UNIVERSITY of York

This is a repository copy of *An Investigation into Alternatives to the CISPR 12 Full Vehicle Measurement Method*.

White Rose Research Online URL for this paper:
https://eprints.whiterose.ac.uk/130813/

Version: Accepted Version

Proceedings Paper:

Paterson, Max and Dawson, John F orcid.org/0000-0003-4537-9977 (2018) An Investigation into Alternatives to the CISPR 12 Full Vehicle Measurement Method. In: 2018 International Symposium on Electromagnetic Compatibility - EMC EUROPE. 2018 International Symposium on Electromagnetic Compatibility - EMC EUROPE, 27-30 Aug 2018 EMC Europe . , NLD , pp. 885-889.

https://doi.org/10.1109/EMCEurope.2018.8485097

Reuse
Other licence.

Takedown
If you consider content in White Rose Research Online to be in breach of UK law, please notify us by emailing eprints@whiterose.ac.uk including the URL of the record and the reason for the withdrawal request.

White Rose
university consortium
Universities of Leeds, Sheffield & York

eprints@whiterose.ac.uk
https://eprints.whiterose.ac.uk/

© 2018 IEEE. Personal use of this material is permitted. Permission from IEEE must be obtained for all other uses, in any current or future media, including reprinting/republishing this material for advertising or promotional purposes, creating new collective works, for resale or redistribution to servers or lists, or reuse of any copyrighted component of this work in other works.
2018 International Symposium on Electromagnetic Compatibility - EMC EUROPE, 27-30 August, 2018

An Investigation into Alternatives to the CISPR 12 Full Vehicle Measurement Method.

Max Paterson
EMC Department
HORIBA MIRA
Nuneaton, United Kingdom
Email: max.paterson@horiba-mira.com

John F Dawson
Department of Electronics
University of York
York, United Kingdom
Email: john.dawson@york.ac.uk

***Abstract*—The current CISPR 12 method has been shown to under estimate vehicle radiated emissions by up to 30 dB. This paper describes and presents a possible alternative test method to the current CISPR 12 procedure. The initial results from investigations into the use of the use of the 'Test Wire Method' are presented, where a reduction in the average error of approximately 8dB compared to the CISPR 12 method has been recorded.**

I. Introduction

In CISPR 12, vehicle emissions are quantified by recording the electric field level at a measurement distance of typically 10 m. Compared with most other radiated emissions standards CISPR 12 uses a reduced test procedure; emissions are only recorded from two sides of the vehicle , not over a full 360 degree azimuth scan and the receive antenna is not scanned in height, a single antenna height of 3 m is used. The consequence of this test regime is that there is the potential for the maximum emissions from the vehicle to not be recorded.

In [1] we showed potential errors of up to 30 dB using the current CISPR 12 method. Whilst it would be possible to reduce these errors by performing a full hemispherical scan of the receive antenna around the vehicle under test, this would be both time consuming and very expensive to perform. Previous studies conducted to investigate the errors in vehicle emissions measurements [2] achieved inconclusive results, due in part to problems they encountered maximising the emissions.

This paper constitutes work in progress in investigating the errors in the full vehicle radiated emissions due to vehicle directivity. The paper continues on the work performed by the authors where the errors in the emissions signature of a representative vehicle bodyshell were investigated [1]. The long term aim of this project is to determine if an alternative method can be found to the current CISPR 12 procedure and as a consequence, reduce the errors introduced.

The paper will firstly offer a brief overview of the 'Test Wire' method, detailing its original design and applications and secondly detail how this method has been used as an alternative to the current CISPR 12 test method for automotive radiated emissions measurements, before finally comparing the results obtained from measurements using the CISPR 12 method to those using a 'Test Strip' system.

978-1-4673-9698-1/18/$31.00 ©2018 IEEE

II. Test Wire Method

A method proposed for testing the in-situ radiated emissions of large machines was first suggested under a European project known as TEMCA2 carried out in 2003 [3]. The system worked by using a wire stretched over the machine to measure the radiated emissions rather than using a conventional antenna.

