

Automotive Wireless Testing with Reverberation Chambers

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A Red Thread for Automotive Wireless Performance Validation

Wireless connectivity has become a key quality attribute in modern vehicles. Cellular links support telematics and connected services, while Wi-Fi and Bluetooth connect infotainment systems, user devices and in-vehicle functions. These systems depend on multiple antennas and MIMO, making overall system performance more important than any single antenna characteristic.

Bluetest reverberation chambers (RCs) provide fast and repeatable over-the-air measurements in a rich multipath environment. The method supports isotropic performance evaluation and can be applied from individual antennas and telematics control units (TCUs) to complete vehicle integration.

Using the same measurement principle throughout development creates a consistent red thread: antenna suppliers can verify basic antenna performance, TCU suppliers can evaluate radiated and system performance, and vehicle manufacturers can quantify the impact of final integration.

This approach supports objective supplier comparison, meaningful wireless KPIs and rapid design iterations. It also helps engineering teams separate antenna, electronics and integration effects and prevents discovering connectivity issues late in the vehicle program.

This White Paper describes how Bluetest RC technology can be used for automotive cellular, Wi-Fi and Bluetooth testing, as well as EMC testing. Finally, it provides an example of this use case by summarizing some automotive studies that have been carried out as part of a Swedish government and vehicle manufacturer co-funded project.



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Why Reverberation Chambers Fit the Automotive Environment

Real wireless propagation is multipath. In urban environments and inside a vehicle, radio signals arrive from many directions after reflections and scattering. There is therefore no single dominant receive direction, and isotropic performance becomes an important measure of how the complete wireless system behaves.

Multipath by Design

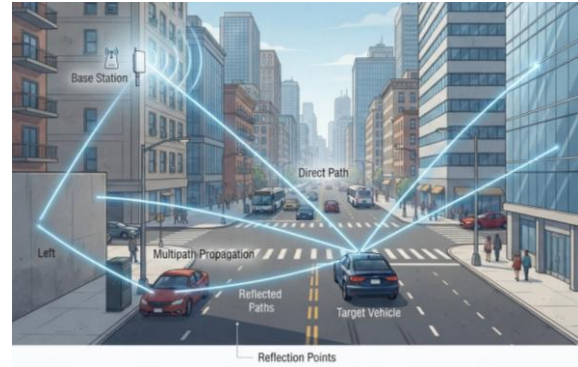
A reverberation chamber deliberately creates a rich multipath field. Mechanical stirring randomizes the electromagnetic field in a way that is conceptually similar to the mode-stirring effect in a microwave oven. This makes the chamber well suited to evaluating devices that use multiple antennas and MIMO.

The test environment represents multipath fading rather than a single line-of-sight direction.

For automotive development, this is particularly relevant because the vehicle body itself is reflective. The Body-In-White creates a rich propagation environment for wireless communication inside the cabin, making an RC a representative environment for infotainment Wi-Fi and Bluetooth testing.

The same principle also enables repeatable cellular testing without relying on a specific antenna orientation. Measurements can focus on the combined radiated performance of the antenna system, radio and vehicle mounting position.

Key benefit: One controlled, repeatable method can be used to evaluate isotropic metrics and MIMO system performance across successive automotive development stages.



Multipath propagation is characteristic of both urban and in-vehicle environments.

Automotive Cellular Communication

Modern TCUs commonly use two to four cellular antennas. With several antennas, RF performance depends not only on the individual antenna elements but also on their correlation, the radio implementation, losses, detuning and the way the TCU is integrated into the vehicle.

System performance - not only individual antenna performance - is the key engineering target.

Bluetest positions the RC as a common measurement platform across the TCU development chain. Reusing comparable test cases at each stage makes it easier to identify when and where performance changes are introduced.

At the antenna-supplier level, the chamber can be used to validate antenna efficiency and correlation. At the TCU-supplier level, testing can expand to Total Radiated Power (TRP), Total Isotropic Sensitivity (TIS) and throughput for multiple-antenna system performance evaluation.

Key benefits

- Antenna designers can validate basic antenna efficiency and correlation before the antenna is integrated into the complete TCU.
- TCU suppliers can evaluate TRP, TIS and throughput, including effects from material losses, antenna detuning, receiver performance and internal data processing.
- Vehicle manufacturers can repeat the same test cases on the integrated system to directly quantify the impact of installing the TCU and antenna system in the vehicle.

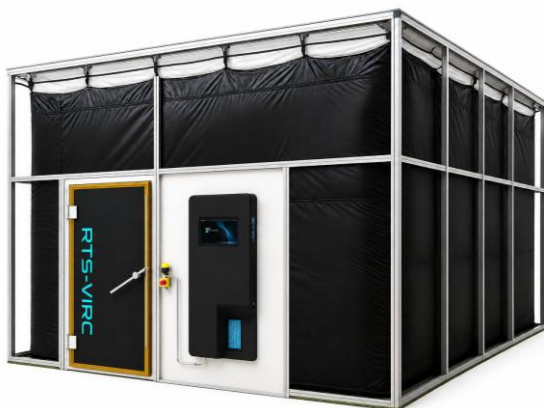
From Component to Complete Vehicle

Using the same method through the development chain greatly facilitates direct comparison of results. This supports root cause analysis and supplier benchmarking because changes can be related to a specific integration step rather than to a change of measurement methodology.

