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THE INTERNATIONAL JOURNAL OF ELECTROMAGNETIC COMPATIBILITY

Europe EMC Guide

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Solid State Tetrode Tube and Combination Amplifiers

Model Number	Freq Range (MHz)	Min Pwr Out (Watts)	Min Sat Gain (dB)
M/TCCX/SCCX Series • *.01-220 MHz*			
SCCX300	.01-220	300	55
SCCX500	.01-220	500	57
M404	.01-220	500	57
M406	.01-220	1000	60
TCCX2000	.01-220	2000	63
TCCX2200	.01-220	2200	63
TCCX2500	.01-220	2500	64
CMX/SMX Series • *.01-1000 MHz*			
SMX301	.01-1000	300/100	55/50
SMX302	.01-1000	300/200	55/53
SMX303	.01-1000	300/300	55/55
SMX501	.01-1000	500/100	57/50
SMX502	.01-1000	500/200	57/53
SMX503	.01-1000	500/300	57/55
CMX10001	.01-1000	1000/100	60/50
CMX100010	.01-1000	1000/1000	60/60

Microwave Solid State and TWT Amplifiers

Model Number	Freq Range (GHz)	Min Pwr Out (Watts)	Min Sat Gain (dB)
T-200 Series • *200-300 Watts CW 1-21.5 GHz*			
T251-250	1-2.5	250	54
T82-250	2-8	250	54
T188-250	7.5-18	250	54
T2118-250	18.0-21.7	250	54
T-500 Series • *500 Watts CW 1-18 GHz*			
T251-500	1-2.5	500	57
T7525-500	2.5-7.5	500	57
T188-500	7.5-18	500	57
MMT Series • *5-150 Watts, 18-40 GHz*			
T2618-40	18-26.5	40	46
T4026-40	26.5-40	40	46
S/T-50 Series • *40-60 Watts CW 1-18 GHz*			
S21-50	1-2	50	47
T82-50	2-8	50	47
T188-50	8-18	50	47

Solid State Amplifiers

Model Number	Freq Range (MHz)	Min Pwr Out (Watts)	Min Sat Gain (dB)
SMCC Series • *200-1000 MHz*			
SMCC350	200-1000	350	55
SMCC600	200-1000	600	58
SMCC1000	200-1000	1000	60
SMCC2000	200-1000	2000	63
SMC Series • *80-1000 MHz*			
SMC250	80-1000	250	54
SMC500	80-1000	500	57
SMC1000	80-1000	1000	60
SMX-CMX Series • *.01-1000 MHz*			
SMX100	.01-1000	100	50
SMX200	.01-1000	200	53
SMX500	.01-1000	500	57
SVC-SMV Series • 100-1000 *MHz*			
SVC500	100-500	500	57
SMV500	500-1000	500	57

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Europe EMC Guide

Letter from the Editor

Sarah Long
ITEM Publications

Upon returning from the IEEE EMC Society Symposium in Long Beach, California, and reflecting on all the new technology on display in the exhibit hall and all the research being reviewed during the technical program, what I found most exciting was the announcement that the 2015 edition of the symposium would be held in Dresden, Germany.

It's easy to see why.

Dresden is not only the portal to the emerging markets of Central and Eastern Europe, but it is also located in the country that is home to the world's fifth largest economy. Dresden has a rich historical and cultural heritage, but the city and the surrounding area also have developed into a major hub for research and development. The area's high-tech companies address microelectronics, electromobility, nanotechnology, photovoltaic, and biotechnology.

There's no need to wait until 2015 for access to Europe's technological offerings, however. In this second installment of the Interference Technology Europe EMC Guide, we've expanded the calendar section to include more EMC-related events across Europe, as well as in the U.S. and Asia. From all-encompassing shows like electronica 2012, hosted again by Germany but this time in Munich, to the more targeted 2012 ESA Workshop on Aerospace EMC in Venice, Italy, these pages will help EMC engineers searching for advanced approaches and techniques in test and design find what they need.

In addition to shiny exhibits from EMC vendors, these events showcase some of the latest research being conducted in the mature yet evolving EMC industry.

Take, for example, Magnus Olofsson's work on the Smart Grid, which is increasingly seen as a means to facilitate climate-friendly renewable energy sources and to enable efficient use of electricity. Beginning on Page 152, Olofsson explains that a consequence of Smart Grid is a drastic increase in use of electronics in the power system, which makes the satisfactory function of electrical and electronic equipment vital for realization of a robust Smart Grid. His article focuses on the satisfactory function of equipment for Smart Grid with respect to electromagnetic disturbances, i.e. electromagnetic compatibility, including power quality, and proposes a framework for the apportioning of responsibilities between network operators and the parties responsible for the connection of equipment.

Engineers involved in design and test for EMC compliance also can get the latest information on the standards governing EMC and the challenges they pose, such as the need to verify emission and susceptibility performance above 1GHz. The key date is 1 October 2011, when EN55022:2006 +A1:2007 becomes the only version of the relevant standard that will support compliance to the technical requirements of the EMC Directive. In fact, 1 October marks the end of a transition period, during which device manufacturers could choose to test products either to the latest revision or to the prior version EN55022:1998 (with amendments A1:2000 and A2:2003). Steve Hayes of TRaC Global fills in the details in his article on Page 38.

We hope you will find the events, standards updates and technical articles in this Europe EMC Guide useful and send us your feedback on what we should include, expand on or change for next year's guide.

Please e-mail me your thoughts at slong@interferencetechnology.com. I'd love to hear from you.

Standards *Europe*

Compliance with standards can make or break the marketing of any new product. This section recaps some of the major new and revised EMC standards in the last year from the three European standards organisations: the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI). Standards information and updates are featured in our *Interference Technology eNews*. Just go to *InterferenceTechnology.com*, subscribe to the *eNews*, and you'll be notified weekly of important changes in EMC standards from Europe and around the world.

European Committee for Standardization (CEN)

EN 617:2001+A1:2010

TECHNICAL BODY: CEN/TC 148 - Continuous handling equipment and systems - Safety

STATUS: Published

DATE OF PUBLICATION: 2011-06-30

TITLE: Continuous handling equipment and systems - Safety and EMC requirements for the equipment for the storage of bulk materials in silos, bunkers, bins and hoppers

SCOPE: This European Standard deals with the technical requirements to minimise the hazards listed in clause 4 and annex A. Safety requirements and/or measures in this standard apply to equipment used in all environments. However, additional risk assessment and safety measures need to be considered in severe conditions, e.g. low or high temperatures out of the range covered by EN 60204-1, corrosive environments, strong magnetic fields, radioactive conditions and bulk materials to be stored included their flow the nature of which could lead to a dangerous situation. This European Standard deals with the technical requirements for electromagnetic compatibility (EMC).

EN 619:2002+A1:2010

TECHNICAL BODY: CEN/TC 148 - Continuous handling equipment and systems - Safety

STATUS: Published

DATE OF PUBLICATION: 2011-04-30

TITLE: Continuous handling equipment and systems - Safety and EMC requirements for equipment for mechanical handling of unit loads

SCOPE: 1.1 This European standard deals with the technical requirements to minimise the hazards listed in Clause 4 and Annex B ... 1.2 This standard applies to mechanical handling devices defined in Clause 3, singly or combined to form a conveyor system, and designed exclusively for moving unit loads continuously on a predefined route from the loading to the unloading points, possibly with varying speed or cyclically ... 1.3 Safety requirements and/or measures in this standard apply to equipment used in all environments ... 1.4 This European Standard deals with the technical requirements for electromagnetic compatibility (EMC). 1.5 This standard does not cover hazards during decommissioning and hazards generated by noise. It also does not cover operation in environments where the electromagnetic disturbances are outside the range of those specified in EN 61000-6-2. This standard does not apply to conveying equipment and systems used underground or in public areas and to aircraft ground support equipment. (...)

EN 620:2002+A1:2010

TECHNICAL BODY: CEN/TC 148 - Continuous handling equipment and systems - Safety

STATUS: Published

DATE OF PUBLICATION: 2011-06-30

TITLE: Continuous handling equipment and systems - Safety and EMC requirements for fixed belt conveyors for bulk materials

SCOPE: This European standard deals with the technical requirements to minimise the risks due to the hazards listed in clause 4, which can arise during operation and maintenance of fixed belt conveyors and systems as defined in 3.1 to 3.2.4 and designed for continuously conveying loose bulk materials from the loading point(s) to the unloading point(s). Requirements for electromagnetic compatibility are also covered.

EN 1175-1:1998+A1:2010

TECHNICAL BODY: CEN/TC 150 - Industrial Trucks - Safety

STATUS: Published

DATE OF PUBLICATION: 2011-05-31

TITLE: Safety of industrial trucks - Electrical requirements - Part 1: General requirements for battery powered trucks

SCOPE: 1.1 This standard specifies electrical and related mechanical safety requirements for design and construction of the electrical installation in battery powered industrial trucks hereinafter referred to as trucks, with nominal voltages of the truck system up to 240 V. The Annex A is normative and gives requirements for "Connectors for traction batteries". Annex B is normative and contains "Electric motors - Output and test rules" and Annex C is normative and contains "Electromagnetic contactors".

European Committee for Electrotechnical Standardization (CENELEC)

EN 50065-1:2011

TECHNICAL BODY: ISO/IEC/JTC 1/SC25

STATUS: Published

DATE OF PUBLICATION: 2012-03-21

TITLE: Signalling on low-voltage electrical installations in the frequency range 3 kHz to 148,5 kHz - Part 1: General requirements, frequency bands and electromagnetic disturbances

EN 50173-1:2011

TECHNICAL BODY: ISO/IEC/JTC 1/SC25

STATUS: Published

DATE OF PUBLICATION: 2012-04-01

TITLE: Information technology - Generic cabling systems - Part 1: General requirements

EN 50174-1:2009/A1:2011

TECHNICAL BODY:: ISO/IEC/JTC 1/SC25

STATUS: Published

DATE OF PUBLICATION: 2012-01-01

TITLE: Information technology - Cabling installation - Part 1: Installation specification and quality assurance

SCOPE: This European Standard specifies requirements for the following aspects of information technology cabling: a) installation specification, quality assurance documentation and procedures; b) documentation and administration; c) operation and maintenance. This European Standard is applicable to all types of information technology cabling including generic cabling systems designed in accordance with the EN 50173 series of standards. Safety (electrical safety and protection, optical power, fire, etc.) and electromagnetic compatibility (EMC) requirements are outside the scope of this European Standard and are covered by other standards and regulations. However, information given in this European Standard may be of assistance in meeting these standards and regulations.

EN 50310:2010

TECHNICAL BODY: ISO/IEC/JTC 1/SC25

STATUS: Published

DATE OF PUBLICATION: 2011-10-01

TITLE: Application of equipotential bonding and earthing in buildings with information technology equipment

SCOPE: This European Standard specifies minimum requirements for earthing networks and connections (bonds) in buildings in which information technology equipment is intended to be installed to protect that equipment and interconnecting cabling from electrical hazards. Additionally this European Standard specifies requirements and provides recommendations for earthing networks and connections (bonds) in order for the information technology installation to achieve a) reliable signal reference, b) adequate immunity from electromagnetic interference carried by the earthing network. The requirements of this European Standard are applicable to all types of buildings ranging from residential to large commercial and industrial premises. Operator buildings are addressed by ETSI EN 300 253. This European standard specifies an earthing and bonding configuration that is appropriate to specific mains and other power supply distribution systems.

EN 50383:2010

STATUS: Published

DATE OF PUBLICATION: 2011-06-01

TITLE: Basic standard for the calculation and measurement of electromagnetic field strength and SAR related to human exposure from radio base

STANDARDS ORGANIZATIONS

CEN, THE EUROPEAN COMMITTEE FOR STANDARDIZATION
CEN is a provider of European Standards and technical specifications. It is a recognized European organization according to Directive 98/34/EC for the planning, drafting and adoption of European Standards in all areas of economic activity with the exception of electrotechnology (CENELEC) and telecommunication (ETSI).
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stations and fixed terminal stations for wireless telecommunication systems (110 MHz - 40 GHz)

EN 50498:2010

STATUS: Published

DATE OF PUBLICATION: 2011-07-01

TITLE: Electromagnetic compatibility (EMC) - Product family standard for aftermarket electronic equipment in vehicles

SCOPE: This European Standard specifies limits and methods of measurement for disturbance emissions and immunity characteristics of aftermarket equipment (ESAs) which are referenced by Automotive EMC Directive 2004/104/EC, Annex I, 3.2.9, and which are not related to immunity-related functions of vehicles as defined in Automotive EMC Directive 2004/104/EC, Annex I, 2.1.12. Any equipment (or part of an ESA) which has a primary function of radio transmission and/or reception according to the ITU Radio Regulations are excluded from the scope of this publication. This European Standard covers the frequency range 9 kHz to 400 GHz. To date, it specifies limits and methods of measurement for conducted and radiated disturbances from ESAs in the frequency range 30 MHz to 1 GHz and immunity requirements for conducted transients. The assessment of an ESA needs to be performed only in the frequency ranges where limits are defined ... As ESAs covered by this standard are not related to immunity-related function, only the following electromagnetic disturbance phenomena are evaluated: • broadband and narrowband radiated electromagnetic disturbances; • conducted transient disturbances; • conducted transient immunity. Accessories that are not connected directly to the vehicle harness, but only via a special interface are normally excluded from vehicular EMC requirements.

EN 50527-2-1:2011

STATUS: Published

DATE OF PUBLICATION: 2012-05-02

TITLE: Procedure for the assessment of the exposure to electromagnetic fields of workers bearing active implantable medical devices - Part 2-1: Specific assessment for workers with cardiac pacemakers

EN 50529-1:2010

STATUS: Published

DATE OF PUBLICATION: 2011-11-01

TITLE: EMC Network Standard - Part 1: Wire-line telecommunications networks using telephone wires

SCOPE: This EMC standard specifies requirements for emissions originating from within wire-line telecommunication networks using telephone wires and the immunity of those networks, including their in-premises extensions by references to harmonised EMC product standards and other standards with EMC requirements in combination with good engineering practice, when installed and operated as intended. This standard covers the frequency range 9 kHz to 400 GHz. The assessment of a network needs to be performed only in the frequency ranges where limits are defined in the relevant product standards. The emission limits set in this standard do not apply to the wanted emissions from embedded radio links within the network.

EN 50529-2:2010

STATUS: Published

DATE OF PUBLICATION: 2011-11-01

TITLE: EMC Network Standard - Part 2: Wire-line telecommunications networks using coaxial cables

SCOPE: This EMC standard specifies requirements for emissions originating from within wire-line telecommunication networks using coaxial cables and the immunity of those networks, including their in-premises extensions by references to harmonised EMC product standards and other standards with EMC requirements in combination with good engineering practice, when installed and operated as intended. This standard covers the frequency range 9 kHz to 400 GHz. The assessment of a network needs to be performed only in the frequency ranges where limits are defined. The emission limits set in this standard do not apply to the wanted emissions from embedded radio links within the network. The requirements have been selected so as to ensure that electromagnetic disturbances generated by a network, or parts thereof, operating normally do not exceed a level above which radio and telecommunications apparatus or other apparatus cannot operate as intended. Fault conditions of the network are not taken into account.

EN 50554:2010

STATUS: Published

DATE OF PUBLICATION: 2011-11-01

TITLE: Basic standard for the in-situ assessment of a broadcast site related to general public exposure to radio frequency electromagnetic fields

SCOPE: This basic standard specifies the method for assessing overall exposure from all fixed radio frequency sources at a broadcast site. This assessment may be applied at any time but must be carried out when the exposure situation changes in or around this site. It plays an essential role in the coordination of different stakeholders, with respect to ensuring EMF exposure compliance in and around a broadcast site especially for equipment installed within the site.

EN 55016-1-4:2010

STATUS: Published

DATE OF PUBLICATION: 2011-03-01

TITLE: Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-4: Radio disturbance and immunity measuring apparatus - Antennas and test sites for radiated disturbance measurements

SCOPE: CISPR 16-1-4:2010 specifies the characteristics and performance of equipment for the measurement of radiated disturbances in the frequency range 9 kHz to 18 GHz. Specifications for antennas and test sites are included. The requirements of this publication apply at all frequencies and for all levels of radiated disturbances within the CISPR indicating range of the measuring equipment. Methods of measurement are covered in Part 2-3, and further information on radio disturbance is given in Part 3 of CISPR 16. Uncertainties, statistics and limit modelling are covered in Part 4 of CISPR 16. This third edition of CISPR 16-1-4 cancels and replaces the second edition published in 2007 and its Amendments 1 (2007) and 2 (2008). It is a technical revision. This edition includes the following significant technical change with respect to the previous edition: provisions are added to address evaluation of a set-up table in the frequency range above 1 GHz. CISPR 16-1-4:2010 has the status of a basic EMC publication in accordance with IEC Guide 107, Electromagnetic compatibility - Guide to the drafting of electromagnetic compatibility publications

EN 55016-2-2:2011

TECHNICAL BODY: IEC/SC CISPR/A

STATUS: Published

DATE OF PUBLICATION: 2011-10-02

TITLE: Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-2: Methods of measurement of disturbances and immunity - Measurement of disturbance power

SCOPE: CISPR 16-2-2:2010 specifies the methods of measurement of disturbance power using the absorbing clamp in the frequency range 30 MHz to 1 000 MHz. This second edition cancels and replaces the first edition (2003), its Amendment 1 (2004) and Amendment 2 (2005). It constitutes a technical revision. It includes the following significant technical changes with respect to the previous edition: provisions for the use of spectrum analyzers for compliance measurements (Annex D) and the use of FFT-based test instrumentation (Clauses 3, 6 and 8) are now included. CISPR 16-2-2:2010 has the status of a basic EMC publication in accordance with IEC Guide 107, Electromagnetic compatibility - Guide to the drafting of electromagnetic compatibility publications.

EN 60939-1:2010

TECHNICAL BODY: IEC/TC 40

STATUS: Published

DATE OF PUBLICATION: 2011-07-01

TITLE: Passive filter units for electromagnetic interference suppression - Part 1: Generic specification

SCOPE: IEC 60939-1:2010 relates to passive filter units for electromagnetic interference suppression for use within, or associated with, electronic or electrical equipment and machines. Both single and multi-channel filters within one enclosure are included within the scope of this generic specification. This generic specification establishes standard terms, inspection procedures and methods of test for use in sectional and detail specifications within the IECQ-CECC system for electronic components. This edition includes the following significant technical changes with respect to the previous edition: a) table 3 has been updated, specifying how to handle the Neutral by 3-phase filter with Neutral; b) all details about 'Quality assessment' have been deleted in this edition, because this standard is a safety standard; c) filters shall be subjected to Test Aa of IEC 60068-2-1 for 16 h, using the degree of severity of the lower category temperature as prescribed in the relevant specification; d) since IEC 60068-2-20 does no longer make a difference between Method 1A and 1B, but only describes Method 1, references to the method to be used are updated.

EN 61000-4-3:2006/A2:2010

TECHNICAL BODY: IEC/SC 77B

STATUS: Published

DATE OF PUBLICATION: 2011-04-01

TITLE: Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field im-

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

The IEC prepares and publishes International Standards for all electrical, electronic and related technologies — collectively known as electrotechnology.

IEC Central Office, 3, rue de Varembé, P.O. Box 131, CH - 1211 Geneva 20, Switzerland; +41 22 919 02 11, Fax: +41 22 919 03 00; info@iec.ch, www.iec.ch

- **IEC's EMC Zone:** www.iec.ch/zone/emc/emc_entry.htm
- **CISPR:** The principal task of CISPR, the International Special Committee on Radio Interference, is at the higher end of the frequency range, from 9 kHz upwards, preparing standards that offer protection of radio reception from interference sources such as electrical appliances of all types, the electricity supply system, industrial, scientific and electromedical RF, broadcasting receivers (sound and TV) and, increasingly, IT equipment (ITE). www.iec.ch/zone/emc/emc_cis.htm

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

A developer and publisher of international standards, ISO is comprised of a network of the national standards institutes of 163 countries, one member per country, with a Central Secretariat in Geneva, Switzerland, that coordinates the system.

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munity test

EN 61000-4-20:2010

TECHNICAL BODY: IEC/SC 77B

STATUS: Published

DATE OF PUBLICATION: 2011-07-01

TITLE: Electromagnetic compatibility (EMC) - Part 4-20: Testing and measurement techniques - Emission and immunity testing in transverse electromagnetic (TEM) waveguides

EN 61000-4-21:2011

TECHNICAL BODY: IEC/SC 77B

STATUS: Published

DATE OF PUBLICATION: 2011-12-03

TITLE: Electromagnetic compatibility (EMC) - Part 4-21: Testing and measurement techniques - Reverberation chamber test methods

SCOPE: IEC 61000-4-21:2011 considers tests of immunity and intentional or unintentional emissions for electric and/or electronic equipment and tests of screening effectiveness in reverberation chambers. It establishes the required test procedures for performing such tests. Only radiated phenomena are considered. The objective of IEC 61000-4-21:2011 is to establish a common reference for using reverberation chambers to evaluate the performance of electric and electronic equipment when subjected to radio-frequency electromagnetic fields and for determining the levels of radio-frequency radiation emitted from electric and electronic equipment. IEC 61000-4-21:2011 does not intend to specify the tests to be applied to a particular apparatus or system.

EN 61000-4-22:2011

TECHNICAL BODY: IEC/SC CISPR/A

STATUS: Published

DATE OF PUBLICATION: 2011-11-01

TITLE: Electromagnetic compatibility (EMC) - Part 4-22: Testing and measurement techniques - Radiated emission and immunity measurements in fully anechoic rooms (FARs)

SCOPE: IEC 61000-4-22:2010 considers immunity tests and emission measurements for electric and/or electronic equipment. Only radiated phenomena are considered. It establishes the required test procedures for using fully anechoic rooms for performing radiated immunity testing and radiated emission measurements. IEC 61000-4-22:2010 establishes a common validation procedure, equipment under test (EUT) set-up requirements, and measurement methods for fully anechoic rooms (FARs) when both radiated electromagnetic emission measurements and radiated electromagnetic immunity tests will be performed in the same FAR. As a basic measurement standard, this part of IEC 61000 does not intend to specify the test levels or emission limits to be applied to particular apparatus or system(s). Its main goal is to provide general measurement procedures to all concerned product committees of IEC or CISPR. The methods described in this standard are appropriate for radiated emission measurements and immunity tests in the frequency range of 30 MHz to 18 GHz.

EN 61788-8:2010

TECHNICAL BODY: IEC/TC 90

DATE OF PUBLICATION: 2011-07-01

STATUS: Published

TITLE: Superconductivity - Part 8: AC loss measurements - Total AC loss measurement of round superconducting wires exposed to a transverse alternating magnetic field at liquid helium temperature by a pickup coil method

SCOPE: IEC 61788-8:2010(E) specifies the measurement method of total AC losses by the pickup coil method in composite superconducting wires exposed to a transverse alternating magnetic field. The losses may contain hysteresis, coupling and eddy current losses. The standard method to measure only the hysteresis loss in DC or low-sweep-rate magnetic field is specified in IEC 61788-13. In metallic and oxide round superconducting wires expected to be mainly used for pulsed coil and AC coil applications, AC loss is generated by the application of time-varying magnetic field and/or current. The contribution of the magnetic field to the AC loss is predominant in usual electromagnetic configurations of the coil applications. For the superconducting wires exposed to a transverse alternating magnetic field, the present method can be generally used in measurements of the total AC loss in a wide range of frequency up to the commercial level, 50/60 Hz, at liquid helium temperature. For the superconducting wires with fine filaments, the AC loss measured with the present method can be divided into the hysteresis loss in the individual filaments, the coupling loss among the filaments and the eddy current loss in the normal conducting parts.

EN 62041:2010

TECHNICAL BODY: IEC/TC 96

DATE OF PUBLICATION: 2011-09-01

STATUS: Published

TITLE: Safety of transformers, reactors, power supply units and combinations thereof - EMC requirements

SCOPE: IEC 62041:2010 applies to transformers, reactors, power supply units and combinations thereof covered by the IEC 61558 series of standards. This standard deals with the electromagnetic compatibility requirements for emission and immunity within the frequency range 0 Hz - 400 GHz. No measurement needs to be performed at frequencies where no requirement is specified. This second edition cancels and replaces the first edition published in 2003. It constitutes a technical revision. This edition includes the following significant technical changes with respect to the previous edition: - the frequency range for tests according to IEC 61000-4-3 has been extended above 1 GHz according to technologies used in this frequency area; - the testing requirements according to IEC 61000-4-11 have been amended significantly; - the inclusion of a clause on tests in series production ...

EN 62132-2:2011

TECHNICAL BODY: IEC/SC 47A

STATUS: Published

DATE OF PUBLICATION: 2011-10-02

TITLE: Integrated circuits - Measurement of electromagnetic immunity - Part 2: Measurement of radiated immunity - TEM cell and wideband TEM cell method

SCOPE: IEC 62132-2:2010 specifies a method for measuring the immunity of an integrated circuit (IC) to radio frequency (RF) radiated electromagnetic disturbances. The frequency range of this method is from 150 kHz to 1 GHz, or as limited by the characteristics of the TEM cell.

EN 62209-2:2010

TECHNICAL BODY: IEC/TC 106

STATUS: Published

DATE OF PUBLICATION: 2011-03-01

TITLE: Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices - Human models, instrumentation, and procedures - Part 2: Procedure to determine the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)

SCOPE: IEC 62209-2:2010 is applicable to any wireless communication device capable of transmitting electromagnetic fields (EMF) intended to be used at a position near the human body, in the manner described by the manufacturer, with the radiating part(s) of the device at distances up to and including 200 mm from a human body, i.e. when held in the hand or in front of the face, mounted on the body, combined with other transmitting or non-transmitting devices or accessories (e.g. belt-clip, camera or Bluetooth add-on), or embedded in garments. For transmitters used in close proximity to the human ear, the procedures of IEC 62209-1:2005 are applicable. IEC 62209-2:2010 is applicable for radio frequency exposure in the frequency range of 30 MHz to 6 GHz, and may be used to measure simultaneous exposures from multiple radio sources used in close proximity to human body. Definitions and evaluation procedures are provided for the following general categories of device types: - body-mounted, - body-supported, - desktop, - front-of-face, - hand-held, - laptop, - limb-mounted, - multi-band, - push-to-talk, - clothing-integrated.

EN 62305-4:2011

TECHNICAL BODY: IEC/TC 81

STATUS: Published

DATE OF PUBLICATION: 2012-01-13

TITLE: Protection against lightning - Part 4: Electrical and electronic systems within structures

SCOPE: IEC 62305-4:2010(E) provides information for the design, installation, inspection, maintenance and testing of electrical and electronic system protection (LPM) to reduce the risk of permanent failures due to lightning electromagnetic impulse (LEMP) within a structure. This second edition cancels and replaces the first edition, published in 2006, and constitutes a technical revision. This edition includes six significant technical changes with respect to the previous edition.

EN 62479:2010

TECHNICAL BODY: IEC/TC 106

DATE OF PUBLICATION: 2011-09-01

TITLE: Assessment of the compliance of low power electronic and electrical equipment with the basic restrictions related to human exposure to electromagnetic fields (10 MHz to 300 GHz)

SCOPE: IEC 62479:2010 provides simple conformity assessment methods for low-power electronic and electrical equipment to an exposure limit relevant to electromagnetic fields (EMF). If such equipment cannot be shown to comply with the applicable EMF exposure requirements using the methods included in this standard for EMF assessment, then other standards, including IEC 62311 or other (EMF) product standards,

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http://ec.europa.eu

- **European New Legislative Framework for marketing of products:** http://ec.europa.eu/enterprise/policies/single-market-goods/regulatory-policies-common-rules-for-products/new-legislative-framework/

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www.eea.europa.eu/

RAPEX
EU consumer alerts about unsafe products
European Commission, Health & Consumers Directorate-General, B – 1049 Brussels, Belgium; http://ec.europa.eu/consumers/dyna/rapex/rapex_archives_en.cfm

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may be used for conformity assessment.

European Telecommunications Standards Institute (ETSI)

EN 301 559-1

TECHNICAL BODY: ERM TG30

STATUS: Start of Public Enquiry PE 20111110 (2011-07-13)

TITLE: Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Low Power Active Medical Implants (LP-AMI) operating in the frequency range 2 483,5 MHz to 2 500 MHz; Part 1: Technical characteristics and test methods 2.48GHz AMI

SCOPE: Equipment covered by Harmonized Standard EN 30X XXX is specialized medical equipment that comprises a system consisting of implanted, body worn and other external devices that form a medical communications system. Due to the application of these devices in the medical field it is proposed to develop a specific product standard for ensuring that the radio links are tested to appropriate levels.

EN 301 559-2

TECHNICAL BODY: ERM TG30

STATUS: Start of Public Enquiry PE 20111110 (2011-07-13)

TITLE: Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Low Power Active Medical Implants (LP-AMI) operating in the frequency range 2 483,5 MHz to 2 500 MHz; Part 2: Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive

SCOPE: Equipment covered by Harmonized Standard EN 30X XXX is specialized medical equipment that comprises a system consisting of implanted, body worn and other external devices that form a medical communications system. Due to the application of these devices in the medical field it is proposed to develop a specific product standard for ensuring that the radio links are tested to appropriate levels.

EN 301 489-1

TECHNICAL BODY: ERM EMC

STATUS: Vote result determination (adopted) (2011-08-16)

TITLE: Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 1: Common technical requirements

SCOPE: To enable multiple enclosure solution base station units (digital radio unit and radio unit separated) to be tested ether combined or separately. Performance criteria for ancillary equipment harmonised across the EN 301 489 series. Check references of basic EMC standards.

EN 301 489-11

TECHNICAL BODY: ERM EMC

STATUS: Start of work (2010-10-01)

TITLE: Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 11: Specific conditions for terrestrial sound broadcasting service transmitters

Revision of EN 301 489-11

SCOPE: Revision of the EMC Standard to bring it into line with current version of EN 301 489-1. This work will comprise: Updating references to latest versions; Making technical changes to align the standard with the latest version of EN 301 489-1. Advising WG-EMC of any resultant changes needed to EN 301 489-1

EN 301 489-23

TECHNICAL BODY: ERM EMC

STATUS: Citation in the OJ (2010-12-29)

TITLE: Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 23: Specific conditions for IMT-2000 CDMA, Direct Spread (UTRA and E-UTRA) Base Station (BS) radio, repeater and ancillary equipment

Inclusion of LTE base stations and repeaters in EN 301 489-23

SCOPE: Update EN 301 489-23 to include the 4G base stations and repeaters (LTE)

EN 301 489-24

TECHNICAL BODY: ERM EMC

STATUS: Citation in the OJ (2010-12-29)

TITLE: Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 24:Specific conditions for IMT-2000 CDMA Direct Spread (UTRA and E-UTRA) for Mobile and portable (UE) radio and ancillary equipment

Inclusion of LTE UE in EN 301 489-24

SCOPE: Update EN 301 489-24 to include the 4G mobile terminals (LTE UEs)

EN 301 489-34

TECHNICAL BODY: ERM EMC

STATUS: Citation in the OJ (2010-12-29)

TITLE: Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 34: Specific conditions for External Power Supply (EPS) for mobile phones Mobile Phone Harmonised External Power Supply EMC aspects of EN 301 489

SCOPE: Under the EMC requirement of the Commission Mandate M/455 Common Charging Capability for Mobile Telephones. Produce a new part for EN 301 489 covering Specific conditions for Mobile Phone Harmonised External Power Supply (EPS as described in Mandate M/455. and Part A Annex II) Considering Part B of Annex II of M/455

EN 300 386

TECHNICAL BODY: ERM EMC

STATUS: Citation in the OJ (2011-02-24)

TITLE: Electromagnetic compatibility and Radio spectrum Matters (ERM); Telecommunication network equipment; ElectroMagnetic Compatibility (EMC) requirements EMC for Telecommunications Network equipment

SCOPE: Include the emission requirements up to 6GHz in line with the EN55022 A1/2007 and update the reference basic standards

EN 300 386

TECHNICAL BODY: ERM EMC

STATUS: Citation in the OJ (2010-04-21)

TITLE: Electromagnetic compatibility and Radio spectrum Matters (ERM); Telecommunication network equipment; ElectroMagnetic Compatibility (EMC) requirements EMC for Telecommunications Network equipment

SCOPE: Update the references of CISPR 16-1, EN50082-1, EN55022, EN61000-4-2, EN61000-4-3, EN61000-4-4, EN61000-4-5, EN61000-4-6, EN61000-4-11 and EN300132-2 and add dates to the basic standards include the reference of EN61000-3-11 and EN61000-3-12 include radiated immunity test (sub-clause 7.2.1.1.2 and 7.2.2.1.2) in the frequency range 2-2.7GHz; test level 3V/m; 80% AM at 1kHz; performance criterion A update the vvoltage dips and short interruption tests on AC port of Other than Telecommunication centre (sub-clause 7.2.2.4.4) according to the latest publication of EN61000-4-11 and the generic standard IEC61000-6-2 remove the ETR238 from the bibliography add the normative Annex A as in EN301489-1 under revision process

EN 301 489-23

TECHNICAL BODY: ERM EMC

STATUS: Start of OAP OP 20111110 (2011-07-13)

TITLE: Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 23: Specific conditions for IMT-2000 CDMA, Direct Spread (UTRA and E-UTRA) Base Station (BS) radio, repeater and ancillary equipment

EN 301 489-23 IMT-2000 CDMA

SCOPE: Part - 23 Revise the document at chapter 6.

TECHNICAL BODY: ERM

STATUS: Creation of WI by WG/TB (2011-06-28)

TITLE: Electromagnetic compatibility and Radio spectrum Matters (ERM); Technical analysis for wireless chargers Internal Report; Technical analysis for wireless chargers

SCOPE: The European Commission has requested ETSI to look at wireless chargers, which are currently under consideration by TCAM, in terms of assessing the suitability of existing regimes (e.g. EMC Directive, R&TTE Directive, Harmonized Standards, EC Decisions, etc.) or potentially a new one for accommodating this kind of devices. The report should answer the Commission's questions regarding the most appropriate path to ensure compliance with regulatory requirements.

DMI/ERM-EMC-310

TECHNICAL BODY: ERM EMC

STATUS: Creation of WI by WG/TB (2011-03-17)

TITLE: Electromagnetic compatibility and Radio spectrum Matters (ERM); The complete report of the CENELEC/ETSI Joint Working Group on the digital dividend

Compilation of contributions to the JWG and outputs of sub

SCOPE: The present document is intended to help in the revision or development of standards by describing the actual operational conditions stemming from the 800 MHz EC Decision (DEC 2010/267/EU).

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EMC *Events*

This section includes information on some important events in the electromagnetic compatibility community. Visit *Interference Technology* online at www.interferencetechnology.eu for the latest listings. If you would like to add an event, please e-mail details to Sarah Long at slong@interferencetechnology.com

10th International Conference on Applied Electromagnetics

WHEN: 25-29 September 2011

WHERE: Niš, Serbia

WHAT: Conference topics include computation of electromagnetic fields, inverse electromagnetic field problems, optimization techniques, electromagnetic field measurement techniques, electromagnetic CAD, EMC problems, non-linear electromagnetic systems, bioeffects of electromagnetic fields and EM circuits and systems.

INFORMATION: http://pes2011.elfak.ni.ac.rs/

EMC Europe International Symposia and Workshops on EMC

WHEN: 26-30 September 2011

WHERE: York, United Kingdom

WHAT: EMC Europe is the pre-eminent EMC Conference in Europe and will be held at the University of York in the UK in 2011. We wish to invite and encourage all those working in electromagnetic compatibility to participate in this prestigious event in 2011. EMC research and conferences in Europe have a long tradition. From the series of independent EMC conferences based in Wroclaw, Zurich and Rome running every second year, has now emerged EMC Europe which will be organised every year in a European city to provide an international forum for the exchange of technical information on EMC. The 2010 EMC Europe Conference was in Wroclaw and in 2011 it will be at York.

INFORMATION: www.emceurope2011.york.ac.uk/

International Exhibition of Testing Equipment, Systems and Technologies for Aerospace Industry

WHEN: 4-6 October 2011

WHERE: Moscow, Russia

WHAT: Aerospace Testing Russia is pleased to present the latest developments and unique methods of aerospace technique, component and subsystem testing to specialists of aerospace sector of Russia and CIS countries.

INFORMATION: www.aerospace-expo.ru/eng

International Electronics Forum 2011

WHEN: 5-7 October 2011

WHERE: Seville, Spain

WHAT: Future Horizons' 21st annual international electronics industry forum covers the full industry food chain, from advanced research, equipment and materials, IP and EDA, government and finance plus semiconductor and OEM system design and production. High level speakers and participants from across the globe. Covers the key issues effecting the electronics industry. High quality information and insight from discussion panels. Debate issues with world leading experts and visionaries. By gathering top industry executives in one place at one time this Forum maximises productivity and delegate ROI Plus...The Latest Industry Analysis From Future Horizons.

INFORMATION: www.futurehorizons.com/page/71/International-Electronics-Forum-2011

European Microwave Week

WHEN: 9-14 October 2011

WHERE: Manchester, UK

WHAT: The 41st European Microwave Conference (EuMC) represents the main event in the European Microwave Week 2011 and now incorporates the wireless topics previously covered in the Wireless Technologies Conference (EuWIT) in a series of dedicated sessions in connection with the European Microwave Integrated Circuits Conference (EuMIC).

INFORMATION: www.eumweek.com/

EMCUK 8th Exhibition & Conference

WHEN: 11-12 October 2011

WHERE: Newbury, UK

WHAT: EMCUK is a targeted event in a location and venue that is very easy to get to. Broad-based UK electronics events are a thing of the past. It's a true Networking event, where the EMC fraternity come to meet every year. It is based on sound research.

INFORMATION: www.emcuk.co.uk/

15th International VDI Conference, 'Electronics in Vehicles'

WHEN: 11-13 October 2011

WHERE: Baden-Baden, Germany

WHAT: This year's focal topics include electromobility, the connected car, high-voltage vehicle electrical systems, driver assistance systems, systems architecture and networking, functional safety, battery technology, vehicle electrical system management, complexity in global markets (taking China as the example) and sensors in the system network. Papers will be delivered in four parallel sections.

INFORMATION: www.vdi.eu

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eCarTec 2011 3rd International Fair for Electric Mobility

WHEN: 18-20 October 2011

WHERE: München, Germany

WHAT: eCarTec, the leading trade fair for electric mobility, took place from October 18 to 19, 2011 at the New Munich Trade Fair Center and featured electric vehicles, storage technology as well as new developments in drive and engine technology. It also covered the topics of energy, infrastructure and financing. The trade fair also included an additional training area where professional clients end consumers were given a chance to familiarize themselves with the latest technology. The trade fair focused on developers, construction engineers, designers, managers, traders, car fleet managers, private car buyers and decision makers from politics and public authorities.

INFORMATION: www.ecartec.eu/

National Symposium for EMC in Electrotechnology and Electronics

WHEN: 20-21 October 2011

WHERE: Lodz, Poland

WHAT: The symposium has been taken place for 10 years. Since then, the subject EMC (eletromagnetic compatibility) has become more and more important, among others due to the increasing understanding of the problems concerning electromagnetic disturbances. The symposium takes place shortly after the the new directive 108/2004 has come into force to the polish law. This directive changes basically the preconditions to obtain the CE mark for electronic and electric devices.

INFORMATION: www.emc11.pl/

EMC Compo 2011

WHEN: 6-9 November 2011

WHERE: Dubrovnik, Croatia

WHAT: The achievements in terms of operating frequency and integration of semiconductor technology are constantly creating new challenges in EMC, which must necessarily be addressed at both the integrated circuit and system level. Keeping up to date is of paramount importance to be successful in this field. The International Workshop EMC Compo 2011 is intended to be a place for exchange of the latest research achievements and experience in IC-level EMC and it is addressed to researchers both from industry and from academia.

