

Automotive EMC Test Harnesses: Standard Lengths And Their Effect On Conducted Emissions

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Abstract: The harness used on any vehicle is unique to that model, having a specific length of wiring to optimize 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.

Keywords: automotive EMC, test harness, conducted emissions, harness length

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 between 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 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 conducted 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 radiated emissions (yet to be published) and immunity tests are planned.

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

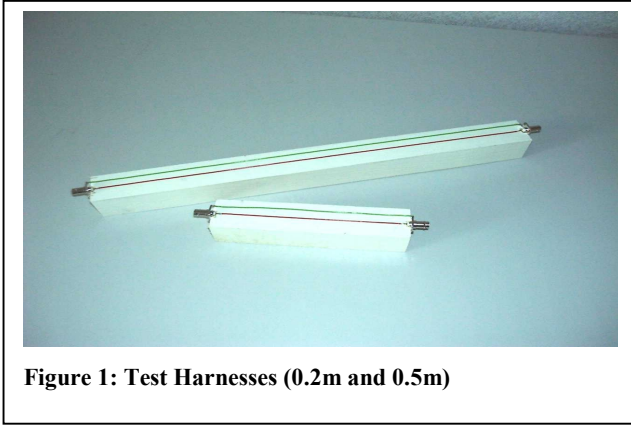


Figure 1: Test Harnesses (0.2m and 0.5m)

Signal Source

A commercially available wideband noise source (comparison noise emitter, CNE) was used to provide a signal for the test harnesses. The CNE 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.

Standard Test Harness

The harnesses used here are all of similar construction consisting of 16-strand 0.2mm² (0.6mm² 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 tests with minimal effect on the support equipment and test set-up. The harness consists of two 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 either BNC connector. This enables the test harnesses to be used to examine the differences between wired ground and chassis grounded ESA.

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 CISPR-25 was used for the tests performed here. The frequency limits of CISPR-25 were applied continuously without the usual spectral gaps (150kHz-108MHz, figure 2). The resolution bandwidths used in CISPR-25 were also applied; 9kHz from 150kHz to 30MHz and 120kHz from 30MHz to 108MHz. No test levels were applied as the testing is comparative only and the CNE is not the item under test.

The CNE is used to generate a test signal for the harnesses to transmit (figure 2). Although the CNE is self-powered by dry-cell batteries, the harness was connected via CISPR-25 LISN's to

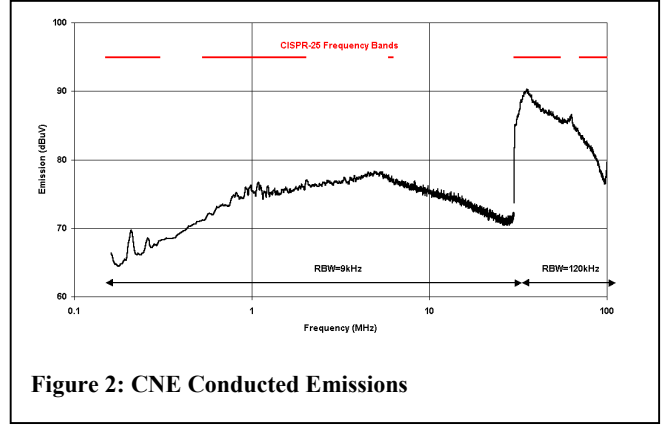


Figure 2: CNE Conducted Emissions

provide 50Ω terminations and to permit comparison of wired and chassis grounded signal return paths. Only the positive terminal or signal line was examined.

Harness Impedance

The characteristic impedance of the harnesses can be calculated using the telegraphers equations [8] for an ideal open wire pair (wired ground) and single wire above ground plane (chassis ground).

Wired ground characteristic impedance (Z_o) is given by;

$$Z_o = \frac{1}{\pi} \sqrt{\frac{\mu}{\epsilon}} \cosh^{-1} \left(\frac{d}{2a} \right) \quad (1)$$

Where d is the distance between wires (10mm) and a is the effective wire diameter (0.6mm here).

The characteristic capacitance (C_o) for the wired ground configuration is given by;

$$C_o = \frac{\pi\epsilon}{\cosh^{-1} \left(\frac{d}{2a} \right)} \quad (2)$$

Chassis ground characteristic impedance is given by;

$$Z_o = \frac{1}{2\pi} \sqrt{\frac{\mu}{\epsilon}} \cosh^{-1} \left(\frac{h}{a} \right) \quad (3)$$

Where h is the height of the wire above the ground plane (50mm).

