HOW TO HANDLE LARGE MACHINERY FOR EMC: ALTERNATIVE METHODOLOGIES FOR THE IN SITU EVALUATION OF EMI EMISSION

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Abstract: On the legal aspect, the new European Directive on ElectroMagnetic Compatibility 2004/108/EC concerns also large machines. On a technical point of view, the special situation to characterise the EMC behaviour of large machines imply that current procedures are complex and very expensive, and in some cases even not possible. Adapted measuring methodologies and procedures are needed.

1. INTRODUCTION

Regarding EMC, the machinery-industry drags along a set of problems that makes testing and characterising very complex and expensive. Therefore, adapted procedures are needed.
Machinery manufacturers have a wide experience in mechanical engineering, but a lack of expertise in electromagnetics and EMC. One of the important aspects is that they are basically system-integrators of electrical and electronic modules, assembled inside the final product.
Moreover, most of the machines have characteristics (size and dimensions, weight, supply voltage, power consumption, other auxiliary provisions as cooling water, pressured air …) that make the self-certification based on the complete machine testing on an EMC test-site or in an EMC laboratory very complex, expensive or even impossible. Most of the times, it is not feasible to transport the machine and evaluation must be carried out "in-situ" at the manufacturer or user premises.

2. EMC DIRECTIVE AND STANDARDS

First of all, the EMC legal aspect should be considered. The new European Directive on ElectroMagnetic Compatibility 2004/108/EC [1] concerns also large machines.
Concerning standards, one should consider the product family standards for machine tools EN 50370-1 [3] and EN 50370-2 [4], respectively for emission and immunity.

The test approach described in these standards is quite informative. Three procedures are applicable:
- procedure A is a test on the complete machine,
- procedure B is a test on the entire electrical set of the machine, and a visual inspection regarding the correct installation of modules and cabling,
- procedure C is to divide the machine in EMC relevant modules and test them separately under lab conditions, if not already done, followed by a visual inspection, and a test as final check at the manufacturer premises.

The methodology applies as well for emission, as for immunity EMC requirements, and is given in the flow chart in figure 1.
It is clear that procedure C sounds interesting to the machinery community, also because this allows a flexible way of handling, especially for these machines including a lot of customer based options.

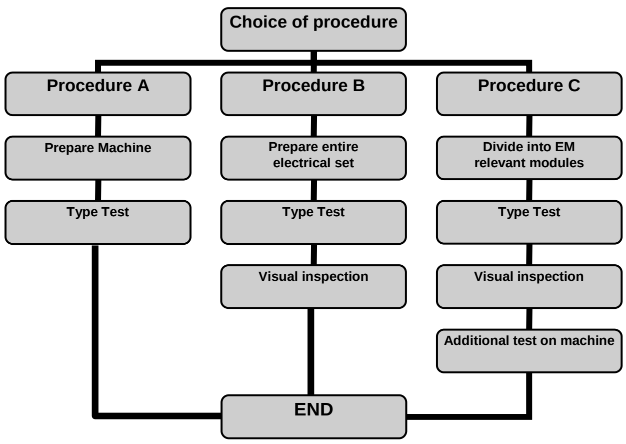


Figure 1. Procedure for compliance as given in EN 50370

3. CONDUCTED EMISSION

The main problem for large machinery is related to two items:
- the current consumption, and the current handling capacity of a LISN
- the fact that it is nearly impossible to insert a measuring probe in the power mains cabling

Therefore, if possible, non-contacting methods should be considered.

3.1. LISN used as a voltage probe (or LISN in parallel)

The LISN is only used as a voltage probe, so that the current density is not a restriction on its use. This method is specified in CISPR 16-2-1 [5], and requires the insertion of inductances between 30 and 50µH in the power mains cabling. The only advantage of this method with respect to the "classical" use of a LISN is that a low current handling LISN can be used.

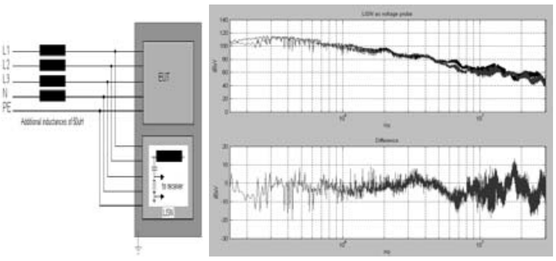


Figure 2. LISN used as voltage probe, and comparison of LISN (black) and LISN as voltage probe (blue)

3.2. Voltage probe 50/1500 Ohm

Referring to both CISPR 16-2-1 [5] and CISPR 11, a voltage probe can be used for measuring the conducted emission levels. This method is not suffering from any restriction about the current density. But it needs a direct contact to the life wires of the power mains, and it introduces an extra attenuation of the signals of about 30 dB, which may cause problems in a noisy environment