The system became known as the 'Test Wire Method' In the initial system the wire was stretched over the machine at a distance of 10 - 50 cm above the surface (the length of the wire was chosen so that this distance could be maintained for different orientations of the wire over the DUT and still maintain the same separation from the largest point of the DUT). Either end of the wire was connected to either the metal chassis of the machine or a metal ground plane between the machine and the floor of the test site using a 150Ω termination. This termination impedance was set to 150Ω at one end and 100Ω in series with with the 50Ω of the measurement system at the opposite end. The voltage across the termination impedance was measured at each frequency of interest. This voltage was then converted to a field strength by means of a so called 'K Factor', which is analogous to a standard receive antenna factor.

The 'K Factor' was calculated as the ratio between the maximum measured E Field (over a full spherical scan) and the measured voltage across the termination resistor. From this equation a range of values for K is obtained

The K Factor can be calculated using the following:

$$K = \left(\frac{E(v/m)}{U(V)}\right) \tag{1}$$

where E is the maximum measured E Field (over a full spherical scan) and U is the measured voltage across the termination resistor.

Initial values for K were produced for each frequency of interest. Using multiple configurations of Test Wire orientation a spread of high and low values were obtained.

The initial studies into the K Factor were performed using Computational Electromagnetic Modelling (CEM) techniques, this enabled a full spherical scan of the E field to be performed with relative ease (as opposed to the very time consuming methods that would be used if a physical model were measured).

One concern that was raised during the investigations was the 150Ω terminations on the Test Wire. The impedance value was chosen as it was assumed that the characteristic impedance of the test wire was 150Ω. However, it was noted, that care in the setup and positioning of the Test Wire above the DUT was required in order ensure that the impedance was actually 150Ω.

Variations to the Test Wire method have been investigated, in part, to try to alleviate the impedance issue noted above. One alternative method suggested was to use a 'stripline' arrangement by placing the Test Wire directly onto the surface of the machine, with the wire gauge and the insulation thickness being chosen to produce a stripline with a characteristic impedance of 50Ω, this would enable the the measurement equipment to be more easily interfaced to the wire. A further development of this design, the 'FlexμStrip' as it was designated, was suggested by Catrysse, Vanhee and Pissort [4]. The 'Test Wire' had its own ground reference plane and was particularly designed to have a characteristic impedance of 50Ω in an attempt to alleviate some of the problems detailed above with the earlier iterations. This is the Test Wire system that has been investigated as an alternative to the CISPR 12 method. Possibly the most practical advantage of this system for this particular application is the fact that it is 'non-intrusive' as a ground bond is not required to the vehicle chassis.

III. Investigation of Vehicle Surface Currents

The original Test Wire papers did not give any details regarding the positioning of the wires themselves, other than reference was made to possibly positioning them to pass over any slots and gaps in the enclosure of the unit. As industrial equipment, which was the subject of the original work, is a very different shape and size to automotive measurements, the position of the Test Wire, based upon the likely distribution of significant surface currents on the vehicle was investigated. The aim of the investigations was to determine the optimum positions for the Test Wires.

The surface currents of an EM model of a simplified body shell were simulated over the frequency range of 100 MHz to 300 MHz. The model was excited using a series of five 300 mm long radiators inside the vehicle. The radiators were located at the positions detailed in Figure 1. At each frequency a 'surface map' plot of current density was produced for each source position, see Figures 2 and 3 for examples. The aim of these plots was to look for common areas of high surface current density and rapid spatial rate change of the current, as these are likely to be areas of higher field radiation. These high points will then be investigated as being possible areas for the Test Wire to be placed.

As one might expect there were a number of points on the vehicle body shell where the surface current density was high and circulating currents were evident, most notably around the seams between the main body shell and the doors and along the seam between the bonnet and the vehicle bodyshell, as detailed in Figure 2. When a source was added inside the engine bay the seams around the bonnet became the major 'hotspots' as seen in Figure 3.

