IN SITU TESTING OF LARGE MACHINES: ALTERNATIVE METHODS FOR CONDUCTED EMISSION MEASUREMENTS

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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.

As a response to this situation and within the European R&D Frameworks, the TEMCA2 project aimed to develop new and adapted methodologies for the assessment of EMC related to this type of industrial large machinery.

KEYWORDS

EMC, large machines, EMC directive, standards, emission, alternative measuring methods.

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, electromagnetic wave propagation and EMC, both in certification/testing and design for compliance. One of the important aspects is that they are basically system-integrators of electrical and electronic modules, assembled inside the final product. In this way, they “inherit” the responsibility of the final machine compliance with the European EMC Directive 2004/108/EC.

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 EMC 2004/108/EC [1] concerns also large machines.

Large machines, in the usual sense of this term, are normally *apparatus* and have to be treated as such, except if they could be considered as *production lines*”. When considering a large machine as an ‘apparatus’, the conformity assessment procedure has been simplified to a single procedure. Even if harmonised standards are not applied, there is no more a compulsory involvement of a third party.

Concerning standards and based on the last Harmonised Standards list published in September 2007, one should consider the product family standards for machine tools EN 50370-1 [3] and EN 50370-2 [4], respectively for emission and immunity. Regarding the scope of these standards, machine tools may include motors, heating elements, sensors, transducers and activators, electric and electronic circuits and may be powered by the mains or any other electrical power source. These standards do not cover *fixed installations* as considered by EMC Directive, neither safety consideration as in the Machinery Directive.

Of course, large machines are not only machine tools but this couple of standards might be applied for other kind of machines as a reference when there are no European harmonised standards or where they do not cover all the protection requirements applicable to the machine.

The test approach described in these standards is quite informative. Type testing of a finished product should be the normal method for conformity assessment. In the case of a complete machine tool or in the case of large machines, a complete testing is only technically and economically feasible for a limited number of machines.

Three procedures are applicable:

- procedure A is a type-test on the complete machine,
- procedure B is a type-test on the entire electrical set of the machine, and a visual inspection of the machine regarding the correct installation of the components 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 is given in the flow chart in table 1.

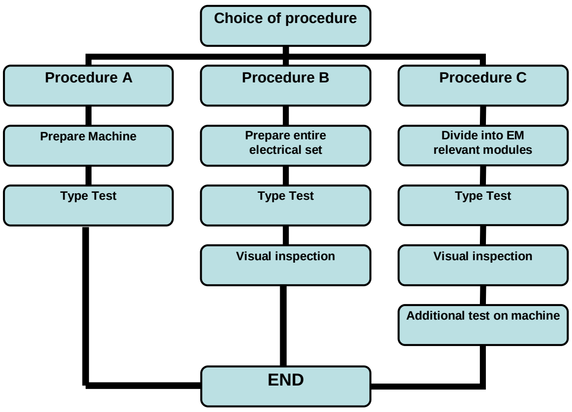


Table 1. Procedure for compliance as given in EN 50370

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. It allows an in-depth characterization and validation of all separate modules, and only an additional test is needed on the complete machine. These final testing may be performed using alternative methods, as developed in the research project TEMCA2. This project was conceived and proposed by a joint Working Group formed by CECIMO (European Committee for Co-operation of Machine Tool Industries) and CENELEC. This group prepared also the EN 50370-1/2 standards, dealing with EMC and Machine Tools.

3. CONDUCTED EMISSION

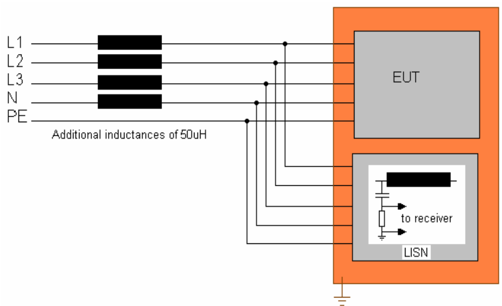
The main problem for large machinery is related to two items:

- 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
- if possible, to develop measuring setups, with a non-contacting probe for the power mains

Therefore, a number of possible alternative methodologies have been analysed, and an example of measuring results is given in the next sections.

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

In this case, 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.



