AUTOMOTIVE EMC TESTING:

CISPR 25, ISO 11452-2 AND EQUIVALENT STANDARDS

EMC Standards and Chamber Testing for Automotive Components

Automotive standards addressing electromagnetic compatibility (EMC) are developed mainly by CISPR, ISO and SAE. CISPR and ISO are organizations that develop and maintain standards for use at the international level. SAE develops and maintains standards mainly for use in North America. In the past, SAE developed many EMC standards which were eventually submitted to CISPR and ISO for consideration as an international standard. As the SAE standards become international standards, the equivalent SAE standard is then withdrawn as a complete standard and reserved for use to document differences from the international standard.

Each vehicle manufacturer has internal corporate standards that specify the levels and testing that components used in their vehicles must meet. As with the government standards, these documents usually refer to the CISPR and ISO documents with differences in scope or test levels. In the past, a vehicle manufacturer based in the U.S. referenced SAE documents in their corporate standards. Today most

Image courtesy of ETS-Lindgren

Photo 1: Automotive test chamber using polystyrene absorber

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U.S. based vehicle manufacturers market worldwide. Therefore, they reference CISPR and ISO standards in their internal corporate standard, and this is also true for other established and emerging manufacturers.

CISPR/D is responsible for developing and maintaining the standards used to measure the emissions produced by vehicles and their components. ISO/TC22/SC32/WG3 is responsible for developing and maintaining the standards used for immunity testing of vehicles and their components. ISO standards for the vehicle industry are mainly broken into two categories, vehicle (ISO 11451-xx) or component (ISO 11452-xx, ISO 7637-xx). Table 1 (pages 22 and 23) provides an overview of the CISPR and ISO EMC standards for the automotive industry.

As with the ISO EMC standards, SAE EMC standards are mainly broken into two categories, vehicle (SAE J551-xx) and component (SAE J1113-xx). As can be seen in the notes of Table 1, many of the SAE standards are inactive because they have been withdrawn as complete standards and reserved for use to document differences from the international standards. Table 2 (page 24) does not show all the EMC standards related to automotive published by the SAE, but it gives an overview of the main standards and cross-references to the equivalent ISO or CISPR document. Table 2 shows the main SAE standards that are still active for both vehicle components and vehicles.

As with Table 1, Table 2 is not intended to show all the different parts of the standard, but to show the complexity of the standard documents and the many parts and methods that are covered under them. As mentioned above, government standards and directives in many cases refer to the CISPR or ISO methods. 2004/104/EC, which surpassed 95/54 EC, is a European directive for vehicle EMC. Its sections related to automotive components follow the directions given in the CISPR 25 document.

CISPR 25 AND CISPR 12

CISPR 12 deals with "radio disturbance characteristics for the protection of off-board receivers" [1]. CISPR 25 deals with "radio disturbance characteristics for the protection of receivers used on-board vehicles, boats and on devices" [2]. It is important to remember that CISPR 12 (the test methods and/or limits) is commonly used for regulatory purposes. The regulatory bodies want to make sure that an item with an internal combustion engine does not cause unwanted interference with TV and radio reception when it drives past (or is used nearby) a residence or business.

CISPR 25 is not typically used for regulatory purposes, it is commonly used by the vehicle manufacturers to assure good performance of receivers mounted on-board the vehicle. If the radio mounted in the vehicle, boat or other device does not perform reliably, then consumer satisfaction and ultimately product sales could suffer.

Both CISPR 12 and CISPR 25 deal with automobiles (vehicles which operate on land) powered by internal combustion engines, boats (vehicles which operate on the surface of water) powered by internal combustion engines, and devices powered by internal combustion engines (but not necessarily for the transport of people). This last category includes compressors, chainsaws, garden equipment, etc. CISPR 12 would apply to all of these devices since they could affect the performance of nearby (off-board) receivers. However, CISPR 25 should only be considered for items which contain on-board receivers. As an example, a chainsaw with an internal combustion engine (but with no on-board receivers) would need to meet the requirements of CISPR 12, but CISPR 25 would not apply to this chainsaw since it does not utilize any on-board receivers.

Document No.	Title	Type	Equivalent	Test Setup	Chamber Requirement
ISO-11451-1	Road vehicles — Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 1: General principles and terminology	N/A	SAE J551/1	Definitions	N/A
ISO-11451-2	Part 2: Off Vehicle Radiation Sources	RI	SAE J551-11 (Note 1)	Vehicle Radiated Immunity test in a anechoic chamber	Vehicle Absorber lined chamber
ISO-11451-3	Part 3: On-board transmitter simulation	RI	SAE J551-12 (Note 2)	Vehicle Absorber Lined Shielded Enclosure (ALSE) is required	Vehicle Absorber lined chamber
ISO-11451-4	Part 4: Bulk Current Injection (BCI)	RI	SAE J551/13 (Note 3)	Test was designed for machines and vehicles too large to fit in a standard vehicle EMC	Outdoor Test Site (OTS) or Vehicle Absorber lined chamber
ISO-11452-1	Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 1: General principles and terminology	N/A	SAE J1113/1	Definitions	N/A
ISO-11452-2	Part 2: Absorber lined chamber	RI	SAE J1113/21 (Note 4)	An absorber lined chamber is required. Antennas and field generator to cover the range are required. No need to scan	Absorber lined chamber
ISO-11452-3	Part 3: Transverse electromagnetic (TEM) cell	RI	SAE J1113/24 (Note 5)	TEM cell	N/A
ISO-11452-4	Part 4: Bulk current injection	RI	SAE J1113/4	Radiated immunity using the BCI method	Shielded room
ISO-11452-5	Part 5: Stripline	RI	SAE J1113/23 (Note 6)	Radiated immunity using a stripline	Shielded room
ISO-11452-7	Part 7: Direct radio frequency (RF) power injection	RI	SAE J1113/3 (Note 7)	Conducted immunity test 250 kHz to 500 MHz	Bench or Shielded room
ISO-11452-8	Part 8: Immunity to magnetic fields	RI	SAE J1113/22 (Note 8)	Helmholtz coils are used	Bench test; no shielded room required
ISO-11452-9	Part 9: Portable transmitters	RI	None	Small antennas are used in conjunction with amplifiers and signal sources to simulate portable transmitters	Absorber lined chamber
ISO-11452-10	Part 10: Immunity to conducted disturbances in the extended audio frequency range	CI	SAE J1113/2 (Note 9)	Conducted immunity test 15 Hz to 500 MHz	Bench test; no shielded room required
ISO-11452-11	Part 11: Reverberation Chamber	RI	SAE J1113/28 (Note 10)	Reverberation chamber – Mode Tuned	Reverberation chamber
ISO 7637-1	Road vehicles — Electrical disturbances from conduction and coupling — Part 1: Definitions and general considerations	N/A	SAE J1113/1	Definitions	N/A
ISO-7637-2	Part 2: Electrical transient conduction along supply lines only	CI	SAE J1113/11	Conducted immunity to transients as they are applied directly to the power leads of the test item.	Bench test; no shielded room required
ISO-7637-3	Part 3: Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines	CI	SAE J1113/12	Conducted immunity to transients as they are applied directly to the I/O lines of the test item.	Bench test; no shielded room required

