Practical Papers, Articles and Application Notes

Robert G. Olsen, Technical Editor

In this issue you will find two practical papers that should interest members of the EMC community. The first is entitled, "Ageing of Shielding Joints Shielding Performance and Corrosion: Part 1 – Measurement Methods" by Lena Sjögren and Mats Bäckström. This work was first presented at EMC Zurich 2005 and generated considerable interest. This is a subject that has not received enough attention and I hope that you will find it to be useful.The second is entitled "The Revised EMC Directive Versus the Current EMC Directive," by Frédéric Broydé and Evelyne Clavelier. In this paper, the authors have summarized the differences between the old and new EMC directives and emphasized how this might change the way the EMC directive is handled. I think that you will find this to be a good introduction to an important subject.

The purpose of this section is to disseminate practical information to the EMC community. In some cases the material is entirely original. In others, the material is not new but has been made either more understandable or accessible to the community. In others, the material has been previously presented at a conference but has been deemed especially worthy of wider dissemination. Readers wishing to share such information with colleagues in the EMC community are encouraged to submit papers or application notes for this section of the Newsletter. See page 3 for my e-mail, FAX and real mail address. While all material will be reviewed prior to acceptance, the criteria are different from those of Transactions papers. Specifically, while it is not necessary that the paper be archival, it is necessary that the paper be useful and of interest to readers of the Newsletter.

Comments from readers concerning these papers are welcome, either as a letter (or e-mail) to the Technical Editor or directly to the authors.

Ageing of Shielding Joints Shielding Performance and Corrosion

Part 1 – Measurement Methods: Transmission loss measurements in the near field and transmission cross-section measurements using a reverberation chamber

Lena Sjögren[1], Mats Bäckström[2]

Abstract — Transmission loss measurements in the near field have been performed for model shielding joints, combining different materials and types of gaskets. A method for transmission loss measurements in the near field, making measurements before and after exposure possible, is described. The method has provided useful results between 100 MHz and 2 GHz, results qualitatively in accordance with transmission cross section measurements in a reverberation chamber up to around 7 GHz. Transmission loss and transmission cross section measured differ between gasket types and material combinations. Changes of varying extent are measured from one-year sheltered outdoor exposure.

I. INTRODUCTION

In order to obtain electromagnetic compatibility, equipment or pieces of equipment emitting electromagnetic fields, or equipment requiring protection from external radiation, may be enclosed in shielded boxes of conductive material. Unless the box is completely closed by welding or soldering all seams, there will be openings forming slots, e.g. between the box and its lid. Such slots act as transmitting antennas and need to be electrically sealed to provide adequate shielding. Contact fingers or conducting gaskets can be used for this purpose, forming a shielding joint. The impedance of such a joint is composed of contact resistance in points of mechanical contact, capacitance between the surfaces and inductance due to surface asperities, see Fig. 1.

[1]Swedish Corrosion Institute, Kräftriket 23A, S-104 05 Stockholm, Sweden, Email Lena.Sjogren@corr-institute.se
[2]Swedish Defence Research Agency - FOI, Box 1165, S-581 11 Linköping, Sweden, Email Mats.Backstrom@foi.se

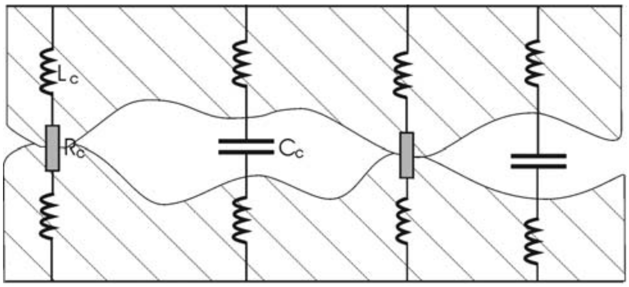

Fig. 1. Electrical representation of a shielding joint. Rc = contact resistance, Cc = contact capacitance and Lc = contact inductance.

Performance of shielding joints is normally evaluated in fresh condition. To ensure electromagnetic compatibility also after some time in use, it is necessary to consider effects of ageing: plastic deformation, decrease in contact force, oxidation and corrosion – all primarily effecting the contact resistance part of the joint impedance, see Fig. 1. Corrosion, resulting in insulating films being formed between points of contact, is governed by materials, material combinations, atmospheric conditions etc. Effects of corrosion on the electrical performance are governed by amounts and properties of corrosion products formed as well as by the design and mechanical properties of the joint. Avoiding unsuitable combinations of materials is thus not sufficient for ensuring continued shielding performance.

Some investigators have considered the effects of corrosion, mostly on the basis of laboratory exposures. Lessner and Inman [1] have evaluated corrosion effects from salt mist exposure of elastomer gaskets, employing model joints connected to the wall of a shielded room. Thibeau and Archambeault [2] as well as Peregrim [3] have employed transfer impedance measurements for evaluating effects of laboratory corrosion testing using mixed flowing gas tests similar to the "Battelle tests" [4]. Kunkel and Kunkel [5] report good correlation between transfer impedance and transmission loss measurements in the near field, using a near field fixture similar to that used in this investigation.

II. TEST OBJECTS

The test objects of this study are composed of two plates: a frame and a cover plate connected via a shielding gasket. The frame and cover plates, representing a shielded box and its cover, are screwed together with the shielding gasket in between, see Fig. 2. Two versions of the test object are used: with steel screws keeping the two metals plates together, and with nylon screws. In the steel screw version, the screws are in electrical contact with one of the metal plates and insulated from the other. The nylon screw alternative has threaded nylon rods with one metal dome nut at each end closing the holes in the two metal plates.