Chassis ground characteristic capacitance is given by;

$$C_o = \frac{2\pi\epsilon}{\cosh^{-1} \left(\frac{h}{a} \right)} \quad (4)$$

The characteristic inductance (L_o) is subsequently obtained from the equation;

$$L_o = C_o Z_o^2 \quad (5)$$

These calculations for the 0.2m harness produce a good impedance match to the 50Ω LISNs and the CNE (tables 2 and 3). The matched impedance gives justification for the selection of the 0.2m harness for conducted emissions testing since this guarantees any noise at the terminals of any equipment under test (EUT) is transmitted to the LISN efficiently.

Table 2: Calculated Transmission Line Characteristics for Chassis Ground Configuration

Length (m)	Chassis Ground		
	Z (Ohms)	C (pF)	L (nH)
0.2	40.23	5.74	232
0.5	100.57	14.36	581
1.0	201.14	28.72	1162
1.5	301.71	43.07	1743
2.0	402.29	57.43	2324

Table 3: Calculated Transmission Line Characteristics for Wired Ground Configuration

Length (m)	Wired Ground		
	Z (Ohms)	C (pF)	L (nH)
0.2	48.55	4.76	280
0.5	121.38	11.90	701
1.0	242.77	23.79	1402
1.5	364.15	35.69	2103
2.0	485.54	47.59	2805

Presented Data

The graphical results presented here are averaged results to reduce the instantaneous noise content to less than 0.5dB [7]. The data is plotted here to 100MHz only to maximise the plot area, data is available to 108MHz.

CNE Results

The emission level taken directly from the CNE, with no harness, was used as a reference level (figure 2). The CNE results are used to determine what, if any, effects the harnesses and ground configuration have on the conducted signal. The result was obtained with a single LISN and the ground connection from the CNE signal connected at the LISN only, although this is similar to the wired configuration, the absent of any harness prevents a distinct ground configuration result being obtained in this CNE only test.

The CNE should have a relatively constant output across its entire frequency range (9kHz to 2GHz). This is observed over the majority of the frequency range examined (the step function at 30MHz is due to change in measurement bandwidth). There is an observed notch in the output at just under 100MHz (97.8MHz). This notch is believed to be due to the short wires connecting the

BNC-to-4mm-plug adaptor connecting the 50Ω coaxial connectors to the LISNs.

Harness Results

The results are what might be expected with the 0.2m harness transmitting the signal with negligible attenuation or resonance effects up to 30MHz. The longer length harnesses produce greater attenuation in an almost linear manner up to approximately 10MHz for both ground configurations.

The magnitude of the increased attenuation for the longer harnesses is relatively small, under 1MHz the differences are barely detectable, with the exception of the 2m harness that appears to exhibit between 1dB and 5dB attenuation across the frequency range examined. Between 1MHz and 10MHz the longer harnesses exhibit increasing attenuation to just over 1dB at 10MHz for each successive harness length increase in both wired and chassis ground configurations.

Above 10MHz the chassis ground continues to exhibit higher attenuation from the longer harness lengths (figure 3) up to the bandwidth change at 30MHz. The wired ground configuration exhibits resonance above 10MHz (figure 4), the onset occurs at a lower frequency in the longer harnesses (table 4). The observed resonant frequency correlates relatively well with the calculated resonant values for the longer harnesses using the transmission line parameters in tables 2 and 3. The 0.2m harness is not predicted by calculation to exhibit resonance within the measurement frequency range under investigation, however, the short connector resonance has caused the measured effect at 26.5MHz and could explain the differences between the measured and calculated values for the other harnesses.

Above 30MHz the wired ground results all exhibit resonance effects, although the overall signal level is similar to the original CNE output. The wired ground results above 30MHz show the resonance dip observed with the CNE due to the interconnect, but vary significantly from harness-to-harness without any generic pattern other than some harmonic content from the resonance. The 1m harness exhibits a distinctive peak at 63.5MHz that is most likely a multi-mode resonance between the harness and short BNC-to-4mm interconnecting leads.

The chassis ground configuration also exhibits some resonance patterns for the longer lengths above 30MHz, however, these are significantly less pronounced than the wired ground results. The 0.2m and 0.5m harnesses still exhibit similar output curves to the original CNE result in the chassis ground configuration, with slightly less pronounced resonance dip due to the BNC-to-4mm interconnection.

