INTENTIONAL ELECTROMAGNETIC INTERFERENCE (IEMI) – BACKGROUND AND STATUS OF THE STANDARDIZATION WORK IN THE INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

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ABSTRACT

Intentional electromagnetic interference (IEMI), or as it is sometimes known, "EM Terrorism," is a new area of concern for public and commercial interests. This paper will review the different categories of EM threats and will also summarize available information concerning the susceptibility levels for commercial equipment. The paper will conclude with a presentation of the standardization work being accomplished by the International Electrotechnical Commission (IEC) in the area of high power transient phenomena. The paper is an updated extract from an article originally published in *The Radio Science Bulletin* No 299 (December, 2001).

WHAT IS INTENTIONAL EMI?

At the URSI XXVIth General Assembly in Toronto, August 1999, a resolution was adopted on "Criminal Activities using Electromagnetic Tools" [1]. According to this, intentional EMI is defined as the "Intentional malicious generation of electromagnetic energy introducing noise or signals into electric and electronic systems, thus disrupting, confusing or damaging these systems for terrorist or criminal purposes." Over the past two years there has been increasing activity in the area of Intentional Electromagnetic Interference (EMI), which is sometimes referred to as EM Terrorism. In particular at the International Zurich Symposium and Technical Exhibition on EMC in February 1999, there was a well-attended session on EM Terrorism that resulted in the publication of five important papers: dealing with the overall problem [2], presenting an approach to protecting systems from the threat [3], providing HPM test data on automobiles [4], reviewing modeling and simulation methods [5], and describing the use of large-scale simulators to evaluate EM threats [6]. In the summer of 2000 there were two important conferences that provided additional information on this subject. At the EUROEM2000 Conference in Edinburgh in May, there was a special session on Intentional EMI that attracted 15 presented papers although no papers were published. Later in June at Wroclaw, Poland the URSI Commission E session resulted in three published papers dealing with the nature of the threat [7], testing strategies [8], and the approach of the International Electrotechnical Commission (IEC) Subcommittee 77C to develop environment and protection standards to deal with the problem [9].

TYPES OF IEMI THREATS

In the simplest of terms there are two basic types of IEMI waveforms -- Narrowband and Wideband. However, the meaning of narrowband and wideband concerning pulses needs to be discussed further and this is planned to be included in the IEC work. The narrowband category describes a nearly single frequency that may be transmitted in a pulse on the order of microseconds in length. This type of threat is often referred to as HPM (high power microwave). The frequency range for HPM is typically higher than 1 GHz, although from an IEMI point of view, frequencies between 0.2 and 5 GHz seem to be the most important to consider as narrowband threats. Of course the "single" frequency may vary with time, and the signal can be modulated. It is generally fairly easy to create fairly high power and energy levels with this type of waveform. An example of this type of waveform is one generated in a microwave oven or by radar tubes. The disadvantage of this type of waveform is that systems are affected by the currents and voltages coupled by the incident field, and many systems have resonances that create significant susceptibilities to particular frequencies. However, different systems will likely have different resonances, thereby limiting the effectiveness of a single frequency IEMI generator.

For the wideband category, a pulse produces frequency content over a wide range of frequencies. One type of wideband waveform is UWB (ultra-wideband). These pulses typically have a rise time of less than 100 picoseconds and a pulse width of a few nanoseconds. The main frequency content of the UWB pulse ranges from 0.3 - 3 GHz. It should be noted that the HEMP waveform described by the IEC [10] has a 2.5 ns rise time and a 25 ns pulse width. This qualifies a wideband waveform, but it is not considered an ultra-wideband pulse. The advantage of the wideband pulses is that the resonances of different sized systems can be stimulated simultaneously. The disadvantage is that the energy produced in a single pulse is spread over many frequencies. In addition, the peak electric field value of the pulse is limited by the breakdown field value of air. For these reasons, the wideband pulses are often repetitively pulsed and therefore pose mainly an interference threat to systems as opposed to a permanent damage threat as provided by narrowband waveforms.