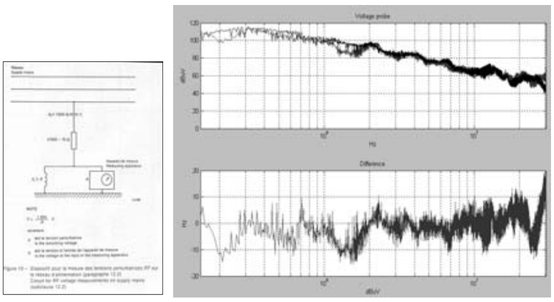


Figure 3. Voltage probe, and comparison of LISN (black) and voltage probe (blue)

3.3. Capacitive Voltage Probe (CVP)

A capacitive voltage probe has been developed, for measuring conducted interference from signal and data communication lines. The probe has also been evaluated for use at the power mains cabling. The main advantage of the CVP is the non-contacting measuring setup and the built-in pre-amplifier, giving an overall flat attenuation factor.

The CVP probe is shown in the next figure 4, which clearly shows the construction and use of the probe, and an example of measured

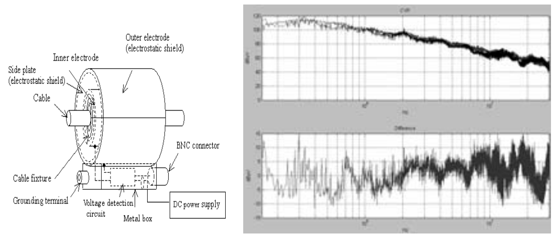


Figure 4. Capacitive Voltage Probe (CVP) and comparison of LISN (black) and CVP (blue)

3.4. EFT capacitive clamp for conducted emission

The EFT capacitive clamp as described in EN 61000-4-4, is normally used to test the immunity of an equipment against Electrical Fast Transients. The EFT capacitive clamp is rather a large and rigid construction, and cannot be used where no flexible access to the cabling is available. The main advantage is the defined impedance level of 50 Ohm, ensuring matched conditions for the measuring receiver. Unfortunately, the attenuation is rather high, and might cause problems in noisy environments.

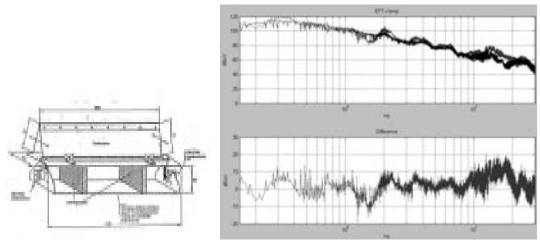


Figure 5. Comparison of LISN (black) and EFT clamp (blue)

3.5. Capacitive Foil Probe (CFP)

In order to combine all advantages of the discussed alternatives, a very flexible Capacitive Foil Probe (CFP) has been developed. It can be inserted in and around any power mains cabling. A capacitor is made by wrapping a foil (aluminium) around the cabling under test. The foil is connected to a measuring receiver or a preamplifier. A typical length of about 30 cm is used for this foil.

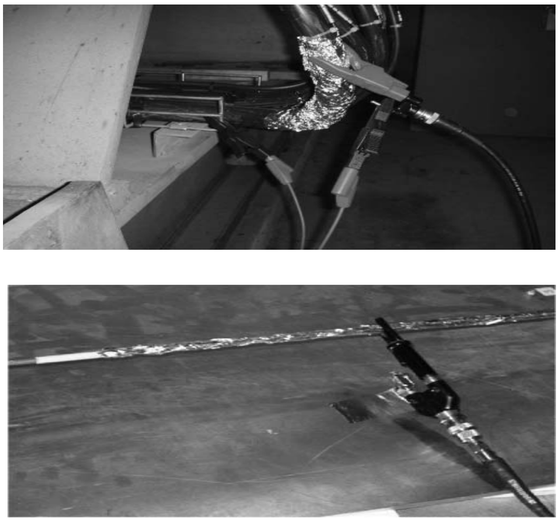


Figure 6. Examples of practical implementation of CFP

To validate this probe, calibration measurements and simulations have been performed, in order to identify and define the attenuation factor. A detailed discussion is given in [6]. Fig. 7 shows the good correlation between the LISN method and the CFP probe.

