The Development of High-Power Electromagnetic (HPEM) Publications in the IEC: History and Current Status

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Introduction
This article reviews the history of IEC Subcommittee 77C (EMC: High Power Transient Phenomena), the publications completed to date, and the new projects underway. The information provided has been extended from the “Development of High Power Electromagnetic (HPEM) Standards” published in the IEEE Transactions on Electromagnetic Compatibility [1] and has been adapted from a paper presented at the 4th International Symposium on Electromagnetic Compatibility in Qingdao, China in October 2007 [2].

The International Electrotechnical Commission
The International Electrotechnical Commission (IEC) was founded in 1906 and recently celebrated its 100th year anniversary in Berlin, Germany. The goal of the Commission is to promote international cooperation on all aspects of standardization in the fields of electricity, electronics and related technologies in order to eliminate barriers to trade. It is the worldwide leader in the development of electromagnetic compatibility (EMC) standards. The technical work of the IEC is carried out by experts in over 160 Technical Committees (TCs) and Subcommittees (SCs). One of the IEC Technical Committees is “Electromagnetic Compatibility”, TC 77. Standardization in the area of high power electromagnetics (HPEM) is performed in a separate Subcommittee, SC 77C, “High power transient phenomena”.

IEC Subcommittee 77C
In 1989, the IEC began the development of environment, protection and test standards for commercial equipment that might be exposed to the electromagnetic fields produced from a high altitude nuclear burst. These fields are generally known as the HEMP (high altitude electromagnetic pulse), although in actuality the term represents a series of pulses with different frequency content that need to be considered. These range from nanosecond pulses to pulses with rise and fall times of seconds. When the active work on HEMP began in 1992, it was assigned to a new Subcommittee 77C (SC 77C) under the parent committee TC 77 (EMC). In June 1999, the scope of work in SC 77C was expanded to include all high power EM transient threats, including those from intentional electromagnetic interference (EMI).

The formal scope of the subcommittee today is: Technical Committee No 77: Electromagnetic Compatibility (EMC) – Subcommittee 77C: High power transient phenomena – Scope: Standardization in the field of electromagnetic compatibility to protect civilian equipment, systems and installations from threats by man-made high power phenomena including the electromagnetic fields produced by nuclear detonations at high altitude. (Note: High power conditions are achieved when the incident field exceeds 100 V/m.)

The Subcommittee 77C has seventeen participating member nations: China, Egypt, Finland, Germany, Italy, Japan, Korea (Republic of), Mexico, Norway, Poland, Romania, Russian Federation, Sweden, Switzerland, Thailand, United Kingdom and USA. In addition, there are sixteen observing member nations: Austria, Belgium, Brazil, Bulgaria, Croatia, Czech Republic, Denmark, France, Ireland, Israel, Netherlands, Portugal, Slovakia, Spain, Turkey, and Ukraine.

The Chairman is Dr. William A. Radasky (USA) and the Secretariat is undertaken by the UK (Mr. Richard Hoad is the Secretary).

Publications Issued by SC 77C
Preparation of SC 77C publications is consistent with the development of EMC publications within the IEC and is therefore structured according to “IEC Publication 61000” which is divided into seven major parts as indicated below:

Part 1: General
Part 2: Environment
Part 3: Limits
Part 4: Testing and Measurement Techniques
Part 5: Installation and Mitigation Guidelines
Part 6: Generic Standards
Part 9: Miscellaneous

Each part is further subdivided into several subparts or sections, published either as International Standards or as Technical Specifications or Technical Reports. A summary of each publication produced before 1 July 2007 by SC 77C follows:

Part 1: General
IEC/TR 61000-1-3 (2002-06)
Electromagnetic compatibility (EMC) – Part 1-3: General - The effects of high-altitude EMP (HEMP) on civil equipment and systems. Project leader: W. A. Radasky, USA.

