Automotive Component EMC Testing: CISPR 25, ISO 11452-2 and Equivalent Standards

Vicente Rodriguez
ETS-Lindgren L.P.
Email: Vince.Rodriguez@ets-lindgren.com

Abstract: This paper presents compiles some information about EMC standards. In particular, the paper concentrates on EMC standards dedicated to testing automotive components. The paper presents an introduction of the primary automotive component standards. Based on this introduction, the CISPR 25 and the ISO 11452-2 automotive EMC standards are analysed since they are the basis for most other standards. The anechoic chamber requirements are studied in detail.
Keywords: EMC measurements, automotive, chamber requirements

Introduction

Automotive standards for EMC are developed mainly by a few organizations. CISPR, SAE and the ISO are those organizations. CISPR and ISO are international organizations. SAE is mainly a United States based organization. As with other areas of EMC, there exist some government organizations that also regulate the testing of components. In most cases their standards refer to the CISPR and ISO documents for guidance on how to perform the test and where to perform it.

Finally, each manufacturer has internal 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. For U.S. based manufacturers, SAE documents are also a guide. The following tables provide an overview of the most common component EMC standards [1].

Table 1 Some of the main SAE automotive component standards

SAE J1113/	Title	Type	Equivalent	Test Setup	Chamber Requirement
1	Electromagnetic Compatibility measurement procedures and limits for vehicle components (except aircraft), 60 Hz~18 GHz	N/A	ISO 11452-1	Definitions	N/A
2	Electromagnetic Compatibility measurement procedures and limits for vehicle components (except aircraft) conducted immunity, 30 Hz to 250 kHz all leads	CI		Conducted immunity test covering 30 Hz to 250 kHz	Shielded room
3	Conducted immunity, 250 kHz to 500 MHz direct injection of radio frequency (RF) power	CI	ISO 11452-7	Conducted immunity test 250 kHz to 500 MHz	Shielded room
4	Immunity to radiated electromagnetic fields—bulk current injection (BCI) method	RI	ISO 11452-4	Radiated immunity using the BCI method	Shielded room
11	Immunity to conducted transients on power leads	CI	ISO 7637-2	Conducted immunity to transients	Shielded room
12	Electrical interference by conduction and coupling—coupling clamp	CI	ISO 7637-3	Conducted immunity to different coupling mechanisms	Shielded room
13	Electromagnetic compatibility procedure for vehicle components-immunity to electrostatic discharge	ESD	ISO 10605	ESD	Shielded room

(Continued)

21	Electromagnetic compatibility procedure for vehicle components—immunity to electromagnetic fields 10 kHz to 18 GHz absorber lined chambers	RI	ISO 11452-2 ECE 10	An absorber lined chamber is required. Antennas and field generator to cover the range are required. No need to scan antenna; a test bench is required.	Absorber lined chamber with a specific arrangement
22	Electromagnetic compatibility measurement procedure for vehicle components—immunity to radiated magnetic fields from power lines	RI	ISO 11452-8	Helmholtz coils are used	Shielded room
23	Electromagnetic compatibility measurement procedure for vehicle components—immunity to radiated electromagnetic fields,10 kHz to 200 MHz stripline method	RI	ISO 11452-5	Radiated immunity with a TEM device	Shielded room, open sides devices
24	Immunity to radiated electromagnetic fields 10 kHz to 200 MHz—Crawford TEM cell, and 10 kHz to 5 GHz wideband TEM cell	RI	ISO 11452-3	Shielded TEM devices	N/A
27	Immunity to radiated electromagnetic fields reverberation method	RI	-	Reverberation chamber design is based on the SAE J1113/27-1995 Standard (or equivalently, General Motors Engineering Standards GM9114P-1997, GM9120P-1993), the draft GM Worldwide Engineering Standard GMW3100GS	Reverberation chamber
41	Limits and methods of measurement of radio disturbance characteristics of components and modules for the protection of receivers used on board vehicles	RE	CISPR 25	An absorber lined chamber is required. Antennas and field generator to cover the range are required. No need to scan antenna; a test bench is required	Absorbed lined chamber or TEM cell

