

# TECHNICAL REPORT

# IEC TR 61000-1-3

First edition  
2002-06

---

---

PUBLICATION FONDAMENTALE EN CEM  
BASIC EMC PUBLICATION

---

---

## **Electromagnetic compatibility (EMC) –**

### **Part 1-3: General – The effects of high-altitude EMP (HEMP) on civil equipment and systems**

*Compatibilité électromagnétique (CEM) –*

*Partie 1-3:  
Généralités – Effets des impulsions électromagnétiques  
à haute altitude (IEM-HA) sur les matériels et systèmes civils*

© IEC 2002 — Copyright - all rights reserved

No part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from the publisher.

International Electrotechnical Commission, 3, rue de Varembé, PO Box 131, CH-1211 Geneva 20, Switzerland  
Telephone: +41 22 919 02 11 Telefax: +41 22 919 03 00 E-mail: [inmail@iec.ch](mailto:inmail@iec.ch) Web: [www.iec.ch](http://www.iec.ch)

---

---



Commission Electrotechnique Internationale  
International Electrotechnical Commission  
Международная Электротехническая Комиссия

PRICE CODE

X

*For price, see current catalogue*

## CONTENTS

FOREWORD .....	4
INTRODUCTION .....	6
1 Scope .....	7
2 Reference documents .....	7
3 Definitions .....	7
4 General considerations .....	9
5 Overview of effects experience .....	10
5.1 Atmospheric testing introduction .....	10
5.2 Simulator testing introduction .....	10
6 Atmospheric nuclear testing experience .....	11
6.1 United States atmospheric test experience – Starfish test .....	11
6.2 Soviet Union atmospheric test experience .....	14
7 HEMP simulator testing with radiated transients .....	21
7.1 Consumer electronics .....	21
7.2 Communication radios .....	25
7.3 Commercial power lines .....	28
7.4 Train power-line coupling experiment .....	31
7.5 HEMP-induced currents on a three-phase line .....	34
8 HEMP simulator testing with conducted transients .....	36
8.1 High-voltage power-line equipment .....	36
8.2 Testing of distribution transformers to conducted HEMP transients .....	37
9 Summary .....	45
Bibliography .....	46
Figure 1 – Starfish-Honolulu burst geometry, with the X indicating the location of Johnston Atoll .....	12
Figure 2 – Front page of <i>New York Tribune</i> , European Edition, 10 July 1962 .....	13
Figure 3 – Ferdinand Street (Honolulu, Hawaii) series lighting system in 1962 .....	14
Figure 4 – The amplitudes of the computed early-time HEMP E-field components versus time for the near end of the 500-km telecom line .....	15
Figure 5 – The amplitudes of the computed early-time HEMP E-field components versus time for the far end of the 500-km telecom line .....	16
Figure 6 – Computed transverse late-time HEMP magnetic flux density at the earth's surface at ground ranges of 433 km and 574 km from the surface zero point .....	17
Figure 7 – Computed early-time HEMP load voltage versus time for the far end of the 80-km long subline 2 (the top figure shows the earliest time, while the bottom figure shows a later time view) .....	18
Figure 8 – Computed early-time HEMP short-circuit current versus time for the near end of the 80 km long subline 2 (the top figure shows the earliest time, while the bottom figure shows a later time view) .....	19
Figure 9 – Computed early-time HEMP short-circuit current versus time for the far end of the 80 km long subline 2 (the top figure shows the earliest time, while the bottom figure shows a later time view) .....	20
Figure 10 – Time response for a typical antenna cable coupled current measured at WRF .....	23

