Institution: University of York

Unit of Assessment: 13, Electrical and Electronic Engineering, Metallurgy and Materials

Title of case study: Electromagnetic Shielding

1. Summary of the impact (indicative maximum 100 words)

One of the main functions of enclosures around electronic systems is to shield electromagnetic fields and reduce their interference with other systems. At the University of York the design of new measurement techniques for Shielding Effectiveness (SE), new instrumentation, and improved numerical model based design techniques have delivered more rigorous engineering processes for smaller equipment shielding enclosures (e.g. PCs) and large enclosures with a secondary shielding function (e.g. airframes).
These have resulted in global sales of specialist equipment to many major electronics companies through York EMC Services Ltd, a revised international standard for the measurement of SE and efficient modelling techniques to determine the SE of complex composite materials.

2. Underpinning research (indicative maximum 500 words)

The ability of the enclosure around an electronic system to shield electromagnetic fields depends on the material it is made from, its shape, size and the presence of apertures. Shielding Effectiveness (SE) is assessed by measuring the ratio of internal to external fields around the enclosure. Conventional approaches to measuring SE were designed for metallic, room sized enclosures, where the contents typically occupied less than 10% of the enclosure volume (volume fill). These attained high SE ratios in excess of 100dB.
Today many enclosures are made of composite materials with inherently lower shielding performance than metal. Enclosure apertures for ventilation, access and displays reduce the SE further and the electronic contents produce a significantly larger volume fill. Conventional methods do not rigorously measure SE of enclosures with these properties.

Marvin and his group at the University of York have undertaken a number of inter-related strands of research which have progressed in parallel to produce new techniques to improve the measurement of the SE of two different classes of enclosure :

- Smaller enclosures specifically designed to house electronic equipment, e.g. PC housings, often made of composite materials.
- Structures that have a secondary shielding function e.g. airframes, also made from composite materials.

Although very different in size, these enclosures have the properties mentioned above in common.

Predicated on the assumption that the function of enclosures is to minimise the flow of electromagnetic energy to and from the enclosure contents, Marvin has advanced techniques for the measurement of these enclosures with larger volume fills:

- A set of instrumented representative contents capable of standardisation have been developed [1]. Rather than measuring the empty enclosure field ratio, the ratio of enclosure contents absorbed power to the incident electromagnetic power density is measured.
- Statistical approaches have been developed to accurately measure the environment around the enclosures, with particular reference to measurements at microwave frequencies [2].
- These statistical approaches have been extended to measure the SE of circuit card level enclosures [3].

One significant problem with the measurement of composite materials is that the conducting components that give the shielding performance may be buried in a non-conducting substrate. Conventional shielding measurement techniques require edge connection to the conducting components. Marvin has developed approaches for the measurement and prediction of the SE of inhomogeneous composite materials [4], including the development of a novel measurement cell, designed to overcome the major limitation of edge connection, with its performance optimised

using numerical modelling [5] (figure 1 below). Extension of the use of this measurement cell has allowed the examination of the shielding properties of structural features such as joints and is being used to develop measurement based macro-models of these features for inclusion in full-size simulations of airframes [6, 7].

Marvin's team have developed efficient digital filter based techniques for incorporation into time-stepping full-wave solvers which have underpinned and informed the measurement work. These enable the modelling of frequency-dependent dissipative materials and fine scale structural features such as joints seams and apertures.

Initial work was on the BAES/EPSRC FLAVIIR programme (BAES, EPSRC, nine academic partners – Staff; J Dawson, L Dawson, Marvin, Robinson, Flintoft; 2005-7). This work was continued under the FP7 HIRF-SE programme (Co-ordinator Alenia-Aerospace, 43 partners – Staff; Marvin, J Dawson, L Dawson, Flintoft, Robinson; 2008–2013).