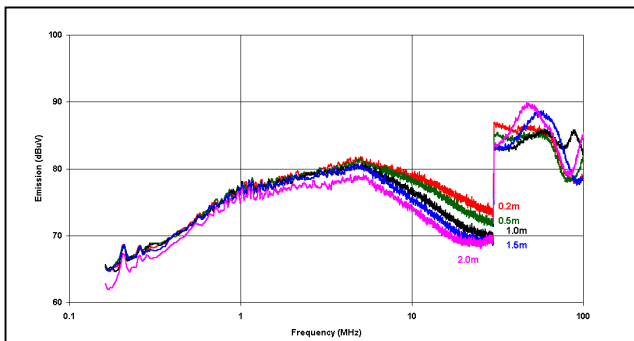


Figure 3: Chassis Ground Conducted Emissions

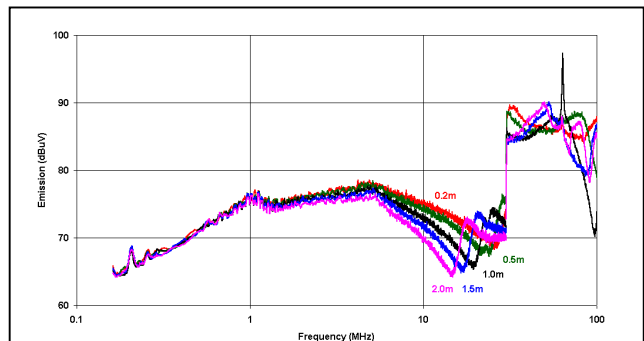


Figure 4: Wired Ground Conducted Emissions

Table 4: Measured and Calculated Conducted Resonance Frequency for Wired Ground Harnesses

Harness (m)	Measured Resonance Frequency (MHz)	Calculated Resonance Frequency (MHz)
0.2	26.5	137.8
0.5	23.5	55.1
1.0	20	27.6
1.5	17	18.4
2.0	15	13.8

Conducted Emissions Standard CISPR-25

The standard used for automotive conducted emissions testing is CISPR-25 [2], this was up-issued in 2002 and within the standard recognises the effect of different harness lengths on the resonant frequency. The updated standard uses the calculated resonance frequency to limit the range acceptable upper frequency limit (f_c in MHz) using the equation;

$$f_c = \frac{30}{l_p} \quad (6)$$

Where l_p is the harness length (in metres). Hence for the harnesses used here the results are similar to the values calculated from the transmission line parameters (table 5).

Table 5: Calculated Conducted Frequency Limit from CISPR-25

Harness (m)	Upper Frequency Limit (MHz)
0.2	150
0.5	60
1.0	30
1.5	20
2.0	15

Conclusion

The choice of 0.2m harness in CISPR-25 is proven to be sensible for both ground configurations. The other harness lengths can be used within the limitations specified in CISPR-25. It is possible to use the longer harnesses, providing the resonances are known although submission based on these longer harness lengths will not conclusively prove compliance to CISPR-25 limits.

In practice the length of harness will never be as short as the CISPR-25 standard and the results obtained here suggest that some resonance will occur and could both filter or amplify any signal levels from an ESA. The results of compliance testing to CISPR-25 are therefore to be considered as guidance only and untypical of what will be experienced in-vehicle.

Acknowledgements

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References

[1] Commission Directive 95/54/EC of 31 October 1995 adapting to technical progress Council Directive 72/245/EEC on the approximation of the laws of the Member States relating to the suppression of radio interference produced by spark-ignition engines fitted to motor vehicles and amending Directive 70/156/EEC on the approximation of the laws of the Member

States relating to the type-approval of motor vehicles and their trailers

[2] CISPR-25: 2002 - Limits and methods of measurement of radio disturbance characteristics for the protection of receivers used on board vehicles.

[3] ISO 7637: Electrical disturbance by conduction and coupling Part 1: Passenger car and light commercial vehicles with nominal 12V supply voltage – electrical transient conduction along supply lines only. (1990)

Part 2: Commercial vehicles with nominal 24V supply voltage – electrical transient conduction along supply lines only. (1990)

[4] ISO 11452: Road vehicles – electrical disturbances by narrowband radiated electromagnetic energy – component test methods

Part 2: Absorber-lined chamber (1995)

Part 4: Bulk current injection (BCI) (2001)

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Part 6: Parallel plate antenna (1997)

[5] ISO 10605: Road vehicles – electrical disturbances from electrostatic discharges (2001)

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Biographical Notes



Martin O’Hara is the author of “EMC at Component and PCB Level”, obtained a BSc in Applied Physics from Durham University and a MSc in Instrumentation from Manchester Polytechnic. Currently working for Trafficmaster UK designing in-vehicle telematic platforms for vehicle tracking and navigation applications.



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