ISO-10605	Road vehicles — Test methods for electrical disturbances from electrostatic discharge	ESD	SAE J1113/13 J551/15	ESD testing performed on a module on a bench or a vehicle in a temperature and humidity controlled environment	Bench test; no shielded room required
CISPR 12	Vehicles, boats and internal combustion engines – Radio disturbance characteristics – Limits and methods of measurement for the protection of off-board receivers	RE	SAE J551/2 (Note 11)	Vehicle Radiated Emissions	OTS or Vehicle Absorber lined chamber
CISPR 25	Vehicles, boats and internal combustion engines – Radio disturbance characteristics – Limits and methods of measurement for the protection of on-board receivers	RE	SAE J551/4 (Note 12)	Clause 5: Vehicle portion of the standard. This is to measure the amount of noise generated by the vehicle will be induced into the on-board receiver antenna port.	Vehicle Absorber lined chamber
CISPR 25	Vehicles, boats and internal combustion engines – Radio disturbance characteristics – Limits and methods of measurement for the protection of on-board receivers	CE & RE	SAE J1113/41 (Note 13)	Clause 6: Component (module) test section where conducted and radiated emissions are measured.	Absorber lined chamber

Note 1: SAE J551-11 Withdrawn as a complete standard and reserved for use to document differences from ISO 11451-2. At the present time J551-11 is not used.

Note 2: SAE J551-12 Withdrawn as a complete standard and reserved for use to document differences from ISO 11451-3. At the present time J551-12 is not used.

Note 3: SAE J551-13 Withdrawn as a complete standard and reserved for use to document differences from ISO 11451-4. At the present time J551-13 is not used.

Note 4. SAE J1113-21 Withdrawn as a complete standard and reserved for use to document differences from ISO 11452-2. At the present time J1113-21 is not used.

Note 5. SAE J1113-24 Withdrawn as a complete standard and reserved for use to document differences from ISO 11452-3. At the present time J1113-24 is not used.

Note 6. SAE J1113-23 This standard has been withdrawn.

Note 7. SAE J1113-3 Withdrawn as a complete standard and reserved for use to document differences from ISO 11452-7. At the present time J1113-3 is not used.

Note 8. SAE J1113-22 Withdrawn as a complete standard and reserved for use to document differences from ISO 11452-8. At the present time J1113-22 is not used.

Note 9. SAE J1113-2 Withdrawn as a complete standard and reserved for use to document differences from ISO 11452-10. At the present time J1113-2 is not used.

Note 10. SAE J1113-28 Withdrawn as a complete standard and reserved for use to document differences from ISO 11452-11. At the present time J1113-28 is not used.

Note 11: SAE J551-2 Withdrawn as a complete standard and reserved for use to document differences from CISPR 12. At the present time J551-2 is not used.

Note 12: SAE J551-4 Withdrawn as a complete standard and reserved for use to document differences from CISPR 25. At the present time J551-4 is not used.

Note 13. SAE J1113-41 Withdrawn as a complete standard and reserved for use to document differences from CISPR 25. At the present time J1113-41 is not used.

Table 1: Some of the main CISPR and ISO EMC standards for the automotive industry

CISPR 12 radiated emissions measurements are made at either 3 meter or 10 meter test distances. The measurements are normally done on an outdoor test site (OTS) or in an absorber lined shielded enclosure (ALSE) if the ALSE can be correlated to an OTS. Measurements for boats can also be made on the water. The correlation of the ALSE to an OTS has been a point of discussion over the past few years within the group of experts who are responsible for the maintenance of CISPR 12. The specification currently does not provide a method to achieve this correlation. A working group has been tasked with developing a

SAE Doc No.	Title	Type	Equivalent	Test Setup	Chamber Requirement
SAE J551/1	Performance Levels and Methods of Measurement of Electromagnetic Compatibility of Vehicles, Boats (up to 15 m), and Machines (16.6 Hz to 18 GHz)				SAE J551/1
SAE J551/5	Performance Levels and Methods of Measurement of Magnetic and Electric Field Strength from Electric Vehicles, 150 kHz to 30 MHz	RE	None At Present. CISPR 36 is currently in development to cover RE < 30 MHz on Electric Driven Vehicles	Vehicle ALSE is required	Absorber lined chamber
SAE J551/15	Vehicle Electromagnetic Immunity – Electrostatic Discharge (ESD)	ESD	ISO-10605 Clause 10	ESD test at the vehicle level would not need a shielded enclosure.	No shielded room required
SAE J551/16	Electromagnetic Immunity - Off-Vehicle Source (Reverberation Chamber Method) - Part 16 - Immunity to Radiated Electromagnetic Fields	RI	None	Vehicle Sized Reverberation Chamber is needed for this test. Method allows for the reverberation test along with a "hybrid test which utilizes direct illumination and reverberation.	Vehicle Sized Reverberation Chamber
SAE J551/17	Vehicle Electromagnetic Immunity - Power Line Magnetic Fields	RI	None	Magnetic Field RI testing at the vehicle level would not need a shielded enclosure.	No shielded room required
SAE J1113/1	Electromagnetic Compatibility measurement procedures and limits for vehicle components (except aircraft), 60 Hz-18 GHz	N/A	ISO-11452-1	Definitions	N/A
SAE J1113/4	Immunity to radiated electromagnetic fields- bulk current injection (BCI) method	RI	ISO-11452-4	Radiated immunity using the BCI method	Shielded room
SAE J1113/11	Immunity to conducted transients on power leads	CI	ISO-7637-2	Conducted immunity to transients	Bench test; no shielded room required
SAE J1113/12	Electrical interference by conduction and coupling - coupling clamp	CI	ISO-7637-3	Conducted immunity to different coupling mechanisms	Bench test; no shielded room required
SAE J1113/13	Electromagnetic compatibility procedure for vehicle components-immunity to electrostatic discharge	ESD	ISO-10605	ESD testing performed on a bench in a temperature and humidity controlled environment	Bench test; no shielded room required
SAE J1113/27	Immunity to radiated electromagnetic fields reverberation method	RI	None	Reverberation chamber – Continuous Stirred	Reverberation chamber