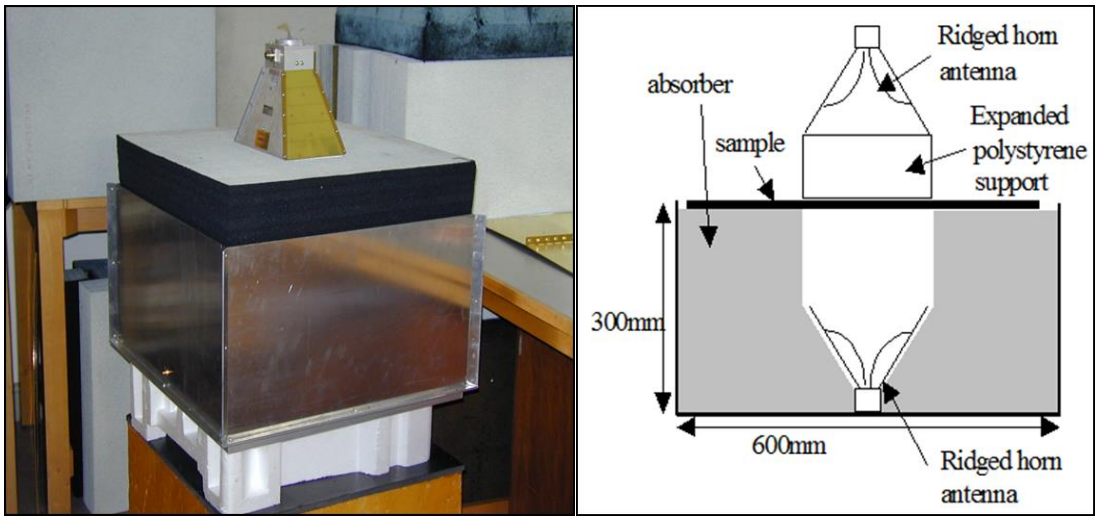

Figure 1 - Image and cross-section of the contactless SE measurement system [5].

3. References to the research (indicative maximum of six references)

[1] A proposed new definition and measurement of the shielding effect of equipment enclosures AC Marvin, JF Dawson, S Ward, L Dawson, J Clegg, A Weissenfeld Electromagnetic Compatibility, IEEE Transactions on 46 (3), 459-468 2004; doi: 10.1109/TEMC.2004.831901 (Citations: Google scholar - 34, Scopus – 21)

[2] Shielding measurements of equipment enclosures in the radiating near field AC Marvin, Y Cui Electromagnetic Compatibility, IEEE Transactions on 49 (4), 860-867 2007; doi: 10.1109/TEMC.2007.908268

[3] An Investigation of the Shielding Performance of PCB-level Enclosures using a Reverberation Chamber H Yuhui, A Marvin. IEEE 2007 International Symposium on Electromagnetic Compatibility; doi: 10.1109/ISEMC.2007.240

[4] A Rectangular Waveguide Cell for Measurement of the Shielding Effectiveness of Anisotropic Materials. L Dawson, I D Flintoft, A C Marvin and J F Dawson. EMC Europe 2010, 9th International Symposium on EMC joint with 20th International Wroclaw Symposium on EMC, Wroclaw, Poland, PprNo. 121, 13-17 September, 2010. ISBN 978-83-7493-426-8 *(Available on request)*

[5] A method for the measurement of shielding effectiveness of planar samples requiring no sample edge preparation or contact AC Marvin, L Dawson, ID Flintoft, JF Dawson Electromagnetic Compatibility, IEEE Transactions on 51 (2), 255-262 2009; doi: 10.1109/TEMC.2009.2015147 (Citations: Google scholar - 22, Scopus – 18)

[6] Building electromagnetic macro models for small structures on aircraft: Characterising and

modelling joints, seams, and apertures. Xia, R., Dawson, J. F., Flintoft, I. D., Marvin, A., Porter, S. J. & Marschke, I 26-Sep-2011 EMC Europe 2011. York, UK p. 575-580.