This technical report provides information concerning the effects of high-altitude EMP (HEMP) on electrical and electronic equipment and systems. This information is based on effects observed during high altitude nuclear testing and from tests performed in HEMP simulators in several countries.

IEC/TR 61000-1-5 Ed. 1.0 (2004-11)
Electromagnetic compatibility (EMC) – Part 1-5: General - High power electromagnetic (HPEM) effects on civil systems. Project leader: F. Tesche, USA.

This technical report discusses the effects of high power electromagnetic (HPEM) fields on civil systems, and illustrates the general protection principles that can be applied to protect systems from this newly emerging threat.

Part 2: Environment
IEC 61000-2-9 (1996-02)

This standard describes the radiated parameters for the early-time, intermediate-time and late-time HEMP waveforms. This includes electric and magnetic field time waveforms, HEMP amplitude and energy, weighting of the early, intermediate and late-time HEMP, and...
also reflection and transmission of the HEMP at the earth’s surface. Typical variations in peak electric fields on the earth’s surface for different burst altitudes are also explained.

IEC 61000-2-10 (1998-11)
Electromagnetic compatibility (EMC) – Part 2-10: Environment – Description of HEMP environment - Conducted disturbance. Project leader: W. A. Radasky, USA.
This standard is based on the radiated waveforms in standard 61000-2-9. It describes the conducted environment induced on conductors for different positions and illumination cases statistically taken into account. The description is based on extensive theoretical calculations and experimental measurements. The object is to establish a common reference for the conducted HEMP environment in order to select realistic stresses to apply to equipment for evaluating their performance. Description of the conducted HEMP environment includes the early, intermediate, and late-time HEMP external conducted environment, antenna currents, and internal (to a building) conducted environments.

IEC 61000-2-11 (1999-10)
Electromagnetic compatibility (EMC) – Part 2-11: Environment – Classification of HEMP environments. Project leader: W. A. Radasky, USA.
This standard presents environment classes for electronic equipment based on the type of EM protection surrounding the equipment. One reason for classification is to provide guidance for equipment builders to help them decide on the proper immunity test levels appropriate for their equipment. Another reason is to provide systems designers with guidance regarding construction methods and protective measures needed to achieve defined EM classes.

IEC 61000-2-13 Ed. 1.0 (2005-03)
This document presents the emerging, man-made, high power electromagnetic (HPEM) threat environments. Such threat environments can produce damaging effects on electrical and electronic equipment in the civilian sector, as described in 61000-1-5. It is necessary to define the radiated and conducted environments, in order to develop protection methods.

Part 3: Limits
Part 3 does not include any SC 77C project.

Part 4: Testing and Measurement Techniques
IEC 61000-4-23 (2000-10)
This part provides the basic reasons behind HEMP testing and gives a brief description of the most important concepts for shielding element testing. It does not provide information on requirements for specific levels for testing.

IEC 61000-4-24 (1997-02)
The standard covers testing of voltage breakdown and voltage-limiting characteristics and also methods to measure the residual voltage on protective devices under HEMP conditions, for the case of very fast changes of voltage and current as a function of time. The document complements the standard 61000-5-5 “Specification of protective devices for conducted disturbance.”

IEC 61000-4-25 (2001-11)
Electromagnetic compatibility (EMC) – Part 4-25: Testing and measurement techniques – HEMP immunity test methods for equipment and systems. Project leader: P. R. Barnes, USA.
This standard describes the immunity test levels and related test methods for electrical and electronic equipment and systems exposed to high-altitude electromagnetic pulse (HEMP) environments. It describes environment waveforms, defines ranges of immunity test levels, selection of test methods, and suggests particular test levels that can be applied.