Table 2: Some of the remaining active SAE automotive EMC standards

method to correlate the ALSE to the OTS; however, we expect this to take several more years and after CISPR 12 7th Edition is published.

CISPR 25 has two parts. One part deals with a full vehicle or system test in which the antennas mounted on the vehicle are used to sense the noise generated by the different electric and electronic systems mounted on the same vehicle. This test shows how much noise generated by the vehicle will be introduced into the radios antenna port (sort of a self-immunity test). The other section of the standard deals with conducted and radiated measurements of vehicle components and modules. In this article, we are going to concentrate on the module radiated emissions test section of CISPR 25, and only briefly highlight some of the additions needed to support electric vehicles. More specifically, this article will concentrate on the chamber requirements for the standard.

CISPR 25 states that the electromagnetic noise level in the test area has to be 6 dB lower than the lowest level being measured. Some of the radiated emissions limits found in CISPR 25 are as low as 18 dB (µV/m). This means that the ambient noise must be 12 dB (µV/m) maximum for a compliant environment. An RF shielded room is typically used to keep RF signals from the external environment out of the test area so that the equipment under test (EUT) remains the dominant source of any radiated interference.

Although the shielded room is too small to support resonant modes at low frequencies, the number of modes increases with frequency above the cut off of the chamber. When these resonant modes appear, they can add significant error to the measurements. To reduce these errors, the shielded room covered with RF absorber material on its ceiling and interior walls, greatly supresses internal reflections so that the dominant coupling path is between the EUT and measurement antenna.

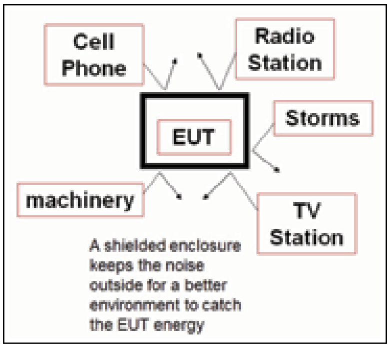

Figure 1: A shielded room blocks the noise from outdoor sources of EM interference

CISPR 25 in its current version (Ed 3:2008) covers a frequency range of 150 kHz to 2.5 GHz and to date absorber technology is unable to provide appreciable absorption at levels down in the 150 kHz range. One beneficial consequence of the low measurement frequency is the fact that the chamber sizes are electrically small at these low frequencies, so no significant resonant behaviour appears. The standard therefore concentrates on absorber performance at 70 MHz and above. The standard requires that the absorber used must have better than -6 dB absorption at normal incidence. To achieve these levels, there are several types of absorber technology on the market today.

One of the most efficient and cost effective is a polystyrene based absorber that combines a high-performance ferrite tile with a polystyrene EMC absorber, having 60cm x 60cm base and 60cm height. The main absorber substrate is based on expanded polystyrene (EPS), which is volumetrically loaded with lossy materials, and environmentally friendly fire retardants. Advanced uniform loading in the manufacturing process results in superior RF performance an excellent absorption uniformity. The closed cell structure of this type of absorber makes it suitable for use even in high humidity environments. These features all contribute to providing for a better controlled and predictable chamber test environment. Figure 2 presents the performance of one type of hybrid polystyrene absorber.

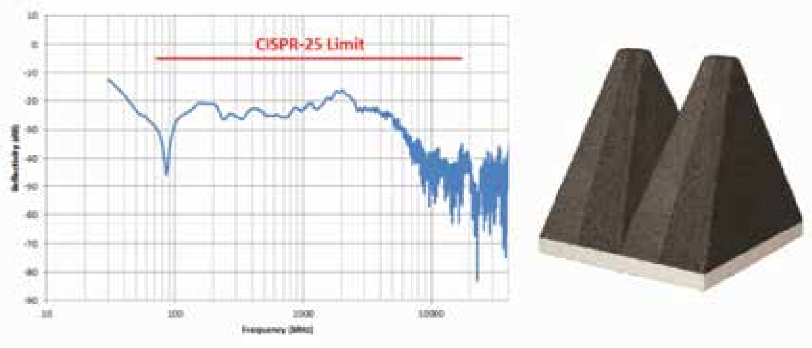

Figure 2: Typical performance of polystyrene absorber

An alternative polyurethane absorber typically 36 inches (1m) in depth, EHP 36, can be used with improved high frequency performance due largely to the increased material length. But, without the benefit of the matching ferrite material used in the hybrid, the polyurethane only absorber suffers from reduced low frequency performance. Figure 3 shows the typical performance of this material and its compliance with the CISPR 25 limit.

The layout and dimensions of the typical CISPR 25 anechoic chamber is guided by the standard. Several guidelines must be followed when sizing the chamber and the starting point is the EUT, which is determines the size of the test bench. Figure 4 shows a typical test bench used in a CISPR 25 and ISO 11452-2 type chamber.

The layout and dimensions of the typical CISPR 25 anechoic chamber is guided by the standard.