Table 2 ISO 11452 and some of its parts

ISO 11452	Title	Type	Equivalent	Test Setup	Chamber Requirement
1	Part 1: General and definition	N/A	SAE J1113/21	An absorber lined chamber is required. Antennas and field generator to cover the range are required. No need to scan	Absorber lined chamber
2	Part 2: Absorber lined chamber	RI	SAE J1113/21	An absorber lined chamber is required. Antennas and field generator to cover the range are required. No need to scan	Absorber lined chamber
3	Part 3: Transverse electromagnetic (TEM) cell	RI	SAE J1113/24	TEM cell	N/A
4	Part 4: Bulk current injection	RI	SAE J1113/4	Radiated immunity using the BCI method	Shielded room
5	Part 5: Stripline	RI	SAE J1113/23	Radiated immunity using a stripline	Shielded room
7	Part 7	RI	SAE J1113/3	-	Shielded room

Table 1 does not show all the EMC standards related to automotive published by the SAE, but it gives an overview of some of them plus it cross-references them to the equivalent ISO standard or CISPR documents.

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. Not shown in Table 2 are parts such as Part 8 that deals with magnetic field immunity and that is equivalent to SAE J1113/22. ISO 11542-8 was introduced in 2007 and it takes some methodology from MIL-STD-461[2].

As mentioned above, government standards and directives in many cases refer to the CISPR or ISO methods. 2004/144EC, 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

Most people tend to think of CISPR 25 as a vehicle component emissions testing. The truth is that CISPR 25 is a far more complex standard. The title of the standard is self-describing; it suggests that CISPR 25 deals with "radio disturbance characteristics for the protection of receivers used on board vehicles, boats and on devices"[3].

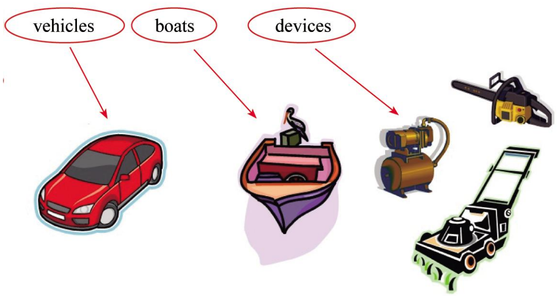


Figure 1 CISPR 25 EUTs

Hence CISPR 25 deals with to what level electric and electronic systems affect receivers mounted on automobiles powered by internal combustion engines, boats powered by internal combustion engines, and devices also powered by internal combustion engines, but not for the transport of people. This last category includes compressors, chainsaws, garden equipment, etc. Furthermore, the standard 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. A sort of a self-immunity test is performed. The other section of the standard deals with measurement of component and modules. We are going to concentrate on this particular section in this paper. More specifically, this paper is going to concentrate on the chamber requirements for the standard. The standard states that the electromagnetic noise level in the test area has to be 6 dB lower than the lowest level being measured. If CISPR 25 is consulted, we find that levels as low as 18 dB (μ V/m) this means that the ambient noise must be 12 dB (μ V/m) minimum. This calls for a shielded room to be used. The shielded room will keep all the noise from the environment out of the test area so that the EUT will be the main source of noise.

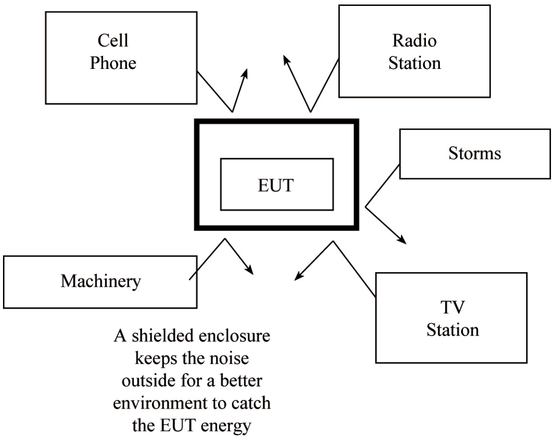


Figure 2 A shielded room blocks the noise from outdoor sources of EM interference

While at low frequencies the shielded room is too small to support resonant modes, it is very possible for these modes to exist as frequency increases. When these resonant modes appear, they can cause significant error on the measurements. To avoid these errors, the shielded room is covered with absorber on its interior walls. CISPR 25 covers a frequency range of 150 kHz to 2 GHz. Unfortunately, absorber technology is unable to provide absorption at levels down in the 150 kHz range. On the other side, as we will see the chamber sizes are small generally so no resonant behaviour appears down at those low frequencies. The standard thus concentrates on 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 two types of technology on the market today. Polyurethane absorbers usually 36 inches (1 m) in depth can be used and hybrid absorbers using ferrite materials and polyurethane foams are also a good choice. Figures 3 and 4 show the typical performance of these materials compared to the CISPR 25 limit.