INFORMATION: www.emccompo2011.org/

EMV Seminare

WHEN: 8-9 November 2011, 6-7 December 2011

WHERE: Stuttgart, Germany

WHAT: EMC is one of the most important criteria in the use of electrical and electronic equipment, systems and components. Due to increasingly complex systems, and increasing integration of new topics such as “smart grid” or “e-mobility”, there is a greater need for specialists familiar with it. Apart from Europe’s leading EMC fair, held annually in the spring, Mesago offers full-day seminars to deepen current knowledge of EMC. The full-day seminars will be held in Stuttgart and Munich and offer participants application-specific, current, and vendor-neutral training on the subject of EMC.

INFORMATION: www.mesago.de/emv-seminare

Innovative Smart Grid Technologies - Europe 2011

WHEN: 5-7 December 2011

WHERE: Manchester, United Kingdom

WHAT: The second European conference and exhibition on Innovative Smart Grid Technologies (ISGT-EUROPE 2011), sponsored by the IEEE Power & Energy Society (PES) and hosted by the School of Electrical and Electronic Engineering of The University of Manchester, will be held December 5 – 7, 2011 at Manchester Central Complex in Manchester, United Kingdom. The Conference will be an international forum for the participants to address and discuss the state-of-the-art innovation in smart grids. The Conference will feature sessions, panels and tutorials by international experts on smart grids.

The Conference Organizing Committee invites researchers and practitioners worldwide to submit papers for review and possible presentation. The Conference scope covers a wide area of topics with respect to smart grids.

INFORMATION: www.ieee-isgt-2011.eu/

EMV 2012

WHEN: 7-9 February 2012

WHERE: Düsseldorf, Germany

WHAT: Europe’s leading application-oriented conference on electromagnetic compatibility is held parallel to the EMV exhibition. EMC has become an important factor for innovation and social acceptance of new technology. Safety engineering in vehicles, automation technology in industrial environments, information supply - nothing works without electrical signals, electrical currents and electrical voltage. And everything has to operate without influencing each other. The bi-annual EMV conference reflects these requirements and provides a comprehensive program. Specialists from all over the world report on the newest products and developments and are available for technical discussions. This is the ideal platform for the dialogue between research, product development and application.

INFORMATION: www.mesago.de/en/EMV/The_Conference

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EMCCompo 2011,
8th International Workshop on Electromagnetic Compatibility of Integrated Circuits
Dubrovnik, November 6-9th, 2011
with focus on "EMC-Aware Design from IC to System Level"

The 8th International Workshop on Electromagnetic Compatibility of Integrated Circuits EMCCompo 2011 is the place to exchange the latest research achievements and experiences. Keeping pace is of paramount importance, as operating frequencies and integration of semiconductor technologies are constantly creating new challenges for EMC. The workshop aims at professionals from industry and academia, tool providers as equipment suppliers in these fields. The workshop focuses on emission, susceptibility, power and signal integrity issues of digital, analogue and mixed-signal integrated circuits, linked to application constraints. The most recent advances in simulation and measurement techniques, modelling, standards, tools, designs, design flows and verification methodologies will be discussed. A Technical Exhibition enables tool providers, equipment manufacturers and suppliers an opportunity to debate technical challenges. Tutorials offer top-level educational opportunities.

Highlights

- *Tutorials by distinguished experts in the field of EMC of ICs;*
- *Key-note presentations*
- *PhD seminar gives studens the opportunity to have experts moderated discussions;*
- *Best paper and best student paper awards;*
- *Welcome reception and gala dinner.*

Programme and website

The workshop is organized to maximize exchanges between participants and presenters. The list of session topics and further details are available at: ***www.emccompo2011.org***

Important Dates

Early registration deadline:	*September 19, 2011*
EMCCompo 2011:	*November 6 -9, 2011*

Venue

Dubrovnik, a city renowned for its beauty, is situated on the coast-line in the southern part of Croatia. It is easily accessible with direct flights from several European hubs. EMCCompo 2011 is hosted by the Centre for Advanced Academic Studies, which is very close to the Old City and guarantees warm atmosphere for participants.

Conference proceedings

The conference proceedings will available to registered participants in electronic format and become indexed and available on IEEE Explore.

Tutorials

1. ***„Tools and methodologies for emission prediction during the IC design flow"***, *B. Vrignon, Freescale Semiconductor France*
2. ***„IC, IC-package to PCB co-design"***, *M. Coenen, EMC MCC bv, The Netherlands*
3. ***„Design considerations in EMI resistant analog integrated circuits"***, *J.-M. Redouté, Monash University, Australia*
4. ***„IC simulation models for electromagnetic emission and immunity from vendor and application point of view"***, *Th. Steinecke, Infineon and W. Hafla, R. Bosch.*
5. ***„Interference issues and coupling effects in RF products, RFIC floorplanning and grounding strategies"***, *J. Niehof, NXP Semiconductors, The Netherlands*
6. ***„IC and module-level EMI measurement and evaluation methods"***, *Hyun Ho Park, Samsung Electronics, Korea*
7. ***„IC immunity modelling with IC-EMC"*** *(hands-on lab, half a day), A. Boyer, E. Sicard, INSA Toulouse, France*

Organizing committee

Renaud Gillon, On Semiconductor (General Chair)
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Vladimir Ceperic, University of Zagreb, (Posters & Demo's)
Johan Catrysse, KHBO (IEEE Liaison Chair)

www.emccompo2011.org

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DATE 2012

WHEN: March 12-16, 2012

WHERE: Dresden, Germany

WHAT: DATE is a leading international event and networking opportunity for design and engineering of Systems-on-Chip, Systems-on-Board and Embedded Systems Software. The DATE exhibition features suppliers of development tools and platforms for hardware and software development, showing a range of products from the front-end to back-end chip design through to silicon test and manufacture, from system architecture through to embedded software implementation and networking.

INFORMATION: www.date-conference.com/main/date

6th European Conference on Antennas and Propagation (EuCAP)

WHEN: 26-30 March 2012

WHERE: Prague, Czech Republic

WHAT: EuCAP2012 provides an ideal and unique place in Europe for the exchange of scientific and technical information, at academic and industrial levels, on the latest results and developments in antenna theory and technology, in electromagnetic wave propagation on antenna measurement techniques.

INFORMATION: www.ieee.org/conferences_events

15th International Trade Fair for Electronic Components, PCBs, Electronic Production

WHEN: 17-19 April 2012

WHERE: Moscow, Russia

WHAT: ExpoElectronica is considered to be the main event of the Russian electronics industry as it gathers three shows and covers the industry base lines: ExpoElectronica - international trade fair for components, PCBs and electronic production. ElectronTechExpo only trade fair in Russia for electronics manufacturing technology. LEDTechExpo - international trade fair for LED solutions, chips and production facilities.

INFORMATION: http://expoelectronica.primexpo.com/

SVIAZ-EXPOCOMM 2012

WHEN: 14-17 May 2012

WHERE: Moscow, Russia

WHAT: The 24th International Exhibition for Telecommunications, Control Systems, IT and Communication Services (Sviaz-Expocomm) serves as a place for industry professionals to network, to promote technology and exchange information. Sviaz-Expocomm enjoys a high international standing and is one of the major events used by overseas IT manufacturers to promote their products and develop their business in Russia, according to organizers.

INFORMATION: www.sviaz-expocomm.ru/en/

2012 Asia-Pacific Microwave and EMC Exhibition

WHEN: 21-24 May 2012

WHERE: Sentosa Island, Singapore

WHAT: This exhibition offers an opportunity for all segments of the Microwave and Electromagnetic Compatibility (EMC) community to meet, providing an international gathering for everyone involved in technologies associated with RF, Microwave, Antenna, EMC Instrumentation and Analysis Software. The Microwave and EMC Exhibition typically represent the state-of-the-art when it comes to devices, components, and subsystems as well as design and simulation software and test and measurement equipment.

INFORMATION: www.apemc2012.org

2012 ESA Workshop on Aerospace EMC

WHEN: 23-27 May 2012

WHERE: Venice, Italy

WHAT: Suppliers and manufacturers in the aerospace industry are facing continuous pressure to meet increasing regulatory requirements. They need to accommodate more and more sophisticated technologies and services and to reduce costs and time in the procurement process. In this scenario, EMC engineers search for advanced approaches and techniques in modelling, design, production and test with the ultimate objectives of achieving built-in-design compatibility and avoid costly fixes for the integrated systems.

INFORMATION: www.congrex.nl/12A05/

2012 IEEE EMC Symposium

WHEN: 5-10 August 2012

WHERE: Pittsburgh, Pennsylvania, USA

WHAT: The 2012 International Symposium on EMC Program is a comprehensive event featuring technical information, collateral industry meetings, professional awards, professional development, networking social events and companion events.

INFORMATION: www.emc2012.isemc.org

electronica 2012 25th International Trade Fair

WHEN: 13-16 November 2012

WHERE: Munich, Germany

WHAT: At this international trade fair for electronic components, systems and applications, the electronica automotive congress will discuss the latest developments for automotive-industry experts, OEMs, component manufacturers and software developers, and the Wireless Congress will focus on key developments involving current and future wireless technologies.

INFORMATION: www.electronica.de

2012 ASIA-PACIFIC EMC

May 21- 24, 2012, Sentosa Island, Singapore

www.apemc2012.org

APEMC Singapore 2012

Call For Papers

2012 Asia-Pacific International Symposium and Exhibition on Electromagnetic Compatibility in Singapore

The **2012 Asia-Pacific International EMC Symposium and Exhibition** will return to its founding place **Singapore**, from May 21 to 24, 2012. The symposium will cover the entire scope of electromagnetic compatibility and include emerging technologies. Prospective authors are invited to submit original papers on their latest research results. We also solicit proposals for topical meetings, the industrial forum, work shops and tutorials.

- EMC Management and Standards
- EMC Measurements and Environment
- Lightning
- High Power Electromagnetics
- Renewal Energy and Smart Grid EMC, Power Quality
- System-Level EMC and Protection
- Electric vehicle , Automotive, Railway and Naval EMC
- EMC in Space
- IC and Semiconductor EMC
- Signal Integrity and Power Integrity
- Wireless Communication EMC
- Computational Electromagnetics
- Bio-Medical EMC
- Nanotechnology in EMC
- (Special Topic) TSV for 3D-IC and 3D System Integration

Important Dates

Preliminary paper submissions	December 9, 2011
Notification of acceptance	February 5, 2012
Final paper submission through the portal www.apemc2012.org	March 15, 2012

All submissions must be electronic. Font embedding must be IEEE Xplore compatible. No hardcopies shall be accepted. Details are given on the symposium website: **www.apemc2012.org**

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EMC 2015
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SAVE THE DATE!

2015 IEEE International Symposium on EMC and EMC Europe 2015, Dresden, Germany

The international IEEE EMC Symposium is taking a journey to the heart of Europe to team up with EMC Europe, the well-established forum for the European EMC Community. Do not miss this unique event connecting EMC experts from around the globe in the beautiful baroque city of Dresden.

IEEE EMC SOCIETY

TECHNICAL PROGRAM

The technical committee will be chaired by Prof. Heyno Garbe, one of Europe's leading EMC experts. The papers will be reviewed by the Technical Advisory Committee of the IEEE EMC Society. Committee meetings and award presentation of the EMC Society will take place in conjunction with this event. Please find more information on the organizing committee on our website.

WHY COME TO DRESDEN?

Dresden, located in the heart of Europe, is the gateway to the emerging markets of Central and Eastern Europe. In addition, Germany is the world's fifth largest economy. With its unique baroque heritage, notable art treasures, architectural landmarks and charming landscape, a visit to Dresden truly combines business with pleasure.

SOME OF DRESDEN'S HIGHLIGHTS:

- The Zwinger Palace: One of the most important baroque buildings that hosts an art museum with famous paintings such as the Sistine Madonna of Raffael
- The Church of our Lady: Dresden's landmark with its magnificent baroque dome rebuilt between 1992 and 2005
- Royal Palace: An important example of Renaissance architecture in Germany
- New Town District: Dresden's night life area and home of the alternative cultural scene
- Many other attractive destinations such as Berlin, Prague, Wroclaw, Vienna, and Munich are within a few hours´ drive from Dresden

In addition to its historical and cultural heritage, Dresden and the surrounding area have developed into a major hub for research and development. The presence of high-tech companies addressing microelectronics, electro-mobility, nanotechnology, photovoltaic, and biotechnology make it a very attractive location for a symposium on electromagnetic compatibility.

THE VENUE

The terrace-style International Congress Center Dresden (ICC) benefits from both state of the art design and enviable location. Enjoying a prime spot on the banks of the River Elbe upstream from the neighbouring state parliament, the facility is considered one of Europe's most modern congress centers. Its various halls and rooms can accommodate up to 6,000 visitors. The host hotel is located just next to the ICC and connected to the convention center by a covered walkway.

CURIOUS? Go to www.emc2015.org for more information or follow us on twitter: twitter.com/emc2015.

UNITED KINGDOM

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Translations available at
www.interferencetechnology.eu

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B

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Products and Services: Testing

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Products and Services: Filters

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Products and Services: Cables & Connectors, Filters

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Products and Services: Consultancy, Testing

I

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Products and Services: Consultancy

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KnitMesh Technologies
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Products and Services: Shielding, Conductive Materials

KTL (TracGlobal)
Unit E, South Orbital, Tracking Park, Hedan Road, Hull, HU9 1NJ United Kingdom; +44(0)1482 801801; www.ktl.com
Products and Services: Testing

L

Langer EMV-Technik GmbH
APC-Novacom, Novalis Place, Deepdale Enterprise Park, Deepdale Lane, Nettleham, Lincoln, LN2 2LL, United Kingdom; +44 1522 751136; Fax: +44 1522 754408; sales@apc-novacom.co.uk; www.apc-novacom.co.uk; www.langer-emv.de
Products and Services: Test Instrumentation

Laplace Instruments Ltd.
3B, Middlebrook Way, Holt Road, Cromer, Norfolk, NR27 9JR, United Kingdom; +44(0)1263 515160; tech@laplace.co.uk; www.laplaceinstruments.com
Products and Services: Amplifiers, Antennas, Shielded Rooms & Enclosures, Test Instrumentation

Link Microtek Ltd.
High Point, Church Street, Basingstoke, Hampshire, RG21 7QN, United Kingdom; +44(0)1256 355771; Fax: +44(0)1256 355118; Hugo Bibby, sales@linkmicrotek.com; www.linkmicrotek.com
Products and Services: Test Instrumentation

M

M.Buttkereit Ltd.
Unit 2, Britannia Road, Ind. Est. Sale Cheshire, M33 2AA, United Kingdom; +44(0)1619 695418; info@buttkereit.co.uk
Products and Services: Cables & Connectors

Magnetic Shields Ltd.
Headcorn Road, Staplehurst, Kent TN12 ODS United Kingdom; +44(0)1580 891521; Fax: +44(0)1580 893345; enq@magneticshields.co.uk; www.magneticshields.co.uk
Products and Services: Shielding

MDL Technologies Ltd.
Unit 11, Devonshire Business Centre, Works Road, Letchworth, Herts, SG6 1GJ, United Kingdom; +44(0)1462 431981; Fax: +44(0)5603 152515; www.mdltechnologies.co.uk
Products and Services: Testing

Mead Testing Ltd.
Unit 25 Mead Industrial Park River Way, Harlow, Essex, CM20 2SE United Kingdom; +44(0)1279 635864; Fax: +44(0)1279 635874; www.meadtest.com
Products and Services: Testing

Mentor Graphics Mechanical Analysis Div.
81 Bridge Road, Hampton Court, Surrey, KT8 9HH, United Kingdom; +44(0)2084 873000; Fax: +44(0)2084 873001; John Parry, Research Manager; john_parry@mentor.com; www.mentor.com/products/mechanical
Products and Services: Software

METECC
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Products and Services: Testing, Training

MILMEGA Ltd.
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Products and Services: Amplifiers

MIRA Ltd.
Watling Street Nuneaton, Warwickshire, CV10 0TU United Kingdom; +44(0)2476 355576; Fax: +44(0)2476 358576; www.mira.co.uk
Products and Services: Testing, Training

MPE Ltd.
Hammond Road, Knowsley Industrial Park, Liverpool, Merseyside, L33 7UL, United Kingdom; +44(0)1516 329100; Fax: +44(0)1516 329112; John Jephcott, sales@mpe.co.uk; www.mpe.co.uk
Products and Services: Filters

Murata Electronics UK
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Products and Services: Amplifiers, Ferrites, Filters, Surge & Transients

N

Noratel UK Ltd.
7 George House Princes Court, Beam Heath Way, Nantwich, CW5 6GD United Kingdom; +44(0)1270 611368; sales@toroid.co.uk; www.toroid.co.uk
Products and Services: Ferrites, Surge & Transients

O

Optical Filters Ltd.
Unit 13 & 14, Thame Park Business Centre, Wenman Road, Thame, Oxon, United Kingdom; +44(0)1844 260377; Fax: +44(0)1844 260355; www.opticalfilters.co.uk
Products and Services: Filters, Shielding

Oxley Group Ltd.
Priory Park, Ulverston, Cumbria, LA12 9QG, United Kingdom; +44(0)1229 582621; Fax: +44(0)1229 585090; Mark Johnson; sales@oxleygroup.com; www.oxleygroup.com
Products and Services: Cables & Connectors, Ferrites, Filters, Shielding, Surge & Transients, Testing

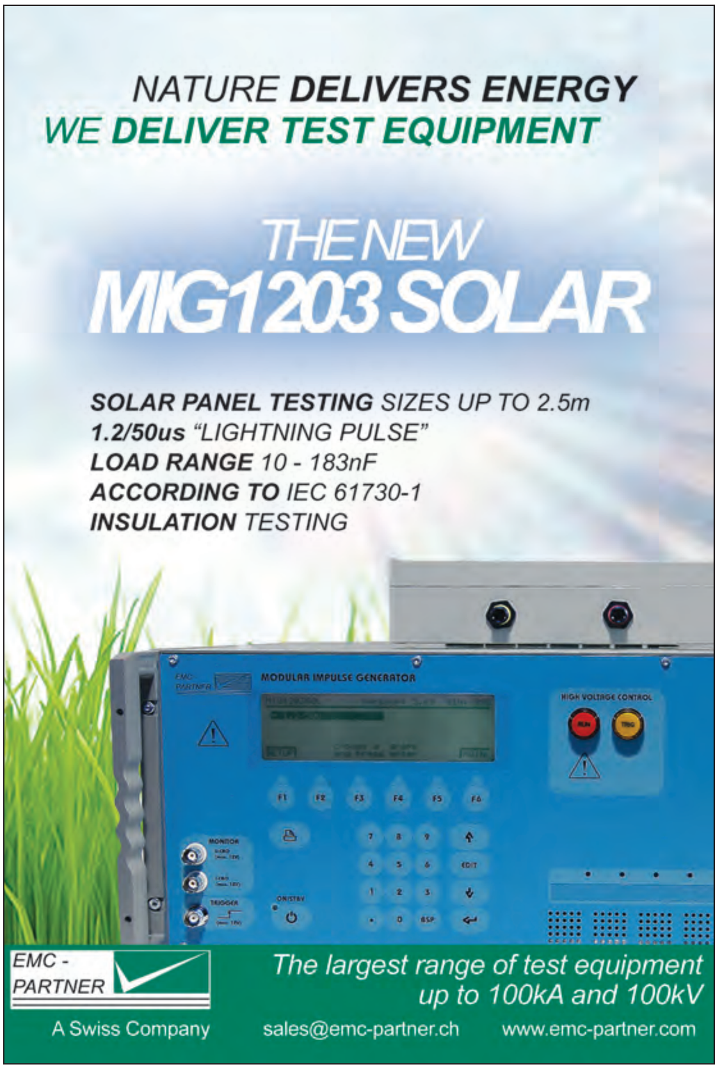
P

P & P Technology Ltd.
Finch Drive, Springwood, Braintree, Essex, United Kingdom; +44(0)1376 550525; Fax: +44(0)1376 552389; www.p-p-t.co.uk
Products and Services: Conductive Materials, Die Cut Shielding Material, EMI Gaskets, Shielding

Panashield (UK) Ltd.
The Bothy, 38 Smarts, Heath Road, Woking, Surrey, GU22 0NP, United Kingdom; +44(0)1483 722020; Fax: +44(0)1483 770330; sales@panashield.co.uk
Products and Services: Filters, Shielded Rooms & Enclosures, Shielding, Testing

Peak Electromagnetics
139 Bank Street, Macclesfield, Cheshire, SK11 7AY United Kingdom; +44(0)1625 269808; sales@peak-em.co.uk; www.peak-em.co.uk
Products and Services: Consultancy

PPI (Power Products International) Ltd.
Commerce Way, Edenbridge, Kent, TN8 6ED, United Kingdom; +44(0)1732 866424; Fax: +44(0)1732 866399; Geoff Robinson; gkrobinson@ppi-uk.com; www.ppi-uk.com
Products and Services: Filters



PPM (Pulse Power and Measurement) Ltd.
65 Shrivenham Hundred Business Park, Watchfield, Swindon, Wiltshire, SN6 8TY, United Kingdom; +44(0)1793 784389; Fax: +44(0)1793 784391; Philip Surman, psurman@ppm.co.uk; www.point2point.co.uk
Products and Services: Antennas, Cables & Connectors, Test Instrumentation, Testing

Precision Micro Ltd
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Products and Services: Shielding

Q

Q-par Angus Ltd.
Barons Cross Laboratories, Leominster, Herefordshire, HR6 8RS, United Kingdom; +44(0)1568 612138l; Fax: +44(0)1568 616373; Rob Lowther; sales@q-par.com; www.q-par.com
Products and Services: Antennas, Testing, Miscellaneous

QinetiQ
CodyTechnology, Park 1005, Ively Road, Farnborough, Hampshire, GU14 0LX, United Kingdom; +44 (0)1252 392000; Fax:+44 (0)1252 393399; www.qinetiq.com
Products and Services: Testing

R

Rainford EMC Systems
St. Helens Merseyside, United Kingdom; +44(0)1942 296190; www.rainfordemc.com
Products and Services: Shielding

Rasmi Electronics Ltd.
Morrison Road, Annfield Plain, Stanley, Durham, DH9 7RX, United Kingdom; +44(0)1207 291300; Dr. Surendra, sales@rasmi.com; www.rasmi.com
Products and Services: Antennas, Filters, Shielded Rooms & Enclosures

RFI Global Services Ltd.
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Products and Services: Testing

Richard Marshall Ltd.
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Products and Services: Consultancy

Rittal Ltd.
Braithwell Way, Hellaby Industrial Estate, Hellaby, Rotherham, South Yorkshire, S66 8QY United Kingdom; +44(0)1709 704000; information@rittal.co.uk; www.rittal.co.uk
Products and Services: Shielded Rooms & Enclosures

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Arnolds Court, Arnolds Farm Lane, Brentwood, Essex CM13 1UT United Kingdom; +44(0)1277 352219; Fax: +44(0)1277 352968; Paul Darragh, paul@RNelectronics.com; www.rnelectronics.com
Products and Services: Testing

Roxburgh EMC
Deltron Emcon House, Hargreaves Way, Sawcliffe Industrial Park, Scunthorpe, North Lincolnshire, DN15 8RF, United Kingdom; +44(0)1724 273200; Fax: +44(0)1724 280353; Diane Kilminster; dkilminster@dem-uk.com; www.dem-uk.com/roxburgh
Products and Services: Filters, Shielded Rooms & Enclosures, Surge & Transients

RS Coatings Ltd.
Unit 10, Britannia Way, Britannia Enterprise Park, Lichfield, Staffordshire, WS14 9UY; +44 01543 410 771; Fax: +44 01543 414 977; rscgroup@btconnect.com; www.rscoatings.com
Products and Services: Shielding

S

Schaffner Ltd.
5 Ashville Way, Molly Millars Lane, Wokingham, Berkshire RG41 2PL, United Kingdom; +44(0)1189 770070; Fax: +44(0)1189 792969; uksales@schaffner.com; www.schaffner.com
Products and Services: Filters

Schlegel Electronic Materials
Kemtron Limited, 19-21 Finch Drive, Springwood Industrial Estate, Braintree, Essex, CM7 2SF; +44(0)1376 348115; Fax: +44(0)1376 345885; David Wall, dbw@kemtron.co.uk; www.kemtron.co.uk
Products and Services: Conductive Materials, Shielding

Sematron UK Ltd.
Sandpiper House, Aviary Court, Wade Road, Basingstoke, Hampshire, RG24 8GX, United Kingdom; +44(0)1256 812222; Fax: +44(0)1256 812666; Glenn Toal, gtoal@sematron.com; www.sematron.com;
Products and Services: Cables & Connectors, Test Instrumentation

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Unit 7, Hanborough Business Park Lodge Road, Long Hanborough, Oxon, OX8 8LG United Kingdom; +44(0)1785 213861; Fax: +44(0)1785 243204; info@slaterplastics.com; www.slaterplastics.com
Products and Services: Filters, Shielding, Test Instrumentation

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Mead House, Longwater Road, Eversley, Hampshire, RG27 0NW, United Kingdom; +44(0)7946 624317; Charlie Blackham, charlie@sulisconsultants.com; www.sulisconsultants.com
Products and Services: Product Approvals, CE Marking

Suppression Devices
Unit 8 - York St Business Centre, Clitheroe, Lancashire, BB7 2DL, United Kingdom; +44(0)1200 444497; Campbell Barker, sales@suppression-devices.com; http://suppression-devices.com
Products and Services: Filters

Syfer Technology Ltd.
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Products and Services: Filters

T

T C Shielding, Ltd.
Unit 2, Ashburton Industrial Estate Ross on Wye, Herefordshire, HR9 7BW United Kingdom; +44(0)1989 563941; info@tcshielding.com; www.tcshielding.com
Products and Services: Shielding

TBA Electro-Conductive Products
Rooley Moor Road, PO Box 56, Rochdale, Laurashire, OL12 7E4 United Kingdom; +44(0)1706 647718; Fax: +44(0)1706 646170; www.tbaecp.co.uk
Products and Services: Conductive Materials, Shielding, Surge & Transients

Tecan Ltd.
Tecan Way, Weymouth, Dorset DT4 9TU United Kingdom; +44(0)1305 765432; Fax: +44(0)1305 780194; www.tecan.co.uk
Products and Services: Shielding

Tech-Etch, Inc.
TBA Electro Conductive Products, P.O. Box 56, Rooley Moor Road, Rochdale, Spotland, Lancs. OL12 7EY United Kingdom; +44(0)1706 647718; Fax: +44(0)1706 646170; davidhurst@tbaecp.co.uk; www.tech-etch.com
Products and Services: Conductive Materials, Shielding

Teledyne Reynolds
Navigation House, Canal View Road, Newbury, Berkshire, RG14 5UR, United Kingdom; +44 (0) 1635 262200; Olivier Dilun, Southern Europe regional sales manager; odilun@teledyne.com; www.teledynereynolds.co.uk
Products and Services: Cables & Connectors

Telonic Instruments Ltd.
Toutley Industrial Estate, Toutley Road, Wokingham, RG41 1QN, United Kingdom; +44(0)1189 786911; Bob Lovell, info@telonic.co.uk; www.telonic.co.uk
Products and Services: Filters, Test Instrumentation

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Ashville Way, Molly Millars Lane, Wokingham, Berkshire, RG41 2PL, United Kingdom; +44(0)8450 740 660; Fax: +44(0) 845 074 0656; uksales@teseq.com; www.teseq.co.uk
Products and Services: Amplifiers, Antennas, Surge & Transients, Test Instrumentation, Testing

The Lighting Association Laboratories
Stafford Park 7, Telford, Shropshire, TF3 3BQ, United Kingdom; +44(0)1952 290905; Fax: +44(0)1952 290906; lab@lightingassociation.com; www.lightingassociation.com;
Products and Services: Surge & Transients

Thurlby-Thandar Instruments (TTI)
Glebe Road, Huntingdon, Cambridgeshire, PE29 7DR United Kingdom; +44(0)1480 412451; www.tti-test.com
Products and Services: Test Instrumentation, Testing

Tioga Ltd.
St Thomas House, Mansfield Road, Derby, DE1 3TN, United Kingdom; +44(0)1332 360884; Fax: +44(0)1332 360885; Angela Bond; angela@tioga.co.uk; www.tioga.co.uk
Products and Services: Testing

TMD Technologies Ltd.
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Products and Services: Amplifiers, Antennas, Filters, Test Instrumentation

TRAC Global, Ltd.
100 Frobisher Business Park, Leigh Sinton Road, Malvern, Worcestershire, WR14 1BX, United Kingdom; +44(0)1684 571700; Fax: +44(0)1684 571701; environmental@tracglobal.com; www.tracglobal.com
Products and Services: Testing

TRW Conekt
Technical Centre, Stratford Road, Solihull, B90 4GW, United Kingdom; +44(0)1216 274242; Fax: +44(0)1216 274243; www.conekt.co.uk
Products and Services: Consultancy and Testing provider

TUV Product Service Ltd.
Octagon House, Concorde Way, Segensworth North, Fareham, Hampshire, PO15 5RL, United Kingdom; Fax: +44(0)1489 558100; www.tuvps.co.uk
Products and Services: Testing

U

Uvox Ltd.
Building 14/Unit 3, Stanmore Industrial Estate, Bridgnorth, Shropshire, WV15 5HR, United Kingdom; +44(0)1746 769369; Fax: +44(0)1746 766001; Robin Shedden, Sales Manager, sales@uvox.co.uk; www.uvox.co.uk
Products and Services: Shielding

V

Vector Fields Ltd. / Cobham Technical Services
24 Bankside, Kidlington, OX5 1JE United Kingdom; +44(0)1865 370151; Fax: +44(0)1865 370277; www.vectorfields.com
Products and Services: Shielding

Visteon Engineering Services Ltd.
Dunton Engineering Centre, Dunton, Essex, SS15 6EE, United Kingdom; +44(0)1245 395000; Martin Black, mblack7@visteon.com; www.visteon.com/testing
Products and Services: Testing

W

Wemtech
Bordesley Hall, The Holloway, Alvechurch, Birmingham, B48 7QQ United Kingdom; +44(0)1527 595066; +44(0)1527 595033; www.wemtech.co.uk
Products and Services: Consultancy, Training

Westbay Technology Ltd.
Main St. Baycliff, Ulverston, Cumbria, LA12 9RN United Kingdom; +44(0)1229 869798; Fax: +44(0)1229 869108; www.westbay.ndirect.co.uk
Products and Services: Testing

Wurth Electronics UK Ltd.
Exchange Quay, The Office Oxfordshire Village, First Floor, Building 24, Salford, Quays, M50 3EQ, United Kingdom; +44(0)1618 720431; Fax: +44(0)1618 720433; sales-uk@we-online.com
Products and Services: Cables & Connectors, Ferrites

Y

York EMC Services Ltd.
Market Square, University of York, Heslington, York, YO10 5DD, United Kingdom; +44(0)1904 434440; www.yorkemc.co.uk
Products and Services: Signal Generators

Z

Zytronic Displays Ltd.
Whitely Road Blaydon-on-Tyne, Tyne & Wear, NE21 5NJ United Kingdom; +44(0)1914 145511; Fax: +44(0)1914 140545; www.zytronic.co.uk
Products and Services: Filters

Contact Sarah Long at slong@interferencetechnology.com for additions and corrections to the Products and Services directory.

UNITED KINGDOM | Resources

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3 Abbey Court, Fraser Road, Priory Business Park, Bedford MK44 3WH, England; 01234 832700; Fax: 01234 831496; sales@rsgb.org.uk; www.rsgb.org

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CCQS UK LTD
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EMC PROJECTS LTD
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LLOYD'S REGISTER VERIFICATION LTD
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MIRA LIMITED
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MMRA LTD
Sea Containers House, 20 Upper Ground, London SE1 9LZ, United Kingdom; +44 (0)20 7593 9700; Fax: +44 (0)20 7928 2471; dave.weaver@mottmac.com; www.railways.mottmac.com

RFI GLOBAL SERVICES LTD
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SAFENET LIMITED
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SAI GLOBAL ASSURANCE SERVICES
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SAMSUNG ELECTRONICS EURO QA LAB
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SGS UNITED KINGDOM LIMITED
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TRAC TELECOM & RADIO LTD
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TUV PRODUCT SERVICE LTD
Octagon House Concorde Way Segensworth North, Fareham Hampshire PO15 5RL, United Kingdom; +44 (0)1489 558230; Fax: +44 (0)1489 570586; info@tuvps.co.uk; www.tuvps.co.uk

YORK EMC SERVICES (2007) LTD
Market Square University of York, Heslington York YO10 5DD, United Kingdom; +44 (0) 1904 434440; Fax: +44 (0) 1904 434434; enquiry@yorkemc.co.uk; www.yorkemc.co.uk

OTHER

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Department of Trade and Industry (DTI), 151 Buckingham Palace Road, UK-London SW1W 9SS; +44 171 215 13 49; Peter Howick, peter.howick@berr.gsi.gov.uk

EMC Testing above 1 GHz: The Deadline Looms

STEVE HAYES
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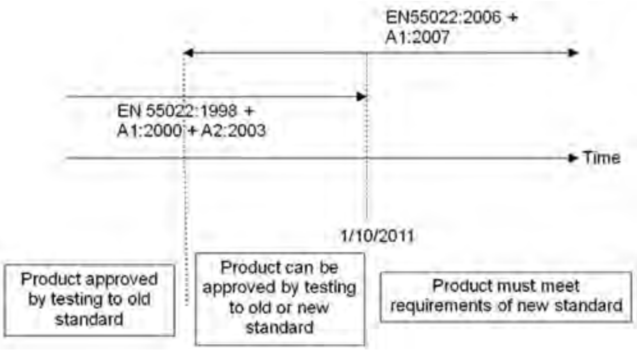
When first mandated in the 1990s, the stated objective of the EU's Directive governing EMC was, in broad terms, that commercial and domestic equipment, and certain industrial systems, should neither cause interference or be susceptible to interference. They should not emit radiated or conducted energy at RF frequencies and they should be immune to such emissions, within specified limits. Some sectors of the industry found the initial specified limits challenging to achieve, despite the fact that the first round of standards were based largely on practice that had been widely required in military equipment procurements for decades prior to their adoption into the commercial arena.

What was initially ambitious has become routine, but now those involved in design and test for EMC compliance are faced with a new challenge — the need to verify emission and susceptibility performance above 1GHz. The key date is 1st October 2011, when EN55022:2006 +A1:2007 becomes the only version of the relevant standard that will support compliance to the technical requirements of the EMC Directive. In fact, 1st October marks the end of a transition period, during which device manufacturers could choose to test products either to the latest revision or to the prior version EN55022:1998 (with amendments A1:2000 and A2:2003).

In many respects, the Directive is merely catching up with the reality of the environment in which today's consumer and commercial products operate. Since the 1998



formulation of the standard, the number of devices in common use that employ frequencies in excess of 1GHz has multiplied many-fold. Cellular radio uses bands at 1800 MHz, 1900 MHz for 2G services, and at 2100 MHz for 3G services; WiFi, Bluetooth and innumerable other services crowd into the 2.4 GHz unlicensed band; and, perhaps most sensitive of all to interference, Global Positioning System satellites transmit in L-band at 1575 MHz. Given that GPS receivers must work with a signal of the order of -130 dBm, and observing the proliferation of products and systems that depend on dependable GPS reception, it could be argued that the arrival of regulatory supervision of radiated emissions above 1 GHz is somewhat overdue.

On the "aggressor" side of the equation, there has also been a massive increase in products that, potentially, can be the source of over-1-GHz emissions; specifically, digital systems and microprocessor-based products with clock speeds in the hundreds of MHz or greater.

Some of the delays associated with the introduction of limits above 1GHz have derived from the 3G-cellular operators. In the UK, they bought their spectrum licences for the unprecedented figure of £23 billion; not surprisingly, they would like a noise-free environment in those bands. Any increase in the general noise floor reduces the coverage of a given base station and increases the number of base stations they must install, which increases costs. The operators were initially reluctant to endorse a standard that specified a permissible level of emissions in "their" bands, on the basis that once a limit has been set, it is very difficult to reduce it.

Nevertheless, EN55022:2006 +A1:2007 is now with us, and it will apply to all information technology equipment,

HIGHEST INTERNAL SOURCE	UPPER FREQUENCY OF TEST
< 108 MHz	1GHz
< 500 MHz	2GHz
< 1GHz	5GHz
> 1GHz	5x highest or 6GHz (whichever is less)

and to microprocessor-based products. While it is unlikely to present technical and logistical challenges on the same scale as did the arrival of the initial EMC Directive, it has implications throughout the product design and certification process. There are increased costs to manufacturers in performing pre-compliance testing, increased costs to test labs that provide the measurements, and these are likely to be passed on – where market conditions permit - to the consumers who purchase the products.

Product design teams that already follow EMC-aware, best-practices rules may encounter few changes; those that are less rigorous run the risk of having products fail testing where previously they would have anticipated a smooth path to certification. All of the familiar potential sources of emission and susceptibility must be considered in the context of higher frequencies. A few cm of PCB track may be a very poor antenna at 300 MHz and a wavelength of 1m; but very efficient at 3 GHz and 10 cm. Similarly, apertures that pass negligible energy at sub-1-GHz frequencies become significant at the new limits.

In the test or pre-compliance phase, material properties may take on a new significance. An open-area test site (OATS) might employ a lightweight equipment cover that is completely transparent to RF below 1 GHz, but may not necessarily be so when calibrated to the new parameters.

Test labs around the world that perform measurements to EN55022 have had to ensure that their test equipment covers the extended frequency range, invest in new antennas where they were limited previously, upgrade cables and finally calibrate their chambers to the new SVSWR requirements in the frequency range. Meeting this upgraded specification for the reflectivity of the chamber lining at higher frequencies can mean enhancing or re-lining a chamber. A poorly funded lab will find these additional requirements very challenging due to the sums of money involved.

EN55022:2006 +A1:2007 does, however, recognise the implications of the architectures of today's IT products, in that it scales the testing regime according to the maximum frequencies used by the design, as listed in Table 1. The highest internal source of an EUT is defined as the highest frequency generated or used within the EUT or on which the EUT operates or tunes. Current microprocessor-based designs invite careful interpretation, and the testing requirements may not be as onerous as they first appear. It has become common practice to quote the clock speed of a multicore processor as a figure of several GHz: however, this may be an aggregate "marketing" figure derived by adding numbers over multiple CPU cores, and the maximum clock speed encountered anywhere on the PCB may only be in the low hundreds of MHz.

In addition to the high frequency tests required, manufacturers will need to limit the electrical noise from 'telecommunication' cables. Whilst this requirement was introduced in previous versions of the standard, the date of withdrawal from the Official Journal of the EU of the older standard meant that many manufacturers have overlooked this requirement until now.

Outside Europe, and the context of the EU Directive, the FCC in North America already sets emissions requirements above 1GHz. The same conditional rules apply to upper frequency of test, but FCC requirements ultimate extend to 18GHz. US exporters to the EU will, therefore, not see any differences compared with domestic arrangements – although the FCC does not require immunity testing. Equally, within the EU many of the product family standards that use EN55022 as their reference standard will be updated to reflect the new requirements. We have already seen EN61000-6-3 and EN61000-6-4 (generic emission standards for both domestic, commercial & light industrial and industrial products) amended and published. These will be listed in the Official Journal of the EU shortly, paving the way for more standards to require the additional tests in due course.

It should not be assumed that all EMC emission standards will require above-1-GHz measurements – the requirements have to take into account the density of use and the operating environment. Take an ISM-band RF welding machine, or perhaps an induction heater, as examples – these are used in noisy industrial environments where wireless communication is already very difficult. If there is no likelihood of deployment of systems, in its locality, that a machine might interfere with, then the option exists to declare that certain aspects of compliance are irrelevant. A study of these particular examples may not have been performed, but it shouldn't be assumed that testing above 1GHz will be required if there is no benefit to the wider community.

While the extension of EMC testing to above-1-GHz is unlikely to produce the same last-minute frenzy of activity as did the initial introduction of the Directive, experience indicates that some manufacturers will leave testing as late as possible to maximise product development time and control test costs. However, the changes discussed here will mean that fewer test houses will be available to perform the testing before the October 2011 deadline, which could leave manufacturers left without compliant products for some time – especially if a redesign is required as a result of the additional requirements.