As Figure 4 shows, the bench must accommodate the largest EUT and all the cables that are needed to power and communicate with the device. The cables are routed in a cable harness that is positioned along the front edge of the bench. The cable harness itself is a significant component of the EUT and is the main component illuminated by the measurement antenna since at lower frequencies (frequencies for which the device under test is electrically small) the main coupling to radiated fields will occur through the cables feeding the device. This same procedure is used in MIL STD 461 [3] and in ISO 11452 [4] and as shown in the illustration, a line impedance stabilization network is used to provide a defined impedance for the power to the device.

Figure 5 shows how the size of the bench is determined. The ground plane bench must extend all the way to the shield and in most cases, it is grounded to the wall of the shielded room. The standard, however, does permit the bench to be grounded to the floor as an alternative.

As defined in CISPR 25, the minimum width of the reference ground plane (bench) for radiated emissions shall be 1000 mm, the minimum length of the ground plane for radiated emissions shall be 2000 mm, or the length needed to support the entire EUT plus 200 mm, whichever is larger.

The minimum overall dimensions of the compliant chamber are determined by a series of dimensional

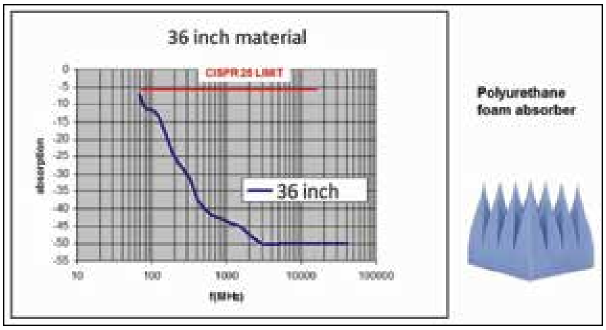

Figure 3: Typical performance of 36" polyurethane absorber material

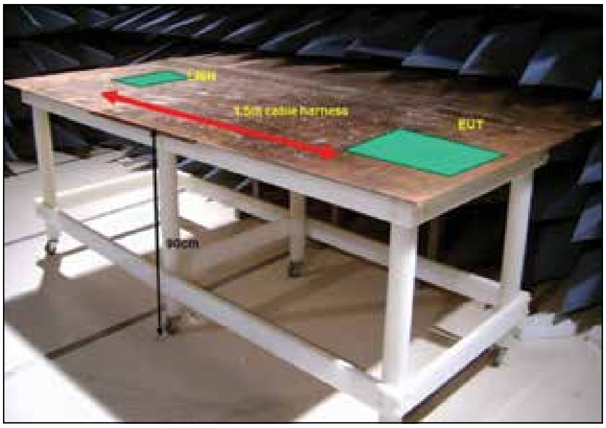

Figure 4: A typical conductive test bench

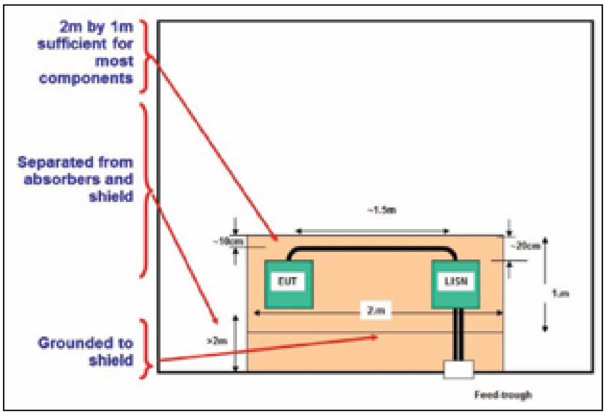

Figure 5: Sizing the bench

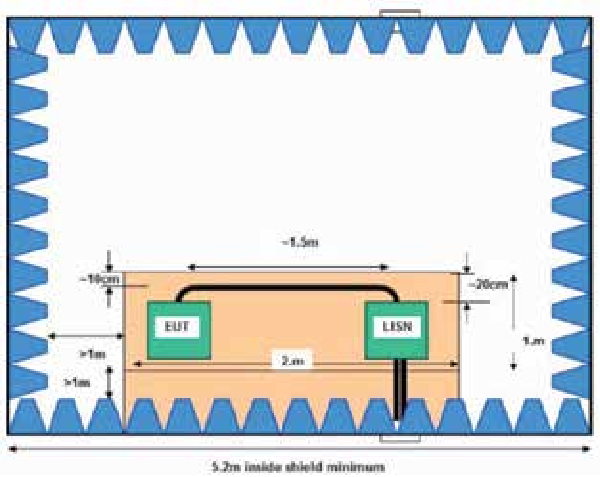

Figure 6: Width of the CISPR 25 chamber

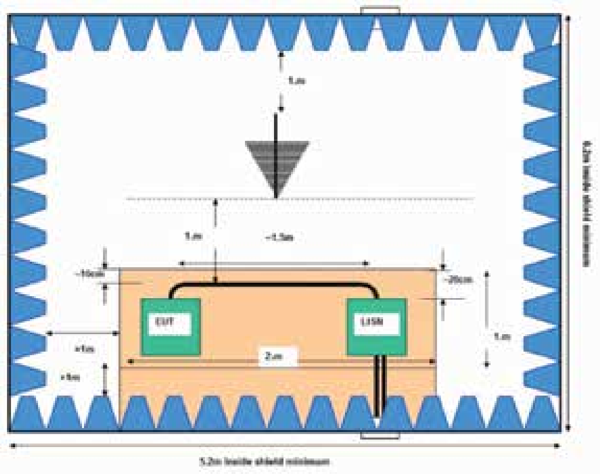

Figure 7: Determining the length of the chamber for CISPR 25

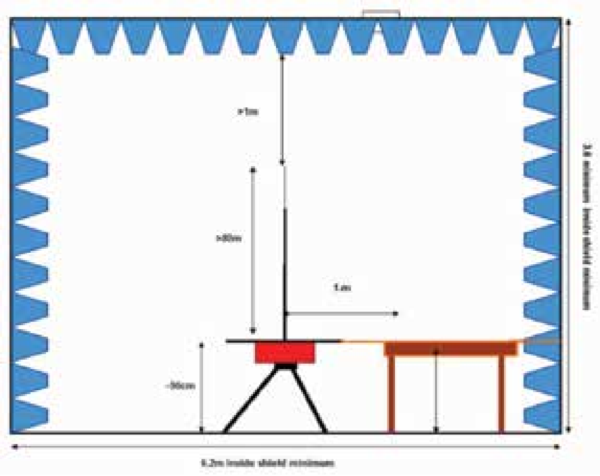

Figure 8: Height of the CISPR 25 chamber

relationships based primarily on the size of the test bench. With the use of hybrid absorber with a depth of 60 cm to line the walls and ceiling of the chamber, Figure 6 shows that the width of the chamber is determined by the length of the absorber material with a one meter space left between the bench and the tips of the absorbing material. For chambers that will also be used for e-motor testing, the motor is also be part of the EUT. In some cases the motor is supported on a separate structure adjacent to the test bench for mechanical reasons. In this case it still needs to be connected to the ground plane so in effect it will be an extension of the ground plane bench and subject to the minimum distances as defined in the standard.

