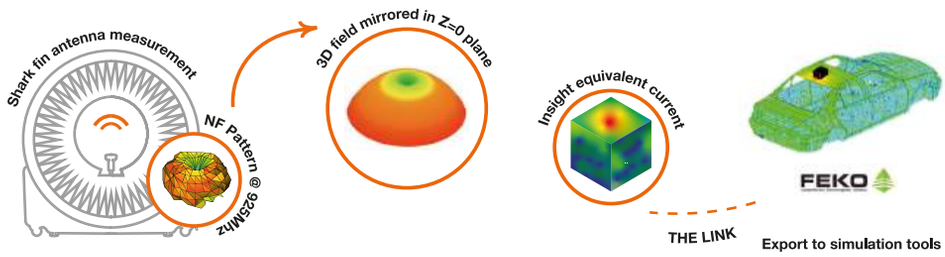
MV-TSWE: Allows mathematical adjustments to coordinate systems, enabling accurate measurements even with non-standard setups.

MV-Echo: Filters out unwanted reflections from anechoic chambers to ensure pristine measurements.

Insight Bridging Measurement and Simulation

Insight™ extends the capabilities of MVG's measurement systems by enabling the computation of EQuivalent Currents (EQC) and extreme near-field data. These EQC models are key for accurately evaluating the Far-field and provide advanced tools for:

- Performing advanced diagnostics by visualizing radiating currents directly on antenna structures.
- Generating "source boxes" from measured near-field patterns for use in simulation software, such as CST or FEKO.
- Analyzing antenna behavior when integrated into larger structures like vehicles or aircraft, simulating real-world conditions with accuracy.



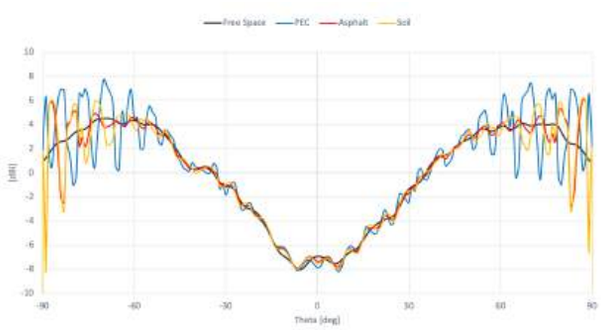
Seamless Link to Simulation Tools

One of Insight™'s most innovative features is its ability to export measured data into simulation environments. By creating equivalent current models based on measured near-field patterns, users can simulate how an antenna performs when mounted on larger structures. This unique capability enables the simulation of complex scenarios from measurements, bridging the gap between isolated antenna testing and system-level performance analysis. It saves time and enhances design accuracy by providing more realistic insights into how antennas interact in real-world environments.

SatSim · SAVANT · FEKO · Ansys HFSS · WIPL-D · CST

ANY Ground

ANY-Ground software emulates real road conditions by mirroring free-space vehicle measurements over an infinite plane, adjusting for ground material properties. This approach, based on Spherical Waves Expansion (SWE), eliminates the need for large chambers or complex lifting mechanisms. By using SWE, ANY-Ground accurately simulates how the antenna interacts with various ground types, providing a more realistic and flexible testing environment.



TSWE

TSWE (Translated Spherical Wave Expansion) is a post-processing technique that measures antennas placed anywhere on a vehicle's structure. It reduces sampling requirements while ensuring accurate data, optimizing antenna performance analysis.

EMC Testing for Automotive

In the automotive industry, electromagnetic compatibility (EMC) testing is crucial to ensure that electronic components and systems perform reliably without interfering with each other. With the increasing complexity of vehicles and the integration of advanced technologies like electric propulsion, ADAS, and infotainment systems, EMC testing plays a pivotal role in validating compliance with industry standards. At MVG, we provide tailored solutions for EMC testing, enabling automotive manufacturers to meet the rigorous standards required for safety and performance.

CISPR25 Chamber

The CISPR25 Chamber is specifically designed for automotive component testing in accordance with CISPR25 and ISO 11452-2 standards. Its compact yet high-performing design ensures accurate and efficient EMC testing.

Key Features:
Meets CISPR25 Annex J and ISO 11452-2 requirements for radiated emissions and immunity.
Hybrid anechoic material (UH-series polypropylene absorbers and ferrite tiles) ensuring durability and optimized performance.
Superior shielding effectiveness (>100 dB) as per MIL-STD-285 / IEEE-299.
Space-efficient design for benchtop testing with customizable dimensions.

Performance range: 9 kHz to 18 GHz (optional up to 40 GHz).

Why Choose CISPR25 Chamber?
This chamber offers exceptional precision in evaluating radiated emissions and immunity, making it the perfect solution for compact, high-performance testing.

EMC - 10 Anechoic Chamber

The EMC-10 is the benchmark for large-scale EMC testing, designed for full-compliance radiated emissions and immunity testing at a 10-meter range.

