AUTOMOTIVE EMC TEST HARNESSES: STANDARD LENGTHS AND THEIR EFFECT ON RADIATED EMISSIONS

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Abstract

The harness used on any vehicle is unique to that model, having a specific length of wiring to optimise connections between circuits and a unique configuration of signal and power cabling for each model. The international automotive EMC standards, however, all specify specific "standard" lengths for test purposes. While using a standard harness length makes comparison of results easier to perform for different electronic-sub assemblies (ESA) for use on vehicles, does it affect the actual test performance? Presented here is the result of radiated emissions tests conducted to the European automotive EMC directive (95/54/EC) utilising five different "standard" length test harnesses and a wide-band noise source. The results illustrate the differences that the harness length has on this one test technique and discussion on the implications this may have on final installation is provided.

Introduction

The plethora of international automotive test standards (EU, ISO, CISPR, SAE) all use a range of standard length harnesses for the testing of automotive electronic sub-assemblies (ESA). For example the CISPR-25 standard suggests up to 2m (1.5m recommended) harness length for radiated emissions tests and 0.2m for conducted emissions tests. In the test chamber this standardisation makes comparison easier between different ESA, but on vehicle there are likely to be significant differences in the actual harness in use and the test harness. The differences are not just in absolute harness length, the length between any ESA and its individual actuators and sensors will undoubtedly not be of equal distance as they are in the test harness. It is not uncommon to find automotive harnesses of over 10m in length from a single ESA with drops from 50cm onwards at irregular intervals, and of course every vehicle has a unique harness and fitting arrangement.

It has been accepted for some time that the differences in on-vehicle harness length and automotive EMC test harness length will be a conundrum unlikely to be solved unless all vehicles adopt the same harness. However, there is a potentially greater problem to cross comparison of test results created by the difference in standard harness length for the same test techniques. The CISPR-25 example above cites two "standard" test harness lengths, but these length differences do not have a significant impact, as the tests are different (i.e. conducted and radiated emissions). Radiated immunity testing in directive 95/54/EC can use a

Table 1: International Automotive EMC Standards and their Test Harnesses

Harness Length (m)		Automotive Standard	Test Type	Test Method
Typical	Maximum			
1.5		95/54/EC	Radiated Emissions	Free Field (SAC)
2.0	2.7	95/54/EC	Radiated Immunity	150mm Stripline
1.0		95/54/EC	Radiated Immunity	BCI
1.5		95/54/EC	Radiated Immunity	Free Field (SAC)
0.2		CISPR-25	Conducted Emissions	LISN
1.5	2.0	CISPR-25	Radiated Emissions	Free Field (SAC)
1.5		CISPR-25	Conducted Emissions	Current Probe
0.5		ISO 7637	Conducted Immunity	Direct Injection
0.5		ISO 10605	ESD	Contact/Air Discharge
1.5	1.7	ISO 11452-2	Radiated Immunity	Free Field (SAC)
1.0		ISO 11452-4	Radiated Immunity	BCI
2.0	3.0	ISO 11452-5	Radiated Immunity	150mm Stripline
1.5	1.7	ISO 11452-6	Radiated Immunity	Parallel Plate

combination of three harness lengths; 2m in a 150mm stripline, 1.5m in free field and 1.0m for bulk current injection (BCI) testing. Can results from different length harnesses really represent the same test set-up and offer cross comparison? Other examples exist and it was this disparity between the test standards and the harnesses they specify that lead the authors to investigate this aspect of automotive EMC testing.

Presented here are the results of radiated emissions testing over a range of five standard harness lengths; 0.2m, 0.5m, 1.0m, 1.5m and 2.0m. Testing has also been performed on the effect of the harness length on conducted emissions [6] and immunity tests are planned.

Standard Harnesses and Noise Source

The harnesses used here are all of similar construction consisting of 16-strand 0.2mm^2 (0.6mm^2 core) automotive grade wire terminated by BNC connectors to isolate the harness under test from the connecting equipment (figure 1). The harnesses are constructed on 50mm insulating plinths to provide a rigid assembly that was easy to change between harnesses with minimal effect on the support equipment and test set-up. The harness consists of 2 wires, a signal wire and a ground wire, these are separated by 10mm along the length of the test harness. The separation is typical of the possible separation in an automotive harness "bunch" and a convenient distance from which loop area can be calculated.