For the height and the length of the chamber, CISPR 25 further defines the separation distances to be followed in determining the minimum space needed. The first and most critical is the test distance where emissions are to be measured at a minimum distance of 1 m from the cable harness to the antenna.

The other rule states that no part of the antenna can be closer than 1 m away from the tips of the absorbing material. These rules and recommended antennas define the length and height of the chamber. The 1 m distance to the cable harness is measured from the axis of the antenna elements for the monopole rod and the biconical antenna. For the log periodic dipole array (LPDA), the distance is measured from the tip of the antenna. Finally, for the horn antennas the distance is measured from the front face or aperture plane of the antenna. The longest antenna is the LPDA. A typical LPDAs for the 200 MHz to 2.5 GHz range is about 1 m in overall length. In addition to the 1 m test distance and the 1 m for the antenna length, we have a 1 m clearance from the back of the antenna to the tips of the absorber. Figure 7 shows the antenna (an LPDA) in the chamber for the CISPR 25 set up.

The height of the chamber will be driven by the longest antenna. The longest antenna is usually the active rod monopole. The monopole is used with an extremely electrically small ground plane. Per the standard, the monopole rod is about 80 cm in length and it is positioned such that the ground plane is at the same level as the bench which as Figure 4 suggests is nominally 90 cm in height. The 1 m rule for the separation between antenna and absorber tip will again determine the size of the chamber as shown in Figure 8.

The CISPR 25 document prepared by the CISPR organization, and the requirements and guidelines on antennas and receivers, are already comprehensively defined in the CISPR 16-1-4 document.

With the components discussed in the previous sections, a chamber lined with hybrid absorber with a size of 5.2 meters wide by 6.2 meters long and 3.6 meters high will meet the minimum size requirements for performing compliant CISPR 25 tests. And, as we will see in the next section of this article, this chamber will also meet the requirements of ISO 11452-2. Furthermore, since this is a shielded environment, most of the tests defined in standards requiring a shielded room can be performed inside the chamber described in the present section.

The CISPR 25 document prepared by the CISPR organization, and the requirements and guidelines on antennas and receivers, are already comprehensively defined in the CISPR 16-1-4 document [5]. The recommended antenna types used for the CISPR 25 measurements are therefore cross referenced to the CISPR 16 document. For low frequencies, an active rod monopole antenna is preferred. At frequencies between 30 MHz and 200 MHz, a typical biconical antenna is the recommended antenna. From 200 MHz to 1 GHz, the antenna of choice is a LPDA and finally from 1 to 2.5 GHz, the dual ridge horn (DRH) antenna can be a more compact and efficient antenna that easily meets the cross pole requirements of the standard, although lower gain LPDAs can still be used.

Regarding updates coming in CISPR 25 4th Edition, the planned publish date is currently late 2016. The next revision of the standard will contain an annex (Annex J) which provides methods to validate the performance of an ALSE used for component level radiated emission tests. Currently, two methods (one method based upon reference measurements and another method based upon modelling) are being proposed for the ALSE validation tests. The user can select either method to evaluate the performance of the chamber as the work done by the committee has shown that either method provides similar results.

As mentioned at the beginning of the article, CISPR 25 also covers the measurement of emissions received by a vehicle antenna for a whole vehicle setup. The next revision of CISPR 25 4th Edition will also contain special setups to be used for the testing of electric vehicles (EVs) and hybrid electric vehicles (HEVs) and the modules (inverters, batteries, etc) to be used on EVs and HEVs. The committee found that special testing and limits are required for the testing of these electric driven vehicles and their components.

These vehicles represent a special case since there are high currents and voltages involved not only in normal operation but also during charging cycles. There will be more detailed information on the measurement setups to be used for EV and HEV measurements under different connection and charging scenarios. The testing adds new conditions for when the vehicle is not being driven, but connected to the mains or a charging station. This is currently already required as part of the European directive ECE Regulation 10, which outlines the EMC requirements for wheeled vehicles marketed in the European Union. This document references both the CISPR 25 and CISPR 12 documents currently under revision. CISPR 25 will be released as the 4th Edition, and CISPR 12 as the 7th Edition when published.

ISO 11452-2

ISO 11452-2 is a vehicle component immunity standard that applies to the 200 MHz to 18 GHz range. This standard, like many automotive, military and aerospace standards, calls for moderately high fields to be generated. Table 3 shows the severity levels. At frequencies below 200 MHz, antennas get physically larger and also less efficient. For frequencies below 200 MHz, the standard recommends the methods stated in parts 4, 3, and 5 of the ISO 11452

Severity Level	Field
I	25 V/m
II	50 V/m
III	75 V/m
IV	100 V/m
V	(open to the users of the standard)

Table 3: ISO 11452-2 severity levels

> The intent of the test is to produce RF field levels which can be disruptive or damaging to the EUT; the shielded room removes the risk of unintended disruption to other sensitive devices outside of the test region.

standard. Those sections describe the bulk current injection, TEM and stripline test methods. These other methods are far more efficient and economical to test for immunity to high fields.

The standard recommends that these tests are performed in a shielded room. As is common with most immunity measurements, the intent of the test is to produce RF field levels which can be disruptive or damaging to the EUT; the shielded room removes the risk of unintended disruption to other sensitive devices or equipment outside of the test region. In the US, as in most other countries, there are limits on the radiation of energy without licenses, at frequencies that could affect licensed broadcasts.