Key Features:
Full compliance with CISPR 16, FCC, and EN standards.
Large quiet zone (>3 m diameter), ideal for large EUTs.
Hybrid absorber technology (HyPyr-Loss™) with ferrite tiles and polypropylene pyramids for superior attenuation.
Modular, relocatable design using SmartShield™ RF shielding for >100 dB attenuation.

Frequency range: 26 MHz to 40 GHz.

Why Choose EMC-10?
The EMC-10 provides unparalleled accuracy and repeatability, making it ideal for larger equipment under test (EUT) and international compliance testing.

Why MVG for Automotive EMC Testing?

Turnkey Solutions: Comprehensive systems tailored to your requirements, from chamber design to installation and validation.
Expertise: Decades of experience in delivering advanced EMC chambers for automotive applications.
Compliance Assurance: Guaranteed adherence to industry standards like CISPR, ISO, and EN.
Scalability: Modular solutions that adapt to evolving testing needs and standards.

MVG Value Proposition

The Broadest range of Electromagnetic Testing Solutions

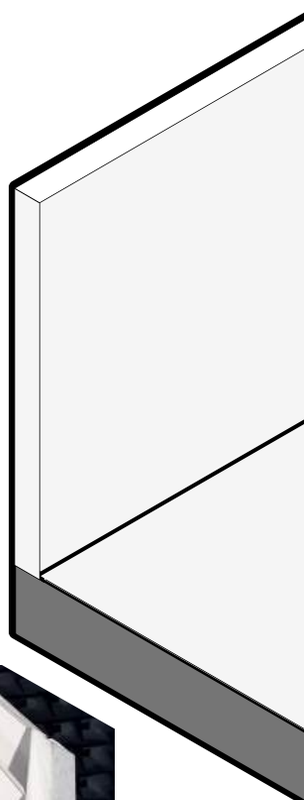
To address every need, MVG delivers a complete portfolio of electromagnetic testing & measurement solutions, spanning from microchips to large platform testing.

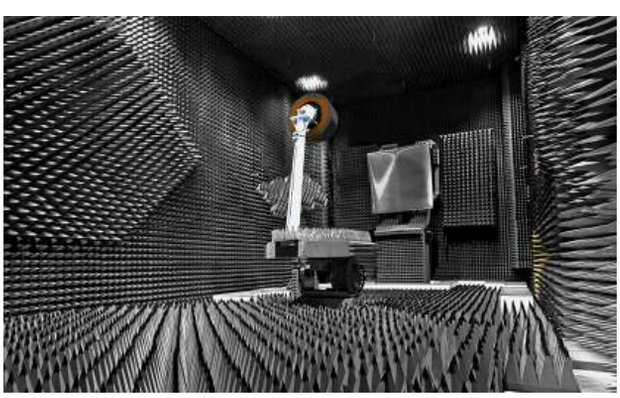
Innovative Testing Technologies, including

- FastFieldTM: State-of-the-art multi-probe arrays for rapid and accurate measurements, offering both OTA testing and passive antenna measurement capabilities. Every probe is precisely calibrated to ensure consistent and uniform signal detection in both amplitude and phase.
- HyperQuietTM: Enhancing compact range quiet zone for optimal measurement precision.

Your All-In-One Solution Partner Committed to Delivering

- Performance-Driven Delivery: We are dedicated to engineering and delivering system-level performance, beyond the sum of individual components.
- Integrated Design Optimization: Performance is optimized right from the design phase of the solution, taking into account not only each individual component but also the synergy between them to ensure an integrated and efficient system (considering aspects such as chamber geometry, interface with the building, absorber layout, measurement probes, etc.).
- Project Management Excellence: Through our vertical integration model, we guarantee efficient project control and the ability to meet stringent deadlines.
- Continuous Support and System Upgrade: Following installation, we provide consistent support and upgrades to maintain your system's relevance and performance





1. Shielded Enclosure and Doors, integration with the building
2. RF Absorptive Materials
3. Mechanical Positioners & Controllers
4. Probes and Sensors
5. RF Measurement Chain & Instrumentation

6. Measurement software suite and advanced post-processing tools
7. DUT handling and logistics
8. Upgrades and Services

MVG - Testing Connectivity for a Wireless World

The Microwave Vision Group offers cutting-edge technologies for the visualization of electromagnetic waves. Enhancing the speed and accuracy of wireless connectivity testing, as well as the performance and reliability of anechoic and EMC technologies, our systems are integral to meeting the testing challenges of a fully connected world.

WORLDWIDE GROUP, LOCAL SUPPORT

Our teams, in offices around the world, guide and support you from purchase, through design, to delivery and installation. Because we are local, we can assure speed and attention in project follow through. This includes customer support and maintenance once the system is in place. For the exact addresses and up-to-date contact information:
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