The ground wire of the harnesses is removable to allow a grounding braid to be connected to the table ground or other reference point at the BNC connector. This enables the test harnesses to be used to examine the differences between wired ground and chassis grounded ESA.

A commercially available wideband noise source (comparison noise emitter, CNE) was used to provide a signal for the test harnesses, this features a BNC connector for coupling with its supplied radiating antennae and was connected to the harness via a 50Ω co-axial cable. The CNE generates a signal over the 9kHz to 2GHz frequency range.

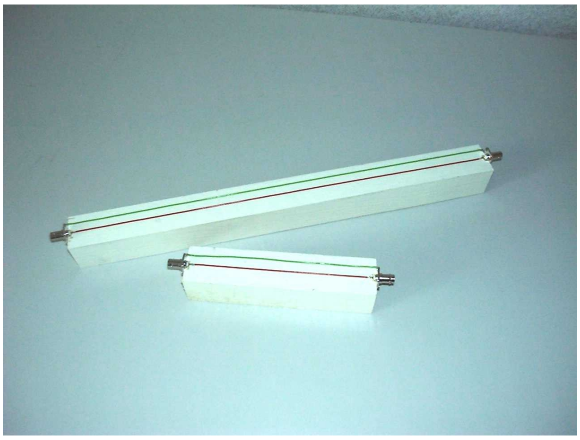
Figure 1: Test Harnesses (0.2m and 0.5m)

International Test Standard Harness Lengths

There are approximately five standard length harnesses used for automotive EMC testing, each is typically used for a different test type (table 1). The effect of these different harness lengths is to increase the complexity and expense of performing automotive EMC tests, particularly as many engineers become familiar with one test harness length and forget that a different harness is required when changing tests. The most popular test length is 1.5m, used for the majority of radiated emissions testing and for many free-field immunity tests.

Test Method

The test set-up of 95/54/EC was used for the radiated emissions tests, this is similar to the set-up described in CISPR-25, and as the only legislative automotive EMC standard is probably one of the most important internationally, although not necessarily the most stringent (figure 2). The frequency limits of 95/54/EC (30MHz-1GHz) and resolution bandwidth (120kHz) were used with peak detector only. No test levels were applied as the testing is comparative only and the CNE is not the item under test.

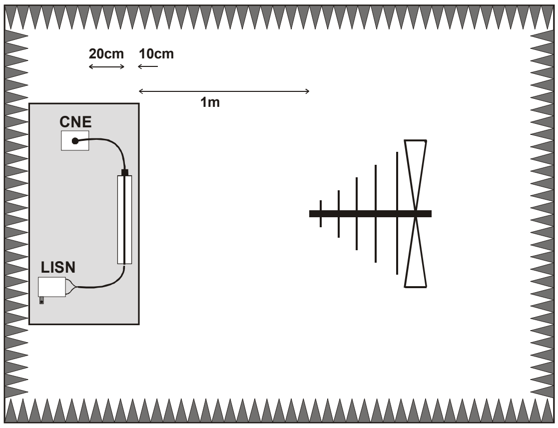

Figure 2: Test Set-Up

The CNE is used to generate a test signal for the harnesses to transmit (figure 3). Although the CNE is self-powered by dry-cell batteries, the harness was connected via CISPR-25 LISN's to provide 50Ω terminations and to permit comparison of wired and chassis grounded signal return paths. Horizontal and vertical polarisations of the receiving antenna were examined.

Tests with the wired ground were performed in each polarisation, then the ground changed to chassis ground and the tests repeated on each harness. The signal wire was always at 10cm from the edge of the ground plane and closer to the antenna than the ground wire for the wired ground tests.

Results

The results are presented in this paper for the maximum emissions from either polarisation (different grounding arrangements are shown independently), this is consistent with the approach taken for the automotive standards under discussion.