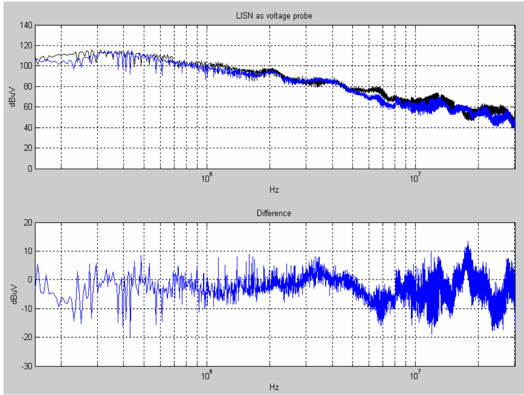
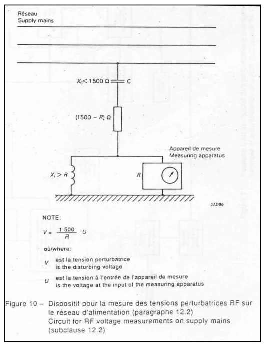


Figure 1. LISN used as voltage probe, and comparison of LISN (black) and LISN as voltage probe (blue)

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.



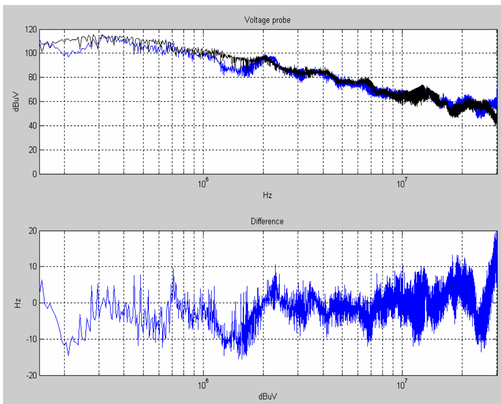


Figure 2. Voltage probe, and comparison of LISN (black) and voltage probe (blue)

3.3. Capacitive Voltage Probe (CVP)

A capacitive voltage probe has been developed, for measuring conducted interference from signal and data communication lines. Originally, it has been standardized in CISPR 22, but is now part of the CISPR 16 set. Within TEMCA2, the probe has been evaluated for use of measuring the conducted interference 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. A disadvantage is the restricted diameter of the cable, to be inserted in the central opening of the probe.
The CVP is shown in the next figure 3, which clearly shows the construction and use of the probe, and an example of measured results is also given in figure 3.

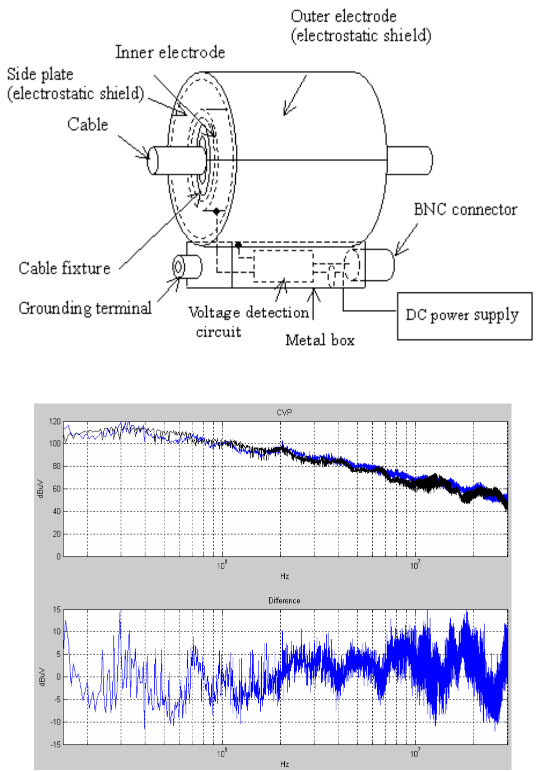
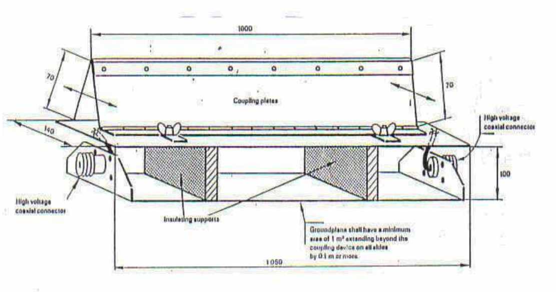


Figure 3. Capacitive Voltage Probe (CVP) and comparison of LISN (black) and CVP (blue)

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. This is a drawback with respect to the CVP (and also the capacitive foil). However, shorter lengths for an EFT clamp could be envisaged for practical use, but making them less sensitive. The main advantage is the defined impedance level of 50 Ohm, ensuring a good match with a preamplifier and/or measuring receiver. Unfortunately, the attenuation of the EFT capacitive clamp is rather high, and will normally need a preamplifier which might cause problems in noisy environments.