Additionally, there will be many consequent changes to EMC emission standards used in the EU that support compliance to the EMC Directive and CE marking. Compliance to the Directive can only be demonstrated (using harmonised standards) if the standard is published in the Official Journal of the EU and hence regular checking of this and the standards is required to maintain compliance to legal requirements.

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Calibration of Toroidal Current Measurement Probes at High Frequency

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Toroidal current transducers are widely used in EMC measurements, both for monitoring currents flowing on single cables or cable bundles and for injecting currents onto such cables or cable bundles. The latter forms the basis of a well-established approach to susceptibility testing (bulk current injection) that is used in the automotive and aerospace industries [1-2]. Induced currents are also monitored in certain immunity tests, such as those used in the aerospace industry [3]. Some methods for characterizing shielded cables employ both current injection and current monitoring transducers [4], and other possible applications are outlined in [5]. For current measurement purposes these devices are calibrated in terms of their transfer impedance, which relates the current on the cable passing through the transducer to the voltage generated at its terminals. For current injection applications these transducers are characterized in terms of insertion loss. The scope of this article, however, is limited to issues concerning the determination of transfer impedance for toroidal current measurement probes at high frequency.

CURRENT PROBE CALIBRATION FIXTURES

Current transducer calibration is normally carried out using a special calibration fixture, which is often provided by the probe manufacturer and can be used for both transfer impedance and insertion loss calibration. The calibration fixture essentially provides a short length of straight wire around which the transducer can be located and which terminates to coaxial connectors at each end. The shells of the coaxial connectors are connected by a simple metal structure that can accommodate the transducer. Typically this is a simple open ended box (i.e. a loop of four flat metal panels) enclosing the wire, which allows easy access to the transducer terminals at the open ends. In some examples, however, the interior is almost completely enclosed, with just a small aperture to allow a cable to be connected to the transducer terminals. Although some current transducers have solid bodies, with the result that the cable under test must be threaded through them, most are constructed with two hinged parts so that it can be more easily clamped around a cable. Nonetheless, the structure of the calibration

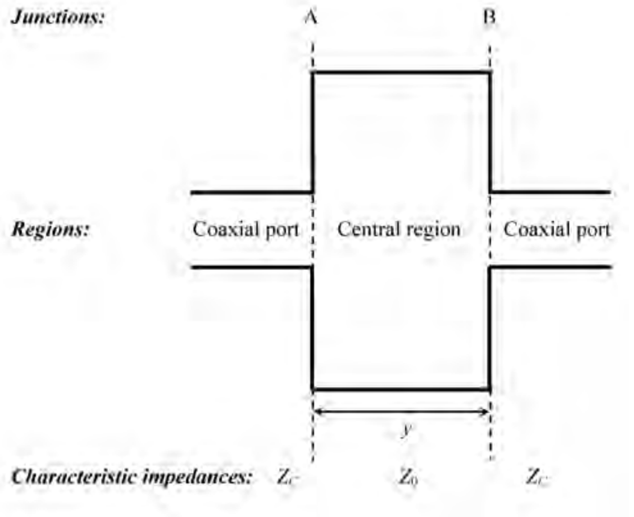

Figure 1. Schematic of transmission line model for empty calibration fixture.

fixture normally needs to be opened in order to allow the current transducer to be mounted around the wire.

At very low frequency the current flowing in the central wire will be the same as that measured or injected at the coaxial ports. At higher frequencies, however, impedance mismatches will result in interference between reflections and a standing wave on the internal wire of the calibration fixture. For these reasons impedance matching structures are often included to reduce the impact of these effects. Minimizing the length of the central wire also helps. However, these measures may not be fully effective, particularly at higher frequencies.

SIMPLE TRANSFER IMPEDANCE DEFINITIONS

The transfer impedance parameter is intended to provide a mapping between the current flowing in the cable passing through the current measurement probe and the voltage that appears at the terminals of the transducer.

The input connector of the calibration fixture is denoted Port 1, the output connector is Port 2, and the transducer output is Port 3. If the scattering matrix for the system with the current probe in the calibration fixture is **P**(f), where f is the frequency, then the voltage at the current probe terminals is:

$$V_3(f)=|P_{31}(f)|V_0(f)=|P_{31}|Z_C I_0(f) \quad (1)$$

where $I_0(f)$ and $V_0(f)$ represent the current and voltage incident at Port 1, $|P_{31}(f)|$ is the magnitude of the frequency dependent transmission coefficient from Port 1 to Port 3, and Z_C represents the characteristic impedance of the measurement system (which is assumed to the 50 Ω and frequency independent). The transfer impedance of the current probe as defined in [1], which is referenced to the input current, is then:

$$Z_0 = \frac{V_3}{I_0} = Z_c|P_{31}| \quad (2)$$

A better transfer impedance estimate may be obtained by using the current flowing out of the device as the reference current. However, the current transducer itself is also likely to have an impact on the system, suggesting two possible options for the reference current: the output current for the empty calibration fixture, or that with the probe present. The current exiting at Port 2 with the probe present is $|P_{21}(f)|I_0(f)$, so using this as the reference current for the transfer impedance gives:

$$Z_1 = Z_c \frac{|P_{31}|}{|P_{21}|} \quad (3)$$

Similarly, if the current flowing out of the empty calibration fixture is used as the reference, the transfer impedance estimate is:

$$Z_2 = Z_c \frac{|P_{31}|}{|J_{21}|} \quad (4)$$

where **J**(f) represents the scattering matrix for the empty calibration fixture (of order 2 x 2, as this has only two ports).

If the probe does not affect the system then $P_{21}(f)=J_{21}(f)$ and the transfer impedances $Z_1(f)$ and $Z_2(f)$ are identical. Furthermore, if transmission through the calibration fixture is near-perfect, by careful impedance matching, then $P_{21}(f)=1$ or $J_{21}(f)=1$ and both $Z_1(f)$ and $Z_2(f)$ reduce to $Z_0(f)$.

TAKING ACCOUNT OF JUNCTION REFLECTIONS

An improved estimate for the current at the center of the wire, taking account of interference between reflections from the coaxial ports, can be obtained using a simple 1D transmission line model to interpret the scattering matrix for the calibration fixture [6]. This analysis requires the phase, as well as the amplitude, for the frequency dependent transmission and reflection coefficients between the coaxial ports of the system, which can be obtained using a vector network analyzer.

It is assumed that the calibration fixture may be considered as a section of uniform transmission line with characteristic impedance $Z_J(f)$ which is terminated at each end with identical transitions to the two coaxial ports of characteristic impedance Z_C (see Figure 1). The junctions between the two types of transmission line will give rise to finite reflection coefficients and the resulting reflections will then interfere in a manner that depends on their electrical separation. This model assumes that the junction reflection coefficients take account of the additional path

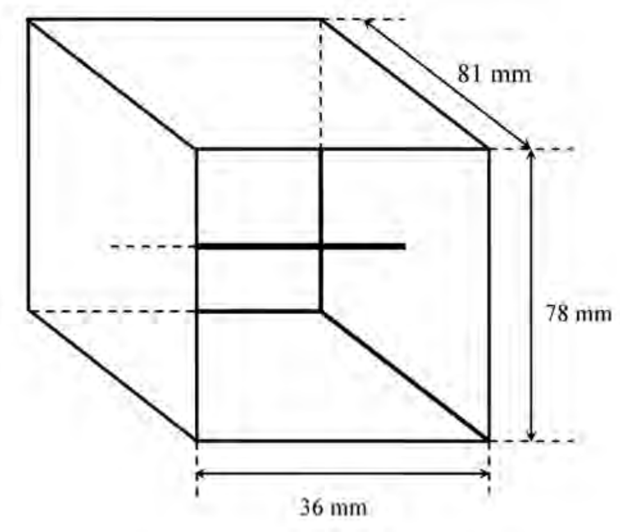

Figure 2. Internal dimensions of calibration fixture.

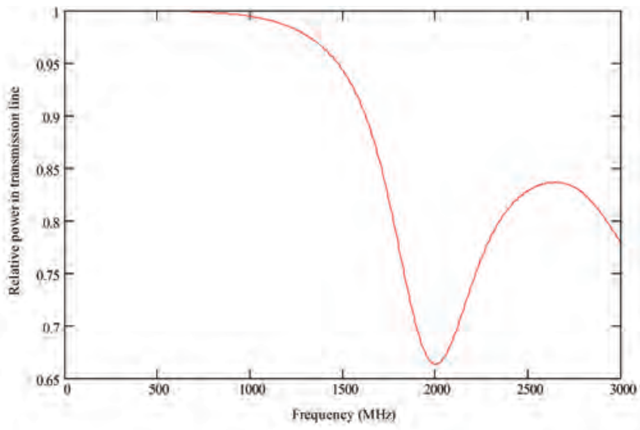

***Figure 3.** Relative power in transmission line from TLM model of calibration fixture.*

lengths that are introduced between the outer conductors of the coaxial ports as a consequence of the geometry of the calibration fixture.

It is assumed that the system is symmetrical and no energy is returned from the output port. Using the current at the center of the wire for the empty calibration fixture as the reference (i.e. at $s=y/2$), it can be shown [6] that the transfer impedance estimate taking account of the junction reflections is given by:

$$Z_3(f)=\frac{Z_C|P_{31}(f)|}{[1-\rho_1(f)]}\left\{\frac{1-\rho_1(f)^2e^{-2iy\beta(f)}}{e^{-\frac{1}{2}iy\beta(f)}+\rho_1 e^{-\frac{3}{2}iy\beta(f)}}\right\} \quad (5)$$

where $\rho_1(f)$ is the reflection coefficient at junction A due to the abrupt change in impedance from Z_C to $Z_J(f)$, $\beta(f)$ is the propagation constant in the empty calibration fixture, and y is the distance between the two junctions.

The parameters $\rho_1(f)$ and $\beta(f)$ can be obtained from the complex components (both amplitude and phase of the reflection and transmission coefficients are required) of the measured scattering matrix $\mathbf{J}(f)$ for the empty calibration fixture as follows:

$$\beta(f)=\frac{1}{y}\cos^{-1}\left\{\frac{1-J_{11}(f)^2+J_{21}(f)^2}{2J_{21}(f)}\right\} \quad (6)$$

$$\rho_1(f)=\frac{J_{11}(f)}{1-J_{21}(f)e^{-iy\beta(f)}} \quad (7)$$

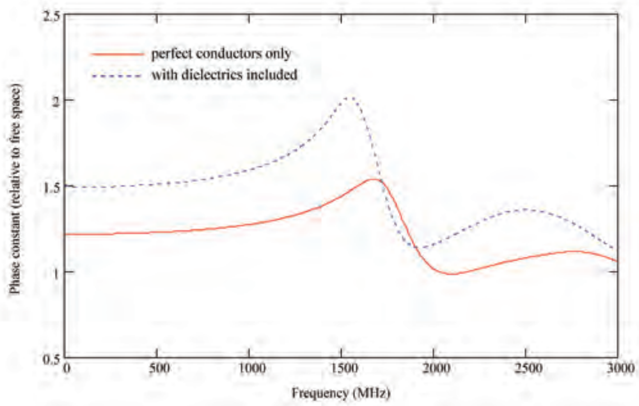

***Figure 4.** Phase constant estimated from TLM model of calibration fixture, with and without dielectric parts.*

The scattering matrix for the calibration fixture can therefore be used to determine the propagation constant for this structure, and hence the reflection coefficients at the coaxial ports. These two quantities are then sufficient to correct the transfer impedance for the effect of finite mismatches in the calibration fixture. The simpler approximations described in the previous section can also be derived from equation (5).

VALIDATION OF 1D TRANSMISSION LINE MODEL

A 3D numerical model of a simple calibration fixture has been used to assess the validity and limitations of the approach described above. The inputs for the real device that was investigated have no special matching structures: the dielectric of the coaxial connectors is trimmed to be flush with the interior surface and the center conductors project through to connect with the central wire. The internal dimensions of this structure are illustrated in Figure 2, and the 3D numerical model was implemented using the transmission line matrix (TLM) technique [7]. In the model, the central wire was terminated with 50 Ω ports, and both the metal panels (≈3 mm thick) and the wire (≈2 mm in diameter) were assumed to be perfect conductors.

The scattering matrix for the modeled structure can be determined from the currents at the ports of the device. The sum of the power reflected at the input and transmitted to the output can then be used to establish where the assumption that the device is lossless begins to break down. It can be seen from Figure 3 that, for this structure, this is a reasonable assumption for frequencies up to about 1 GHz (where the loss is only 0.5%).

For this structure the wire length corresponds to around 0.1 wavelengths at this frequency, while the dimensions of the larger plates are approaching 0.25 wavelengths. At higher frequencies the power lost through radiation becomes increasingly significant. Measurements can similarly be used to determine the frequency range over which a real structure can be regarded as lossless. The current at the center of the wire can be computed directly from the TLM model for comparison with estimates based on the port currents or derived from the computed scattering matrix for the system (as described in the previous section).

The real calibration fixture has thin layers of insulating material (≈1 mm thick) bonded to the inner faces of structure, and the central wire is surrounded by insulation (≈0.6 mm thick). The electrical properties of these materials are unknown and therefore difficult to model with any certainty. Results for the propagation constant estimated from the computed scattering matrix are illustrated in Figure 4, which is derived from simulations based on only the metal parts of the structure, and with representative dielectric materials added to the model (assumed to be lossless, with relative permittivity of 3 for the insulating sheets and 2.5 for the wire insulation).

The values for the real component of $\beta(f)$ are greater than the free space propagation constant for the purely metallic case, and the effect of the dielectric material is to further increase this parameter. The imaginary components are zero up to about 1 GHz, where the behavior of the device is becoming more complicated. The results of Figure 5 illustrate that, although the current at the output provides a

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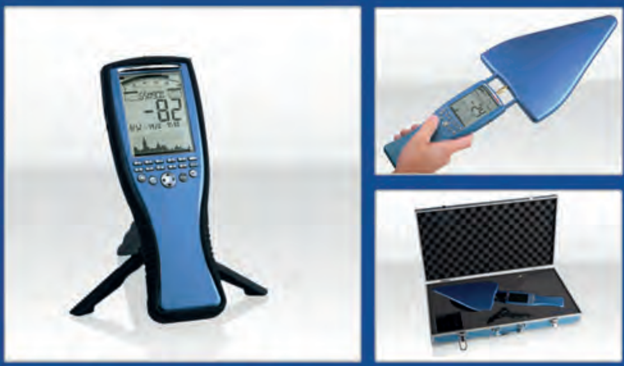

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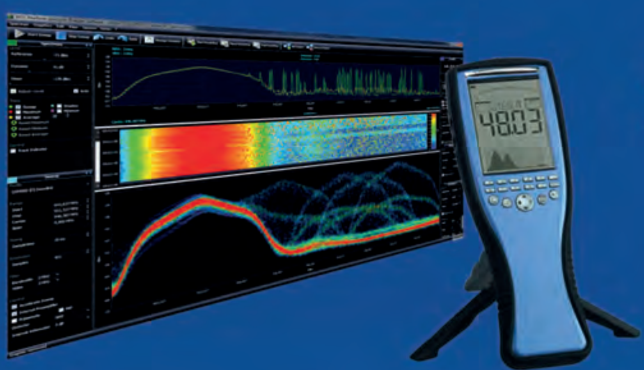

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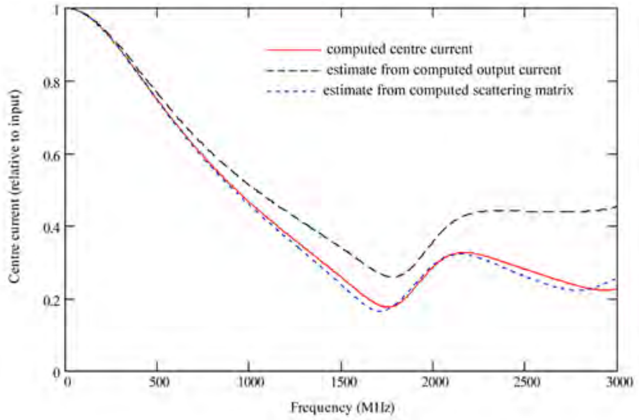

Figure 5. Computed current at center of calibration fixture wire compared with output current and estimate derived from computed scattering matrix.

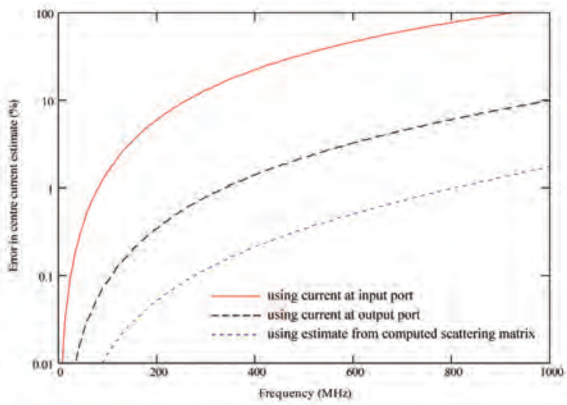

Figure 6. Error in estimates for current at center of wire based on incident current, output current and estimate derived from scattering matrix.

reasonable estimate for the current at the center of the wire for low frequencies, the value obtained from the scattering matrix for the device provides a much better estimate. Moreover, this method continues to provide a very good indication of the current at the center of the wire, even at much higher frequencies where losses become more significant. Although the structure begins to radiate at the higher frequencies, the junctions remain lossless and the transmission line model still provides a good estimate for the current at the center of the wire. The errors resulting from estimating the current by different methods are compared in Figure 6, showing errors of little more than 1% at 1 GHz for the proposed method, compared with around 10% for estimates based on the output current and much larger errors using the incident current.

INCLUDING PROBE FOR OVERSIZED CALIBRATION FIXTURES

If the probe width is sufficient to fill the calibration fixture

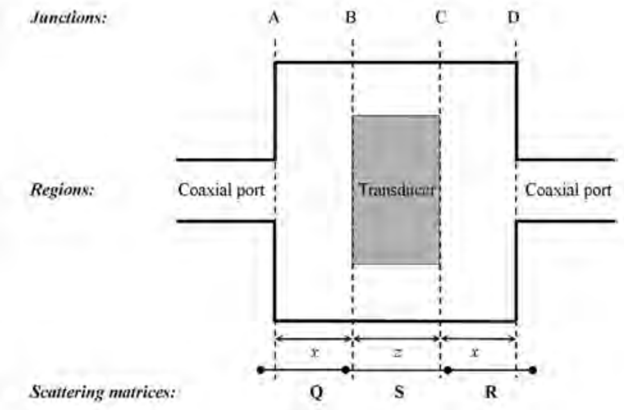

Figure 7. *Alternative transmission line model for partially filled calibration fixture used to determine the current at the centre of the transducer.*

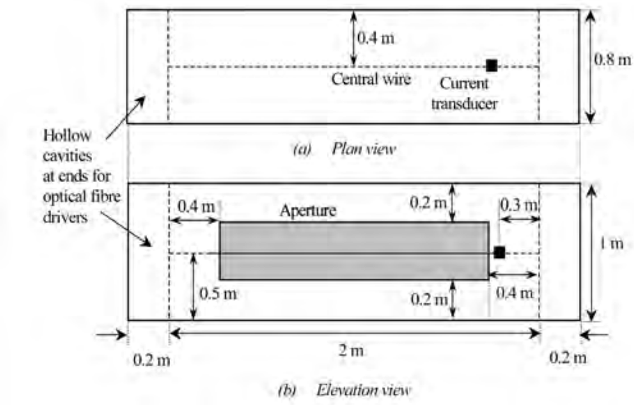

Figure 8. *Geometry of test object, illustrating relative positions of aperture, current transducer and interior wire.*

then equation (5) could also be used to obtain a transfer impedance estimate relative to the current at the center of the probe by replacing $J_{11}(f)$ and $J_{21}(f)$ in equations (6) and (7) with $P_{11}(f)$ and $P_{21}(f)$. However, if the calibration fixture is wider than the thickness of the current transducer, the latter may then introduce additional mismatches when the calibration measurements are made. Although a transfer impedance estimate referenced to the current at the center of the empty calibration fixture is still possible in this case, another option could be to reference the transfer impedance to the current at the center of the probe partially filling the calibration fixture.

In cases where the transducer does not completely fill the calibration fixture longitudinally, the significance of the additional mismatches that are introduced by the transducer can be estimated using an extended 1D transmission line model as illustrated in Fig. 7, in which there are now four impedance junctions and the region occupied by the current transducer is represented by the scattering matrix $\mathbf{S}(f)$.

Assuming that the current probe is located centrally in the calibration fixture, the networks represented by matrices **Q**(*f*) and **R**(*f*) in Figure 7 simply comprise the junctions at the coaxial ports cascaded with transmission line sections representing the lengths (*x*) of empty calibration fixture on either side of the current transducer. Consequently, their scattering matrices can be described in terms of the parameters $\rho_1(f)$ and $\beta(f)$, obtained from measurements of the scattering matrix **J**(*f*) for the empty calibration fixture.

For this symmetrical network it can be shown [8] that the elements of the scattering matrix **S**(*f*) for the probe region can be extracted from the measured scattering matrix **T**(*f*) for the calibration fixture with the transducer positioned at the center of the calibration fixture, together with the parameters $\rho_1(f)$ and $\beta(f)$ obtained for the empty calibration fixture. The scattering matrix for the device region can be de-embedded from that for the overall network using:

$$S_{11}(f)=\frac{T_{11}(f)\left[1+\rho_1(f)^2\right]-\rho_1(f)\left[1+T_{11}(f)^2-T_{21}(f)^2\right]}{\left\{\left[1-\rho_1(f)T_{11}(f)\right]^2-\rho_1(f)^2T_{21}(f)^2\right\}e^{-2ix\beta(f)}} \quad (8)$$

$$S_{21}(f)=\frac{\left[1-\rho_1(f)^2\right]T_{21}(f)e^{2ix\beta(f)}}{\left[1-\rho_1(f)T_{11}(f)\right]^2-\rho_1(f)^2T_{21}(f)^2} \quad (9)$$

The region occupied by the current transducer, represented by the matrix **S**(*f*), is again approximated as a symmetrical pair of lossless junctions separated by a length z of transmission line of propagation constant $\gamma(f)$. Consequently, the same analysis method used to extract the transmission line model for the empty calibration fixture can then be applied to the matrix **S**(*f*) to extract the propagation constant $\gamma(f)$ for the transducer region and the reflection coefficients $\rho_2(f)$ associated with the faces of the device. Thus, following equations (6) and (7):

$$\gamma(f)=\frac{1}{z}\cos^{-1}\left\{\frac{1-S_{11}(f)^2+S_{21}(f)^2}{2S_{21}(f)}\right\} \quad (10)$$

$$\rho_2(f)=\frac{S_{11}(f)}{1-S_{21}(f)e^{-iz\gamma(f)}} \quad (11)$$

The transfer impedance for those cases where the transducer does not fill the calibration fixture, using the current at the center of the transducer (i.e. at $t=z/2$) as the reference, can be shown [8] to be:

$$Z_4(f)=\frac{Z_C\left|P_{31}(f)\right|\left[a(f)^2-b(f)^2e^{-2iz\gamma(f)}\right]e^{ix\beta(f)}e^{\frac{1}{2}iz\gamma(f)}}{\left[1-\rho_1(f)\right]\left[1-\rho_2(f)\right]\left[a(f)+b(f)e^{-iz\gamma(f)}\right]} \quad (12)$$

where the parameters *a*(*f*) and *b*(*f*) represent additional terms as follows:

$$a(f)=1+\rho_1(f)\rho_2(f)e^{-2ix\beta(f)} \quad (13)$$

$$b(f)=\rho_1(f)+\rho_2(f)e^{-2ix\beta(f)} \quad (14)$$

NUMERICAL MODEL VALIDATION EXAMPLE

This investigation of current probe calibration methods was prompted by disparities found between numerical simulations and "measured" results. The measurements employed a small current transducer (25 mm in diameter and 16 mm thick). This device, therefore, did not completely fill the calibration fixture (illustrated in Figure 2), in which the central wire was 36 mm long. Consequently, the original simulation is used here to judge the success of the various calibration options.

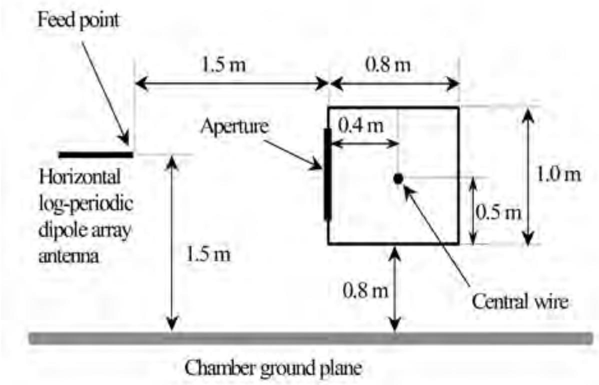

Figure 9. *Geometry of test object, illustrating relative positions of aperture, current transducer and interior wire.*

A common test case used in the validation of numerical modeling techniques for EMC applications comprises a cavity containing a wire and an aperture that permits coupling with an external field. In such an experiment, the current at a point on the cable was recorded under external illumination from a log-periodic dipole array antenna in a semi-anechoic chamber. The chamber is 25.6 m long, 13.6 m wide and 8.8 m high, and is lined with a 1.8 m long twisted pyramidal foam absorber. It is used primarily for commercial radiated immunity testing of vehicles ranging in size from cars to industrial vehicles.

The object under test (see Figure 8) was a rectangular aluminum box with sides of length 0.8 m, 1 m and 2.4 m. One of the 1 m wide faces was equipped with a 1.2 m long, 0.6 m wide aperture that was centrally located. The interior cavity was 2 m long and contained a wire that was located along the longitudinal axis of the box and terminated with 50 Ω loads. The current transducer was placed at 0.3 m from one end of the wire. The cavities at each end of the box (0.2 m long) housed the cable terminations and an optical fiber transmission system linking the current probe to the data acquisition system.

The lowest face of the box was mounted at 0.8 m above the ground plane (using wooden trestles) and the face containing the aperture was vertical and illuminated by the antenna, which was aligned with the transverse axis of the box (see Figure 9). The center of the aperture was located above the center of the chamber. The longitudinal axis of the antenna was 1.5 m above the ground and the feed point was 1.5 m from the box.

A 3D numerical model of this system was constructed using TLM. Both the measurements and the simulations included a preliminary "empty chamber" calibration in which the "threat" field at the point corresponding to the center of the aperture was determined. Measured and simulated results obtained with the test object in place may then be normalized to the corresponding threat field in order to obtain data sets that are directly comparable. This approach is useful for model validation purposes as it avoids the need to model the real antenna and its excitation in fine detail and also limits the effects of systematic errors in the field

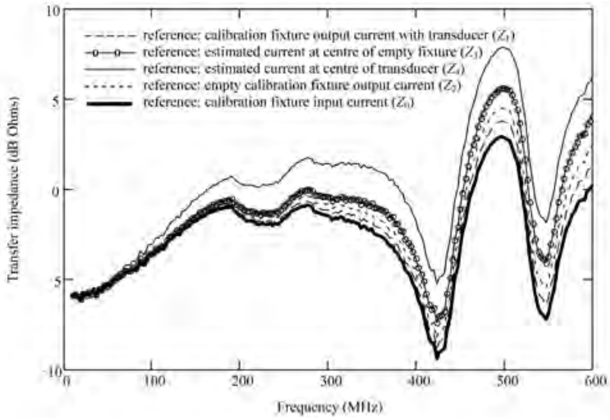

***Figure 10.** Transfer impedance estimates obtained for current transducer used in model validation measurement.*

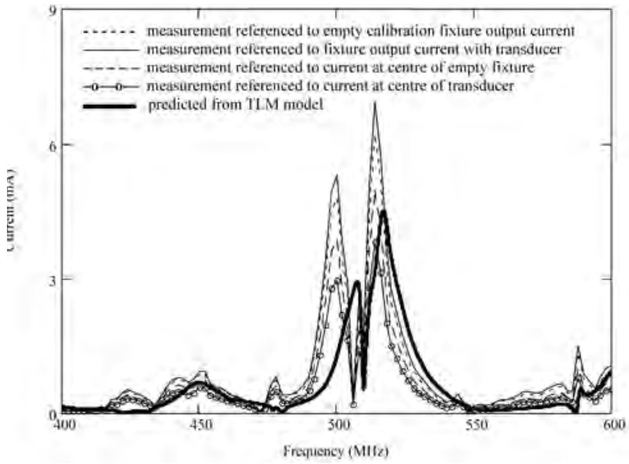

***Figure 11.** Measured current magnitude for wire inside test box calibrated by four methods and compared with numerical simulations.*

measurements.

Transfer impedance estimates obtained for the current transducer used in the measurements are illustrated in Figure 10, including all of the current reference options described above. The impact of the various transfer impedance estimates on the interpretation of measured currents from the model validation experiment is illustrated in Figure 11, which compares the current predicted from the TLM model with measurements that are calibrated using the various options described above.

Comparing the results for the feature around 500 MHz, the measurement calibrated using the transfer impedance Z_4 defined in equation (10), based on the estimated current at the center of the transducer during the calibration, is at almost the same level as the corresponding (but displaced) feature in the model results. The amplitude of the dominant feature (around 520 MHz), which is larger than the predicted value for the other calibration schemes, is smaller than the prediction for this case, but the overestimate for the feature that occurs at around 590 MHz is smaller than for the calibrations based on the calibration fixture output currents (with or without the transducer present) or the estimated center current for the empty calibration fixture.

Since the frequencies and relative magnitudes of the features in the measured and predicted current spectra are not identical, it can be expected that it will become increasingly difficult to judge the success of more refined calibration approaches. The disparities that arise can probably be ascribed to limitations of both the model and the measurement. The numerical model used for the validation experiment did not include any representation of either the current transducer or its associated coaxial cable (which linked the device to a bulkhead connector, and hence to an optical fiber transmitter housed in a cavity inside the test object). The log-periodic dipole array antenna that was used to illuminate the test object for the measurements was also too complicated to be represented in detail in the simulations, due to computational limitations at the time this work was carried out. In addition, the model neglected material losses, so predicted levels might be expected to be higher than in the measurements. Frequency shifts between similar features found in models and measurements are also routinely encountered in model validation experiments. Furthermore, the impact of the transducer on the wire that passes through it is unlikely be the same in the validation measurements as in the calibration measurements, and the influence of the transducer is not represented in the simulations.

Although referencing the calibration to the estimated current at the center of the transducer results in a lower "measured" current than predictions for the dominant feature, the overall results suggest that this approach provides a more satisfactory reference for the calibration in this example. In addition, it is expected that the predicted resonances may be slightly higher than the measurements due to the use of perfect conductors in the simulation.

CONCLUSIONS

A simple 1D transmission line model has been used to assess the impact of the reflections that occur within a calibration fixture when calibrating a current transducer, including the case where the current transducer does not completely fill the calibration fixture longitudinally. A number of alternative estimates for the transfer impedance of the current transducer have also been derived, based on referencing the transducer output to the current at different points in the calibration fixture, with and without the current probe present. The various currents that are used for this purpose are estimated from measurements of the scattering matrices for the calibration fixture under empty and loaded conditions using the 1D transmission line model.

The relative success of the various calibration approaches has been investigated for frequencies up to 600 MHz using measured and computed results from a model validation experiment. Measurements of the current induced on a wire inside a cavity backed aperture illuminated by a nearby log-periodic dipole array antenna in a large semi-anechoic chamber were reinterpreted using the various calibration options and then compared with currents predicted from a numerical model of this system.

The results from this analysis suggest that the output current from the oversized calibration fixture with the transducer in place does not provide a reliable reference for the transducer calibration. Using the output current for the empty calibration fixture as the calibration reference brings the measured measurements closer to the simulations for the validation experiment, and further improvements are obtained by referencing the calibration to the estimated current at the center of the empty calibration fixture. However, it is considered that a more reliable estimate for the transfer impedance of the current transducer is achieved by referencing the transducer output to the estimated current at the center of the transducer during calibration using an over-sized calibration fixture.

Other approaches for improving the calibration of current probes at high frequency have also been proposed, including a long wire calibration system [9], which aims to be more representative of real measurement conditions and combines frequency and time domain measurements in order to obtain wide-band results for both transfer impedance and insertion loss. A method for direct measurement of the current at the probe location has also been developed [10], which again allows the calibration to reflect a realistic test configuration but avoids the need for corrections to mitigate the limitations of the calibration system. A further interesting approach [11] employs a reverberation chamber in order to produce an environment that is more representative of more complex real-world situations where the cable under test is not near a ground plane and propagation is therefore no longer TEM in character. The reverberation chamber approach has low frequency limitations (because there is a minimum operating frequency below which insufficient modes are available to obtain the required field statistics) and is therefore complementary to other techniques that are more effective at low frequencies.

An advantage of the approach presented in this article, which aims to estimate the current distribution within the calibration fixture from external measurements of the scattering matrix, is that the necessary measurements can be carried out on the bench using existing calibration fixtures and a vector network analyzer. The extension of the 1D transmission line model to account for current probes that do not fill the calibration fixture also allows current measurement transducers to be calibrated using calibration fixtures that may have been designed for use with larger current transducers, such as those intended for current injection applications.

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EMV 2012 mit aktuellen Themen und neuen Herausforderungen

INTERNATIONALE FACHMESSE UND KONGRESS
für Elektromagnetische Verträglichkeit
Düsseldorf, 07.-09.02.2012

Aktuelle Themen wie Elektromobilität, regenerative Energien, oder Smart Grids schaffen neue Herausforderungen. Die Antworten sind auf der EMV, Europas führender Messe mit Kongress für elektromagnetische Verträglichkeit zu finden.

Die Messe. Im März 2011 bewies die EMV einmal mehr ihre Position als Europas bedeutendste Veranstaltung der Branche. Aussteller und Besucher zeigten sich überaus zufrieden mit den Ergebnissen der dreitägigen Veranstaltung. „Eine rundum gelungene Messe. So viele Kontakte wie dieses Jahr hatten wir noch nie" fasste Hartmut Berndt von ServiceForce.Com GmbH seine Erfahrungen vor Ort zusammen.

Für die EMV 2012 stehen die Zeichen bereits jetzt gut. Die Keyplayer der Branche haben frühzeitig Ihre Positionierung in der Messehalle reserviert. Renommierte Unternehmen der Branche wie Aaronia AG, Agilent Technologies, Bonn Elektronik GmbH, EMCO Elektronik GmbH, EM Test GmbH, EMV GmbH, Frankonia EMC Test-Systems GmbH , Haefely Test AG, Hilo-Test GmbH, Phoenix Testlab GmbH, Rohde & Schwarz GmbH & Co.KG, Spitzenberger & Spiess GmbH & Co.KG, Teseq GmbH – um nur einige zu nennen – sind bereits dabei. Die Unternehmen werden Ihre neuesten Produkte und Dienstleistungen präsentieren und für Fachgespräche zur Verfügung stehen.

Durch aktuelle Themen wie eMobility, regenerative Energien oder Smart Grids entstehen neue Herausforderungen und EMVFragestellungen. Bereits auf der EMV 2011 stand das Thema Elektromobilität im Vordergrund. Erstmalig gab es eine Aktionsfläche zum Thema mit zahlreichen Exponaten und Impulsvorträgen. Das Projekt wird auf der EMV 2012 wieder aufgenommen und ausgebaut. Auf einer Sonderfläche von über 160 Quadratmetern werden zum Thema Elektromobilität und EMV komplexe Fragestellungen beantwortet und interessante Exponate ausgestellt.

Der Kongress. Auch die Workshops der EMV 2011 erfreuten sich hoher Nachfrage. Ein besonderes Highlight der EMV Workshops war der Plenarvortrag von Dr. Willibert Schleuter, ehem. Leiter Entwicklung Elektrik/Elektronik AUDI AG, mit dem Thema "eMobility - Herausforderungen, Chancen und Risiken". Sehr anschaulich erläuterte Dr. Schleuter die treibenden Kräfte der Elektromobilität, verschiedene Fahrzeug- und Ladekonzepte, Geschäftsmodelle sowie die Herausforderungen der vernetzten Zusammenarbeit.

Auch für die EMV 2012, die vom 07. bis 09. Februar 2012 in Düsseldorf stattfindet, hat das Programmkomitee unter Leitung von Prof. Dr. Heyno Garbe von der Leibniz Universität Hannover wieder ein hochkarätiges Programm zusammengestellt. In 27 Sessions mit insgesamt 85 Vorträgen informieren anerkannte Experten über die neuesten Entwicklungen in der elektromagnetischen Verträglichkeit.

In der Session „Störquellen und Lokalisierung" spricht u.a. Martin Frey von der Rundfunk-Betriebstechnik GmbH über eine „Minimal-invasive Methode zur Lokalisierung von Schaltnetzteilen mit schadhaftem Zwischenkreis-Kondensator in hochverfügbaren Anlagen". Auch das Thema Elektromobilität wird auf dem Kongress der EMV 2012 wieder eine Rolle spielen.

Frank Kremer von der Technische Universität Dormund berichtet in der Session „Bordnetzverkopplungen in Elektrofahrzeugen" über die „Simulationsbasierte Bewertung der zulässigen Kopplung zwischen verschiedenen Spannungsebenen". Weitere Sessions befassen u.a. sich mit den Themen „Modenverwirbelungskammern", „Fahrzeuganalyse", „Leitungsgeführte Störgrößen in Elektrofahrzeugen" und „Störfestigkeitsprüfung".

Der Plenarvortrag der EMV 2012, gehalten von Prof. Dr.-Ing. habil. Hansjörg Mixdorff von der Beuth Hochschule für Technik Berlin, befasst sich mit dem Thema „Audio- und Videokompression mit MPEG".

Ausführliche Informationen zur EMV 2012 mit Kongress in Düsseldorf und die Möglichkeit der Registrierung einer kostenlosen Tageskarte finden Sie unter www.e-emv.com

Knackratenanalyse nach CISPR 16 und CISPR 14 basierend auf der Technologie der EMV Zeitbereichsmesstechnik

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English translation available at
www.interferencetechnology.eu

I. EINLEITUNG

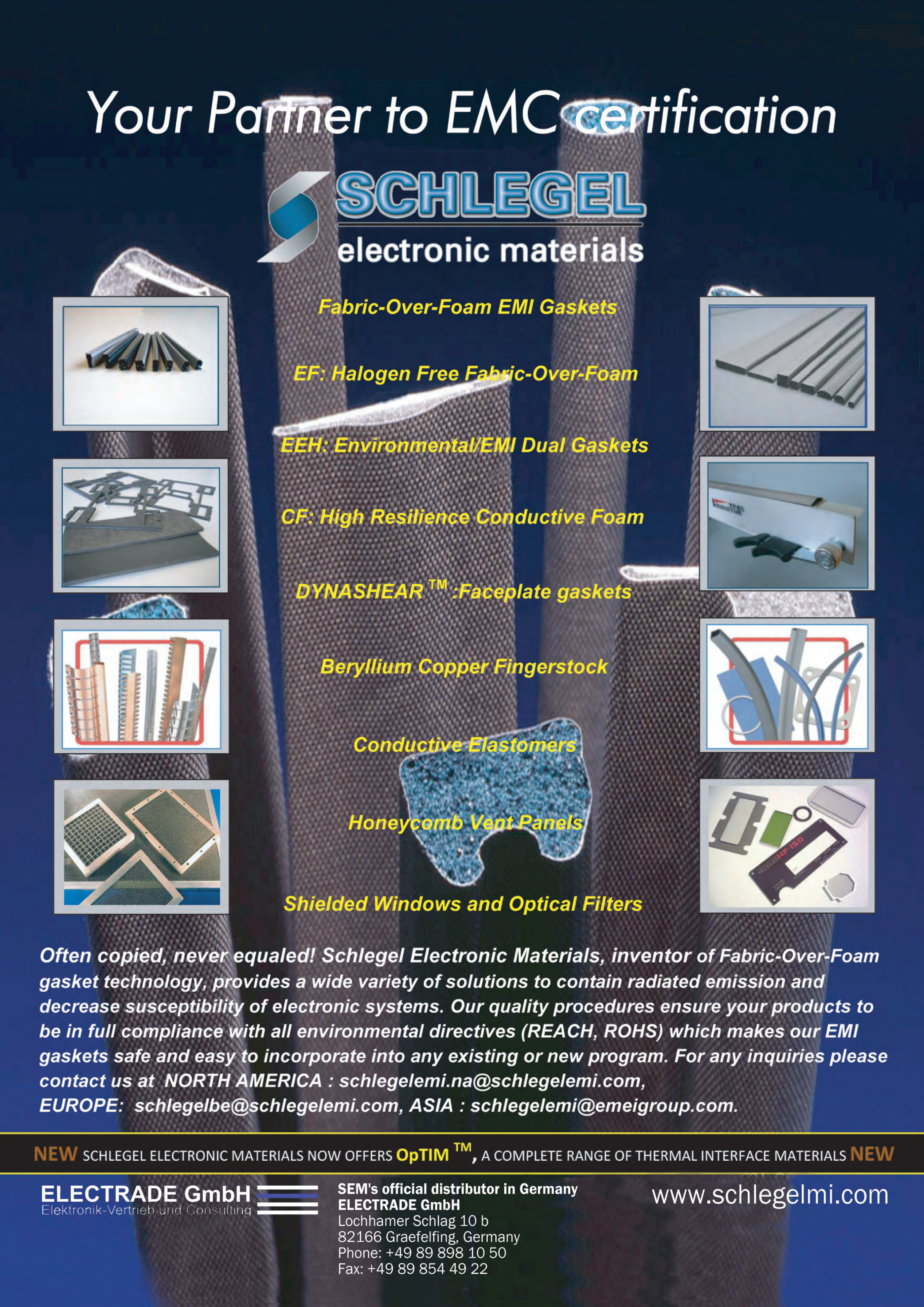
Mit der Aufnahme des "FFT-based Measuring Instruments" in die Fachgrundnorm 16-1-1 sind die Weichen für einen Technologiewechsel im Bereich der Funkstörmessempfänger gestellt. Derartig neuartige Messgeräte können die Zuverlässigkeit von Emissionsmessungen für komplexe Systeme erhöhen, die Prüfzeiten reduzieren, und damit die heutigen Anforderungen an immer kürzeren Innovationszyklen im Bereich der Produktentwicklung erfüllen.