In addition to the waveform type, there is the issue of how the disturbing waveform is delivered to the system. The two general categories described in the electromagnetic compatibility discipline are radiated and conducted. In the case of radiated waveforms, an antenna is used to produce electromagnetic fields that propagate to the vicinity of a "target" system. These radiated fields will propagate through the air and through apertures in buildings, automobiles or aircraft. The electromagnetic fields will either couple directly to the cables attached to a piece of equipment or will penetrate directly inside of the equipment, where damage or upset to system operations will occur. Conducted disturbances can be injected directly, capacitively, or inductively onto power or telecommunication cables. These disturbances will then propagate along the cables until they reach equipment connected to the cables. As in the case of radiated disturbances, both narrowband and wideband waveforms can be injected, however, often the cables transfer functions will limit the frequency content of conducted disturbances to below 1 MHz, particularly on power lines.

SUSCEPTIBILITY LEVELS OF COMMERCIAL EQUIPMENT

PC Cable Experiments

A recent paper by Radasky, et. al. at the Zurich EMC Conference surveyed equipment failure data from a series of laboratory experiments [11]. Four sets of data, two conducted and two radiated, provided valuable information. Power cords and Ethernet cables connected to personal computers were tested and surveyed in this paper. Two types of conducted pulse waveforms were used: the CWG (Combination Wave Generator) waveform (1.2/50 microsecond pulse) and the Telecom waveform (10/700 microsecond pulse). The results indicated that the power ports were not affected for delivered voltages as high as 1.2 kV, although higher levels have been reported to cause damage. For the Ethernet cables, the 10Base-2 cards were damaged at 500 volts, which was the lowest test level. The 10Base-T interface was not damaged until a level of 4 kV was reached using the Telecom waveform. It is interesting to note that the 10Base-2 uses a coax cable, however, the shield is not connected at the card, thereby creating an easy damage path.

Building Power Cable Experiments

An experiment was performed by Fortov et. al. [12] by injecting both narrowband and wideband waveforms onto the power lines entering a five story office building and by making measurements at various power plugs within the building. The measurements indicated that voltages injected on external wiring could propagate well through the internal wiring of a building even when considering multiple switchboards inside the building. It is clear from their work that frequencies less than 1 MHz propagate with low attenuation, as do pulses with widths greater than 1 microsecond. Although this study did not address the issue of wiring breakdown directly, it is felt that for the types of pulses considered, that normal building wiring should be able to support peak voltages in the range of 10 kV. In terms of the vulnerability of computers, both the analyses and limited testing revealed that computer power supplies, and in particular the input filters, appear to be vulnerable to levels of 6 kV for a 50-microsecond pulse. Analyses indicate that levels of 1 - 2 kV would create damage for a 1 ms wide pulse. By considering both aspects of this work, it appears possible to inject significant levels of voltage into the power wiring system of a building, and that voltage can propagate easily and cause damage to computer power supplies. Of course it is possible that other types of equipment connected to the power system will be vulnerable to injected pulses, although other types of equipment have not yet been considered.

Radiated Field Effects on PCs

Three types of PCs were tested by LoVetri, et. al. [13] by irradiating them with different frequencies, modulation types and field strength levels. An effort was made to determine the lowest field levels at various frequencies using narrowband waveforms. Angles of incidence and polarization variations were minimal, so the results should not be considered to be the lowest levels where effects could occur. The authors concluded in their study that relatively weak fields, as low as 30 V/m, reaching the inside of a personal computer could disrupt its operation. In addition, they noted that the effects were observed only at particular frequencies due to resonances present inside each computer.

Automobile Test Results and Conclusions

Another experiment was performed in Sweden by Bäckström [4] by irradiating an automobile with narrowband waveforms at high power and field levels (HPM). The frequencies of illumination varied between 1.3 and 15 GHz. Two angles of incidence to the automobile were considered. The authors of this study noted that effects were more prominent at the lower test frequencies with automobile upsets (including the stoppage of the engine) noted at the lowest test value of 500 V/m. Permanent damage occurred at 15 kV/m at 1.3 GHz and 24 kV/m at 2.86 GHz. They also noted that permanent damage occurred when the automobile was not operating. The types of damage observed included: engine control units, relays, speedometer, revolution counter, burglar alarm, and a video camera. It is clear that an unprotected (from HPM) electronics system such as an automobile can be vulnerable to HPM fields at relatively low levels. A field level of 500 V/m or lower has the capability to stop the vehicle. Based on this test data and the capability today of building a van with an HPM power source of 10 MW and a directional antenna, it would be possible to damage an automobile at a range of 15 meters and to stop its operation at 500 meters.