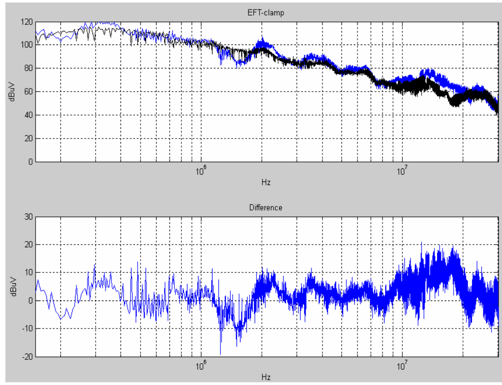


Figure 4. Comparison of LISN (black) and EFT clamp as voltage probe (blue)

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, without any restriction on current comsumption or voltage range of the machine.

A big advantage of this setup is that there are no restrictions about the diameter of the power cable, and that no direct access is needed to the power mains installation, because it is a non-contacting setup that can be applied at any point of the power cable.

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. A couple of practical examples is shown in the next figure.

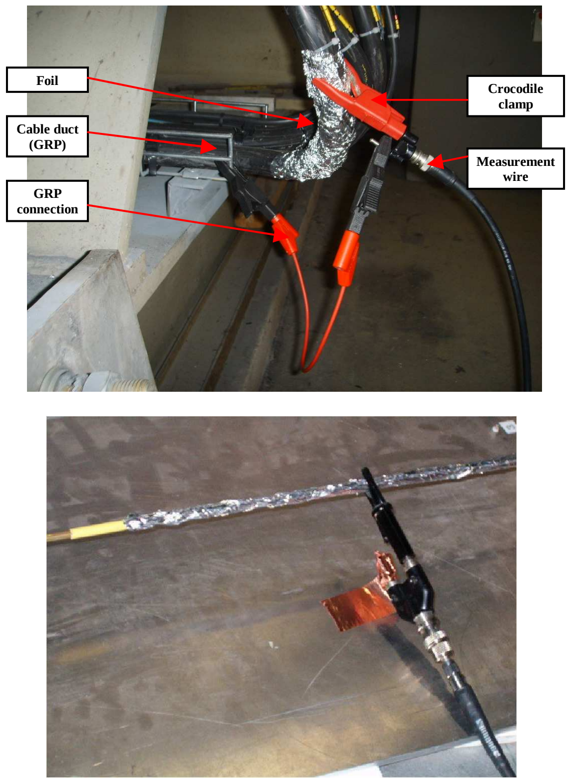


Figure 5. Examples of practical implementation of CFP

Instead of using a self-wrapped aluminium foil, another practical implementation could be made by using cable shielding material such as made by Zippertubing ®.

To validate this probe, both calibration measurements in the laboratory and simulations have been performed, in order to identify and define the attenuation factor (or correction factor to be applied).

For the simulations, both a lumped capacitor model, and a transmission line model have been used. The laboratory setup and the resulting attenuation factor are given in figure 6. Simulation details are shown in figure 7.
From both, it follows that a short CFP of about 30 cm, rigidly wrapped around a cable, may be estimated to generate a capacitor of 50 up to 70 pF.