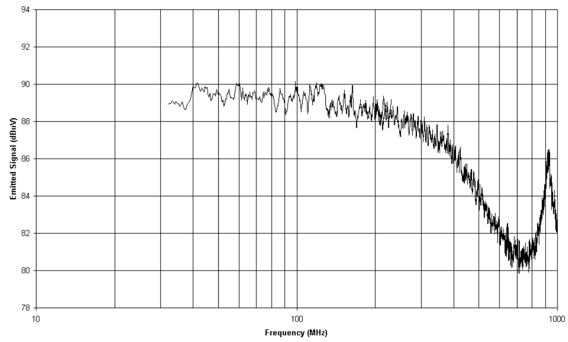

Figure 3: CNE Output

The results are not what were initially expected. The preference for longer harness lengths in the radiated emissions test standards might suggest that the emissions from the 1.5m and 2.0m harnesses have significantly greater amplitude than the shorter harnesses. The emissions results obtained here are of similar magnitude for all the harness lengths above 100MHz, in all configurations (horizontal and vertical polarisation, chassis and wired ground arrangements), only below 100MHz do the longer harnesses have a dominant effect on general radiated emission levels.

There are noticeable differences at lower frequencies (particularly below 50MHz) where the longer harnesses do tend to exhibit higher emitted levels, particularly for the wired ground arrangement. The emissions traces are of similar shape below 50MHz for all the harnesses (although different from the raw CNE output, figure 3). The trend is more easily observed below 100MHz and the traces appear to converge in the 50MHz-60MHz region, regardless of harness length, before the on-set of some harness dependant resonance (conducted emissions measurements and calculations using the telegraphers equations suggesting resonance in the 20MHz region for 2m down to 200MHz for the 0,2m harness lengths [6]).

At higher frequencies there is a noticeable difference in the resonance characteristics of the harnesses but these occur at similar peak magnitudes, the longer harnesses appearing to have more resonance modes. There are more noticeable differences between wired and chassis grounded arrangements at higher frequencies (above 100MHz), the chassis ground appearing to exhibit slightly less magnitude variation across resonance peaks.

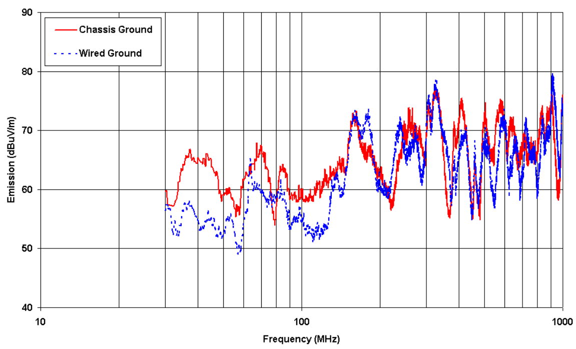

Figure 4: 0.2m Harness Maximum Emissions

0.2m Harness. The shortest harness has relatively flat emissions up to 100MHz. The chassis and wired ground configurations exhibit similar emission envelopes, being either co-incident or at a slight offset from each other across most of the frequency range examined.

0.5m Harness. This harness has similar relatively flat emissions as the 0.2m harness at lower frequencies, with slightly higher levels below 50MHz. The chassis and wired ground exhibit similar emission envelopes with exceptions of significantly lower emissions in the resonance dips at 58MHz and 465MHz for the wired ground arrangement.

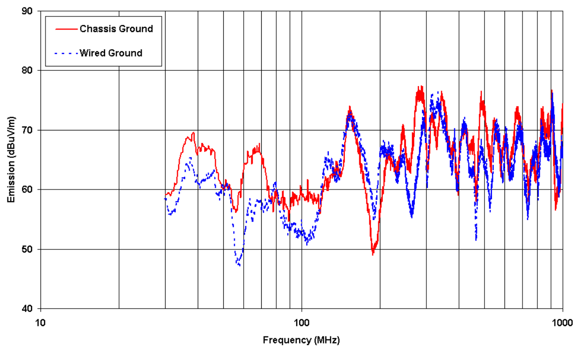

Figure 5: 0.5m Harness Maximum Emissions

1.0m Harness. The lower frequency emissions (below 50MHz) are significantly higher than the shorter harnesses, but similar to the longer harness emission levels. There is a significant divergence of the ground arrangement levels between 58MHz and

65MHz, and at the 300MHz and 486MHz resonance dips where the wired ground arrangement has significantly lower emission levels.

1.5m Harness. The 95/54/EC standard harness exhibits several interesting phenomena at low frequency for the chassis ground configuration, where noticeable dips at 39MHz and 79MHz occur with a higher frequency dip at 375MHz. Wired ground arrangement continues to exhibit a similar envelope to the shorter harness lengths, with significant resonance dips at 110MHz, 159MHz, 212MHz and 426MHz. The two ground configurations are almost co-incident over the upper frequency span only (900MHz to 1GHz).

