

Electromagnetic compatibility (EMC) —

Part 2-10: Environment — Description of HEMP environment — Conducted disturbance

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British Standard

ICS 33.100.10

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National foreword

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 38, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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English version

Electromagnetic compatibility (EMC)
Part 2-10: Environment — Description of HEMP
environment
Conducted disturbance

(IEC 61000-2-10:1998)

Compatibilité électromagnétique (CEM)
Partie 2-10: Environnement
Description de l'environnement
IEMN-HA — Perturbations conduites
(CEI 61000-2-10:1998)

Elektromagnetische Verträglichkeit (EMV)
Teil 2-10: Umgebungsbedingungen
Beschreibung der HEMP-Umgebung
Leitungsgeführte Störgrößen
(IEC 61000-2-10:1998)

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European Committee for Electrotechnical Standardization
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Foreword

The text of document 77C/61/FDIS, future edition 1 of IEC 61000-2-10, prepared by SC 77C, Immunity to high altitude nuclear electromagnetic pulse (HEMP), of IEC TC 77, Electromagnetic compatibility, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61000-2-10 on 1999-01-01.

The following dates were fixed:

- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 1999-10-01
- latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 2001-10-01

Annexes designated “normative” are part of the body of the standard.

Annexes designated “informative” are given for information only.

In this standard, Annex ZA is normative and Annex A, Annex B, Annex C and Annex D are informative. Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61000-2-10:1998 was approved by CENELEC as a European Standard without any modification.

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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 (insofar as these limits do not fall under the responsibility of the 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 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.

1 Scope

This International Standard defines the high-altitude electromagnetic pulse (HEMP) conducted environment that is one of the consequences of a high-altitude nuclear explosion.

Those dealing with this subject consider two cases:

- 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: blast, ground shock, thermal and nuclear ionizing radiation are not present at the ground level.

However, the electromagnetic pulse associated with the explosion may cause disruption of, and damage to, communication, electronic and electric power systems thereby upsetting the stability of modern society.

The object of this standard is to establish a common reference for the conducted HEMP environment in order to select realistic stresses to apply to victim equipment for evaluating their performance.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 61000. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of IEC 61000 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60050(161):1990, *International Electrotechnical Vocabulary (IEV) — Chapter 161: Electromagnetic Compatibility*.

IEC 61000-2-9:1996, *Electromagnetic compatibility (EMC) — Part 2: Environment — Section 1: Description of HEMP environment — Radiated disturbance — Basic EMC publication*.

IEC 61000-4-24:1997, *Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 24: Test methods for protective devices for HEMP conducted disturbance — Basic EMC publication*.

3 General

A high-altitude (above 30 km) nuclear burst produces three types of electromagnetic pulses which are observed on the earth's surface:

- early-time HEMP (fast);
- intermediate-time HEMP (medium);
- late-time HEMP (slow).

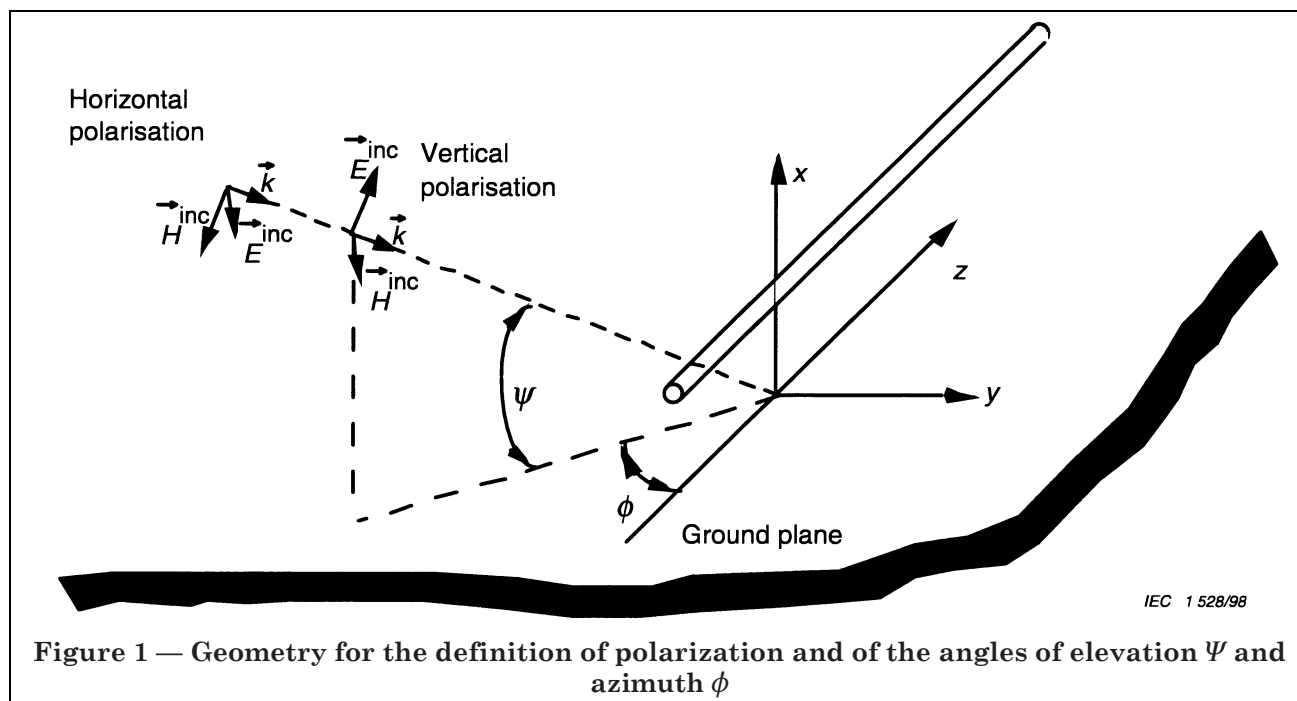
Historically most interest has been focused on the early-time HEMP which was previously referred to as simply HEMP. Here we will use the term high-altitude EMP or HEMP to include all three types. The term NEMP¹⁾ covers many categories of nuclear EMPs including those produced by surface bursts (SREMP)²⁾ or created on space systems (SGEMP)³⁾.