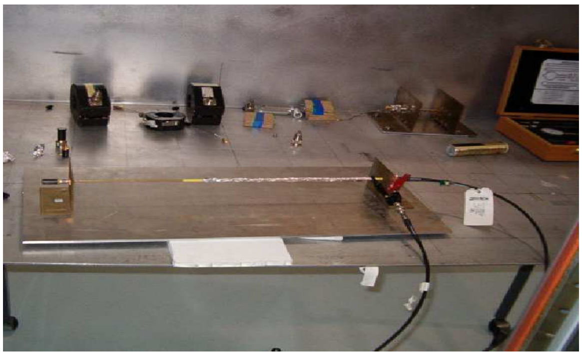


Figure 6 a. Calibration setup in the laboratory

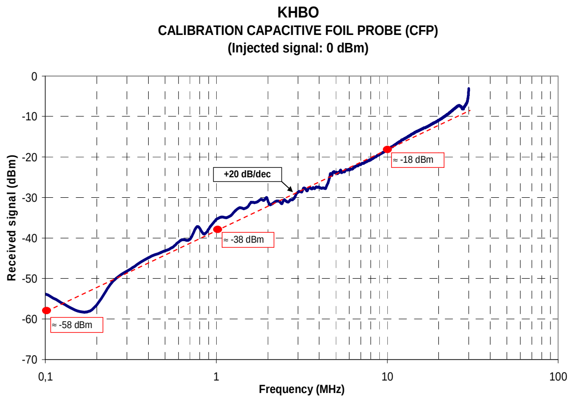


Figure 6 b. Calibration data of the CFP

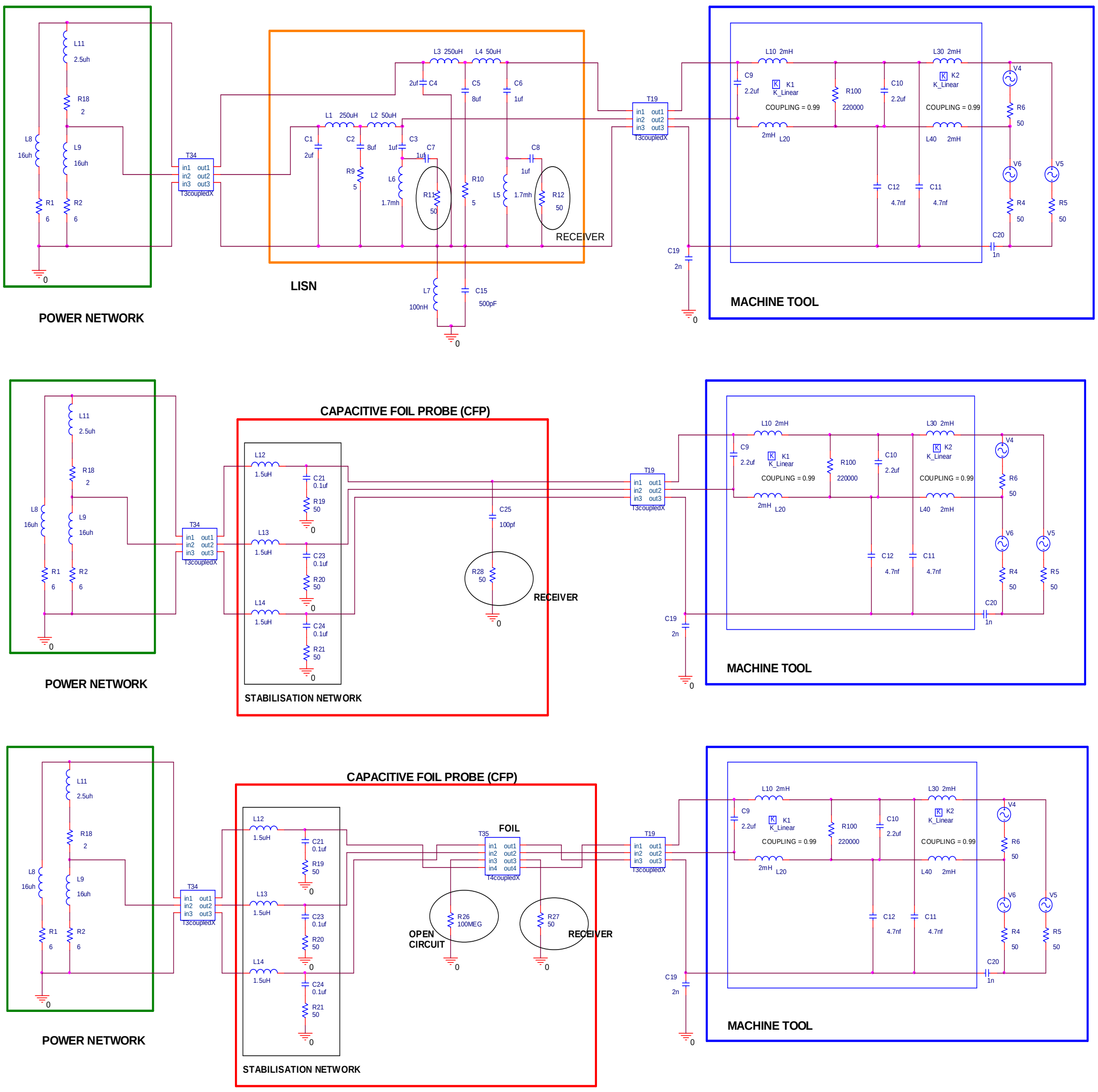


Figure 7. Equivalent circuits for LISN (upper), CFP lumped and CFP transmission line (lower)