Susceptibility Conclusions

It is apparent from the data summarized here, that both conducted and radiated disturbances are a threat to commercial systems. Clearly it is possible to generate conducted wideband waveforms similar to those used for EMC testing of equipment, but with somewhat higher peak levels than those specified for normal home or commercial usage. For radiated waveforms, it is possible to apply microwave oven parts and those from surplus military radars to generate threatening electromagnetic field levels. Of course generators can be built in laboratories with higher level capabilities, however, source size is an important factor to be considered when creating threat level criteria.

INTRODUCTION TO THE IEC

The objective of the International Electrotechnical Commission (IEC) is to produce international standards for electrical and electronic equipment and systems. In particular, the electromagnetic compatibility (EMC) aspects are of interest worldwide for the electronics and power industries in order to harmonize methods of testing and to develop protection methods and devices. The main part of the EMC immunity work is centered in IEC Technical Committee 77 that has three subcommittees dealing with different aspects of EMC (77A, 77B, 77C). The work described below is part of the approved program of IEC SC77C, "EMC: High Power Transient Phenomena." The intention of the subcommittee is to apply openly published information and to reference existing IEC EMC standards wherever possible, so that there is no duplication of effort. Those working in the SC77C subcommittee and on particular project teams represent their countries and not particular organizations (civilian or military).

Subcommittee 77C currently has sixteen participating member nations: Austria, Bulgaria, China, Finland, France, Germany, Italy, Japan, Mexico, Romania, Russia, Sweden, Switzerland, Turkey, United Kingdom and USA. In addition there are sixteen observing member nations: Belgium, Canada, Croatia, Czech Republic, Denmark, Ireland, Israel, Republic of Korea, Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Thailand, and Ukraine. The Chairman is Dr. W. A. Radasky (USA) and the Secretariat has been undertaken by Sweden (Messrs. M. W. Wik, J-O. Sjödin). The preparation of SC77C standards is consistent with the development of EMC standards within other parts of TC77 (EMC) and is thus structured according to "IEC Publication 61000" which is divided into seven major parts. Only Parts 1, 2, 4, 5 and 6 are utilized by SC77C at present. The current development of standards and reports includes seventeen active projects and/or publications, covering High Altitude Electromagnetic Pulse (HEMP) and Intentional Electromagnetic Interference (IEMI). Due to limited space in this article only the most recent projects related to IEMI are described.

PROGRESS OF WORK AND HIGHLIGHTS

Part 1 "*General*" of the IEC 61000 series includes terminology, definitions and other general aspects. "High power electromagnetic (HPEM) effects on civil systems" (61000-1-5, F. M. Tesche, USA) will result in an IEC Technical Report that discusses the effects of HPEM fields on civilian systems and illustrates the general protection principles that can be applied to protect systems from this newly emerging threat. The present stage of the project is Committee Draft (CD).

Part 2 "*Environment*" gives a description of the high power electromagnetic environment and covers radiated and conducted parts. One project is entitled, "High power electromagnetic (HPEM) environments - radiated and conducted"

(61000-2-13, D. V. Giri, USA). It defines the current and near-future high-power electromagnetic (HPEM) environments that are a potential threat to civilian systems, including both the radiated and conducted environments. It is expected that this standard will become the basis for defining appropriate protection methods in the future. The present stage of the project is Committee Draft (CD).

Part 4 "*Testing and Measurement Techniques*" presently includes five projects. One of them is "Measurement Methods for High-Power Transients," (61000-4-33, A. Kaelin, Switzerland). It is presently in the stage of Committee Draft (CD). 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 one nanosecond. The intention of this work is to identify appropriate sensor calibrations and measurement methods to be used for the measurement of high-power transient electromagnetic disturbances.

CONCLUSIONS

This paper has defined the meaning of Intentional EMI and has briefly described the basic categories of the disturbances. In addition, past experiments have been reviewed to indicate the relatively low levels of radiated and conducted environments that have been shown to affect commercial equipment ranging from PCs to automobiles. Since it is clear that the levels of fields and voltages that can be created using current technology are sufficient to upset and/or damage equipment, there is a standardization effort in the IEC to develop a solution. IEC Subcommittee 77C is in the process of developing a family of HEMP and high power EM transient standards and reports that will help manufacturers and facility owners to protect their equipment from the effects of these disturbances.

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