IEC/TR 61000-4-32 (2002-10)
Electromagnetic compatibility (EMC) – Part 4-32: Testing and measurement techniques – High-altitude electromagnetic pulse (HEMP) simulator compendium. Project leader: J. C. Giles, USA.
The specific aim of this project is to provide information on the various types of existing HEMP simulators throughout the world, their uses, performance parameters, limitations, and availability. This will allow all potential simulator users to evaluate the adequacy of available simulators for testing large systems. Individual data sheets for 42 simulators from 14 countries are identified. The information comes from Canada, China, France, Germany, India, Israel, Italy, Netherlands, Russia, Sweden, Switzerland, Ukraine, United Kingdom, and United States.

IEC 61000-4-33 Ed. 1.0 (2005-09)
This project provides information on the techniques applicable to the measurement of high-power transient waveforms. It is important for sensor performance to be standardized so that errors are not made during high field and current testing. Very often normal sensor design and qualification methods are not applicable when high intensity fields and currents are present, often with rise times on the order of 1 nanosecond.
The standard provides a basic description of the methods and means (e.g., instrumentation) for measuring responses arising from high power transient electromagnetic fields.
Part 5: Installation and Mitigation Guidelines

IEC/TR 61000-5-3 (1999-07)
Electromagnetic compatibility (EMC) – Part 5-3: Installation and mitigation guidelines – HEMP protection concepts. Project leader: M.
The Development of High-Power Electromagnetic (HPEM) Publications in the IEC:

Ianoz, Switzerland.

This technical report provides elements for:

- The design of adequate protection for civil facilities against HEMP;
- The evaluation of already existing protection methods with respect to stresses imposed by HEMP;
- The comparison of the requirements of HEMP and lightning protection in order to show if they can be combined at low cost;
- An emphasis of the differences between the requirements of HEMP and lightning protection in order to permit an evaluation of the consequences of HEMP when no additional measures are taken beyond existing lightning protection.

IEC/TS 61000-5-4 (1996-08)


This technical specification defines how protective devices for HEMP protection of civil systems are specified. Specifications of electromagnetic properties of shielding devices include (where applicable) electric, magnetic and plane wave attenuation, d.c. resistance, transfer impedance, transfer admittance, and electrical conductivity.

IEC 61000-5-5 (1996-02)


This standard defines how protective devices for HEMP conductive disturbance protection shall be specified. The standard covers protective devices currently being used for protection against induced HEMP transients on signal and low voltage power lines. For basic specifications, reference is made to other relevant standards dealing with phenomena other than HEMP. When such standards do not adequately consider the requirements of modern electronics, additional specifications, modifications or extensions based on non-HEMP-relevant standards are defined.

IEC/TR 61000-5-6 (2002-06)

Electromagnetic compatibility (EMC) – Part 5-6: Installation and mitigation guidelines – Mitigation of external influences. Project leader: W. A. Radasky, USA.

This technical report covers guidelines for the mitigation of external electromagnetic influences impinging upon a facility, aimed at ensuring electromagnetic compatibility (EMC) among electrical and electronic apparatus or systems. These influences include lightning, RF transmitters, power line and telecom transients, high altitude electromagnetic pulse (HEMP) and other high power electromagnetic transients. More particularly, this publication is concerned with the arrangement of shielding and screening against radiated disturbances, and with mitigation of conducted disturbances. These arrangements include appropriate electromagnetic barriers for industrial, commercial, and residential installations.

IEC 61000-5-7 (2001-01)

Electromagnetic compatibility (EMC) – Part 5-7: Installation and mitigation guidelines – Degrees of protection provided by enclosures against electromagnetic disturbances (EM code). Project leader: C. Jones, USA.

The purpose of this standard is to provide a repeatable means for evaluating the electromagnetic shielding performance of empty mechanical enclosures, including cabinets and subracks, and to specify a marking code to allow a manufacturer to select an enclosure with a known capability for attenuating electromagnetic fields.

Part 6: Generic Standards

IEC 61000-6-6 (2003-04)

Electromagnetic compatibility (EMC) – Part 6-6: Generic standards – HEMP immunity for indoor equipment. Project leader: P. R. Barnes, USA.