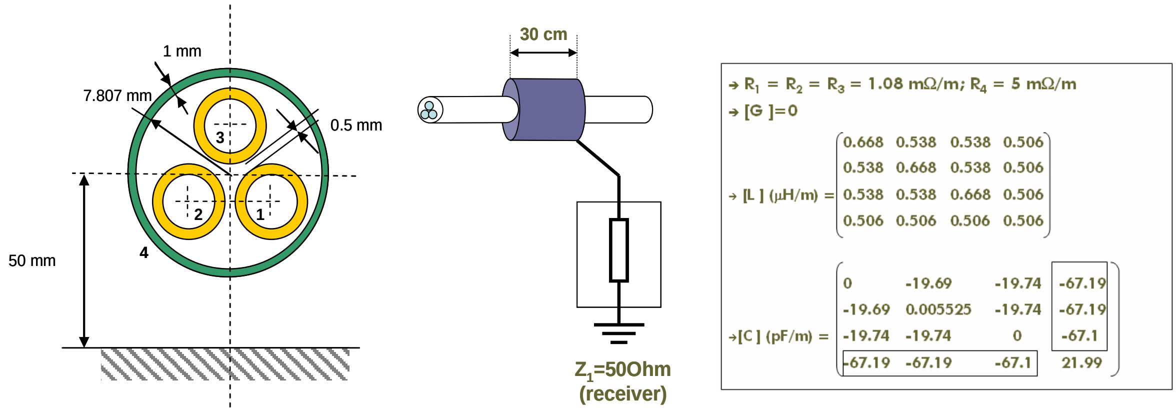


Figure 8. Parameter extraction details, obtained from CRYPTE, showing 67 pF capacitance

The characteristics for the transmission line model of the CFP were obtained by using the parameter extraction software CRYPTE, available in the TEMCA2 project via the partner ONERA (France). They have been used to be implemented in the transmission line model as shown in figure 7c.
In the next figures, more details are given concerning the parameter extracted values, and the resulting data for the attenuation factor and an example of measurements are given.

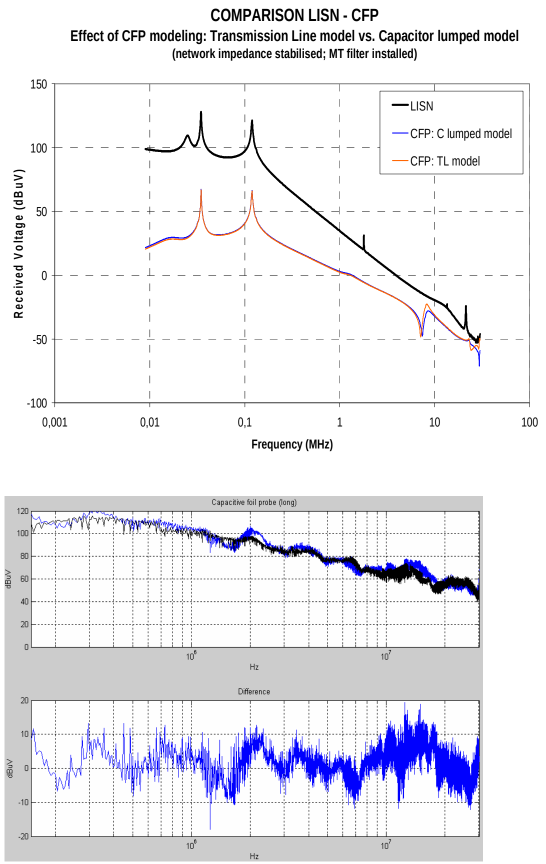


Figure 9. Comparison between the simulated attenuation factors of the LISN and the CFP (lumped and transmission line model) (left), and comparison of LISN (black) and CFP (blue) measuring results (right)

4. EXAMPLE OF TESTING OF A LARGE MACHINE IN PRACTICE

In this section, an example is given how to apply the preferred CFP method discussed above and to perform the tests under practical conditions.

The machine to be tested is and Electrical Discharge Machine (EDM) tool from the company ONA ™. The machine uses a wire for spark erosion machining and has been used as a reference machine in the TEMCA2 project.