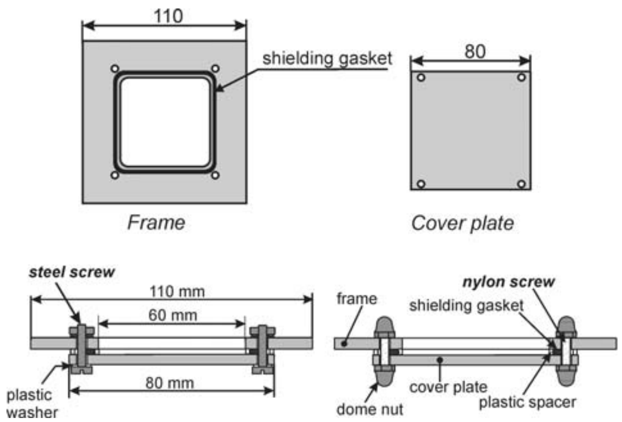

Fig. 2. Test object composed of a frame and a cover plate, screwed together with a shielding gasket in between. For closing the joint, steel screws (bottom left) or nylon screws (bottom right) are used.

Gaskets of different types and materials are combined with plates of different metal surfaces. Although the gaskets are of different types, per Fig. 3, they are all of similar size, adapted to a 1,4-1,8 mm slot between the frame and cover plates.

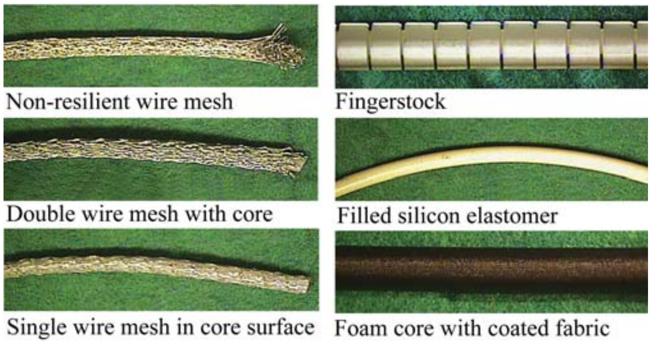

Fig. 3. Examples of shielding gaskets included in the investigation.

Two reference objects are included at all measurement occasions: a solid plate representing a perfect shielding joint and a frame and cover plate with an insulating rubber gasket representing a non-functioning shielding gasket.

III. MEASUREMENT METHODS

The "standard" method for measuring shielding effec-tiveness employs a test object mounted over an opening in the wall of a shielded room e.g. according to IEEE STD-299. Shielding effectiveness is measured as the quotient between power transmitted with and without the shield. Using a full size shielded room implies measurements mostly under far field conditions.

In this investigation, two methods are employed: transmission loss measurements using a fixture working in the near field and transmission cross section measurements using a reverberation chamber.

A. Transmission loss measurements in the near field

A tin-plated steel box in two halves is used for measurements mainly in the near field, see Fig. 4. The test object is fixed between the two box halves, with a tin plated fingerstock gasket between the flanges of the box and the frame of the test object. Transmitting and receiving antennas are positioned at each side of the test object. Both antennas are square copper plates. The transmitting antenna is terminated with 50 W.

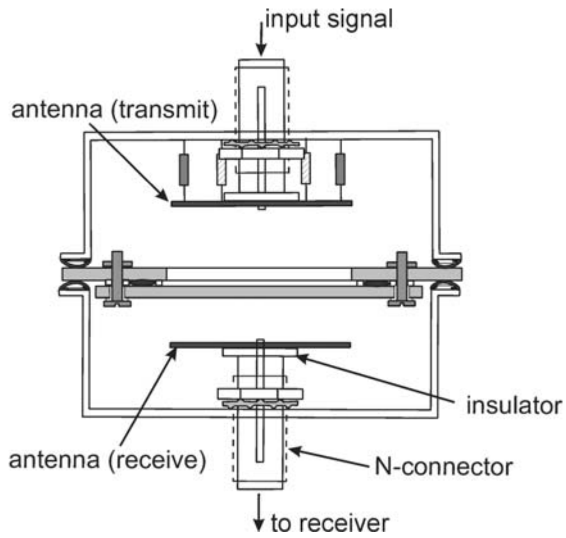

Fig. 4. Near field fixture: Box for transmission loss measurements in the near field.

An HP 8546A spectrum analyser with tracking generator is used for the measurements. A sinus signal, source power –1 dBm, is swept between 20 MHz and 2.9 GHz. The resonance frequency of the fixture, the box, is estimated at around 2.2 GHz, see Harrington [6]. The field transmitted by the test object is measured with 100 Hz resolution bandwidth, averaging response for three frequency sweeps. The relation between the transmitted and received signal is checked regularly, with a cable directly connecting the tracking generator output and the instrument input. Transmission loss measured is normalized to 0 dBm source power and expressed as dBm.