[7] Use of a Genetic Algorithm in Modelling Small Structures in Airframes; Characterising and modelling joints, seams, and apertures R Xia, J F Dawson, I D Flintoft, A C Marvin, S J Porter EMC Europe 2012, Rome, September 2012; doi: 10.1109/EMCEurope.2012.6396718

Notes:
All authors referenced above are from the University of York; Marvin – Professor; J Dawson – Senior Lecturer (SL); L Dawson – Research Associate; I Flintoft – Research Associate; S Porter – SL; J Clegg – Research Associate; Xia, YuHui, Cui, Ward – PhD students.
EMC Europe is the premier conference for work in this area
Citation data for Google Scholar and Scopus from 11/11/13

4. Details of the impact (indicative maximum 750 words)

The underpinning research has advanced conventional approaches in measuring Shielding Effectiveness (SE) to produce measurement techniques for two different classes of enclosure. These are a) smaller enclosures with linear dimensions between 2m and 100mm specifically designed to house electronic equipment and b) structures such as vehicle bodies that have a secondary shielding function.

The impact from this research is in three related themes, (i) the development and sales of specialist radiation sources for SE measurements, (ii) the development of a new version of the principal international standard for shielding measurements of enclosures covering smaller enclosures with linear dimensions between 100mm and 2m, (iii) the development of new measurement techniques and the enhancement of modelling of the shielding of complex structures fabricated from composite materials.

(i) Specialist Radiation Sources for SE measurements

Marvin's work on enclosure SE measurements has been supported through York EMC Services Ltd (YES) [I1], a University of York spin-off company, where Marvin is the Technical Director. Building on the underpinning research, a series of development contracts from the Intel Corporation produced a number of wide-bandwidth miniature radiation sources to measure the SE of their suppliers' enclosures. The sources are intended to mimic the radiated energy emitted by VLSI processor chips. The outcome of these contracts has been a series of comb-generator sources.

YES have invested in the development of further sources to provide a suite of products (CGE01, CGE02, CGE03, YRS01 & YRS02 [I2]) that between them cover the frequency range 5kHz to 40GHz. These are specialist devices, selling for around £2k - £5k each, used by EMC test facilities and enclosure manufacturers worldwide. In the period 2008 – 2013 170 of these sources have been sold in the US, the Far-East and Europe through the YES distributor network [I3, I4, I5]. Customers are from both the commercial and the academic sectors. Commercial customers since 2008 include Intel, Apple, Microsoft, Nokia, IBM, Google, Samsung, Sun Microsystems, Sony, Sony Ericsson, Dell, NEC, Research in Motion, Thales, Honeywell, EMV, TUV Sud, TUV Rheinland, TDK, Fujitsu and Honda R & D. Academic customers over this time period include the Slovak University of Technology, Seo Kyeong University, South Korea and Curtin University of Technology, Australia. Typically manufacturing customers use the sources to assess the SE of their suppliers' enclosures or to ensure that their suppliers undertake SE assessment, as well as undertaking their own in-house development – for example Dell have used a CGE01 source to develop enclosure SE measurement techniques for which they have filed a patent [I8]. While competitor products exist, (Com-Power, Teseq, AET and LaPlace Instruments), YES provides the broadest range of products, covering the widest frequency range.

(ii) New standards development

The move from SE measurements of small numbers of high performance systems to larger numbers of measurements of lower performance enclosures has also driven measurement

innovation. The sources have been used in collaborative research with partners including the United States National Institute of Standards and Technology (NIST) and others to inform the development of a revised Standard IEEE P299.1 for the measurement of the SE of enclosures with linear dimensions between 100mm and 2m [I6 (*engineering technique*), I7 (*standard*)]. The original IEEE 299 standard covered the larger room sized enclosures. This latest version, 299.1, covers typical equipment enclosures (Marvin and students Yong Cui, 2003 – 2007 and Yuhui He, 2005 - 2009). YES has also sponsored a research student (Armstrong 2008 to 2012) to undertake part of this work. Marvin is a Vice-Chair of the associated Standard Development Working Group.