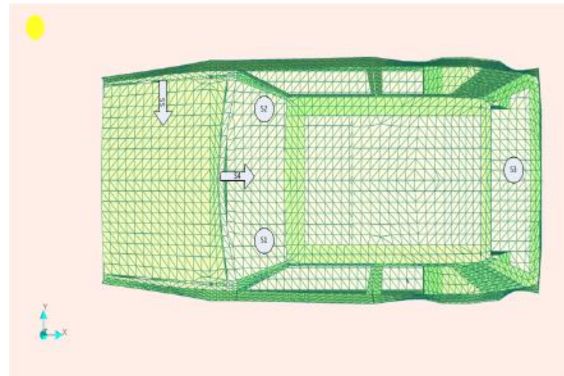

Fig. 1. Representative Small Vehicle Body Shell Source Positions (Plan View)

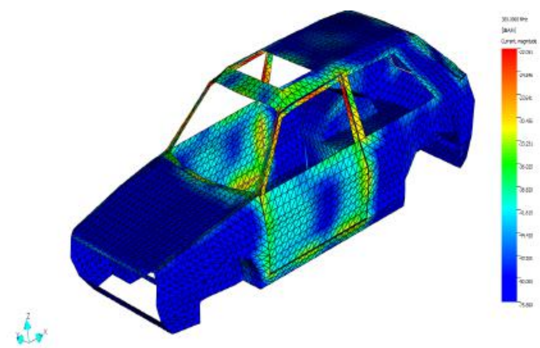

Fig. 2. Representative Small Vehicle Body Shell at 300 MHz, Single Source in Position 1

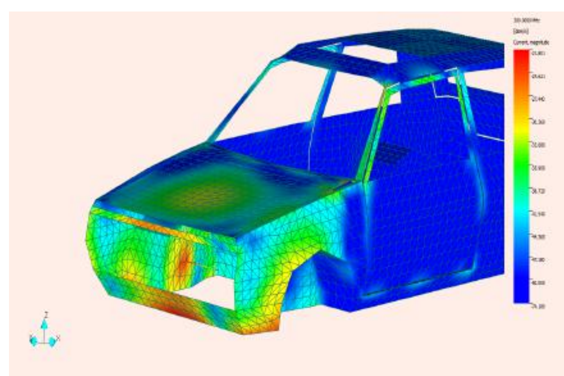

Fig. 3. Representative Small Vehicle Body Shell at 300 MHz, Single Source in Position 5

Based upon the simulation results measurements were then performed on a full scale production vehicle to attempt to validate the simulation results findings. Due to simulation model availability the vehicle type used for the measurements was not the same as used in the simulations (a saloon car was used for the simulations, whereas a 4 x 4 type vehicle was used for the measurements). However, as the purpose of this investigation was to determine if the 'hot spots' recorded on the simulation model were replicated on the physical vehicle, absolute values were not compared, just relative high and low levels. A wide band noise source (York EMC CNE 3) was placed at similar locations inside the vehicle as those used during the simulations to induce the required currents into the bodyshell. Current measurements were performed between 100 MHz and 300 MHz at each of the selected test points using a Fischer Custom Communications Skin Current Probe (Model F-92) connected to an EMC measurement receiver. The location of the test points used can be seen in Figure 4. The amplitude of the measured current was recorded at each frequency for each test point.

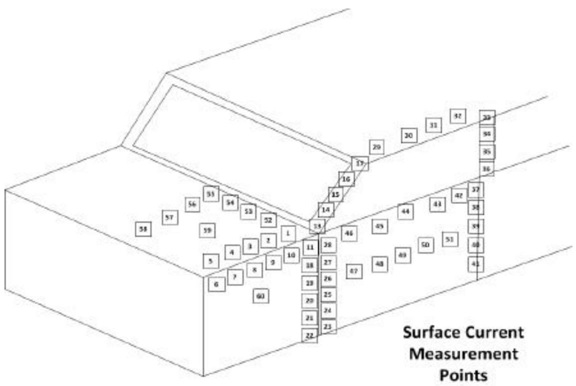

Fig. 4. Surface Current Probe Test Positions

A. Surface Current Investigations Results

Data taken from the simulations performed on the vehicle bodyshell was validated by comparison with the measurement results. The log value of the current amplitude recorded at each test point was normalised for ease of comparison, (using unity based normalisation). The data for the simulated and measured results were then presented on the same axis in Figures 5, 6 and 7.