B. Transmission cross section measurements employing a reverberation chamber

A serious shortage in using comparative type of methods for determination of shielding effectiveness (SE) is that the measured SE for a given aperture cannot, in general, be used to calculate SE for an arbitrary enclosure furnished with that aperture. The problem originates from the fact that the shielding effectiveness of an enclosure is not only determined by the properties of the apertures causing the leakage, but also by properties of the enclosure itself. This serious shortage, also applicable to the near field transmission loss measurements used here, can be removed if, instead, the shielding properties of the aperture is expressed in terms of the aperture's transmission cross section, σ_a, as described by Bäckström, Martin and Lorén [7]. For an electrically large enclosure, the average shielding effectiveness $\langle SE \rangle$ can be estimated using

$$\langle SE \rangle = \frac{S_{inc}}{S_{sc}} = \frac{2\pi \cdot V}{\sigma_a \cdot \lambda \cdot \varrho}, \qquad (1)$$

where V is the volume and ϱ the quality factor of the enclosure, λ the wavelength and S_{inc} is the power density of the incident field. S_{sc} is the so called scalar power density inside the enclosure. The transmission cross section of the aperture, σ_a, is defined by

$$P_1 = \sigma_a \cdot S_{inc} \qquad (2)$$

where P_1 is the power transmitted through the aperture. From Eq. (2) it follows that the dimension of σ_a is given in square meters. In general, the transmission cross section will depend on the polarization and angle of incidence of the plane wave exciting the aperture. A measurement of σ_a carried out in a reverberation chamber yields an isotropic average corresponding to plane waves arriving from all possible angles of incidence and polarizations from the half space irradiating the aperture.

The method described is included in IEC 61000-4-21 [8], a more general description of the reverberation chamber, history and applications, is given in [9].

The reverberation chamber used in this investigation is composed of two chambers: approximately 5.1 x 2.5 x 3.0 and 3.6 x 2.5 x 3.1 m^3, joined by a common wall. The wall has a 290x290 mm opening over which the test object, with the joint to be measured, is fitted and connected to the wall. Two mechanical stirrers, one in each chamber, are used for moving around the maxima and minima of the electric field. Transmitting and receiving antennas are positioned in the chambers on each side of the test object. The power received is measured relative to the source power, employing a network analyser HP 8510C. Amplifiers are used for both the transmitted and received signal. Source power after amplification is approximately 20 dBm. For each stirrer position, measurements are performed at 201 frequencies equally distributed over the frequency interval 2-18 GHz. For each frequency, measurement results are averaged for 128 measurements per point and for 3x3 stirrer positions.

The transmission cross section of the test object is calculated, for each frequency, as the quotient between the power picked-up by the receiving antenna for the test object and the received power for a ∅30 mm reference hole, multiplied by the "true" transmission cross section for the reference hole. The "true" transmission cross section has been measured previously in a calibrated chamber, as described by Bäckström and Lundén [10].

IV. EXPOSURE CONDITIONS

After initial measurements, the specimens have been exposed for one year, July to July, under a hood (vent between roof and walls, no floor) on a terrace close to a lake, immediately north of the Stockholm City boundary (Kräftriket). The specimens are exposed in a vertical position, 25 mm between individual objects. Two specimens with steel screws and one with nylon screws are used for each plate-gasket combination. The three specimens are positioned apart form each other under the hood.

Besides test objects, zinc and steel reference coupons have been exposed for corrosivity measurements according to ISO 9223 [11], resulting in a category C2 (low corrosivity) classification for both materials.

V. RESULTS AND DISCUSSION

Specimens with steel screws generally show higher transmission loss than nylon screw specimens. One example of results obtained is shown in Fig. 5, where changes in shielding effectiveness from the one-year weather protected exposure are manifested for the nylon screw version only. For the steel screw specimens, leakage due to the screws dominates over leakage through

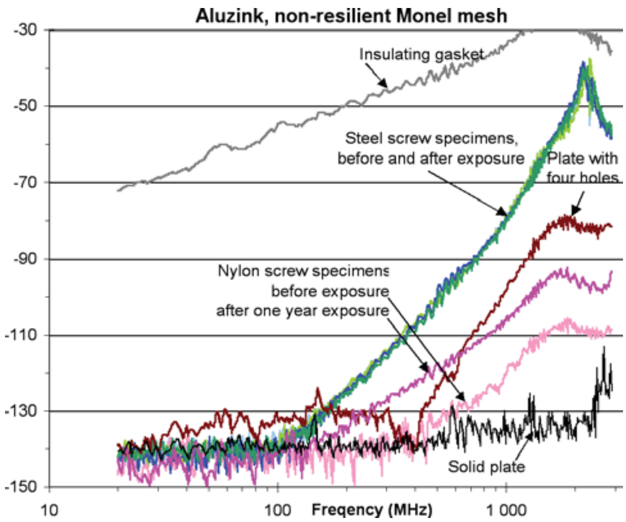

Fig. 5. Transmission loss as measured in the near field fixture of Fig. 4, normalized to 0 dBm source power. Test object: Aluzink frame and cover plates connected via a non-resilient Monel mesh gasket (knitted wire mesh formed to shape, no core, no hollow center). A solid plate with four holes is included for comparison.