2.0m Harness. The longest harness examined exhibits some of the largest amplitude changes across the complete frequency range under consideration. The harness exhibits a similar low frequency dip that occurs on the 1.5m harness in the chassis ground configuration at 39MHz and very low dips between 50MHz and 55MHz in the wired ground result. The resonance dips at higher frequencies 125MHz and 245MHz for wired ground and 327MHz in the chassis ground result are much sharper than occur with the other harness lengths.

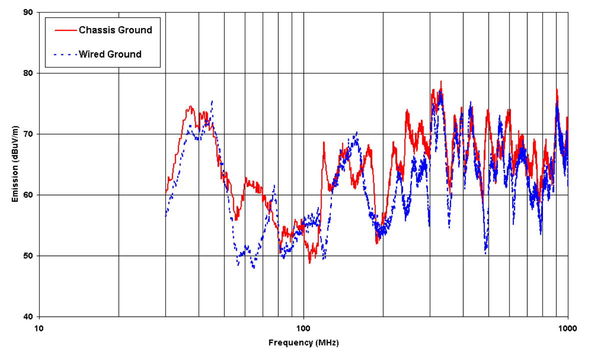

Figure 6: 1.0m Harness Maximum Emissions

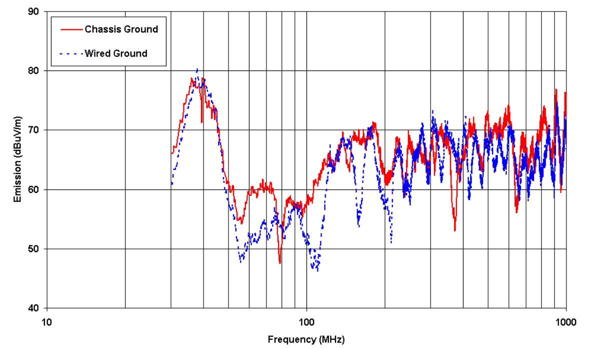

Figure 7: 1.5m Harness Maximum Emissions

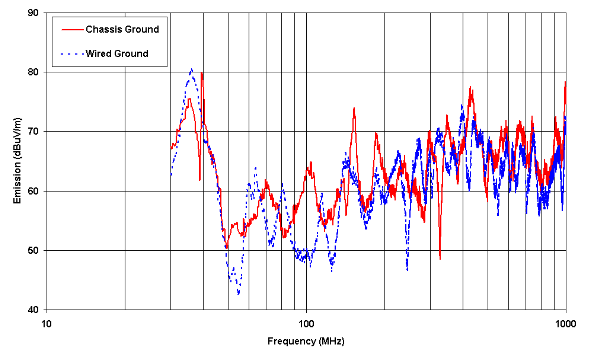

Figure 8: 2.0m Harness Maximum Emissions

Conclusion

Although the standards for radiated emissions dictate use of a 1.5m harness in 95/54/EC and up to 2m in CISPR-25, the length of the harness itself appears to have little overall effect on the magnitude of the emissions above 100MHz and primarily affects the resonance pattern. Using a harness of any length other than those specified in the standards may not be suitable to obtain compliance, but for pre-compliance testing the results will be close enough to suggest if an ESA will pass the standard limits or not above 100MHz.

Below 100MHz the effect of harness length is significant on the radiated emissions levels obtained, with the longer harnesses providing significantly better antennae at these lower frequencies. This was slightly unexpected as up to resonance the conducted results suggest the longer harnesses produce higher impedance [6], consequently it would be predicted that lower power was conducted into the harness.

The effect of the harness length dependant resonance patterns above 100MHz should not be underestimated and significant difference (over 20dB) at any particular frequency can easily mean the difference between pass and failing the relevant standards. Hence although overall the levels are not significantly different, at any specific frequency, the resonance pattern will affect the result, as will the grounding method.

The wired ground arrangement generally appears to offer the lowest radiated emission levels as might be expected from a slightly smaller loop area compared to the chassis ground arrangement. The longer harness lengths do exhibit increased signal level differences between wired and chassis grounded emissions, again as might be expected due to increase in loop area. The differences in the measurement set-up are relatively small, but in a real installation there could be significant differences as the length of the wired path will generally be greater than the standard harnesses used here and therefore greater loop area, more resonance peaks and potentially different on-vehicle characteristics.

Acknowledgements

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References

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