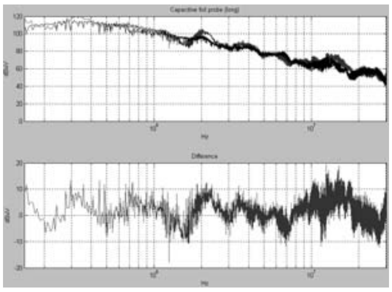


Figure 7. Comparison between the simulated attenuation factors of LISN and CFP (lumped & transmission line model) (upper), and LISN (black) and CFP (blue) measuring results (lower)

4. RADIATED EMISSION

The main problems for in-situ measurements of large machinery for radiated emission are:

- the lack of space to perform adequate measurements using antenna's
- the background noise in an industrial environment

Therefore, an alternative methodology has been developed, by putting a simple wire over the machine. This wire acts as an antenna, and is able to capture radiated emissions. The problem is to identify and define a correlation factor (or antenna factor) for this "test-wire" method. The general concept of measuring setups using antenna's and using a "test-wire" is shown in figure 8.

In order to understand the underlying phenomena, theoretical models have been developed, as well as a representative test-specimen (GTO or Generic Test Object). The GTO is shown in figure 9.

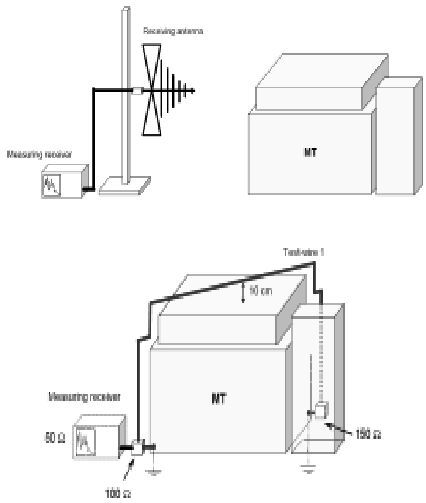


Figure 8. Antenna setup (upper) and test-wire setup (lower)

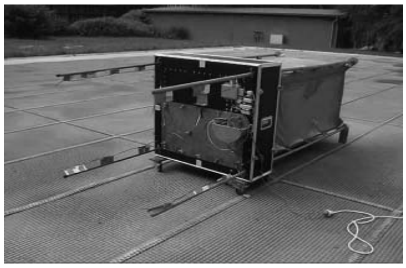


Figure 9. Picture of the GTO on a test-site

Both for simulations and measurements, by comparing the field strength at 3m or 10m distance (as defined in the standards), and the voltage measured at the termination of the test wire, an "antenna factor" or "correction factor" CF can be defined. In that way, measured voltages at the 150 Ohm termination of the test-wire can be re-calculated into the established limit values for radiated emission.

In figure 10, different proposals forthcoming from different simulations and measuring campaigns are shown for this correction factor CF.

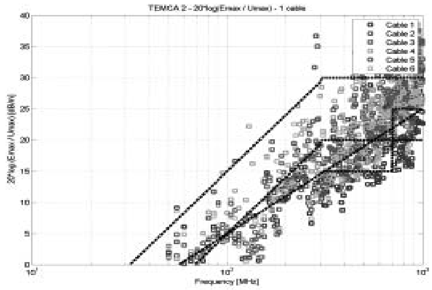
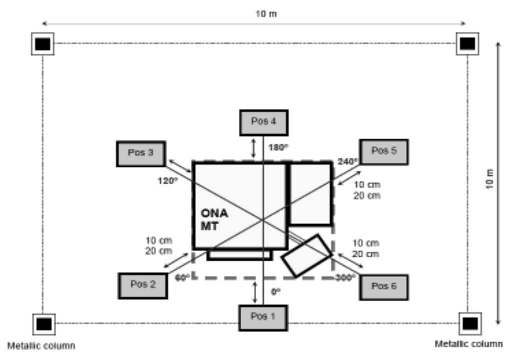


Figure 10. Different proposals for CF, given simulated results

An example is given how to perform the tests under practical conditions. These results are taken from an European research project TEMCA2 [2] and reproduced with permission of the working group.

The next figures show the setup using 6 positions of the test-wire and its practical layout, as well as the measured results for radiated emission, using an antenna method at 3m distance, and the test-wire method. No CF-factor has been applied to the test-wire measuring results. It is also referred to [7] for more details about the theoretical background and the practical application of the method.