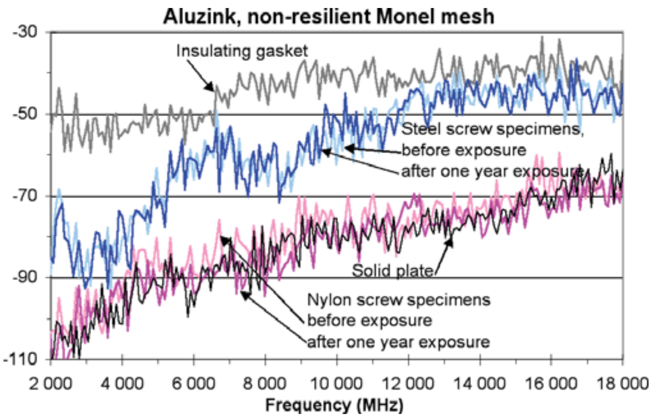

Fig. 6. Transmission cross-section as measured in a reverberation chamber. Aluzink frame and cover plates connected via a non-resilient Monel mesh gasket, same specimens as in Fig. 5.

the shielding joint. The gap formed from insulating the steel screw from one of the plates, a plastic washer is used as shown in Fig. 2, will cause leakage, but cannot be the main cause. As shown in Fig. 5, leakage through four open holes is lower than through a joint closed by steel screws. The higher transmission loss obtained with steel screw specimens is most likely due primarily to the coaxial structure formed by the shaft of the steel screw sticking through and slightly out of the metal plates.

A similar difference between steel screw and nylon screw specimens are seen at higher frequencies, in the transmission cross section measurements, see Fig. 6. In this case, the nylon screw specimen results are below the practical measurement floor, i.e. coincides with the solid plate reference results, both before and after exposure.

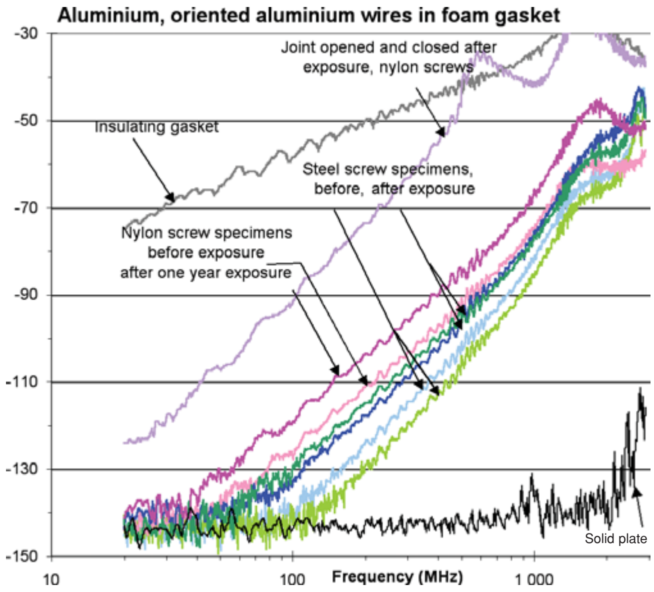

Fig. 7. Transmission loss as measured in the near field. Aluminium frame and cover plates connected via a foam gasket with embedded aluminium wires perpendicular to the gasket surface. Nylon and steel screw specimens.

In Fig. 7, near field results from a joint offering in lower shielding effectiveness are shown. The gasket is a foam gasket with aluminium wires embedded perpendicular to the surface, the wires sticking out slightly, connecting aluminium frame and cover plate. With this joint, changes from exposure are measured also with the steel screw specimens, i.e. leakage through the joint is higher than leakage due to the steel screws. Included in the figure is a graph showing effects of opening and closing the joint after exposure, resulting in strong deterioration (according to the gasket supplier, gaskets of this type should be exchanged after opening the joint). Transmission cross-section results for the same objects are shown in Fig. 8. With this joint, also the nylon screw specimens are above the practical measurement floor. Results after opening and closing the joint more or less coincides with the insulating gasket reference.

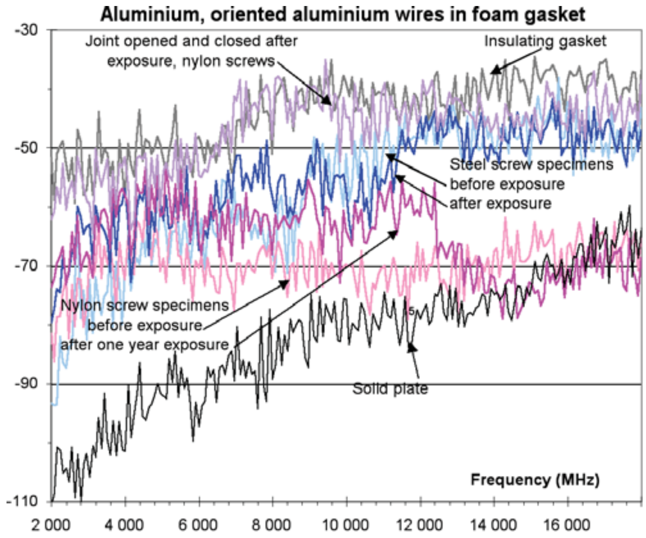

Fig. 8. Transmission cross-section as measured in a reverberation chamber. The same specimens as in Fig. 7.

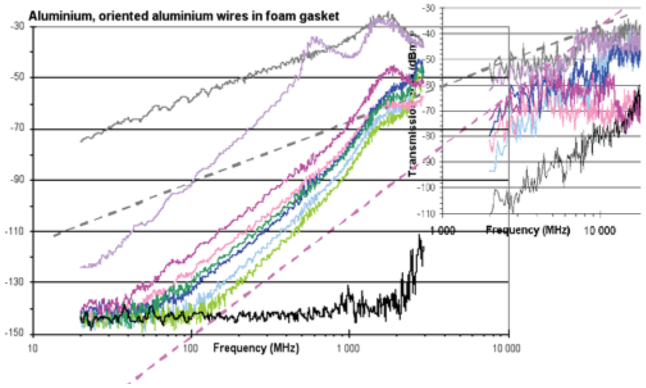

Fig. 9. Transmission loss and transmission cross-section (reverberation chamber) results from Fig. 7 and Fig. 8 plotted using the same relative scale. Dotted lines show the slopes of the graphs, excluding resonances.