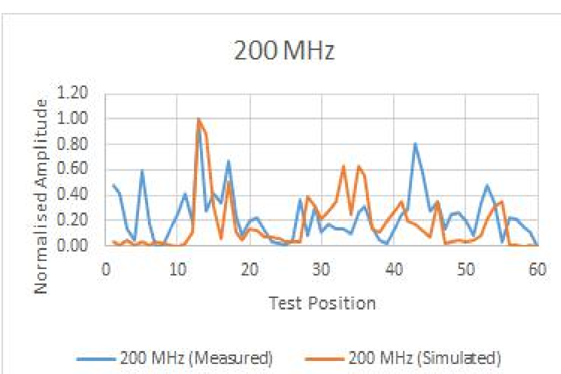

Fig. 5. Comparison of Simulated Surface Current to Measured Data (200 MHz)

It can be seen from the results that there is a good level of similarity between the two sets of data, with the main

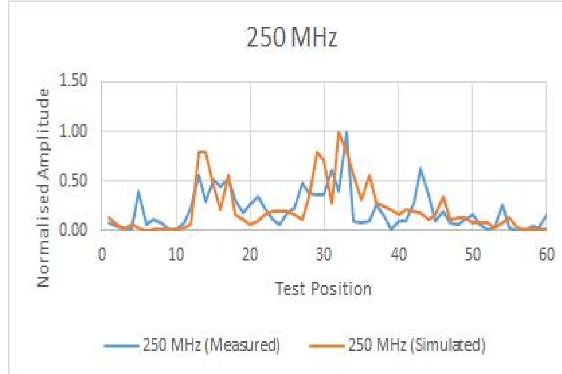

Fig. 6. Comparison of Simulated Surface Current to Measured Data (250 MHz)

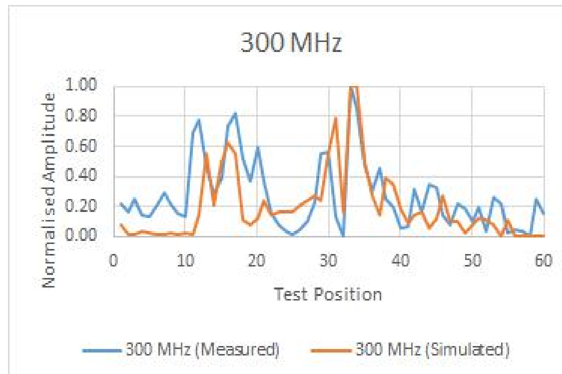

Fig. 7. Comparison of Simulated Surface Current to Measured Data (300 MHz)

areas of high surface current amplitude (test points 13 - 17and 29 - 36) being recorded in both the simulation model and the 'real vehicle' measurements, despite the fact that the simulation model was of a different vehicle type to that used for the measurement. The plots are presented to confirm hot spot areas are in similar positions rather that compare absolute amplitude values. These similarities were observed at frequencies above 150 MHz, with the lower frequency results showing a poorer overall agreement. The lower frequency differences were thought to be due to possible coupling of the radiated signal into the measurement system used, further tests at frequencies below 150 MHz are planned to determine if the cause of the poor correlation is due to a problem with the measurement system or a physical reality.

IV. 'Test Strip' Measurements Compared with CISPR 12 Measurements

The 'Test Strip' (as the authors have designated it) used for the purposes of these investigations, was based upon the 'FlexμStrip' as detailed above. For ease of construction the Test Strip was built using a 300 mm long, 10 mm x 0.7 mm copper strip positioned on top of a 4 mm sheets of perspex (50 mm wide, 300 mm long), this whole arrangement was then placed onto a copper sheet (50 x 300 mm). The strip was terminated to two N connectors, one for connection to the measurement receiver, the second was terminated with a 50Ω load.

Based upon the results of the surface current investigations (above 150 MHz) locations for the Test Strip measurements were chosen. The locations chosen for the initial investigations were (1 and 3),(13 - 17) and (29 - 36), an example setup photo can be seen in Figure 8. These positions covered the major 'Hot Spots' highlighted in the surface current tests.