The typical CISPR 25 anechoic chamber is guided by the standard. Several guidelines must be followed when

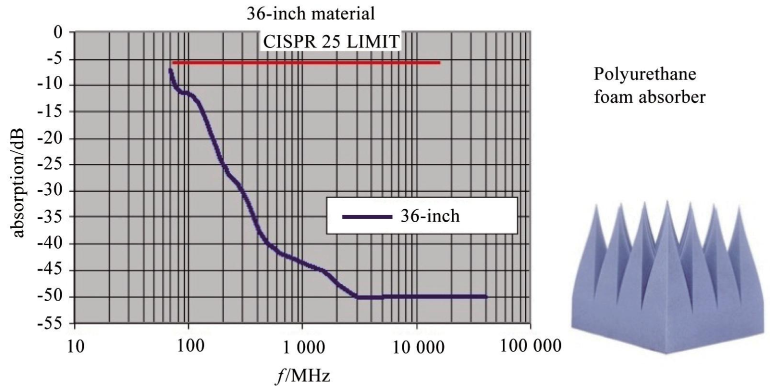


Figure 3 Typical performance of 36" material

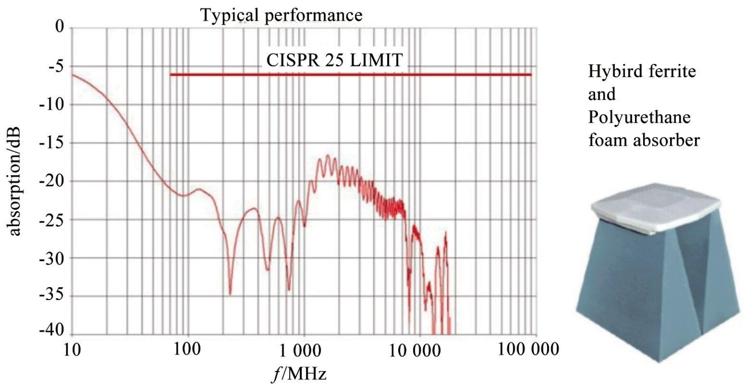


Figure 4 Typical performance of hybrid material

sizing the chamber and the starting point is going to be the EUT, which is going to determine the size of the test bench. Figure 5 shows a typical test bench used in a CISPR 25 chamber and an ISO 11452-2 type chamber.

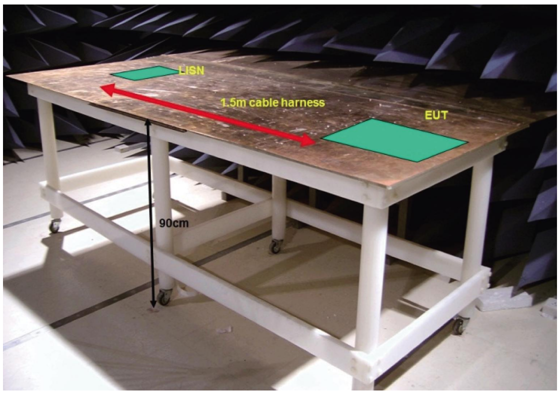


Figure 5 A typical conductive test bench

As Figure 5 shows, the bench must accommodate the largest EUT and all the cables that are needed to power and to send signals to that device. The cables are put together in a cable harness that is placed in the front of the bench. It is the cable harness that is illuminated 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 process is used in MIL-STD-461 and in ISO 11452[2]. A line impedance stabilization network is used to bring power to the device.

Figure 6 shows how the size of the bench is determined. The bench must extend all the way to the shield. In most cases, it is grounded to the wall of the shielded room. But it can be grounded to the floor as well.

Once the size of the bench has been determined based on the largest EUT, the next step is to determine the width of the chamber. For the present exercise we will assume that hybrid absorber with a depth of 60 cm is used to line the walls and ceiling of the chamber. Figure 4 has shown that this type of absorber is sufficient to meet the CISPR 25 requirements. Figure 7 shows the width of the chamber. The width is based on the thickness of the absorber material and a one meter space is then left between the bench and the tips of the absorbing material. The bench of course must fit inside the chamber and it is the dominant factor.