Because the HEMP is produced by a high-altitude detonation, we do not observe other nuclear weapon environments such as gamma rays, heat and shock waves at the earth's surface. HEMP was reported from high-altitude nuclear tests in the South Pacific by the US and over the USSR during the early 1960s, producing effects on electronic equipment far from the burst location.

This standard presents the conducted HEMP environment induced on metallic lines, such as cables or power lines, external and internal to installations, and external antennas.

4 Definitions

For the purpose of this International Standard, the definitions given in IEC 60050(161) apply, as well as the following definitions:



¹⁾ NEMP: Nuclear electromagnetic pulse.

²⁾ SREMP: Source region EMP.

³⁾ SGEMP: System generated EMP.

4.1**angle of elevation in the vertical plane, Ψ**

angle Ψ measured in the vertical plane between a flat horizontal surface such as the ground and the propagation vector (see Figure 1)

4.2**azimuth angle, ϕ**

angle between the projection of the propagation vector on the ground plane and the principal axis of the victim object (z axis for the transmission line of Figure 1)

4.3**composite waveform**

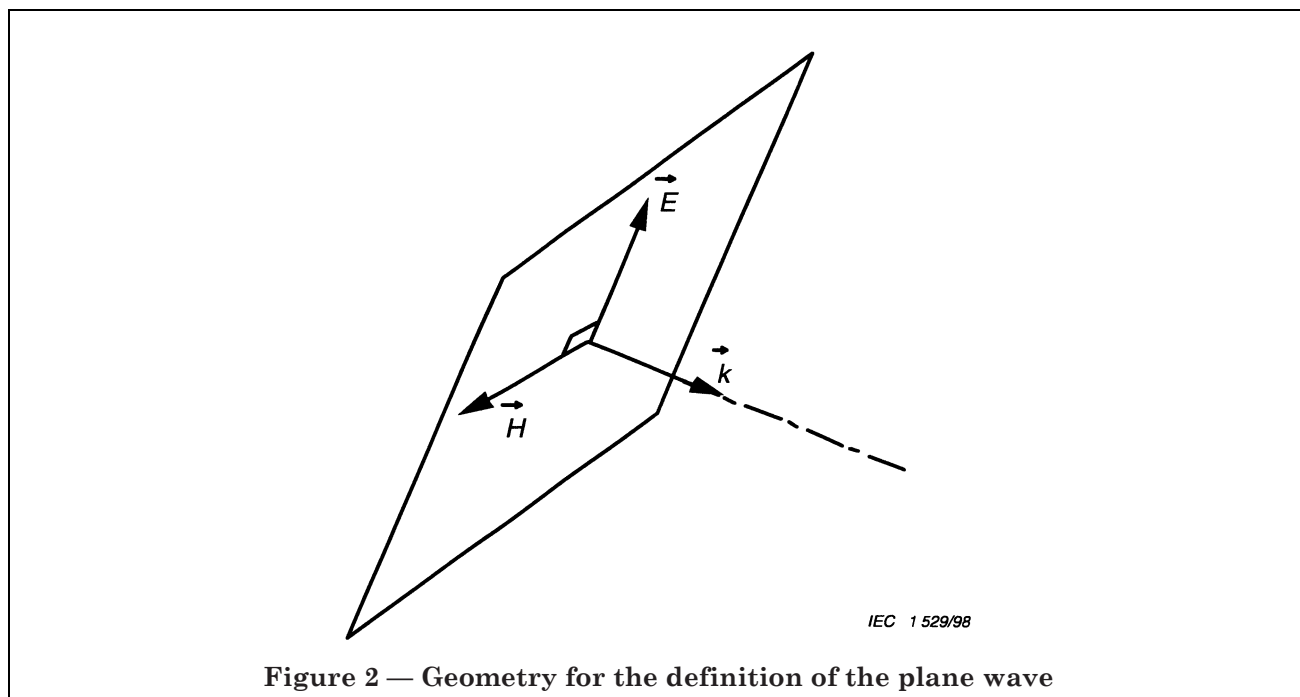
waveform which maximizes the important features of a waveform