Figure 10. Picture of the EMD from ONA ™ (spark erosion machine tool)

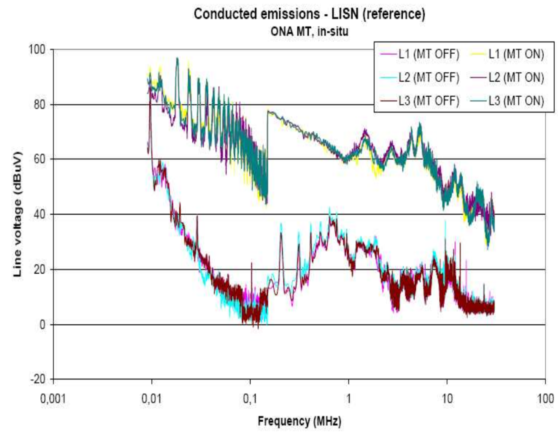
For the practical implementation, it is referred to figure 5 of section 3.5. of this paper, where it is shown how a foil of aluminium is just wrapped around the power cable. Given the fact that the method is dealing with rather low frequencies (conducted emission ranging from 150 kHz up to 30 MHz), so called "banana- and crocodile connectors" might be used, without introducing too big measuring errors.

It is clear that the proposed probe-factor, resulting from the earlier research work, both from the simulation results as forthcoming from the laboratory calibration tests provides a fair agreement between LISN reference measurements and CFP results on this test machine.

It must be noted that the actual available data and first conclusions are only based on these preliminary results.

More validation work is needed on more machines of different sizes and applications, in order to get enough data for a statistical analysis of the proposed probe-factor under practical (industrial) conditions.

The only conclusion at this moment is that the method looks very promising for use as the final control measurement, when applying procedure C of the standard EN 503780-1.



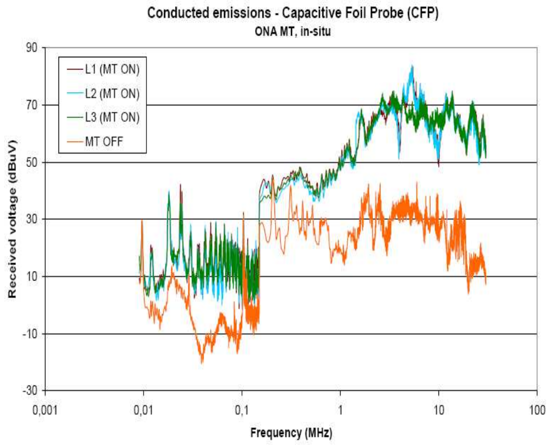


Figure 11. Conducted emission using LISN (upper) and CFP probe (lower)

It must be noted that in figure 11, no probe-factor has been applied for the CFP probe measurements, and that these results should be "corrected" in order to allow a direct comparison with the LISN results.

5. CONCLUSIONS

In this paper, an overview has been given on the work performed and the results obtained during the TEMCA2 research project, on "Alternative EMC testing methods for large machines", especially for checking conducted emission by large machinery.

The main advantage of the proposed CFP probe is that it can be wrapped around the power cable at any accessible position and needs no direct access to the power mains (non-contacting setup).

A technical disadvantage could be that the attenuation by the CFP is rather large at lower frequencies, so that some signals might "disappear" in the noise of the measuring equipment. But there is the identical restriction when using the 1500/50 Ohm voltage probe.

For conducted emission, an "easy to apply" CFP (Capacitive Foil Probe) has been identified, characterized and evaluated. This paper shows first results from both a research part, and a preliminary validation part of the method. More measurements must be performed on large machinery, in order to be able to perform a valuable statistical analysis of the method, and of the proposed probe-factor.

People interested in such a validation program may contact the main author, johan.catrysse@khbo.be

Anyway, it is referred to the standards EN 50370-1/2 [3,4] for EMC testing of large machinery, and especially to the "path C" to show evidence of compliance, by characterising relevant subparts and modules, and by checking the final implementation in the machine by combined visual inspection and simple testing.

ACKNOWLEDGEMENT

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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, 2005

[6] Knockaert J. et al., Comparison of alternative conducted emission measurement methods using FSV and IELF algorithms, Proceedings EMC Europe 2006, Barcelona, pp. 718-722

[7] Final report TEMCA2 (can be obtained from johan.catrysse@khbo.be)

[8] S.Coets, V.Beauvois, J.Catrysse and W.Legros, Accuracy of the measurements performed in conducted emissions in case of large systems, Proceedings EMC Zurich 2003

[9] S.Coets, V.Beauvois, J.Catrysse and W.Legros, Comparaison de methods de measures alternatives en emission conduite pour les équipements de puissance, CEM 2006, Saint-Malo, 2006

[10] R. de Vré, Application de la directive CEM 2004/108/EC aux installations fixes, Revue E, 2007