These tests are conducted at frequencies above 200 MHz and as discussed previously, the chance of resonant modes being developed inside the shield room is increased, so to reduce measurement errors the use of absorber is required. The chamber is treated such that the reflectivity in the area of the EUT is -10 dB. Figures 2 and 3 show that for the 200 MHz to 18 GHz range, the -10 dB level is higher than the typical reflectivity of the recommended materials. This means that the same absorber used in the CISPR 25 chamber can be used in the ISO 11452-2 chamber, although ISO 11452-2 provides no further guidance on the design or layout of the ALSE. Antenna selection is in keeping with the need to generate the required field levels in the most effective and efficient manner given the cost of amplifiers. It is recommended that a dual ridge horn antenna be used for the 200 MHz to 2 GHz range. Above that, octave horns and standard gain horns with high gain are the preferred antenna choice.

ON ANTENNAS, PATTERNS AND GROUND BENCHES

To conclude this article, we shall talk a bit about the antennas used for automotive EMC testing. Specifically, we are going to concentrate on the typical biconical antenna, LPDA and DRH antenna recommended for CISPR 25, and the DRH antenna recommended for ISO 11452-2. Recently it has become important to understand the radiation characteristics of these antennas. The typical biconical antenna as shown in Figure 9 is an omnidirectional radiator. Its pattern shown in Figure 10 at 100 MHz is typical of the radiation pattern across the entire range. From these patterns we can extract the high power beam width (HPBW). For the H plane, it is clear that the HPBW is larger than 180 degrees, there is no main beam. For the E plane, the beamwidth ranges between 40 and 90 degrees. On the measured data we can see the effects of the stem and balun holder on the pattern. The stem is oriented to the 180 degree mark. We can see how on the H plane the balun holder reduces by 2 to 3 dB the intensity of the radiation. The beamwidth of the measured data and the computed data tracks each other nicely.

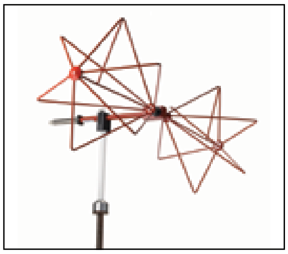

Figure 9: Typical biconical antenna

Figure 11 (page 30) shows a picture of the LPDA antenna and the numerical model as created with specialized software. This is the other typical antenna recommended by CISPR.

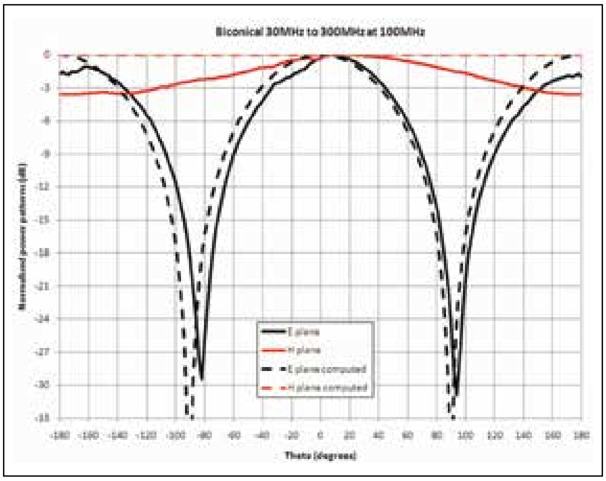

Figure 10: Measured and computed patterns at 100 MHz

It is important to keep in mind that the data shown for the patterns is free space and far field data, and while it is true that it provides an idea of the antenna coverage, it can be misleading once we are in the presence of conductive benches.

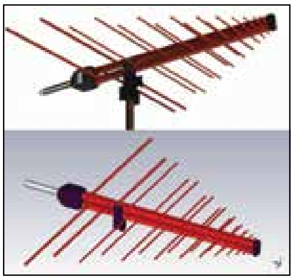

Figure 11: A picture of the measured LPDA antenna and the numerical model geometry

In Figures 12 and 13, we see the measured and modelled performance of the LPDA antenna. There are clearly some differences between the measured data and the computed results. Close examination reveals that the error is under 3 dB. There are several sources of error in the measurement. Using the measured values for the HPBW, the EMC engineer will err on the side of safety.

Figure 12 shows the data at 400 MHz; there is very good agreement between the measured and the computed results. The data for 1 GHz (shown in Figure 13) shows good agreement between measured and computed data for the main beam.

The HPBW of the LPDA antenna is usually fairly flat. This is especially the case for the center of the frequency band that the antenna covers. From about 200 to 1000 MHz the antenna being measured exhibits a HPBW ranging from 100 to about 60 degrees for both planes.

DRH antennas are the antenna of choice for higher frequencies. This family of antennas have been described numerous times in literature. Their radiation pattern has been described starting with [6]. Reference [6] described issues with the radiation pattern of these antennas at frequencies above 12 GHz for models operating in the 1 to 18 GHz range. References [7] and [8] introduced a new design for the 1 to 18 GHz range that has a better behaved pattern where the main beam does not split into multiple beams. Figure 14 shows the measured radiation patterns for the horn analyzed in [6] and the one introduced in [7] and [8]. The data on the left shows a better behaved pattern without the narrow beams and the split main