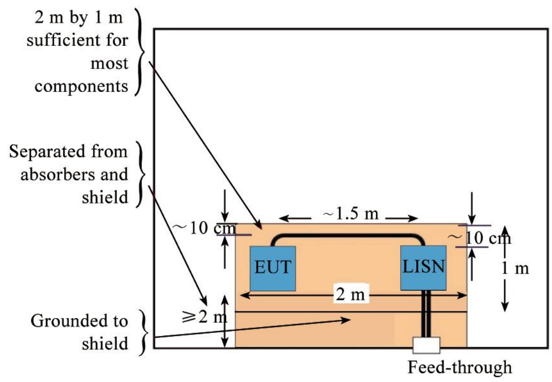


Figure 6 Sizing the bench

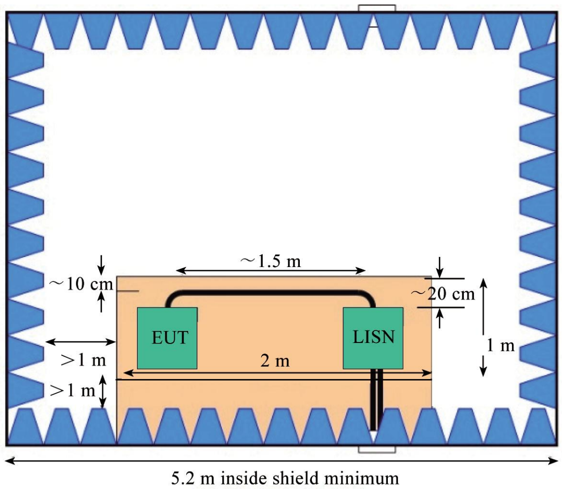


Figure 7 Width of the CISPR 25 chamber

At this point, only the height and the length of the chamber are yet to be determined. CISPR 25 has some rules that are going to determine the necessary space. The first and most important rule is the test distance. Per CISPR 25, the emissions are measured at a distance of 1 m from the cable harness to the antenna. Since CISPR is a document prepared by the CISPR organization, its rules on antennas and receivers are given by the CISPR 16 document [4]. The recommended antennas are listed in the standard. 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 log periodic dipole array (LPDA) and finally from 1 to 2 GHz, the author recommends a dual ridge horn antenna. The other rule stated in CISPR 25 is 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 LPDA, the distance is measured from the tip of the antenna. Finally, for the horn antennas the distance is measured from the front or aperture plane of the antenna. The longest antenna is the LPDA. Typical LPDAs for the 200 MHz to 2 GHz range are about 1 m in length. In addition to the 1 m test distance and the 1 m for the antenna size, we have 1 m from the back of the antenna to the tips of the absorber.

Figure 8 shows the antenna (an LPDA) in the chamber for the CISPR 25 set up. The height is the only dimension left. The largest antenna is going to be 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 5 suggests is 90 cm in height. The 1 m rule for the separation between antenna and absorber tip will determine the size of the chamber as shown in Figure 9.