Generic standards are intended to provide a template for testing equipment to a particular environment when there is no specific product standard. This generic standard sets high altitude electromagnetic pulse (HEMP) immunity requirements for electrical and electronic equipment intended for use indoors. The indoor HEMP environment depends on the electromagnetic shielding quality of a facility and level of protection against the conducted environment. This standard is intended for all facility types including residential, commercial, light industrial, hospitals, heavy industrial, power substations and power generation facilities. Indoor equipment is intended to be connected to a low-voltage (1 kV or less) power network, to the telecom network and/or to external antennas.

Part 9: Miscellaneous

Part 9 does not include any SC 77C project.

New SC 77C Projects

Three new projects have been initiated by the National Committees of IEC SC 77C in 2006. Work has begun, and a brief summary of each project is given below:

IEC/TR 61000-4-35 (CD produced 2007-06)

Electromagnetic compatibility (EMC) – Part 4-35: Testing and measurement techniques – High power electromagnetic (HPEM) simulator compendium. Project leader: F. Sabath, Germany.

This technical report provides information about existing system-level High-Power Electromagnetic (HPEM) simulators and their applicability as test facilities and validation tools for IEC SC 77C immunity test requirements. In the sense of this report, the group of HPEM simulators consists of high and medium power narrow band microwave test facilities and wideband simulators for radiated fields.

IEC/TS 61000-5-8 (CD expected 2008-02)

Electromagnetic compatibility (EMC) – Part 5-8: Installation and mitigation guidelines – HEMP protection methods for distributed infrastructure. Project leader: W. A. Radasky, USA.

The aim of this technical specification is to provide guidance on how to protect the distributed civil infrastructure (power, telecommunications, transportation, natural gas, food and water distribution, etc.) from the threat of a high altitude electromagnetic pulse (HEMP). In order to accomplish this goal, it is necessary to describe the special aspects of the HEMP threat to systems that are distributed in nature. For example, any connected infrastructure such as power or telecommunications will observe disturbances...
simultaneously over a wide area.

IEC/TS 61000-5-9 (CD produced 2007-06)
Electromagnetic compatibility (EMC) – Part 5-9: Installation and mitigation guidelines – System-level susceptibility assessments for HEMP and HPEM. Project leader: A. Wraight, UK.

The aim of this technical specification is to provide information on methods and techniques available to assess the impact of HEMP and HPEM on systems. In this context, a system refers to a collection of sub-systems, equipment and components brought together to perform a function. Specifically, a methodology for the assessment of systems to the effects of HEMP and HPEM is given along with their advantages and disadvantages.

Conclusions
Significant work has been performed in the IEC dealing with high power electromagnetic (HPEM) phenomena since 1989. The basic work covering both the high-altitude electromagnetic pulse (HEMP) and electromagnetic weapons that have the capability to produce intentional electromagnetic interference (IEMI) is now complete. Future work is planned to use the existing basic publications as a “tool box” to solve more complex problems dealing, for example, with the distributed civil infrastructure. Engineers with interest in the field of high power electromagnetics are invited to join the work in the IEC. Please contract William Radasky at wradasky@aol.com if you wish to obtain information concerning IEC SC77C and how you may become active in the work.

References

Dr. Radasky received his Ph.D. in Electrical Engineering from the University of California at Santa Barbara in 1981. In 1984, he founded Metatech Corporation in Goleta, California, which performs applied electromagnetics research for customers throughout the world. He has published over 370 reports and papers dealing with high power electromagnetic (HPEM) environments and effects during his career. He is the Chairman of IEC SC 77C (EMC: High Power Transient Phenomena) and the Chairman of the IEC Advisory Committee on EMC (ACEC). He received the Lord Kelvin Medal from the IEC in 2004 for outstanding contributions to international standardization. Dr. Radasky is a Senior Member of the IEEE and is the Chairman of TC-5 (High Power Electromagnetics) in the IEEE EMC Society. He is also a registered Professional Electrical Engineer in the State of California.