(iii) Improved modelling for composite materials

The use of composite materials has become common over the last decade for the construction of vehicle bodies where they offer significant weight and structural advantages and for equipment enclosures where cost and weight reduction can be achieved. The novel measurement cell and Marvin's colleagues' (Flintoft, J Dawson) work on the modelling of these materials and their structures has been applied to airframe applications through the EU FP7 HIRF-SE programme , which includes the majority of major airframe manufacturers as part of the 43 strong consortium, including Alenia Aeronautica (co-ordinator), Augusta Westland, BAE Systems, EADS, Thales. The new measurement techniques have delivered efficient modelling of the complex structures through the Finite Time-Domain Solver in the HIRF SE framework and have enabled validation of models for multilayer composites (see figure 2) and the electromagnetic performance of structural joints within the HIRF-SE research programme. These new modelling techniques are accessible for commercial use to all partners in the programme through the HIRF SE Framework [I9, I10].

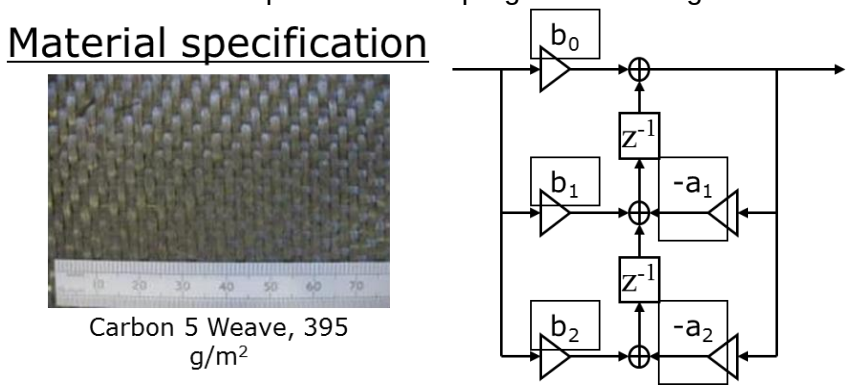

Figure 2 - Carbon fibre woven structural material and the novel digital filter architecture of the material implemented in the numerical model in the HIRF-SE Framework [I9, I10].

5. Sources to corroborate the impact (indicative maximum of 10 references)

[I1] Chief Executive, York EMC Services (YES Ltd.) – written statement
[I2] http://www.yorkemc.co.uk/instrumentation/ Instrumentation website of York EMC Services
[I3] http://www.yorkemc.co.uk/worldwide/ Distributor network data for York EMC Services
[I4] http://www.reliantemc.com/small-enclosures.html Reliant EMC site advertising CGE sources
[I5] http://www.credencetech.com/products/product.php?productId=CGE01,%20CGE02 Credence Technology site advertising CGE Sources
[I6] "Use of reverberation chambers to determine the shielding effectiveness of physically small, electrically large enclosures and cavities" *CL Holloway, DA Hill, M Sandroni, JM Ladbury, J Coder, G Koepke*, **A C Marvin, Y He** , IEEE Transactions on Electromagnetic Compatibility, 50 (4), 770-782 2008 (23 citations) (*NIST Authors*, **York Authors**). Doi: 10.1109/TEMC.2008.2004580 Paper describing the engineering techniques contributed to the new IEEE P299.1 standard.
[I7] http://standards.ieee.org/develop/project/299.1.html Website of the IEEE P299.1™/D5 "Standard Method for Measuring the Shielding Effectiveness of Enclosures and Boxes Having All Dimensions between 0.1m and 2m" project.
[I8] http://www.google.co.uk/patents/US8198903 Patent by Dell for a SE measurement technique. Fig 4j is the spectrum of a CGE01 that YES can identify as having been supplied to Dell.
[I9] hirfse.axessim.eu Website offering commercial use of the HIRF-SE Framework
[I10] Professor, University of Granada – written statement