4.4**coupling**

interaction of the HEMP field with a system to produce currents and voltages on system surfaces and cables. Voltages result from the induced charges and are only defined at low frequencies with wavelengths larger than the surface or gap dimensions

4.5**direction of propagation of the electromagnetic wave**

direction of the propagation vector $\vec{k}$ perpendicular to the plane containing the vectors of the electric and the magnetic fields (see Figure 2)

**4.6****E1, E2, E3**

terminology for the early, intermediate and late-time HEMP electric fields

4.7**EMP**

any electromagnetic pulse, general description

4.8

geomagnetic dip angle, θ_{dip}

dip angle of the geomagnetic flux density vector $\vec{B}_e$, measured from the local horizontal in the magnetic north-south plane, $\theta_{\text{dip}} = 90^\circ$ at the magnetic north pole, -90° at the magnetic south pole, (see Figure 3)

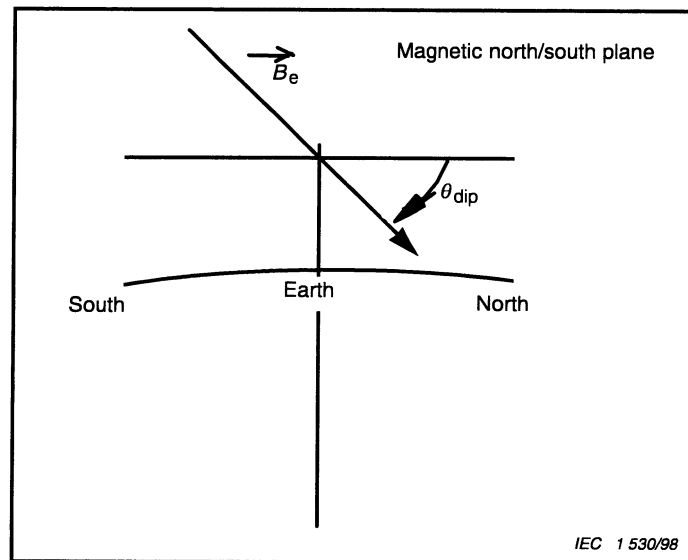


Figure 3 — Geomagnetic dip angle

4.9

HEMP

high-altitude nuclear EMP

4.10

high-altitude (nuclear explosion)

height of burst above 30 km altitude

4.11

horizontal polarization

an electromagnetic wave is horizontally polarized if the magnetic field vector is in the incidence plane and the electric field vector is perpendicular to the incidence plane and thus parallel to the ground plane (see Figure 1) [This type of polarization is also called perpendicular or transverse electric (TE).]

4.12

incidence plane

plane formed by the propagation vector and the normal to the ground plane

4.13

low-altitude (nuclear explosion)

height of burst below 1 km altitude

4.14

NEMP

nuclear EMP; all types of EMP produced by a nuclear explosion

4.15**point-of-entry (PoE)**

the physical location (point) on an electromagnetic barrier, where EM energy may enter or exit a topological volume, unless an adequate PoE protective device is provided. A PoE is not limited to a geometrical point. PoEs are classified as aperture PoEs or conductive PoEs according to the type of penetration. They are also classified as architectural, mechanical, structural or electrical PoEs, according to the functions they serve

4.16**pulse width**

the time interval between the points on the leading and trailing edges of a pulse at which the instantaneous value is 50 % of the peak pulse amplitude, unless otherwise stated

4.17**rectified impulse (RI)**

the integral of the absolute value of a time waveform's amplitude over a specified time interval

4.18**rise time (pulse)**

the time interval between the instants in which the instantaneous amplitude of a pulse first reaches specified lower and upper limits, namely 10 % and 90 % of the peak pulse amplitude, unless otherwise stated

4.19**short-circuit current**

the value of current that flows when the output terminals of a circuit are shorted. This current is normally of interest when checking the performance of surge protection devices

4.20**source impedance**

the impedance presented by a source of energy to the input terminals of a device or network

4.21**vertical polarization**

an electromagnetic wave is vertically polarized if the electric field vector is in the incidence plane, and the magnetic field vector is perpendicular to the incidence plane and thus parallel to the ground plane (see Figure 1) [This type of polarization is also called parallel or transverse magnetic (TM).]