Messsysteme mit FFT-basiertem Funkstörmessempfängermodus nach CISPR 16-1-1 [1] werden mittlerweile in der Produktionentwicklung und Zertifizierung eingesetzt. Mathematisch ist der Zusammenhang bekannt, dass die Kurzzeit-FFT an einem Frequenzpunkt genau einem traditionellen Messempfänger entspricht. Dies wurde unter anderem in [2] gezeigt und ist auch in der CISPR 16-3 dargestellt. Anders formuliert, ein traditioneller Funkstörmessempfänger ist eine Ausführung eines "FFT-based Measuring Instruments" mit einer FFT Länge von eins. Bzw. ein "FFT-based measuring Instrument" entspricht mehreren Funkstörmessempfängern mit äquidistantem Frequenzraster. Grundvoraussetzung für diese Annahme ist allerdings, dass das "FFT-based Measuring Instrument" in Echtzeit arbeitet.

Ein echtzeitfähiges FFT-based Measuring Instrument, benutzt Hochgeschwindigkeits Analog-Digital-Wandler sowie Field Programmable Gate Arrays (FPGAs) welche dedizierte Logik und Rechenblöcke beinhaltet um die Auswertung der Daten der Analog-Digital-Wandler in Echtzeit durchzuführen. Derartige Messsysteme ermöglichen es unterschiedliche Messgeräte, wie ein selektives Voltmeter (traditioneller Messempfänger), sowie Knackratenanalsator zu ersetzen. Des weiteren können sehr schnelle Scans durchgeführt werden.

A. Einsatz als Selektives Voltmeter

Aufgrund der mathematischen Aquivalenz und eines zusätzlichen digitalen Mischers vor der Kurzeit-FFT ist es möglich an einen beliebigen Frequenzpunkt einzustel-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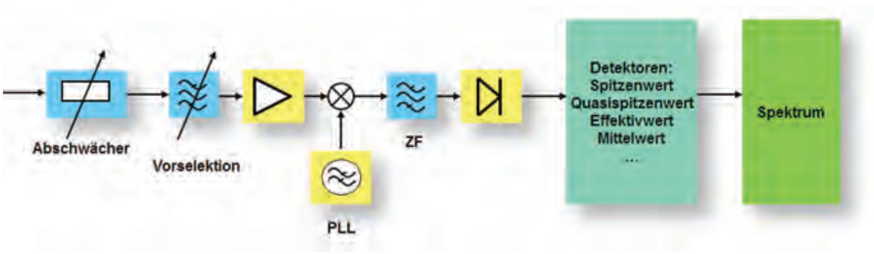

Fig. 1. Konventioneller Superheterodynempfänger.

len, und das demodulierte ZF-Ausgangssignal mit den Detektoren Spitzenwert, Quasi-Spitzenwert, Mittelwert, CISPR-AVG und CISPR AVG-RMS Detektor auszuwerten. Dies entspricht der Funktionalität eines traditionellen Messempfängers bei einer Frequenz, oder eines Spektrumanalysators im "Zero Span". Eine Anwendung ist z.B. ein Höhenscan bei einer Frequenz.

B. Anwendung Schnelle Scans

Durch die parallele Auswertung an mehreren tausend Frequenzpunkten, kann eine typischer Scan, welcher oft aus bis zu 20000 Frequenzpunkten besteht um bis zu einem Faktor 4000 reduziert werden. Dies ermöglicht es z.B. Messungen ohne Vor- und Nachmessung, sondern in einem Scan durchzuführen. Damit kann z.B. eine leitungsgebundene Emissionsmessung in nur einer Minute durchgeführt werden.

C. Knackratenanalyse

Bei der Knackratenanalyse werden die Daten der Kurzzeit-FFT an vier Frequenzpunkten 150 kHz, 500 kHz, 1.4 MHz und 30 MHz ausgewertet. Die Auswertung mittels Quasi-Spitzenwertdetektor und Spitzenwertdetektor erfolgt in Echtzeit. Des weiteren erfolgt die Triggerung und Auswertung der Pegel gegenüber der Grenzwertlinie in Echtzeit nach CISPR 14-1 und CISPR 16-1-1. Zur Durchführung der Messung wird der Prüfling, z.B. eine Waschmaschine mit einer Netznachbildung verbunden. Das Störsignal wird ausgekoppelt und erfasst. Die Auswertung der Störungen erfolgt nach Pulsbreite, Pulshöhe, sowie nach dem Anzeigepegel des Quasispitzenwertdetektors. Hält der Prüfling die Ausnahmeregeln für diskontinuierliche Störgrößen gegenüber des Grenzwertes hinsichtlich der CISPR 14 ein, so ist der Test bestanden. Da die Auswertung an allen vier Frequenzpunkten gleichzeitig durchgeführt wird, muss die Messung gegenüber einem traditionellen Funkstörmessempfänger nur an einem Frequenzpunkt durchgeführt werden. Spezielle Knackratenanalysatoren welche aus einer Anordnung aus parallelen Messempfängern bestehen reduzieren ebenfalls die Messzeit, sind allerdings sehr aufwendig in der Realisierung.

II. FUNKSTÖRMESSEMPFÄNGER UND SPEKTRUMANALYSATOREN

Funkstörmessempfänger messen das Emissionssignal im Frequenzbereich. Die Messung erfolgt dabei sequentiell, an mehreren tausend Frequenzpunkten. Heute werden üblicherweise Superheterodynempfänger eingesetzt. Ein Blockdiagramm eines konventionellen Superheterodynempfängers ist in Abbildung 1 dargestellt. Eine Vorselektion unterdrückt Signale außerhalb des Bandes, in welchem die Messungen durchgeführt werden. Dadurch wird die Dynamik, insbesondere für breitbandige Störungen im Vergleich zu Spektrumanalysatoren erhöht.

Ein Mischer, sowie ein Überlagerungsoszillator führen eine Frequenzkonversion zu einer Zwischenfrequenz. Das Signal wird durch das ZF-Filter band-pass gefiltert. Das ZF-Filter muss die Selektivität nach CISPR 16-1-1 einhalten. Das Ausgangssignal wird gewichtet mittels eines Spitzenwert, Quasi-Spitzenwert, Mittelwert, CISPR-AVG, CISPR-AVG-RMS Detektors. Üblicherweise wird das ZF-Signal sIF auch analog bereitgestellt. Spektrumanalysatoren können einen gesweepten Scan durchführen, und benutzen üblicherweise eine Video Filter zur Mittelwertbildung. Man spricht hier von einer logarithmischen Mittelwertbildung.

III. KNACKRATENANALYSATOREN

Zur Messung und Ausswertung nicht kontinuierlicher Störungen, d.h. Störungen welche bei einer Verweilzeit 15 s an einem Messempfänger immer noch keine eindeutige Anzeige liefern werden Knackratenanlysatoren eingesetzt. Dabei wird das ZF-Signal sowie as Signal des Quasispitzenwert Detektors ausgewertet. Sobald der Quasispitzenwert die Grenzwertlinie für kontinuierliche Dauerstörgrößen überschreitet wird der Pegel des Quasispitzenwertes, sowie die Pulsbreite gemessen. Pulsfolgen mit Abständen zwischen den Pulsen von mehr als 200 ms werden als Einzelereignisse ausgewertet. Bei Pulsfolgen, bei denen hingegen der Abstand zwischen den Pulsen weniger als 200 ms ist, wird das Gesamtereignis als Puls bewertet. Falls die Gesamtdauer des Ereignisses kleiner 200 ms ist, so entspricht dies der Definition eines Klicks. Falls hingegen die Gesamtdauer eines Einzelereignisses größer als 200 ms ist, so muss untersucht werden, ob Ausnahmeregelungen angewendet werden können.

In Abbildung 2 ist das Nassi-Shneidermann Diagram zur Auswertung der Knackrate nach CISPR 16-1-1 dargestellt.

Die Knackrate ist definiert als die Anzahl der Klicks pro Minute. Falls die Knackrate N größer als 30 ist hat der

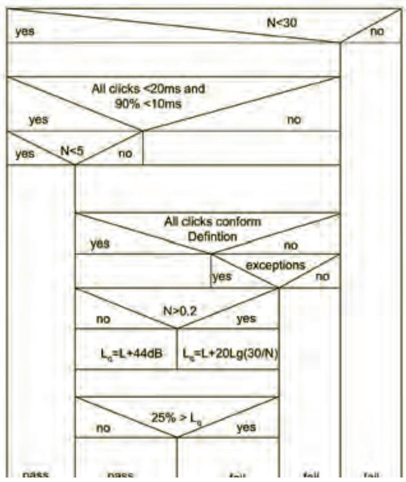

Fig. 2. Auswertung der Klicks nach CISPR 16-1-1 , aus [3].

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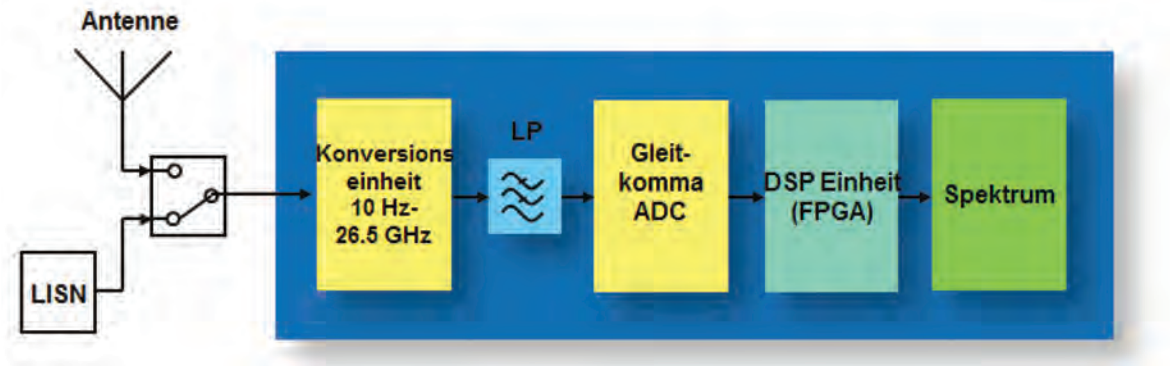

Fig. 3. EMV-Zeitbereichsmesssystem.

Prüfling nicht bestanden. Ansonsten wird die Auswertung fortgesetzt. Falls 90% der Klicks eine Pulsbreite kleiner als 10 ms haben, sowie die Pulsbreite aller Klicks kleiner 20 ms ist, sowie die Klickrate kleiner 5 ist, hat der Prüfling bestanden. Ansonsten wird überprüft ob alle Klicks der Definition d.h. kleiner 200 ms entsprechen wie in CISPR 16-1-1 beschrieben. Dabei sind Ausnahmen zu prüfen. Falls alle Klicks der Definiton genügen wird eine neue erleichterte Grenzwertlinie berechnet:

$$L_q = L + 20 \log_{10} (30 / N) \ \forall \ N > 0.2 \quad (1)$$

$$L_q = L + 44 \ dB \ \forall \ N \leq 0.2 \quad (2)$$

Falls weniger als 25% oberhalb der neuen Grenzwertlinie sind, hat der Prüfling bestanden, ansonsten ist der Prüfling durchgefallen. Man spricht hier von der "upper quartile method".

IV. EMV-ZEITBEREICHSMESSSYSTEM TDEMI

Das Eingangssignal wird mittels einer Analog-Digital-Wandler-Einheit zur Messung im Frequenzbereich 9 kHz - 1 GHz abgetastet und digitalisiert. Für Messungen oberhalb 1 GHz erfolgt eine breitbandige Frequenzumsetzung.

Die spektrale Berechnung erfolgt mittels Kurzzeit-FFT. Ein Blockschaltbild eines EMV-Zeitbereichsmesssystems ist in Abbildung 3 dargestellt. Für gestrahlte Emissionsmessung verwendet man typischerweise eine breitbandige logarithmischperiodische Antenne. Alternativ können Messungen mittels Absorberzange oder Netznachbildung durchgeführt werden.

Zur Untersuchung der Einkopplung an Antennen im KFZ kann das EMV-Zeitbereichsmesssystem direkt angeschlossen werden. Das Eingangssignal wird mittels eines mehrstufigen Analog-Digital-Wandler-Systems digitalisiert. Durch das mehrstufige Analog-Digital-Wandler-System erfolgt die Digitalisierung in eine Gleitkommazahl [4]. Dies erlaubt es einen äquivalenten Dynamikbereich von ca. 20 Bit zu erreichen.

Damit ist es möglich die eine hohe Sensistivität von ca. $-20 \ dB\mu V$ (Band B) zu erreichen und gleichzeitig Pulse von mehreren Volt zu erfassen. Mittels leistungsfähiger FPGAs mit einer Rechenleistung, welche ca. 20 handelsüblichen PCs entspricht, erfolgt die Auswertung in einer Bandbreite von 162,5 MHz lückenlos in Echtzeit. Ein derartiges EMVZeitbereichsmesssystem wurde erstmalig in [5] vorgestellt. Die Messung konnte hierbei um einen Faktor 1000 beschleunigt werden. Das kommerziell erhältliche System TDEMI 1G arbeitet über den gesamten Frequenzbereich mit Basisbandabtastung und reduziert die Messzeit um bis zu einen Faktor 4000. Das System TDEMI 26G mit zusätzlicher Frequenzumsetzung deckt den Frequenzbereich 10 Hz - 26,5 GHz ab.

A. Kurzzeit-FFT

Die Kurzzeit-FFT wird als eine FFT-Berechnung über einen begrenzten Abschnitt verstanden, welche im Zeitbereich verschoben wird. Mittels Kurzzeit-FFT wird ein Spektrogramm berechnet, welches einer Darstellung des Spektrums über der Zeit entspricht. Während stationäre Signale ein konstantes Spektrum über der Zeit aufweisen, zeigt sich beim Spektrogramm das instationäre Verhalten des Störsignals. Die mathematische Definition der Kurzzeit-FFT is gegeben durch:

$$Z[m,k] = \sum_{n=0}^{N-1} x[n]w[n-m]e^{\frac{-j2\pi kn}{N}}. \quad (3)$$

Da die Fensterfunktion w[n] symmetrisch ist, existieren mehrere Möglichkeiten Gl. 3 umzuformen. Zur realen Berechnung erfolgt die Umwandlung derart, dass nicht die Fensterfunktion verschoben wird, sondern das Eingangssignal. Weitere Vereinfachungen sind möglich, insbesondere für die Applikation der Störemssionsmessung, da hier die Phase nicht weiter ausgewertet wird. *w[n]* ist die Fensterfunktion, welche das ZF-Filter eines Messempfängers nachbildet [6].

B. Vergleich zu einem konventionellen Messemfänger

Es ist aus der Literatur bekannt, dass die Kurzzeit-FFT äquivalent zu einer Anordnung von Basisbandmischern und einer Filterbank ist [7],[8]. Die Kurzzeit-FFT kann ebenfalls aus einer Anordnung einer Filterbank hergeleitet [2] werden. Ein Blockschaltbild einer derartigen Anordnung ist in Abbildung 4 dargestellt. Das Verhältnis des Dezimators ist gegeben durch:

$$M = f_s / f_{sbb}, \quad (4)$$

wobei f_s die Abtastrate des Analog-Digital-Wandlers ist, und f_{sbb} die inverse Schrittweite der Kurzzeit-FFT, welche der Basisbandabtastfrequenz entspricht. W[*f*] ist die diskretisierte Übertragungsfunktion. Die Basisbandabtastfrequenz f_{sbb} muss so groß sein, dass die Nyquistbedingung im Basisband beispielsweise bei der digitalen Implementierung des Quasispitzenwertdetektors eingehalten wird. Ein zu geringe Abtastrate führt zu Messfehlern bei transienten

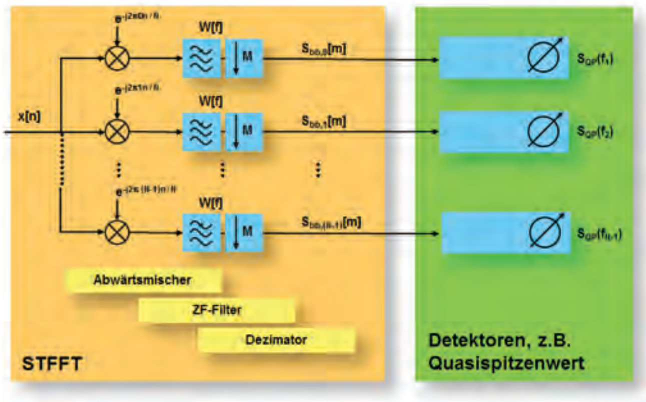

Fig. 4. *Filterbank.*

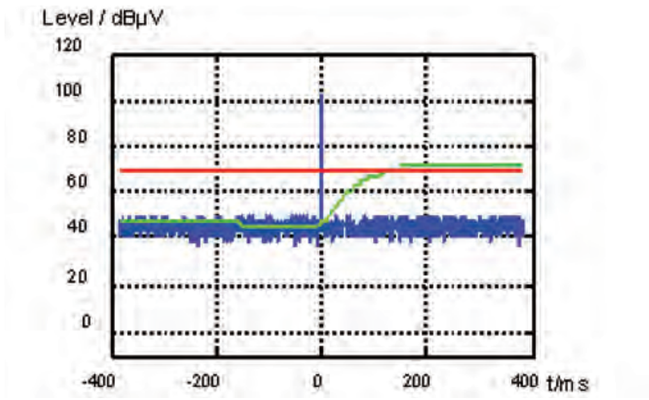

Fig. 5. *Impulsantwort ZF-Filter (blau), Quasispitzenwert (gr¨un), aus [3].*

Signalen.

V. NORMGERECHTE MESSUNGEN NACH CISPR

Die CISPR 16-1-1 [1] verlangt ein bestimmtes Anzeigeverhalten eines Instruments für unterschiedliche Prüfsignale. Man unterscheidet zwischen:

- Anzeigeverhalten für Sinus und Pulsfolgen
- Anforderungen an die Dynamik
- Anforderungen für Ein- und Ausgänge

Diese Punkte werden von den TDEMI Geräten eingehalten.

A. Messungen oberhalb der Nyquistfrequenz

Typischerweise ist die Abtastrate verfügbarer Analog-Digital-Wandler um eine Größenordnung niedrieger, als die verfügbaren Frequenzbereiche von Mischern. Eine Kombination von einer sehr breitbandigen Konversionseinheit [9], welche den Frequenzbereich bis 26,5 GHz in den Bereich unterhalb 1 GHz mischt, wird verwendet, um Messungen oberhalb der Nyquistfrequenz zu ermöglichen. Damit sind Messungen nach den Normen CISPR 16-1-1, MIL461F sowie DO160 möglich.

B. Knackratenanalyse

Nach CISPR 14-1 [10] und CISPR 22 [11] muss die Messung an den Frequenzpunkten 150 kHz, 500 kHz, 1.4 MHz und 30 MHz durchgeführt werden. Durch die STFFT wird ein Signal berechnet das dem demodulierten ZF-Signal an mehreren tausend Frequenzpunkten entspricht. Durch ein Selektionsmodul wird das Signal an 4 Frequenzpunkten extrahiert. Dies wird sowohl für das demodulierte ZF-Signal, wie auch für die Quasispitzenwertsignale durchgeführt. Die Auswertung erfolgt lückenlos.

Als Beispiel wurde ein CISPR 16-1-1 Impuls gemessen. Das Ergebnis ist in Abbildung 5 dargestellt. Man kann deutlich die Impulsantwort des ZF-Filters sowie die des Quasispitzenwertdetektors erkennen.

Das Blockschaltbild eines Kanals an einer einzelnen Frequenz, wie bei der Knackratenanalyse auf dem TDEMI implementiert ist in Abbildung 6 dargestellt.

VI. MESSUNGEN

Messungen wurden mittels einer Netznachbildung ohne Impulsbegrenzer durchgeführt. Messungen von Knackstörungen sollten stets ohne Impulsbegrenzer durchgeführt werden, da dieser durch die Begrenzung der Amplitude zu einer zu niedrigen Bewertung führen kann.

Das benutzte TDEMI mit interner Vorselektion, Oversampling und mehrstufigem Analog-Digital-Wandler System stellt für den Einzelimpuls im Band B eine zusätzliche Dynamikreserve von ca. 30 dB bereit. Eine derart riesige Gesamtdynamik von deutlich über 100 dB wird beispielsweise auch durch die interne Gleitkommadarstellung erreicht. Die folgende Messung wurde an einer herkömmlichen Kaffeemaschine durchgeführt. Das Thermostat schaltet kontinuierlich an und aus, um das Schwallbrühverfahren durchzuführen. Das Resultat der Messung mittels Knackratenanalyse an der Frequenz 500 kHz ist in Tabelle I dargestellt. Die Knackrate N wurde zu einem Wert von 1.72 berechnet. Jedoch nach Tabelle A.2 der CISPR 14-1 muss die Knackrate um den Faktor f = 0.5 korrigiert werden. Man erhält folglich eine Knackrate von 0.86. Da der Wert kleiner als 5 ist and die Pulsbreiten aller Klicks kleiner 20 ms sind sowie 90% aller Klicks eine Pulsbreite von weniger als 10 ms haben besteht der Prüfling entsprechend Abbildung 2.

Die zusätzliche Linearitätsreserve beträgt mehr als 6 dB. Die maximale Anzeige des Spitzenwertdetektors beträgt ca. 110 dBµV. Der angezeigte maximale Quasispitzenwert ist mehr als 24 dB oberhalb der Grenzwertlinie für Dauerstörgrößen.

Eine weitere Messung wurde an einer Waschmaschine durchgeführt. Das Ergebnis der Messung bei 500 kHz ist in Tabelle II dargestellt. Während der Messung betrug die zusätzliche Linearitätsreserve 21 dB. Die Messung wurde mit der

Zeit	Typ	Pulsbreite	Quasispitzenwert	Thermostat
00:00:01.43	< 10 ms	0.81 ms	67.07 dBμV	ON
00:01:14.85	< 10 ms	1.22 ms	61.63 dBμV	OFF
00:01:41.90	< 10 ms	1.22 ms	75.03 dBμV	ON
00:02:21.88	< 10 ms	1.22 ms	61.51 dBμV	OFF
00:02:52.38	< 10 ms	1.22 ms	79.61 dBμV	ON
00:03:25.92	< 10 ms	2.44 ms	62.22 dBμV	OFF
00:04:00.97	< 10 ms	1.22 ms	81.69 dBμV	ON
00:04:32.38	< 10 ms	0.41 ms	58.65 dBμV	OFF

Table I. *Messungen von klicks an einer kaffeemaschine.*

Zeit	Typ	Pulsbreite	Quasispitzenwert
00:00:03.49	< 10 ms	2.84 ms	57.49 dBμV
00:02:38.69	< 10 ms	6.91 ms	57.83 dBμV
00:04:22.05	< 20 ms	16.25 ms	68.59 dBμV
00:24:08.84	< 20 ms	13.00 ms	68.69 dBμV
00:43:26.87	< 10 ms	4.88 ms	61.52 dBμV
00:50:00.06	< 10 ms	4.88 ms	56.54 dBμV

Table II. *Messung der knacks einer waschmaschine.*

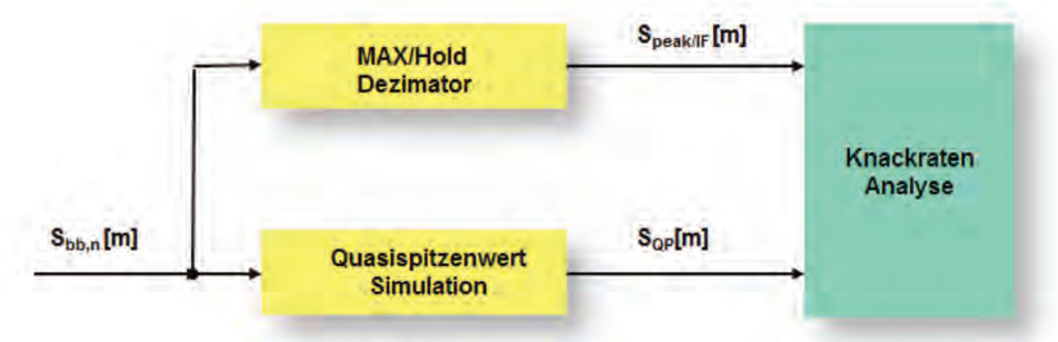

***Fig. 6.** Blockschaltbild eines einzelnen Kanals.*

Einstellung eines einzigen Dämpungswertes durchgeführt.

VII. ZUSAMMENFASSUNG

In diesem Artikel wurde ein System zur Knackratenanalyse vorgestellt welches im Gegensatz zu einem Messempfänger die Messung an allen Frequenzpunkten gleichzeitig durchführt. Ein derartiges System erfüllt die Anforderungen nach CISPR 16-1-1 sowie CISPR 14-1. Die Testzeit wird durch die Messung an allen Frequenzen gleichzeitig, sowie die Messung bei einer Abschwächereinstellung um den Faktor 8 reduziert. Dabei reduziert sich die Messung z.B. bei einer Waschmaschine auf den Durchlauf eines Programms. Dadurch wird die minimal physikalische mögliche Testzeit für eine derartige Prüfung erreicht.

VIII. DANKSAGUNG

Der Author bedankt sich bei der Bayerischen Forschungsstiftung für die Unterstützung des Forschungsprojektes Emissionsmessungen oberhalb 1 GHz.

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EMV auf IC-Ebene

Teil 2: Ermittlung der Störaussendungseigenschaften von ICs

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English translation available at
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ABSTRACT

EMC at IC Level

The successful development of electronics with good EMC characteristics today largely depends on the EMC behaviour of the ICs used.
Part 1 of this paper was titled "Immunity of ICs in different packages to pulse disturbances" and showed that the same ICs behave differently in different packages when exposed to pulse disturbances. (Available at www.interferencetechnology.com/uploads/media/DE_Konig_Eng.pdf)
In this part 2, the authors consider the EM (electromagnetic) emission characteristics of these ICs within the scope of emissions from electronic modules.

EINLEITUNG

Erfolgreiche Elektronikentwicklungen mit guten EMV-Eigenschaften sind heutzutage in hohem Maße vom EMV-Verhalten der verwendeten ICs abhängig.

Im 1. Teil "Pulsstörfestigkeit von ICs mit verschiedenen Packages" wurde festgestellt, dass die gleichen ICs in verschiedenen Gehäusetypen unterschiedliches Verhalten auf pulsförmige Störgrößen haben (www.interferencetechnology.com/uploads/media/EU_DE_Konig.pdf).

Im vorliegenden 2. Teil sollen die Störaussendungseigenschaften dieser ICs bei der Störaussendung von elektronischen Baugruppen betrachtet werden.

Wird ein schneller Schaltkreis mit seinen hochfrequenten Strömen und Spannungen ungünstig im Gerät platziert, können z.B. direkte oder indirekte Beeinträchtigungen von Signalen der Baugruppe auftreten. Andererseits können seine magnetischen oder elektrischen Nahfelder metallische Elemente im Gerät oder angeschlossene Kabel zur Störaussendung anregen.

Versucht der Hardwareentwickler in der Praxis EMV-Störungen auf der Elektronik zu beseitigen, wird er feststellen, dass mit den bestehenden EMV-Testmethoden für ICs (z.B. TEM-Zelle) diese Ziele nicht zu erreichen sind. Dazu muss der Entwickler den gesamten physikalischen Prozess in seiner Baugruppe tiefer durchdringen und im Vorfeld der Entwicklung die EMV-Eigenschaften von ICs abfordern. Im Artikel werden die EMV-Eigenschaften eines Controllers im 144-Pin LQFP und im 144-Pin BGA Gehäuse ermittelt und verglichen.

WEGE VOM IC-NAHFELD ZUR STÖRAUSSENDUNG

Verantwortlich für die Störaussendung in der Praxis sind oft die magnetischen und elektrischen Nahfelder der integrierten Schaltkreise. Sie werden durch sich schnell ändernde Ströme und Spannungen der ICs erzeugt. Durch die komplexen Netzwerke im Inneren der Schaltkreise entsteht

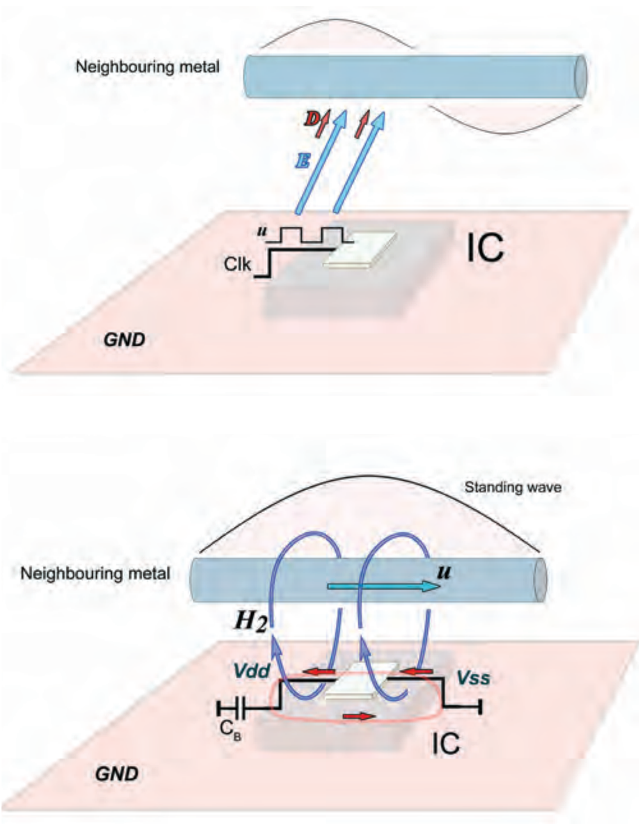

Abbildung 1a, 1b. *Koppelmechanismen der elektrischen und magnetischen Felder.*

eine Vielzahl solcher Felder. Besonders die Bereiche um Bonddraht, Leadframe und Pin bilden große Oberflächen für die Abgabe des elektrischen Feldes (E-Feld) sowie große Stromschleifen für die Entstehung des magnetischen Feldes (H-Feld).

Diese Erregerfelder entstehen ebenfalls durch die mit dem Schaltkreis verbundenen Leitungsnetze auf der Baugruppe. Die HF-Ströme und Spannungen der IC-Pins können dadurch auch die Ursache der Störaussendung sein.

In Abbildung 1 sind die Koppelmechanismen für das elektrische sowie das magnetische Feld direkt aus einem IC in der Prinzipdarstellung zu sehen.

Durch die physikalischen Koppelmechanismen können die elektrischen Felder und der damit verbundene Verschiebestrom die Ursache für Strom- bzw. Spannungswellen auf dem GND-System der Flachbaugruppe oder auf benachbarten Metallteilen sein (Abbildung 1a).

Diese metallischen Teile (z.B. Kabelbäume, Hutschienen...) wirken als Antennen, die über ihre Resonanzfrequenz, je nach räumlicher Ausdehnung zur elektromagnetischen Störaussendung angeregt werden.

Die im IC entstehenden H-Felder (Abbildung 1b) können ebenfalls in das GND-System der Flachbaugruppe (H1-Feld, Selbstinduktion) oder in benachbarte Metallteile (H2-Feld, Gegeninduktion) eine Spannung induzieren. Diese Induktionsspannung wird das metallische Teil ebenfalls in bestimmten Frequenzbereichen zur Störaussendung anregen.

Der Entwickler benötigt für die optimale Platzierung und Einbindung eines ICs in seine neue Schaltung folgende Informationen:

- die magnetische und elektrische Nahfeldcharakteristik,
- die hochfrequenten Ströme und Spannungen an Aus- und Eingängen des ICs.

TESTMETHODEN

Im Folgenden wird ein Mikrocontroller hinsichtlich verschiedener EMV-Testmethoden in unterschiedlichen Packagevarianten verglichen. Ausgewählt wurde ein Controller, der im 144-Pin LQFP und im 144-Pin BGA Gehäuse angeboten wird.

Auf den beiden Typen läuft die identische Firmware mit denselben Taktfrequenzen, generiert durch einen externen 12 MHz Quarz.

Die Nahfelder der ICs wurden zum einen mit der TEM-Zellen Methode (nach IEC 61967-2) und zum anderen mit einer hochauflösenden Surface Scan Methode (nach IEC 61967-3) gemessen. Die leitungsgebundene HF-Strom- und Spannungsauskopplung über die Pins (Messung nach IEC 61967-4) können in der Praxis ebenso für die Störaussendung verantwortlich sein.

Leitungsgebundene HF-Strom-und Spannungsmessung

Bei diesem Testprinzip, im Standard als 1Ω/150Ω-Aussendungsmessung bezeichnet, handelt es sich um eine Standard-Methode zur Messung von leitungsgebundenen HF-Strom und HF-Spannung an IC-Pins. Dabei wird messtechnisch der Erregerstrom ermittelt und die 150 Ω sollen eine typische Lastimpedanz für Antennen darstellen.

Aus praktischen Erfahrungen weiß man, dass durch diese Ströme und Spannungen auf den Leitungsnetzen wiederum elektrische und magnetische Nahfelder erzeugt werden. Die maximale Störaussendung wird durch maximale Spannung (erzeugt maximales E-Feld) oder maximalen Strom (erzeugt maximales H-Feld) bewirkt. Um diese Störgrößen zu bestimmen, ist es sinnvoll, die Leerlaufspannung und den Kurzschlussstrom direkt an den einzelnen Pins zu bestimmen.

Dazu ist es notwendig, möglichst niederohmig (<< 1 Ω) den Kurzschlussstrom bzw. sehr hochohmig (>> 150 Ω) die Leerlaufspannung zu bestimmen. Damit werden größere Messfehler durch die IC-internen Impedanzen für niedrige (unter 50 MHz) bzw. hohe Frequenzbereiche (bis 3 GHz) vermieden.

Wenn eine Strom- und Spannungsmessung am IC nur in einer spezifischen Schaltungsumgebung durchgeführt werden kann und aufgrund der Bauteildichte kein Anschluss der Messmittel möglich ist, wird mittels Sonden über die Magnetfeldmessung auf den HF-Strom geschlossen.

Am Beispiel-IC im BGA-Gehäuse (Ball Grid Array) wurde durch die dichte Einbettung der Ein- und Ausgänge in Ground kein nennenswertes Magnetfeld gemessen.

TEM-Zelle

Die Messung nach der TEM-Zellen-Methode gehört heutzutage zu einer der Standardbewertungen der Störaussendung von ICs. Bei dieser Messmethode wird der Schaltkreis auf ein spezielles Testboard montiert, so dass sich der IC auf der einen Seite und sämtliche andere Schaltungsteile auf der anderen Seite befinden. Das Tes-

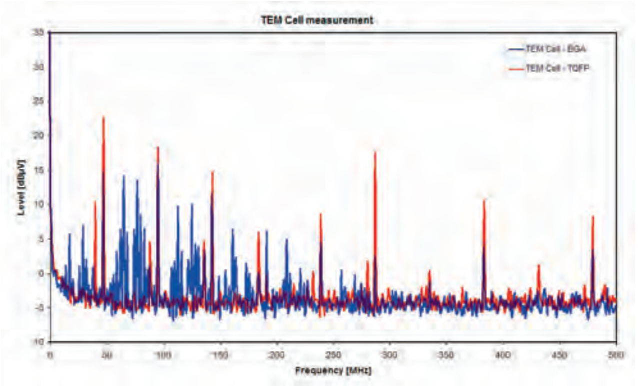

Abbildung 2. *Messaufbau P1600 / P1700.*

tboard wird nun in der Öffnung der TEM-Zelle befestigt, so dass sich der zu testende IC innerhalb der Messkammer befindet und das Testboard Teil der Wand der TEM-Zelle wird. Im Inneren der TEM-Zelle wird über ein so genanntes Septum die Störemission gemessen.

Mit dieser Methode wird kein eindeutiger Unterschied zwischen elektrischem und magnetischem Feld ermittelt. Hier werden immer beide Felder gemeinsam gemessen. Es kommt, je nach Orientierung des Testobjektes, zu Addition oder Subtraktion von Spannungen, die vom magnetischen sowie vom elektrischen Feld erzeugt werden können. Nachteilig bei der TEM-Zelle ist ebenso, dass die Richtung des magnetischen Erregerfeldes nicht eindeutig nachgewiesen werden kann. Es sind nur Drehungen des Testboards um 90° möglich.

Durch das sehr breite Septum und den großen Abstand zu dem Testobjekt wird nur ein Bruchteil der real existierenden Nahfelder gemessen.

Bei den Messungen der HF-Felder in der TEM-Zelle zeigte sich, dass der Controller im TQFP-Gehäuse (Thin Quad Flat Pack) erwartungsgemäß die größeren Amplituden aufweist. Hier spielen vor allem die großen Flächen und Schleifen, die durch den Controller in diesem Gehäuse aufgespannt werden, eine entscheidende Rolle. Gut zu erkennen ist der 48 MHz Core-Clock und seine Vielfachen. Diese findet man auch beim BGA-Chip wieder, der im Gegensatz zum Controller im QFP-Gehäuse deutlich geringere Messpegel aufweist.