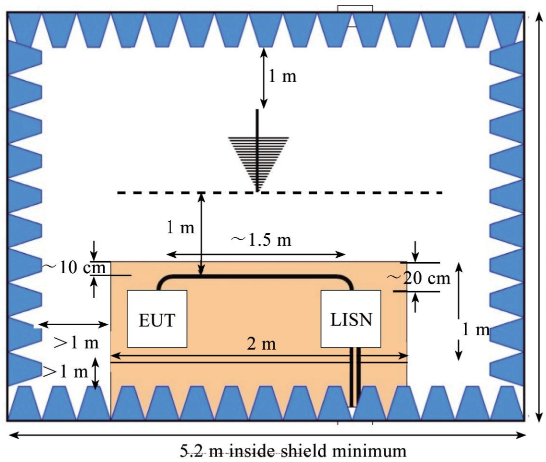


Figure 8 Determining the length of the chamber for CISPR 25

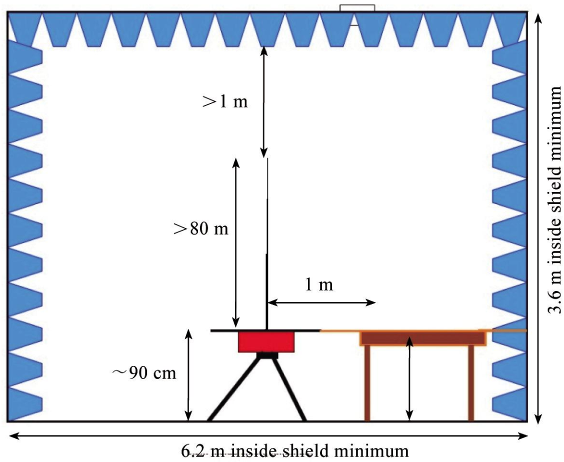


Figure 9 Height of the CISPR 25 chamber

Hence, from what we've seen above, a chamber lined with hybrid absorber with a size of 5.2 m wide by 6.2 m long and 3.6 m high will meet the requirements for performing CISPR 25 tests. But as the tables above suggest, such a chamber will also be usable for SAE J1113/41 and, as we will see in the next section of this paper, this chamber will also meet the requirements of

ISO 11452-2. Furthermore, since this is a shielded environment, most of the standards requiring a shielded room can be performed inside the chamber designed in the present section.

CISPR 25 does not have a mandatory test to validate the chamber. The latest versions call for a comparison between the performance in the chamber and the OATS. One must be very careful in this comparison. Especially at low frequencies (below 30 MHz or below 100 MHz if no hybrid absorber is used) the grounding of the bench is going to have a large effect. It is important to perform the measurement on the OATS using a bench that it is grounded in the same way as the bench is grounded in the chamber. Since it is easier to ground the bench at the OATS to the ground plane, it is recommended that the same grounding is used in the chamber during the comparison measurements. Additionally, damped resonant behaviours related to the chamber size will not be seen on the OATS. Some manufacturers prefer to do an inter-comparison between chambers using a golden unit or a reference radiator.

ISO 11452-2

The ISO 11452-2 standard applies to the 200 MHz to 18 GHz range. This is an immunity standard and like many automotive, military and aerospace standards, it calls for very high fields to be generated. Table 3 shows the severity levels. At frequencies below 200 MHz, antennas get physically large and also they tend to be less efficient. For frequencies below 200 MHz, the standard recommends the methods stated in Parts 4, 3, and 5 of the ISO 11452 standard. Those sections describe the bulk current injection, TEM and stripline methods. These other methods are far more efficient and economical to test for immunity to high fields.

Table 3 ISO 11452-2 severity levels

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

The nature of the immunity test calls for a shielded room. After all, the test calls for high levels of electromagnetic energy to be generated to make electronic systems fail. In addition, most countries forbid the indiscriminate radiation of energy across wide frequency bands without licenses. Since the test is conducted at frequencies above 200 MHz, the chances of resonant behaviours being developed inside the shield room is increased. Hence, the use of absorber is required. The chamber is treated such that the reflectivity in the area of the EUT is -10 dB. Figures 3 and 4 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. ISO 11452-2 does not have any specifications on the chambers. 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 choice.

On Antennas, Patterns and Grounded Benches

To conclude this paper, we shall talk a bit about the antennas. Specifically, we are going to concentrate on the typical biconical antenna, LPDA and DRHA recommended for CISPR 25 and the DRHA recommended for ISO 11452-2. Recently it has become important to understand the radiation characteristics of these antennas. The typical biconical antenna, shown in Figure 10, is an omnidirectional radiator.

Figure 10 Typical biconical antenna

Its pattern shown in Figure 11 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°, there is no main beam. For the E-plane, the beamwidth ranges between 40° and 90°. 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° 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.

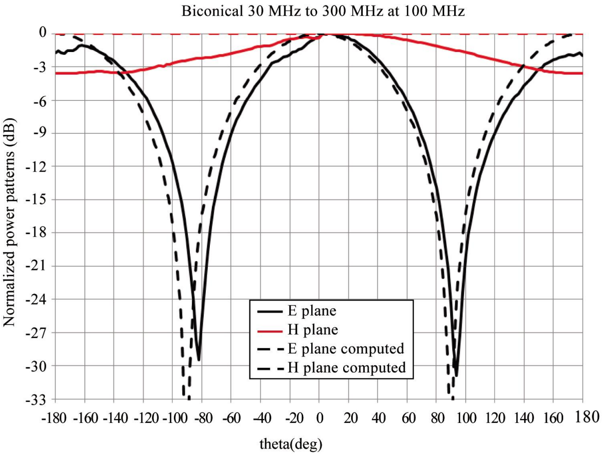


Figure 11 Measured and computed patterns at 100 MHz

Figure 12 shows a picture of the LPDA antenna and the numerical model created in MW Studio™. This is the other typical antenna recommended by CISPR.