5 Description of HEMP environment, conducted parameters**5.1 Introductory remarks**

The electromagnetic field generated by a high-altitude nuclear explosion described in IEC 61000-2-9 can induce currents and voltages in all metallic structures. These currents and voltages propagating in conductors represent the conducted environment. This means that the conducted environment is a secondary phenomenon, a consequence of the radiated field alone.

All metallic structures (i.e. wires, conductors, pipes, ducts, etc.) will be affected by the HEMP. The conducted environment is important because it can direct the HEMP energy to sensitive electronics through signal, power, and grounding connections. It should be noted that there are two distinct categories of conductors: external and internal conductors (with regard to a building or any other enclosure). While this may seem simplistic, this separation is critical in terms of the information to be provided in this standard.

The difference between these two types of conductors is explained by electromagnetic topology. In general, external conductors are those which are located outside of a building and are completely exposed to the full HEMP environment. This category includes power, metallic communication lines, antenna cables, and water and gas pipes (if metallic). For the purposes of this standard the conductors can be elevated above the ground or buried in the earth. Internal conductors are those which are located in a partially or completely shielded building where the HEMP fields have been reduced by the building. This is a much more complex situation, because the HEMP field waveforms will be significantly altered by the building shield, and the coupling to internal wires and cables is consequently very difficult to calculate, although some measured data are available from simulated HEMP tests.

In this standard the external conducted common mode environments are calculated using simplified conductor geometries and the specified HEMP environments for the early, intermediate, and late-time waveforms. These conducted external environments are intended to be used to evaluate the performance of protection devices outside of a building, and because of variations in telecom and power systems, the effects of transformers and telephone splice boxes are not considered here. This process results in approximate, but well-defined waveforms that are needed to test protective elements on external conductors in a standardized manner. For the internal conductors, a procedure is defined to estimate the conducted environments appropriate for equipment testing. For unshielded multiconductor wires, it is assumed that the line-to-ground currents are equal to the common-mode current.

5.2 Early-time HEMP external conducted environment

For the early-time HEMP, the high-amplitude electric field couples efficiently to antennas and to any exposed lines such as power and telephone lines. The antenna coupling mechanism is extremely variable and dependent on the details of the antenna design. In many cases, it is advisable to perform continuous wave (CW) testing of an antenna and to “combine” the response function of the antenna with the incident HEMP environment using a convolution technique. We have, however, provided simple equations to compute the response of thin antennas (see 5.5). For long lines, it is possible to perform a comprehensive set of common mode calculations that are reliable and depend only upon a few parameters. These parameters include conductor length, exposure situation (above ground or buried), and the surface ground conductivity (for depths between 0 m and 5 m). In addition, because the HEMP coupling is dependent on angle of elevation and polarization (see Figure 1), it is possible to statistically examine the probability of producing particular levels of current.

Table 1 below describes the calculated, coupled, common-mode short-circuit currents and the Thévenin equivalent source impedances (used to determine the open-circuit voltages) as functions of severity level, length of conductor, and ground conductivity. These results are appropriate for the common-mode currents flowing on bare wires, overhead insulated wires, and the shields of shielded cables or coaxial transmission lines. For shielded cables one should use measured or specified cable transfer impedances to determine internal wire currents and voltages. Although some waveform variation occurs for different exposure geometries, a single time waveform is specified for elevated lines. The waveform is defined in terms of the rise time (10 % to 90 %) and the pulse width (at half maximum); when the pulse characteristics of rise time and pulse width are described together, the usual description is $\Delta t_r / \Delta t_{pw}$.

In Table 1a severity level of 99 % indicates that 99 % of the currents produced will be less than this value. The buried line currents calculated vary much less with angle of incidence and indicate a very broad probability distribution (small differences between 10 % and 90 % severity) and therefore are not described in terms of severity levels; variations are shown for ground conductivity. In terms of applicability for Table 1, the elevated conductor currents are accurate for heights above 5 m while the buried currents can be used for conductors slightly ($h < 30$ cm) above the surface and below the surface. For conductor heights below 5 m, the values in Table 1 may be linearly interpolated (between 0,3 m and 5 m). For cases where the lines from an elevated geometry enter the ground in an insulated manner, the currents will initially resemble waveform 1, decreasing as a function of burial distance until waveform 2 is reached (requires approximately 20 m). Consult Annex A for further information regarding the derivation of these waveforms.