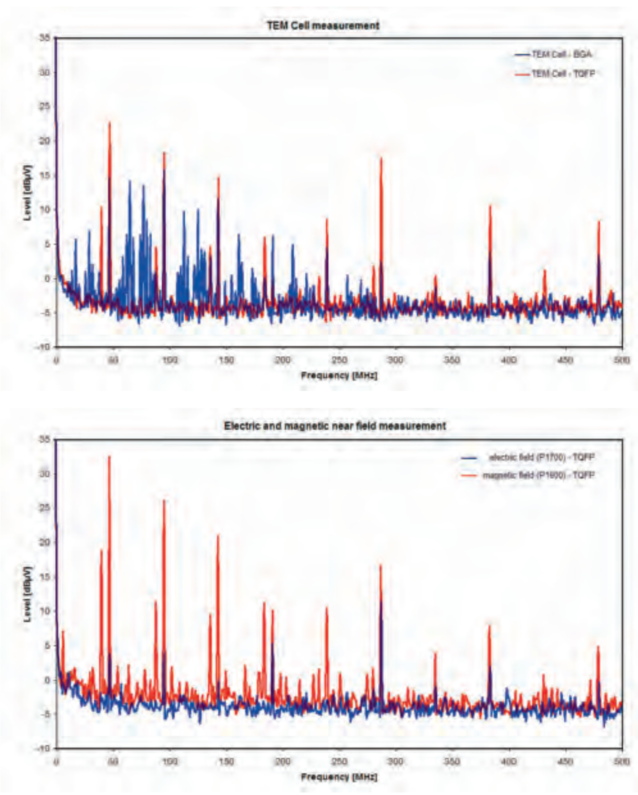

Abbildung 3a, 3b. *Vergleich der Frequenzspektren.*

Messung magnetischer und elektrischer Nahfelder

Die Trennung von magnetischen und elektrischen Feldanteilen erfolgt mit speziell dafür entwickelten Nahfeldsonden.

Die magnetischen Felder werden mit einer Magnetfeldschleife (30 x 20 mm) gemessen. Diese Schleife kann in Höhe und Richtung über dem IC-Gehäuse variiert werden. So können die Maxima und die Minima des magnetischen Feldes und damit die Richtung des HF-Stromes exakt bestimmt werden.

Die elektrischen Feldanteile werden mit einer höhenverstellbaren Messelektrode (25 x 25 mm) aufgenommen. Diese ist über einen sehr hochohmigen Eingangswiderstand an einen Vorverstärker angeschlossen.

Beide Messsysteme können im Frequenzbereich von 16 kHz bis 3 GHz verwendet werden. Das intern verstärkte Messsignal wird über einen 50Ω HF-Messausgang an einem Spektrumanalyzer angezeigt.

Für den Vergleich zwischen den beiden Gehäusetypen wurden die beiden Messsonden 10 mm über der GND-Fläche angeordnet. Um die gemessenen Spektren der TEM-Zelle und der Nahfeldsonden direkt vergleichen zu können, wurde die Richtung der H-Feld-Schleife gleich der Richtung des Septums in der TEM-Zelle in Übereinstimmung gebracht.

In Abbildung 3 sind beispielhaft einige aufgenommene Spektren dargestellt. Einmal das Spektrum gemessen in der TEM-Zelle sowie die Spektren aufgenommen mit den Probes P1601 für magnetische Felder und P1701 für elektrische Felder.

Durch die Differenzierung der Nahfelder mit unterschiedlichen Messeinrichtungen werden die physikalischen Koppelmechanismen deutlich. Der Peak bei 288 MHz des QFP-Controllers wird überwiegend vom elektrischen Feld, der Peak bei 240 MHz des QFP-Controllers fast ausschließlich vom magnetischen Feld erzeugt (Abbildung 3b).

Beim BGA-Controller konnte mit der vorliegenden Technik kein elektrisches Feld nachgewiesen werden. Dies ist der Tatsache geschuldet, dass der BGA ziemlich kompakt aufgebaut ist und in einem wesentlich kleineren Gehäuse verwendet wird.

Surface Scan Methode

Mit einem Volumen- oder Oberflächenscan lassen sich mit sehr hoher Auflösung die örtlichen HF-Quellen des ICs für magnetische und elektrische Felder nachweisen. Mit Magnetfeldsonden in unterschiedlicher Richtung und Polarisation können die aus Hochfrequenz-Strömen resultierenden Felder über dem IC gemessen werden.

In Abbildung 4a ist ein Volumenscan mit einer vertikal

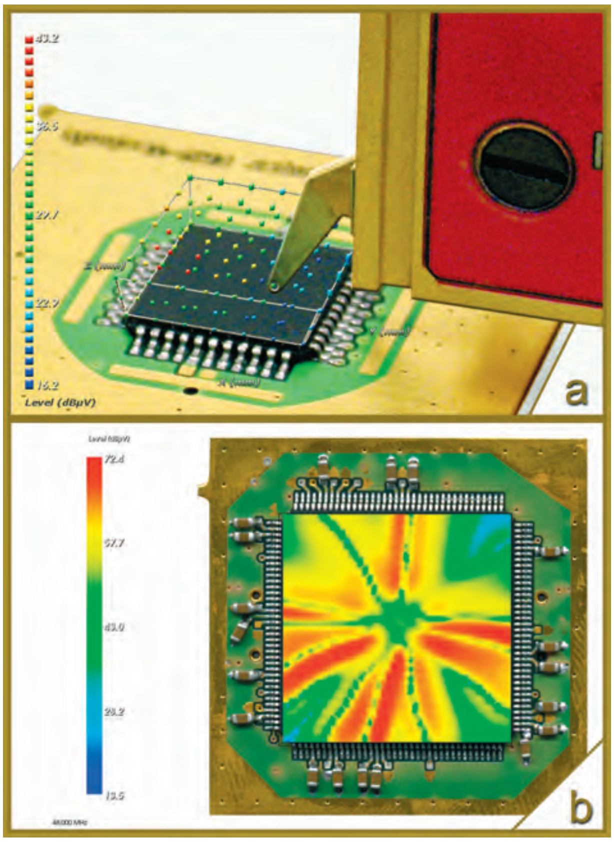

Abbildung 4. *Surface Scan Methode.*

angeordneten Magnetfeldprobe zu sehen. Die Punkte stellen in Abhängigkeit ihrer Farbe die entsprechende Magnetfeldstärke an den Messpunkten in den verschiedenen Ebenen dar. Die Abbildung 4b zeigt das Ergebnis eines Oberflächenscans mit einer horizontal angeordneten Sonde direkt über dem IC-Gehäuse.

Die hier dargestellte Frequenz beträgt 48 MHz. Deutlich zu sehen ist, wie der 48 MHz Core-Clock sternförmig auf die Bonddrähte des ICs aufgeprägt wird. Ist die Versorgung des Mikrocontrollers in der Applikation schlecht ausgeführt oder liegt ein metallischer Leiter über dem Schaltkreis, kann dies zur Störaussendung beitragen.

ZUSAMMENFASSUNG UND AUSBLICK

Die Aufgaben der IC-Anwender bei der Entwicklung elektronischer Geräte und Systeme werden immer komplexer. Das Verhalten der ICs als Quelle der Störaussendungen lässt sich bisher nicht vollständig voraussagen. Sind die EMV-Eigenschaften der verwendeten ICs schon von Entwicklungsbeginn an bekannt, kann bei der Auswahl der ICs oder bei der Layoutgestaltung reagiert und Entwicklungszeit, -aufwand und -kosten gesenkt werden.

Bereits bei Entwicklungsbeginn müssen deshalb die EMV-Eigenschaften von den einzusetzenden Schaltkreisen hinsichtlich ihrer Störaussendung und Störfestigkeit ermittelt werden.

Die Messungen der Beispiel-ICs zeigen deutlich die Vorteile des BGA Gehäuses bei der Verhinderung einer Störaussendung der Baugruppe. Sie zeigen aber auch die Notwendigkeit, neben den etablierten EMV-Tests weitere physikalische Messungen vorzunehmen, um eine optimale Nutzung der Schaltkreise in unterschiedlichen Baugruppen zu gewährleisten.

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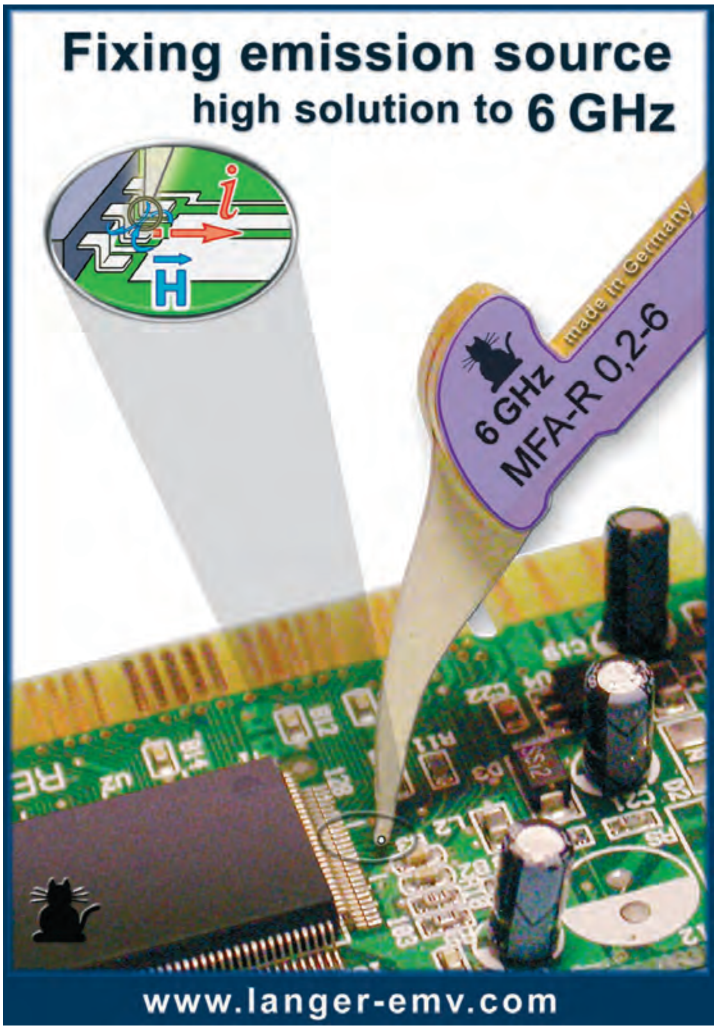

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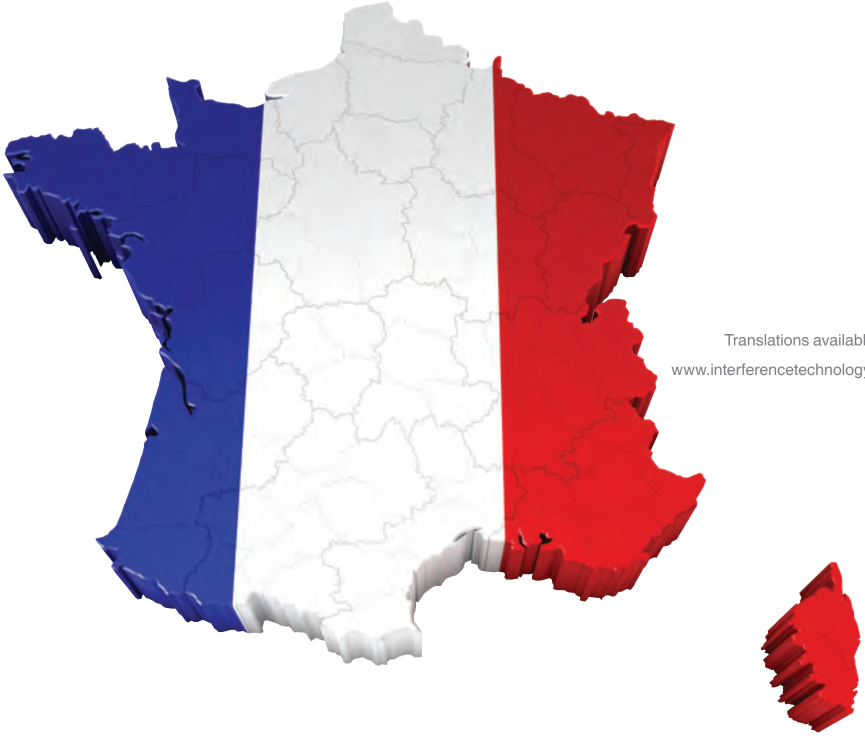

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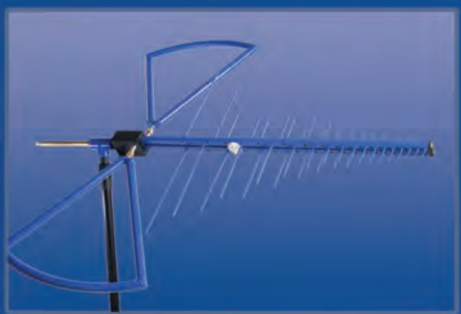

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Un Environnement de Développement Intégré pour la Modélisation des Émissions Électromagnétiques Rayonnées

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Un outil de pointe pour la modélisation des émissions électromagnétiques est présenté dans ce document. Avec la plupart des outils d'analyse de compatibilité électromagnétique (CEM) existants, soit exigeant des ressources informatiques importantes soit n'étant disponibles que pour une utilisation par des experts, cet outil est principalement destiné à simplifier l'analyse CEM pour le milieu industriel. Il fournit un environnement d'outils bien construit pour prédire et reproduire le rayonnement électromagnétique au niveau des composants et du système. Le noyau incorpore des modèles extrêmement fiables développés à l'IRSEEM. Différentes caractéristiques et capacités de l'outil sont présentées.

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ABSTRACT

An Integrated Development Environment for Modeling the Radiated Electromagnetic Emissions

A cutting-edge electromagnetic emission modeling tool has been presented in this paper. With most of the existing electromagnetic compatibility (EMC) analysis tools, either demanding large computational resources or being available only for expert use, this tool is principally aimed to simplify EMC analysis at the industry-level. It provides a well abstracted tooling environment for predicting and reproducing the electromagnetic radiations at component and system level. The kernel incorporates highly reliable models developed in IRSEEM. Different features and capabilities of the tool have been presented.

INTRODUCTION

La compatibilité électromagnétique (CEM) est devenue un élément important à prendre en considération lors de la conception des composants et des circuits électroniques, avec les optimisations de la CEM, au niveau des cartes ou des applications, atteignant leurs limites. La récente Directive Européenne 2004/108/EC sur la CEM exige des appareils électroniques des émissions électromagnétiques très faibles et une forte immunité au stress électromagnétique. Ces directives sont soumises à des modifications dans le futur lorsque les contraintes CEM seront définitivement resserrées comme jamais, faisant de la CEM une des causes majeures de re-design des circuits intégrés (CI). Pour aider les industries à développer, d'une part, des produits conformes à la CEM, la dernière décennie a vu une forte croissance indescriptible des modèles de CEM expliquant le comportement électromagnétique des composants et des systèmes électroniques, et d'autre part, le besoin en outils de développement concernant la CEM s'est accentué. Dans presque toutes les disciplines de l'ingénierie, l'utilisation et l'application d'outils de conception assistée par ordinateur (CAO) est largement acceptée. Les outils de CAO pour la modélisation CEM n'ont pas suivi le rythme de leurs homologues, essentiellement dû aux importantes capacités de

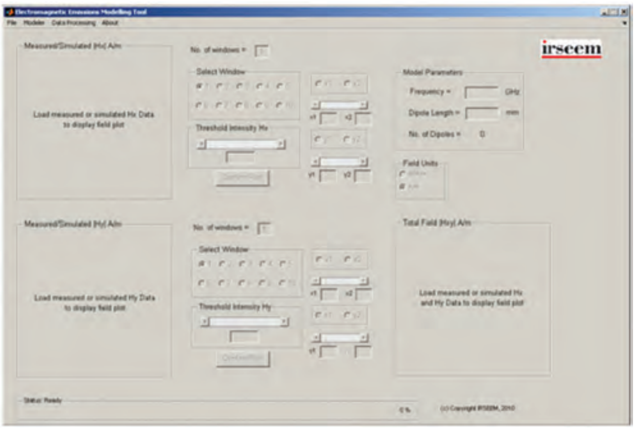
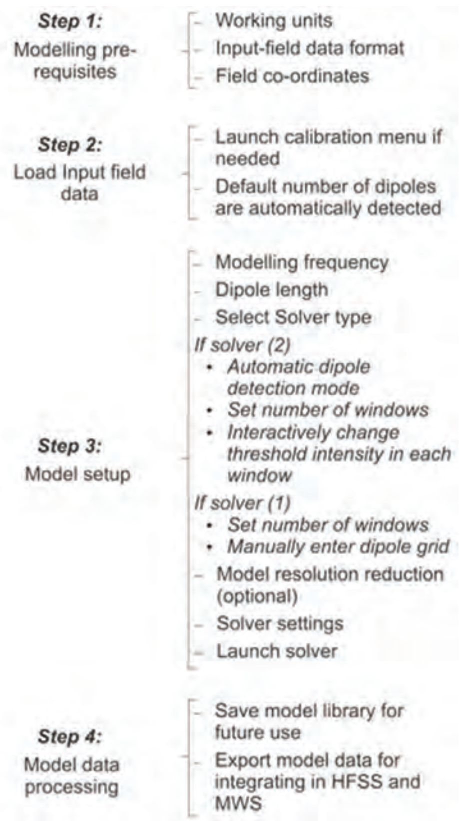


***Figure 1.** L'écran initial de l'outil développé.*

calcul requises, au besoin bien comprendre les phénomènes électromagnétiques en cause, la confidentialité des données, et, encore plus important, au fait que leur utilisation est limitée aux spécialistes.

Bien que les outils de modélisation CEM ont rendu le travail de l'ingénieur CEM bien plus aisé, certains problèmes persistent que seul un expert est capable d'aborder. Aujourd'hui, un ingénieur en CEM a besoin d'un environnement de modélisation spécialisé pour prédire et simuler le comportement électromagnétique des circuits et cartes électroniques. Un outil, tel que IC-EMC, a été développé pour tenter de créer une interface entre les concepteurs et les fournisseurs de circuits électroniques [1]. L'outil peut être utilisé pour prédire et analyser les émissions rayonnées, les émissions conduites, et l'immunité des circuits intégrés aux perturbations conduites. La modélisation est basée sur la connaissance des données IBIS et ICEM du circuit soumis au test, qui requiert une bonne compréhension du fonctionnement de l'outil. Dans



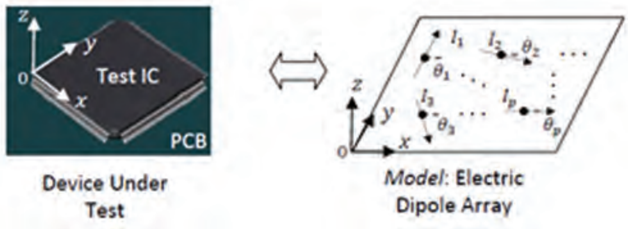


***Figure 2:** Diagramme d'opérations du modèle.*

cet article, un nouvel outil de modélisation des émissions électromagnétiques, ludique pour l'industrie est présenté. Il fournit une interface pour permettre l'utilisation du modèle générique d'émissions rayonnées développé à l'IRSEEM. L'outil est bien construit dans une manière qu'il rend convivial à utiliser et il est destiné aux concepteurs de semi-conducteurs, aux chercheurs et ingénieurs CEM.

Fonctionnalités

Le but principal de cet outil est de fournir un environnement intégré pour la modélisation des rayonnements électromagnétiques des circuits intégrés et du système. L'interface d'utilisateur est intuitive et interactif, qui le rend très convivial. L'outil incorpore deux technologies de solveur itératif dans le domaine fréquentiel à haute performance. Ces solveurs sont adaptés aux modèles développés par l'IRSEEM et publiés dans [2], [3] respectivement. Le dernier est une version optimisée, qui est capable de résoudre rapidement des systèmes complexes. Néanmoins, l'ancienne version est aussi un solveur très fiable pour les systèmes simples et petits. Après des tests intensifs, le noyau a été rendu stable pour une convivialité fiable. Selon le type de solveur choisi, les prérequis pour la modélisation sont différents. La figure 1 présente l'écran initial de l'outil lors du lancement.

L'outil comprend un outil interne de calibrage de la mesure du champ proche, qui est très pratique pour les ingénieurs. Les données brutes de mesures depuis un analyseur de spectre (données d'amplitude) ou un analyseur de réseau (paramètre de dispersion) peuvent être converties en données de champ proche équivalentes en une seule étape.

L'outil incorpore une interface pour visualiser les détails et les paramètres du modèle. Ceci est conçu pour la réduction du modèle lors du post-traitement des données. Une fois que les paramètres du modèle sont extraits en utilisant un des solveurs, ils peuvent être exportés pour leur intégration dans les outils électromagnétiques 3D courants dans l'industrie tels que Ansoft HFSS et CST Microwave Studio, tel que précisé dans [4], [5]. De plus, les données des modèles peuvent être sauvegardées sous forme de bibliothèques, qui peuvent être directement importées dans l'outil pour le post-traitement et pour une utilisation ultérieure. La figure 2 présente le flot de conception afin de paramétrer le modèle pour des analyses, des validations et des optimisations.

NOYAU DE MODÉLISATION

L'outil implémente deux modèles d'émissions électromagnétiques rayonnés dans la dorsale [2], [3]. Selon le type de solveur choisi, un de ces modèles est utilisé. Fonda-

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AUTOMATISATION ESSAIS

Concepteur de la gamme BAT-EMC, logiciel leader en France pour l'automatisation des essais CEM/RF dans tous les domaines et diffusé largement dans les laboratoires privés, les grands groupes et les PME.

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Analyse du placement des composants *sur une carte PCB par des mesures d'émission champ proche*

Spatial

Analyse de risque CEM *d'équipements RF satellites type récepteur et convertisseur*

*Simulation TLM (transmission line method) de l'****efficacité de blindage d'un boitier équipement*** *et validation en CRBM*

Automobile

Investigation d'un défaut *d'immunité composant face à une injection BCI par mesure et* ***simulation de paramètres S.***

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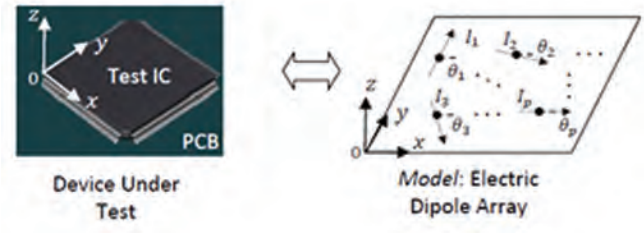

***Figure 3.** Représentation graphique du modèle d'émissions électromagnétiques.*

mentalement, dans les deux modèles, le dispositif testé est représenté avec un réseau de dipôles électriques élémentaires placés sur le plan x-y. La représentation graphique des modèles est présentée dans la Figure 3. Chaque dipôle du réseau est représenté par sa position, son orientation par rapport l'axe x (θ ∈ R), sa longueur (dl ∈R) et le courant qui le traverse (θ ∈ C). Dans les deux modèles, les paramètres des dipôles sont extraits en se basant sur certaines informations données, avec l'utilisation d'un algorithme d'optimisation itératif finement élaboré basé sur la technique de Levenberg-Marquardt. Le grand avantage des modèles est qu'ils sont génériques, c'est-à-dire, les modèles peuvent être appliqués pour calculer les champs électromagnétiques rayonnés de tout dispositif sous test, qu'ils soient actifs ou passifs, à toute hauteur au-dessus des dispositifs. Aucune autre information sur le dispositif à tester n'est nécessaire pour la modélisation.

Le premier modèle développé et décrit dans [2] extrait les paramètres du modèle avec la longueur et les positions des dipôles prédéterminées. Il prend en compte l'importance de la permittivité relative effective (ε_{reff}) lors de l'extraction; il doit par conséquent être fourni comme un paramètre d'entrée. Les paramètres sont directement extraits uniquement à partir des mesures champ magnétique proche.

Solver Type	Input Data	Description
Solver A	H_x	x – component of the near-magnetic field
	H_y	y – component of the near-magnetic field
	P_d	Position of the dipole array
	$d\ell$	Length of all the dipoles used in modeling
	ε_{reff}	Effective relative permittivity of DUT
Solver B	H_x	x – component of the near-magnetic field
	H_y	y – component of the near-magnetic field
	E_z	z – component of the near-electric field
	$d\ell$	Length of all the dipoles used in modeling

***Tableau 1.** Prérequis pour la modélisation.*

Solver Type	Extracted Parameters	Description
Solver A	I_r	Real part of dipole currents
	I_i	Imaginary part of dipole currents
	θ	Orientation of the dipoles
Solver B	P_d	Position of the dipole array
	I_r	Real part of dipole currents
	I_i	Imaginary part of dipole currents
	θ	Orientation of the dipoles
	ε_{reff}	Effective relative permittivity of DUT

***Tableau 2.** Liste des paramètres extraits selon le type de solveur.*

Le modèle a été validé sur une variété de dispositifs microondes tels que les lignes microruban, les antennes patch miniature et sur-puce (on-chip), les diviseurs de puissance et les coupleurs microondes. Le principal inconvénient du modèle est la perte de performance de calcul lorsque le dispositif sous test devient grand et complexe. De plus, la méthode est applicable uniquement si le dispositif possède une ε_{reff} unique. Néanmoins, la méthode de modélisation est hautement optimisée et fiable dans le cas d'étude petits et simples.

Le deuxième modèle déploie une méthode de nouvelle génération pour extraire les paramètres du modèle avec uniquement la longueur du dipôle prédéterminée [3]. La méthode détecte automatiquement les dipôles représentant le modèle et de plus extrait aussi la εreff. Dans ce cas, tous les paramètres sont extraits à partir des mesures champ magnétique et électrique proche. L'algorithme incorpore des techniques de seuillage et de fenêtrage afin de respectivement détecter et d'optimiser le nombre de dipôles. L'utilisateur peut contrôler interactivement l'intensité du seuil dans chaque fenêtre indépendamment. Le modèle, comme avant, a été validé sur un grand nombre de dispositifs microondes, simples et complexes, tel que précisé par [3]. Le grand avantage de ce modèle est qu'il est capable de résoudre des systèmes grands et complexes rapidement et efficacement.

CHOIX DE LA BON SOLVEUR

L'étape la plus importante en utilisant cet outil est le choix du bon solveur pour le but à attaindre. atteindre. L'objectif principal du développement d'un outil est d'élaborer des solutions simples pour des problèmes complexes. Tel qu'énoncé précédemment, l'outil incorpore deux solveurs de pointe, adaptés aux deux modèles d'émissions électromagnétiques présentés dans la section précédente. Les données d'entrée et les paramètres à extraire dépendent du choix de solveur. Les Tableaux 1 et 2 résument les prérequis et les paramètres du modèle extraits pour les solveurs existants. Pour les deux solveurs, l'utilisateur peut choisir entre l'utilisation d'un jacobien dynamique et d'un jacobien

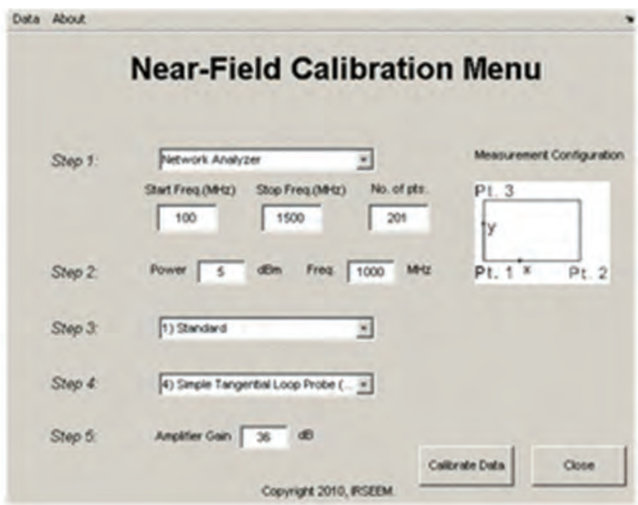

***Figure 4.** Capture d'écran du menu de calibrage du champ proche.*

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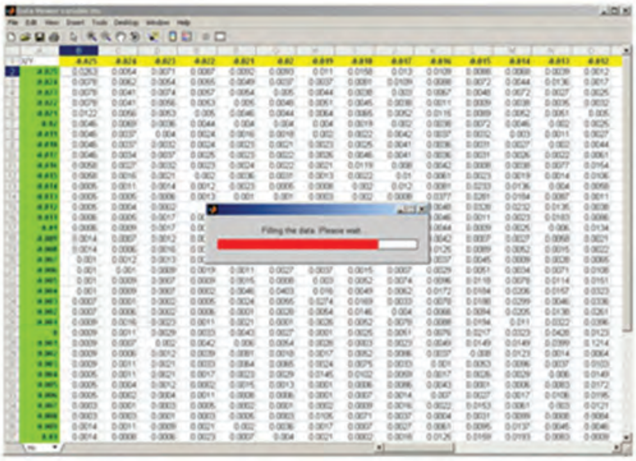

***Figure 5.** Visualiseur de données affichant les composantes du champ désiré.*

prédéterminé. Le solveur A, par défaut, utilise la méthode des différences finies pour le calcul de la matrice jacobienne [2] et le solveur B utilise une matrice jacobienne de système prédéterminée telle que présentée dans [3]. L'utilisation du solveur B améliore le temps de calcul, c'est-à-dire, le problème est résolu rapidement avec une utilisation optimal de la mémoire. Mais dans une itération donnée, si le jacobienne a une déficience de rang, le solveur B calcule la matrice jacobienne en utilisant la méthode des différences finies pour l'itération correspondante. Pour éviter un éventuel problème de singularité, les solveurs calculent le pas d'itération en utilisant les transformations orthogonales ou la technique de décomposition QR, sans compromettre ni le temps de calcul ni l'exactitude de la solution.

Les deux solveurs ont été soigneusement mis au point, fortement testés, et sont extrêmement stables et très fiables. La seule contrainte d'utilisateur est dans la sélection du solveur lorsque le nombre de dipôles pour la modélisation est supérieur à 500. Bien que ce nombre ne soit qu'aléatoire, à partir de plusieurs essais nous avons trouvé que le solveur A est plus coûteux en calcul et nécessite beaucoup de ressources mémoire pour plus de 500 dipôles. C'est pour cette raison que l'outil résout automatiquement le modèle en utilisant le solveur B. Pour les systèmes plus petits, comprenant 100-200 dipôles, il est important de noter que les performances des deux solveurs sont presque identiques. Lorsque nous utilisons de 200-500 dipôles, l'utilisateur peut choisir entre l'utilisation du solveur A et B selon la disponibilité des données d'entrée (voir le Tableau 1).

MENU DE CALIBRAGE CHAMP PROCHE

L'environnement de modélisation comprend un outil de calibrage du champ proche. Il fournit la bonne interface pour un utilisateur s'il/elle veut calibrer les données de mesure brutes. Les mesures d'un analyseur de réseau et d'un analyseur de spectre peuvent être directement converties en données de champ proche équivalentes. L'outil de calibrage peut être utilisé pour toutes les mesures effectuées en utilisant les normes internationales décrites dans l'IEC 61967, 3e partie. La Figure 4 présente l'interface du menu de calibrage.

L'outil comprend toutes les fonctionnalités de mesure champ proche de l'IRSEEM, et les caractéristiques détaillées de sondes standard et de sondes maison qui ont été préalablement calibrées et validées par plusieurs études [2]. Pour certains sondes, leur facteur d'antenne est intégré. Pour d'autres, leur facteur d'antenne est calculé analytiquement. L'utilisateur est aussi libre de charger un fichier externe pré-calculé pour le calibrage. Le menu peut soit être lancé de manière isolée ou dans l'environnement de modélisation des émissions, avant de charger les données champ proche. L'utilisateur peut visualiser toutes les composantes du champ calibré dans un format Excel tel que présenté dans Figure 5. Il n'y a pas de restriction du nombre d'occurrences du lancement du visualiseur.

UN EXEMPLE DE MODÉLISATION

Une application-typique de l'outil est illustrée par un exemple. Dans ce cas, le dispositif sous test est un dispositif complexe comprenant trois substrats distincts tels que présentés dans [3]. Le champ proche simulé avec Ansoft HFSS à 1 mm au-dessus du dispositif est utilisé pour extraire les paramètres du modèle et est ainsi chargé dans l'environnement de l'outil. Le solveur B, avec la matrice jacobienne prédéterminé, est utilisé pour résoudre le système, qui comprend 642 dipôles. Comme développé dans [3], sept fenêtres sont sélectionnées et leurs valeurs d'intensité sont choisies de manière interactive. La Figure 6 présente l'environnement de modélisation ainsi que les données chargées pour l'exemple choisi.

Pour ce cas test, les paramètres du modèle sont extraits en 31 itérations dans un délai dans 11 minutes et 40 sec-

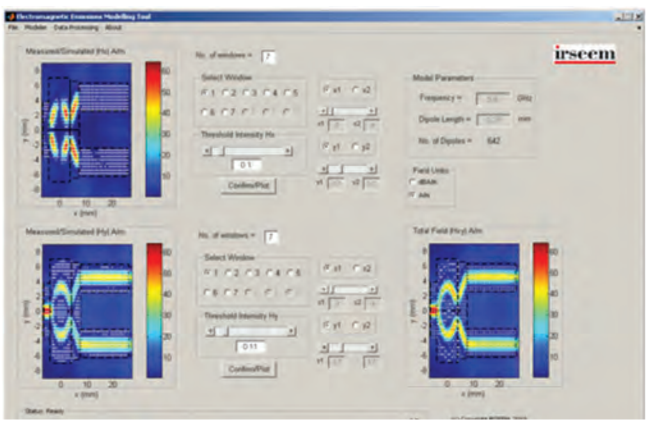

***Figure 6.** L'environnement de modélisation illustré par un exemple.*

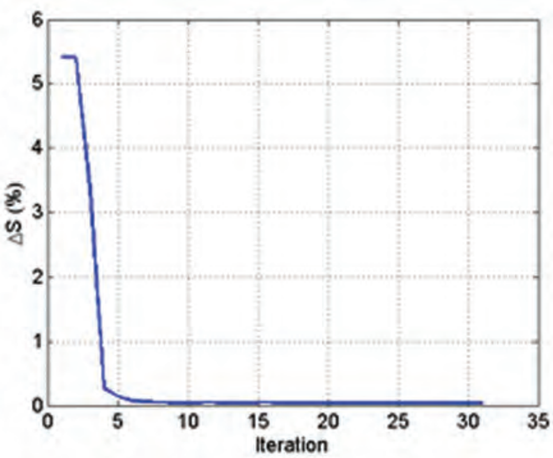

***Figure 7.** Convergence de l'algorithme.*

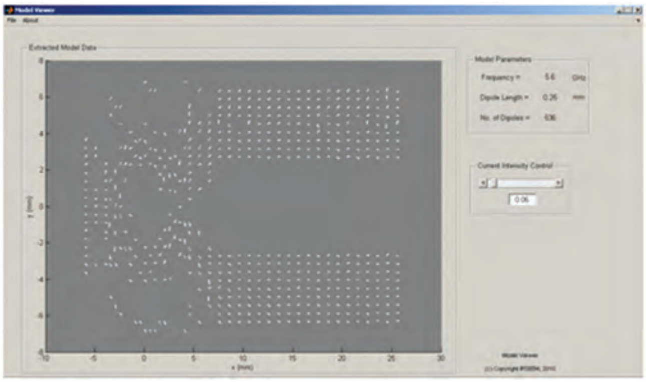

Figure 8. Interface du visualiseur du modèle.

ondes sur un PC équipé d'un processeur de 3,2 GHz et d'une RAM de 3,2 GB. Le point de convergence du solveur est présenté dans la Figure 7. Les paramètres du modèle, qui ont été extraits, peuvent être visualisés en utilisant un « Visualiseur de Modèles » dédié. Le réseau de dipôles, ainsi que leurs paramètres, est affiché et permet donc à l'utilisateur de comprendre le comportement électromagnétique exact du dispositif testé. Il est aussi possible d'ajuster interactivement le facteur Intensité du courant afin de négliger les dipôles avec des courants négligeables. Ceci est extrêmement avantageux pour la réduction du modèle et l'intégration du modèle dans d'autres outils. Les données du modèle peuvent aussi être exportées depuis cette fenêtre. Une capture d'écran de la fenêtre du « Visualiseur de Modèle », après extraction du modèle, est illustrée dans la Figure 8.

Les paramètres du modèle étant extraits, il est alors possible de simuler et de prédire les rayonnements électromagnétiques à toute hauteur souhaitée au-dessus du dispositif. Un exemple des champs modélisés à une hauteur de 22 mm au-dessus du dispositif comparé aux simulations HFSS est présenté dans Figure 9. Il faut aussi noter que les simulations HFSS prennent 2 heures et 37 minutes sur la même PC.

CONCLUSION

Un outil spécialisé et convivial pour des ingénieurs CEM a été développé et est présenté dans cet article. Plusieurs caractéristiques et avantages de l'outil ont été bien discutés. L'outil est développé avec l'objectif d'améliorer la productivité des méthodes de modélisation de CEM et de faciliter leur application par les ingénieurs et les chercheurs. L'environnement de modélisation comprend un outil de calibrage du champ proche indépendant pour convertir les mesures brutes en valeurs équivalentes de champ proche. L'interface interactive basée sur menu fournit un environnement facile à utiliser, sans qu'on soit expert. La recherche continue pour améliorer les capacités fonctionnelles de l'outil.

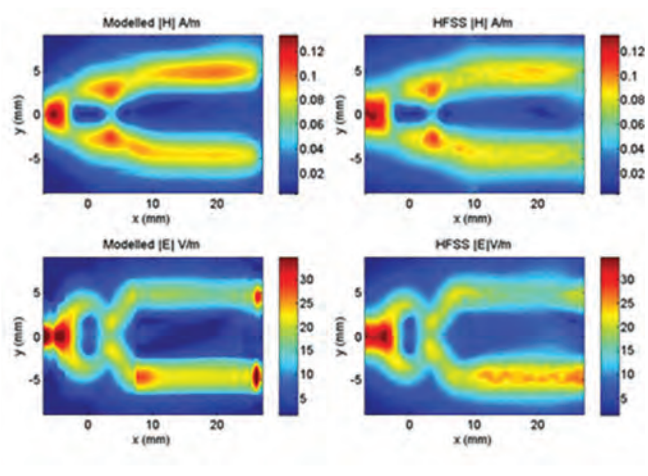

Figure 9. Résultats modélisés à 2 mm au-dessus du dispositif par rapport à HFSS.

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NET-EMC, logiciel de simulation CEM simple et rapide pour l'aide au dimensionnement des grands systèmes

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La multiplication des équipements électroniques entraîne logiquement un accroissement des phénomènes de perturbation et d'auto-perturbation dans les systèmes. Il est indispensable de tenir compte de ces aspects le plus tôt possible au cours de la conception. Dans les phases amont des projets, on a souvent besoin d'avoir des informations rapidement sur le positionnement des antennes ou des équipements. Ces informations peuvent être données par des codes de calcul 3D, ce qui peut s'avérer être long. De plus, les résultats dépendent très fortement des données d'entrées qui sont souvent mal renseignées durant les phases amont du projet compte tenu de la méconnaissance précise de la topologie durant cette phase. Dans cet article, nous présentons un logiciel qui supporte une méthode de simulation innovante pour la modélisation des systèmes complexes basée sur une représentation sous la forme de circuits électriques équivalents. Cet outil numérique permet d'utiliser ces modèles pour caractériser un couplage entre des antennes et des câbles disposés à l'intérieur d'un aéronef. Les résultats du calcul sont en accord avec les mesures et sont quasiment instantanées alors que la résolution par un logiciel de calcul 3D est beaucoup plus couteuse en ressources informatiques et en temps de calcul.

INTRODUCTION

À la suite des récentes évolutions technologiques, les besoins de l'industrie ont beaucoup évolués en matière d'intégration d'équipements électroniques. En effet, l'électronique contribue de manière de plus en plus importante à la conception de grands systèmes plus performants, et plus sûrs du point de vu de la compatibilité électromagnétique.

C'est le cas dans l'aéronautique. Par exemple, les niveaux de bruit induits sur les antennes des éléments de radio communication sont actuellement évalués par un essai système, ce qui nécessite la mise à disposition couteuse

de l'aéronef. A chaque modification majeure d'équipement ou de système, cet essai doit être reproduit soit partiellement soit totalement. Cela pose des problèmes de coût et de disponibilité de l'appareil. Par ailleurs, la démarche de dimensionnement amont d'un aéronef se résume le plus souvent à une extrapolation, basée sur l'expérience et le jugement d'ingénieurs et des résultats d'essais en laboratoire.