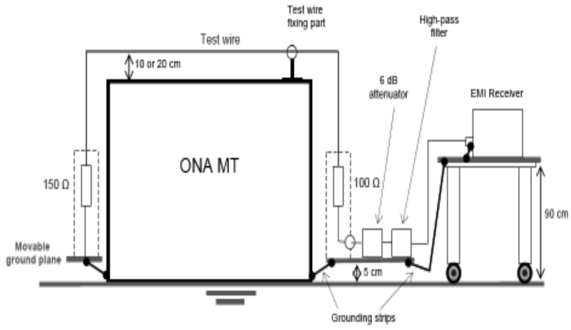


Figure 11. Sketch of the measuring setup for radiated emission using the test-wire method

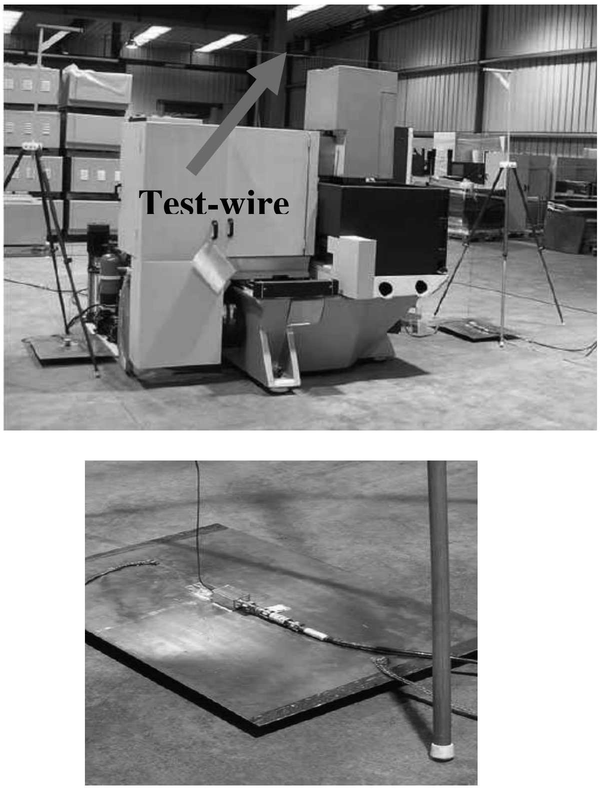


Figure 12. Applying the test-wire in practice (left) and its termination in 100/50 Ohm

Figure 13 shows the measured spectra using the standardised antenna method at 3m distance, and the calculation to for the standard distance of 10m. The third measurement shows the spectrum obtained from the test-wire method, without applying any correction factor .

In figure 14, a "correction factor" CF for the test-wire is proposed, with reference to the 10m antenna measurement.

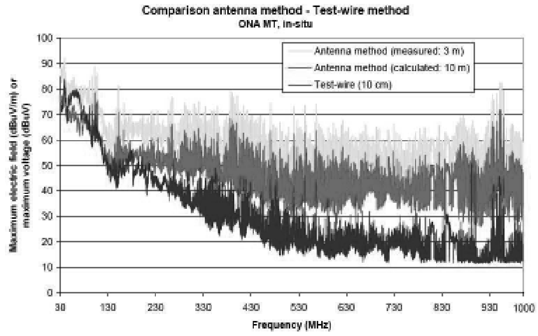


Figure 13. Comparison of measured radiated emission by antenna method and test-wire

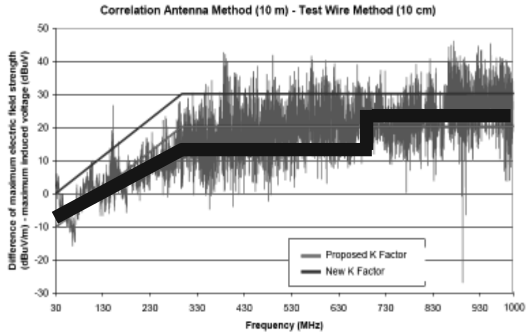


Figure 14. Example of comparison between antenna method and test-wire method, and proposed CF-factors

CONCLUSIONS

In this paper, alternative test methods for the "in situ" characterization of both conducted and radiated EMI emission have been identified and evaluated.

References

[1] Directive 2004/108/EC of the European Parliament and of the Council of the 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC.

[2] TEMCA2, "Alternative EMC testing methods for large machines", No. G6RD-CT-2002-00865 for the 5th European Framework Program, GROWTH, Objective 6.2.1. (Methodologies to support standardisation)

[3] CENELEC, EN 50370-1, EMC – Product family standard for machine tools. Part 1: Emissions, 2005

[4] CENELEC, EN 50370-2, EMC – Product family standard for machine tools. Part 2: Immunity, 2003

[5] CISPR 16-2-1, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods – Part 2-1: Methods of Measurement of Disturbances and Immunity – Conducted Disturbance Measurements, IEC, Rev. 1.1, 2003

[6] Johan Catrysse et al., "In situ testing of large machines: alternative methods for conductive emission measurement", Proceedings IEEE Int. Symp. on EMC, Detroit, Aug. 2008

[7] Johan Catrysse et al., "In situ testing of large machines: alternative methods for radiated emission measurement", Proceedings IEEE Int. Symp. on EMC, Detroit, Aug. 2008