In Fig. 9 the near field and reverberation chamber results are shown using the same relative scales. This comparison shows similar frequency behaviour and similar differences between objects with both measurements methods: transmission loss in the near field, up to 2 GHz, transmission cross section measurements, from 2 GHz up to 6-7 GHz. 7 GHz would correspond to the second resonance frequency of a 65 mm slot (wave length equivalent to 2/3 of the slot length), i.e. corre-sponding to one side of the rectangular test object (Fig. 2).

Initial near field results for several combinations of gasket types and materials are included in Fig. 10, showing the distribution of measurement results. For most test objects, transmission loss is above the measurement floor, the solid plate reference, between 100 MHz and 2 GHz. Corresponding transmission cross-section area measurements are shown in Fig. 11. With the small size test objects used, many measurement results are equivalent to the measurement floor, the solid plate reference, while leakage equivalent to the insulating gasket reference is measured for other specimens. More detailed results for different gasket/material combinations will be presented in subsequent papers.

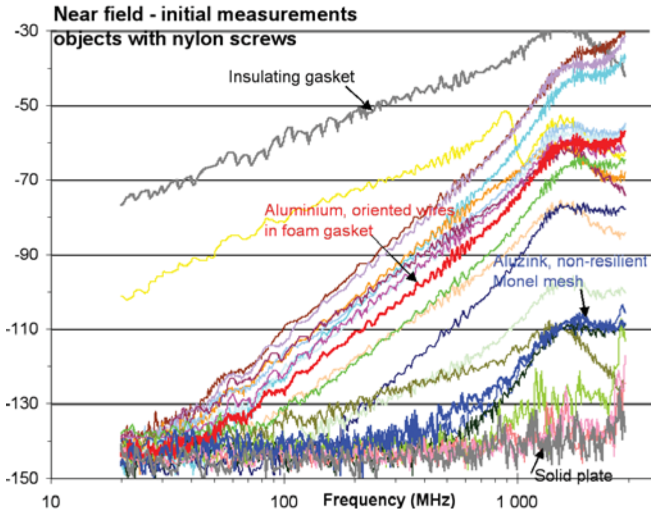

Fig. 10. Transmission loss as measured in the near field. Different combinations of materials and gasket types, initial measurement results with nylon screw specimens. Test objects included in Fig. 5 to Fig. 9 are marked.

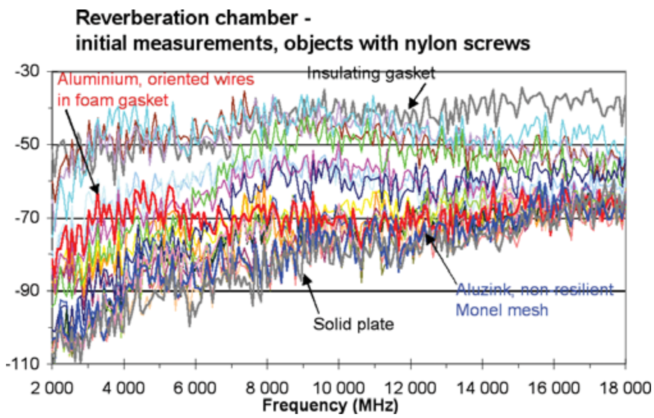

Fig. 11. Transmission cross-sections as measured in a reverberation chamber. Different combinations of materials and gasket types, initial measurement results with nylon screw specimens. Test objects included in Fig. 5 to Fig. 9 are marked.

VI. CONCLUSIONS

The near field measurement method employed with specimens without protruding metal screws, provides sufficiently sensitive measurements for distinguishing between different gasket types and material combinations, as well as for revealing effects of ageing. The comparatively simple and cheap method yields useful measurement results between 100 MHz and 2 GHz. Up to around 7 GHz, the results are qualitatively in accordance with transmission cross section measurements in a reverberation chamber, a method known to be properly correlated to actual conditions.

Different combinations of materials and shielding gaskets yield measurement results distributed over the usable measurement range, at 1 GHz differences up to 85 dB have been measured.

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Biographies

Lena Sjögren (M'1988) was born in Fagersta, Sweden in 1953. She received the M.Sc. degree in chemical engineering from the Royal Institute of Technology, Stockholm, Sweden, in 1976.

She is currently employed at the Swedish Corrosion Institute, primarily active in atmospheric corrosion research and consultancy, including: atmospheric corrosion sensors, corrosion under indoor conditions, corrosion of electronic equipment, and corrosion protection from inorganic coatings. With a background from the telecommunications industry, she has previously been involved in reliability issues for electrical contacts, including joints and connections for electromagnetic compatibility, as manager of a contact test lab and as a consultant.

Mats Bäckström (M'91) was born in Stockholm, Sweden in 1953. He received the M.Sc. degree in engineering physics and the Ph.D. degree in physics from Uppsala University, Uppsala, Sweden, in 1978 and 1985, respectively.

He currently holds the position as Director of Research in Electromagnetic Effects at the Swedish Defence Research Agency, FOI. He is project leader for the FOI projects on HPM (High Power Microwaves) Protection and System Effects. Before he joined FOI, he was head of the Electromagnetic Effects group at Saab Military Aircraft.