The development chain can be summarized as follows:

Development phase	Primary focus	Typical metrics	Integration scope
Tier 2	Antenna performance	Efficiency, correlation	Antenna
Tier 1	TCU system performance	TRP, TIS, throughput	Antenna + TCU
Vehicle manufacturer	Integrated system	Repeated system test cases	TCU + vehicle
Infotainment	In-cabin connectivity	Wi-Fi / Bluetooth system performance	TCU and/or infotainment unit

For complete-vehicle cellular testing, Bluetest has presented a modular semi-rigid VIRC (Vibrating Intrinsic Reverberation Chamber) concept. The purpose is to extend reverberation-based system testing from components and TCUs to the fully integrated vehicle.



Bluetest RTS-VIRC reverberation chamber

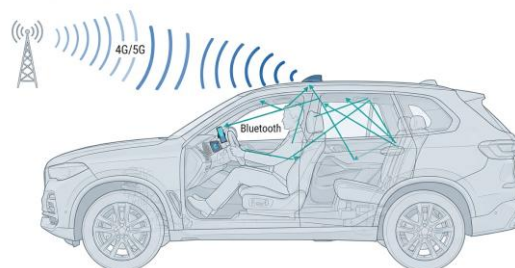
For in-vehicle Wi-Fi and Bluetooth, an infotainment unit can be measured in an RTS65 as a representative environment for the reflective vehicle cabin. The same system can be used for TCU system or antenna performance evaluation.



Bluetest RTS65 reverberation chamber

Cellular Integration

The vehicle manufacturer can repeat TCU-level test cases after installation in the vehicle. Comparing the results before and after integration provides a direct view of integration impact and supports decisions on antenna placement, distributed antenna architectures and TCU location.



The objective is a continuous, comparable performance baseline from antenna design to final vehicle integration.

Wi-Fi and Bluetooth

Inside the vehicle, Wi-Fi and Bluetooth are used by infotainment systems and connected user devices. Because the reflective vehicle structure naturally creates multipath, reverberation-chamber testing provides a relevant way to evaluate the complete infotainment radio and antenna implementation.

System coexistence

A complete-vehicle reverberating environment also enables system-level comparison for coexistence scenarios; to understand how other radios or electronic equipment impact the wireless communication system. This can be done at the TCU-level, but also at the complete-vehicle level by having the vehicle active (and potentially wheels spinning) during the tests.

Automotive Studies and Demonstrated Use Cases

Swedish vehicle manufacturers evaluated reverberation-chamber methods in the government co-funded SIVERT* and SIVERT 2** research projects between 2018 and 2025. The work included both component test setups in a reverberation chamber and complete-vehicle testing using a reverberating tent.



Test setup in RC with car*.

References:

* www.vinnova.se/en/p/simulation-and-verification-of-wireless-technologies-sivert

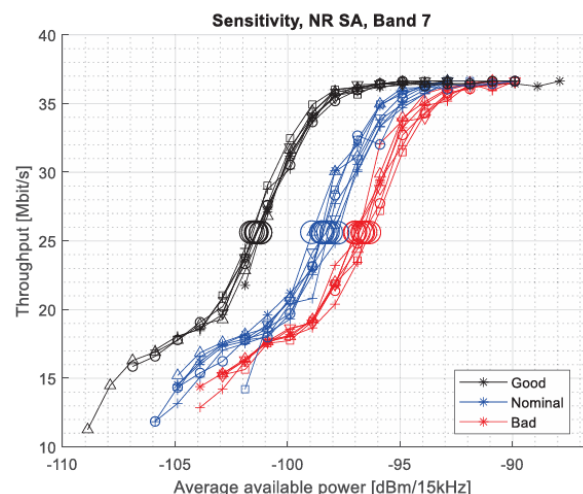
** www.vinnova.se/en/p/sivert-2



Test setup in RC with truck.**

The reported results demonstrate the ability to distinguish stronger and weaker wireless device designs for both 4G and 5G. A better-performing implementation can achieve the same throughput at lower available power.

Such results can be used to benchmark suppliers or a reference device and to study performance changes caused by distributed antenna systems or different TCU integration locations.



Device comparison and repeatability from SIVERT2**.

These use cases show how controlled multipath testing can support both development decisions and system-level verification.

EMC

Vehicular EMC is important for electric cars and as the vehicles communication systems move up in frequency. Reverberation chambers are a well-established method for EMC testing. The stirred field exposes the complete vehicle or sub-system from all directions and polarizations during the measurement sequence, without repositioning the DUT. With the Bluetest RTS, field strengths up to 200 V/m can be generated for radiated immunity testing. Radio performance and EMC testing of automotive equipment can thereby be combined in the same chamber, following the reverberation chamber method described in IEC 61000-4-21, ISO 11452-11 and ISO 11451-5.

For vehicular EMC, work is also ongoing within CISPR D to define RC as an alternative method to the ALSE method in ISO 11452-2, based on IEC 61000-4-21.

Summary

For automotive wireless development, the central value of the RTS approach is consistency. The same isotropic and multipath-based measurement principle can support EMC, antenna efficiency and correlation, TCU TRP/TIS/throughput, infotainment Wi-Fi and Bluetooth, and system-level vehicle integration. This creates a practical red thread from supplier selection and early design to final verification, with fast, repeatable measurements that support iterative engineering decisions.