Dans ce contexte, les ingénieurs sont de plus en plus attirés par les logiciels de simulations numériques pour le dimensionnement des grands systèmes. Les méthodes de type *« full wave » (MoM, FDTD,...)* permettent de simuler des systèmes à géométries complexes comme un avion de manière précise mais leur mise en œuvre nécessite des ressources informatiques très importantes et des temps de développement et de calculs beaucoup trop longs.

Pour cette raison, des solutions alternatives ont été développées afin d'éviter ces contraintes comme la topologie développée dans les années 1980 par C.Baum [1] et appliquée aux couplages électromagnétiques par J.P.Parmentier [2] en 1990. Plus récemment, une méthode basée sur la modélisation des grands systèmes par une association de circuits électriques équivalents a été développée par O.Maurice [3]. C'est cette dernière technique qui sert de base au logiciel de simulation présenté dans cet article.

Dans le cadre du projet de recherche européen *(Eurostars/Eureka) NET-EMC* (www.net-emc.com) dont *NEXIO* est le leader, le formalisme introduit dans cet article a permis le lancement du développement d'un logiciel éponyme de nouvelle génération d'aide au dimensionnement des grands systèmes.

Le principe du logiciel consiste tout d'abord à considérer une maquette simplifiée du système réel. Ainsi, l'aéronef est simplement dissocié en sous-volumes topologiques constitués de cavités, d'ouvertures (hublots, ports d'accès,...), de câbles et d'antennes.

Ce découpage topologique permet d'utiliser indépendamment pour chaque sous-volume les avantages de différentes méthodes numériques pour améliorer le compromis entre la précision et le temps de calcul de la simulation du système entier. Par exemple, les modèles peuvent être issus de formules analytiques, de la théorie des lignes, de méthodes numériques 2D ou 3D comme la MoM ou la FDTD, ce peut être aussi une mesure localisée sur le sous-volume sensible.

L'ensemble des modèles est ensuite converti sous la forme d'une association de circuits électriques équivalents entre lesquels sont introduites les interactions EM de mode conduit et/ou de mode rayonné. La mise en équation du problème est facilitée par l'utilisation du formalisme tensoriel des réseaux électriques instauré par G.Kron [4,5] dans les années 1930. Ce formalisme permet une visualisation originale et intéressante des phénomènes physiques mis en jeu tout en diminuant le système d'équation à résoudre et donc d'accélérer les temps de calcul du système complexe.

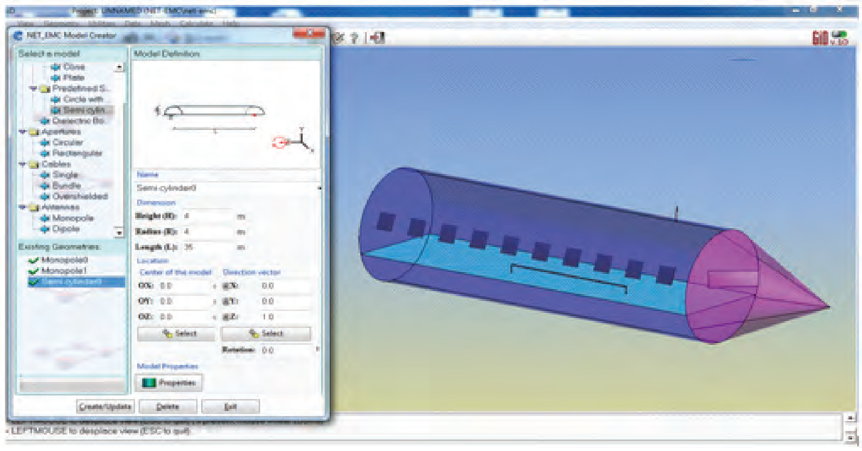

Figure 1. *Interface graphique de NET-EMC.*

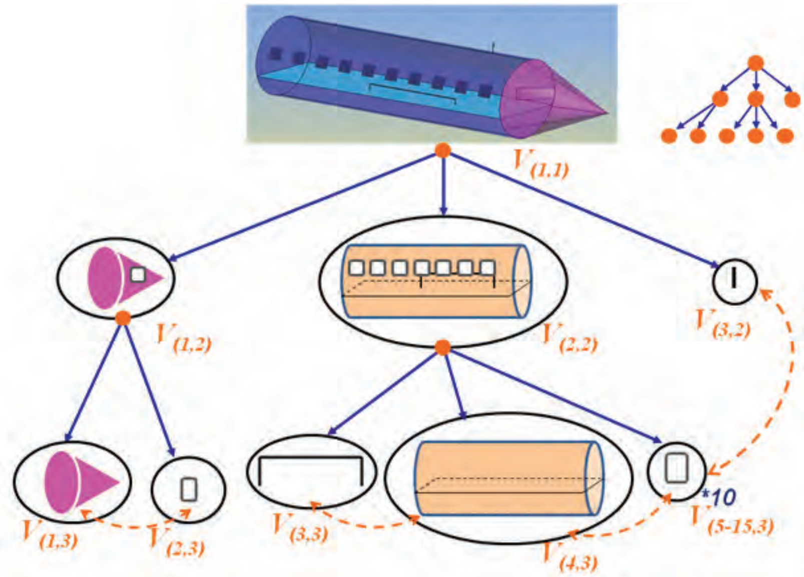

***Figure 2** : Diagramme topologique du système.*

PRINCIPE DE FONCTIONNEMENT DU LOGICIEL NET-EMC-DÉCOUPAGE TOPOLOGIQUE DU SYSTÈME

NET-EMC se positionne dans un contexte de dimensionnement des grands systèmes. Les structures géométriques, les positionnements des antennes, des ouvertures ou des équipements ne sont pas encore parfaitement figés. Pour cela, le logiciel s'oriente de manière à optimiser à la fois la précision des résultats tout en conservant des temps de calcul intéressants pour faciliter l'analyse paramétrique.

Pour cela, *NET-EMC* propose de simuler des sous-volumes disponibles dans une large base de données faisant appel à des modèles équivalents existants optimisés. La figure 1 présente l'interface graphique du logiciel.

La première étape de l'étude d'un grand système est l'analyse topologique [1,2,6]. Le travail de l'ingénieur est de

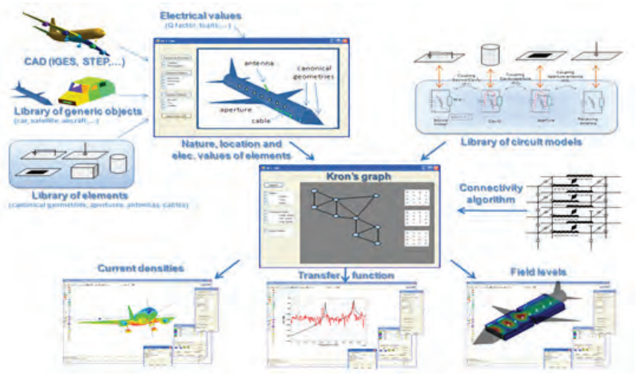

Figure 3. *Résumé du principe de fonctionnement du logiciel NET-EMC.*

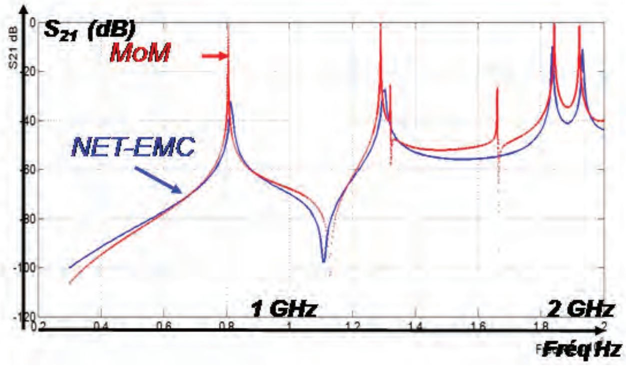

Figure 5. *Paramètre S21 du couplage entre les deux monopoles dans la cavité.*

découper le système complexe en différents sous-volumes $V_{(i,j)}$ plus simples à modéliser indépendamment. La figure 2 propose le diagramme topologique d'un aéronef simplifié. L'ingénieur a sélectionné une cavité en forme de cône $V_{(1,3)}$, une ouverture $V_{(2,3)}$, une ligne de transmission $V_{(3,3)}$, une cavité cylindrique avec un plancher $V_{(4,3)}$, dix ouvertures $V_{(5\text{-}15,3)}$ et une antenne monopole $V_{(3,2)}$. L'utilisateur renseigne les caractéristiques géométriques et électriques de chaque sous-volume ainsi que les bandes de fréquences d'analyse.

L'étape suivante concerne les interactions électromagnétiques entre les sous-volumes. Certaines d'entre elles sont illustrées dans la *figure* 2 par des flèches en traits pointillées. Lorsqu'une interaction est possible entre deux sous-volumes, l'utilisateur est invité à activer ou désactiver le couplage par un simple clic.

Les paramètres spécifiques à chaque sous-modèle sont calculés automatiquement afin de faciliter l'utilisation du logiciel. Un mode manuel permet aux plus expérimentés de configurer des paramètres supplémentaires des modèles équivalents. C'est le cas par exemple du choix du maillage *2D* de la section de la cavité pour le modèle *FDFD*, le choix du nombre de mode *TE* et/ou *TM* ou encore des paramètres devant respecter les hypothèses d'utilisation de la théorie des lignes. Ces paramètres sont naturellement liés au rapport entre les dimensions du système et la longueur d'onde d'étude.

La figure 3 résume le principe de fonctionnement de NET-EMC.

Les deux paragraphes suivants présentent respectivement les résultats d'un couplage entre deux antennes installées dans une cavité semi-cylindrique, et le couplage entre une antenne et deux lignes de transmission installées dans une cavité parallélépipédique.

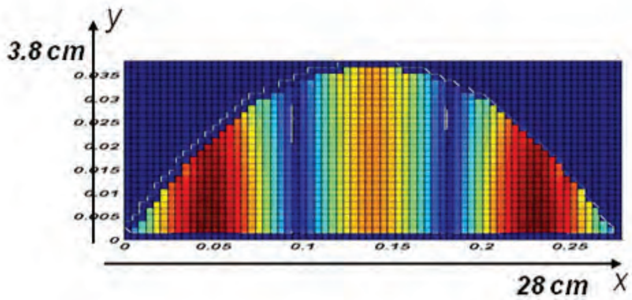

Figure 4. *Composante de champ Ey sur la section de cavité*

EXEMPLE D'UN COUPLAGE ENTRE DEUX MONOPOLES DANS UNE CAVITÉ SEMI-CYLINDRIQUE

Nous utilisons dans ce paragraphe les résultats présentés lors du congrès *CEM-10* à Limoges *[7]* dans lequel nous avons traité un couplage entre deux monopoles installés dans une cavité semi-cylindrique. Les dimensions de la cavité sont rappelées : *a=24cm, b=3.8cm* et *d=42cm*. Les coordonnées des deux monopoles de hauteur $h_{ant}=1cm$ et de diamètre *dia=1.5mm* sont respectivement en centimètres *(x1,y1,z1)=(14,1,21) et (x2,y2,z2)=(21,1,21)*. La gamme de fréquence d'étude est de *10 MHz à 2 GHz* et le nombre de points de fréquences calculés de *201 points*.

L'utilisateur non expérimenté en *CEM* pourra exécuter le calcul par un simple clic pour afficher 20 secondes après le paramètre S_{21} entre les deux monopoles et les cartes de champs électromagnétiques de la section de la cavité.

La figure 4 présente la carte de champ de la composante de champ E_y correspondant au troisième mode *TE* de résonance apparaissant à la fréquence de résonance $f_{res} = 1.8$ *GHz*.

La figure 5 suivante présente la comparaison entre un logiciel basé sur la *MoM* et les résultats fournis par *NET-EMC* du paramètre S_{21} de couplage entre les deux monopoles installés dans la cavité.

Les temps de calcul sont respectivement de *45 min* avec une méthode des moments contre 20 secondes avec ce prototype de *NET-EMC*. Nous retrouvons les fréquences de résonance de la cavité excitées par les deux antennes.

En contre parti, l'ingénieur est limité aux sous-systèmes usuels disponibles dans une large base de données de modèles équivalents.

EXEMPLE D'UN COUPLAGE ENTRE UNE ANTENNE ET DEUX LIGNES DE TRANSMISSION DANS UNE CAVITÉ PARALLÉLÉPIPÉDIQUE

Cette fois, l'utilisateur souhaite estimer les niveaux de couplage *EM* entre une antenne et des lignes de transmission installées dans une cavité parallélépipédique *[6,7,8,9,10]*. Il sélectionne dans la large base de données de modèles équivalents proposée par *NET-EMC* les sous-volumes correspondant à une antenne $V_{1,3}$, deux lignes de transmission $V_{2,3}$ et $V_{3,3}$ et la cavité parallélépipédique $V_{2,2}$ comme illustré sur le diagramme topologique de la *figure 6*.

Les dimensions de la cavité sont *a=28cm, b=3.8cm* et *d=42cm*. L'antenne de hauteur $h_{ant}=1cm$ et de diamètre

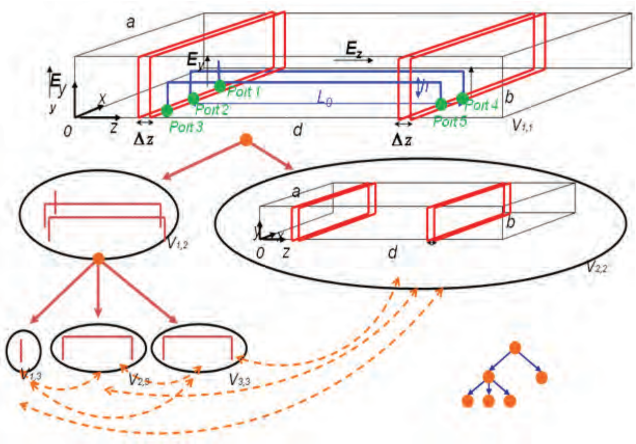

Figure 6. Diagramme topologique du système 2la cavité.

dia=1,7mm est disposée aux coordonnées du *port 1* exprimées en centimètres $(x_{ant}, y_{ant}, z_{ant})=(14,0,7)$.

Les deux câbles de longueur $L_0=28cm$ espacés de *2 cm*, surmontent le plan de référence à une hauteur de *h=1cm*. Les diamètres des conducteurs sont de *1.5mm*. Les coordonnées des *ports 2 et 3* sont en centimètres: *(9,0,7) et (7,0,7)*.

Les charges présentes aux extrémités des lignes et de l'antenne sont fixées à *50 Ohm*. La bande de fréquence d'étude est de *10 MHz à 4 GHz*.

Le logiciel *NET-EMC* propose à l'utilisateur d'activer

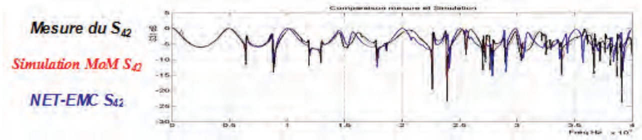

Figure 7. Comparaison Mesure, simulation MoM ,NET-EMC du S_{42}.

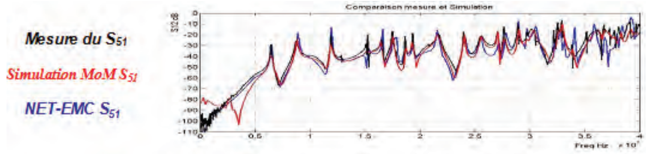

Figure 8. Comparaison Mesure, simulation MoM ,NET-EMC du S_{51}.

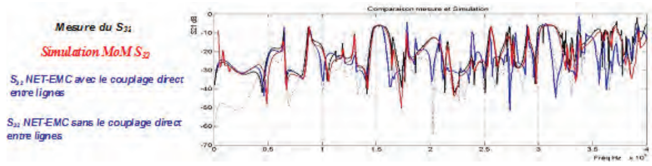

Figure 9. Comparaison Mesure, simulation MoM, NET-EMC du S_{32}.

ou de désactiver les six différentes combinaisons possibles d'interactions entre les sous-volumes illustrées par les flèches en traits pointillés sur la figure 6.

Les figures 7 à 9 présentent certains résultats des paramètres S. La courbe noire représente la mesure, la courbe rouge est une simulation par la méthode des moments *(MoM)*, et la courbe bleue correspond aux simulations avec *NET-EMC*.

De manière générale, nous observons une bonne concordance des résultats jusqu'à une fréquence de *2 GHz*. Au delà de cette fréquence, des écarts commencent à apparaitre et particulièrement pour le couplage entre les ports 1 et 2 car les hypothèses d'utilisation du modèle concernant les brins verticaux des lignes de transmission permettent une bonne efficacité seulement jusqu'à *2 GHz*. Le logiciel se charge d'en alerter l'utilisateur.

La figure 9 montre qu'avec la possibilité d'activer ou de désactiver certains couplages *EM*, l'ingénieur peut rapidement identifier la source de perturbation EM critique.

L'utilisateur remarque qu'en dessous de *400 MHz*, c'est le couplage direct entre les deux lignes qui domine par rapport au couplage entre les lignes et les parois de la cavité. L'ingénieur se concentrera alors sur la recherche de solutions de protections *EM* liées aux lignes de transmission (positions des câbles, blindages, câbles torsadés,...).

Les temps de simulation effectués sur un ordinateur de bureau sont de l'ordre de 20 minutes pour *NET-EMC* contre environ 6 heures avec une méthode des *MoM*. En abaissant la fréquence d'étude maximale à *2 GHz*, le temps de calcul est de l'ordre de *2 min* avec *NET-EMC*.

Pour plus de précisions techniques concernant les modèles équivalents des sous-volumes, leurs réductions à des circuits électriques équivalents ou à leurs mises en équation par le formalisme tensoriel des réseaux électriques de *G.Kron*, nous vous invitons à consulter les références [3] à [10].

CONCLUSION

Le logiciel *NET-EMC* repose sur une décomposition topologique des systèmes complexes permettant de réduire l'étude à une association d'interactions entre circuits équivalents mis en équation par le formalisme des réseaux électriques de *G.Kron*.

Le logiciel propose une large base de données de modèles équivalents personnalisables en fonction du contexte industriel. Dans le cadre de projets de recherches Européen, des travaux importants visent à développer ces modèles équivalents adaptés au formalisme des circuits de *G.Kron*. La difficulté majeure consiste à établir l'analogie entre les circuits électriques et les différentes méthodes théoriques existantes (méthodes full wave, théorie des lignes, expressions analytiques...).

L'objectif du logiciel est de mettre à disposition des ingénieurs une nouvelle solution de simulation rapide et précise pour l'aide au dimensionnement des grands systèmes *CEM*.

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Il Test Multi-tonico può far risparmiare tempo e denaro

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ABSTRACT
Multi-tone Testing Can Save Both Time and Money
Given the huge amount of time required to conduct a radiated immunity test, it is no wonder operators "dream" of ways to improve efficiency to speed up the test. What if there was a way to dramatically reduce test time while still meeting the stringent requirements of the test standard? A way has been found: a product that uses a patented test process that adds additional test frequencies, or tones, for each test period, or dwell time. Rather than testing one tone per dwell period, additional tones are added to effectively increase the test efficiency by a factor approximately equal to the number of tones used. For example, if four tones were used, the test would be completed in about one quarter of the normal time or four times faster. One of the future applications of this technology would be to mimic real world threats which are multi-tone in nature.

Data l'enorme quantità di tempo necessaria a condurre un test di immunità irradiata, non c'è da meravigliarsi se gli operatori sognano metodologie per rendere questo test più veloce. La riflessione procede in genere in quest'ordine:

- Può un'unica antenna coprire l'intera gamma delle frequenze?
- Può la variazione di RF essere automatizzata?
- Proviamo ad aggiungere un dispositivo di controllo che inverta automaticamente le polarità dell'antenna e che possa perfino commutare automaticamente l'EUT per rivelare tutti e quattro i quadri del campo di RF.
- E se potessimo velocizzare il tempo di stazionamento di poco senza compromettere il risultato del test?

Nonostante tutte le riflessioni sopra dette risultino di una certa utilità, esse ottengono soltanto una riduzione dei tempi di transizione, i quali rappresentano solo una frazione del tempo totale di test. Se invece individuassimo un metodo per la significativa riduzione del tempo di test riuscendo al tempo stesso a soddisfare i rigorosi requisiti dello standard di test? Quello sarebbe davvero un sogno che diventa realtà.

Tenetevi forte … è stato trovato un metodo. Il titolo di quest'articolo dà un'indicazione su come ciò si possa realizzare. La AR RF/Microwave Instrumentation ha sviluppato un prodotto che utilizza un processo di test brevettato, il quale aggiunge frequenze di test addizionali, ovvero dei toni, per ogni periodo di test ovvero tempo di stazionamento. Piuttosto che testare un singolo tono per periodo di stazionamento, noi aggiungiamo toni addizionali per migliorare effettivamente l'efficienza di test di un fattore uguale con approssimazione al numero di toni impiegati. Ad esempio, se sono impiegati quattro toni, il test si completa in circa un quarto del tempo normale ovvero quattro volte più velocemente.

IL CONCETTO DI MULTI-TONO

Dal momento che il concetto dell'utilizzo di multi-toni è tanto ovvio, ci si chiede perchè non sia mai stato adottato prima. Pur essendo semplice concettualmente, la concreta

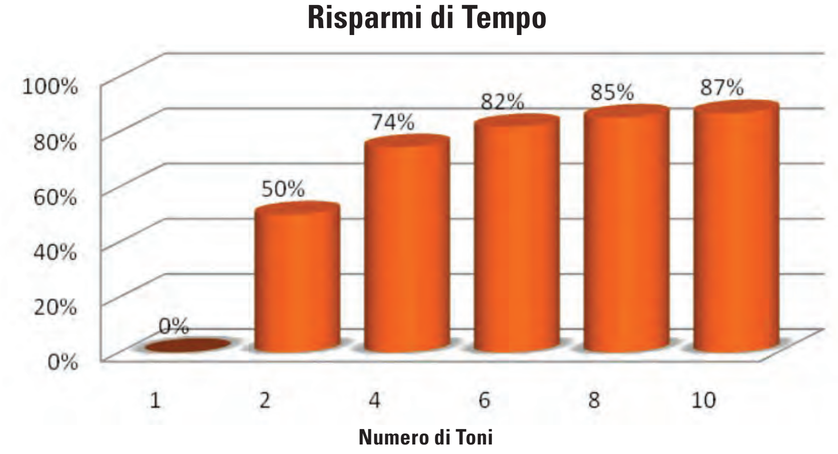

Figura 1. *% di risparmio di tempo per tempo di stazionamento.*

implementazione strumentale ha sempre rappresentato un ostacolo. Fonti di segnali multipli che fossero allo stesso tempo controllate e propriamente combinate in maniera ripetibile hanno rappresentato un passaggio non compreso nel campo d'azione della disponibile strumentazione per test. Per fortuna, un recente progresso nella capacità dei generatori di segnali ha prodotto strumenti in grado di soddisfare i rigidi requisiti del test multi-tonico. Mentre la buona notizia è che il dilemma della generazione del segnale è risolto, altre considerazioni si presentano all'attenzione riguardo alla configurazione di un test multi-tonico. Ad esempio, in che modo l'amplificatore di potenza è condizionato dalla introduzione di multi-toni? Questo metodo rispetta i requisiti dello standard di test? Nel nostro tentativo di ridurre il tempo di test, includiamo tuttavia il raggiungimento dei risultati?

Per quanto concerne l'effetto sull'amplificatore di potenza del sistema, si è determinato che i requisiti di potenza sono da aumentare. Perciò un test su due toni richiede un amplificatore di potenza largo due volte rispetto alla specifica per quello di un test standard con un solo tono. Di conseguenza, un test che consista di cinque toni avrà necessità di un amplificatore di potenza cinque volte la misura di base. Anche l'introduzione di prodotti di inter-modulazione basati su due o più toni richiederà potenza addizionale. Tale effetto può essere minimizzato dall'utilizzo entro la sua area lineare di un amplificatore di potenza di Classe A. Data la complessità nel combinare più di un segnale di test ed al tempo stesso rispettare rigidi requisiti di integrità del segnale, si è sviluppato un sofisticato software di controllo test. Questo software proprietario usa complessi algoritmi per misurare e individuare il numero massimo possibile di toni rientrando al tempo stesso nelle limitazioni di un valido test multi-tono.

DETERMINARE LA POTENZA RICHIESTA DELL'AMPLIFICATORE

Una delle limitazioni del test multi-tono è la potenza massima disponibile dell'amplificatore. Un approccio efficace e sperimentato nella determinazione della potenza dell'amplificatore è il determinare la quantità minima di potenza necessaria a generare il campo di test richiesto secondo lo standard IEC 61000-4-3 di immunità delle radiazioni e raddoppiarlo per tener nel conto le perdite di sistema.

Dal momento che la potenza richiesta varia quale funzione della frequenza, l'unico modo per determinare affidabilmente la potenza necessaria è compiere la calibrazione del campo uniforme secondo lo standard IEC 61000-4-3. La figura 2 è uno schema tipico della potenza richiesta quale funzione della frequenza. Si noti che la potenza richiesta cade rapidamente seguendo la frequenza. In questo punto il test multi-tono ha l'opportunità di avvantaggiarsi della piena (precedentemente inutilizzata) potenza dell'amplificatore e ridurre il tempo complessivo di test. In questo specifico caso un amplificatore di 250 watt rende disponibile un'accelerazione doppia alle frequenze più basse, con una più grande riduzione del tempo di test alle frequenze più alte. In molto casi i laboratori di test hanno la potenza necessaria per produrre campi di alta capacità ma effettuano i test a livelli più bassi per la maggior parte delle volte. Con il test multi-tono, i laboratori di test riuscirebbero a far migliore uso della loro potenza di amplificazione non utilizzata, riducendo contemporaneamente i tempi di test. La discussione sull'aggiunta di amplificatori di maggior potenza nei laboratori di test è divenuta ora più facile, poichè essa permetterà l'effettuazione di test a livelli di campi più alti, ma la potenza addizionale potrà tradursi in una riduzione del tempo di test.

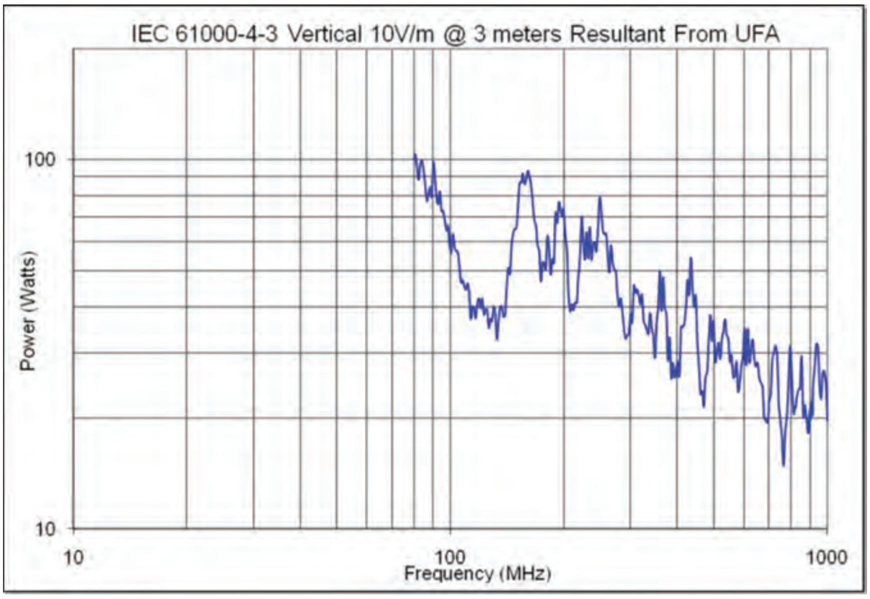

Figura 2. *Potenza richiesta per 10V/m dalla calibrazione UFA.*

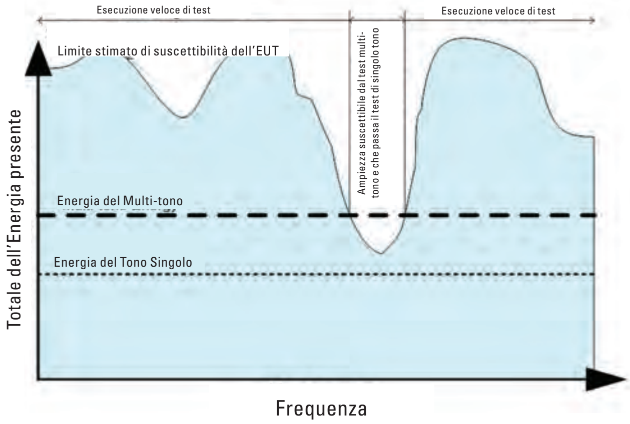

Figura 3. *Test Multi-tono simulato.*

CALIBRAZIONE PER LE FREQUENZE 80 MHZ – 6 GHZ DELL'IMMUNITÀ DELLE RADIAZIONI SECONDO LO STANDARD IEC 61000-4-3

Tale standard di test spiega molto chiaramente la procedura di calibrazione e test che dev'essere seguita per dimostrare la conformità. Il lungo processo di calibrazione a 16 punti impiega sonde di campo isotropico che non selezionano le frequenze e non possono analizzare e misurare i toni multipli. Quindi, il tempo di calibrazione non può essere migliorato adottando un processo multi-tono. La stessa procedura condotta per la calibrazione annuale del campo uniforme è tuttora seguita ed i risultati sono valutati quindi per la determinazione dell'idoneità e dell'estensione per il test multi-tono.

Le misurazioni di linearità e di contenuto armonico sono richieste quali parti del processo di calibrazione. Quando si pianifica un test multi-tono, si dovrebbe comprendere che tutti i toni devono sottostare a queste misurazioni così come a test aggiuntivi. I controlli ulteriori utilizzano gli stessi criteri elencati nella specificazione IEC per linearità ed armoniche, sono inoltre richiesti allo scopo di definire il numero massimo di toni che è possibile impiegare ad ogni punto dato nel test. A questo punto, il raggruppamento multi-tono per il processo di test multi-tono è stato stabilito.

Effettuazione del test

Allorchè si dispone di una determinazione di quanti toni possono essere utilizzati e a quali punti del test, l'effettuazione del test può procedere a velocità record. Per ciascun tempo di stazionamento si sottopone un set di toni all'EUT. Se non si verifica alcun default dell'EUT, il test prosegue. Se si verifica un default, l'utente ha la possibilità di investigare immediatamente con l'uso di un singolo tono per verificare se il problema persiste anche quando una singola frequenza di test è in uso, oppure di continuare con il test multi-tono annotando i punti ove si sono verificati dei problemi. Nel secondo caso, dopo il completamento del test, la gamma delle frequenze che hanno registrato problemi saranno testate di nuovo con l'uso di un singolo tono per vedere se il problema è unicamente relativo al test multi-tono oppure persiste anche nell'esecuzione del tes con singola frequenza. A questo punto si può eseguire un'ulteriore analisi e definizione delle soglie. Se l'EUT dimostra sensibilità ai multi-toni ma non ad un singolo tono, l'EUT si considera conforme allo standard di test. L'unico aspetto negativo è che almeno a queste particolari frequenze non si può ridurre il tempo di test. Nonostante ciò, poichè larghe sezioni dello spettro delle frequenze possono essere esplorate e testate con velocità, il tempo complessivo di test è tuttavia diminuito.

Mentre i toni singoli impiegati nel test multi-tono non sovraccaricano l'EUT, l'energia addizionale ottenuta dalla combinazione di due o più segnali può indurre una risposta nell'EUT che cade al di fuori dello standard di test. Qualora ciò avvenga, la modalità di test veloce deve essere sospesa in favore della convenzionale modalità di test a singolo tono. Se l'EUT continua a presentare problemi se sottoposto soltanto al test di una singola frequenza, allora l'esecuzione del test ha di fatto scoperto una criticità che dev'essere risolta. Si tenga presente che la ragione stessa per l'esecuzione del test multi-tono è il risparmio di tempo. All'analisi finale, lo standard IEC 61000-4-3 richiede soltanto che l'EUT sia soggetto ad una frequenza test alla volta. Perciò la metodologia dovrebbe esser l'operare con multi-toni laddove possibile allo scopo di risparmiare tempo, ma di tornare ai toni singoli quando si verifichi un prob-

lema. La rappresentazione grafica nella Figura 3 sintetizza visivamente questo concetto di esecuzione del test. Si noti che il test procede velocemente dalla frequenza più bassa fino al punto dove si riscontra un problema. A tal punto il test multi-tono viene sospeso ed il test ritorna alla modalità convenzionale di test a singolo tono. In questo scenario ipotetico, si vede che l'EUT passa il test a singolo tono ed il test multi-tono è ripreso senza altre avarie attraverso il rimanente spettro di frequenze.

Conformità

Lo standard EMC è sempre rispettato con l'implementazione del test multi-tono di AR RF/Microwave Instrumentation. La maggiore differenza tra il test convenzionale e il nostro approccio al test multi-tono è che l'esecuzione del test è molto più veloce. Seguiamo per la calibrazione la stessa procedura descritta nello standard e possiamo bilanciare sia la potenza aumentata sia il livello del campo senza variazione. Il margine di compressione permesso di 2 dB è controllato e adottato quale criterio per la ricerca di quanti toni possono essere impiegati. Il requisito armonico di -6dBc (dB dal portatore) nel campo è adottato come secondo controllo sul numero massimo di toni impiegati. Quando i gruppi di toni vengono identificati, vengono utilizzati per il completo test multi-tono. Mentre il numero di di toni permessi è determinato automaticamente, l'utente ha la capacità di sovrapporsi al controllo da software e riconfigurare il numero massimo di toni per ogni gruppo di toni.

OGNI SINGOLO TONO DURANTE IL TEST:

- Sarà fissato alla corretta ampiezza per produrre il campo necessario
- Sarà fissato alla frequenza richiesta
- Sarà fissato al passaggio % richiesto di frequenza, ovvero in questo caso al % d'intorno
- Supporterà la richiesta modulazione pari a 1 kHz, 80%AM
- Stazionerà al tempo richiesto di stazionamento per ogni frequenza/tono

Tutti i requisiti dello standard EMC verranno rispettati. L'abilità di testare e dimostrare la conformità mentre si riduce significativamente il tempo di test è ora realtà e siamo lieti di annunciare che "il sogno è divenuto realtà".

IL FUTURO

Una delle future applicazioni di questa tecnologia sarà la costruzione di ipotesi di pericoli nel mondo reale che abbiano natura multi-tonica. Le applicazioni nel mondo reale espongono gli EUT a più di un tono per volta. Il test convenzionale a singolo tono non riuscirebbe mai a scoprire la rilevanza di tali pericoli "reali". Alcuni produttori di strumenti hanno già sperimentato problemi di tipo EMC causati da multi-tono ed hanno applicato i test multi-tono per l'identificazione e la correzione delle vulnerabilità di prodotto. Il sistema di test AR multi star (MT06000 Multi-Tone) potrebbe semplificare tale compito di settare e testare con gli algoritmi integrati allo scopo di verificare e assicurare che il segnale non sia affetto da anomalie derivanti dai prodotti di inter-modulazione e causate dalla non-linearità.

Jason Smith è stato l'ingegnere delle applicazioni manager alla AR dal 2004. L'esperienza precedente di lavoro comprende l'essere stato ingegnere di test e manager di laboratorio EMC alla Analalb, LLC. Jason ha più di dieci anni d'esperienza nell'esecuzione di test EMC con applicazioni nel settore militare, commerciale, automobilistico, medico, dell'aziavione, e delle telecomunicazioni. È membro dell'USNC al SC77B ed al SC77C ed è membro partecipante del WG10 (IEC 61000-4-3, -6). Si è laureato allUniversità del Delaware nel 1997 con un B.S. in Tecnologia dell'Ingegneria. Può essere contattato all'indirizzo email jsmith@arworld.us

Pat Malloy è stato l'ingegnere delle applicazioni ad uso commerciale alla Amplifier Research, ora AR, dal 1987. La sua esperienza professionale precedente comprende quattro anni con la U.S. Navy in qualità di tecnico elettronico dei missili guidati, sette anni in un team d'ingegneri ai AT&T Bell Laboratories, sedici anni in qualità di senior sales engineer per la Tektronix. Si è laureato al Lafayette College nel 1972 con un B.S.E.E. Può essere contattato all'indirizzo email pmalloy@arworld.us

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Wavecontrol S.L., Pallars, 65-71, 08018-Barcelona España; +34 93 320 805-5; Fax: +34 93 320 805-6; info@wavecontrol.com; www.wavecontrol.com; www.langer-emv.de
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Contact Sarah Long at slong@interference technology.com for additions and corrections to the Products and Services directory.

Interferencias electromagnéticas en el centro de datos: blindar o no blindar

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INTRODUCCIÓN

Al diseñar un centro de datos, es necesario tener en cuenta muchas cosas. Entre ellas están la disponibilidad y las interrupciones, dependiendo de la configuración según el Nivel que se desee (consultar Tabla 1). En los centros de datos Nivel III y Nivel IV, además de redundancia de los elementos, existen posibles amenazas y reglas de diseño que deben tenerse en cuenta para evitar futuros incidentes inesperados y asegurar la actividad de los sistemas alojados en su interior.

Las interferencias de campos electromagnéticos (EMI) de baja y alta frecuencia causadas por equipos eléctricos, teléfonos móviles, microondas, señales de radio y televisión, etc. pueden tener efectos nocivos sobre el equipo informático, reduciendo la calidad del servicio y la disponibilidad. La EMI suele ignorarse al diseñar un centro de datos. En las siguientes líneas se exponen algunos motivos por los que la EMI, a pesar de ser invisible, puede producir graves efectos visibles, por lo que es necesario tomar medidas de protección.

English translation available at www.interferencetechnology.eu

ABSTRACT

Electromagnetic Interference in the Data Center: To Shield or Not to Shield

When designing a data center, many things need to be taken in account. One of them is availability and downtime depending on desired Tier configuration (see Table 1). For Tier III and Tier IV data centers, apart from redundancy of the elements, there are potential threatens and design rules that need to be considered to avoid future unexpected incidents and assure uptime of the systems hosted inside. Low and high frequency electromagnetic fields interference (EMI) caused by power equipment, cell phones, microwaves, TV and radio signals, etc. can produce harmful effects on IT equipment, thus reducing quality of service and availability. EMI is usually ignored when designing a data center; in the following lines you'll be presented some reasons why EMI, though invisible, may produce serious visible effects and why protection measures need to be taken.

ENTORNO DEL CENTRO DE DATOS

Una ubicación ideal para un centro de datos es aquella que ofrezca muchas de las cualidades que el propio centro de datos proporciona a una empresa:

- Protección contra peligros
- Fácil acceso
- Características que permitan el cambio y el crecimiento futuros

Factores de riesgo del emplazamiento

Todo terreno tiene sus peligros intrínsecos. Conocer los peligros asociados a cualquier propiedad sobre la que se piense situar un centro de datos resulta muy útil, y debería ser un factor determinante.

Independientemente de si los peligros son naturales o se deben a la mano del hombre, resulta útil comprender cómo pueden afectar a un entorno de servidores y saber

MILMEGA

La diferencia entre lo normal y lo extraordinario

- El mejor amplificador de su gama para conseguir potencia **garantizada**
- Las sub secciones extraíbles mejoran la operatividad del equipo
- Garantía total durante 5 años
- Tamaño muy reducido (la mitad que sus equivalentes de la competencia)
- Arquitectura modular ampliable

La nueva gama de amplificadores de MILMEGA, que cubre el rango 80 – 1000 MHz, es todo lo que esperaría de una empresa reconocida por ofrecer productos y servicios excepcionales, y que define los estándares a los que los competidores aspiran

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__Figura 1.__ Chapa de blindaje.

qué modificaciones son necesarias en el diseño de su centro de datos para estar preparados a la hora de afrontar dichos peligros.

Interferencias electromagnéticas

Las interferencias electromagnéticas, o interferencias de radiofrecuencia, se producen cuando un campo electromagnético interrumpe o distorsiona el funcionamiento normal de un dispositivo electrónico. Dichas interferencias las generan a pequeña escala objetos cotidianos, que van desde teléfonos móviles hasta tubos fluorescentes. Las grandes fuentes de interferencias, como instalaciones que emiten señales de telecomunicaciones, aeropuertos o trenes eléctricos, pueden interferir con los dispositivos de red y los servidores del centro de datos si se encuentran cerca.

