IEC 61000-2-9

Edition 2.0 2025-05

INTERNATIONAL STANDARD

**Electromagnetic compatibility (EMC) –
Part 2-9: Environment – Description of HEMP environment – Radiated disturbance**

ICS 33.100.01

ISBN 978-2-8327-0393-9

THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2025 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, 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 either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD 4
INTRODUCTION 6
1 Scope 7
2 Normative references 7
3 Terms and definitions 7
4 Types of HEMP waveforms 12
5 Description of HEMP environment, radiated parameters 12
5.1 High-altitude bursts 12
5.2 Spatial extent of E_1 HEMP on the earth's surface 14
5.3 HEMP time dependence 14
5.3.1 General 14
5.3.2 Early-time HEMP waveform 14
5.3.3 Intermediate-time HEMP waveform 19
5.3.4 Late-time HEMP waveform 20
5.3.5 The complete standard HEMP electric field time waveform 21
5.4 Early-time HEMP magnetic field component 22
5.5 HEMP amplitude and energy fluence spectrum 23
5.6 Comparison of the early-, intermediate- and late-time HEMP 25
5.7 Reflection and transmission of the early-time HEMP 25
Annex A (informative) Background of HEMP environments 30
A.1 Development of a standard early-time (E_1) HEMP waveform 30
A.2 Alternate analytic standard early-time HEMP waveform 32
A.2.1 Overview and comparisons 32
A.2.2 Formulae for the difference of exponentials (DEXP) 34
A.2.3 Formulae for the quotient of exponentials (QEXP) 35
A.3 Far field region for the early-time HEMP 36
A.4 Additional information for the late-time HEMP 37
Bibliography 41

Figure 1 – Geometry for the definition of polarization and of the angles of elevation Ψ and azimuth ϕ 8
Figure 2 – Geometry for the definition of the direction of propagation 9
Figure 3 – Geomagnetic dip angle 10
Figure 4 – Schematic representation of the early-time HEMP from an example of a high-altitude burst 13
Figure 5 – HEMP tangent radius as a function of height of burst (HOB) 15
Figure 6 – Typical variations in peak electric fields on the earth's surface for burst altitudes between 30 km and 500 km and for ground zero between 30° and 60° northern latitude 16
Figure 7 – Different waveforms for three typical cases indicated in Figure 6 (point A, point B, point C) and the composite curve fit 16
Figure 8 – Plots of the early-time HEMP standard waveform (Formula (1)) and a world map indicating the variation of the dip angle of the geomagnetic field used in Formula (2) 19
Figure 9 – Standard late-time HEMP waveform 21
Figure 10 – Complete standard HEMP time waveform 22

Figure 11 – Amplitude spectrum of each HEMP component 23
Figure 12 – Fraction of energy fluence from f = 10^3 Hz to f_1 24
Figure 13 – Representation of incident, reflected and refracted waves 25
Figure 14 – Calculated total horizontal electric field as a sum of the incident plus reflected fields for a HEMP (early-time part only) 27
Figure 15 – Calculated total horizontal electric field as a sum of the incident plus reflected fields for a HEMP (early-time part only) for different angles of elevation 28
Figure 16 – Calculated transmitted horizontal electric fields for a HEMP (early-time part only) 29
Figure A.1 – Three sample early-time HEMP time waveforms and the standard pulse (with a peak value of 50 kV/m) 30
Figure A.2 – The Fourier transform amplitudes of the time waveforms in Figure A.1 31
Figure A.3 – Comparison of the DEXP and the QEXP time waveforms and their time derivatives 33
Figure A.4 – Frequency amplitudes for the DEXP and QEXP E_1 HEMP waveforms 34
Figure A.5 – Analytic B-field waveform estimated to be the worst-case late-time HEMP waveform 37
Figure A.6 – Analytic E-field waveform estimated to be the worst-case late-time HEMP waveform, σ = 0,1 S/m 38
Figure A.7 – Analytic E-field waveform estimated to be the worst-case late-time HEMP waveform, σ = 10 mS/m 39
Figure A.8 – Analytic E-field waveform estimated to be the worst-case late-time HEMP waveform, σ = 1,0 mS/m 39
Figure A.9 – Analytic E-field waveform estimated to be the worst-case late-time HEMP waveform, σ = 0,1 mS/m 40

Table A.1 – E_1 HEMP time waveform parameters 32

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 2-9: Environment – Description of HEMP environment – Radiated disturbance

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of 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, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). 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. 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 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 IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at https://patents.iec.ch. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 61000-2-9 has been prepared by subcommittee 77C: High power transient phenomena, of IEC technical committee 77: Electromagnetic compatibility. It is an International Standard.

It forms Part 2-9 of IEC 61000. It has the status of a horizontal basic EMC publication in accordance with IEC Guide 107.

This second edition cancels and replaces the first edition published in 1996. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) updating the document to provide new information on the variation of the early-time HEMP on the earth's surface and to provide new information on the late-time HEMP;
b) adding a new informative Annex A which provides details concerning the development of the early- and late-time standard waveforms in the main body, an explanation of the advantages and disadvantages for the use of the double exponential waveform, and an explanation of the far field region for the early-time HEMP.

The text of this International Standard is based on the following documents:

Draft	Report on voting
77C/347/FDIS	77C/350/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 61000 series, published under the general title *Electromagnetic compatibility (EMC)*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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 sections, 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 2-9: Environment – Description of HEMP environment – Radiated disturbance

1 Scope

This part of IEC 61000 defines the high-altitude electromagnetic pulse (HEMP) environment that is one of the consequences of a high-altitude nuclear explosion.

There are two cases of nuclear detonations:

– high-altitude nuclear explosions;

– low-altitude nuclear explosions.

For civil systems, the most important case is the high-altitude nuclear explosion. In this case, the other effects of the nuclear explosion such as blast, ground shock, thermal and nuclear ionizing radiation are not present at the ground level. However, the electromagnetic pulse associated with the explosion can cause disruption of, and damage to, communications, electronic systems, electric power systems and other portions of the commercial critical infrastructures, thereby upsetting the stability of modern society.

The object of this document is to establish a common reference for the HEMP environment in order to select realistic stresses to apply to victim equipment for evaluating their performance and in order to develop protection methods to minimize the impacts of the HEMP.

2 Normative references

There are no normative references in this document.