Fig. 8. 'Test Strip' Measurement Setup, Position 3

Test Strip measurements were performed with a wide band noise source (York CNE 3) at 4 different positions inside the vehicle (on the passenger seat, drivers seat, in the middle of the boot and on the centre of the dashboard). The measured voltage across the terminals of the μStrip was recorded over a frequency range of 50 MHz to 500 MHz for each noise source position. The source positions used were the same as those used during the surface current investigations detailed earlier in this paper.

Once the Test Strip measurements had been performed, radiated emissions measurements of the test vehicle were performed (using the same vehicle and noise source positions. Tests were performed at HORIBA MIRA (formerly known as 'MIRA') OATS facility with measurements being taken with the vehicle rotated through 360^0 in 5^0 increments (the increment angle was chosen in order to ensure the measurements were completed within the available time), with the receive antenna 3 m from the test vehicle and positioned between 1m and 3 m above ground level (in 0.5 m increments). Due to the azimuth increment angle used the polar patterns are probably under-sampled. Whilst this method does not give the full details that might be obtained from a full hemispherical scan it will give an approximation of the 'absolute' maximum emissions from the vehicle. As well as recording the received E field from each source, the voltage at the connector of the μStrip was also recorded for each source position. This voltage was then used to determine the K Factor for each measured frequency (as detailed in Equation 1).

Once all the emissions and Test Strip data had been recorded a range of K Factor values could be determined for each noise source position. For the purposes of this initial investigation only the data recorded at 50 to 500 MHz in 50 MHz steps is detailed.

When the polar data from just 90^0 and 270^0 were considered a maximum error between the emissions data and the maximum emissions over all receive antenna heights, azimuth positions and source positions) of approximately 10 dB was recorded. This again highlights that the current CISPR 12 method has the potential to under-estimate the emissions recorded significantly, this has previously reported by the author [1].

The range of K Factor values was obtained at each frequency (based upon the source position in the model, the receive antenna polarisation and the voltage across the Test Wire termination), shown graphically in Figure 9.

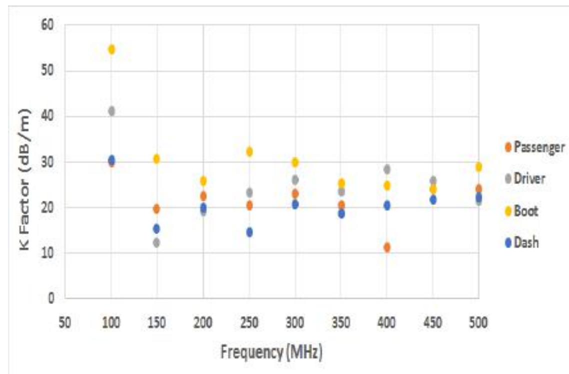

Fig. 9. Measured K Factor for Source Positions 1 to 4

A. Test Strip Measurement Results

Across all the recorded data the mean value of the K Factor was found to vary by between 20 dB and 25 dB, with the exception of the value calculated at 50 MHz, where 39 dB was recorded. The mean of all the log values of the K Factor recorded at each frequency was used define a K Factor to be used in Equation 1 to determine whether the Test Strip Method offered any improvement in the error recorded compared to a standard CISPR 12 measurement program. Comparisons were performed using two batches of Test Strip measurements, the first consisted of the maximum amplitude recorded from all 15 Test Strip positions, the second only considered the measurements performed at positions 13, 16, 29 and 32, to compare the results using a smaller number of measurements to see if an improvement in error was still recorded.

Based on the K Factor calculated the difference between the error recorded during a CISPR 12 type measurement and using both batches of Test Wire method data was compared. The graph in Figure 11 below shows how the mean of the dB values of the error recorded using the Test Wire Method is typically lower than that when the CISPR 12 method is employed. Across all frequencies and source positions the mean error of 10 dB was recorded using the CISPR 12 setup compared to approximately 0.7 dB dB using the Test Wire Method (all test points) and 2 dB (4 test points).