Figure 11 – Time response for a typical telephone cable coupled current measured at WRF	23
Figure 12 – Time response for a typical power cable coupled current measured at WRF	24
Figure 13 – Time response for a typical speaker wire coupled current measured at WRF	24
Figure 14 – Time response for a typical computer keyboard coupled current measured at WRF	25
Figure 15 – Geometry of the medium voltage (MV) power lines with respect to the EMP simulator	29
Figure 16 – Comparison of measured (left) and calculated (right) HEMP simulator-induced voltage (line to ground) at position M in figure 15, where the line turns 90°	30
Figure 17 – Comparison of the measured currents in amperes at four different locations: 1 and 2 at 48 m on either side of the simulator centreline (points M and N in figure 15), and 3 and 4 near the far end of the line (near point Q in figure 15)	31
Figure 18 – Geometry for HEMP simulation test of locomotive with single power line	32
Figure 19 – Measured HEMP-induced current on power line directly above left end of locomotive	33
Figure 20 – Geometry for three-phase line placed under a hybrid HEMP simulator	34
Figure 21 – Comparison of measured (solid line) and calculated (dashed line) currents flowing on the shielding wire	35
Figure 22 – HEMP current measured in the centre of one of the open-circuited phase wires when the grounding wire was removed	36
Figure 23 – Experimental HEMP investigation of high-voltage equipment showing the importance of testing power lines when they are energized. Note that the lower figure b) is for a 110-kV power line	39
Figure 24 – Simulation of HEMP effects on a 110 kV power line under operating voltage	40
Figure 25 – Investigation of HEMP effects on high-voltage transformers	41
Figure 26 – Simulation of HEMP effects on a mobile diesel power station under operating voltage	42
Figure 27 – Types of interference caused by HEMP penetration through the electric power supply system	43
Figure 28 – HEMP test layout for power systems under operation	44
Table 1 – Data on the arrester firing voltage as a function of the voltage waveform characteristics (from [6])	21
Table 2 – The peak pulse currents in kA damaging the fuse SN-1 (from [6])	21
Table 3 – Summary of operational observations at FEMPS [7]	22
Table 4 – Summary of information on radios tested [8]	26
Table 5 – Summary of distribution transformer tests [15]	38

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

### ELECTROMAGNETIC COMPATIBILITY (EMC) –

#### Part 1-3: General – The effects of high-altitude EMP (HEMP) on civil equipment and systems

#### FOREWORD

- 1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.
- 3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.
- 4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.
- 5) The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.
- 6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example “state of the art”.

Technical reports do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful by the maintenance team.

IEC 61000-1-3, which is a technical report, has been prepared by subcommittee 77C: High power transient phenomena, of IEC technical committee 77: Electromagnetic compatibility. It has the status of a basic EMC publication in accordance with IEC Guide 107.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
77C/109/CDV	77C/121/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

This document, which is purely informative, is not to be regarded as an International Standard.

The committee has decided that the contents of this publication will remain unchanged until 2007. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

## INTRODUCTION

IEC 61000 is published in separate parts according to the following structure:

**Part 1: General**

General considerations (introduction, fundamental principles)  
Definitions, terminology

**Part 2: Environment**

Description of the environment  
Classification of the environment  
Compatibility levels

**Part 3: Limits**

Emission limits  
Immunity limits  
(in so far as they do not fall under the responsibility of product committees)

**Part 4: Testing and measurement techniques**

Measurement techniques  
Testing techniques

**Part 5: Installation and mitigation guidelines**

Installation guidelines  
Mitigation methods and devices

**Part 6: Generic standards**

**Part 9: Miscellaneous**

Each part is further subdivided into several parts published either as International Standards or as technical specifications or technical reports, some of which have already been published as sections. Others will be published with the part number followed by a dash and a second number identifying the subdivision (example: IEC 61000-6-1).

## **ELECTROMAGNETIC COMPATIBILITY (EMC) –**

### **Part 1-3: General – The effects of high-altitude EMP (HEMP) on civil equipment and systems**

#### **1 Scope**

The purpose of this part of IEC 61000 is to describe the effects that have occurred during actual and simulated electromagnetic pulse testing throughout the world. These effects include those observed during the high-altitude nuclear tests conducted by the United States and the Soviet Union in 1962, and the HEMP simulator tests conducted by many countries during the years after atmospheric testing ended. In addition to direct effects, this technical report also contains information on HEMP coupling to “long lines” as it is important to verify that particular levels of currents and voltages can be induced by HEMP on these lines; this provides a basis for direct injection testing of electronic equipment. It should be noted that, in most cases, the electrical equipment tested or exposed did not contain the sensitive electronics in use today. Also it should be emphasized that all tests and exposures did not produce failure of the equipment; factors such as the geometry of the HEMP interaction and the electromagnetic shielding of the equipment are variables that can produce differing results. The description of these effects is intended to illustrate the seriousness of the possible effects of HEMP on modern electronic systems.

#### **2 Reference documents**

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-161:1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

IEC 61000-2-9, *Electromagnetic compatibility (EMC) – Part 2: Environment – Section 9: Description of HEMP environment – Radiated disturbance*. Basic EMC publication

IEC 61000-2-10: *Electromagnetic compatibility (EMC) – Part 2-10: Environment – Description of HEMP environment – Conducted disturbance*

IEC 61000-4-32: *Electromagnetic compatibility (EMC) – Part 4-32: Testing and measurement techniques – HEMP simulator compendium*. Basic EMC publication<sup>1</sup>

---

<sup>1</sup> To be published.