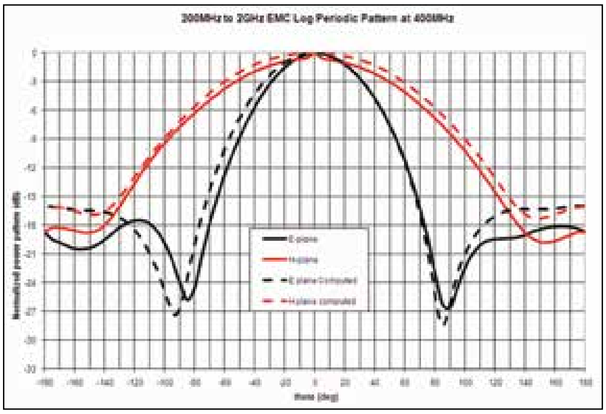

Figure 12: LPDA measured and computed pattern at 400 MHz

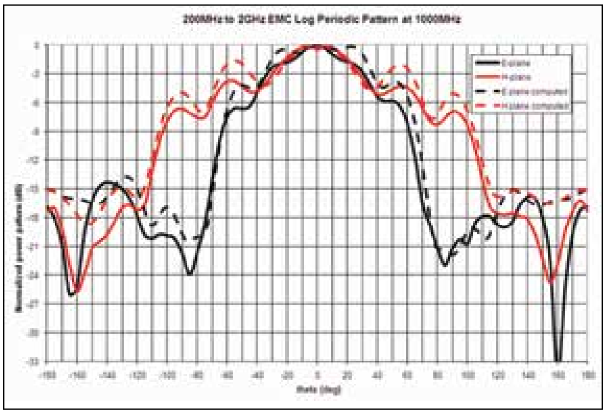

Figure 13: LPDA measured and computed pattern at 1 GHz

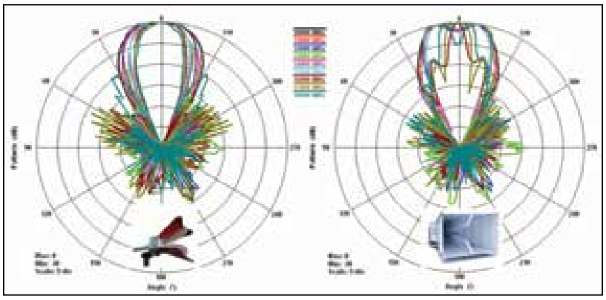

Figure 14: H plane radiation patterns from 10 to 18 GHz. The new (left) and traditional (right) DRH antenna for the 1 to 18 GHz range are shown

lobe of the pattern from the antenna on the right. In references [8, 9] several improvements were made to the radiation patterns of DRH antennas operating in the 200 MHz to 2 GHz range. These are the horns recommended by the authors for ISO 11452-2. These modifications corrected the nulls in the middle on the main beam.

It is important to keep in mind that the data shown for the patterns is free space and far field data, and while it is true that it provides an idea of the antenna coverage, it can be misleading once we are in the presence of conductive benches. Figure 16 shows a typical setup for either CISPR 25 or ISO 11452-2. An antenna is placed 1 m away from the bench that is grounded. For the horizontal polarization case, Figure 17 shows the dramatic effect on the fields that the bench has. While the cable harness will be covered by the antenna, the EUT will barely be in the illumination. This happens at all frequencies and it is related to the boundary conditions that are part of the electromagnetic phenomena.

The LPDA, DRH and SGH antennas have been a stable and long standing part of immunity measurements for many years. Within these we have witnessed the development of model variants with higher gain, customized bandwidths (for radar pulse testing, for example), extended bandwidths and higher power handling, all in an effort to improve the efficiency of the measurement setup with reduced antenna changes and reduced amplifier power.

This trend is continuing and we have already started seeing the emergence of the next generation of immunity antennas.

The DRH) antenna remains an attractive antenna for automotive EMC testing largely due to its wide operating bandwidth, stable radiating characteristics and small size. However, the lower gain at its lower frequency end drives the need for high amplifier input power, which is sometimes impractical to achieve the required high field strength as required by ISO 11542-2. In addition to achieving higher field levels for many immunity tests, it is also critical that the field uniformity (FU) requirements are satisfied (also required by ISO 11451-2). It is accepted that higher antenna gain is typically associated with narrower beam width which may lead to FU deterioration, so finding the correct compromise of size, gain, bandwidth and

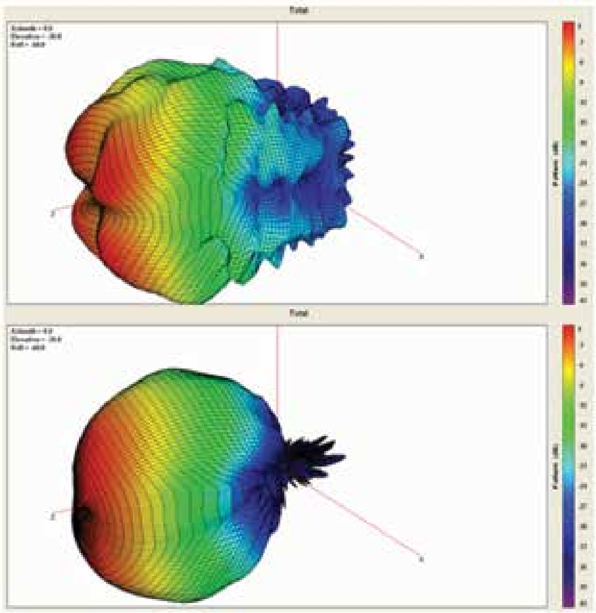

Figure 15: Comparison of pattern at 2 GHz for the traditional and improved 200 MHz to 2 GHz DRHA

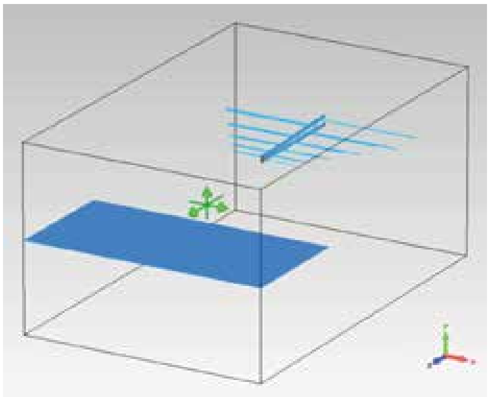

Figure 16: A horizontally polarized LPDA antenna placed in front of a conductive bench

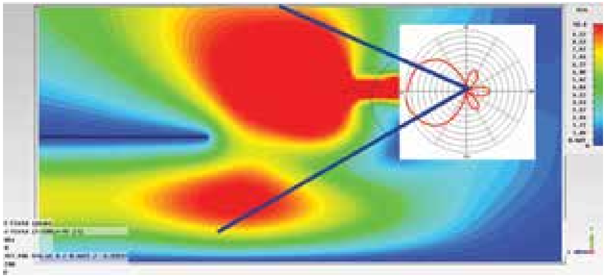

Figure 17: Field distribution from the LPDA shown in Figure 16. The cable harness which rests 5 cm above the bench is covered, but most of the EUT will not be