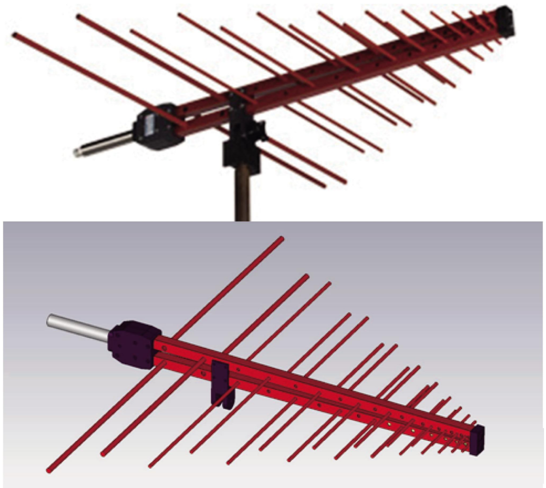


Figure 12 A picture of the measured LPDA and the numerical model geometry in MW Studio™

In Figures 13 to 14, 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.

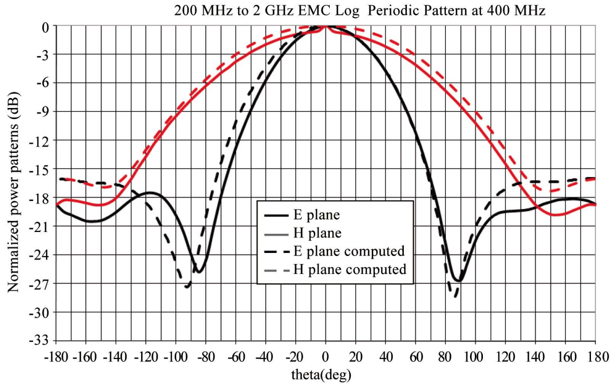


Figure 13 LPDA measured and computed pattern at 400 MHz

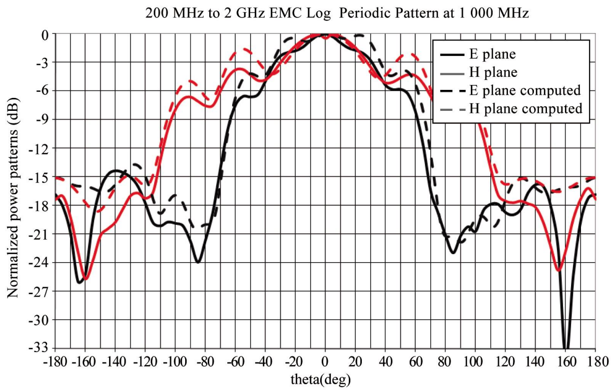


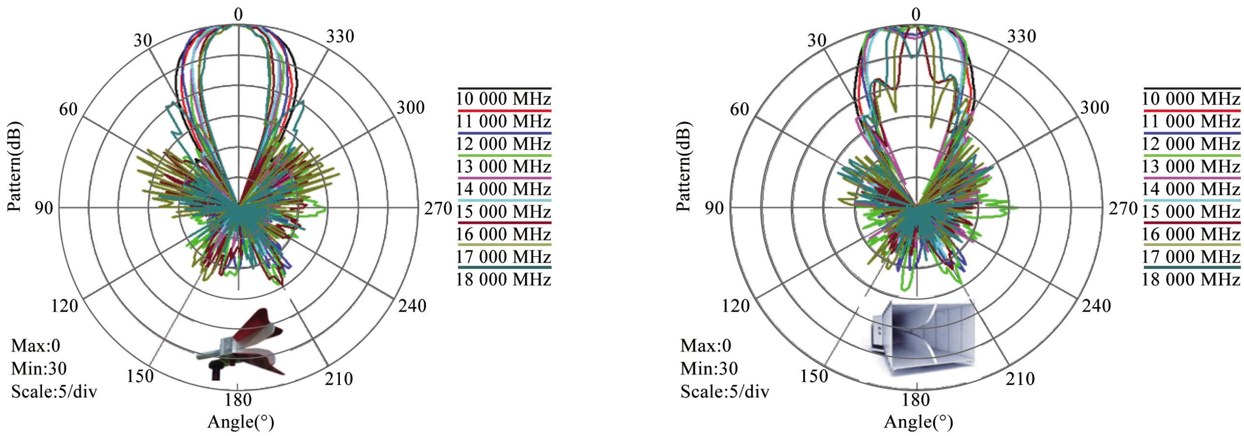
Figure 14 LPDA measured and computed pattern at 1 GHz

Figure 13 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 14) shows good agreement between measured and computed data for the main beam.