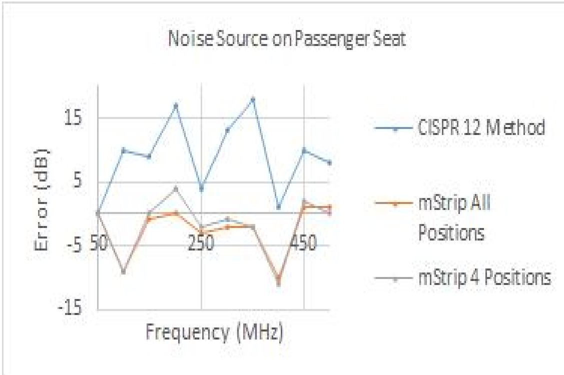

Fig. 10. Comparison of the Average CISPR 12 Method Error with an Example Test Strip Method, Source Position 1

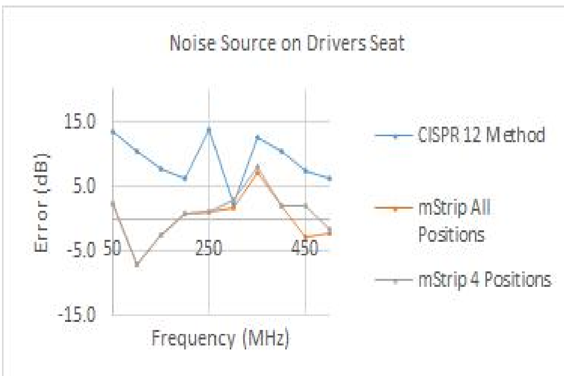

Fig. 11. Comparison of the Average CISPR 12 Method Error with an Example Test Strip Method, Source Position 2

It is planned that as future measurements are performed on different source configurations (and other models). The K Factors will be evaluated in order to see if reduction in errors noted above can be further improved. Statistical analysis of the range of K Factor values will be performed and the results again compared to those recorded during a CISPR 12 measurement. This will allow us to evaluate the error performance over a larger range of configurations. The current Test Strip measurements have been performed on a single vehicle. In order for the method to be used across a variety of different vehicles, the exact positions for the Test Strip to be located during the test will need to be defined. Due to the wide range of size and style of commercial passenger vehicles further work will be required to identify the relative positions.

V. Conclusions

The use of the Test Strip Method has been investigated as a possible alternative to the current CISPR 12 full vehicle radiated emissions test procedure. As has previously been shown the current method can potentially significantly under-estimate the maximum emissions recorded during the test due to using single receive antenna height and only two azimuth positions to perform the measurement. Initial investigations into the use of a Test Strip system for carrying out radiated emissions measurements have been performed on a single production vehicle. The measurement data from the investigation was also used to calculate the K Factor. A reduction in the error of recording the maximum amplitude of the emissions signature of the vehicle within the measurement environment has been recorded. Additional measurements have since begun to investigate the ‘Test Strip’ method and the K factor derived from this study, on a wider range of vehicle types. Initial results suggest that the the errors recorded from the additional vehicle types are at a similar level to those reported earlier sections of this paper. The results of these additional measurements will be reported at a later date once complete.

Acknowledgements

The authors would like to thank the EMC department at HORIBA MIRA for the use of their emissions measurement facilities and their continued funding support during this programme of research.

References

[1] M. Paterson and J. F. Dawson, “An investigation into the errors in the cispr 12 full vehicle radiated emissions measurements due to vehicle directivity,” in *Electromagnetic Compatibility (EMC EUROPE), 2013 International Symposium on*, 2013, pp. 310–315.

[2] A. Ruddle, “Investigation of Automotive Emission Measurement Frequencies, Test Methods and Operating Modes.” Laboratory for Electromagnetic Fields and Microwave Electronics, 2005.

[3] J. Catrysse, F. Vanhee, J. Knockaert, I. Hendrickx, and V. Beauvois, “In situ testing of large machines: Alternative method for radiated emission measurement,” in *Electromagnetic Compatibility, 2008. EMC 2008. IEEE International Symposium on*, Aug 2008, pp. 1–6.

[4] J. Catrysse, F. Vanhee, and D. Pissoort, “Flexustrip: a new measuring probe for the characterisation of large machines in situ.” EMC Europe 2010, 09 2010.