Dr. Bäckström is chairman of the Swedish URSI Commission E, Electromagnetic Noise and Interference. He is co-chairman of the URSI working group on Intentional EMI. He has been recognized as an EMP Fellow by the US Summa Foundation. He has been the secretary of the Swedish Chapter of the IEEE EMC Society.

The Revised EMC Directive Versus the Current EMC Directive

Frédéric Broydé, senior member, IEEE, and Evelyne Clavelier, senior member, IEEE

Affiliation of Frédéric Broydé:
Excem — 12, chemin des Hauts de Clairefontaine — 78580 Maule — France
Tel. + 33 (0) 1 34 75 13 65 Fax. + 33 (0) 1 34 75 13 66
e-mail: fredbroyde@excem.fr

Affiliation of Evelyne Clavelier:
Excem — 12, chemin des Hauts de Clairefontaine — 78580 Maule — France
Tel. + 33 (0) 1 34 75 13 65 Fax. + 33 (0) 1 34 75 13 66
e-mail: eclavelier@excem.fr

Abstract — A "revised" EMC Directive has been published on the last day of 2004. Manufacturers will be able to take advantage of its provisions as from 20 July 2007. This paper presents the main differences between the "current" and "revised" EMC Directives, with an emphasis on several key aspects: items subject to the directive, installations, the compatibility assessment procedure and EMC standards. In general, the "revised" EMC Directives provides more flexibility, but also requires a more rigorous approach.

I. INTRODUCTION

The EMC Directive [1] of 3 May 1989 is applicable in the European Community (now the European Union) since 1 January 1992. Since 1 January 1996, *all apparatus liable to cause electromagnetic disturbance, or the performance of which is liable to be affected by such disturbance*, must comply with the requirements of the EMC Directive before being placed on the market or taken into service in the territory of the Member States. In this Directive, *apparatus* means *all electrical and electronic appliances together with equipment and installations containing electrical and/or electronic components*.

It was found early that the implementation of this legal document presented several areas where clarification was needed. In 1997, the Commission issued a Guide [2], which was a substantial contribution toward homogeneous application of the EMC Directive. Unfortunately, it was only an informal document which did not provide the necessary legal certainty.

The Simpler Legislation for the Single Market (SLIM) initiative was launched by the Commission in May 1996 with strong encouragement and support from Internal Market Ministers. The first task was to identify ways in which the existing single market legislation could be simplified. The resulting EMC SLIM report [3] is the foundation of the revision of the EMC Directive which was completed on 31 December 2004 with the publication in the *Official Journal of the European Union*. The European Communities also published a document [4] referred to as the *Independent study*, which was prepared within the revision process†.

† The employer of the authors (Excem) was awarded a study contract with the European Commission to provide technical support to the activities carried out within the context of the revision of the EMC Directive. The authors worked on this project from February 2000 to November 2000. During this period, they took part in the activities of the *EMC SLIM Working Group* in charge of the revision process and produced the *Independent study*.

This paper discusses the main differences between the "revised" EMC Directive [5] of 15 December 2004 (hereafter referred to as REMCD) and the "current" EMC Directive [1] (hereafter referred to as CEMCD). The above-mentioned Guide shall be called "Guide for CEMCD" hereunder.

II. GENESIS AND DATE OF APPLICATION OF THE REVISED EMC DIRECTIVE

The Commission, helped by a working group including representatives of the member states and representatives of enterprises, reached the stage of a draft Directive, during the first quarter of 2001. In December 2002, this document became a proposal for a new EMC Directive, presented in the document COM(2002)759 final [6]. It contained significant changes. For instance, according to its Article 7 and to the paragraph 1 of its Annex II, the manufacturers would become entitled to deviate from harmonized standards, provided they can demonstrate that they comply with the essential requirements of the Directive. Today, Article 10.2 of the "current" EMC directive [1] requires that any such deviation be investigated by a "competent body".

The paragraph 7 of the explanatory memorandum of this proposal for a Directive indicates that the technical findings of the independent study have brought to "include ready-made connecting devices within the scope of the Directive and to regulate specifically fixed installations".

In 2004, the European Parliament introduced 39 amendments to the proposal, 33 of which were adopted after a vote [7]. Considering that all adopted Parliament's amendments were acceptable, the Commission introduced an amended proposal in June 2004, which was finally approved by the Council on 29 November 2004 and became a directive [5] on December 15, 2004. This REMCD entered into force on 20 January 2005, but this date is without practical significance for manufacturers, because European Directives are not directly applicable to them. European Directives rather define provisions which each Member State (currently, 25 Member States) must transpose into laws and other regulations. Specifically, the provision which the Member States shall adopt to comply with the REMCD shall be applicable as from 20 July 2007, at which date the CEMCD shall be repealed. It will nevertheless remain possible to place on the market and/or put into service equipment complying with the requirements of directive 89/336/EEC, if they were placed on the market before 20 July 2009.

III. MAIN DIFFERENCES

The major differences between the REMCD of 2004 and the CEMCD of 1989 are the following:

- the definition of apparatus is changed;
- two classes of items are subject to the directive, *apparatus* and *fixed installation*, different obligations and procedures being applicable to each class;
- a conformity assessment procedure is defined for apparatus, which prescribes the creation of a technical documentation providing evidence of the conformity;
- the competent bodies are replaced by *notified bodies*, but their intervention is not mandatory, even where the manufacturer has not applied harmonized standards, as explained above;
- when a manufacturer does not apply all the relevant harmonized standards, the manufacturer must perform an *electromagnetic compatibility assessment* demonstrating that the apparatus meets the protection requirements;
- a specific regulatory regime is applicable to fixed installations.