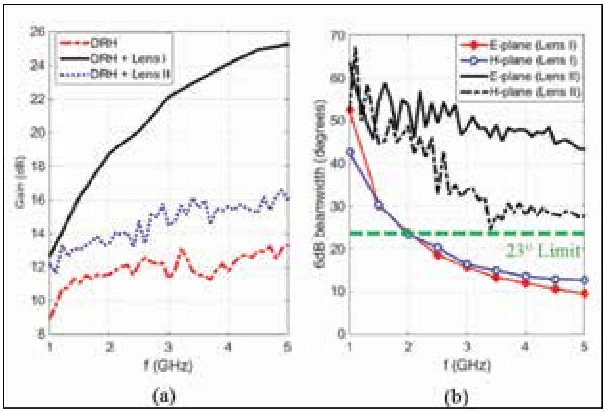

Figure 18: Simulated results of a typical DRH with lenses, (a) gain, (b) 6 dB beamwidth

beamwidth remains one of the antenna designer's goals. To solve this problem, horn antennas with lenses have become increasingly popular for automotive EMC testing applications. With dielectric lenses having properties such as low loss and wide operational frequency range, ridged horn antennas have been able to meet both field strength and FU requirements for automotive EMC testing in the 1 - 5 GHz frequency range. Figure 18 shows how adding a lens to a ridged horn antenna can drastically improve the gain vs bandwidth balance.

Figure 19: A ridged horn lens antenna

A ridged horn antenna with lens (1-3.1GHz), mounted over a stand, is shown in Figure 19. Its lightweight meta-material lens increases the gain of the horn at 1 m distance by 9 dBi. This characteristic makes the antenna ideal for automotive component immunity testing. Such high gain antennas help to meet the narrow band high field strength requirement with less input power for automotive immunity testing. Figure 20 shows the required power vs frequency plots for this antenna to achieve 200V/m and 600V/m.

As described previously, a compliant CISPR 25 chamber with a 2m long ground plane bench for component testing can be as small as 6.2m x 5.3m x 3.6m. For full vehicle testing however, a larger chamber is needed depending on vehicle size, test range length and testing scope. The EMC chamber facility shown on page 20 is an example of a full vehicle chamber where the hybrid polystyrene absorbers previously mentioned have been used to achieve the desired test volume reflectivity performance. The interior dimensions of this 10 meter chamber are approximately 20.8m x 12m x 8m with a 5m diameter quiet zone and 10m range according to CISPR 16-1-4. Absorber coverage was provided on all wall and ceiling surfaces (see Photo 1 on page 20, results shown in Table 4). This newly retrofitted chamber has been designed for automotive EMC testing in accordance with commercial standards CISPR 12, CISPR 25, ISO 11451, ISO 11452 and IEC 61000-4-3, as well as military standard MIL-STD-461E/F.

CONCLUSION

The reader has been introduced to the two main standards for automotive vehicles and components with an overview of the revision status of these and several related standards produced by CISPR and ISO. In this article, we concentrated on designing a chamber to meet the requirements of CISPR 25 and showed that the same chamber is usable for ISO 11452-2. Finally, we have shown some radiation patterns of the typical antennas recommended by the standards, and the performance improvements for a ridged horn fitted with a lens, and benefits in reducing the power demand. The various patterns will give the user an idea of the illumination area that the antennas

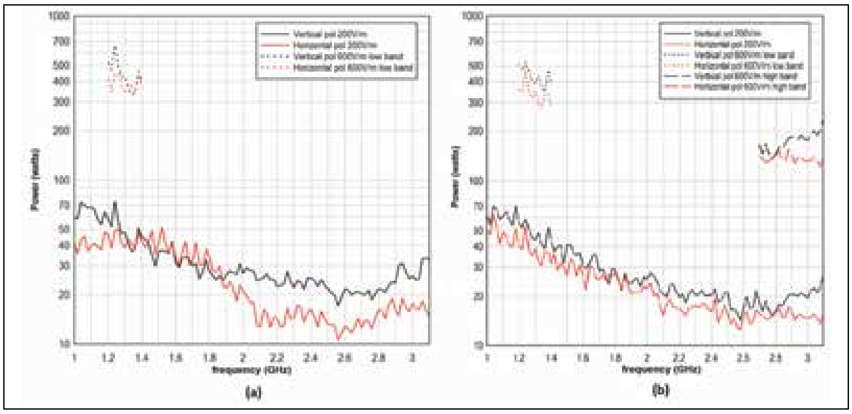

Figure 20: Typical power of ridged horn antenna with lens, (a) for conductive bench, (b) for non-conductive bench

cover when used, and how the presence of the bench can have a dramatic effect on the radiation pattern and the coverage of the antennas. This is an clearly an aberration caused by the setup used for these standards and not of the antennas being used, so as with most measurements, caution is recommended in the selection of antennas, setup and validation steps taken to verify that the intended fields are present over the entire area of the EUT accounting for any distortions or resonances that may be present.

The chamber installation example presented in closing highlights the notion that new installations where possible, should take advantage of the best available technology and latest revisions of the relevant standards, as is shown with the use of the proposed CISPR 25 4th Edition chamber validation method.

ACKNOWLEDGEMENT

The authors would like to thank Mr. Stéphane Blanc of UTAC CERAM Group for providing the measurement data of their automotive EMC 10 meter chamber.

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Nr.	Test type	Standard	Freq. range	Performance
1.	NSA at 10m for 4m dia. QZ	CISPR-16-1-4	30-1000MHz	<4dB
2.	sVSWR	CISPR-16-1-4	1-18GHz	compliant
3.		CISPR 25 Ed 3	70M-2500MHz	Better than 6dB
4.		CISPR 25 Ed 4	150k-1GHz	Long wire compliant
5.	Field Uniformity	IEC-61000-4-3	60M-6GHz	Less than 6dB
6.	Absorber reflectivity	MIL-STD-461E		better than 6 dB from 80 M-250MHz. Better than 10 dB above 250 MHz
7.	Shielding effectiveness	EN 50147-1		Compliant

Table 4: Chamber verification methods and performance results for chamber in Photo 1 (page 20)