The HPBW of the LPDA antennas is usually fairly flat. This is especially the case for the center of the frequency band that the antenna covers. From about 200 to 1 000 MHz the antenna being measured exhibits a HPBW ranging from 100° to about 60° for both planes.

Dual ridge horn antennas are the antenna of choice for higher frequencies. This family of antennas have been described numerous times in the literature. Their radiation pattern has been described starting with [5]. Reference [5] 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 [6] and [7] 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 15 shows the measured radiation patterns for the horn analyzed in [5] and the one introduced in [6] and [7]. The data on the left shows a better behaved pattern without the narrow beams and the split main lobe of the pattern from the antenna on the right.

In references [8] and [9] several improvements were made to the radiation patterns of dual ridge horn antennas operating in the 200 MHz to 2 GHz range. These are the horns recommended by the author for ISO 11452-2. These modifications corrected the nulls in the middle on the main beam.



The new (left) and traditional (right) dual ridge horn antenna for the 10~18 GHz range are shown.

Figure 15 H-plane radiation patterns from 10~18 GHz

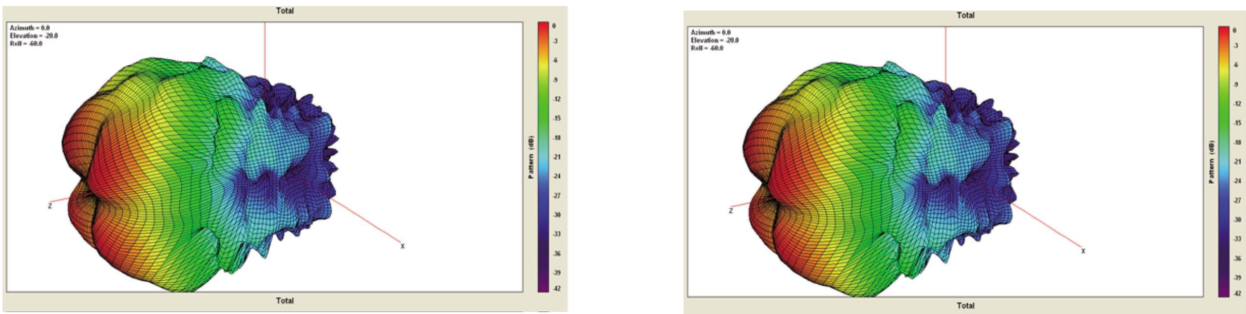


Figure 16 Comparison of pattern at 2 GHz for the traditional and improved 200 MHz to 2 GHz DRHA

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 17 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 18 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.

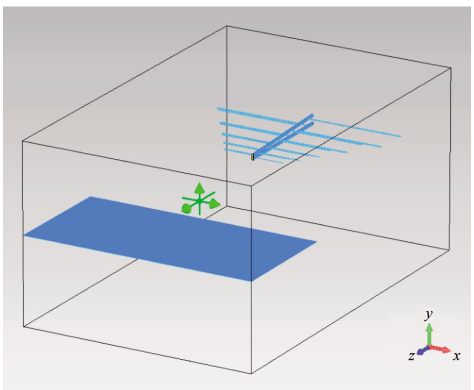


Figure 17 A horizontally polarized LPDA antenna placed in front of a conductive bench