IV. ITEMS SUBJECT TO THE DIRECTIVE

The general principle is that the CEMCD and REMCD apply to all items which can generate electromagnetic disturbances, or the performance of which may be affected by electromagnetic disturbances. However, several categories of items covered by more specific directives are totally or partially excluded from the CEMCD and REMCD, such as radio and telecommunications terminal equipment, medical devices, motor vehicles and equipment to be fitted in cars, some marine equipments, etc. Some other categories of items not covered by specific directives are also excluded, such as home-made radio equipment used by radio amateurs (in CEMCD and REMCD), aircraft covered by regulation (EC) No. 1592/2002 (in REMCD only), etc.

Let us now consider items which are not excluded by such provisions (i.e. Article 2 of CEMCD or Article 1 of REMCD). If we for instance consider an integrated circuit, or a printed circuit assembly, or a microcomputer, or a network of information technology equipment in a building, we clearly see that EMC requirements cannot be uniformly applied to them. The CEMCD is not satisfactory in this respect because it considers a single category of items, called *apparatus* (see section I above). Consequently, areas where the clarifications of the Guide for CEMCD [2] have been most needed (and still are) cover:

- defining categories of items subject to the directive,
- expressing meaningful protection requirements,
- modulating the protection requirements according to the categories of items,
- designating which item should be CE marked.

This Guide for CEMCD presents a "decision flow chart" and states that "the manufacturer has to determine the classification of his electrical apparatus as component, finished product, system or installation". In the end, the Guide for CEMCD uses five classes to which different obligations apply: "component without direct function", "component with direct function", "finished product", "system" and "installation". This is an objective classification, based on properties of the item, but of course it has loopholes. The Guide for CEMCD says that components without direct function (e.g. the integrated circuit) are not considered as apparatus within the meaning of the CEMCD, and explains that the applicability of the directive to fixed installations is limited, contrary to the words of the CEMCD, but in line with the contents of recognized EMC standards and practices.

The approach of the REMCD as regards the different classes of items is more satisfactory; it contains an objective classification of items, and prescribes obligations applicable to installations. In order to achieve this, the definition of *apparatus* is changed in the REMCD to the following:

- *any finished appliance, or combination thereof made commercially available as a single functional unit intended for the end-user, and liable to generate electromagnetic disturbance, or the performance of which is liable to be affected by such disturbances*, or
- a component or a sub-assemblies *intended for incorporation into an apparatus by the end-user, which are liable to generate electromagnetic disturbances, or the performance of which is liable to be affected by such disturbances*, or
- a mobile installation *defined as a combination of apparatus and where applicable, other devices, intended to be moved and operated in a range of locations*.

Two other classes of items are defined in the REMCD:

- *fixed installation means a particular combination of several types† of apparatus and, where applicable, other devices, which are assembled, installed and intended to be used permanently at a predefined location*,
- *equipment means any apparatus or fixed installation*.

The REMCD *regulates the EMC of equipment*, apparatus and fixed installation being subject to the same protection requirements, but different procedures are applicable.

Apparatus are subject to a *conformity assessment procedure* and to *"CE" marking* prior to placing on the market and/or putting into service. The manufacturer of an apparatus must provide information on any specific precautions needed to obtain the conformity to the protection requirements, and, in cases where compliance with the protection requirements is not ensured in residential areas, a restriction of use must be indicated.

Fixed installation must be installed applying *good engineering practices*, but are not subject to CE marking. When there are indications of non-compliance of a fixed installation, the competent authorities may request evidence of compliance of the fixed installation, and initiate an assessment.

V. INSTALLATIONS

As explained in section II, the approach of the REMCD regarding installations is rooted in the independent study, in which "installing" means placing items in position, and establishing the necessary electrical connection and other technical provi-

† Clearly, the word "type" should not appear in this definition. If a network of different computers is an installation, a network of identical computers should also be an installation. Anyhow, "type of apparatus" is not defined. In fact, if "of several types" had been deleted, this definition would have been more consistent with the definition of mobile installation.

sions for use. An installation is defined as the new item resulting from installing one or several items. In this manner, an installation does not necessarily include any cabling. Even a hand-held, battery-operated, cordless item is installed prior to be used. At the other extreme, an installation may only include cabling. For instance, the cables and connectors laid and fixed in a building for later (eventual) use as a medium for a local area network are installed.

Point 24 of the SLIM report [3] starts with "In practice installation rarely cause EMC problems to neighboring installations". The point of view of the independent study is exactly the opposite: only installations have EMC problems. In fact, using the above definitions of *installing* and *installation*, this statement is almost a tautology because, by definition, it is not possible to use an item that has not been installed. A second aspect is that the larger the installation, the more important the coupling phenomena (couplings between the cables of the installation, couplings between external fields and currents on these cables, couplings between currents on these cables and the fields produced by the installation, etc) are likely to be. This point is well known from EMC specialists who work on systems and installations.