Es probable que los primeros en observar los síntomas, aunque no identifiquen su causa, sean los administradores de sistemas, los ingenieros de redes y las demás personas que trabajen directamente con el equipo. Si observa que un servidor presenta errores de datos sin explicación, y la resolución de problemas estándar no soluciona la situación, compruebe que no existan fuentes de interferencias electromagnéticas.

Unos niveles altos de campos electromagnéticos tendrán efectos desastrosos sobre los equipos informáticos, los servidores, las pantallas con tubos de rayos catódicos, los equipos médicos y otros dispositivos electrónicos. Los resultados pueden ir desde temblores en las pantallas de los monitores hasta fallos intermitentes e inexplicables.

Las frecuencias electromagnéticas están por todas partes. En los edificios de oficinas, las fuente de generación de estas frecuencias pueden ser las líneas de alta tensión, los transformadores, los sistemas de alimentación ininterrumpida (SAI) y los cuadros de interruptores de alta tensión, y estas fuentes pueden estar ocultas en las paredes o tras puertas, libres de toda sospecha.

Existen muchos productos de blindaje (revestimientos, compuestos y metales, mallas, tiras e incluso tejidos metalizados) para bloquear las interferencias electromagnéticas.

	NIVEL I	NIVEL II	NIVEL III	NIVEL IV
TIPO DE EDIFICIO	ALQUILER DE UNA SALA	ALQUILER DE UNA SALA	ALGUILER DEL EDIFICIO ENTERO	ALGUILER DEL EDIFICIO ENTERO
DOTACIÓN DE PERSONAL	NINGUNA	1 TURNO	MÁS DE 1 TURNO	24 HORAS AL DÍA, LOS 365 DÍAS DEL AÑO
UTILIZABLE PARA CARGA CRÍTICA	100% N	100% N	90% N	90% N
VATIOS BRUTOS INICIALES POR PIE CUADRADO (W/FT2) (TÍPICO)	20-30	40-50	40-60	50-80
W/FT2 BRUTOS FINALES (TÍPICO)	20-30	40-50	100-150[1,2,3]	150+[1,2]
REFIGERACIÓN ININTERRUMPIBLE	NINGUNA	NINGUNA	QUIZÁ	SÍ
RELACIÓN ESPACIO DE SOPORTE-PISO ELEVADO	20%	30%	80-90%[2]	100+%
ALTURA DEL PISO ELEVADIO (TÍPICA)	12"	18"	30-36"[2]	30-36"[2]
CARGA SOBRE EL PISO LB/FT2 (TÍPICA)	85	100	150	150
TENSIÓN DE LA RED (TÍPICA)	208, 480	208 480	12-15KV[2]	12-15KV[2]
PUNTOS ÚNICOS DE FALLO	MUCHOS + ERROR HUMANO	MUCHOS + ERROR HUMANO	ALGÚN + ERROR HUMANO	NINGÚN + ERROR HUMANO
INTERRUPCIONES DE TI ANUALES CAUSADAS POR LAS INSTALACIONES (REALES)	28,8 HORAS	22 HORAS	1,6 HORAS	0,4 HORAS
DISPONIBILIDAD DE LAS INSTALACIONES	99.67%	99.75%	99.98%	99.995%
MESES PARA IMPLEMENTAR	3	' 3-6	15-20	15-20
AÑO DE LA PRIMERA IMPLEMENTACIÓN	1965	1970	1985	1995
COSTE DE CONSTRUCCIÓN (+30%)1,2,3, PISO ELEVADO POTENCIA SAI UTILIZABLE	$220/FT2 $10,000KW	$220/FT2 $11,000KW	$220/FT2 $20,000KW	$220/FT2 $20,000KW

__Tabla 1.__ Clasificación de centros de datos por Niveles del Uptime Institute.

Tan fácil como coser y cantar.

Para realizar Pruebas de inmunidad conducida de radiofrecuencia según las normas IEC, militares y del sector de la automoción.

Los Sistemas de prueba de inmunidad conducida originales de AR consiguieron facilitar un proceso complicado y aumentar su precisión. Simplificaron todos los aspectos que implica el proceso: calibración, pruebas, solución de problemas de DUT y generación de informes. El Sistema CI presenta la flexibilidad integrada de realizar pruebas personalizadas y control de software que incluye selección de normas, calibración, ejecución de pruebas y generación de informes directamente en Microsoft® Word o Excel.

Estos excelentes sistemas presentan, además, un alcance de sensibilidad más amplio, excelente velocidad y la posibilidad de realizar precisas pruebas de margen.

Ningún otro producto se le había, ni siquiera, acercado. Hasta ahora.

Porque ahora AR presenta su nuevo Sistema de CI, el CI00401A. Gracias a los tres Sistemas de pruebas de inmunidad conducida que puede elegir, no tendrá que volver a realizar nunca más laboriosos procedimientos de prueba de CI manuales, ni tampoco tendrá que preocuparse de la fiabilidad de los resultados.

Nadie puede mejorar los resultados de AR Systems:

1. Modelo CI00250A (amplificador de 75 vatios, 10 kHz – 250 MHz): soluciones de pruebas completa para las siguientes normas: EN/IEC 61000-4-6, IEC 60601-1-2, EN 50130-4, EN 61000-6-1/2 y EN 55024.
2. Modelo CI00400A (amplificador de 100 vatios, 10 kHz – 400 MHz): soluciones de pruebas completa para las siguientes normas: Pruebas MIL-STD-461D y E CS114, DO160D y E BCI, EN/IEC 61000-4-6, IEC 60601-1-2, EN 50130-4, EN 61000-6-1/2, EN 55024.
3. Modelo CI00401A (amplificador de 150 vatios, 100 kHz – 400 MHz): soluciones de pruebas completa para las siguientes normas: ISO 11452-4, GMW 3097, ES-XW7T-1A278-AC, DC-11224, BMW GS95002 y otras normas del sector de la automoción.

AR distribuye una amplia variedad de soluciones de radiofrecuencia exclusivas a algunas de las empresas más conocidas de todo el mundo. Nuestros productos están respaldados por la garantía más potente y completa del sector, y por una red de asistencia técnica internacional sin igual. Llame a su asociado comercial de AR para solicitar una demostración.

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Nivel de potencia	< 3 kVA	> 3 < 6 kVA	> 6 kVA
Trayectorias	50 mm (2 in)	1,5 m (5 ft)	3 m (10 ft)
Espacios	50 mm (2 in)	3 m (10 ft)	6 m (20 ft)

Tabla 2. *Separación mínima para sistemas de cableado UTP.*

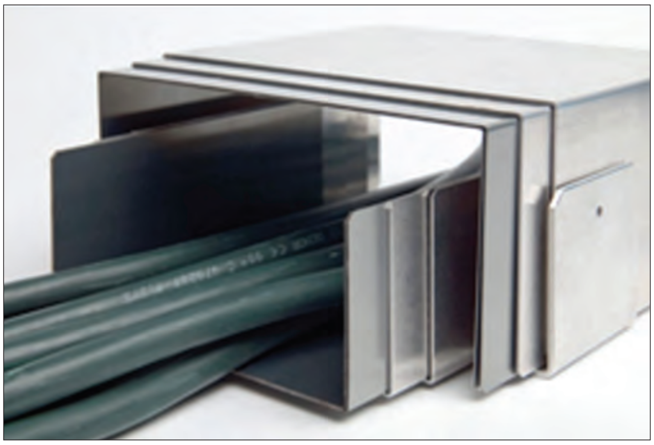

Figura 2. *Bandeja blindada.*

EFECTOS DE LOS CAMPOS ELECTROMAGNÉTICOS

Efectos en el cableado de comunicaciones

Cuando los cables están cerca de campos electromagnéticos potentes, puede inducirse en los mismos tensión y corriente contra nuestra voluntad. Si el nivel de la potencia es suficientemente alto, el ruido eléctrico puede interferir con las aplicaciones de datos y voz que utilicen el cableado. En la comunicación de datos, unas interferencias electromagnéticas (EMI) excesivas dificultan que los receptores remotos detecten correctamente los paquetes de datos. El resultado final será un mayor número de errores, más tráfico en la red debido a las retransmisiones de los paquetes y congestión en la red. En la comunicación de voz analógica, la EMI puede crear ruido sofométrico, que distorsiona la calidad de la transmisión.

- El acoplamiento capacitivo se produce entre cables de telecomunicaciones y cables eléctricos dispuestos en paralelo en algún tramo de una instalación determinada. Pueden blindarse los cables eléctricos para blindar el canal desde el circuito perturbador.
- El acoplamiento inductivo se produce por la inductancia mutua entre dos o más circuitos o canales. Cuando la corriente fluye en un circuito que termina con una carga, produce un flujo magnético proporcional a la corriente. Este flujo magnético puede inducir ruido de tensión en un canal adyacente, generando un lazo de corriente en el circuito perturbado. Este tipo de acoplamiento es uno de los más comunes. La geometría de los conductores, así como el rango geométrico entre dos líneas en el espacio, determina la intensidad del acoplamiento inductivo. Otro factor importante es el entorno que contiene las líneas. Por ejemplo, una bandeja portacables o un conducto eléctrico metálico pueden contribuir a atenuar o propagar señales indeseadas más allá de la fuente inicial de la interferencia.

Para reducir el efecto del acoplamiento inductivo entre circuitos, es importante mantener la geometría del cable a lo largo de toda la longitud del canal, y guardar una separación adecuada entre circuitos. La intensidad del campo magnético es directamente proporcional a la corriente presente en el canal perturbador, e inversamente proporcional a la distancia entre las líneas.

Protección de los sistemas de cableado frente a la EMI

Las interferencias electromagnéticas pueden afectar a la calidad de los resultados de los sistemas de cableado estructurado, pero el blindaje contra la EMI es un método eficaz para evitarlo.

El blindaje es una de las técnicas utilizadas para proteger los sistemas de cableado de telecomunicaciones de la EMI. Al diseñar e instalar soluciones blindadas, la conexión a tierra y los enlaces deben planificarse cuidadosamente. Unos buenos enlaces y una conexión a tierra adecuada son obligatorios para garantizar la eficacia de los sistemas blindados.

En caso de que no exista suficiente separación entre los cables, es posible instalar bandejas blindadas AST SMART SHIELD para el cableado eléctrico (ver Figura 2).

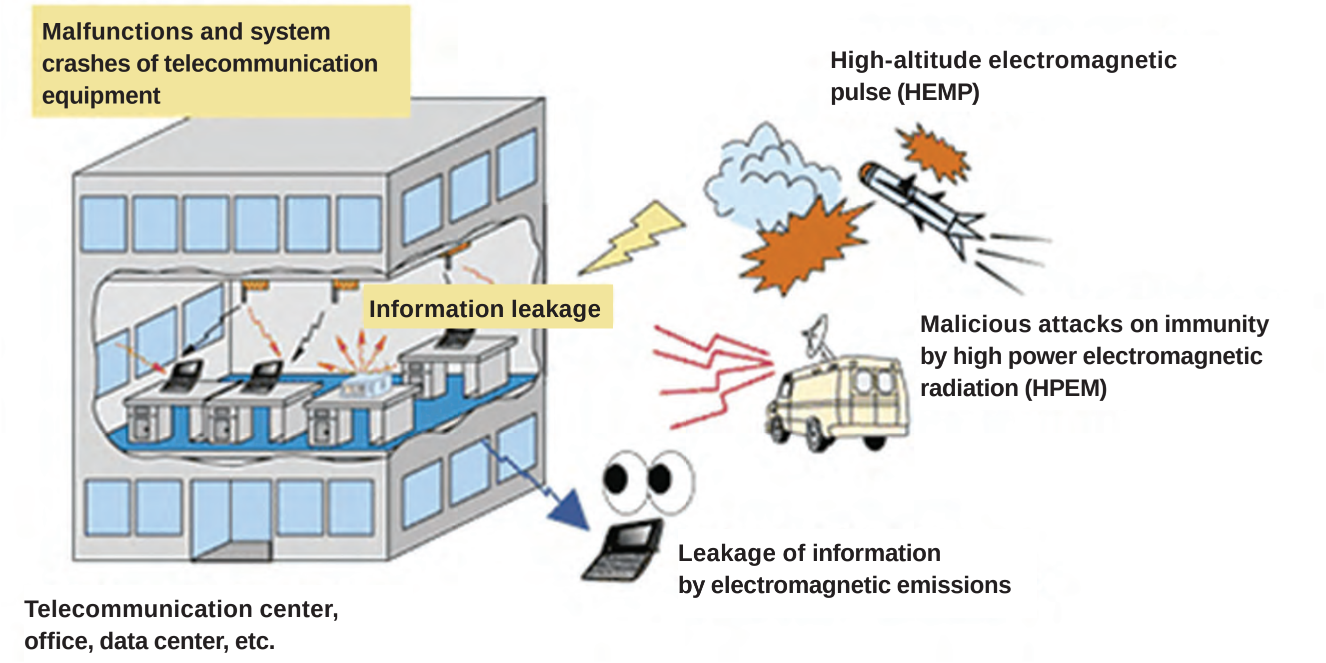

Figura 3. *Amenazas para la seguridad de la información derivadas de las emisiones electromagnéticas y para la inmunidad.*

Efectos en el hardware

La EMI de baja frecuencia causada por fuentes eléctricas puede producir efectos muy nocivos en el hardware, p. ej., un disco duro puede borrarse muy fácilmente solo con la acción de un campo magnético cercano.

Ataques de campos electromagnéticos

Otra razón para blindar son los ataques de campos electromagnéticos. La ciberfrontera más antigua es un ataque físico real o la amenaza de un ataque que inhabilite los centros de datos.Esto puede hacerse sin necesidad de que los saboteadores accedan al interior del centro de datos.

CAMPOS ELECTROMAGNÉTICOS: SEGURIDAD DE LA INFORMACIÓN

Se tiene constancia de que, en algunos casos, equipos informáticos (ITE) como ordenadores personales han filtrado información a través de ondas electromagnéticas no intencionadas, que emiten sobre todo las pantallas. En este documento, asumiremos que existen tres amenazas principales para la seguridad de la información derivadas de las emisiones electromagnéticas y para la inmunidad (Figura 3).

- Filtración de información por emisiones electromagnéticas: la información se obtiene a partir de una radiación electromagnética débil procedente de los equipos de telecomunicaciones (incluidos los terminales).
- Ataques intencionados a la inmunidad mediante ondas electromagnéticas de alta potencia
- Fallos o errores del sistema causados por exposición intencionada a ondas electromagnéticas de alta potencia

Entre los peligros de la filtración de información por emisiones electromagnéticas se incluyen:

-emanaciones no intencionadas que incluyen información en forma de imágenes, emitida desde las pantallas de equipos informáticos como PC, y desde impresoras láser, tarjetas de circuitos integrados y lectores de tarjetas, y

- explotación de información de bases de datos gestionadas por servidores de centros de datos financieros y de centros de infraestructura de clave pública (PKI).

Se tiene constancia de que, incluso si el nivel de dicha radiación electromagnética se encuentra por debajo de los límites establecidos por el Consejo de Control Voluntario de Interferencias (VCCI) para equipos informáticos, puede obtenerse información a partir de las señales débiles a cierta distancia. Como amenaza de ataques intencionados con ondas electromagnéticas de alta potencia contra la inmunidad, consideramos la irradiación intencional de equipos de telecomunicaciones con ondas electromagnéticas de alta potencia procedentes de transmisores de alta potencia, como radares (detección y medición de distancias por radio) y radiotransmisores alterados intencionadamente, hornos microondas, aparatos de alta tensión para defensa (p. ej., el táser) y generadores de sobrecorrientes para pruebas. Como primer paso para tomar medidas contra estos problemas de seguridad de la información electromagnética, se recomienda blindar el centro de datos convenientemente para conseguir una sala de alta seguridad blindada contra la radiación electromagnética.

Jordi Ferri dirige la División de Blindaje, Alimentación y Refrigeración de AST, una firma especializada en infraestructuras físicas modulares para TI, con varias patentes internacionales en distintas innovaciones y presencia en más de 20 países. Jordi cuenta con 13 años de experiencia en infraestructuras fundamentales y telecomunicaciones. Jordi es Ingeniero de Telecomunicaciones por la UPC, tiene un máster en Gestión de Proyectos de la Universidad de La Salle, en Barcelona, y un MBA de la ESADE Business School.

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122 **Wyładowanie elektrostatyczne człowiek-przedmiot metalowy według norm IEC, ANSI oraz MIL**

JANUSZ BARAN, Częstochowa, JAN SROKA, Politechnika Warszawska, IETiSIP

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Wyładowanie elektrostatyczne człowiek-przedmiot metalowy według norm IEC, ANSI oraz MIL

Analiza w dziedzinie częstotliwości

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Streszczenie—Definicja impulsu wyładowania elektrostatycznego osoby trzymającej przedmiot metalowy (human-metal ESD) jest różna w zależności od normy. Wymusza to różne pasma częstotliwości narzucane na stanowisko pomiarowe służące do kalibracji generatorów ESD. Oszacowanie wymaganego pasma częstotliwości przy pomocy odwrotności iloczynu czasu narastania impulsu i stałej π, słuszne dla ciągu impulsów trapezowych, daje w przypadku impulsu ESD niedoszacowanie. Autorzy proponują inne, wiarygodniejsze oszacowanie. Jest nim częstotliwość przecięcia wykresu widma gęstości mocy (Power Spectral Density) impulsu teoretycznego z widmem gęstości mocy szumów toru pomiarowego. Według tego oszacowania pasmo częstotliwości toru pomiarowego wymagane w normie IEC wystarcza do tego, aby tor pomiarowy nie wprowadzał zniekształceń mierzonego impulsu. Nie można tego powiedzieć o normie ANSI i w konskwencji o normie MIL.

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ABSTRACT

Human-Metal Electrostatic Discharge IEC, ANSI and MIL Standards: Frequency Considerations

Simulation of the human-metal electrostatic discharge alters slightly from one to another standard. In consequence setups with different frequency bandwidth are required for calibration of the ESD simulators. The rule of thumb valid for the trapezoidal sequence of pulses (reciprocal of the product of ϖ and rise time) for determining the bandwidth gives the underestimated result. The authors propose another sophisticated rule of thumb. It is crossing point of the power spectral densities (PSD) of the theoretical pulses with noise level of the measurement path. According to this rule, bandwidth required in the IEC standard is wide enough but it is to narrow in the ANSI standard and in consequence in the MIL-STD.

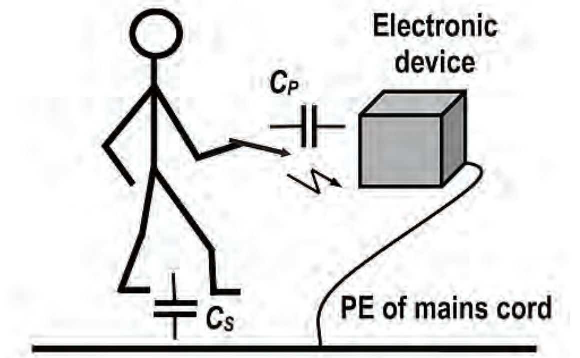
I. WSTEP

W artykule rozpatrywane jest pasmo częstotliwości wyładowania elektorstatycznego (ESD) osoby trzymającej przedmiot metalowy. Autorzy porównują opis tego zjawiska w trzech normach wydanych przez: International Electrotechnical Commission (IEC), American National Standards Institute (ANSI) i U.S. Department of Defense (MIL-STD).

Weryfikacja generatorów ESD polega na pomiarze w dziedzinie czasu prądu wyładowania dotykowego. Weryfikowane są następujące metryki impulsu: pierwsza wartość szczytowa, czas narastania, mierzony między 90%, a 10% wartości szczytowej oraz wartości prądu w 30 ns i 60 ns.

Informacja o paśmie częstotliwości prądu wyładowania

Temat ten był prezentowany na Europejskim Sympozjium EMC York'2011



Rys.1. *Model zjawiska wyładowanie elektrostatycznego [6].*

jest niezbędna przy doborze takich elementów toru pomiarowego, które zapewniają pomiar impulsu bez zniekształceń wprowadzanych przez tor.

O paśmie częstotliwości impulsu decyduje jego czas narastnia. Według normy IEC [4] wynosi on 0.8 ns. Według normy ANSI [1] musi być on mniejszy niż 0.4 ns[1]. Norma MIL-STD [2] odwołuje się do normy ANSI [1][2].

Pytanie o szerokość pasma częstotliwości niezbędną do wiarygodnego pomiaru impulsu w dziedzinie czasu jest ze wszechmiar uzasadnione. Trudno jednak oprzeć się wrażeniu, że w przeszłości odpowiedź na to pytanie była podyktowana dostępnością na rynku szybkich, cyfrowych oscyloskopów z pojedyńczym wyzwalaniem. Nadszedł już czas, aby ten komercyjny wyznacznik szerokości wymaganego pasma zastąpić innym, inżynierskim. Niniejszy artykuł jest podsumowaniem badań autorów w tym względzie.

II. MODEL ZJAWISKA

Jeżeli osoba, naładowana elektrycznością statyczną, trzymająca w dłoni ostry przedmiot metalowy, taki jak śrubokręt lub długopis zbliża szybko dłoń do urządzenia elektronicznego, może nastąpić wyładowanie elektrostatyczne (Rys.1).

Zgodnie z normą [4], idealny prąd wyładowania można opisać analityczne następującym wzorem:

$$i(t)=\frac{I_1}{k_1}\cdot\frac{\left(\frac{t}{\tau_1}\right)^n}{1+\left(\frac{t}{\tau_1}\right)^n}\cdot e^{\frac{-t}{\tau_2}}+\frac{I_2}{k_2}\cdot\frac{\left(\frac{t}{\tau_3}\right)^n}{1+\left(\frac{t}{\tau_3}\right)^n}\cdot e^{\frac{-t}{\tau_4}}, \quad (1)$$

$$k_1=\exp\left[-\frac{\tau_1}{\tau_2}\cdot\left(\frac{n\cdot\tau_2}{\tau_1}\right)^{1/n}\right],\quad k_2=\exp\left[-\frac{\tau_3}{\tau_4}\cdot\left(\frac{n\cdot\tau_4}{\tau_3}\right)^{1/n}\right]$$

Parametry występujące we wzorze (1) zebrane są w tabeli I.

Wartości prądu I1 I2 są podane dla napięcia statycznego 4kV. Impulsowi temu przyporządkujemy nazwę znamionowego impulsu IEC.

W zjawisku wyładowania elektrostatycznego można

τ_1 [ns]	τ_2 [ns]	τ_3 [ns]	τ_4 [ns]	I_1 [A]	I_2 [A]	n
1.1	2.0	12.0	37.0	16.6	9.3	1.8

Tabela 1. *Parametry znamionowego impulsi IEC.*

wyróżnić dwa elementy. Składnik szybkozmienny, wyrażony pierwszym składnikiem wzoru (1) i czerwoną, linią przerywaną na Rys.2.a, opisuje przebicie łukowe małej pojemności Cp między ostrzem metalowego przedmiotu, a urządzeniem. Składnik wolnozmienny, wyrażony drugim składnikiem wzoru (1) oraz niebieską kropkowaną linią na Rys. 2.a, odpowiada za rozładowanie prądem przesunięcia dużej pojemności Cs ciała osoby względem podłogi. Czas narastania znamionowego impulsu IEC wynosi 0,8ns.

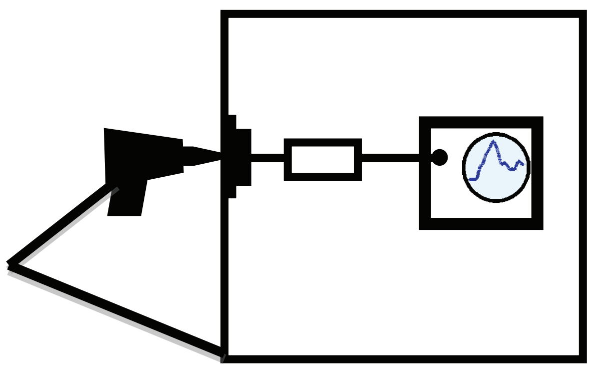
W artykule [6] autorzy użyli widma gęstości mocy (Power Spectral Density) do przedstawienia impulsu wyładowania elektrostatycznego w dziedzinie częstotliwości. PSD sygnału jest kwadratem amplitudy jego transformaty Fouriera. Dla spróbkowanego sygnału x(n) PSD może być przedstawione następująco:

$$P_{xx}(\omega)=\frac{1}{N}\left|\sum_{n=0}^{N-1}x(n)e^{-j\frac{\omega}{f_s}n}\right|^2=\frac{1}{N}X(\omega)X^*(\omega) \quad (2)$$

gdzie X(ω) jest N-próbkową szybką transformatą Fouriera sygnału x(n), X*(ω) jest sprzężeniem zespolonym X(ω), a fs jest częstotliwością próbkowania. Autorzy wybrali PSD, ponieważ jest to wielkość najczęściej stosowana w analizie statystycznej sygnałów w dziedzinie częstotliwości. PSD jest dodatnią i rzeczywistą funkcją, którą można łatwo zinterpretować jako moc sygnału na jednostkę częstotliwości.

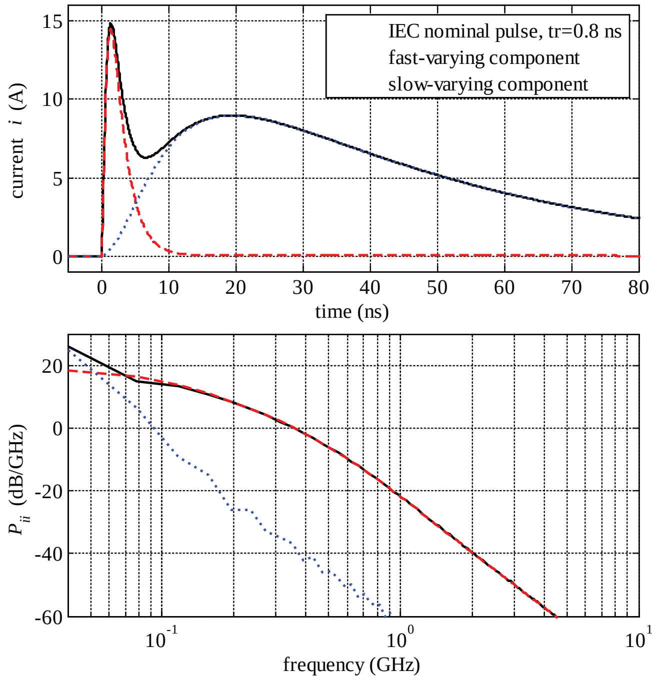
Estymaty PSD na Rys. 2.b i w dalszej części artykułu były wyznaczone metodą Welcha (funkcja pwelch w Matlab Signal Processing Toolbox). Liczba próbek N=2000, dla zarejestrowanego czasu 100ns oraz fs=20GHz, była podzielona na 4 bądź 8 nakładających się segmentów. Na segmenty te nałożono okna Hanning'a w celu zredukowania efektu nieciągłości na brzegach, a następnie uśredniono.

PSD znamionowego impulse IEC oraz jego szybki i wolny składnik są przedstawione na Rys. 2.b.



***Rys.3. Stanowisko** pomiarowe do weryfikacji generatorów ESD.*

1. W normie ANSI [1] jest również mowa o tzw. wyładowaniu „chair discharge" do ruchomych, metalowych mebli takich jak wózek czy krzesło. Czas narastnia impulsu w takim wyładowaniu jest większy niż 1ns. Z tego względu wyładowanie to nie jest istotne w niniejszych rozważaniach.
2. Istnieje inna norma MIL-STD [3] traktując o badaniu odporności na wyładowania elektrostatyczne elementów elektronicznych w stanie bez zasilania. Czas narastania impulsu w takim wyładowaniu jest większy niż 1ns. Z tego względu wyładowanie to nie jest istotne w niniejszych rozważaniach.



***Rys.2.** Znamionowy impuls IEC dla 4kV i jego składniki: a) w dziedzinie czasu [6], b) widmo gęstości mocy (PSD).*

III. WERYFIKACJA GENERATORÓW ESD

Stanowiska do weryfikacji według normy [1] oraz [4] są identyczne. Weryfikowany jest prąd wyładowania w trybie dotykowym.

W skład stanowiska wchodzi tarcza wyładowcza (target), tłumik, kabel koncentryczny oraz szybki oscyloskop cyfrowy z pojedyńczym wyzwalaniem (Rys. 3).

Najbardziej krytycznymi elementami stanowiska, ze względu na wiarygodny pomiar metryk impulsu, są tarcza oraz oscyloskop. Ich pasma przenoszenia muszą być większe niż pasmo częstotliwości samego zjawiska wyładowania. Wtedy w pomiarze impulsu można wykorzystać niskoczęstotliwościowy model toru pomiarowego. W przeciwnym wypadku trzeba uwzględnić zniekształcenia impulsu przez tor pomiarowy. Ma to wpływ na sposób przeliczania wskazania oscyloskopu na prąd rozładowania oraz na szacowanie niepewności pomiaru.

IV. TOLERANCJE PARAMETRÓW IMPULSU

A. Impuls IEC

Tolerancja czasu narastania impulsu w normie [4] wynosi ±25%. Oznacza to, że najszybszy i najwolniejszy dopuszczalny impuls ma czas narastania odpowiednio 0.6 ns i 1.0 ns. Nazwiemy je impulsem szybkim i wolnym. Można je przedstawić wzorem (1) ze zmodyfikowanymi parametrami τ_1 oraz I_1 , tzn. odpowiednio τ_1=0.67 ns I_1=10.2 A oraz τ_1=1.6ns i I_1=18.5A. Pozostałe parametry są takie jak w Tabeli I.

Prąd szczytowy [A]	*Czas narastania [ns]*	*Prąd po 30ns [A]*	*Prąd po 60ns [A]*
15 ± 15%	0.8 ± 25%	8 ± 30%	4 ± 30%

***Tabela II.** Metryki znamionowego impulsu IEC dla napięcia statycznego 4 kV[3] [4]*

B. Impuls ANSI

Prąd szczytowy [A]	*Czas narastania [ns]*	*Prąd po 30ns [A]*	*Prąd po 60ns [A]*
24 ± 10%	<0.4	13 ± 30%	6 ± 30%

***Tabela III.** Metryki wolnego impulsu ANSI dla napięcia statycznego 4 kV.*

W normie [1] impuls jest zdefiniowany w inny sposób. Jego czas narastania nie może być większy niż 0.4 ns. Nazwiemy go wolnym impulsem ANSI. Impuls ten można przedstawić wzorem (1) z parametrami zebranymi w tabeli IV

τ_1 [ns]	τ_2 [ns]	τ_3 [ns]	τ_4 [ns]	I_1 [A]	I_2 [A]	n
0.38	1.7	4.0	60.0	24.7	10.44	3.0

***Tabela IV.** Parametery wolnego impulsu ANSI.*

Typowy impuls ANSI, z czasem narastania 0.3 ns można przedstawić wzorem (1) ze zmienionymi wartościami τ_1=0.26 ns i I_1=21.6A oraz z pozostalymi parametrami z tabeli IV.

V. SZACOWANIE WYMAGANEJ SZEROKOŚCI PASMA CZĘSTOTLIWOŚCI

W celu porównania czterech rozpatrywanych impulsów tzn. wolnego i szbkiego impulsi IEC, oraz wolnego i typowego impulsu ANSI, znormalizowaliśmy je ze względu na wartość szczytową. Znormalizowane impulsy mają wartość szczytową równą jedności. Są one przedstawione w dziedzinie czasu na Rys. 4.a.

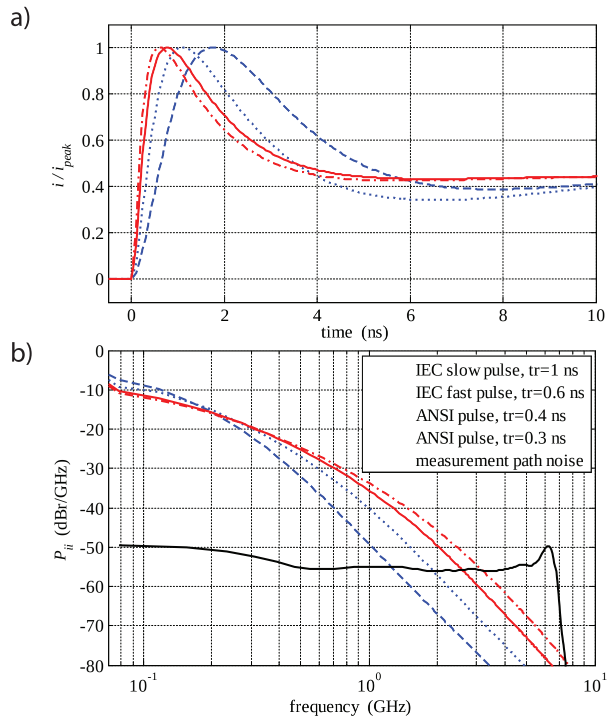
W artykule [6] autorzy przeliczyli PSD danych pomiarowych z badań porównawczych, zaczerpniętych z pracy [5]. Badania porónawcze przeprowadzone na stanowisku z oscyloskopem o paśmie analogowym wynoszącym 6 GHz i gęstości próbkowania 20 GS/s. Tarcza wyładowcza miała płaską charakterystykę częstotliwościową w zakresie do 4 GHz, zgodnie z wymaganiami normy [4]. Stanowisko pomiarowe o takim paśmie przenoszenia jest wystarczające dla pomiaru impulsu prądu bez zniekształceń toru. Nowatorskim w pracy [6] było przeliczenia PSD szumów toru pomiarowego wraz z generatorem ESD.

Proponujemy użyć częstotliwości, przy której przecinają się wykresy PSD impulsu i szumów jako prostego kryterium na minimalne wymagane pasmo toru pomiarowego. Częstotliwości te zaznaczone są na Rys. 4.b owalami. Taki wybór jest uzasadniony, ponieważ na prawo od punktu przecięcia moc impulsu jest mniejsza od mocy szumów. Jak wykazano w artykule [6], pasmo „gadkiego" impulsu rzeczywistego jest mniej więcej takie samo jak pasmo impulsu teoretycznego.

	Pochodzenie impulsu			
	IEC		***ANSI***	
Czas narastania [ns]	1	0.6	0.4	0.3
Pasmo [GHz]	1.3	2.0	2.6	3.1

***Tabela V.** Wymagania szerokości pasma w zależności od czasu narastania impulsu.*

3. W normie [4] zdefiniowane są cztery różne poziomy narażeń. W artykule wykorzystano przykładowo poziom 2 z napięciem statycznym 4 kV.



Rys.4. *Impuls znormalizowany w dziedzinie czasu (t_r – czas narastania) a), i w dziedzinie częstotliwości wraz z PDS szumów toru pomiarowego b).*

VI. WNIOSKI

Czas narastania impulse, zmieniający się w zależności od stosowanej normy, implikuje różne wymagania dotyczące pasma częstotliwości stanowisk weryfikacyjnych. Dotyczy to w pierwszym rzędzie tarczy wyładowczej i oscyloskopu.

Jak wykazano w pracy [6], inżynierska metoda szacowania pasma jako odwrotności iloczynu czasu narastania impulsu i stałej π, $f_B=1/(\pi \cdot t_r)$ prowadzi w przypadku impulsu ESD do pasma niedoszacowanego. Autorzy proponują inne, wiarygodniejsze oszacowanie wynikające z porównania PSD szumów toru pomiarowego i PSD impulsu. Jest to częstotliwośc, dla której poziom PSD impulsu opada poniżej poziomu PSD szumów.

W artykule pominięto impuls wyładowania do ruchomych, metalowych mebli, zdefiniwane w normie [1] oraz impuls do badania elementów elektroniki w stanie beznapięciowym, zdefiniowany w normie [3], gdyż są one o wiele wolniejsze i z tego względu nieistotne w tych rozważaniach.

Rezultaty zebrane w Tabeli V pokazują, że pasmo oscyloskopu wymagane w normie [4] (nie mniej niż 2 GHz), jest wystarczające dla impulsu IEC. Inaczej jest z normą [1], w której 1GHz pasmo socyloskopu jest za małe na pomiar impulsu ANSI bez zniekształceń. Ta uwaga dotyczy również normy MIL [2].

Korzyść ze znajomości pasma częstotliwości wyładowania ESD jest oczywista. Jeżeli pasmo stanowiska kalibracyjnego jest od niego większe, wtedy przeliczenie wskazania oscyloskopu na prąd wyładowania może być po prostu przemnożeniem przez niezależny od częstotliwości współczynnik. Ponadto szacowanie niepewności pomiaru jest bardzo proste. Jeżeli pasmo wyładowania jest porównywalne z pasmem stanowiska pomiarowego, wtedy zarówno przeliczanie wskazania oscyloskopu na prąd wyładowania jak i szacowanie niepewności pomiaru zależą od częstotliwości.

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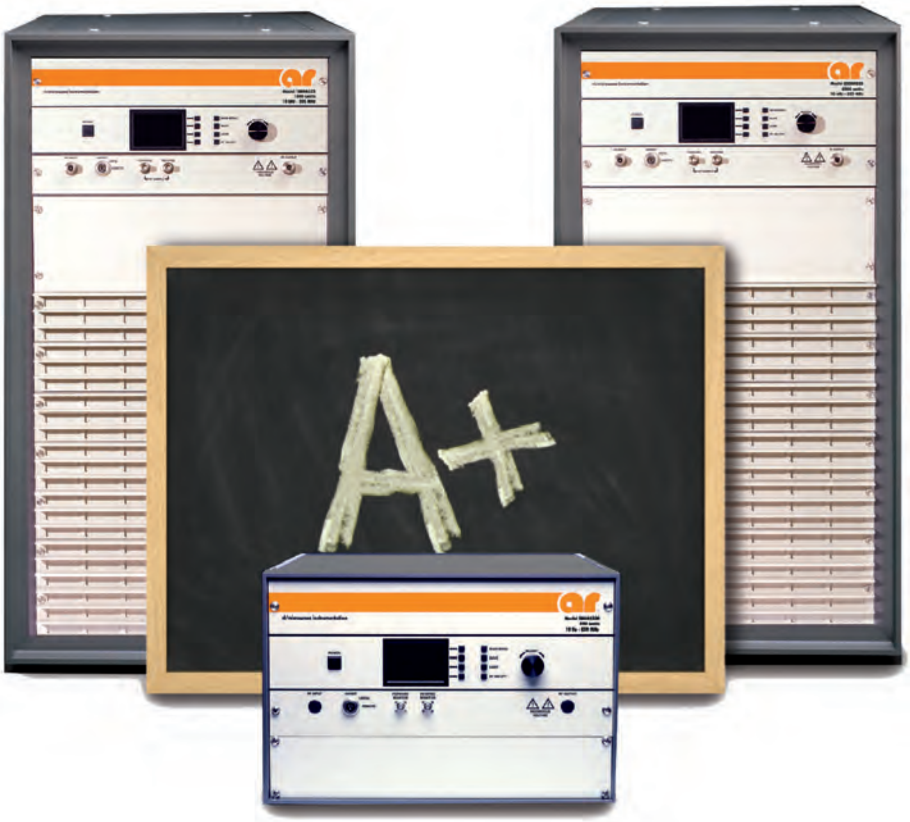

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ABSTRACT

Swiss Experimental Station on Lightning Research at Mount Säntis

Due to a variety of factors, the adequacy of the present statistical lightning current data, which are used extensively by researchers and engineers today, has become questionable and there is an pressing need to obtain high-quality, directly-measured lightning data.

To address this need, the authors have set up a new experimental station for the measurement of lightning currents on the Säntis Tower, a unique structure to collect experimental information related to the lightning discharge. A multiyear analysis on the lightning incidence to several towers in various places in Switzerland resulted in the choice of the Säntis tower, which is struck by lightning about 100 times a year.

The new station has been instrumented using advanced and modern equipment including remote monitoring and control capabilities for an accurate measurement of lightning current parameters.