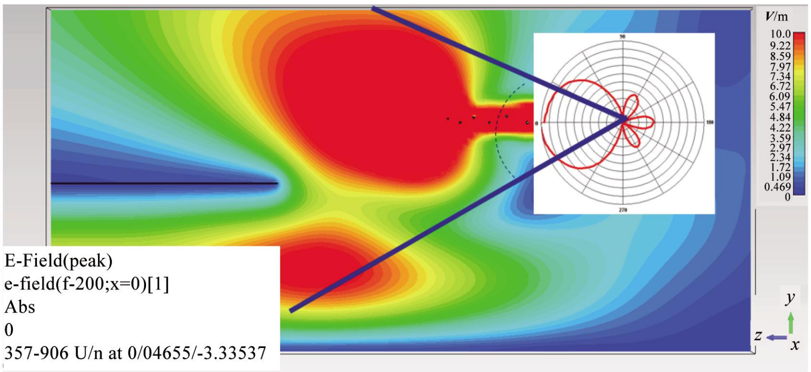


Figure 18 Field distribution from the LPDA shown in Figure 17

Conclusion

The reader has been introduced to the two main standards for automotive components. In this paper, we concentrated on designing a chamber to meet the requirements of CISPR 25 and show that the same chamber is usable for ISO 11452-2. Finally, we have shown some radiation patterns of the typical antennas recommended by the standard. The patterns will give the user an idea of the illumination area that the antennas cover when used. However, it has been shown how the presence of the bench can have a dramatic effect on the radiation pattern and the coverage of the antennas. This is, however, inherent to the setup used for these standards and not to the antennas being used.

References

[1] SAE. Surface Vehicle Electromagnetic Compatibility (EMC) Standards Manual: 1999 Ed. [M]. Warrendale: Society of Automotive Engineers, Inc.,1999.

[2] U.S. Department of Defense. MIL-STD-461F Department of Defense Interface Standard: requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment [S]. U.S.: Department of Defense,2007.

[3] IEC. CISPR 25 Radio disturbance characteristics for the protection of receivers used on board vehicles, boats, and on devices-Limits and methods of measurement 2nd Ed [S]. Geneva: IEC, 2002.

[4] IEC. CISPR 16-1-4 Specification for radio disturbance and immunity measurement apparatus and methods Part 1-4 radio disturbance and immunity measuring apparatus - Antennas and test sites for radiated disturbance measurements. 3rd Ed [S]. Geneva: IEC,2010.

[5] C. Bruns, P. Leuchtmann, and R. Vahldieck. Analysis of a 1-18 GHz Broadband Double-Ridge Antenna [J]. IEEE Transactions of Electromagnetic Compatibility, 2003, Vol 45: 55-60.

[6] V. Rodriguez. New Broadband EMC double-ridge guide horn antenna [J]. RF Design, 2004,(5): 44-50.

[7] V. Rodriguez. A new broadband Double Ridge guide Horn with improved Radiation Pattern for Electromagnetic Compatibility Testing [C]// R. Vahldieck. 16th international Zurich symposium on Electromagnetic compatibility. Zurich: ETH Zurich, 2005.

[8] V. Rodriguez. Improvements to Broadband Dual Ridge Waveguide Horn Antennas [C]// Anthony Q. Martin. 2009 IEEE International Symposium on Antennas and Propagation and USNC/URSI National Radio Science Meeting. Charleston: IEEE AP-S, 2009.

[9] V. Rodriguez. Recent Improvements to Dual Ridge Horn Antennas: The 200MHz to 2GHz and 18GHz to 40GHz Models [C]// Glen Watkins. 2009 IEEE International Symposium on EMC. Austin: IEEE EMC-S, 2009.

Vicente Rodriguez attended Ole Miss, in Oxford MS, where he obtained his B.S.E.E. M.S. and Ph.D. degrees in 1994, 1996 and 1999 respectively. In June 2000, Dr. Rodriguez joined EMC Test Systems (now ETS-Lindgren) as an RF and Electromagnetics engineer. In 2006, Dr. Rodriguez became Acting Antenna Product Manager placing him in charge of the development, marketing and maintenance of the antenna product line. In 2010, Dr. Rodriguez became the Antenna Product Manager. He has been involved in the RF anechoic design of several chambers, including rectangular and taper antenna pattern measurement chambers, some of which operate from 100 MHz to 40 GHz. He was the principal RF engineer for the anechoic chamber at the Brazilian Institute for Space Research (INPE), the largest chamber in Latin America and the only fully automotive EMC and Satellite testing chamber. Dr. Rodriguez developed new broadband double and quad-ridged guide horn antennas with single lobe pattern and high field generator horn antennas for the automotive and defense industry.

Dr. Rodriguez is a Senior Member of the IEEE and several of its technical societies. He is also a Senior Member of the Antenna Measurements Techniques Association (AMTA) and a member of its Board of Directors.