In the REMCD, the requirements concerning installations are different from the one found both in the CEMCD (which says that installations are only a particular specie of apparatus, all requirements therefore applying to them) and in the Guide for CEMCD (which considers that installations can often be disregarded):

- separate provisions are applicable to fixed installations, such as an *a posteriori* assessment in case of complaints about disturbances generated by the installation (as opposed to the *a priori* conformity assessment procedure applicable to apparatus);
- an item which would normally be regarded as an apparatus, may eventually be exempt from conformity assessment procedure and CE marking if it is *intended for incorporation into a given fixed installation and is not otherwise commercially available*;
- when this option is not used, the manufacturer of an apparatus must *provide information on any specific precaution that have to be taken when the apparatus is assembled, installed, maintained or used, in order to ensure that the protection requirements are met*.

Note that networks of electricity-carrying conductors (power networks, telephone networks, etc) are fixed installations.

VI. COMPATIBILITY ASSESSMENT PROCEDURE AND EMC STANDARDS

The Commission periodically publishes a list of harmonized standards for the implementation of the CEMCD. The REMCD also refers to harmonized standards published in the same manner.

For apparatus, the REMCD defines an *electromagnetic compatibility assessment*, the purpose of which is to establish that the apparatus meets the protection requirements, *in all the possible configurations identified by the manufacturer as representative of its intended use*, taking into account *all normal intended operating conditions* and *based on relevant phenomena*. In addition, the manufacturer must draw up a technical documentation on this subject matter, *providing evidences of the conformity of the apparatus with the essential requirements* of the REMCD, not with a given standard. The REMCD even says that *compliance with a "harmonized standard" is not compulsory*. In general, this is a formidable task, even for specialists. However, the REMCD says that *the correct application of all relevant harmonized standards* can replace the electromagnetic compatibility assessment.

We observe that:

- the REMCD is flexible because it allows manufacturers to perform the conformity assessment procedure without reference to particular standards, without control of a third party (the "competent body" of the CEMCD), at the cost of conducting a detailed and documented electromagnetic compatibility assessment;
- the REMCD allows one to bypass the step of the electromagnetic compatibility assessment by merely applying all relevant harmonized standards.

Of course, it is intended that the simplest way of carrying out the conformity assessment procedure should be the use of harmonized standards. However, this route requires *the correct application of* ***all*** *relevant harmonized standards*. At the present time, it could be difficult to establish the list of all harmonized standards among the 111 listed in [8], which could be relevant to an innovative product combining several functions. One hardly needs to mention the fact that one needs to purchase standards to read their scope, and that the cost of these standards is not negligible. Let us hope that this situation will improve before 20 July 2007.

VII. CONCLUSION

The revised EMC Directive (REMCD) offers many improvements over the existing legislation, including clarification and flexibility. Since it accurately defines the compatibility assessment procedure, it also requires a more rigorous approach. Manufacturers will be able to take advantage of its provisions as from 20 July 2007. Note that a Guide for the REMCD is being prepared by the European Commission.

A remark concerns the fact that more equipment implements radio communications. Such equipment will not directly be covered by the REMCD, but will remain covered† by the R&TTE Directive [9], which incorporates the protection requirements of the CEMCD.

Excem is currently providing technical assistance to the Enterprise directorate-general of the European Commission, relating to the application of the EMC Directive and R&TTE Directive. Because of this particular situation, it is necessary to stress that this paper only reflects an approach followed by the authors, independently of any work performed by them for the Commission.

† A *radio equipment* covered by the R&TTE Directive is an item capable of communication by means of the emission and/or reception of electromagnetic waves of frequencies from 9 kHz to 3 THz, propagated in space without artificial guide. Several categories of items are excluded from the R&TTE Directive, among which broadcasting receivers.

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Biographies

Frédéric Broydé (S'84 - M'86 - SM'01) was born in France in 1960. He received his "ingénieur" degree in physics engineering from the physical engineering department of the Ecole Nationale Supérieure d'Ingénieurs Electriciens de Grenoble (ENSIEG), in 1984, and the Ph.D. in microwaves and micro technologies from the Université des Sciences et Technologies de Lille (USTL), in 2004. He co-founded the Excem Corporation in May 1988, and became its chairman, a position he holds to this day. He supervises engineering or R&D projects related to EMC and electronic design. Some of his most active research areas related to EMC are the development of high data rate transmission systems, the characterization and design of cylindrical shields, and the control of the fields close to linear antennas. He currently takes part in a technical assistance to the European Commission for the implementation of the R&TTE and EMC directives. He is also working on secure transmission in cables, on the design of an advanced RF amplifier for mobile communications and on models for improving the design of switch-mode power circuits. He is a radio amateur (F5OYE) and a member of the Audio Engineering Society (AES). He is author or co-author of 60 technical papers, and inventor or co-inventor in patent applications for 29 inventions. A complete bibliography including published papers and patents applications of Dr. Broydé is available on the http://www.eurexcem.com web site. He may be reached at fredbroyde@eurexcem.com.

Evelyne Clavelier (S'84 - M'85 - SM'02) also with Excem, was born in France in 1961. She received her "ingénieur" degree in physics engineering from the physical engineering department of the Ecole Nationale Supérieure d'Ingénieurs Electriciens de Grenoble (ENSIEG), in 1984. She is cofounder of the Excem Corporation (May 1988), and later became general manager of this company. She is a senior EMC and reliability engineering consultant. She is in charge of scientific and technical software development, and as such works on cylindrical shield and cable modeling. She is also currently working on free-space optical transmissions, on the description of the near field of portable transmitters, and on schemes capable of increasing the efficiency of RF amplifiers. She is a radio amateur (F1PHQ). A complete bibliography of Ms. Clavelier is available on the http://www.eurexcem.com web site, with the full text of a selection of her published papers. She may be reached at eclavelier@eurexcem.com.