Das Problem der Entstehung elektromagnetischer Störungen durch Blitze hat in den letzten Jahren verstärkt zu gründlichen Überlegungen geführt, weil ihr Einfluss auf zunehmend komplexere, elektrische Stromversorgungs- und Telekommunikationsnetzwerke und auf immer empfindlichere elektronische Geräte zunimmt.[1]. Blitze sind tatsächlich die wichtigste Ursache für transiente Störsignale, Defekte und Ausfälle bei der elektrischen Stromübertragung und –verteilung sowie die Hauptursache elektromagnetischer Interferenzen, welche alle elektronischen und Telekommunikationssysteme beeinträchtigen können (z. B. [2]).

Unsere gegenwärtigen Kenntnisse der Stromparameter von Blitzen stammen im Wesentlichen von direkten Messungen, die mittels entsprechend ausgerüsteter Türme gewonnen wurden [3]. Die durch das Team von Prof. Berger aufgezeichneten, umfangreichen, experimentellen Daten aus den 70-er Jahren auf den beiden Fernmeldetürmen des Monte San Salvatore im Tessin führten zu einer vollständigen statistischen Charakterisierung der Stromparameter von Blitzen [4]. Allerdings litten die von Prof. Berger und seinem Team erhaltenen Ergebnisse unter den technischen Beschränkungen der damals verfügbaren Messgeräte, insbesondere wegen der unzureichenden Bandbreite einiger weniger hundert kHz, die nicht genügten, das Spektrum von Blitzströmen aufzuzeichnen, welche für Frequenzen bis zu einigen MHz eine erhebliche Energie aufweisen [5]. Aktuelle experimentelle Beobachtungen und theoretische Analysen legen außerdem nahe, dass die Stromdaten von Blitzen, welche von Fernmeldetürmen erhalten wurden, auch von der Anwesenheit der Türme selbst beeinflusst werden können [3, 6]. Infolgedessen wird die Eignung der

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Abbildung 1. *Säntis Tower.*

statistischen Daten von Blitzströmen, welche heute von Forschern und Ingenieuren ausgiebig verwendet werden, infrage gestellt und es gibt einen hohen Bedarf, hochqualitative, direkt gemessene Blitzdaten zu gewinnen.

Um diesen Anforderungen gerecht zu werden, haben wir eine neue Experimentalstation für die Messung von Blitzströmen auf dem Säntis-Turm eingerichtet (siehe Abb. 1). Dieser Turm ist speziell zum Sammeln von experimentellen Informationen über die Blitzentladung eingerichtet. Eine mehrjährige Analyse der Häufigkeit des Einschlags von Blitzen in verschiedenen Türmen an diversen Orten der Schweiz führte zur Auswahl des Säntis-Turms, der etwa hundertmal pro Jahr von Blitzen getroffen wird.

Die neue Station wurde mit fortschrittlichen modernen Ausrüstungen ausgestattet, zu denen auch Fernüberwachungs- und Prüfgeräte für eine korrekte Messung der Stromparameter von Blitzen gehören [7].

DAS MESSSYSTEM

Der Blitzstrom wird in zwei verschiedenen Höhen gemessen, bei 24 m und 82 m.

An der unteren Position haben wir zwei Rogowski-Spulen mit unterschiedlicher Empfindlichkeit installiert, jede mit ihrem analogen Integrator, mit dem die aktuelle Wellenform gewonnen wird. Diese Rogowski-Sensoren wurden von PEM Inc. bzw. ROCOIL hergestellt.

Zwei Sensoren wurden in einer Höhe von 82 m installiert. Der erste ist eine Rogowski-Spule (PEM Inc.) mit ihrem analogen Integrator. Der zweite in dieser Höhe verwendete Sensor ist ein speziell zur Messung der Ableitung des Blitzstroms entwickelter Magnetschleifensensor (B-Dot) [8].

Abbildung 2 zeigt eine schematische Darstellung des aktuellen Strommesssytems. Die analogen Ausgänge der Sensoren werden mittels optischer 12-Bit A/D – D/A-Verbindungen mit einer Gesamtbandbreite von Gleichstrom bis 25 MHz an eine Digitalisiereinheit weitergeleitet.

Zustand und Einstellungen jedes Sensor-Paars können mit dem jeweiligen mittels National Instruments Compact-RIO-Modulen über Faseroptik auf Basis von 100Base-FX Ethernet verbundenen Steuerungssystem überwacht und eingestellt werden. Ein solches System ermöglicht die Fernwartung, Überwachung und Steuerung der gesamten Messkette über das Internet.

Der Steuerungsraum, einige zehn Meter von dem Turmsockel entfernt, beherbergt einen lokalen Server, auf dem Überwachungs- und Speicherabläufe ausgeführt werden, und eine mit dem Internet über einen Router und einen Standard-ADSL-Anschluss verbundene Front-End-Station. Weitere Details zum installierten Messsystem finden Sie unter [8, 9].

Beispiel einer gemessenen Strom-Wellenform, die zu einem positiven Blitzschlag gehört

Obwohl positive Blitzschläge weniger häufig auftreten als negative, sind diese aus verschiedenen Gründen von besonderem Interesse, vor allem weil sie sich durch hohe Spitzenströme und hohe Impulsladungen auszeichnen [10]. Infolgedessen sind sie von besonderer Bedeutung für die Entwickler von Blitzschutzsystemen für Einrichtungen wie Windkraftanlagen und Fernmeldetürme. Das Phänomen ist noch nicht ganz klar, aber es wird angenommen, dass positive Blitze mit Ladungsansammlungen in den oberen Bereichen von Gewitterwolken zusammenhängen, und es scheint, dass es mit Blitzentladungen zusammenhängt, welche über den Wolken in der mittleren Atmosphäre auftreten [11].

Allerdings sind experimentelle Daten zu positiven Blitzen sehr beschränkt verfügbar und werden oft kontrovers diskutiert [10]. Es ist insofern ein besseres Verständnis der positiven

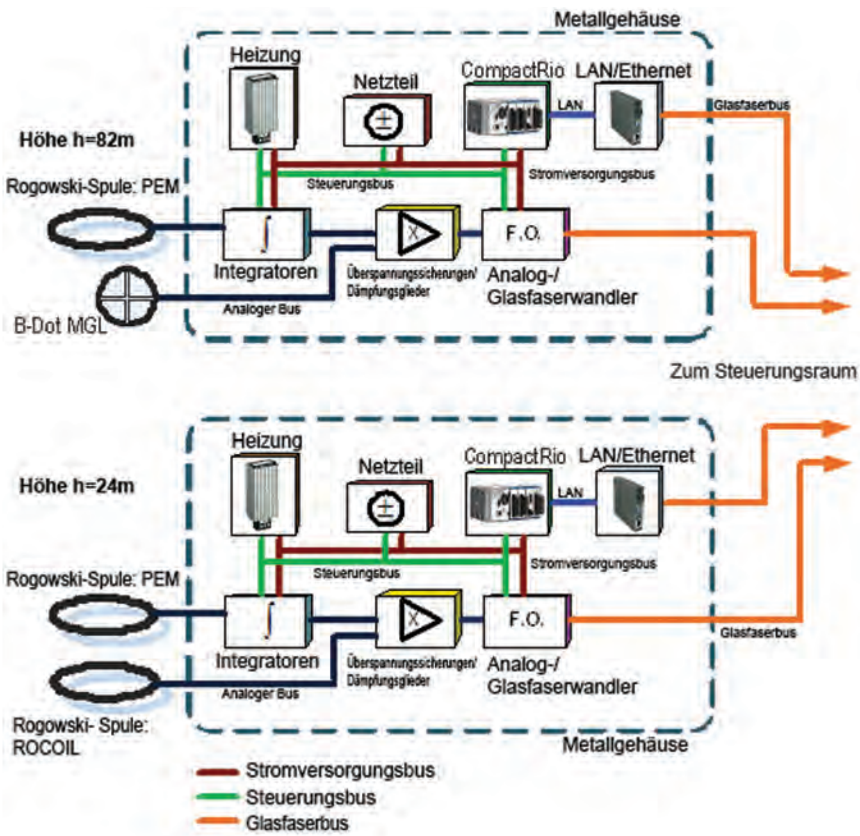

Abbildung 2: *Schaltung des Strommesssystems des Säntis-Turms. (Angepasst nach [9])*

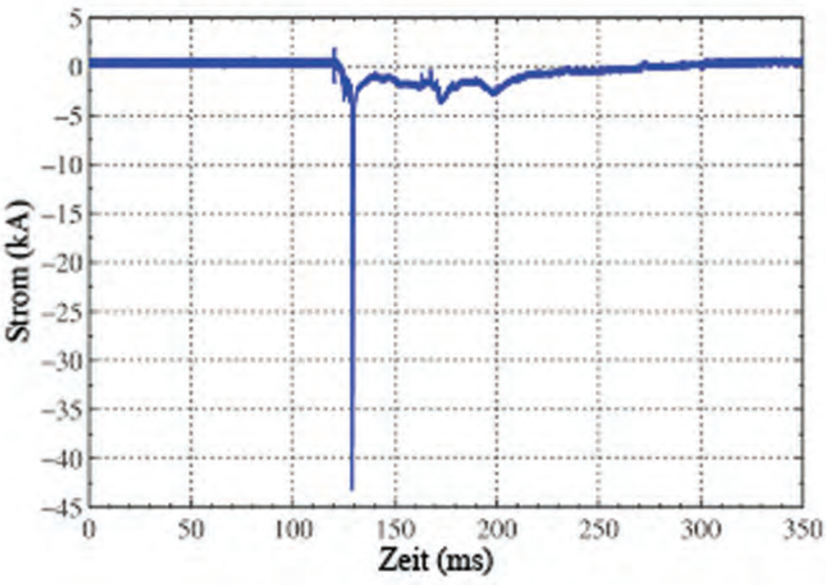

***Abbildung 3.** Strom-Wellenform eines positiven Blitzes, der am 21. Juli 2010 um 19:05 Uhr aufgezeichnet wurde.*

Blitze erforderlich, um Mechanismen der Aufladung von Wolken, Ladungsverteilungen in Gewitterwolken, Blitzentladungen in der oberen und mittleren Atmosphäre sowie den besseren Blitzschutz von Systemen zu studieren [10].

Etwa 20% der im Jahre 2010 aufgezeichneten Blitze auf dem Säntis-Turm hatten eine positive Polarität, alle wurden im Sommer aufgezeichnet [12]. Der Anteil ist wesentlich höher als der in anderen Studien während der Sommermonate beobachtete, der dort zwischen 3% und 6,5% liegt [10]. Alle beobachteten Blitze waren vom Typ Aufwärts (sie wurden von Fangentladungen vom Turm aus initialisiert).

Abbildung 3 zeigt die Grafik eines Stroms mit dem zugehörigen positiven Blitz. Der Strom zeichnet sich durch einen anfangs langsam ansteigenden Abschnitt aus, der einige Millisekunden anhält und dem ein lang anhaltender Strom folgt [12]. Der Spitzenstrom beträgt 43 kA und seine Gesamtdauer ist etwa 150 ms. Die zum Boden übertragene Gesamtladung entspricht etwa 290 C.

Es ist vorgesehen, dass die Einrichtung außerhalb der Rahmenbedingungen dieses Projektes betriebsbereit sein wird und dass sie von der EPFL und der HEIG-VD sowie weiteren internationalen Partner genutzt wird, um Daten über Blitze zu erhalten.

Dieses Projekt wurde vom Staatssekretariat für Bildung und Forschung, vom Schweizerischen Nationalfonds und von der Europäischen COST-Aktion P18 unterstützt.

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Power Quality and EMC in Smart Grid

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Smart Grid is increasingly seen as a means to facilitate climate friendly renewable energy sources (renewables) and to enable efficient use of electricity. For example, modern electrical networks can link wind- and solar power with electric cars. A consequence of Smart Grid is a drastic increase in use of electronics in the power system. This makes the satisfactory function of electrical and electronic equipment vital for realization of a robust Smart Grid. This paper focuses on the satisfactory function of equipment for Smart Grid with respect to electromagnetic disturbances, i.e. EMC – Electromagnetic Compatibility including Power Quality. Finally, a framework for the apportioning of responsibilities between network operators and the parties being responsible for the connection of equipment is proposed.

Keywords — Power Quality, Voltage Quality, EMC, Electromagnetic Compatibility, Smart Grid, Smart Grids, SmartGrid, SmartGrids, Renewables

I. SMART GRID – ENABLING GREEN ENERGY

A. European Union Outlook

The European Union, EU, is committed to reducing its overall carbon dioxide emissions to at least 20 % below 1990 levels by 2020. It has also set itself the target of increasing the share of renewables in energy use to 20 % by 2020 [1]. Electricity is obviously of great importance for renewables in terms of e.g. solar and wind power generation, but also for transformation of the car fleet into electrical propulsion.

The European Union SmartGrids Technology Platform vision and strategy for Europe's Electricity Networks of the Future was launched in 2006 [2]. The Smart Grid vision is aiming for "new products, processes and services, improving industrial efficiency and use of cleaner energy resources while providing a competitive edge for Europe in the global market place". Furthermore, Smart Grid is seen as an important element for achieving the largest knowledge-

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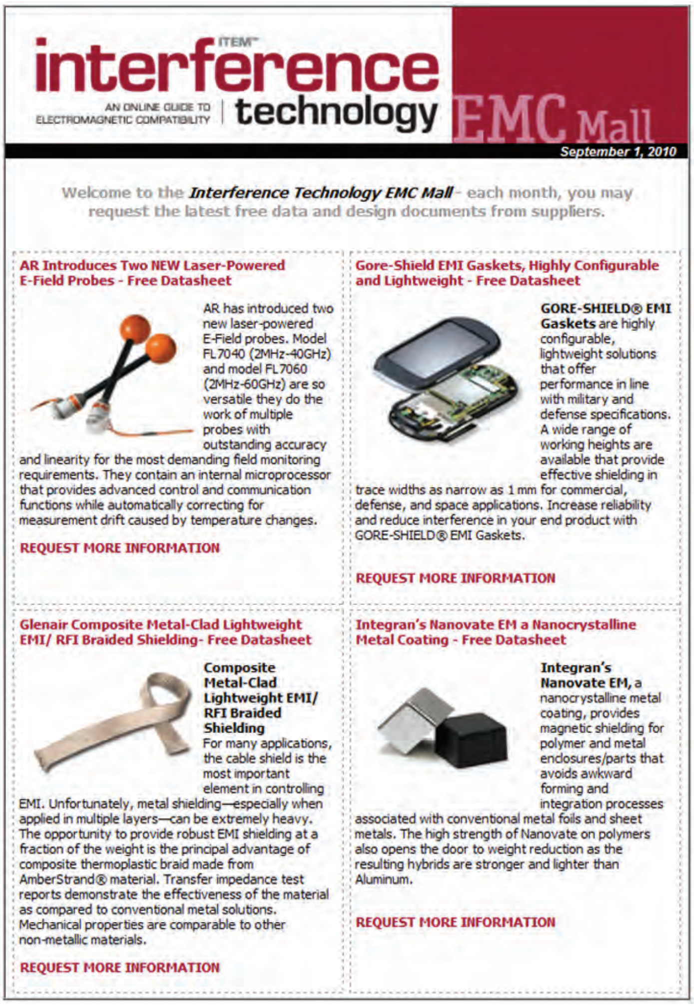
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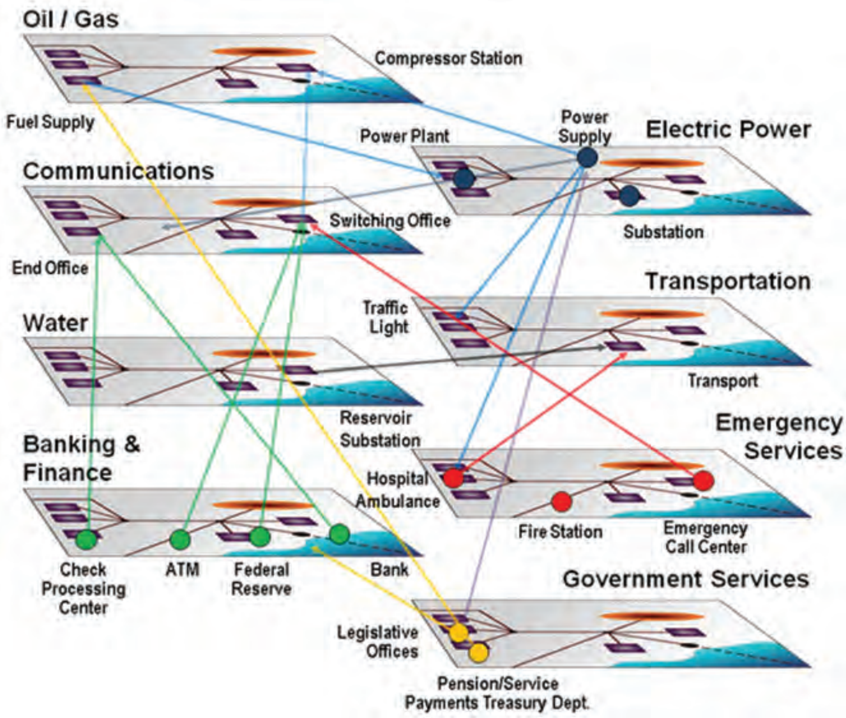

Figure 1. A conceptual illustration of the interconnectedness of elements contained within each critical infrastructure [9].

based economy in the world and also helping to improve daily life of ordinary citizen.

This paper was invited and presented at the IEEE Sponsored Conference EPQU'09 – Electrical Power Quality and Utilisation Conference 2009 in Lodz, Poland, 15-17 September 2009.

Clearly, the Smart Grid vision is highly important as a means to support the EU environmental as well as economical ambitions. Within Smart Grid there are a number of technologies involved: renewables such as solar and wind, electric cars, and transmission system power flow control equipment. Also it can be expected an increased use of digital communication and control including smart metering and advanced grid wide area real-time monitoring.

One example of Smart Grid application is the possibility of charging electric car batteries during hours with a surplus of low cost renewable energy. When electricity price is high, electric cars may feed energy back to the electrical network. This can be achieved using a continuous transfer of electricity price information with automatic control of the power flow to and from the electric cars. The term Smart Grid is then enabling a Smart Electrical System – the entire power system with networks as well as connected equipment converting between electrical energy and other forms of useful energy.

B. United States of America Outlook

The Obama administration recently announced availability of $ 3,9 Billion to invest in Smart Grid technologies and electric transmission infrastructure [3]. The initiative is part of the recovery act related to the financial crisis and funding is made to create jobs and to help modernize nation's electric grid.

In an earlier Smart Grid announcement from the Obama administration [4], it was stated that "Before it can be constructed, however, there needs to be agreement on standards for the devices that will connect the grid".

C. International Standardisation Activities

According to IEC – International Electrotechnical Commission, "Smart Grid is the concept of modernizing the electric grid. The Smart Grid is integrating the electrical and information technologies in-between any point of Generation and any point of Consumption." [5]. This definition was an outcome of a meeting in late April 2009 gathering experts from a broad range of countries and expertise in a strategic group for Smart Grid. The strategic group identified 19 IEC technical committees with published international standards that play a role in the Smart Grid structure. Recently IEC opened a Smart Grid web portal [6]. Standardization is indeed a vital part of realization of Smart Grid technologies.

The IEEE – Institute of Electrical and Electronics Engineers is also ac-

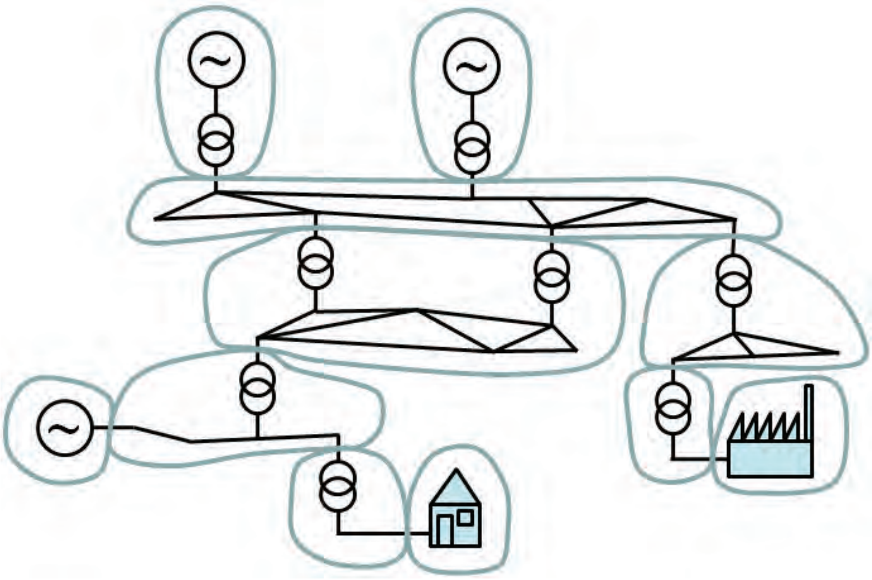

Figure 2. Power system made up of fixed installations.

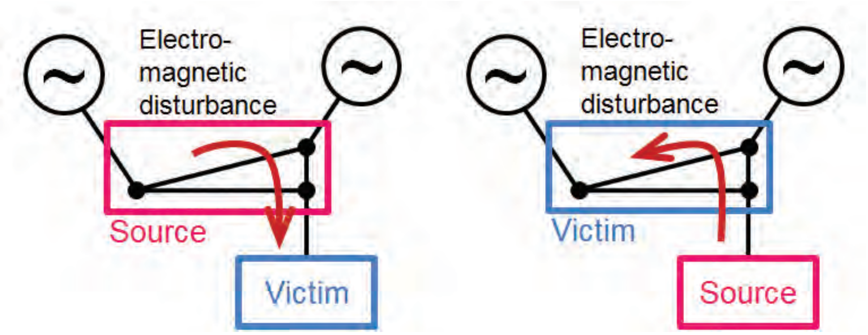

Figure 3. Propagation of an electromagnetic disturbance between the network and equipment connected to the network.

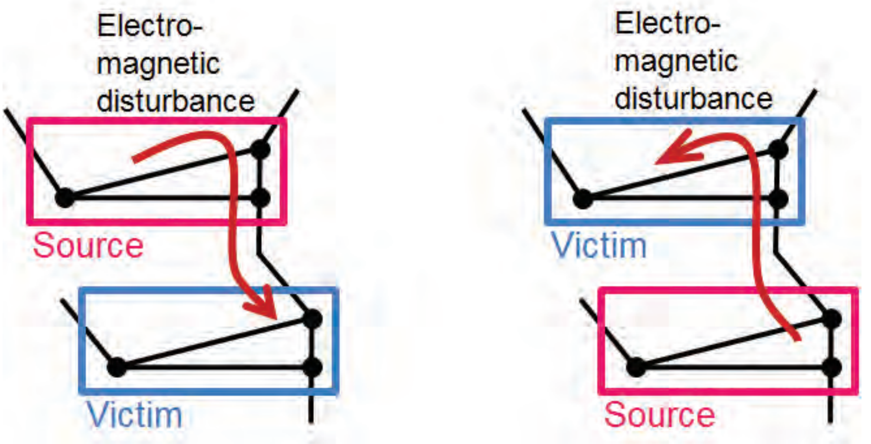

Figure 4. Propagation of an electromagnetic disturbance between networks.

tive in the development of Smart Grid technologies [7].

II. SMART GRID ROBUSTNESS AND VULNERABILITY

Smart Grid opens up the opportunity for an evermore sophisticated electrical system containing lots of electronic devices both controlling the power flow itself, so called power electronics, and electronics controlling the power electronics and other devices. A power system based on Smart Grid has naturally a tremendous number of computers for information exchange and control.

The electricity dependency of our society has been and is steadily increasing. Smart Grid will impose electricity even more as a fundamental of modern civilization, at least technically. Virtually no essential societal infrastructure can function properly without electricity. Considering that importance, vulnerability of Smart Grid is a most relevant concern [8].

Under the authority of the United States (U.S.) Congress, a Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack has assessed the threat of intentional electromagnetic interference – IEMI [9]. The electrical power supply system is concluded to be a highly critical infrastructure for our society, see Fig. 1.

Out of seven characteristics, the U.S. Department of Energy's (DOE's) National Energy Technology Laboratory (NETL) states that the "Modern Grid" will have the ability to Resist Attack [10]. Another characteristic listed is that it Self-Heals:

- Self-Heals
- Motivates and Includes the Consumer
- Resists Attack
- Provides Power Quality for 21st Century Needs
- Accommodates All Generation and Storage Options
- Enables Markets
- Optimizes Assets and Operates Efficiently

Also the European Union Smart Grid Technology Platform [11] addresses security saying Europe's electricity networks must be "Reliable: assuring and improving security and quality of supply, consistent with the demands of the digital age with resilience to hazards and uncertainties".

Example of Smart Grid on a large scale is the initiative aiming for large-scale solar electrical energy from the Sahara desert up to Europe [12]. Robustness and vulnerability are naturally to be considered for such a large system [13].

Consequently, while the importance and complexity of the electrical power system is increasing, it is reasonable to require a higher robustness in days ahead.

III. EMC AND VOLTAGE QUALITY IN SMART GRID

A. EMC – Electromagnetic Compatibility

The physical characteristic of Smart Grids technologies with an increased incorporation of potentially sensitive electronics has naturally implications with respect to Electromagnetic Compatibility – EMC. The satisfactory function of electrical and electronic equipment with respect to electromagnetic disturbances is the aim of EMC. The IEC – International Electrotechnical Commission [14] defines Electromagnetic Compatibility as "the ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment". In the European Union EMC Directive [15] "equipment and system" of IEC corresponds to the EU term equipment, where equipment is subdivided into apparatus and fixed installation. See also [16].

Electromagnetic disturbances may be radiated or conducted and electrical/electronic equipment potentially sensitive to any or to both of these types of disturbances. Disturbances are in turn subdivided into a number of low and high frequency phenomena, where IEC defines low frequency up to and including 9 kilohertz.

B. Relation between Voltage Quality and EMC

Both IEC and EU define EMC to cover electromagnetic phenomena from zero hertz. Furthermore the IEC defines the following principal electromagnetic conducted phenomena [17]:

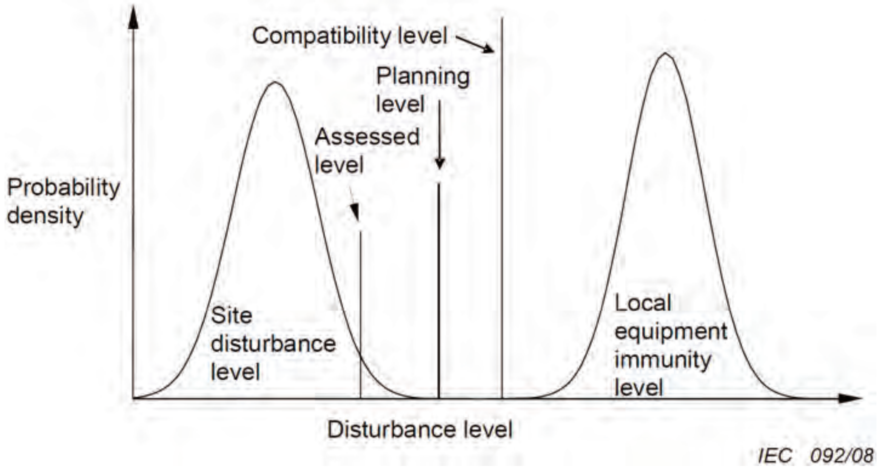

Figure 5. Voltage quality concepts with time statistics in a site within a network [28].

Conducted low-frequency phenomena:

- Harmonics, interharmonics
- Signals superimposed on power lines
- Voltage fluctuations
- Voltage dips and interruptions
- Voltage unbalance
- Power frequency variations
- Induced low frequency voltages
- DC component in AC networks

Conducted high-frequency phenomena:

- Induced voltages or currents
- Unidirectional transients
- Oscillatory transients

Voltage Quality can be seen as an umbrella name for deviations from ideal voltage conditions at a site in a network [18]. This is equivalent to electromagnetic disturbances of the voltage at the site. With no disturbances the Voltage Quality is perfect, otherwise not. Electromagnetic disturbances are defined as electromagnetic phenomena that may degrade the performance of equipment [19].

Adequate Voltage Quality contributes to the satisfactory function of electrical and electronic equipment in terms of Electromagnetic Compatibility. Electromagnetic disturbances as imperfect Voltage Quality at a site in a network can be regarded as electromagnetic emission from the network [20]. According to the EMC Directive network is equipment. This is in line with the original name of IEC Technical Committee (TC) 77 which was "EMC between electrical equipment including networks"; now simply EMC [21].

The technical function of an electrical network is electromagnetic energy transfer with adequate Voltage Quality at its sites, i.e. at connection points. Similarly, immunity of an electrical network can be seen as the ability to absorb disturbing emissions such as distorted current with adequate Voltage Quality while transferring energy, i.e. with satisfactory function. For e.g. low order harmonics and voltage fluctuations, network strength is relevant for network immunity [22], [23]. Geomagnetically induced current caused by space weather is another example of electromagnetic immunity relevant to an electric grid [24] to keep its function satisfactory.

The importance of Voltage Quality to achieve EMC is clearly stated in a report from CEER – Council of European Energy Regulators [25]: "Due to the nature of electricity, voltage quality is affected by all the parties connected to the power system. When voltage quality is too poor, a key question is whether the disturbance (e.g. a harmonic disturbance) from a customer's installation in to the power system is too big or whether the power system (the short circuit power) at the point of connection is too weak. The aim should be to have an electromagnetic environment where electrical equipment and systems function satisfactorily without introducing intolerable electromagnetic disturbances to other equipment. This situation is referred to as electromagnetic compatibility (EMC)."

C. Field Experiences with Smart Grid Technology

Examples of lack of EMC in relation to evolving Smart Grid technologies have been reported in Sweden. Kilowatt-hour meters in households sending data signals on the power lines have caused interference with e.g. dimmer controlled lamps and electrical appliances. There are also cases reported where electrical apparatuses in households have interfered with electronic kilowatt-hour meters with adverse errors in registration of energy. Power electronics in wind power plants have emitted disturbances interfering with transfer of kilowatt-hour meter readings as signals on power lines.

Power electronic based photovoltaic solar and wind energy equipment may emit disturbances causing e.g. voltage fluctuations and unbalance [26]. However, with a proper design such equipment may well improve Voltage Quality, e.g. reducing depth of voltage dips [27].

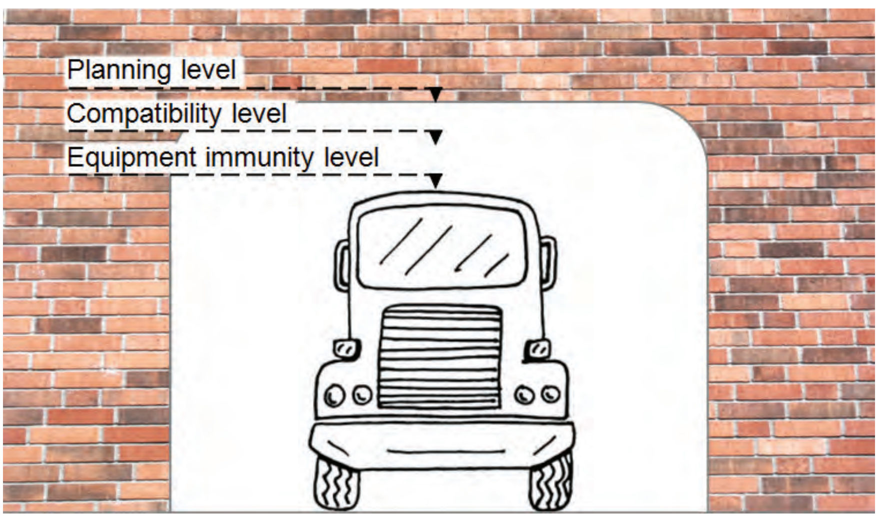

Figure 6. Mechanical compatibility – Viaduct clearance and vehicle height.

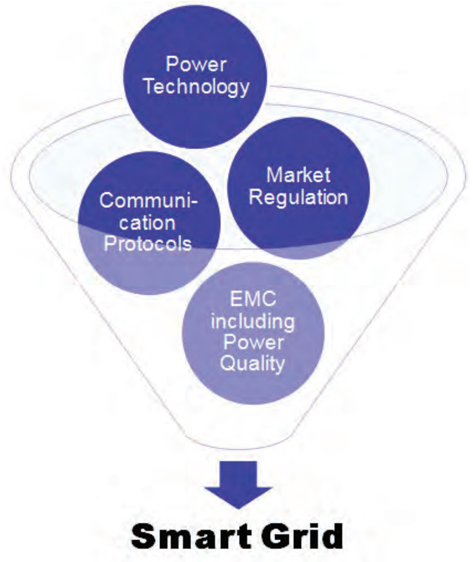

Figure 7. Some components needed to realize Smart Grid.

IV. EMC DIRECTIVE AND ELECTRICAL NETWORKS

The preamble (14) of the EMC Directive 2004/108/EC of European Union [15] reads: "(14) Manufacturers of equipment intended to be connected to networks should construct such equipment in a way that prevents networks from suffering unacceptable degradation of service when used under normal operating conditions. Network operators should construct their networks in such a way that manufacturers of equipment liable to be connected to networks do not suffer a disproportionate burden in order to prevent networks from suffering an unacceptable degradation of service. The European standardization organizations should take due account of that objective (including the cumulative effects of the relevant types of electromagnetic phenomena) when developing harmonized standards."

This means that both parties responsible for networks (being equipments) as well as for equipment connected to networks are supposed to contribute to EMC.

V. ELECTROMAGNETIC COMPATIBILITY IN POWER SYSTEMS

A Power System is exemplified in Fig. 2. Fixed installations are indicated with closed loops in light blue colour.

Applying the concept of fixed installation, there is principally no difference between electrical networks or connected equipment in terms of electromagnetic disturbances. Both networks and connected equipment can emit electromagnetic disturbances and immunity is similarly relevant in this context. A network may well be connected to other network(s) which may emit disturbances or be affected by disturbances in terms of imperfect Voltage Quality. Lack of immunity can also degrade the very basic function of the grid of energy transfer. One such case is where energy transfer is interrupted due to interference caused by geomagnetically induced currents.

Disturbances can propagate from a network to connected equipment or vice versa as presented in Fig. 3 [20]. Disturbances may also propagate between networks as illustrated in Fig. 4 and emission from a network may be seen as a cumulative effect of emissions from a large number of connected equipment in terms of imperfect Voltage Quality at a specific site.

VI. VOLTAGE QUALITY PLANNING LEVELS

In public low voltage networks within the European Union it can be assumed that an increasingly large portion of connected equipment has CE marking. This means that equipments shall be in conformity of protection requirements on emission and immunity as of the EMC Directive. So called harmonized standards are generally available and applied by manufacturers with the benefit of presumption of conformity with the EMC Directive among others.

The objective of protection requirements for equipment, including fixed installations such as electrical networks and connected equipment, is for the achievement of EMC.

When aiming at EMC in electrical power systems it is reasonable to apply the same reference for Voltage Quality in electrical networks as for limits on emission and immunity of connected equipment. This is schematically indicated in Fig. 5 where a common level is applied for Voltage Quality as well as for immunity of connected equipment. This common disturbance level is the so called compatibility level. Electromagnetic compatibility levels are defined in the IEC 61000-2-series for use as references for emission and immunity of equipment.

Voltage Quality planning levels are defined with a margin in relation to compatibility levels, indicated in Fig. 5.

For continuous phenomena such as voltage harmonics, the probability of not achieving compatibility is normally very small at a certain site in an electrical network [28].

A mechanical analogy of compatibility is illustrated in Fig. 6; here in terms of infrastructure clearance and vehicle height above road. The defined compatibility level may be e.g. 4,5 meter. With this as a reference, the party responsible for the infrastructure will design the viaduct with a certain margin considering variation in the road surface, ice and snow and possibly future pavement renewals. Similarly, the truck manufacturer would consider variations in wheel diameter, suspension and vehicle manufacturing precision.

VII. APPORTIONING OF RESPONSIBILITIES BETWEEN NETWORK AND CONNECTED EQUIPMENT

A. Allocation of Available Emission Limits

In electrical networks other than public low voltage networks within the European Union, there are normally no harmonized standards for emission and immunity of connected equipment, including fixed installations. In the context of Electromagnetic Compatibility, this makes apportioning of responsibilities between parties accountable for electrical networks and parties connecting equipment to the network essential. A key task is the allocation of available emission levels in order to comply with Voltage Quality planning levels within the electrical network. Such apportionment is discussed in [20] and [18] and an important subject in IEC documents [28], [29] and [30].

B. Emission Allocation between Networks

Allocation of available emission levels is also relevant between networks. As an example, planning levels for low order harmonics should normally be stricter at higher voltages in comparison with at lower voltage levels. Thus, for certain low frequency phenomena a network at a higher voltage level should be normally planned with higher Voltage Quality than at lower voltage levels. It is desirable to apply standards for compatibility based planning levels for all voltage levels, i.e. from low voltage up to the highest transmission voltages.

VIII. TOWARDS CONVERGENCE OF POWER QUALITY AND EMC

As expressed in [31], in 1990s, 10 national committees of IEC initiated standardization actions in the direction towards convergence of Power Quality and EMC. The fruits of these efforts are e.g. the EMC standard on Power Quality measurements [32], from where Power Quality principally can be seen as including Voltage Quality and Current Quality.

The innovative and sensible approach of the EMC Directive in which electrical networks are considered equipment is a basis for a holistic and fruitful application of EMC within power systems.

IX. SMART GRID, EMC AND POWER QUALITY

EMC including Power Quality is one of several components needed to realize Smart Grid, which is illustrated in Fig. 7.

It is desirable to consider EMC including Power Quality a prerequisite for power systems, i.e. being a fundamental technical requirement prior to any market regulations etc. As a consequence, the regulatory system for parties responsible for electrical networks should be designed accordingly. As for electrical safety, EMC should be a minimum performance level to be considered in the design of power systems. Network regulatory systems should consequently make it possible to pass on costs for EMC including Power Quality to users of networks as is done for electrical safety.

X. PROPOSAL ON ACTIONS WITHIN STANDARDISATION

The following actions of the standardisation communities are suggested to support EMC including Power Quality for Smart Grid:

1. Standardise electromagnetic compatibility levels for disturbances in terms of Voltage Quality for all standard voltage levels of public electrical power networks. This means extending the IEC 61000-2-series to coverage of voltage levels from 230 V up to the highest transmission voltages of public national electrical networks.
2. Standardise how to define planning levels, i.e. limits of electromagnetic disturbances in terms of Voltage Quality at sites in electrical networks, based on compatibility levels.
3. Standardise how to apportion available immunity of electrical networks in order to meet planning levels, i.e. explain how to fairly allocate the ability of networks to absorb distorting current emissions among present and possibly forthcoming connected equipment at sites in networks. Connected equipment may well be other network(s). The work is recommended to take origin in documents IEC TR 61000-3-6 [28], IEC TR 61000-3-7 [29] and IEC TR 61000-3-13 [30].
4. Produce a technical document facilitating the work of network operators to fulfil the EU EMC Directive requirements on protection requirements with respect to emission and immunity of networks being fixed installations.

XI. CONCLUSION

Smart Grid can enable more renewables and efficient use of electricity. Smart Grid is expected to boost an increased use of electronically based equipment in the electrical power system.

To realize Smart Grid the following issues are important to consider:

1. EMC is essential for a robust Smart Grid; both with respect to radiated and to conducted disturbances.
2. Power Quality is a means to achieve EMC between the Smart Grid and connected equipment.
3. Electrical networks including Smart Grids are equipment.
4. Protection requirements, i.e. on emission and immunity, are valid also for electrical networks.
5. Protection requirements on networks and connected equipment should be economically fairly balanced.
6. The standardisation community is recommended to develop a complete set of standards for EMC in power systems including Power Quality.
7. With a view of EMC as a technical issue where cost optimisation to a large extent is made in the standardisation community, regulatory frameworks should be designed without links to market mechanisms, i.e. similar to handling of electrical safety.

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